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Visions for Sustainability is an indexed scientific journal published in open access by the University of Turin, Italy. The journal promotes a debate on how the concept of sustainability can be addressed and applied in existing and foreseeable societies worldwide. Emphasis is placed on facilitating communication between researchers of different disciplines, supporting educational projects and examining the role of contemporary science in dealing with issues related to sustainability. Papers are welcome from researchers and scholars of natural, political, social and other sciences as well as philosophical and humanistic disciplines, and in particular from anyone wishing to make a contribution which combines multiple viewpoints. The aim is to host as wide a range as possible of multidisciplinary, interdisciplinary and transdisciplinary perspectives on sustainability. Discussions or comments on articles which have previously appeared in the journal are also welcome. All submissions will be refereed before publication.

Articles can be submitted directly online at the journal website https://www.ojs.unito.it/index.php/visions through the login procedure. Any further questions and/or submission enquiries can be addressed to m.dodman@univda.it or g.barbiero@univda.it.

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Editorial

Engaging visions

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If, as Donella Meadows says, vision without action is useless, then vision must be engaging. A vision should help its viewers look, see, understand, and feel, and so be shown directions forward and be stimulated to get involved.

The vision enabled by science of how human activities have long been dramatically changing all fundamental plenetary equilibria is now available to viewers of different ages, from the very young to the elderly, at different levels, from individual to collective, and in different discourse arenas, both in material and virtual places.

In recent years more and more scientists have increasingly expressed dismay and indignation as a result of (above all, if not only) political inaction, based on a lack of understanding and/or will to act, and the way in which the relentless pursuit of vested corporate interests peddles misinformation and frustrates initiatives.

In the face of this, to be engaging, visions must contain a vital mix of awareness, advocacy and activism. The papers in this issue of Visions for Sustainability offer a range of perspectives on engaging with and for sustainability.

Engaging young people

The engagement of young people, both in terms of the information they access and the forms of activism they perceive as being pertinent and available to them, is fundamental.

In "Radical climate activism. Motivations, consequences, and approaches", Vuon et al. argue that environmental activism is crucial in increasing awareness of environmental degradation and preventing actions that harm the environment. They focus on radical environmentalist groups' motivations, their actions and their consequences and the risk that some of their actions may result in adverse outcomes and diminish public support for environmental engagement. They propose an alternative solidarity approach whereby activists focus their efforts on disseminating information to the general public on climate change and other environmental issues, advocating for the adoption of eco-surplus culture, and fostering cooperation to develop effective solutions.

In "Young audiences and climate change. Communication analysis in different public arenas", Semova et al. consider climate change discourse from the perspective of young audiences in terms of the mass media arena, collaborative-activist arena, personal arena, and discussion arena. They pose questions related to thematic categories and level of engagement in the traditional media arena where young audiences are users of news and messages and the public arenas where they become generators of information. They show that traditional media pay less attention to environmental issues from the perspective of activism, social justice or culture, and how this contrasts with the approaches and activism of young audiences in other arenas formed by social networks.

Engaging Higher Education

Higher Education institutions should clearly be engaged in developing vision and action for sustainablility, both in terms of their research and didactic activities and their organization as sustainable institutions.

In "Beyond the Global Warming issue. Understanding students' motivations as volunteers in youth environmental community" Melati et al. investigate the motivation of student volunteers joining an environmental community and the building of an effective voluntary system for students focusing on synergizing personal and community goals. Their study looks at circular economy implementation in suburban areas and considers how an environmental community

management concept can facilitate both the personal goals of the volunteers and the common goals of the community.

In "A technocreativity learning model based on volunteers for waste management. Can it support Green Campus and Green Entrepreneurship for students?" Sumarmi et al. propose a technocreativity learning model based on environmental volunteers for waste management to support Green Campus and Green Entrepreneurship for students. The model consists of stages involving an initial briefing for students, collecting trash, waste sorting, waste processing for manufacture, waste processing, and waste profits. The results suggest that the longer an individual has been a member of an environmental volunteer group, the more they develop an interest in participating in Green Campus and Green Entrepreneur activities. for waste management in university.

In "Young people's awareness, perception and attitude towards Sustainable Development Goals in India" Minimol & Sebastian set out to understand how young people's attitudes toward sustainable development goals are formed and the roles that awareness, perception, and personal value propositions play. They also investigate the role that worldviews play in shaping young people's attitude towards sustainable development goals.

Engaging focuses on Sustainable Development

Our journal has often expressed its reservations about an uncritical reference to the Sustainability Development Goals, starting from the need to question what is actually meant by development and its all-too-common association with the idea that economic growth is a necessary prerequisite to achieving it. At the very least, we believe that researchers should examine the many problematic aspects concerned with the design and implementation of what UNESCO defines as "common goals that humanity has chosen for itself" (UNESCO, 2023). While we are pleased to receive and publish papers which deal with aspects of the SDGs, we urge authors to go beyond mere reference to them as if they were a unique and ineluctable benchmark and to propose visions that critique the way in which they have been conceived, proposed and implemented.

Even if we are critical in this respect, engaging the SDGs directly on their own terms is a necessary part of sustainability discourse. In "Sustainability Development Goals: overcoming barriers and catalysing innovation for a sustainable future" Jarrah et al. consider sustainable development goals from the point of view of barriers to their achievement and what is necessary to overcome these obstacles. They focus on the need to promote sustainability and social equity and the

importance of applying environmental, social, and economic elements of sustainable business practices.

In "Comparison of environmental Kuznet Curve testing before and during the implementation of Sustainable Development Goals" Adzim et al. analyse comparative environmental Kuznet Curve testing before and during the implementation of sustainable development goals. They focus on 10 high, upper middle and lower middle-income countries on the Asian continent during the 2011-2020 period in order to study the variables Gross Domestic Product, Population Density, Foreign Direct Investment, Human Development Index, Agricultural Land, and Industrialization in terms of their influence on CO2 emissions in the countries studied.

Engaging rethinking energy

Like all living organisms, their populations, communities and ecosystems, human beings need a constant source and flow of energy for all their activities. Satisfying this need has led to an ever more excessive demand and consequent plundering of natural resources to satisfy that demand, in such a way as to irremediably compromise the fragile planetary equilibria on which all life depends. Changing such perverse supply and demand dynamics driven by blind greed and a wilful and pathological quest for economic growth predicated on inequality and injustice requires a engaging in a radical rethinking of human energy needs, production, consumption and distribution.

In "Enhancing energy justice through solar power proliferation in Kenya's devolved units. Insights from Makueni and Nyeri" Chisika & Yeom examine the concept of energy justice in relation to solar power and the persistence of widespread energy injustices persist. Their study examined the socio-cultural, economic, and environmental contexts relevant to energy justice and solar power usage through case studies involving the Nyeri and Makueni counties in Kenya, highlighting the influence of contextual factors and governance policies and the need to balance affordability and public participation and long-term community involvement.

In "Future directions for solar energy in a global context with particular emphasis on Saudi Arabia, the Middle East, and Noth Africa" Alamrani analyse future directions for solar energy in a global context, with a particular emphasis on the Kingdom of Saudi Arabia (KSA), and the Middle East and North Africa (MENA) region. They consider the challenges and opportunities relating to solar

cell adoption in such regions, particularly since there is a potential paradox of countries who are among the largest producers of fossil-fuels being in the forefront of the move to carbon-negative technologies.

In "Electric vehicle grid demand: Potential analysis model and regional architectural planning approach for charging using Pvsyst tool", Bukya et al. argue that electric transportation is a societal necessity to mitigate the adverse effects of local emissions and global climate change and that there is a need to maintain a steady operation of regional power grids as demand increases. Their study emphasizes how PV systems can alleviate grid peak loads, in terms of their cost-effectiveness, low maintenance, and adaptability to peak-time loads.

Engaging public participation

Whatever sustainable development means, both in terms of its conception and realization, it must necessarily include the question of what forms of engagement should be envisaged for the members of the human populations that are participants in the process.

In "Enhancing citizen participation in local development planning in Nairobi and Makueni Counties in Kenya, Chisika & Yeom argue that public participation in development planning is critical for achieving sustainable development outcomes since implementing public participation enhances responsiveness to community needs, leverages diverse skills, and instils a sense of ownership for sustainable development projects. Their paper proposes a case study that examines the preparation process of the 2023- 2027 County Integrated Development Plans for Nairobi and Makueni Counties in Kenya, considering how to enhance participation by devising strategies for sustainable participation practices.

In "Fostering environmental innovation programs in Madiun Regency, East Java, Indonesia" Handoko et al. study an area that faces numerous challenges in maintaining environmental sustainability amidst economic development. Their study examines the implementation of regional innovation programs for the promotion of a smart environment which focuses on utilizing technology to manage resources efficiently, promote sustainability, and mitigate environmental impacts in the context of collaborative and innovative efforts.

Engaging producers and consumers

Radically modifying unsustainable and irresponsible production and consumption of goods and services within a market logic of supply and demand is an essential but highly complex challenge for humanity, and visions must be engaging for both producers and consumers. Although satisfying very different demands, fast fashion and bottled water have in common processes of production, consumption and waste generation that have far-reaching implications for our planet in terms of their profound effects on ecosystems and the resources they provide.

In "Sustainable and responsible creation of shared values in the fast fashion industry", MacGregor Pelikánová et al. consider the negative social and environment impacts of the fashion industry and its problematic compliance with criteria related to sustainability, corporate social responsibility and creating shared value. In particular they examine claims by fast fashion businesses in terms of the fundamental virtues of respect and no waste and their importance as precursors of the sustainable and responsible creation of shared values. Their study focuses on a number of well-known fast fashion businesses in the EU, comparing their claims with what emerges from third-party websites.

In "Sustainable performance of bottled water firms in Ethiopia: The role of green supply chain management", Ababulgu et al. consider how pressure from customers, government and stakeholders for firms to adopt green supply chain management practices to minimize environmental consequences while enhancing social and economic performance. Their study examines the impact of such practices on environmental, economic, and social performance in the bottled water manufacturing industry in Ethiopia and how variable their effect can be.

Engaging forest ecosystems

Forest ecosystems are of immense significance for our planet in terms of the vast range of ecosystemic services they furnish at the level of the entire biosphere. They have a crucial role to play for engaging with whatever kind of sustainable development we may be able to define and achieve.

In "Investigating wildlife crop pests and farmers' willingness to pay for pest management in the Batand Toru Forest, Indonesia", Harahap et al. study the challenges faced by farmers, the strategies they employ, and their willingness to contribute to managing pest-related issues in the Batang Toru region. Their findings highlight the complex and context-specific nature of pest management strategies,

emphasizing the importance of understanding local ecological dynamics and cultural factors when designing interventions.

In "Optimizing environmental education and awareness strategies for sustainable forest management in Kenya. Lessons. From Cherangany, Mt. Kenya, Aderdares and Kakamega forest ecosystems, Chisika & Yeom offer a case study of four forested ecosystems in Kenya designed to examine the relationship between strategies to achieve sustainable forest management and environmental education. Their results show that important elements are formal education infrastructure, community engagement panels, digital platforms, corporate responsibility initiatives, media, arts, policy advocacy, and research with feedback loops on initiatives.

In "The challenges of private sector engagement in forest landscape and ecosystem restoration in Kenya. The case of Makueni and Elgeyo Marakwet Counties", Chisika & Yeom explore the current status of private sector engagement in forest restoration and identify the key challenges facing private actors through cases of the Elgeyo Marakwet and Makueni Counties in Kenya. Their results show the importance of a collaborative and well-coordinated approach to restoration, policy reviews, and conducting a total economic valuation of forest landscapes to sustain private sector interest and engagement in the restoration efforts.

Engaging human building

If the *oikos*, the etymological root of both ecology and economy, is a place to live in, then human building is of immense significance in terms of dwelling and engaging in a vast range of activities that characterize our species. What constitutes sustainable human-building ecosystems can be explored in terms of both present and past design and construction.

In "Thermal performance study of traditional slate roofed mud houses in the sub-tropical sub montane and low hills of Himachel Pradesh", Sharma & Sharma consider how the indoor environment of an area affects its overall functionality and sustainability. Their study examines the thermal performance of slate-roofed mud huts, which are common in Himachal Pradesh. Their findings show how well these traditional dwellings demonstrate thermal characteristics that render them functional and sustainable in different seasons with a wide range of temperatures.

In "Sustainable practices in Keylong's vernacular architecture. A detailed study of construction and thermal efficiency in the Himalayas", Singh et al. investigate

the resilience and sustainable attributes of vernacular architecture in Keylong, a paradigmatic region located in the Himalayan highlands. Their research focuses on indigenous construction techniques and materials, and their impact on thermal performance, highlighting the relationship between traditional wisdom, vernacular architectural practices, and sustainable practices. It offers practical insights for architects, planners, and policymakers engaged in the development of resilient and sustainable habitats in the Himalayas and similar contexts.

In "Enhancing cogntive performance and emotional well-being in Nature-induced learning environments. Insights from neuro-architecture research", Rai et al. explore the impact of nature-induced design on cognitive performance and emotional well-being in educational settings. Their research shows how biophilic, nature-infused educational environments can significantly enhance critical cognitive processes essential for learning, suggesting their potential in environmental design for cognitive and emotional development.

Engaging human culture

If sustainablility has principally been considered in terms of environmental, economic and social dimensions, human culture has in recent years emerged as a significant component of proposals for engaging with sustainable development.

In "The transcendence of the Roman Catholic Church's Holy Bread. Bearer and usher of cultural sustainability", Benito proposes a vision of culture that focuses on the significance of food and religious practices. He argues that for the Roman Catholic Church Holy Bread is a bearer and proof of the fundamental nature of sustainability's cultural pillar and that this pillar should be considered an essential prerequisite for the existence of the environmental, economic and social pillars of sustainability.

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Position Paper

Radical climate activism: motivations, consequences and approaches

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Keywords: climate activism; climate change denialism; radical activism; public support; solidarity approach.

Abstract. *Environmental activism is crucial in increasing awareness of environmental degradation and preventing actions that harm the environment. A radical environmentalist movement has emerged within the community of activists. They advocate using illegal measures to attain their goals. This paper discusses these radical environmentalist groups' motivations, their actions and their consequences. Activities that many*

consider unacceptable, such as art vandalism and road blockades, may result in adverse outcomes and diminish public support for environmental endeavors. We propose an alternative solidarity approach whereby activists focus their efforts on disseminating information to the general public on climate change and other environmental issues, advocating for the adoption of eco-surplus culture, and fostering cooperation among governments, businesses, and individuals to develop effective solutions.

"Only by uniting the power of the entire village could they chase Snake away"

"Virtue of Sacrifice"; *The Kingfisher Story Collection* (2022)

1. Climate change, public denialism, and governments' lack of responsiveness

In recent years, climate change has become a global emergency, as it contributes to accelerating rises in sea level, increasing uncertainties about weather conditions and frequency and intensity of natural hazards like hurricanes, tropical storms, and drought, and expanding detrimental effects on human welfare and socio-economic sustainability (McCrystall et al., 2021; Shivanna, 2022; Summers et al., 2022). Morever, the biodiversity among terrestrial and aquatic species is also progressively endangered by climate change. By reviewing 519 observational studies, Maxwell et al. (2019) found that 57% of the studied groups (including amphibians, birds, fish, invertebrates, mammals, reptiles, and plants) exhibited negative ecological responses to extreme climate events, more than 100 cases experienced more than 25% population decline, and 31 cases faced local extirpation. Meanwhile, mass mortality events of aquatic species induced by climate change have frequently been reported in recent years, such as the emperor penguins in Antarctica (Fretwell et al., 2023), the coral reefs in the Caribbean (Chow, 2023), gray whales in the West Bank (Baumhardt, 2023), and dolphins in the Brazilian Amazon rainforest (The Associated Press, 2023).

Over the past year the world has experienced record-breaking heat for every consecutive month (Farhat, 2024), while the global average concentration of CO_2

in the atmosphere reached a new record in March 2024 (Milman, 2024). If the global temperature exceeds the 1.5°C threshold compared to the preindustrial period, this can trigger multiple climate tipping points that lead to abrupt and irreversible changes in the Earth's climate system and endanger humanity (Armstrong McKay et al., 2022). As anthropogenic activities (e.g., burning fossil fuels and land use change) are the main causes of climate change, decisive structural economic transformations and socio-cultural transitions towards sustainability are urgent.

However, despite the urgency of addressing the existential threats of climate change to humans and other species, public skepticism and denialism, coupled with governments' lack of responsiveness, remain critical issues hindering the necessary action for climate change mitigation. Although there exists highly consistent evidence and scientific consensus for climate change and global warming (Cook et al., 2013; Cook et al., 2016; Earth Science Communications Team, 2023; Met Office Hadley Centre, n.d.), a lack of understanding of reasons for and implications of human-induced climate change still persists among a large number of people in the society. A recent study by Gounaridis and Newell, using artificial intelligence and network analysis to analyze data from Twitter (now X), discovered that 14.8% of Americans did not believe in climate change (Gounaridis & Newell, 2024). This figure is relatively similar to the results of Vlasceanu et al.'s (2024) survey of 59,440 participants from 63 countries, that around 85.7% believed in climate change, meaning that roughly 14.3% did not believe in climate change. Such persistence of denialism is linked to political affiliation, educational level, COVID-19 vaccination rates, carbon intensity of the regional economy, social identities, absence of need satisfaction, and income (Gounaridis & Newell, 2024; Treen et al., 2020; Ucar et al., 2023; Wullenkord, 2022).

International organizations and governments have also struggled to balance policies and actions between competing priorities. The occurrence of the COVID-19 pandemic led to a delay in the implementation of climate policies and prioritization of short-term economic recovery (Vo et al., 2023). In such a scenario, the growth-versus-environment debate has intensified and caused polarization between and within many countries, especially between the Democrats and Republicans in the United States, which can hamper international and national climate actions (Falkenberg et al., 2022; Vuong et al., 2023). Recent geopolitical conflicts have also exacerbated the climate crises directly by increasing greenhouse gas emissions and indirectly by creating additional

pressures on economic growth (Barbarà & Galea, 2024; Bun et al., 2024; Vuong et al., 2024).

Given these hindrances, climate activism has emerged as an endeavour to raise public awareness and push for economic and political shifts toward climate change mitigation resolutions (Hadden, 2015; Maher, 2021). Some members of the movement support radical activism methods. In this paper, we discuss the motivations behind these radical activists' actions and their possible consequences. Then, we advocate for a solidarity approach through which climate activists can facilitate the shift of underlying values in society, especially the business sector, toward an eco-surplus culture.

2. Climate activism, radical approaches, and their risks

Climate activism has experienced a considerable acceleration since the late 1980s and early 1990s, particularly following the Copenhagen Summit in 2009 and the signing of the Paris Agreement in 2016 (Hadden, 2015; Maher, 2021). The movement can take different forms, ranging from behavior change promotion campaigns to actions within political and economic systems (e.g., litigation, shareholder activism, campaigns to pressure businesses, collaboration with the government) and actions outside the systems (e.g., boycotting, striking, protesting). While each form of activism has shown some positive outcomes on climate change mitigation efforts, activism outside the political and economic systems seems to be the most effective in mobilizing society for the cause. One typical example is the School Strike for Climate (a.k.a. Fridays for Future and Youth for Climate), initiated by the Swedish teenager Greta Thunberg. The activism movement led to the September 2019 climate strikes, which were considered the largest climate strikes in world history, with the participation of an estimated 7.6 million people from over 185 countries (Della Porta & Portos, 2023).

At the same time, several groups of environmental activists have begun embracing radical activities, such as vandalism of artworks crafted by globally renowned artists, assault on business owners and people related to large corporations, and road blockades. They support using illegal actions to achieve their primary goal of environmental protection (Carson et al., 2012). The actions carried out by such radical environmentalist groups are not impulsive but rather part of a deliberately planned and organized following a long-term strategy.

Several reasons lead to embracing such actions. First, radical environmentalist groups wish to provoke large-scale interest from both the general public and the media, thereby stimulating greater awareness of the environmental issues they champion. Thus, they frequently target priceless artworks in museums or disrupt public activities and events to draw the focus of a large audience. In 2022, members of the Just Stop Oil group routinely carried out vandalism on priceless artworks by world-renowned painters, such as Horatio McCulloch, John Constable, Leonardo da Vinci, Vincent Van Gogh, Joseph Mallord William Turner, and many other artists, in museums and galleries across England (Alao, 2022). The Last Generation organization resorted to gluing themselves to the roads, causing blockages during rush-hour traffic on more than 30 traffic routes in Berlin on April 25, 2023, leading to severe traffic congestion on many major roads in the city and some neighboring areas. It was reported that up to 500 police officers were deployed on the city's streets to prevent and disperse these illegal traffic blockades (Armstrong, 2023; Grieshaber, 2023).

Radical activists also aim to pressurize governments and businesses to change direction by highlighting the environmental urgency their actions wish to make clear. If recent scientific evidence shows that several tipping points have been crossed and the most recent status update of the planetary boundary suggests that six out of nine safely operating spaces have been transgressed, including two core boundaries – climate change and biosphere integrity (Biino, 2023; Fretwell et al., 2023; Lenton et al., 2019; Purich & Doddridge, 2023; Richardson et al., 2023), then extreme measures are necessary to make this understood. The statement delivered by a member of Last Generation during the assault on *Monet's Haystacks* painting captures well this motivation of radical environmentalist groups:

"I'm afraid because science tells us that we won't be able to feed our families in 2050. […] Does it take mashed potatoes on a painting to make you listen? This painting is not going to be worth anything if we have to fight over food. When will you finally start to listen? When will you finally start to listen and stop business as usual?"

Nevertheless, the effects of such actions can be seen as counterproductive, risking intensifying environmental tensions and conflicts, and diminishing trust in environmental protection endeavors. While activists undertake radical actions against artworks to communicate messages regarding climate change or other environmental concerns, these actions infringe upon the law and can be interpreted as undermining the cultural values they seek to preserve. Rather then promoting public support for environmental movements, such radical actions

often spark public indignation and encounter significant resistance (Davis, 2022; Gayle, 2022).

Although the activities of radical environmentalist groups are almost non-violent and aim at causing property damage rather than injuring or killing humans (Carson et al., 2012), there is a risk that they can escalate into violence and even result in fatality. The traffic blockage of activists can face many forms of confrontation from traffic participants and social media influencers (Chung, 2023; Mann, 2023). A case of traffic obstruction in Berlin blocked the way of an ambulance dispatched to save a severely injured cyclist, leading to the victim's demise (Connolly, 2022). In Panama, the violence escalation due to the road blockade was deadly since two climate protestors blocking the highway were shot dead (Neath, 2023). Ineffective and disruptive actions risk failing to attract the understanding and attention the environmental activists desire and instead tend to generate hostility and criticism and even endanger the safety of people involved and affected.

The potential negative outcomes of radical environmental activism can result in bad impressions and reasons that movement opposing forces can capitalize on to calumniate and defame the whole climate movement. A divide exists in the environmental movements between groups intentionally pursuing illegal and sometimes violent strategies and groups promoting non-violent resistance (Carson et al., 2012). Some view environmental groups that direct their resources towards direct action (e.g., destruction of assets as well as death threats and harassment) rather than lobbying and non-violent protest as 'eco-terrorists' due to their actual and potential threats to social safety and wellbeing (Barnum & Logan, 2023; Carson et al., 2012; Gruenewald et al., 2015). However, it should also be recognized that at times green activists conducting acts of non-violent civil disobedience have been accused of and even charged with terrorism by courts, simply for chalking slogans on the sidewalk (Potter, 2011). Thus, the risk that opposing corporations, politicians, and denialists utilize negative outcomes induced by radical activism to discredit the movement should not be eliminated.

In some cases, radical actions such as art vandalism might be at odds with the effectiveness of other forms of activism that use the same means of expression. For example, artivism, the utilization of artistic mediums such as paintings, music, and films in environmental activism, is increasingly recognized as a crucial tool in addressing environmental crises, particularly climate change, owing to its capacity for expression, communication, and mobilization towards transformative political action (Rodríguez-Labajos, 2022; Vuong & Nguyen, 2023). The vandalism of priceless artworks can be seen as devaluing their intrinsic

worth, thereby diminishing the effectiveness of artivism. If the value of art cannot be capitalized for climate activism, it might be used by climate change denialists to negatively influence other citizens' understanding and constrain climate change mitigation endeavors (Vuong et al., 2023).

The business sector contributes substantially to the anthropogenic impacts that fuel climate change and environmental degradation but also holds enormous socio-economic power. Therefore, addressing the current environmental crisis necessarily requires their active participation (Vuong, 2021). However, radical environmentalist organizations often consider business owners and large corporations only as risks to the environment, especially those operating in environmentally sensitive sectors like oil or transportation. They have conducted many radical actions to sabotage, hinder activities, and even inflict violence toward these people and organizations (Binde, 2023; Healy, 2023; Limb, 2023; NTV, 2023; Speare-Cole, 2022), which risk forcing the business sector into a direct confrontation, rather than cooperation. There is a risk that activism can create confusion or even be *weaponized* on the one hand to defame the climate movement and on the other to attack business competitors. Environmental activist groups that conducted vandalism of artworks, like Extinction Rebellion and Just Stop Oil, are funded by the Climate Emergency Fund, which was founded by Aileen Getty – the granddaughter of J. Paul Getty, the oil tycoon (Angeleti, 2022). Targeting institutions with no ties to funders involved in the fossil fuel industry risks not distinguishing beween them or even casting doubt on the protest's true intentions.

3. Adopting a solidarity approach

It is clear that to optimize both the impact and the outcome of their action environmental activists need to employ appropriate and effective strategies for raising public awareness and support. Actions such as vandalism, harassment, and blockades, if deemed inappropriate by a large cross-section of the population, can have negative repercussions, including declining public support for the environmental cause, creating opportunities for opposing forces to discredit the movement, undermining the effectiveness of other forms of activism, and risking being weaponized for political and economic purposes.

We believe that activists should avoid such actions and concentrate on educating the public about climate change and other environmental concerns, promoting an eco-surplus culture based on pro-environmental norms, practices, and values to reduce negative anthropogenic impacts on environments and conserve and

restore nature, and facilitating collaboration among governments, businesses, and citizens to formulate solutions (Nguyen & Jones, 2022; Vuong, 2021; Vuong & Nguyen, 2024). Businesses are fundamental to our societies as they create jobs and foster innovations. Excluding them from climate mitigation endeavors is almost impossible, and considering them enemies is unwise. Instead, businesses should be encouraged and motivated to be involved in the climate change adaptation and mitigation processes by changing their priorities and recognizing that environmental values must be considered fundamental outcomes in the business operation processes (Vuong, 2021).

It should also be acknowledged that while structural transformation and social transition are important for addressing climate change, doing it the right way is no less crucial. Priorities are shaped based on underlying core values, goals, and worldviews. For these factors to be transformed, deep leverage points (e.g., restructuring institutions with consideration for stability, reconnecting humans and nature, and rethinking how knowledge is produced and used) are required (Abson et al., 2017; Vuong & Nguyen, 2023). Such a transformation will risk destabilizing or even damaging the existing organizations and social and economic structures that are securing the lives of large groups of people if the process is not stimulated and facilitated through criteria based on consideration, learning, and adaptation. When existing structures are changed, a precarious equilibrium between promoting action that may be perceived as being advantageous for some while having adverse consequences others must be sought and maintained. A degree of social resistance to change and ensuing conflicts is inevitable, but keeping this under control is vital since intensified conflicts and wars do not help solve the climate problems but rather exacerbate them (Vuong et al., 2024).

The passion and commitment of climate activists should be acknowledged and advocated. As well as focusing on raising awareness and putting pressure on the political and economic systems to address the ongoing climate change, activists should also participate in supporting and facilitating the process to reduce the cost of structural transformation and social transitions. Climate change and extreme weather conditions should be viewed together with other urgent issues such as existing socio-economic injustices caused by pre-existing fragilities and inequalities on the ground since they are concomitant causes of current and ongoing disasters (Lahsen & Ribot, 2022). Climate activists' recognition of and contribution to addressing such critical issues are also essential for the movement's success in climate change mitigation and adaptation, especially when the Earth needs more human wisdom and solidarity than ever.

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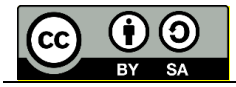

Original Paper

Young audiences and climate change.
Communication analysis in different public arenas

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Keywords: public arenas; climate change; young audiences; environmental activism; social platforms.

Abstract. *This article focuses on the agenda on the different public arenas in relation to the climate change discourse from the perspective of the young audiences: mass media arena, collaborative-activist arena, personal arena, and discussion arena. The variables represent the different axes of environmental sustainability, summarizing the Sustainable Development Goals of the 2030 Agenda and applied to the field of the media and communication. Research*

questions are related to thematic categories and level of engagement both, on the traditional media arena where young audiences are mere users of news and messages, and the public arenas where they turn out to be generators of information. The results show that mainstream media pay less attention to environmental issues from the perspective of activism, social justice or culture, and this can be a problem when it comes to connecting with young audiences which are very active and gives widely feedback for issues that have to do with these particular approaches and which are predominant on other arenas formed by social networks such as Instagram, Twitter and TikTok. Activism (climate action) turned out to be the topic that generates the highest level of response/engagement.

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1. Introduction: key concepts

The public sphere is a forum where deliberation processes happen and where the premises of *dialogue* and *consensus* become the central objectives of the *communicative action* (Habermas, 1962, 2010). With the rise of the digital space, the concept of differentiated public spheres has been reconsidered and new approaches have gained force. Schmidt (2013) focuses on interpersonal and mass media communication and their capacity to generate public arenas: *mass media*, *expert*, *collaborative* and *personal arenas*. Based on Schmidt, Lörcher and Neverla (2015: 21) propose a distinction between *mass media arena*, *expert arena*, *discussion arena* and *mass media-induced discussion arena* (MDA):

The Mass media arena has high barriers for communication and a dispersed anonymous audience as seen on journalistic websites. The communicators are usually journalists. The Expert arena also has high barriers for communicators and its audience is an expert community consisting of, for example, scientists or other specialised groups. It contains specialised information such as scientific journals or expert blogs. The Discussion arena - which is our extension of Schmidt's concept - is characterised by low barriers to communication and an audience that has not been further specified. Since access to communication is open and equal for everybody, diverse stakeholders can be found here. The MDA includes Discussion arenas with initial mass mediated input. e.g. reader comments found on online news media (Lörcher & Neverla, 2015: 21).

The effect of the online environment and social networks on human population has also focused the attention of several studies from an anthropological perspective (Geismar & Knox, 2021; Miller, 2016; Miller, 2021). Thus, Geismar & Knox (2021) shed light on the concept of digital anthropology as a stream of research that analyses the impact of digital technologies on the concept and experience of human beings.

Various studies point to social media and television as the main sources of information on climate change (Teso, 2021). Specifically, the results of the transnational study Digital News Report 2022 published by the Reuters Institute of the Oxford University, confirm that audiovisual content broadcast by the media continues to be the main source of information on climate change for citizens, including young people, although this group is more likely to seek alternative online sources of information and to follow activists and celebrities, who are becoming new communicators on the social media scene.

In this study we will focus on the agenda on the different public arenas in relation to the climate change discourse from the perspective of the young audiences: *mass media arena*, *collaborative-activist arena, personal arena* and *discussion arena*. Under *mass media arena* we understand the online edition of the mainstream media where the information in circulation is elaborated by journalists; that is, trained and accredited professionals. The *personal* and *collaborative-activist arenas* are related to social media platforms as communication tools. In the first case, we will focus on the arena formed by TikTok and, in the second, by Instagram and Twitter. We consider, on the one hand, that the arena formed by TikTok contains specific characteristics and must be analysed separately, and on the other hand, that this network is based on the individual interest of the user, which gives it this personal feature. It has a unique "For You" page, where most of the content viewed is randomly selected rather than drawn from a pool of "friends". TikTok generates a wider and more diverse audience than the traditional "follower"-based social media model (Ostrovsky & Chen, 2020). Finally, the *discussion arena* is composed of comments, likes and shared messages, i.e. of the audience's response.

There are many studies and evidence showing that Twitter and Instagram are the platform preferred by activists or social movements, acting as a real *collaborative-activist arena*: Li, M. et al. (2021), Reyes-Menendez et al. (2020). Xiong, Cho, & Boatwright (2019) analyse it as a tool for feminist social movements; Skill, Passero & Francisco (2021), Reyes-Menendez et al. (2018) and Carew (2014)

stress that Twitter is the platform where environmental activism materialises; Zoller & Casteel (2021) study a social media campaign of health activism in Twitter; Sinpeng (2021) describes young political activism, etc.; Yuen & Tang (2021) and Molder et al. (2021) analyse Instagram as an activist tool.

In recent years, a large number of publications on climate change focus on the study of the subject in relation to a specific event[1] and this is easy to understand since this perspective helps focus attention on specific moments with a high concentration of information flows that heighten the effect of the communicative phenomenon (Villagra et al., 2023). However, it is becoming increasingly necessary to also observe periods that are not directly related to major events, since there are serious differences in the intensity and direction of communicative cycles. Besides, biases can occur due to the specific topic of the event and the stakeholders involved. Moreover, many studies highlight the need to focus on longer timespans (e.g. Brossard et al., 2004; Nisbet & Huge, 2006; Shih et al., 2008).

Regarding the news and messages collection, in this article the authors decided to avoid moments which coincide with important events related to climate change (conferences, meetings, actions and protests, signing of agreements, etc.), with the aim to observe the communication flows in their natural state and not conditioned by the dynamics created by a specific situation. The study is part of a project that runs from 2021 to 2023 and includes several stages, however, the first collection of empirical material, which is the basis of this article, covers the period from 10 January 2022 to 10 February 2022. The coding and subsequent analysis of the results runs from March 2022 to January 2023.[2]

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1 The events that have traditionally escalated the media coverage of climate change coincide with events generated on the different agendas of the political, scientific and social spheres, in addition to extreme meteorological phenomena. The coverage of climate conferences stands out on the international political agenda. The international scientific agenda is the subject of media coverage with the presentation of successive scientific reports issued by the IPCC. Actions involving ecological activists stand out on social agenda, such as the arrest of Juan López de Uralde at the COP 15 climate conference held in Copenhagen in 2009. Other events that make the news are the frequent extreme meteorological phenomena, such as Hurricane Katrina. The presentation in 2015 of the Encyclical Letter *Laudato Si* by Pope Francis and the statement and actions by such leaders as Donald Trump also cause media coverage highs (Fernández-Reyes, 2018: 51).

2 Due to the journal's rules, the name of the project and the titles of the rest of the articles published will not be shown in the review period.

2. Methodology

2.1. Research technique and corpus

The technique applied to obtain data is the content analysis in primary data sources: mainstream media (digital edition) and social media. This is a research method that provides an objective, systematic and quantitative description of the content of all units with a view to their interpretation (Berelson, 1952: 18), although this is not just limited to content but also considers the structure, since it addresses both the meanings and the significance of communication (Bardin, 1986, p. 29). Accordingly, the paper analyses communication in different online media and sources, considering the characteristics of each public arena.

The content analysis is a technique of a systematic, objective, and quantitative nature (Wimmer & Dominick, 2011), although, as indicated by Gaitán and Piñuel (1998), the distinction between quantitative and qualitative is weak, because qualitative aspects can be found in all research based on a theory to build the scientific aim of the study. Accordingly, in relation to the different public arenas a qualitative sampling of a strategic nature, as explained before, has been performed for the choice:

- *Mass media arena*: the online edition of the mainstream media.
- *Collaborative-activist arena*: Instagram and Twitter;
- *Personal arena*: TikTok
- *Discussion arena*: comments, likes and shared messages.

The monitoring period for this cross-cutting study was defined trying to avoid events on the political, scientific and social agenda that have traditionally conditioned the coverage of climate change issues. Since this is an exploratory study, a single line of enquiry was carried out, lasting for one month from 10 January 2022 to 10 February 2022 (see annex).

In the case of the online publications of the mainstream media (*mass media arena*), the keywords "young people" and "climate change" were used as search filters. The concept of climate change can also be referred to as the "climate crisis", "climate emergency" and "global warming" (Erviti-Ilundáin, 2020), and hence these terms were also used as synonyms[3].

[3] The company that provided the monitoring of the online media was Kantar Media.

To identify the publications on the *collaborative-activist arena*, Instagram and Twitter accounts for the main associations of young climate activists in Spain were monitored. The number of accounts monitored is as follows: 12 Twitter accounts: "Fridays for Future"-"JuventudxClima" , "Extinction Rebellion (XR)" and their local and regional accounts; 7 Instagram accounts: belonging to "XR" and "Fridays for Future"-"JuventudxClima", and their local and regional accounts.

Similarly, the units of analysis corresponding to the *personal arena* correspond to publications in the accounts of young users of TikTok commenting on climate change, the climate crisis, climate emergency and global warming. The search begins with five main online environmental influencers and through their "followers" (young people under 30 who follow the influencer), a second account profile of an influencer was selected for each of these first five accounts. Then, after obtaining the five account profiles, another five are selected until the total number of profiles analysed is completed (the chain ends where the influencer accounts stop being of environmental content or are repeated).

Applying the foregoing criteria, 667 publications were obtained in the monitoring period, distributed as follows:

Online sources (mainstream media): A total of 768 publications on climate change were detected in the period, only 72 of which focused on the youth perspective.

Instagram: 31 publications.

TikTok: 388 publications.

Twitter: 176 publications.

This is a probe study, the results of which are not generalizable but descriptive – focusing on the description of certain dynamics.

2.2. Variables

The protocol of the analysis applied contains "formal variables" tied into the characteristics of the media and "content variables" obtained regardless of the media (Naccarato & Neuendorf, 1998). The formal variables are designed to identify the media and the name of the online sources in the case of the *mass media arena*, and the user's account in the case of *personal and collaborative-activist arenas*. In the case of the mainstream media (online publications), a second variable is used that is codified *a posteriori* to identify the type of source (website

of the online media, website of an institution, website of a news agency or content aggregator). If the publication corresponds to social media, the name of the media platform is stated, and the name of the account or user is recorded.

The content variables are designed to record the presence or absence of the following thematic categories in the publication, which represent the different axes of environmental sustainability summarizing the Sustainable Development Goals of the 2030 Agenda [4], and applied to the field of the media and communication.

Variable 1. Politics and climate change

Variable 2. Science and climate change

Variable 3. Economy and climate change

Variable 4. Culture and climate change[5]

Variable 5. Activism and climate change[6]

Variable 6. Social justice and climate change.

Numerical variables have also been used to measure and collect data relating to the engagement of the public in social media: These variables are:

- number of *likes*
- number of comments
- number of *retweets*
- number of visualisations.

The protocol has been applied systematically to the 667 publications. The data have been recorded in an Excel spreadsheet and then analysed using the programme *SPSS Statistics*. The protocol has been applied by six analysts, performing Krippendorff's (2013) Alfa test to measure the degree of inter-rater agreement or concordance, giving a result for the variable 1 and variable 2- 0.861; variable 3, variable 4, variable 5, variable 6 -1.

[4] The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015: https://www.undp.org/sustainable-development-goals.
[5] The concept of culture has been applied in its broad sense: culture and education, including the gender perspective.
[6] Based on the SDGs nº 13: Climate Action.

2.3. Research questions

The cross-cutting nature of the climate crisis has turned 'climate change' into a habitual reference on the traditional and social media, either as a main issue or as a secondary issue in the context of the discourse of many other crises and eco-social problems. This cross-cutting nature of the climate crisis coexists with a digital, hyperconnected and multi-platform communication ecosystem, such that the communication of climate change takes place simultaneously on different public arenas which, in turn, interact with each other.

The specific research questions used in this article are as follows:

Q.1. Predominant thematic categories on the different public arenas where the young people are the generators of content (c*ollaborative-activist arena and personal arena).*

Q.2. Predominant thematic categories on the different public arenas where the young people are, in general, users of content (*mass media arena*).

Q.3. Level of interference between *discussion arena* and *mass media/ collaborative-activist* and *personal arena.*

3. Results and discussion.

According to the results, the predominant thematic categories on the *mass media arena*, even when it is a question of a discourse directed at a young public, is based on *hard topics*; that is, climate change is reflected through the binomial Politics-Climate Change.

According to the data obtained, the predominant topic in the online version of the mainstream media is *politics*, with 45.8%, followed by *science*, with 12.5%, and thirdly, *activism*, with 5.6%. As regards the topic of *politics*, it can be observed that it coincides with other reports issued and which detect the same trend (Teso & Lozano, 2022). With this variable we refer to the news or messages that address the issue of climate change and the SDGs from a political perspective: political speeches and debates, political positions, measures proposed by the pollical parties or by Governments, etc.

On the other hand, the *mass media arena* is where the fewest number of activism messages are posted. The variable *activism and climate change* refers to information about movements and associations in defence of the environment, protests, but also to individual initiatives (especially in the case of social networks).

media/platform

			Instagram	Traditional Media	Tiktok	Twitter
Issue	Social justice and CC	Number	0	1	0	14
		% within media/platform	0.0%	1.4%	0.0%	8.0%
	Activism and CC	Number	20	4	205	90
		% within media/platform	64.5%	5.6%	52.8%	51.1%
	Activism+ social justice and CC	Number	1	1	0	12
		% within media/platform	3.2%	1.4%	0.0%	6.8%
	Culture and CC	Number	0	3	47	2
		% within media/platform	0.0%	4.2%	12.1%	1.1%
	Activism+ culture and CC	Number	1	0	7	1
		% within media/platform	3.2%	0.0%	1.8%	0.6%
	Economy and CC	Number	0	1	0	2
		% within media/platform	0.0%	1.4%	0.0%	1.1%
	Science and CC	Number	0	9	4	10
		% within media/platform	0.0%	12.5%	1.0%	5.7%
	Science+ activism and CC	Number	1	0	9	6
		% within media/platform	3.2%	0.0%	2.3%	3.4%
	Science+ activism+ social justice and CC	Number	2	0	0	0
		% within media/platform	6.5%	0.0%	0.0%	0.0%
	Science+ economy and CC	Number	0	3	0	0
		% within media/platform	0.0%	4.2%	0.0%	0.0%
	Politics and CC	Number	0	33	0	7
		% within media/platform	0.0%	45.8%	0.0%	4.0%
	Politics+ social justice and CC	Number	0	2	0	1
		% within media/platform	0.0%	2.8%	0.0%	0.6%
	Politics+ activism and CC	Number	1	1	0	3
		% within media/platform	3.2%	1.4%	0.0%	1.7%
	Politics and science and y activism	Number	0	0	0	2
		% within media/platform	0.0%	0.0%	0.0%	1.1%
	Not applicable/Did not answer	Number	5	8	116	24
		% within media/platform	16.1%	11.1%	29.9%	13.6%

Table 1. Content Variable-Media cross table. Source: Authors' own elaboration.
**CC: climate change.*

Another result indicates that news based on scientific data and discourses are concentrated exclusively on the *mass media arena*. Both, on the *collaborative-activist arena* and the *personal arena*, the interest in these contents is very low. The situation is worse in the case of information approached from an economic-financial perspective (economic consequences of climate change, costs of the measures, sustainability). The *economy and climate change* variable doesn't reach 2% of the total content in any of the arenas. Otherwise, we observe that this percentage

improves when it comes to *social justice and climate change*, especially, because of the results of the *collaborative-activist arena*. This is mainly due to the mobilizing nature of messages focused on the social cost of the current situation or of the proposals for improvement, kind of information highly used in this arena.

Finally, we detected high levels of content related to climate change developed from a cultural perspective (*culture and climate change*) in the *personal arena*. This is mainly due to the large number of publications on TikTok about ecological, sustainable artistic products, many of them posted for commercial purposes.

After presenting the data obtained through the statistical study, we proceed to answer the research questions:

Q.1. Predominant thematic categories on the different public arenas where the young people are the generators of content (c*ollaborative-activist arena and personal arena).*

Q.2. Predominant thematic categories on the different public arenas where the young people are, in general, users of content (*mass media arena*).

If we examine the impact of the predominant thematic categories in the different public arenas where young people are the generators of content (*collaborative-activist arena* and *personal arena*), we find that the variable *activism* stands out from the rest (64.5% of posts on Instagram, 51.1% of tweets and 52.8% of content on TikTok). The following variables of interest, *culture and climate change*, *social justice and climate change*, represent a fifth of the total content generated (20.1%). Also, we can conclude that the interest in topics related to the political (4% on the *collaborative-activist arena a*nd 0% on the *personal arena*), economic (1,1% vs. 0%) or scientific (5,7% vs. 1%) perspective is extremely low both on the *collaborative-activist arena* and on the *personal arena*, but that this result improves slightly if the activism component is added: *science and activism* -6.6% of all the publications on the *collaborative-activist arena* and 2,3% on the *personal arena*; *politics and activism* – 4,9% vs. 0%.

Regarding the thematic categories on the arena where young people are, generally, content users (the *mass media arena*) we observe the predominance of two topics: *politics*, used in 33 % of cases, and *science*, in 12.5 % of cases.

From this result, we can deduce that there is a significant difference between, on the one hand, the topics generated by young people, and, on the other hand, those addressed to them as an audience. This situation may cause the disconnection of the young audiences from the mainstream media and professional journalism when seeking information on climate change.

The next issue we are looking at has to do with the level if engagement of the young audiences: Q.3. Level of interference between *discussion arena* and *mass media/ collaborative-activist* and *personal arena*.

		Valid		Cases lost		Total	
Topic	Media/platform	No.	Percentage	No.	Percentage	No.	Percentage
Social justice and CC	Twitter	14	100.0%	0	0.0%	14	100.0%
Activism and CC	Traditional Media	2	50.0%	2	50.0%	4	100.0%
	Twitter	90	100.0%	0	0.0%	90	100.0%
	Instagram	20	100.0%	0	0.0%	20	100.0%
	Tiktok	205	100.0%	0	0.0%	205	100.0%
Activism+ social justice and CC	Twitter	12	100.0%	0	0.0%	12	100.0%
	Instagram	1	100.0%	0	0.0%	1	100.0%
Culture and CC	Twitter	2	100.0%	0	0.0%	2	100.0%
	Tiktok	47	100.0%	0	0.0%	47	100.0%
Science and CC	Traditional Media	6	66.7%	3	33.3%	9	100.0%
	Twitter	10	100.0%	0	0.0%	10	100.0%
	Tiktok	4	100.0%	0	0.0%	4	100.0%
Science + activism and CC	Twitter	6	100.0%	0	0.0%	6	100.0%
	Tiktok	9	100.0%	0	0.0%	9	100.0%

Table 2. List of likes by topic. Source: Authors' own elaboration based on the data obtained in the study.

The result show that *activism* (climate action) turned out to be the topic that generates the highest level of response/engagement both on the *collaborative-activist arena* and on the *personal arena*. In the case of the *personal arena*, the variable *climate change and culture* also features highly.

It can be observed that the most active social media in terms of the number of likes and comments is TikTok, where *activism* is particularly represented, followed by Twitter and Instagram, which also feature highly on this topic. Finally, the *mass media arena* barely generates a direct reaction among the audience in terms of feedback.

Finally, we should mention that one of the problems faced by studies comparing information flows on different platforms has to do with the difference in the total number of units of analysis. For example, TikTok generates a large number of messages and interaction, while mainstream media are at the other extreme, due to the nature of the message and its uses by the audience. So, when it comes

to establishing comparisons, the quantitative differences can be affected, and this can hinder or even invalidate approaches that seek to monitor all platforms simultaneously. Even so, we must continue to carry out comparative studies on information flows on the different platforms, given that it is a viable way to obtain information about certain communicative dynamics in all their complexity and even more so, when the public under study is made up of young prosumers.

		Valid		Cases lost		Total	
		N	Percentage	N	Percentage	N	Percentage
Instagram	Activism	20	100.0%	0	0.0%	20	100.0%
	Activism and social	1	100.0%	0	0.0%	1	100.0%
	Science and activism	1	100.0%	0	0.0%	1	100.0%
Traditional Media	Activism	2	50.0%	2	50.0%	4	100.0%
	Culture	2	66.7%	1	33.3%	3	100.0%
	Science	7	77.8%	2	22.2%	9	100.0%
Tiktok	Activism	205	100.0%	0	0.0%	205	100.0%
	Science and activism	9	100.0%	0	0.0%	9	100.0%
	Culture	47	100.0%	0	0.0%	47	100.0%
	Science	4	100.0%	0	0.0%	4	100.0%
Twitter	Activism	90	100.0%	0	0.0%	90	100.0%
	Activism and social	12	100.0%	0	0.0%	12	100.0%
	Science and activism	6	100.0%	0	0.0%	6	100.0%
	Social	14	100.0%	0	0.0%	14	100.0%
	Culture	2	100.0%	0	0.0%	2	100.0%
	Science	10	100.0%	0	0.0%	10	100.0%

Table 3. List of comments by platform/media. Source: authors' own elaboration based on the data obtained in the study.

4. Conclusions

The study undertaken has allowed us to address the research questions proposed in this study and to provide a dynamic approach to analysis, since it focuses on the study of public arenas that allows us to see how a young audience receives and shares information in relation to climate change based on the SDGs in each of these forums for interaction.

This is an exploratory study where the spontaneous discourse on climate change produced by the mainstream media and the activists and users of the social networks was analysed. The monitoring period was chosen with a strategic

criterion in order to prevent that a specific event may condition the media and social agenda. Likewise, the accounts followed in social networks have a strategic value for this study, as they belong to the main climate activist groups. It is therefore a non-probabilistic and qualitative sample, so the results obtained are not statistically representative, although they offer valuable data to formulate future working hypotheses that should be contrasted with statistically representative samples of the different arenas.

From the results obtained in this study and similar to findings in other studies cited in our article, it is clear that the mainstream media (mass media) follow traditional patterns of news coverage, opting for *hard topics*, which translates into a large number of news stories from a political or economic perspective. It is obvious that traditional media pay less attention to environmental issues from the perspective of social justice, culture or activism, and this can be a problem when it comes to connecting with the young audience, which is very active and gives widely feedback for issues that have to do with these latter approaches and which are predominant on other arenas formed by social networks such as Instagram, Twitter, TikTok.

It is becoming increasingly evident that young audiences demand access to information where they have the opportunity to leave an opinion or simply show their attitude. Interaction with other users is essential.

It is important to underline that the proposed structuring of each of the arenas should not be seen as fixed and immovable. Without going any further, the changes that are coming to Twitter, according to some forecasts, may bring this platform closer to TikTok and turns out, among other things, in a decrease in its use for mobilisation or protest, a characteristic that has accompanied this platform since its creation.

On the one hand, professional journalism is not covering all the aspects of interest for the young audiences regarding the Sustainable and Development Goals and as a result, the youngsters migrate to other spaces in search of information that is closer to their reality. To correct this situation, all the aspects included in the 2030 Agenda must be covered: social justice, peace, reduced inequalities, gender, education, etc., and especially the climate action. Finally, it is necessary to mention the need to increase news of a scientific nature and look for tools to make them accessible to the audience; the same happens with questions that have to do with the economic and financial implications of the climate change.

It is important to highlight that, although the role of the media (mass media arena) can contribute to knowledge and the collaborative-activist arena and personal arena can foster debate and social mobilization, the achievement and implementation of the SDGs is a complex phenomenon that requires a global commitment at all levels and the collaboration between countries and all social actors: governments, regional and international organizations, multinational businesses and entrepreneurs (Reyes-Menendez et al., 2023) and individuals.

To achieve this, it is necessary to rethink the current economic and political models, for example, it is required to ensure an economic development that reduces social inequality and poverty (Mboumboue & Njomo, 2016) and gives a voice and greater importance to developing countries. Munamati et al. (2016) also point out the importance of investing in education that enables the acquisition of the competencies and technical skills necessary to implement the innovative initiatives that are needed. Governments, for their part, should promote policies that favor the achievement of the SDGs by identifying long-term goals instead of short-term policies focused on the mandate (Van Vuuren et al., 2014).

Caiado et al. (2018) discuss the difficulties of implementation of the sustainable development goals and suggest that addressing the challenges posed by the SDGs requires: 1) greater investments in education and information, 2) political leadership and governance, 3) global integrated compromise and partnership, 4) innovative solutions and 5) aggregated and reliable indicators, which can assess the relative contribution of each SDG and their interaction with each other.

These five measures require leadership and, at the same time, involvement and participation of citizens, especially youngsters. For instance, decarbonization of the economy is an essential aspect for achieving the SDGs and, however, it is an issue rarely addressed on social networks. In addition to the above, the results of the engagement analysis (table 2 and table 3) indicate that political and economic issues barely generate interaction with the audience despite their relevance. The measures taken by governments and institutions and the commitments to decarbonize the economy are matters of utmost interest for the future of young people and must be rigorously incorporated into the social debate.

In summary, it is necessary to develop research that analyzes this complex phenomenon from different perspectives and the role that media and social media can have in young audiences to contribute to an in-depth debate on these issues as well as social engagement and mobilization.

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Supplementary Information

Annex 1: online source/account (social media) analysed
https://ojs.unito.it/index.php/visions/article/view/8014/7400

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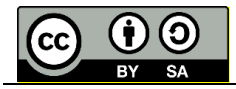

Original Paper

Beyond the Global Warming issue.

Understanding students' motivations as volunteers in youth environmental community

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Abstract. *Regardless of their status as environmental activists, student volunteers tend to have more complex motivations when deciding to join an environmental community. This study aims to understand more deeply the motivation of student volunteers joining an environmental community and*

to formulate an effective voluntary system for students focusing on synergizing personal and community goals. This study involved 20 student registrars of the local community concerning Circular Economy (CE) implementation in sub-urban areas. The findings reveal that the three highest motivations for student volunteers are to gain proper organizational experience, make new friends, and use community activities for other personal benefits. The results of this study place the motivation to save the environment in fifth place out of the seven motivations measured. The findings are then analysed with relevant theories and studies to create an environmental community management concept that is expected to be able to facilitate both the personal goals of the volunteers and the common goals of the community.

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1. Introduction

The participation of volunteers in the green community is one of many ways to create a green lifestyle among youth (Manik et al., 2021). Volunteering is generally associated with individuals willingly offering their time and skills to benefit society. However, there are instances where volunteer work may not be entirely voluntary. Here are a few examples of situations where volunteer work may not be entirely voluntary: (1) Mandatory Volunteerism, in some educational institutions or workplaces, volunteer work is a requirement for graduation, promotion, or other benefits. However, a study stated that although negative perceptions arise when students are forced to volunteer, after actually volunteering, most of them really like the experience and the experience of forced volunteering does not have a negative impact on voluntary intentions in the future (Henney et al., 2017). (2) Government Mandates, governments may institute mandatory community service programs, where individuals are required to engage in volunteer work as a condition of receiving certain benefits or to fulfil a legal obligation. It usually is found in the form of the corporate social responsibility (CSR) programs held by big corporates. In this case, CSR hard to distinguish from basic regulatory compliance and, hence, voluntarism does not necessarily lead to value creation (Dentchev et al., 2015). (3) Unpaid Internships, although not typically considered volunteer work, unpaid internships can blur the line between volunteering and mandatory work. In some cases, interns may be required to perform tasks that are essential to the organization's operations

without receiving fair compensation or educational benefits. Unpaid internship violates the principles of social representation and equality of outcomes especially in view of the fact that apprenticeships are usually undertaken in pursuit of high-status careers (Morrison, 2022).

Community empowerment can be realized in various programs (Priambodo et al., 2022), and one of them is through volunteering activities. Volunteering is a positive way to contribute to gain valuable experience (Sumihudiningsih et al., 2019). There are numerous opportunities available for students interested in environmental conservation, sustainability, and awareness campaigns. Some of them are joining an environmental community or organization online (Park & Yang, 2012) and offline (Curtis et al., 2013); engaging in tree planting initiatives (Elton et al., 2022; Moskell et al., 2011; Pike et al., 2020); assisting in wildlife conservation efforts (Scott & van Etten, 2013; Shum et al., 2023; Sujarittanonta, 2014); supporting sustainable agriculture initiatives (Niewolny et al., 2012; Sylvester et al., 2017; Tiraieyari & Krauss, 2018); educating others about environmental issues (Dlimbetova et al., 2019; Ongon et al., 2021); and volunteering with environmental advocacy groups (Cruz & Tantengco, 2017; M. F. Johnson et al., 2014).

A potential research gap in the field of student voluntary work could be focused on understanding the motivations and long-term benefits for students who engage in voluntary activities. While there is existing research on the positive effects of volunteering on individuals, there may be specific factors that influence student volunteers differently. The advance research findings of study revealed that youth volunteering only earns a psychological benefit only when it is done voluntarily regardless the fact that it does have a positive impact on educational attainment and even future earnings for both voluntary and involuntary youth service (Kim & Morgül, 2017). This sincerity issues lead us to deeper question: if it is not done voluntarily then what underlies them to do voluntary activities? Answering this question could provide a deeper understanding of student voluntary work, its benefits, and the factors that influence student participation. In terms of environmental voluntary activities, this knowledge can inform the development of effective strategies to promote and support student engagement in environmental volunteering, both within educational institutions and in the broader community.

2. Literature review

2.1. Youth-Led organization theory

To construct an extensive framework of positive youth development, a grand theory requires the integration of multiple theoretical orientations (Benson et al., 2006). The youth-led organization theory consists of at least three main theories which interconnected one to another, they are: human development, community organization and development, and social and community change.

2.1.1. Human Development. This theory explains that how does the capacity of young people to change fosters individual well-being and social goodness; how do contextual and ecological factors contribute to these changes; and, what are principles and mechanisms that essential to maximizing the dynamic and constructive interaction of individuals and contexts. The human development model is intended to have practical significance for mobilizing communities. Humans have several assets which are collected into 20 external assets and 20 internal assets (Benson, 2002). External assets degenerate into four categories: (1) support, including: family support, positive communication within the family, relationships with other adults, good neighbours, good school climate, and parental involvement in education; (2) empowerment, including the value of the youth community, youth as a resource, community service, security, family ties, school ties, neighbourly ties; (3) boundaries and expectations, including: adult role models, positive peer influence, and high expectations; and (4) constructive use of time. Meanwhile, internal assets have four categories: (1) commitment to learning, including: achievement motivation, school involvement, homework, bond with school, willingness to read, caring, equality and social justice; (2) positive values include: integrity, honesty, responsibility, self-restraint, planning and decision-making, interpersonal competence, and cultural competence; (3) social competence, which includes survival skills, peaceful conflict resolution, and personal strength, and (4) positive identity, which includes self-esteem, goals and a positive view of personal future.

2.1.2 Community Organization and Development. Community institutions influence youth development, but their presence is underappreciated (Wynn, 1997 in Benson et al., 2006). Youth participation in community institutions is voluntary because youth have the right to choose their participation, what they will do and how their participation will be. The organization ideally provides opportunities for young people to take initiative and participate actively. Examples of organizations youth can join include arts groups and extracurricular programs, sports clubs; community service groups and youth entrepreneurship;

and community libraries, museums, and the like. Youth support can best function when the surrounding environment strengthens and connects other sectors, especially family, school, health services, and other services. The main factor that is important for the effectiveness of youth organizations is high expectations; group problem solving; concrete products and performances; prospects for progress and expanded opportunities; adults act as caregivers, catalysts, and coaches; membership; availability and continuity; respect and reciprocity; and investments made by adults.

2.1.3 Social and Community Change. The third formulation in a comprehensive theory of positive youth development focuses on processes, strategies, and tactics that can directly or indirectly change contexts and communities (Benson et al., 2006). Change is a complex endeavour. Therefore, a comprehensive theory of change is needed to guide research and efforts to create change. Benson et al (Benson et al., 2003) suggest five synergistic strategies for community change. These five strategies, when adapted to the context of building a waste-aware student community in a tertiary institution, are: (1) involving adults: adult communities build sustainable relationships and build youth assets; (2) mobilizing youth involvement: youth use their capacities by building networks of peers in activities that help improve the quality of their communities; (3) activating the sector around youth to support community activities; (4) strengthening community programs, including regular programs, weekend events, and holiday events; and (5) influencing community decisions regarding financial, leadership, media, and policy resources so that they can be mobilized to support and sustain the transformation required in points 1, 2, 3, and 4 previously mentioned.

2.2. Environmental Volunteering Motives

Volunteers play critical roles in empowering society by leading environmental protection activities to address the environmental crisis. Some studies have explored the aspects that inspire individuals to participate in various environment voluntary actions. Measham & Barnett (Measham & Barnett, 2008) proposed six factors motivating volunteers to take part of environmental activities, including (1) contributing to community; (2) social interaction; (3) personal development; (4) learning about the environment; (5) a general ethic of care for the environment; (6) an attachment to a particular place. These findings are related to a study that placed helping the environment and enhancing personal use of the environment on the first and second motivation of environmental volunteers before then listed other factor, such as: furthering career goals, engaging in social

interactions, having opportunities for learning, being involved in effective projects, and expressing values and esteem (Jacobson et al., 2012). Recently, it is stated that the two most important reasons for volunteer participation in a novel experiment in Mexico was their interest in learning and their values or sense of responsibility for the environment (Shinbrot et al., 2023).

Interestingly, environmental issues are also marginally significant in other studies. Asah & Blahna (Asah & Blahna, 2012) stated that volunteers' frequency of participation is most motivated by personal and social benefits rather than by environment-related reasons. A majority of the volunteers had previously taken part in environmental education, however, only a small number of them practice it personally (Liarakou et al., 2011).

3. Research Methodology

3.1. Study context

This study employed a case-oriented understanding methodology with the objective of comprehending a phenomenon through the participant's perspective. The case-oriented understanding approach aligns with an interpretive research philosophy, eschewing the identification of causes and instead offering an alternative means of elucidating social phenomena (Pratama & Mukhlis, 2023). The current study was conducted in Universitas Negeri Semarang (UNNES), Central Java, Indonesia, which is a state university with conservatory vision. We established a community named Komunals which stands for "Komunitas Nol Sampah" (Zero-Waste Community) to promote a zero-waste lifestyle using Circular Economy (CE) concept among students in UNNES. After two months of online campaign, we invited youth in Semarang City to contribute to our activities through voluntary programs. The open recruitment for volunteers was open during 1st -17th May 2023 and as many as 20 people were registered in our program, including UNNES students, UNNES alumni, and youth who living around UNNES who have been working in different workplaces within Semarang City.

3.2. Study design

Using online questionnaire, we surveyed 20 people registered in Komunals voluntary program. The instrument to measure volunteers' motivation was adopted from Bruyere & Rappe (Bruyere & Rappe, 2007) who developed a total of seven factors influencing volunteer motivation, including: help the environment; career; user; learning; social; project organization; and values and

esteem. Respondents were asked to choose 37 motivational statements for volunteers, such as 'concern for the environment' or 'make contacts that might help career'. Additional survey items addressed demographic information (age, education level, etc.) and frequency of volunteering. The paper uses conceptual content analysis to examine the occurrence of each motivation indicator in the data set, measure validity and reliability, and identify means of each motivation indicator to justify the order of volunteers' motivations registered the Komunals voluntary program.

4. Results

Registrars consist of 8 males and 12 females and mostly in the range of age 19-25 years old (80.0%) and are studying as undergraduate program students in UNNES (75.0%). The detail of respondent's demographic characteristics can be seen in Table 1.

Gender	**%**	**Age**	**%**	**Education**	**%**	**Info**	**%**	**Team**	**%**	**Skills**	**%**
Male	40	19-20	30	Undergraduate	75	IG	35	Waste	35	Waste Sorting	40
Female	60	21-22	25	Postgraduate	35	Friend	40	BSF larvae	30	BSF farming	0
		23-24	25	Professional	15	Lecturer	25	Social Media	35	Organizing	90
		>25	20							Writing	30
										Photographing	30
										Graphic design	15
										Arts	5
										Act	5
										Video graphing	2
										Social media adm	2
										Other	5

Table 1. Demographic Characteristics

On the basis of Table 1, almost all registrars have experienced to be a member some organization (90%) and have knowledge about how to sort waste (40%). Some of them also have skills in writing (30%) and photography (30%), and

graphic design (15%) which will significantly support the community programs. Other skills including arts, act, social media administrator can also become great resources for the community, even though no one have been experiencing Black Soldier Fly (BSF) larvae farming to transform organic waste into BSF larvae as animal feed which is the main project of Komunals. The community offer three main projects for volunteers, they are: (1) waste inspection squad (waste); (2) farming squad (BSF larvae); and (3) administrator squad (social media). The distribution of volunteer interest in the tasks offered by the community is quite even. The postgraduate students and professionals tend to choose a remote job, such as social media administrator, while undergraduate students like to involve directly as the waste inspection squad and farming squad.

Table 2 provides information about factors influencing volunteer in registering as Komunals volunteers. As was stated before, there were 37 statements that can be chosen as the motivation of volunteers joining this community, which are sorted into seven main motives, including help the environment, career, user, learning, social, project organization, values and esteem. Registrars were instructed that it is possible to choose more than one statement as long as their choices can be best reflected their true motivations in joining Komunals.

5. Discussion

The finding of current study reveals that interestingly, 'help the environment' is not the first motivation of youth to register themselves as Komunals volunteers. The highest score of motivation is gained by 'project organization' motive (12.000), with the highest statement chosen by the respondents is respectively: be part of a well-organized project (90%); work with a good leader (50%); and know what is expected of me (40%). Some studies support that being part of a well-organized project can indeed be a motivating factor for students to volunteer since this kind of project has clear objectives (De Clerck et al., 2021), effective structure and planning (Joseph & Carolissen, 2022), professional development opportunities and develop wide collaboration and networking (J. E. Johnson et al., 2017). Meanwhile, being a volunteer under a great leader can be motivating for students due to the inspiration and guidance they provide (Dwyer et al., 2013), including the opportunity to learn from their experience, positive role modelling, building confidence and self-belief. The expectation towards leaders may vary personally. Therefore, it is recommended to communicate openly with the project leader to get a clear understanding of volunteers' expectations. Effective communication plays a pivotal role within the group dynamic, influencing decision-making processes, shaping attitudes, and

Statements	Rf(N)	Rf (%)	Mean	SD
Help the Environment			9.857	3.024
Concern for the environment	15	75		
Protecting natural areas from disappearing	6	30		
Do something for a cause that is important to m	7	35		
See improvements to the environment	9	45		
Ensure future of natural areas for my enjoyment	10	50		
Help restore natural areas	12	60		
Help preserve natural areas for future generation	10	50		
Career			8.800	4.919
Get a foot in the door at a place where I would like to work	4	20		
Make contacts that might help career	17	85		
Explore possible career options	7	35		
Experience will look good on resume	9	45		
Help me succeed in chosen profession	7	35		
User			10.333	6.506
Allow me to work on an area where I visit	4	20		
Enrich my future recreation experiences	17	85		
Enhance the activities I enjoy doing	10	50		
Learning			9.500	6.137
Learn about specific animals	5	25		
Learn about specific plants	4	20		
Learn about environment	17	85		
Observe Nature	12	60		
Social			10.750	4.924
Meet new people	17	85		
Work with friends	11	55		
See familiar faces	5	25		
Have fun	10	50		
Project Organization			12.000	5.291
Work with a good leader	10	50		
Know what is expected of me	8	40		
Be part of a well-organized project	18	90		
Values and Esteem			10.000	4.243
Feel better about myself	15	75		
To express my values through my work	7	35		
Feel needed	6	30		
To live closely to my values	12	60		

Table 2. Factors Influencing Volunteers' Motivation

contributing to human behaviour in the formulation of decisions (Thamrin Tahir et al., 2020).

Acknowledging the extensive history of engaging volunteers in environmental management is crucial, as changes in their motivations are significantly shaped by various factors such as structural factors and cultural values (Grönlund et al.,

2011). Structural factors include the political system, democratic history, the presence of a welfare state, economic development level, income distribution, and the age and ethnic composition of the population. Cultural aspects encompass values such as individualism, religiosity, and trust prevalent within a country.

In terms of political system and democratic history, engaging in formal volunteer activities for organizations or associations has a longer history in Western Europe. However, in Central and Eastern Europe, it emerged as a new phenomenon in the late 1980s and early 1990s following the collapse of the communist regime. Under communist rule, volunteering was mandatory for both children and adults, contributing to a less developed culture of volunteerism in the region compared to Western Europe (Sillo, 2016). Currently, the state of volunteerism in Central and Eastern Europe is evolving, with efforts to establish and promote a more robust volunteer culture, catching up with the longstanding tradition observed in Western European countries. Countries with a more extended history of democratic governance, such as Belgium, Canada, Finland, the Netherlands, New Zealand, the UK, and the US, tend to have a more robust voluntary sector. In contrast, transitional democracies like Croatia and Korea, along with communist countries like China and Croatia, generally exhibit a comparatively weaker presence in the voluntary sector.

Concerning the existence of a welfare state, in the early 21st century, faced with significant constraints, particularly in terms of funding and advanced technology tools, for cataloguing their natural resources, the government and scientists witnessed a surge in popularity of the environmental volunteer movement. The government in Australia, UK, USA, and Canada actively endorsed and supported this movement as a means to overcome limitations in resource allocation for comprehensive natural wealth inventories (Measham & Barnett, 2008). Volunteers played roles such as collecting botanical specimens and engaging in monitoring initiatives like bird-banding programs.

It's important to note that volunteer rates are cyclical and contingent on social and cultural changes. Events that serve as national traumas, such as wars, natural disasters, and the 9/11 attacks, can significantly impact volunteerism trends (Chambré, 2020). These occurrences often spark heightened civic engagement, leading to fluctuations in volunteer rates as societies respond to changing circumstances and priorities. In terms of culture, the variation in volunteering across different cultures could be attributed to communication anxiety (Stojcic et al., 2016). Individuals with a genotype linked to increased social anxiety may choose a less risky course of action when faced with uncertainty if they perceive

prosocial behaviour, such as providing assistance, as uncertain or potentially risky (Stoltenberg et al., 2011). In a parallel context, religious involvement consistently showed a significant association with heightened volunteering across diverse types and domains. The extent of this effect varied based on the specific types and domains considered, and even after accounting for various socio-demographic and denominational factors, indicating that the impact of background characteristics on volunteering is more intricate than previously recognized (Yeung, 2017).

Meanwhile, age matters significantly in understanding volunteer motivations, as younger individuals are primarily driven by the desire to foster interpersonal relationships and achieve relational outcomes, while older volunteers are more significantly motivated by a sense of service and community obligation (Omoto et al., 2000). Young volunteers may be more interested in the organization of a project rather than the specific goal of the community itself. It happens because young volunteers may see project organizations as platforms for personal development and growth (Han et al., 2019; Magrizos et al., 2021). Engaging in well-organized projects exposes them to new challenges, leadership roles, and opportunities to develop important skills such as problem-solving, communication, and teamwork. The structure and organization of a project can provide a supportive environment for their personal growth. However, it is important to note that while the project organization may initially attract young volunteers, the specific goal of the community and the impact of their work should still be meaningful to them (Measham & Barnett, 2008). The organization's effectiveness in communicating the importance of the community's goal and the impact of their volunteer work can further engage and motivate young volunteers to contribute to the specific cause. It is in line with the concept of Self-Determination Theory (SDT) that emphasizes the importance of intrinsic motivation and the satisfaction of basic psychological needs: autonomy, competence, and relatedness (Sheldon et al., 2022). By designing volunteer roles and activities that align with volunteers' interests, provide opportunities for skill development and growth, and foster a sense of connection with others in the community, you can enhance their motivation and engagement.

The second highest motive of volunteers registered in Komunals is social motive (10.750), which said that volunteers want to join the community because they want to meet new people, work with friends, see familiar faces, and have fun. Volunteering in a community setting provides opportunities to meet new people and expand social networks. It allows volunteers to connect with individuals who

share similar interests, values, and passions. This phenomenon can be explained by social exchange theory which highlights the importance of reciprocity and mutual benefits in social relationships (Lai et al., 2020). In the context of volunteer management, creating a supportive and inclusive environment where volunteers feel valued, acknowledged, and rewarded for their contributions can strengthen their commitment to the community's goals. Building connections and forming friendships within the community can create a sense of belonging and fulfilment (Allen, 2020). Volunteering with friends can be a fun and rewarding experience. It allows volunteers to strengthen their existing friendships while also working together towards a common goal. Having familiar faces around can create a supportive and comfortable environment, enhancing the overall volunteering experience. It is important for volunteer organizations to recognize the significance of these social aspects and create opportunities for volunteers to connect, collaborate, and have fun while contributing to the community's goals. By fostering a supportive and inclusive environment that values social connections and enjoyment, volunteer organizations can attract and retain enthusiastic volunteers (Worker et al., 2020).

Creating an environmental community management concept that effectively balances the personal goals of volunteers with the common goals of the community requires a thoughtful approach. There may not be a specific theory or study that provides a comprehensive framework for this concept. However, further discussion could get insights from various theories and research related to community engagement, motivation, and goal alignment, such as: (1) transformational leadership which focuses on inspiring and empowering others to achieve their potential by providing a clear vision, fostering a sense of trust and respect, and offering mentorship and guidance (Wilson, 2013); (2) participatory decision-making concept that encourages to involve volunteers in decision-making processes related to the environmental community in order to enhance their sense of ownership and commitment (Jerome et al., 2017); and (3) positive psychology which focuses on promoting positive emotions, strengths, and virtues (Mills et al., 2017). Applying positive psychology principles in environmental community management involves creating opportunities for volunteers to experience positive emotions, such as joy and gratitude, while engaging in meaningful activities.

6. Conclusion

Understanding students' motivations as volunteers in youth environmental communities is crucial for fostering active participation and creating sustainable change. The current study reveals that saving the environment is not always the primary motivation for volunteers in environmental projects. While the overarching goal of environmental conservation is crucial, volunteers often have a diverse range of motivations that drive their engagement. The motivation of registrars to join as environmental community members in this study based on the order from highest to lowest is as follows: project organization, social, user, values and esteems, help the environment, learning, and career. Theories and concepts discussed provide valuable insights, it is essential to adapt and tailor them to the specific context of managing an environmental community.

This study is subject to certain limitations inherent in its methodology. Primarily, the reliance on reviewing existing literature and research may restrict the depth of original data collection. Additionally, the use of a small sample size and the examination of only one geographical area limit the generalizability of the findings. Despite the limitations, it is crucial to emphasize that the findings in this research offer valuable insights. While the study may be considered an initial phase with a small sample size and limited geographical scope, the promising results obtained provide a foundation for future exploration. These insights, though preliminary, adds meaningful value to the existing body of knowledge and represents a valuable starting point for continued investigation and advancement in the field. Future research should explore cross-cultural variations in students' motivations for environmental volunteerism, conduct longitudinal studies on volunteer retention, and incorporate qualitative methods for a deeper understanding. Additionally, investigations into emerging trends, intervention studies for motivational enhancement, and expanding the geographical scope with diverse samples will further contribute to refining strategies for sustainable youth-driven environmental initiatives.

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Original Paper

A technocreativity learning model based on environmental volunteers for waste management

Can it support Green Campus and Green Entrepreneurship for students?

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Abstract. *The present condition of waste management in Indonesia has a negative impact on the environment. This study aimed to: (1) develop a technocreativity learning model based on environmental volunteers for waste management to support Green Campus and Green Entrepreneurship for students; and (2) evaluate the effectiveness of the technocreativity learning model. The research method used is the Research and Development (R&D) method with the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). Data collection techniques is used questionnaires, observation, documentation from the implementation of environmental volunteers. Data analysis was carried out by analyzing quantitative data utilizing tabulation analysis, percentages, and graphical representation. According to the findings of the study, the development of the technocreativity learning model based on environmental volunteers for waste management to support Green Campus and Green Entrepreneurship for students is still in early stages. These stages consist of an initial briefing for students, collecting trash, waste sorting, waste processing for the manufacture (biomol, eco-enzyme, ecobrick, organic fertilizer, briquettes), waste processing, and waste profits. The technocreativity learning model based on environmental volunteers for waste management is effective for supporting Green Campus and Green Entrepreneurship for students, because the longer an individual has been a member of an environmental volunteer group, the higher they interest in participating in Green Campus activities. Moreover, the longer a person has been a member of the environmental volunteer group, the more likely they are to become a Green Entrepreneur for waste management in university.*

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1. Introduction

Waste is a significant issue in Indonesian regions, particularly during development (Sharba, 2019). The rise in population and socioeconomic development has led to increased pollution and waste problems, impacting public

health and the environment (Karak et al., 2012; Olofinnade et al., 2021; Wilson & Webster, 2018). This includes areas around universities. It is crucial to balance the increase in landfills with public awareness for effective waste management (De S. Pereira & Fernandino, 2019).

According to the Minister of Environment and Forestry, the annual quantity of waste disposed is approximately 67.8 million tons, and this number will continue to rise following with the population. Besides from having a physical effect on the ecosystem, ineffective disposal of waste may affect the number of microplastics in the coast and sea, affecting the quality of the marine ecosystem that eats these microplastics. In the end, it impacts the general level of human health. Each year, between 4 and 12 million tons of plastic reach the oceans. Less than 20% comes from marine resources such as fisheries and fishing vessels, while the remaining 80% comes from sources on land that migrate into the sea through rivers (Anugrah, 2020; GESAMP, 2015). The growing amount of microplastics will have an influence on marine life (Jambeck et al., 2015).

Population growth, urbanization, and industrialization are causing an increase in waste problems in Indonesia (Olofinnade et al., 2021; Sharma & Jain, 2020; Wilson & Webster, 2018). The waste problem is closely related to environmental awareness and concern (Chang et al., 2020). The challenges to waste management include: (1) the lack of a waste management plan; (2) the lack of waste separation; (3) the low quality of public cleaning services; (4) the limited availability of environmental education; (5) the lack of social control over waste management policies; and (6) the lack of socialization programs for waste recycling cleaners (De S. Pereira & Fernandino, 2019). The waste management studies that based on community have been shown to be helpful in overcoming waste management issues (Mulasari et al., 2016; Wynne et al., 2018).

Students, as future leaders in society, are required to continually work for environmental quality (Debrah et al., 2021; Karak et al., 2012). It is essential to be prepared using the classroom-based learning model and become volunteers in maintaining a clean campus (Aleixo et al., 2021). Through waste care movement activities involving students as volunteers, environmental awareness will develop among them, driving them to demonstrate their values by developing solutions to ecological issues. Moreover, it also engaging in sustainable entrepreneurship through waste management (Barba-Sánchez et al., 2022; Thelken & De Jong, 2020).

Green entrepreneurship is a form of sustainable entrepreneurship that focuses on business development of natural products, conservation, lifesaving

equipment, and environmental community commodities. Universities as educational institutions can facilitate and enhance green entrepreneurship through sustainable value creation and activity strategies (Yasir et al., 2021). Through the right implementation of the technocreativity learning model based on environmental volunteer to support the Green Campus, the university will be clean and clear of waste, and therefore students will develop an entrepreneurship mindset (Barba-Sánchez et al., 2022; Thelken & De Jong, 2020).

The technocreativity learning model is a method of learning outside of the classroom that integrates technology and real-world application to increase student creativity (Perumal & Iyer, 2022). Prior studies have indicated that the technocreativity model will lead to an increase in students' creativity (Camacho-Miñano & Del Campo, 2017). Developing students' creativity affects their thought processes, enabling them to evaluate and generate solutions to challenges (Castillo-Vergara et al., 2014). The technocreativity model can be implemented in environmental learning in the form of waste management by actualizing the use of waste management technology and environmental initiatives (Carenzo, 2018). One method is to produce fertilizer from organic waste.

Technocreativity learning prioritizes service and community engagement, enhancing divergent thinking skills, collaboration, project management techniques, empathy, curiosity, and creativity (Lake et al., 2022). The collaboration of transdisciplinary students positively affects the quality of project learning and activity output (Biberhofer & Rammel, 2017). It also encourages critical thinking about waste issues in the community while increasing networking and communication skills (Klein, 2018). This contributes to the sustainability of waste care movement initiatives through environmental volunteering (Nordén, 2018).

The waste management system at the Waste Bank involves short-term, medium-term, and long-term planning. Short-term planning focuses on public education, while medium-term planning generates revenue from exchanging waste for recyclables. Long-term planning ensures uninterrupted waste mobility and conversion of waste into economically valuable products (Istanabi et al., 2022; Kristianto, 2020; Razzaq et al., 2021). The emergence of waste management problems can be linked to a lack of sorting systems and inefficient trash processing and recycling planning. Prior research has identified challenges in waste management including insufficient knowledge about waste separation and inadequate processing and recycling management. In many developing countries, household wastes are directly disposed at final disposal sites without prior sorting

efforts. To address these issues, the technocreativity model is utilized as a problem-solving approach in managing wastes through integrating technology with environmental awareness to enhance students' critical thinking abilities and creativity related to environmental issues.

This research has both theoretical and practical implications for the technocreativity learning model based on environmental volunteer for waste management, particularly in campus surroundings that is easily accessible. Theoretically, this research supports the theory that an individual's experience and active participation can enhance their skills and expertise (Wibowo et al., 2023). The practical benefit of this research aimed to reduce the negative impacts of waste on campus areas, particularly in the faculty canteens. This research also encourages students, particularly environmental volunteers, to care about waste for a clean and healthy campus, as well as fostering an entrepreneurship mindset among students. Based on the background of the identified problems, the objectives of this study are the following: (1) to develop the technocreativity learning model based on environmental volunteers for waste management to support Green Campus and Green entrepreneurship for students; (2) to evaluate the effectiveness of the technocreativity learning model based on environmental volunteers to support Green Campus and Green entrepreneurship for students.

2. Materials and methods

2.1 Research location

The research was conducted on Universitas Negeri Malang area on Jalan Semarang 5, Malang, Indonesia. The learning activities conducted in plant nurseries areas, campus green open spaces, campus parks, and the compost processing facility, all of which are still located on the Universitas Negeri Malang areas.

2.2 Research design

This research is conducted using the Research and Development (R&D) method and the ADDIE model (analysis, design, development, implementation, and evaluation) (Sugiyono, 2010). The ADDIE development model was chosen because it is a systematic model that is consistent with the theoretical foundation of the learning design. The ADDIE development research technique is carried out in a systematic method based on the development stages. The development research procedure is shown in Figure 1.

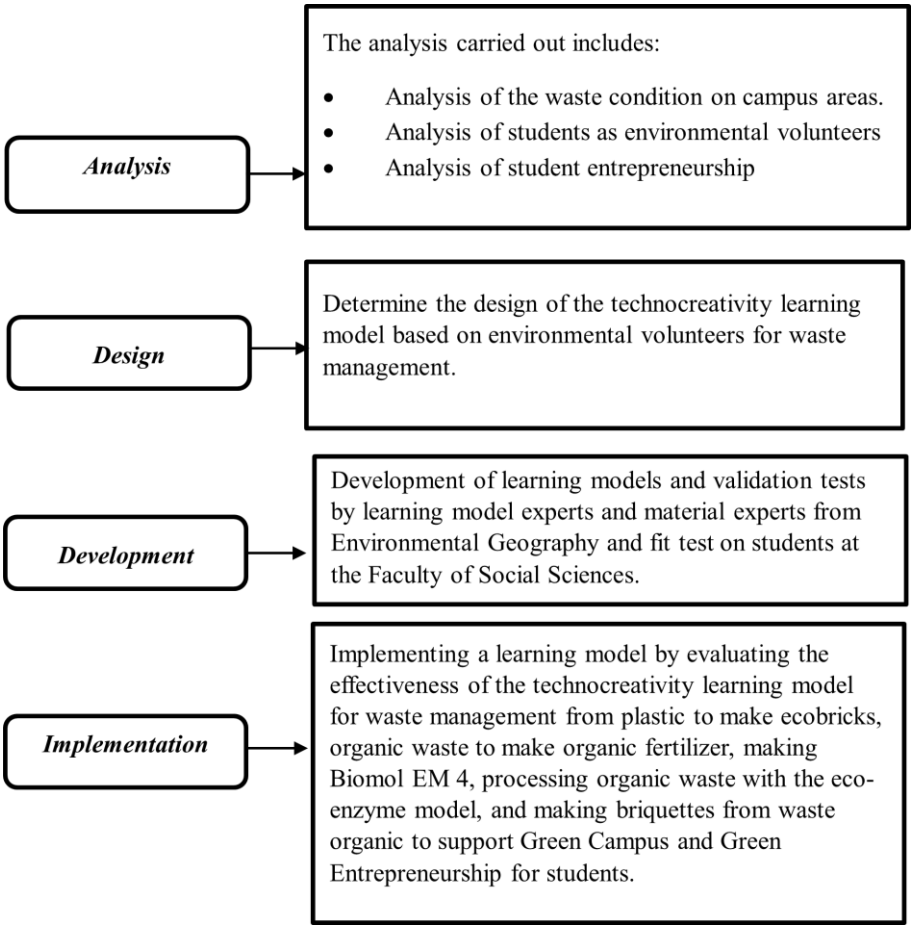

Figure 1. The stages in Research and Development (R&D)

2.3 Data collecting technique

Data collecting methods include questionnaires, observation, and documenting of environmental volunteer implementation. Waste management activities developed with technocreativity are divided into four groups: group 1 processes plastic waste using the ecobricks model; group 2 processes organic waste; group 3 processes organic waste using the eco-enzyme model; and group 4 processes organic waste using the briquette model. Each group is responsible for

processing sorted waste into economical products. The plastic recycling group is responsible for separating and preparing plastic waste as raw materials, which are then processed using ecobricks. The organic waste recycling group is responsible for sorting and preparing processed materials in the form of organic waste that can be converted into fertilizers, eco-enzymes, and briquettes. All groups have the duty and responsibility to educate other students and the general public about technocreativity in waste management by providing training and publication.

The data collected is quantitative and is calculated monthly to see: (1) how many waste volunteers are actively participating, (2) how many kilograms of plastic waste have been collected, (3) how many kilograms of fertilizer can be produced, (4) how many works can be produced from plastic waste, and (5) how many profits can be earned from waste management sales. The validation results of the learning model are carried out by experts and the fit test for the technocreativity learning model based on environmental volunteers are measured using test scores and the results of recycled waste products.

Furthermore, qualitative data were gathered through interviews regarding the level of satisfaction felt by environmental volunteers, the challenges faced in waste management, and the efforts made to ensure that Green Entrepreneurship and waste management by environmental volunteers on campus can be sustained.

2.4 Data Analysis

Data analysis was carried out in two methods, quantitative data analysis with tabulation analysis, percentages, illustrating in graphical form and the results of processing the data were discussed further from the results of observations.

The learning model was validated by experts and tested using Classroom Action Research on Environmental Volunteers to measure its effectiveness. The evaluation was conducted using test scores and surveys. The validation result is shown in the following Table 1.

3. Results and discussion

3.1 Developing the technocreativity learning model based on environmental volunteers for waste management to support Green Campus and Green Entrepreneurship for students

The study discussed the technocreativity learning model, which involves outdoor learning using technology and student participation in waste management

No	Aspects	Validator 1	Validator 2
1	Reasons for developing the Technocreativity Model	4	3
2	The purpose of developing the Technocreativity Model	4	4
3	Description of the Technocreativity Model	4	4
4	Steps of the Technocreativity Model	3	4
5	The suitability of the steps in the Technocreativity Model	3	3
6	The compatibility between the learning objectives and the subject topic	4	4
7	Effectiveness of evaluation	3	4
8	Completion of learning objectives.	3	3
TOTAL		28	29

Table 1. Experts' validation results for the Technocreativity Learning Model based on environmental volunteers

activities around the Universitas Negeri Malang campus areas. The model includes various waste management techniques such as eco-enzymes, ecobricks, briquettes, biomol, and compost production. It has been shown to positively impact students' attitudes towards environmental sustainability (Lestari et al., 2021). The method starts with educating students about waste management's importance and aims to instill a sense of responsibility for waste produced. This approach enhances student behavior identification by building fundamental knowledge onwaste management (Molina & Catan, 2021). The initial activity is shown in Figure 2.

Figure 2. Giving instruction to students at the beginning of the learning

Furthermore, students will apply waste management theory through practical exercises. This practice allows students to apply knowledge gained from educational activities and gain a deeper understanding of the implementation of accurate waste management, fostering environmental awareness (Shutaleva et al., 2020). In one activity, students create eco-enzymes by collecting organic waste from faculty canteens such as fruit and vegetable scraps. The goal is to reduce campus waste while producing eco-friendly materials. Students then prepare the necessary materials for creating eco-enzymes including scissors, jerry cans, water, and dissolved brown sugar.

Ecoenzym is a fermentation produced from organic waste (Benny et al., 2023). Ecoenzym is an environmentally friendly product composed of a mixture of natural enzymes, bacteria, and other substances that effectively decompose different forms of trash and organic materials (Istanti & Utami, 2022). Research has found that the utilization of ecoenzymes is effective in cleaning a wide range of surfaces, including as houses, bathrooms, kitchens, and even liquid waste (Suwarsono et al., 2023). Eco-enzymes function by decomposing organic waste into simpler substances, such as water and carbon dioxide, through the utilization of enzymes and microbes contained in their composition. This feature enhances its efficacy in eliminating stains, smells, and other contaminants, without needing for chemicals that might be hazardous.

After preparing the necessary tools and materials, the first step is to cut all the organic waste into smaller pieces. Next, all of the waste is placed in a half-full garbage can with water and given a 500-ml solution of brown sugar. Lastly, these cans can be sealed and reopened after three months. The university uses the eco-enzymes produced by the technocreativity model as room cleaners. The Production of eco-enzyme in shown in Figure 3.

The next learning activity in the technocreativity model is biomolecule synthesis (biomol). Similarly, the main components of organic waste are required for the production of eco-enzymes, biomol, or natural EM4, which are used to accelerate waste decomposition. Biomol is a product obtained through the fermentation of organic waste from vegetables and fruit. Biomol is produced by placing crushed or sliced vegetables and fruits into a container for fermentation. Optimizing the process of biomolecular fermentation by utilizing rice bran and inexpensive liquid sugar. The organic liquid fertilizer can be derived from the fermentation process, which typically lasts for about one month. The advantage of utilizing biomol is to enrich the soil with nutrients. Biomol consists of microorganisms that help the decomposition of organic waste and function as a biological controller. Biomol offers advantages as an organic pesticide. Prior

study has revealed that the utilization of biomol positively impacts the growth of sweet potato plants (Shaji et al., 2021). The use of biomol as a liquid organic fertilizer has an impact on the growth of corn plants. In addition, the utilization of Biomol liquid in the production of compost fertilizer might enhance the rate of decomposition of organic waste.

Figure 3. Eco-enzyme production from organic waste.

Furthermore, biomol is also known as natural EM4. Effective Microorganisms (EM4) is a fermented extract of microorganisms and organic waste that promotes plant growth. The use of Effective Microorganisms will accelerate the process of fermenting organic materials, hence enabling the absorption of nutrients for plant growth (Fuadi et al., 2022). These findings align with earlier studies indicating that Effective Microorganisms are utilized as components to accelerate the fermentation process in compost production (Puspitasari et al., 2022). In addition, research has shown that combining organic resources such as compost with Effective Microorganisms (EM4) can effectively enhance agricultural productivity (Siswati et al., 2009).

Therefore, at the beginning of making the biomol, students must search the canteens for organic waste in the form of vegetable and fruit waste. After organic waste has been collected, it is chopped and combined with rice bran and melted brown sugar to accelerate fermentation; the mixture is then sealed within one

month in jerry cans. The results of the biomol fermentation processes will be used as an activator for composting decomposition, allowing for the production of compost much more quickly. The process of producing and packing eco-enzymes can be seen in Figure 4.

Figure 4. a) producing biomol, b) packing eco-enzym, c) presenting in school exhibition.

Figure 3 demonstrated the production of biomol and eco-enzymes that carried out by students in the environmental volunteer group, along with lecturers and administrative staff. The purpose is to raise awareness about environmental responsibility within the academic community on campus. Different sizes of bottles contain eco-enzymes for various purposes such as room fresheners, floor cleansers, bathroom cleaners, and accelerating organic waste fermentation. These are limited to use within the campus area.

After the production of biomol, there was a learning activity focused on composting leaf waste. Compost made from leaf litter around the campus area can be used to fertilize plants and reduce waste. Composting is a simple process that does not require much effort. Students collected leaf debris for about a month before starting composting activities, which included two types of examinations. Compost management has environmental benefits by reducing the need for toxic fertilizers and decreasing waste production by adding organic liquids such as EM4 and biomol.

Composting leaf waste also helps raise public awareness about waste management and fosters environmental consciousness. Similar innovations are expected to continue in other universities, especially in Indonesia. The conversion of campus-area leaf waste into useful compost serves as an example of how organic materials can be processed effectively for plant fertilization without relying on expensive commercial products. The processing of organic waste materials can be seen in the following Figure 5.

Figure 5. a) decomposition of leaf waste with a grinding machine, b) refined organic waste, and c) compost fermentation boxes to accelerate decomposition

Organic fertilizer is a nutrient source for plants derived from organic substances, including plant wastes, animal feces and other organic components (Shaji et al., 2021). Organic fertilizer is created via a process of natural decomposition facilitated by microorganisms like bacteria and earthworms. These microorganisms turn the fertilizer into nutrients that can be readily absorbed up by plants (Roidah, 2013; Sayara et al., 2020). Prior study has revealed that organic fertilizer plays a significant role in environmental conservation by utilizing organic waste as a fundamental component for its production (Bahri et al., 2022). An important benefit of organic fertilizer is its ability to enhance soil structure and promote soil microbial activity, leading to improved soil fertility (Zhou et al., 2022). In addition, organic fertilizer has the capability to reduce soil erosion, enhance water retention, and minimize use on chemical fertilizers that can have negative impacts on the environment (Assefa, 2019). Further, the processing of organic waste into ready-to-use compost can be seen in Figure 6.

Figure 6. a) sorting organic waste materials, b) separating organic waste materials, c) Harvesting compost, d) Packing compost.

Figure 5 showed the first stage in processing basic organic waste materials, which involves the separation of organic and non-organic materials to enhance the effectiveness of the fermentation process. Then, the materials that have been stored in the trash container are regularly rotated on a set schedule of every 3 days. Afterwards, the compost is collected and put in plastic containers weighing either 5 kg or 10 kg, to be distributed to the academic community.

Leaf litter was quickly incorporated into a soil excavation, resulting in coarse compost after one month. In the second experiment, the collected leaf waste was ground with a machine and treated with a solution of EM4 or biomol from previous fermentation. The modified storage box accelerated decomposition, producing quicker and more uniform compost used as organic fertilizer for campus plants. This approach also supports recycling efforts and reduces the need to purchase additional compost for campus surroundings.

Figure 7. a) Applying fertilizer to sweet potatoes (Ipomoea batatas L), b) fertilizing herbal plants.

Figure 7 demonstrated the use of compost for food and herbal plants on campus, aiming to reduce operational expenses. The selection is limited to prolific plants that can be immediately used by the academic community, aligning with the objective of managing the campus as a green environment with zero waste indicators. Waste management strategies should be implemented for effective utilization and recycling of campus waste.

The next learning activity is ecobrick construction. Created from plastic trash, ecobricks are a creative way to recycle waste materials (Widiyasari et al., 2021). To minimize plastic waste, one can utilize ecobricks as a means of recycling plastic trash (Antico et al., 2017; Mihai et al., 2021). The process of creating

ecobricks is recognized as an environmentally friendly practice and serves as an effective way for reducing the accumulation of plastic trash (Siregar & Fitri, 2021). Prior studies have discovered that ecobricks have the potential to serve as construction materials, specifically for furniture in gardens and rooms (Akbar et al., 2023; Antico et al., 2017). Ecobricks, which are produced from recyclable plastic waste, are considered durable due to their resistance to decomposition (Cai et al., 2023). In addition, the making of artwork using ecobricks is also attractive to both local and international tourists (Adyantari, 2022). Similar with research findings, the utilization of ecobricks has been shown to enhance revenues in the tourism industry (Ariyani et al., 2021; Kiswantono et al., 2019).

Students collect plastic waste from canteens, cut it into pieces, and arrange it in a specific pattern to create ecobricks. This process shows that student involvement as environmental volunteers can reduce waste and enhance the campus environment (Sunassee et al., 2021). The production of ecobricks is shown in Figure 8.

Figure 8. The production of ecobricks from plastic waste.

The final step in the technocreativity learning model involves producing biobriquettes, which are natural charcoal made from organic byproducts like sawdust, coconut shell powder, and leaf waste compost. Briquettes are formed by compressing powdered or small fragments of organic or inorganic substances

to create a solid fuel (Kumar et al., 2021). They can be used as an alternative to wood or coal for industry and household use (MS et al., 2020), serving as an eco-friendly energy source with benefits including efficient combustion, practical transportation and storage, and the ability to be recycled from organic waste or biomass. The process includes crushing the collected waste into smaller pieces for processing with other materials before being combined with a binding agent (Haryanti et al., 2021; Marreiro et al., 2021), consisting of ash powder left over from burning, sawdust and coconut shells (Handayani et al., 2023). This mixture is then compressed using a press machine and dried using methods such as sunlight or dryers before they can be used as an alternative fuel for cooking or heating. The process of producing briquette is shown in Figure 9.

Figure 9. A) Processing organic waste, B) printing briquette, C) making sun-dried briquettes, D) packing briquette.

Figure 9 showed the method of producing briquettes from organic waste. The process begins with the collection and processing of organic waste, followed by

turning it into certain shapes and sizes through printing. Following the printing process, the briquettes get sun drying to decrease their moisture content. The briquettes are dried for around 5-7 days before being packaged in plastic and labeled with the brand.

The technocreativity model involves students as environmental volunteers to manage waste within the campus environment, inspiring creative and critical student thinking (Alm et al., 2022; Chusni et al., 2021). This can also lead to increased entrepreneurship skills for commercializing the results of waste management on campus (Owojori et al., 2022). Cooperation and commitment between students, professors, and the campus are essential for sustainable waste management with a broader impact.

3.2 Evaluating the technocreativity learning model based on environmental volunteers for waste management to support Green Campus and Green Entrepreneurship for students

The evaluation demonstrated that the technocreative learning model based on environmental volunteers, effectively enhances students' understanding and experience in waste management. This learning model fosters the development of students' critical and creative thinking skills to address waste problems by generating innovative solutions. This is evident from the activities in which students participate, including the production of compost, waste banks, and creative waste products. The results of student activities implementing the technocreativity learning model for one month are presented in Table 2.

No.	Activities	Unit	Total
1	Total quantity of active environmental volunteers	Person	35
2	Quantity of plastic waste collected	Kg	225
3	The quantity of fertilizer that can be produced	Kg	350
4	Plastic waste can be transformed into a material called Ecobrick	Pieces	24
5	Profit generated from the sale of organic waste management products	Rupiah	750
6	Quantity of Biomol that can be produced	Liter	30
7	The quantity of Eco-enzyme that can be produced	Liter	20
8	Quantity of briquettes that can be made from waste	Kg	50

Table 2. Student activities in implementing the Technocreativity Learning Model for one month

The number of students that participate in environmental volunteer organizations is an essential indicator for assessing their level of awareness and involvement in environmental conservation. This also demonstrates the

effectiveness programs aimed at fostering environmental awareness among students. The results of student participation in volunteer groups in shown in Table 3.

N.	Name of environmental volunteer group	Students	Percentage
1	The Ministry of Environment from Student Executive Board of Universitas Negeri Malang	2	4%
2	The Environmental Conservation Division from Faculty of Social Sciences Student Executive Board	10	20%
3	The Student Activity Unit "Bhumi"	9	18%
4	The Student Activity Unit "MPA Jonggring Salaka"	4	8%
5	The Environmental Division of Geography Department Student Association	8	16%
6	Graduate student environmental volunteers from the Faculty of Social Sciences	7	14%
7	Don't join the group	10	20%
TOTAL		50	100%

Table 3. Percentage of students in environmental volunteer groups

According to the table above, 80% of the 50 respondents analyzed were members of the environmental volunteers at Universitas Negeri Malang, while just 20% were not.

N.	Name of environmental volunteer group	Join period (in months)	Percentage
1	The Ministry of Environment from Student Executive Board of Universitas Negeri Malang	12	17%
2	The Environmental Conservation Division from Faculty of Social Sciences Student Executive Board	4	6%
3	The Student Activity Unit "Bhumi"	10	14%
4	The Student Activity Unit "MPA Jonggring Salaka"	24	34%
5	The Environmental Division of Geography Department Student Association	18	26%
6	Graduate student environmental volunteers from the Faculty of Social Sciences	2	3%
TOTAL		70	100%

Table 4. Join time of students in environmental volunteer groups

Based on the average duration of environmental volunteers have been a part of the group, the MPA Jonggring Salaka unit has the longest, at 24 months, while the Postgraduate Environmental Volunteer Group has the shortest, at 2 months. The following Table 5 showed the average comparison of the duration volunteers joined the environmental volunteer group.

N.	Name of environmental volunteer group	Amount
1	The Ministry of Environment from Student Executive Board of Universitas Negeri Malang	60
2	The Environmental Conservation Division from Faculty of Social Sciences Student Executive Board	62
3	The Student Activity Unit "Bhumi"	89
4	The Student Activity Unit "MPA Jonggring Salaka"	58
5	The Environmental Division of Geography Department Student Association	66
6	Graduate student environmental volunteers from the Faculty of Social Sciences	80
7	Don't join the group	56
TOTAL		67

Table 5. Average score of student awareness for campus environmental conditions

According to the results of the data analysis presented in the table above, the average score of student awareness for the condition of the campus environment is highest among UKM Bhumi members, with an average score of 89, and lowest in students who did not join to any environmental volunteer group. The following Table 6 demonstrated the average level of student awareness for the condition of the campus environment.

N.	Name of environmental volunteer group	Amount	Percentage
1	The Ministry of Environment from Student Executive Board of Universitas Negeri Malang	Rp 100.000	12%
2	The Environmental Conservation Division from Faculty of Social Sciences Student Executive Board	Rp 150.000	18%
3	The Student Activity Unit "Bhumi"	Rp 350.000	41%
4	The Student Activity Unit "MPA Jonggring Salaka"	Rp 150.000	18%
5	The Environmental Division of Geography Department Student Association	Rp 100.000	12%
6	Graduate student environmental volunteers from the Faculty of Social Sciences	Rp 0	0%
7	Don't join the group	Rp 0	0%
Total		Rp850.000	100%

Table 6. Sales value of waste management results on the campus

The Bhumi UKM group had the highest sales value for the results of waste management on the Universitas Negeri Malang performed by environmental volunteer students, followed by the Postgraduate environmental volunteer group and students who did not join.

Table 7 presented the results of evaluating students' attitudes towards waste management in implementing the Technocreativity Learning Model, based on environmental volunteers. The table provided a detailed illustration of the shifts in students' attitudes about the issue of waste throughout two implementation cycles of the learning model. This table served as a crucial tool for assessing the effectiveness and effect of the learning model used to enhance environmental awareness among students. It included attitude categorized into specific score ranges and measures the percentage changes in attitudes between the first and second cycles.

N.	Score	Qualification	Cycle I	Percentage	Cycle II	Percentage
1	91-100	Very High	0	0 %	9	25,7 %
2	81-90	High	0	0 %	16	45,7 %
3	71-80	Moderate	9	25,7 %	10	28,6 %
4	61-70	Low	8	22,9 %	0	0
5	< 60	Very Low	18	51,4 %	0	0
Total			**35**	**100 %**	**35**	**100 %**

Table 7. Evaluation results of students' environmental awareness towards waste in implementing the Technocreativity Learning Model based on environmental volunteers.

The results of evaluating student entrepreneurship in implementing the Technocreativity Learning Model based on environmental volunteers are presented in Table8. The table provided a detailed overview of the development of students' entrepreneurial characteristics during the two cycles of implementing the learning model. This table is a crucial tool for assessing the effectiveness of the Technocreativity Learning Model in fostering entrepreneurial skills among students. It included qualifying scores that measure the level of entrepreneurship and percentage changes between the first and second cycles.

Based on the description and assessment of the data in the table above, it can be concluded that student's awareness and participation in Green Campus activities increase the longer they are a member of the Environmental Volunteer group. And the longer a student has been a member of the Environmental Volunteers, the more likely it is to become a Green Entrepreneur in waste management.

N.	Score	Qualification	Cycle I	Percentage	Cycle II	Percentage
1	91-100	Very High	0	0 %	7	20 %
2	81-90	High	0	0 %	14	40 %
3	71-80	Moderate	10	28,6 %	11	31,4 %
4	61-70	Low	13	37,1 %	3	8,6 %
5	< 60	Very Low	12	34,3 %	0	0 %
Total			**35**	**100 %**	**35**	**100 %**

Table 8. Evaluation results of students' entrepreneurship in implementing the Technocreativity Learning Model based on environmental volunteers.

The sale of organic fertilizers can be considered an example of eco-friendly entrepreneurship because they can be used to solve environmental issues. This is in line with the positive impact of waste processing, which waste utilization and management has a positive impact on environmental resilience and economic health. The application of green entrepreneurship in the campus environment requires university support, as this will increase the intentions and role of students in green entrepreneurship implementation (Qazi et al., 2021).

Thus, waste management activities based on intensive environmental volunteers can be a suitable method of creative economy for enhancing student creativity and increasing their economic income (Istanabi et al., 2022). Student understanding of environmental issues contributes to ecological problems, particularly in waste management. The majority of students have a positive attitude and are aware of environmental issues in their environment, but due to a lack of practical education from educational activities that assist students in waste management, they also contribute to environmental problems. Therefore, a policy is required to incorporate environmental education into both academic and extracurricular activities (Debrah et al., 2021).

Environmental education is the involvement of students as environmental volunteers through the waste care movement (Boca & Saraçlı, 2019). In environmental education, universities should encourage their students to create actions and maintain their own internal environment, as this environment is a location of learning and students spend the majority of their time on campus (Aleixo et al., 2021). Environmental education can educate students to become future activists and prepare them for a sustainable environment. This is in line with the fact that environmental education can positively affect the perceptions, behavior, and commitment of pro-environmental students, thereby supporting the Sustainability Development Goals (SDGs) on campus (Yu et al., 2019).

Making strategic plans for the waste care movement on campus with the whole participation of the university community is essential for saving energy through recycle, reuse, and composting operations. Thus, these environmentally responsible activities can reduce waste production, thereby accelerating the implementation of sustainable environmental strategies (Ugwu et al., 2020).

4. Conclusion

The results of developing the technocreativity learning model for waste management based on environmental volunteers to support Green Campus and Green entrepreneurship for students are in the beginning of the learning stages. These stages consist of an initial briefing for students, waste collection, waste sorting, waste processing according to the purpose of manufacture (biomol, eco-enzyme, ecobric, organic fertilizer, briquettes), waste gathering, and waste profits.

The longer a student has been a member of the environmental volunteer group, the greater their awareness and involvement in Green Campus activities. In addition, the longer a student has been a member of the environmental volunteer organization, the more qualified they are to become a Green Entrepreneur in campus waste management.

This study offers suggestions in promoting environmental volunteer groups' participation in order to promote and invite students to care about the green campus movement. Conducting education and training to develop students' green entrepreneurship abilities. Collaboration with external parties to construct infrastructure as part of green campus activities. Further research will involve monitoring and evaluating the development and implementation of the technocreativity learning model based on environmental volunteer.

5. Limitation

The limitations of this study include its early stage of the development of the technocreativity learning model, which might hinder the comprehensive assessment of its long-term effectiveness. Although it shows a positive correlation between longer membership in environmental volunteer groups and increased interest in Green Campus activities and Green Entrepreneurship, its contextual focus on Indonesia may limit generalizability to other regions with different dynamics. Furthermore, it does not provide an extensive review of the fundamental processes. Moreover, there can be a lack of funding for the suggested partnership with outside parties to build the infrastructure needed for

green campus activities. These limitations provide important information for future research and projects in the fields of waste management and environmental education.

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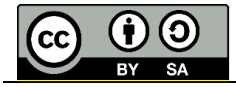

Original Paper

Young people's awareness, perception, and attitude towards Sustainable Development Goals in India

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Keywords: Sustainable development goals; awareness; attitude; perception; value propositions; worldviews; ecocentrism; anthropocentrism.

Abstract. *To understand how young people's attitudes toward sustainable development goals (SDGs) are formed, this research examines the roles that awareness, perception, and personal value propositions play. We have also tried to investigate the role that worldviews play in young people's attitude development. Our research showed that, in addition to people's knowledge, which is important in fostering a better attitude toward the SDGs, their value*

propositions and worldviews are also essential in understanding it. We found that people with anthropocentric worldviews will specifically have a better attitude toward and perception of sustainable development goals. The study's findings add to the body of knowledge already available on sustainable development goals by offering empirical proof of the relationship between knowledge, perception, value propositions, worldviews, and attitudes toward such goals. This study also revealed that young people's value propositions have a significant impact on how they feel about and perceive sustainable development goals. Therefore, it is crucial to develop policy-level interventions that could result in better human values among young people.

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1. Introduction

Sustainable Development Goals are the global goals for ensuring sustainable development. These integrated goals aim to create a better and sustainable world by the year 2030. Ending poverty, fighting against inequality, ensuring good health and well-being, providing quality education, facilitating decent work and economic growth, etc. are some of the ways through which the world can move towards sustainability. Business organizations, Governments, and individuals need to work together to create a better future for everyone on this planet. It is imperative to raise the awareness of these global goals among the public and to create partnerships for the implementation of various activities targeting the attainment of these goals. Integrated efforts are required to address the concerns raised by these goals. In this context, higher educational institutions have to play a significant role in spreading the awareness of SDGs among youngsters and in molding their attitude and perception of sustainable development goals. It is against this background the current study attempted to assess the awareness, attitude, and perspectives of young people towards sustainable development goals.

Awareness is a mental ability that allows one to selectively focus attention into specific moments in the past, present, or future (Eileen, 1968). It is an emotion that transcends the degree of sensitivity that directs behavior (Suzanne, 1967). According to Funk & Wagnalls (1968), awareness is knowledge derived from sensory or intellectual evidence, and they contend that the term "concept" refers

to more than merely a cursory recording of a sensation, perception, or situation. Awareness of SDGs indicates the level of information possesses by someone regarding the concept of sustainable development goals, as a result they assign importance to SDG practices (Jati et al., 2019). According to Gutwin & Greenberg (1999) Awareness is information regarding a particular environment, and changes in that environment. The term awareness is defined in the current study as the extent of information possessed by someone about something.

The way one sees the world is perception. According to Markus & Kitayama (1991), people from different cultures perceive things very differently. As Singer (1987) points out, "We experience everything in the world not as it is—but only as the world comes to us through our sensory receptors," we selectively process and only take in a portion of the information from our surroundings. According to Nurohman (2018), "perception is a word that is directly related to human psychology." It has been described in a variety of ways, such as an intentional act of observing one's environment through physical experiences, demonstrating one's ability to perceive. According to Sahal (2010), perception manifests as a viewpoint regarding a phenomenon and is an actualization of the human brain process. We have adopted the definition of perception as in Sahal (2010) in this study. So, by perception we mean the viewpoints of people about something.

An individual's attitude refers to their perspective and assessment of something or someone, their inclination or propensity to react favorably or unfavorably to a particular concept, item, person, or circumstance. It is typically organized into three categories: behavioral (actions or stated intentions toward the object based upon the "cognitive" and "affective" responses) and cognitive (perceptions and beliefs). Affective (likes and dislikes, feelings, or evoked emotions) is another dimension (Vargas-Sanchez, Plaza-Mejia & Porras-Bueno, 2016). According to Venes (2001), attitude is behaviour based on conscious or unconscious mental views developed through cumulative experience." Three crucial characteristics of a "attitude" are that it is bipolar, contains a cognitive, affective, and behavioral component, and is a reaction to a stimulus. These qualities cover every facet of cognition and conduct (Altmann, 2008). Unal and Iseri (2012), claimed that attitude is a condition of mental and emotional readiness that is developed via experiences and that has a guiding or dynamic influence on a person's behaviors toward everything and everyone. In this study, attitude is taken as the perspective and behavior of people based on their experiences.

Value proposition in this study is taken as the personal values possessed by people. It is about what we do and how we do it (Kelly, 1979). According to Schwartz (2012) there are 10 basic human values such as universalism, self-

direction, tradition, security, power, achievement, hedonism, stimulation, conformity and benevolence. Individual values, in Schwartz's view, are responses to the three universal needs of human existence—the need for people to survive and thrive as groups, the need for agreement in social actions, and the needs of people as biological organisms (Schwartz, 1992).

Worldviews is all about how one perceives the world around him/her. Two types of worldviews are dealt with in this study. They are ecocentricism and anthropocentricism. Ecocentricism in this study encompasses the concern for the environment and the ecosystem, while anthropocentricism is used to denote concern for human welfare (Kopnina & Cocis, 2017).

Garcia-Feijoo, Eizaguirre & Rica-Aspiunza (2020) conducted a systematic review of sustainable development goals deployment in B-schools using the web of science, Scopus, and Eric databases. After applying the multi-stage exclusion process, they have concluded that business schools play a significant role in attaining sustainable development goals. The study also provides insights into how business schools can integrate SDGs into their core activities. The authors recommended more proactive responses integrating the creation of awareness, generating paradigm shifts in attitude, facilitating cooperation, partnerships, etc. through clubs run by students, innovative teaching-learning methodologies, and student co-curricular activities. The study also provides the existing gaps in the literature and directions for future research.

Existing literature revealed that most studies are conducted at regional as well as international levels to assess the attitude of public towards the sustainable development goals (GlobeScan, 2016) A survey conducted among 28 European Union member states in the year 2015 reported that around 36 percent of the Europeans are aware of sustainable development goals (Eurobarometer, 2016). According to Devcom (2017) among the general public, young people are more aware of sustainable development goals. Guan et al. (2019) investigated the public support for sustainable development goals in China. They have used the heuristic–systematic model of Chaiken (1980) for understanding how the value prepositions and knowledge levels of the general public lead to public support towards sustainable development goals. Based on a survey conducted among the public in 5 cities in China, they concluded that public support for SDGs in China is primarily determined by demographic factors such as age, gender, and educational qualifications. Value propositions and knowledge levels of the public interact with each other and acts as a decisive factor in their support of SDGs. The study also revealed that Chinese people predominantly view sustainable development goals as part of developmental policy initiative rather than

considering them as part of environmental policy initiative. Guan et al. (2019) concluded that most of the studies exploring the support for SDGs are reporting either the status-quo or the trends over some time and are not driven by theoretical support. Most of the studies are focusing one or two of the goals specifically and are not covering SDGs as a whole.

Attitude is a concise assessment of a psychological object that can be expressed in continuums of harmful-beneficial, pleasant-unpleasant, good-bad, and likable-dislikable (Ajzen & Fishbein, 2000; Eagly & Chaiken, 2007; Petty, Wegener & Fabrigar, 1997). People generate attitudes towards a topic or a concept by following either the heuristic processing approach or the systematic processing approach. While the heuristic processing approach explains how value prepositions influence the attitude, the systematic processing approach reinforces the role of awareness and knowledge in forming the attitude (Guan et al., 2019). Value propositions of individuals towards nature and society can be either derived from their worldviews like anthropocentrism or ecocentrism, post-materialist values, and altruistic values. Anthropocentrism holds the view that human beings are the most important on the earth, while ecocentric people believe in the importance of nature. So, ecocentric people are said to have a better attitude toward the environment (Schultz et al., 2004; Thompson & Barton, 1994; Kopnina, 2013). Hence, we propose that:

H1: Young people with ecocentric worldviews exhibit a positive attitude towards sustainable development goals.

H2: Young people with anthropocentric worldviews exhibit a negative attitude towards sustainable development goals.

H3: Young people with ecocentric worldviews exhibit a better attitude towards sustainable development goals.

Relying on the systematic processing view of attitude formation as proposed by Guan et al. (2019), we hypothesized that:

H4: Young people's awareness of SDGs will have a positive effect on their attitude towards sustainable development goals.

H5: Young people's perception of SDGs will have a significant effect on their attitude towards sustainable development goals.

H6: Young people's attitude toward SDGs will have a significant effect on their perception of sustainable development goals.

Extant studies also revealed that the personal values of individuals play a significant role in formulating their attitude towards sustainable development goals (Cirnu & Kuralt, 2013; Xu & Fox, 2014; Brunoand Lay, 2008). Personal values have a big impact on how people feel about sustainable development and its underlying principles (Schultz & Zelezny, 1999; Stern, 2000; Tuziak, 2010; Hards, 2011; Bernat, 2012). In 2005, Hemingway made the argument that personal morality, motivated by a person's own socially conscious personal beliefs, may also play a role in the promotion of social responsibility. Personal values are the subjective beliefs people have that they are connected to affect, referring to objectives that inspire action, transcending particular circumstances, serving as standards of evaluation, ranked in order of relative importance, and directing people's behaviour (Schwartz, 2012). Personal values, in Schwartz's view, are answers to three universal conditions for human existence: the need for people as biological beings, the need for social agreement, and the need for group survival and well-being (Schwartz, 1992). Ten fundamental individual values have been theorized by Schwartz and colleagues, and empirical evidence has been provided to support their claims (Schwartz, 1992; Schwartz & Boehnke, 2004). These include Universalism, Self-Direction, Tradition, Security, Power, Achievement, Hedonism, Stimulation, Conformity, and Benevolence. Values have particular motivations and objectives; therefore, the substance of any given value is compatible with some and incompatible with others. The circumplex paradigm, in which compatible values border on each other and oppose those that are incompatible, is the most frequently acknowledged way to describe individual values. The paradigm emphasizes the conflict between maintaining the status quo and changing it while also simplifying these compatibility-incompatibility relations within a two-dimensional structure, notably Self-Enhancement vs. Self-Transcendence and Conservation vs. Openness (emphasizing the dichotomy between personal- and other-related interests) and, thus, we propose that:

H7: Personal values of young people will have a positive effect on their attitude toward sustainable development goals.

The current study is an attempt to understand the awareness, attitude, and perception of young people on sustainable development goals. The study attempts to answer specifically, the research questions such as, How their attitude toward SDGs are formulated? How precisely the awareness and attitude influence their perspectives? and whether their attitude towards sustainable development goals is influenced by the nature of their world views. How personal values of young people impacted their attitude toward sustainable development

goals? It was also attempted to identify the influence of demographic factors on young people's attitude towards sustainable development goals.

2. Materials and Methods

The overall purpose of this study was to explore the awareness, perception, and attitude of young people towards sustainable development goals. The participants for this study were young people in India. The youth population is taken as those belonging 18 to 28 years of age. An online survey method was used for this study. The study used a descriptive research design to carry out research. The constructs used in this study were world views, awareness, perception, and attitude. These constructs were measured using a five-point Likert scale with responses ranging from strongly disagree to strongly agree. The construct's awareness and world views in this study were measured using a five-item scale as in Guan et al. (2019), The constructs attitude and perception were measured using a 12-item scale developed by Balakrishnan, Tochinai & Kanemitsu (2020). Personal values were assessed using a 21- item version of the Portrait Value Questionnaire developed by Schwartz (2003). So, the survey instrument used was a questionnaire with 50 indicators. Questionnaires were sent through e-mail to the participants. Validity and reliability were tested through a pilot survey among 30 young people from various parts of the country, before conducting the original study. Data were collected from 640 young people from March – April 2022. Around 9 questionnaires were found to have inconsistent information or mistakes in responses and hence, were removed from the sample. So, the final sample size for this study is taken as 631 respondents. All statistical analysis was carried out with IBM SPSS Statistics 25.0 and Stata 17.0 software. We have used multiple regression analysis to explore the relationship between the variables (see Annex 1).

The regression models to test the relationship between the dependent and independent variables are as follows:

$$Att\_Sdg = \beta O + \beta 1Aw\_Sdgt + \beta 2Per\_Sdg + \beta 3World\_ViewEcot + \beta 4Per\_Valut + \beta 5Aget + \beta 6Gender + \beta 7Edut + \beta 8Strem\_edut + et \quad (1)$$

$$Per\_Sdg = \beta O + \beta 1Aw\_Sdgt + \beta 2Att\_Sdg + \beta 3World\_ViewEcot + \beta 4Per\_Valut + \beta 5Aget + \beta 6Gender + \beta 7Edut + \beta 8Strem\_edut + et \quad (2)$$

$$Att\_Sdg = \beta O + \beta 1Aw\_Sdgt + \beta 2Per\_Sdg + \beta 3World\_ViewAnthrot + \beta 4Per\_Valut + \beta 5Aget + \beta 6Gender + \beta 7Edut + \beta 8Strem\_edut + et \quad (3)$$

Per_Sdg = þO+ þ1Aw_Sdgt + þ2Att_Sdg + þ3World_ViewAnthrot + þ4Per_Valut + þ5Aget +þ6Gender+ þ7Edut + þ8Strem_edut+ et (4)

Where Att_Sdg = attitude towards SDGs, Aw_Sdg = level of awareness, Per_Sdg = perception of SDGs, World_ViewEco = ecocentric worldview, þ3World_ViewAnthro = anthropocentric worldview, Per_Valu = personal values

3. Results

We examined the nexus between youth's awareness, perceptions, personal value propositions, and attitudes toward sustainable development. The data collection instrument consisted of various constructs to indicate the constructs such as awareness, perception, personal values worldview, and attitude. Table 1 gives the descriptive statistics of these constructs.

Constructs	N	Minimum	Maximum	Mean	SD
Worl_ViewEco	631	1.00	5.00	2.300	0.49142
Worl_ViewAnthro	631	1.00	5.00	3.300	0.49142
Per_Valu	631	1.00	5.00	3.247	0.00245
Aw_Sdg	631	1.00	5.00	2.828	0.44989
Att_Sdg	631	1.00	5.00	3.619	0.31233
Per_Sdg	631	1.00	5.00	2.058	0.32940
Age	631	17.00	28.00	19.54	1.41

Table 1. Descriptive Statistics of the constructs

It is evident from Table 1 that the mean awareness level of participants is 2.83, which is indicative of the fact that the participants are aware of sustainable development goals to a considerable extent. For the construct ecocentric worldview, the mean value is 2.3 which means that even though they are aware of sustainable development goals, they tend towards human orientation, rather than environmental orientation. The construct anthropocentric worldview also is having an average value of 3.3, which is above the middle value that is 2.50,

and, hence confirming the earlier finding that the participants are more oriented toward anthropocentrism. The average attitude of the participants towards sustainable development goals is favourable with a mean value of 3.619, while most of them perceive sustainable developmental goals positively with an average perception level of 2.058. The average age of the participants was 19.54.

To understand the relationship between awareness, perception, worldview, and attitude towards sustainable development goals, the authors used regression analysis. Four regression models were run to explore the underlying relationships. The first model was to test the relationship between the participant's level of awareness, perception, personal values, and attitude toward sustainable developmental goals. The second model is intended to test how the participant's level of awareness, personal values, and attitude toward sustainable development goals influences their perception of sustainable development goals. The third model explores the relationship between the participant's level of awareness, perception, personal values, and attitude toward sustainable developmental goals when their worldview differs. The fourth model tested how the participant's level of awareness, personal values, and attitude toward sustainable developmental goals, influences their perception of sustainable development goals with differing worldviews.

In the first model – the attitude model, we examined how young people's awareness of SDGs, their value propositions, and perception of SDGs impact their attitude toward sustainable development goals. Our dependent variable in this model is young people's attitude towards Sustainable development goals, independent variables are awareness, perception, value propositions as indicated by their personal values, age, gender educational qualification and stream of education. The results are given in Table 2.

The R-squared and adjusted R-squared values are 0.482 and 0.467 respectively, indicating that around 47 percent variation in the dependent variable is explained by the independent variables together. The results indicate that the model proposed in the current study to examine the relationship between the variables is statistically significant (F statistic – 4.784, p= 0.006). All the independent variables together were capable of explaining young people's attitude toward sustainable development goals with an R squared value of 0.482 and an adjusted R- squared value of 0.467. Hence, it is assumed that all the independent variables together accounted for about half of the variation in the dependent variable. Young people's awareness of sustainable development goals, their perception of SDGs, and their value propositions are all significantly and positively influencing their attitude towards SDGs (coefficients: 0.535, 0.241, 0.358). It is also inferred

Dependent Variable: Young people's attitude towards sustainable development goals
Method: Least Squares Sample: 631

Independent Variables	R-squared & Adjusted R-sq.	F statistic & ModelSignificance	Coefficient	St. Error	t-Statistic	Sig.
Constant			10.540	8.923	0.986	0.004
Aw_Sdg			0.535	0.099	1.458	0.000**
Per_Sdg	0.482	4.784	0.241	0.126	1.234	0.034**
Per_Valu	(0.467)	(0.006)	0.358	0.432	1.065	0.000**
Age			0.344	1.055	2.867	0.078*
Gender			0.137	0.166	1.367	0.052*
Edu			0.456	1.149	1.316	0.000**
Strem_Edu			0.064	1.003	2.978	0.529

Table 2. Awareness, perception, value propositions and attitude towards sustainable development goals – Model 1. Source: Regression results. Note: Figures in parenthesis indicate the adjusted R-squared and model significance values. *significant at 10%, ** significant at 5% level of significance.

that the constructs, awareness, perception, and personal values are statistically significant in explaining the participant's attitude towards sustainable development goals ($p<0.05$). It was also attempted to find out how the demographic factors influence the attitude towards SDGs. The findings indicate that the demographic constructs, age, gender, and educational qualification are statistically significant in explaining young people's attitude toward sustainable development goals (p=, 0.078, 0.052, and 0.000). Overall results from Model 1 are indicative of the significant role of awareness, perception, and personal value propositions on attitude formation towards sustainable development goals.

In the second model, we examined how young people's awareness of SDGs, their value propositions, and attitude toward SDGs impacts their perception of sustainable development goals. The independent variables used in this model are awareness, attitude value propositions as indicated by the personal values, age, gender education and stream of education. The results are given in Table 3.

The results reveal that the model proposed in the current study to examine the relationship between the variables is statistically significant (F statistic – 7.129, $p<0.05$). All the independent variables together were capable of explaining young people's perception of sustainable development goals with an R squared value of 0.327 and an adjusted R- squared value of 0.304. Hence, it is assumed that all the independent variables together accounted for about one-third of the variation in

Dependent Variable: Young people's perception of sustainable development goals
Method: Least Squares. Sample: 631

Independent Variables	R-squared & Adjusted R-sq	F statistic & Model Significance	Coefficient	St. Error	t-Statistic	Sig.
Constant			12.540	8.923	0.743	0.000
Aw_Sdg			0.473	0.099	1.378	0.007**
Att_Sdg	0.327 (0.304)	7.129 (0.000)	0.477	0.529	2.148	0.021**
Per_Valu			0.213	0.455	1.346	0.000**
Age			0.154	1.112	0.876	0.000**
Gender			0.912	0.050	2.867	0.062*
Edu			0.283	0.196	1.367	0.095*
Strem_Edu			0.645	0.173	1.316	0.038**

Table 3. Awareness, perception, and attitude towards sustainable development goals – Model 2. Source: Regression results. Note: Figures in parenthesis indicate the adjusted R-squared and model significance values. *significant at 10%, ** significant at 5% level of significance

the dependent variable, perception of SDGs. Young people's awareness of sustainable development goals, their attitude toward SDGs, and their value propositions are all significantly and positively influencing their perception of SDGs (coefficients: 0.473, 0.477, 0.213). It is also inferred that the constructs, awareness, attitude, and personal values are statistically significant in explaining the participant's attitude towards sustainable development goals ($p<0.05$). We also attempted to find out whether demographic factors influence young people's perception of SDGs. The findings indicate that the demographic constructs, age, stream of education, gender, and educational qualification are statistically significant in explaining young people's perception of sustainable development goals at 5% and 10% levels of significance respectively. Overall results from Model 2 are indicative of the crucial role of awareness, attitude, and personal value propositions in developing a positive perception of sustainable development goals.

The third model is intended to test how young people's awareness about SDGs, their value propositions, and perception of SDGs impacts their attitude towards sustainable development goals when they differ in their worldviews – ecocentric worldviews or anthropocentric worldviews. The results are given in Table 4.

Dependent Variable: Young people's attitude towards sustainable development goals
Method: Least Squares Sample: 631

Independent Variables	R-squared & Adjusted R-sq.	F statistic & Model Significance	Coefficient	Std. Error	t-Statistic	Sig.
Constant			10.094	5.560	1.704	0.000
Aw_Sdg			0.612	0.112	0.758	0.00**
Per_Sdg			0.540	0.656	1.878	0.000**
Worl_ViewEco	0.218	6.964	-0.267	0.003	0.718	0.032**
Worl_ViewAnthro	(0.201)	(0.000)	0.368	0.045	1.530	0.000**
Per_Valu			0.452	1.239	0.006	0.004**
Age			0.842	0.009	1.557	0.006**
Gender			0.123	0.271	2.333	0.065*
Edu			0.201	0.107	0.116	0.002**
Strem_Edu			0.058	1.006	1.124	0.274

Table 4. Awareness, perception, value propositions and attitude towards sustainable development goals – Model 3. Source: Regression results. Note: Figures in parenthesis indicate the adjusted R-squared and model significance values. *significant at 10%, ** significant at 5% level of significance.

The results are indicative of the fact that the model can examine the relationships envisaged in the model (F statistic – 6.964, $p<0.05$). All the independent variables, together explain young people's attitude toward sustainable development goals very well (R squared- 0.218, adjusted R- squared - 0.201). Hence, it is assumed that all the independent variables together accounted for about 20% of the variation in the dependent variable, attitude towards SDGs. Young people's awareness of sustainable development goals, their perception of SDGs, and their value propositions are all significantly and positively influencing their attitude towards SDGs (coefficients: 0.612, 0.540, 0.452). It is also inferred that the constructs, awareness, perception, and personal value propositions are statistically significant in explaining the participant's attitude towards sustainable development goals ($p<0.05$). Another important finding from this model is that young people's worldviews – whether they are more concerned towards the environment or human beings – also play a significant role in their attitude formation toward sustainable development goals. We found that people with more anthropocentric worldviews exhibit a more favourable attitude towards sustainable development goals (coefficients: 0.267, 0.368). We also confirmed that young people's worldviews are statistically significant in their attitude

formation towards SDGs ($p<0.05$). Young people with ecocentric worldview exhibited a negative attitude towards sustainable development goals. We also tried to explore the role of demographic factors in determining young people's attitude toward SDGs. The findings indicate that the demographic constructs, age, educational qualification, and gender are statistically significant in explaining young people's attitude toward sustainable development goals at 5% and 10% levels of significance respectively. However, in this model, the stream of education is not at all relevant to attitude formation among young people. Overall results from Model 3 are indicative of the critical role of young people's awareness, perception, personal value propositions, and worldviews in developing a more favourable attitude towards sustainable development goals.

In the last model, we tried to explore how young people's awareness of SDGs, their value propositions, and attitude toward SDGs impacts their perception of sustainable development goals when they hold different worldviews – ecocentric worldviews or anthropocentric worldviews. The independent variables used in this model are awareness, perception, value propositions, world views (ecocentric as well as anthropocentric), age, gender, education, and stream of education. The results are given in Table 5.

The results are indicative of the fact that the model can explain the relationships envisaged in the study (F statistic – 6.532, $p<0.05$). All the independent variables, together explain young people's perception of sustainable development goals very well (R squared- 0.412, adjusted R- squared - 0.402). Hence, it is assumed that all the independent variables together accounted for nearly half of the variation in the dependent variable, perception of SDGs. Young people's awareness of sustainable development goals, their attitude toward SDGs, and their value propositions are all significantly and positively influencing their perception of SDGs (coefficients: 0.473, 0.514, 0.597). The model also revealed that young people holding ecocentric worldviews are exhibiting less favourable perceptions of SDGs as the regression coefficient is negative. It is also inferred that the constructs, awareness, attitude, and personal value propositions are

statistically significant in explaining the participant's perception of sustainable development goals ($p<0.05$). Another important finding from this model is that young people's worldviews – whether they are more concerned about the environment or human beings – also play a significant role in determining their perception of sustainable development goals. We found that people with more anthropocentric worldviews exhibit a more favourable attitude towards sustainable development goals (coefficients: -0.362, 0.368). We also confirmed that young people's worldviews are statistically significant in determining their

Dependent Variable: Young people's perception of sustainable development goals Method: Least Squares. Sample: 631						
Independent Variables	R-squared & Adjusted R-sq.	F statistic & Model Significance	Coefficient	Std.Error	t-Statistic	Sig.
Constant			12.540	8.923	0.743	0.000
Aw_Sdg			0.473	0.099	1.378	0.007**
Att_Sdg			0.154	1.112	0.876	0.000**
Worl_ViewEco	0.412	6.532	-0.362	0.095	0.233	0.029**
Worl_ViewAnthro	(0.402)	(0.000)	0.597	1.411	0.084	0.000**
Per_Valu			0.389	1.104	2.117	0.037**
Age			0.912	0.050	2.867	0.034**
Gender			0.283	0.196	1.367	0.065*
Edu			0.645	0.173	1.316	0.002**
Strem_Edu			0.097	1.045	2.978	0.616

Table 5. Awareness, perception, value propositions and attitude towards sustainable development goals – Model 4. Source: Regression results. Note: Figures in parenthesis indicate the adjusted R-squared and model significance values. *significant at 10%, ** significant at 5% level of significance

perception of SDGs ($p<0.05$). We also tried to explore the role of demographic factors in determining young people's perception of SDGs. The findings indicate that the demographic constructs, age, educational qualification, and gender are statistically significant in explaining young people's perception of sustainable development goals at 5% and 10% levels of significance respectively. However, in this model also, we found that the stream of education is not at all relevant in explaining the perception of young people. Overall results from Model 4 are indicative of the crucial role of young people's awareness, attitude, personal value propositions, and worldviews in developing a more positive perception of sustainable development goals.

4. Discussion

Based on the results from various models, used in this study, the authors, inferred that the relationship between young people's awareness of SDGs, their perception, value propositions, worldviews, and attitude towards sustainable development goals is statistically significant. It is also confirmed that young people's awareness, attitude, personal values, and worldviews significantly

contribute to their perception of sustainable development goals. These results conform with the findings of Guan et al. (2019); Devcom (2017); Chaiken (1980); Cirnu & Kuralt (2013); Xu & Fox (2014); and Bruno & Lay (2008). However, it contradicts the findings of Schultz et al. (2004); Thompson & Barton (1994); and Kopnina (2013), who argued that people holding more ecocentric worldviews will have a more positive attitude and perception toward the environment and thus, towards sustainable development goals also. The hypothesis testing results are summarized in the following Table 6.

No.	Hypotheses	Status
H1	Young people with ecocentric worldviews exhibit a positive attitudetowards sustainable development goals.	Not Supported
H2	Young people with anthropocentric worldviews exhibit a negativeattitude towards sustainable development goals.	Not Supported
H3	Young people with ecocentric worldviews exhibit a better attitudetowards sustainable development goals.	Not Supported
H4	Young people's awareness of SDGs will have a positive effect on theirattitude towards sustainable development goals.	Supported
H5	Young people's perception of SDGs will have a significant effect on their attitude towards sustainable development goals.	Supported
H6	Young people's attitude toward SDGs will have a significant effect on theirperception of sustainable development goals.	Supported
H7	The personal values of young people will have a positive effect on their attitude towards sustainable development goals.	Supported

Table 6. Summary of Hypotheses Testing Results.

The unique value proposition of this study is that it contributes to the existing body of knowledge on sustainable development goals, by providing empirical evidence for the nexus among awareness, perception, value propositions, worldviews, and attitude toward sustainable development goals. It also provides substantial evidence that people with more anthropocentric worldviews will have a better attitude towards SDGs. This finding is confirming the results of the Bill & Melinda Gates Foundation that people in the United States of America ranked "end hunger and end poverty" as the most important goal among the 17 sustainable development goals. This may be attributed to the fact that while

expert researchers and academia care more about the environment, young people care more about basic human needs. More importantly, young people, perceive sustainable development goals as a policy- level intervention for the upliftment of human society, through the upgradation of various environmental, social, and governance infrastructure, and hence, it is not always necessary that ecocentric people care more about sustainable developmental goals. Moreover, it is logical to understand that people who consider other human beings will naturally be concerned about sustainable development goals.

The study also contributes to the finding that the personal value propositions of young people contribute much to their attitude and perception of sustainable development goals. So, it is imperative to formulate some kind of interventions that may lead to better human values among young people, which in turn will reflect on their attitude towards sustainable development goals and their attainment. The finding also confirmed the interaction between young people's attitudes towards sustainable development goals and their perception of SDGs.

This is indicative of the role of policymakers in envisaging, developing, and implementing more educational programmes that can influence the attitude and perception of young people on SDGs and thus, to the accomplishment of the goals and for the betterment of society at large. The findings of this study would be useful for corporates when they plan for their corporate social responsibility activities. They would be able to select the most appropriate Corporate Social Responsibility activities, based on the understanding that young people will be attracted more to human-oriented activities while perceiving sustainable development goals.

5. Conclusions

This study explored the nexus among young people's awareness, perception, personal values worldviews, and attitude toward sustainable development goals. Our results revealed that not only the knowledge of people is significant in developing a better attitude toward SDGs but also their values and worldviews play a crucial role in explaining it. Specifically, the study concluded that people with anthropocentric worldviews will have a better attitude and perception of sustainable development goals. It is also significant to have better awareness and personal value propositions to appreciate and contribute to sustainable development goals. The study also reported that there is an interaction between attitude and perception of sustainable development goals. Young people's ecocentric worldviews were negatively related to sustainable development goals,

while their anthropocentric worldviews were positively associated with attitude and perception of Sustainable development goals. This may be because the focus of sustainable development goals is on the interconnectedness of humans and the environment. Though, the focal point of ecocentricism is the environment, it never considers the human-beings and their interconnectedness with the environment and hence may not be suited to promote sustainable behavior. However, according to anthropocentric viewpoints, technological advancement can provide solutions to sustainability problems and humans can exert control over their environment (Kopnina, 2014). Nevertheless, people would recognize that the ecosystem supports life if they were genuinely anthropocentric. Norton (1984) also pointed out that self-interest is the best justification for adopting a sustainable lifestyle. Hence it is even more important to understand that the way to promote SDGs is to appreciate the interconnectedness of humans and their environment. Despite the common understanding that the involvement of people from various walks of life, is crucial for the accomplishment of sustainable development goals, very few studies have done empirical research on this. Our study targeted to cover this research gap and thus, contributes to the existing literature. This study never attempted to explore the willingness of young people to participate in the implementation of sustainable development goals. Future researchers can consider this as a research gap and can work on this. Though this study considered the variable personal value propositions, as a determinant of attitude towards SDGs, we have not attempted to find out the impact of each category of personal value propositions on young people's attitude towards SDGs. This also can be explored by further researchers. This study is conducted in the Indian context, and thus, we have not incorporated the cultural context in this research. However, future researchers can investigate this further and identify how socio-cultural aspects impact people's attitudes towards sustainable development goals.

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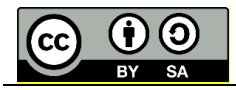

Original Paper

Sustainability Development Goals: overcoming barriers and catalysing innovation for a sustainable future

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Keywords: SDGs; barriers; innovations; UAE; sustainable future; 2030 agenda; Abu Dhabi.

Abstract. *The Sustainable Development Goals (SDGs) provide a universal framework for addressing the world's most pressing economic, social, and environmental challenges. Achieving the SDGs will require overcoming significant barriers and catalyzing innovation across various sectors, from energy and transportation to agriculture and healthcare. This paper reviews*

the literature on the barriers to achieving the SDGs and the potential for innovation to overcome these obstacles. The analysis suggests that achieving the SDGs will require a coordinated effort across government, civil society, and the private sector. While innovation is critical to achieving the SDGs, it must be accompanied by policies that promote sustainability and social equity. The paper concludes with a call to action for policymakers, business leaders, and civil society to work together to overcome the barriers to achieving the SDGs and create a more sustainable and equitable world. In the United Arab Emirates (UAE) and the larger Gulf Coast Countries (GCC) region, responsible market solutions are supported by an academic theory examined in this article. According to the analysis in this article, sustainability theory implementation is crucial for future market development in contemporary marketplaces. The research project contributes to the body of knowledge about organizational and corporate obstacles associated with operating a socially and environmentally responsible firm, as well as issues associated with applying environmental, social, and economic elements of sustainable business practices. The first stage of the study's scope was restricted to data analysis that clarified the model's concept as defined in the research. The model will be used and evaluated in collaboration with the research participants' organizations to demonstrate its validity.

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1. Introduction

The United Nations Sustainable Development Goals (SDGs) represent a universal call-to-action to end poverty, protect the planet, and ensure that everyone enjoys peace and prosperity (Mori Junior et al., 2019). The SDGs are a set of 17 goals and 169 targets adopted by world leaders in 2015 as part of the 2030 Agenda for Sustainable Development. The SDGs address many issues, from ending poverty and hunger to promoting gender equality, reducing inequality, and combating climate change.

Achieving the SDGs is a complex and multifaceted task that requires overcoming significant barriers and catalyzing innovation across various sectors (Cordova & Celone, 2019). This paper reviews the literature on the barriers to achieving the SDGs and the potential for innovation to overcome these obstacles. The analysis

suggests that achieving the SDGs will require a coordinated effort across government, civil society, and the private sector (Muñoz-La Rivera et al., 2020).

Ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all are crucial to creating a more just, prosperous, and sustainable future for all. Education is a basic human right and a key driver of sustainable development. By providing education to all, we can break the cycle of poverty, reduce inequality, and create a more diverse and inclusive society. Education empowers individuals to make informed choices, enhances their skills and knowledge, and helps them contribute to developing their communities and society. Furthermore, promoting lifelong learning opportunities ensures that people can continue to learn and adapt to the rapidly changing world, which is essential for personal and professional growth. By investing in education and promoting lifelong learning opportunities, we can build a better future for ourselves and future generations. Ensuring that everyone has access to high-quality education and opportunities for lifelong learning. Millions of kids are still not in school despite significant advancements in enrollment, particularly in areas where educational systems find it difficult to keep up with population growth. Even when more kids are enrolled, many do not learn the fundamentals. Inadequate school facilities and a shortage of qualified teachers are barriers to providing high-quality education. Intensified initiatives, especially in sub-Saharan Africa and Southern Asia, directed at vulnerable populations, including people with disabilities, native people, refugees, and the rural poor, are necessary to achieve this goal.

In the specific context of Dubai, ensuring inclusive and equitable quality education and fostering lifelong learning opportunities are imperative for a just, prosperous, and sustainable future. Education serves as a fundamental human right and a pivotal driver of sustainable development. Universal access to education can break the cycle of poverty, reduce disparities, and cultivate a more diverse and inclusive society. Education empowers individuals, augments their skills and knowledge, and encourages active participation in community and societal development. The promotion of lifelong learning guarantees that people can continuously adapt to our rapidly changing world, a prerequisite for personal and professional growth. Addressing barriers to education, especially among vulnerable populations, such as individuals with disabilities, indigenous communities, refugees, and the rural poor, is paramount to realizing this goal. From an academic standpoint, studying 'sustainable development' in the 'UAE' offers a unique opportunity (Al Sarrah et al., 2021). The UAE "is focused on establishing its presence as a global sustainability leader," claims KPMG Lower

Gulf Limited (Seretny et al., 2019). Despite this goal, the UAE still has a long way to go regarding sustainability metrics. The nation scored 77 on the 2018 Environmental Performance Index (EPI) based on 24 performance indicators, including ecosystem health (Wolf et al., 2022). As a result, there are favorable economic crises in UAE, including leadership that promotes sustainable growth and a sizable market for 'sustainable' solutions (Zarim et al., 2017). The leadership of the UAE places a strong emphasis on the value of sustainability in national development. Since 2012, there has been a "Green Economy for Sustainable Development" initiative. Government policy emphasizes 'sustainability' is key to the national 'economy's success and offers the framework for UAE's economy to compete globally, as shown in Figure 1 in which the Green Economy is predicated on the six pillars.

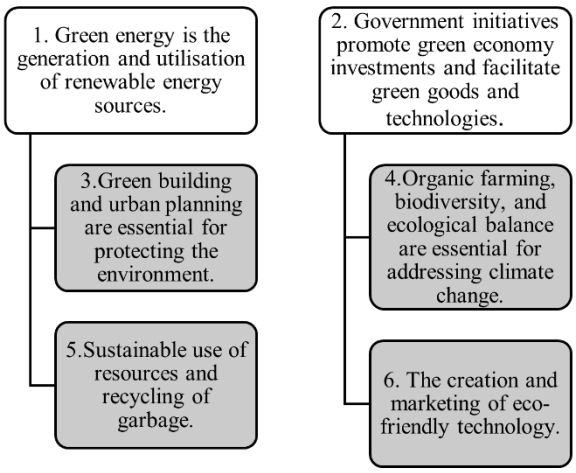

Figure 1. The six pillars of green economy

The peculiar circumstances in the UAE prompted several questions. As researchers, we questioned how much government goals influenced the growth of businesses that promote sustainable development in the private sector (Al Sarrah et al., 2021). Businesses in the UAE are aware of the UAE's sustainable development goals but cannot compare legal frameworks. Small and medium-sized businesses are unaware of sustainable development, and psychological obstacles prevent the application of sustainable solutions. Traditional marketing

strategies cannot effectively encourage the adoption of sustainable market solutions, and sustainable firms still face obstacles in a supportive environment (Small & Mazrooei, 2016).

During the project's initial phase, unstructured interviews with business representatives were done during Abu Dhabi Sustainability Week to learn more about their perspectives on ethical business, the legal system, and how to support a change in clients' and managers' mindsets. Additionally, it was clear from interactions with businesses that a change in marketing practices was urgently needed. Interview respondents also mentioned aspects of the corporate environment that are important for adopting ethical goods and services. They emphasized the significance of elements intrinsic to their companies and external to the environment, integrating them into the UAE's sustainable development market realities. The topics that participants brought up in their interviews are what we focus on in the following literature study.

Business models should be re-examined to address economic, social and environmental factors. Rodriguez (Rodriguez et al., 2020) argue that current commercial practices do not account for the Earth's role as primary shareholder and point of origin, leading to the development of management theory and practice. This presumption is pervasive in current management theory. Sustainable business is essential for advancement, allowing businesses to innovate and flourish, increasing their benefits to society (Szczepańska-Woszczyna & Kurowska-Pysz, 2016), (Gazzola & Colombo, 2014). Enterprises must create value that combines the advancement of society and the economy (Azeem & Mataruna, 2019; Milla & Mataruna-Dos-Santos, 2019). Management must comprehend and use new tactics to provide this value (Goehrig, 2008). People should act morally and responsibly, regardless of the outcome (Mataruna-Dos-Santos et al., 2019). On the other hand, the development of a company's sustainable business depends heavily on its employees. To ensure the success of the company's environmental and pro-social initiatives, managers must tell their staff about all of these initiatives (Szczepańska-Woszczyna & Kurowska-Pysz, 2016). Enforcing relevant knowledge and appropriate behaviors is significantly impacted by the integration of the corporate level with the lower level. The goal of managers is to foster an environment that will support the organization's sustained growth.

Modern business management activities heavily involve marketing. Marketing actively participates in the development of the economy. The rapid changes are happening in the world. The standard marketing strategy is no longer sufficient to address all developments in the modern market, and traditional marketing is

also receiving more and more criticism (Seretny et al., 2019). Marketing is criticized for its widespread overconsumption and detrimental effects on society, such as cultural contamination, false desires, consumerism, and societal health disorders. This suggests discipline of marketing requirements to review its conceptual prototype (Wind, 2009).

Researchers have studied and theorized about corporations' responsible activities for over three decades. The stages of sustainable marketing are summarized in Figure 2, along with the authors who have significantly contributed to the literature.

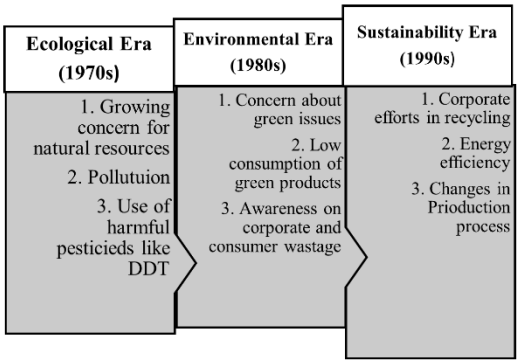

Figure 2. The stages of sustainable marketing

Branding is an important way to communicate environmental activities to customers, as customers are more likely to trust and believe in brands that communicate their objectives through proper platforms. Young consumer demographics like the millennial generation and Generation Z are concerned about purchasing sustainable goods and services, with 66% of customers spending more on a consequence coming from a 'sustainable' trademark. Recognizing consumers' interest in sustainable brands is essential when creating an entire marketing communication plan (GRI, 2015).

Several barriers impede progress toward achieving the SDGs. Many countries lack the financial resources to invest in the infrastructure, technologies, and

services needed to achieve the SDGs. This is particularly true for the least developed countries, where poverty and underdevelopment are most severe (Arcuri & Giolli, 2022). Many countries lack the technological capabilities to implement sustainable solutions, particularly in areas such as energy, agriculture, and healthcare. This limits their ability to adopt new technologies and processes to help achieve the SDGs (Williams & Murphy, 2023). Many countries lack the institutional capacity to implement policies and programs to help achieve the SDGs. This includes weak governance structures, inadequate legal frameworks, and limited regulatory capacity (Rosati & Faria, 2019). Limited public awareness: Many people lack awareness of the SDGs and their importance. This limits public support for policies and programs that can help to achieve the SDGs (Odoom et al., 2023). Inadequate international cooperation: The achievement of the SDGs requires international cooperation and coordination. However, many countries are unwilling to cooperate on climate change, trade, and migration (Moomen et al., 2019).

Innovation is critical to overcoming the barriers to achieving the SDGs. Several types of innovation can help to achieve the SDGs, including technological, social, and institutional innovation (Mulà et al., 2017). Technological innovation involves the development of new technologies and processes that can help to achieve the SDGs. For example, renewable energy technologies such as solar and wind power can help to reduce greenhouse gas emissions and combat climate change. Similarly, new agricultural technologies can help to increase food production while reducing the environmental impact of farming (Manzini & Meroni, 2014).

Social innovation involves the development of new models and approaches to social and economic development that can help to achieve the SDGs. For example, microfinance programs can help to promote financial inclusion and reduce poverty (Manzini & Meroni, 2014). Similarly, social entrepreneurship can help to promote economic growth while addressing social and environmental challenges. Researchers and business professionals addressing the challenges opposed by 'sustainable businesses' have not agreed on the root causes or best fixes. Given the complicated issues, such a development should not be unexpected. Although the exact list of reasons posing challenges to sustainable business is still up for debate, experts classify the challenges as inward or outward to the organization. Additionally, they typically divide the variables into 'economic', 'marketing', 'socio-psychological', 'legal', and 'environmental' categories (Ramani et al., 2017). Academics and businesspeople support three main tactics as solutions: sustainable marketing, sustainable business models, and

sustainable attitudes (Mulà et al., 2017). longer be able to support the levels of living that modern societies require (Seretny & Seretny, 2012). Sustainable development, typically described as providing a good value of life for both present and future origination, is a key remedy. Every year, more governments, international organizations, and non-governmental organizations (NGOs) support sustainable development. Organizations that prioritize sustainability face challenges when trying to offer sustainable solutions (Hoyos & Angel-Urdinola, 2019). This essay examines the difficulties faced by businesses in the United Arab Emirates (UAE) that provide sustainable solutions. Contrary to many other jurisdictions, the UAE government is a staunch supporter of 'sustainable development' and has included ideas about strategic plans (Abdo & Paris, 2017). UAE should theoretically be an advantageous location for sustainable firms. Nevertheless, there are difficulties faced by businesses in the UAE that provide sustainable solutions. After conducting informal interviews with managers from more than 60 companies in the UAE, we hypothesized about the main issues facing sustainable businesses and compared our findings to survey data (Al Sarrah et al., 2021).

Businesses that provide sustainable solutions typically operate in highly complex legal situations. Every corporation, like every other business, is subject to its own set of local, regional, and federal laws and regulations. The business must abide by local, regional, and national laws of the foreign jurisdiction when entering a foreign market (Palepu et al., 2020). The legal landscape for businesses providing sustainable solutions may contain hundreds of conventions, multilateral treaties, state declarations, international organization decisions, plans of action, and codes of conduct. The implementation of international treaty regimes and determining the legal impact of such instruments on national laws and customs provide specific difficulties (Tanzi & Arcari, 2021). While the legal definition of sustainable development is unchanging, standards associated with the idea must be ever-evolving since they are inextricably linked to advancements in social, environmental, and scientific knowledge.

As a result, what constitutes sustainable development will necessarily evolve over time. The concept's pliability has drawn a great deal of criticism. Some critics have asserted that the idea lacks substance or cannot be classified legally. Whatever the case, sustainability is emphasized in UAE government policies, which also adopt the UN's concept of sustainability. The UAE Vision 2021 is the most significant of the additional sustainable objectives launched by the UAE's Green Economy program, which was previously highlighted (Islam, 2021). The UN Global Sustainable Development Goals are reflected in a series of long-term

indicators included in the Vision. UAE National Agenda 2021 demonstrates the nation's dedication to sustainable development by establishing the following objectives:

A cohesive society with identity preservation, a safe public, a just judiciary, a competitive knowledge economy powered by innovation, a top-notch educational system, top-notch healthcare, and a sustainable environment and infrastructure are all desirable. The objectives of National Agenda 2021 are to promote sustainable development, protect the environment, and strike the ideal balance between social and economic advancement.

Additionally, there are governmental changes at the level of each individual emirate, such as the Dubai Expo 2020, the Abu Dhabi Economic Vision 2030, the Dubai Plan 2021, the Dubai Integrated Energy Strategy 2030, the Dubai 10X Goals, the Dubai Green Building Regulations, the Estidama building rating systems, the Environment Protection and Development Authority (Ras Al Khaimah) Strategic Plan, and the Sharjah Environment and Protected Areas Authority Strategy.

This research examines the difficulties, barriers, and innovations that businesses in the United Arab Emirates (UAE) that provide sustainable solutions must overcome. The UAE government firmly supports sustainable development and incorporates the idea into its strategic efforts, in stark contrast to many other jurisdictions. The UAE should, in theory, be a favourable environment for sustainable enterprises. However, businesses in the UAE that provide sustainable solutions face difficulties. After conducting informal interviews with managers from more than 68 organizations in the UAE, we hypothesized about the main issues and innovations encountered by sustainable businesses. We then compared our findings to the findings of the survey.

2. Research methodology

In order to comprehend the perceived obstacles that ethical businesses (organizations offering 'sustainable solutions') confront in the UAE market, an explorative research design has been used. The research sample was created through connections with businesses that took part in the "Sustainability Week" event held in Abu Dhabi, United Arab Emirates, in March 2023. The 2023 Abu Dhabi Sustainability Week (ADSW) is an international forum for addressing the complex issues preventing the mainstream adoption of sustainable development. Participants came from various businesses, including waste management,

suggestions for clean energy, clean water, ecological farming, and sustainable building.

Analysis and research findings in this research article are meant to highlight the complexity of the problems that must be solved to implement sustainable market solutions in the Middle East, focusing on the business climate in the United Arab Emirates. Businesses involved in 'Sustainability' Week 2023 in Abu Dhabi helped conduct the current study.

The theoretical framework elucidates the diverse elements that underlie the constructs influencing the success of enterprises engaged in the implementation of responsible solutions. This framework primarily centers on internal factors related to business operations that shed light on the performance of responsible businesses in the UAE market. These internal factors encompass corporate governance, marketing strategies, and economic considerations. Additionally, there are external factors that account for the broader business environment, encompassing legal frameworks, psychological aspects, geographical and natural conditions, as well as social dynamics. The study delved into how these factors collectively impact the sustainability levels of businesses engaged in the implementation of responsible solutions within the UAE market. The degree of "sustainability" of businesses using ethical solutions in the UAE market and the perceived effects of these components were presented in framework shown in Figure 3.

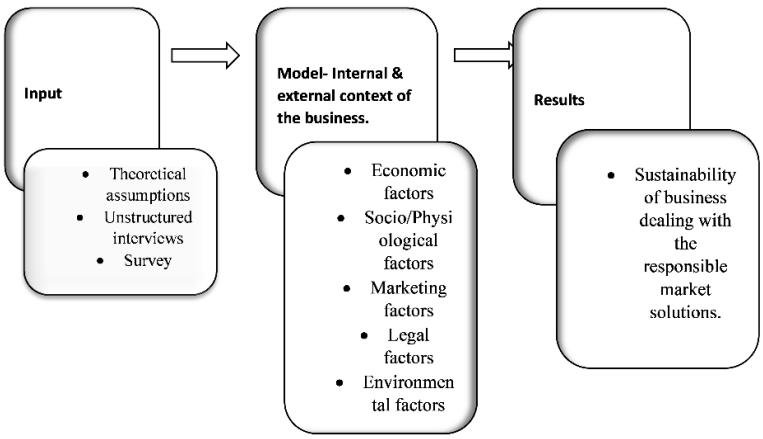

Figure 3. Theoretical Research Framework

The research has only addressed the issue of the difficulties businesses in the UAE encounter while implementing ethical markets and business practices. To achieve the study's goals, the following hypotheses were developed as shown in Table 1:

S. No.	***Hypotheses***
H1:	*Businesses attempting to participate in the sustainable market sector see the UAE's legal climate as favorable.*
H2:	*Businesses view economic, sociocultural, and environmental aspects as being extremely important to the long-term sustainability of the UAE market.*
H3:	*In the UAE, psychological obstacles prevent the adoption of sustainable solutions.*
H4:	*The UAE cannot adopt effective, sustainable solutions because of the typical marketing strategy.*

Table 1. Hypotheses of the research

To gather information, a mixed-method approach was carried out. In the first method open ended interviews were conducted with Abu Dhabi's "Sustainability Week" participants for qualitative research. The second method closed-ended survey questionnaire for quantitative research were undertaken to collect data, which could be used to generate marketing strategic solutions for achieving sustainability objectives for companies that deal in sustainable goods and services.

The qualitative insights from unstructured interviews offer depth and context, while the quantitative data from the survey provide statistical rigor and generalizability. Together, they create a holistic and comprehensive understanding of the challenges and opportunities faced by ethical businesses in the UAE market, bridging the gap between qualitative richness and quantitative rigor in research. In the first stage, unstructured interviews were carried out in the initial phase with 68 different organizations. Participants shared their eco-inventions, clean production ideas, and innovations focused on sustainability, including ecological and social factors in their final goods, manufacturing procedures, and organizational structures. Unstructured interviews describe the circumstances and context to put the interviewee at ease by fostering a comfortable environment (Qu & Dumay, 2011). Unstructured interviews allow

the respondent to open up and speak in their own way by enabling the interviewer and respondent to converse using open-ended questions. Unstructured or discovery interviews are flexible and do not need a preset list of questions (Fontana & Frey, 2005). Because of the method's ability to give the interviewer a more comprehensive picture of the situation, they are utilized to produce qualitative data and have greater validity. Unstructured interviewing has many drawbacks. The period is a constraint compared to organized interviews, doing the interview and analyzing the data can take a lot of time. Unstructured interviews were a good choice for this study because they were a crucial first step in creating the real survey.

The study's second stage involved analyzing and presenting 39 companies' responses. Open-ended questions were asked to elicit qualitative information about the market. Section 1 collected demographic data, and Section 2 collected participants' perception of the UAE and their home country markets. The 68 businesses that expressed interest in participating in the study received the research tool. 39 businesses completed the online survey. The Google forms' obligatory fields were used to address the issue of missing data by making it impossible for responders to submit a response with any blank fields. The data was removed from five responses that were not engaged. The study's 37 instances formed part of the final data set. The sample size poses a serious constraint. A larger sample size could lead to outcomes that are more broadly applicable.

Direct unstructured interviews were done as part of the research's initial phase. Businesses in Sustainable Week bemoaned the lack of market readiness for sustainable strategies, preventing their use of sustainable resources from having an impact. We learned about the impact of expatriates on the country throughout the conversation because so many of the representatives of the sustainable week were foreigners. Due to the greater proportion of foreigners living in the UAE, foreigners heavily represent decision-making management and consumers. This directly impacts any new trend's deployment and success. UAE is a centre for international trade. Research is needed to determine how much response policymakers and business owners will give to new trends that threaten their existing establishment. Policymakers and business owners are well equipped with financial and energy resources, with strong backing from the government in the business processes. New trends may be affordable and can be implemented for cost reduction.

Most of 'Dubai's' lowest to mid-level employees are foreign nationals. As a result, recruiting personnel with unique or current skill sets is a difficult and drawn-out process that frequently involves advertising, traveling, and selecting qualified

applicants prepared to immigrate abroad. Status symbols are important for consumers to consider when choosing and utilizing products. The UAE recorded 16 million visitors in 'Dubai' and 2 million in 'Abu Dhabi in 2022, demonstrating how difficult it is to implement new trends that are not tourist friendly. The population of the UAE is 10 million, and status symbols are reflected in business. The tourism sector contributes significantly to the economy, and the region has a larger tendency towards culture and tradition. Either business owners or policy leaders are from the UAE or are partners in the firm. The region has an open business climate and is tolerant of technological advancements, but it may be resistant to new trends that could negatively impact culture and tradition. Respondents often compare their country's market situation to the UAE's whereby enterprise officials are unaware of and do not acknowledge the commitment to SDGs.

Business leaders spoke about legal and business conditions, while marketing and its influence on sustainable solutions were the main topics. The researchers' ability to generate a list of topics from unstructured interviews was the basis for the questionnaire used in the second phase.

The following section provides demographic information about the 37 survey respondents. Frequency analysis, and correlation analysis were used to create graphs and calculations for the data analysis. Most businesses in this survey have offices in the United Arab Emirates, with a little over 13% having locations inside and outside the UAE. This shows that businesses that deal in sustainable goods and services value having a consistent physical appearance in the neighborhood markets to provide sustainable solutions. Additionally, businesses implementing cutting-edge sustainable solutions find office space in the UAE market appealing.

The most important details in this text are that businesses with headquarters in the United Arab Emirates run their business out of the UAE branch office and that local businesses find it easier to operate in the market than foreign businesses. This shows that locally owned businesses seriously threaten any foreign companies operating in the United Arab Emirates. The study included German, South Korean, Italian, South African, and Angolan companies from abroad. Most businesses only dealt with their brands, with 30% selling their brands and 24% selling and distributing goods made by other businesses. More information is needed to understand these companies' distributors or retailers' functions fully.

Our analysis shows roughly 11% of newly founded enterprises (Figure 4). Additionally, 11% of the businesses have between one and three years of

experience selling these products. About 19% of businesses have been around for more than three years. The Expo 2024 mega-event may increase the number of newly founded businesses. Foreign businesses are being welcomed into the UAE by the government. 60% of businesses have an average amount of experience of five years or more. The existence of enterprises operating for five years or more suggests that Middle Eastern consumers are becoming more aware of sustainable products, creating a potential market that has drawn investors to this industry. This outcome also suggests that people know that UAE government initiatives support the use of ecologically, socially, and economically sustainable products and services.

The size of the companies cannot be categorized in a clear-cut manner. According to the criteria of the number of employees, 32% of the organizations had more than 500 employees, placing them in the category of big-size corporations. 68% of the remaining businesses are SMEs. Accordingly, it can be assumed that these SMEs contribute to sustainable development, consistent with the research findings. According to the authors of the study, small and medium-sized businesses have become increasingly recognized as major contributors to sustainable development over the past ten years, and this has started to create knowledge on the specifics of "sustainability-oriented innovations" in these businesses. Our study found that sustainable innovation practices comprise product and service offerings, processes, and organizational practices. Additionally, the offered solutions were more focused on eco-innovations than solutions that addressed the triple bottom line of sustainability. This suggests that a similar pattern may exist in this area, as shown in figure 4.

3. Results

Our analysis presents data concerning the extent of concurrence or disparity among participants' viewpoints on a range of internal and external factors relevant to the provision of sustainable products or services. Each respondent was asked to select from five options: Strongly disagree, Disagree, Neutral, Agree, or Strongly Agree. These statements gauge the participants' perspectives on six distinct factors: legal, economic, social, psychological, marketing, as well as geographical and environmental considerations.

Businesses face challenges in the current economic climate, leading to a demand for sustainable products. They also thought the current economic downturn was a chance to enter the market, as it would raise potential rewards. Additionally,

favorable import tariff rates motivated them to profit from the UAE market. The respondents expressed optimism and hope for the future of sustainable goods.

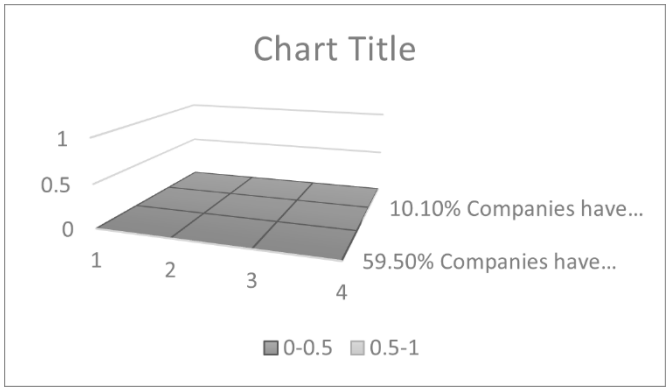

Figure 4. Distribution of experience in dealing with the sustainable solution.

The current business climate has improved with time, supporting the development of sustainable product solutions. New laws and regulations can be passed to encourage the use of sustainable products in the area. Additionally, market information accessibility, consumer awareness campaigns, and the promotion of sustainable business practices are important.

3.1 Thematic analysis

1. Primary obstacles to achieving sustainable development objectives

From the first response, it emerges that:
"Global cooperation and political will are crucial for sustainable development, but often prioritize immediate economic gains over long-term sustainability, hindering effective action to address climate change, resource depletion, and poverty".

From the second response it emerges that:
"Climate change and environmental degradation pose significant challenges, including extreme weather events, biodiversity loss, and resource scarcity. Addressing these requires global action, policy changes, and societal changes to reduce greenhouse gas emissions and protect ecosystems".

2. Innovative methodologies or technologies that can overcome challenges and accelerate sustainability advancements.

From the first response, it emerges that:
"One concrete instance is the development of advanced solar panel technologies, such as perovskite solar cells, which have the potential to greatly increase the efficiency and affordability of solar power generation, thus reducing dependence on fossil fuels and mitigating climate change".

From the second response, it emerges that:
"Precision agriculture, utilizing IoT sensors and data analytics, optimizes resource use in farming, enhancing crop yields and minimizing environmental impact through reduced water and chemical usage".

3. The significance of public awareness and education in promoting sustainable development

From the first response, it emerges that:
"Public awareness and education are crucial for promoting sustainable development, as they encourage individuals to understand, advocate for, and support sustainable practices, leading to responsible consumption and participation in environmental and social initiatives".

From the second response, it emerges that:
"Public awareness and education are crucial for sustainable development, promoting responsibility and informed choices, leading to more support for policies and initiatives focusing on environmental and social sustainability".

4. Advantages of aligning operations with sustainability goals

From the first response, it emerges that:
"To align operations with sustainability goals, firms should integrate sustainability into supply chain practices, use resource-efficient technologies, and invest in renewable energy. This promotes circular economy, reduces environmental impact, and enhances brand reputation".

From the second response, it emerges that:
"Firms should align their operations with sustainability objectives by setting clear goals, fostering employee engagement, focusing on sustainable packaging, conducting regular audits, and collaborating with stakeholders. These strategies contribute to regulatory compliance, consumer loyalty, and long-term resilience".

5. Enhancing visibility and impact of neglected sustainability regions

From the first response, it emerges that:

"Underrepresented areas in sustainability initiatives, such as technology and conservation, can significantly improve conservation efforts. Integrating indigenous knowledge and practices is also crucial for cultural preservation. Increased research funding, collaboration with indigenous communities, and awareness campaigns are essential".

From the second response, it emerges that:
"Sustainable urban planning and sustainable fashion and textiles are underrepresented areas in sustainability initiatives. Implementing eco-friendly design, efficient public transportation, and green infrastructure can mitigate environmental degradation and improve quality of life. Increased awareness through educational campaigns and stakeholder involvement can further enhance these areas".

3.2 Quantitative analysis

1. Frequency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1-3 years	5	13.9	13.9	13.9
	4-5 years	8	22.2	22.2	36.1
	5-7 years	20	55.6	55.6	91.7
	Other	3	8.3	8.3	100.0
	Total	36	100.0	100.0	

Table 2. Distribution of respondents by experience level. The table 2 shows that 13.9% of respondents have 1-3 years of experience, 22.2% have 4-5 years, 55.6% have 5-7 years, and 8.3% are in the 'Other' category. The cumulative percent is 91.7% with 7 or fewer years of experience, while 8.3% is in the 'Other' category

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Large Corporation	11	30.6	30.6	30.6
	SME	25	69.4	69.4	100.0
	Total	36	100.0	100.0	

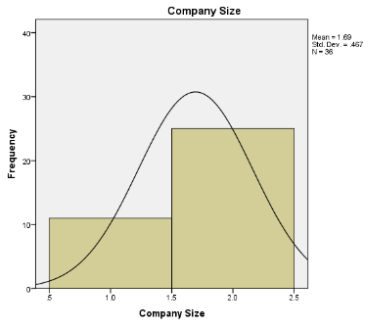

Table 3. Distribution of companies by size. The table 3 shows that 30.6% of companies are large corporations, while 69.4% are Small and Medium-sized Enterprises (SMEs). The cumulative percent indicates that all surveyed companies fall into these two categories, with no other categories included in the data.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	12	33.3	33.3	33.3
	Agree	13	36.1	36.1	69.4
	Neutral	5	13.9	13.9	83.3
	Disagree	6	16.7	16.7	100.0
	Total	36	100.0	100.0	

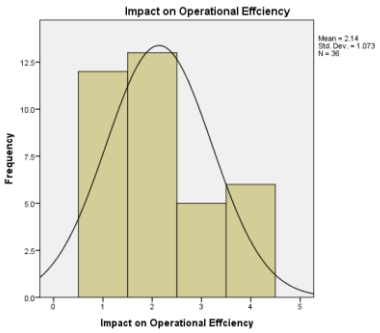

Table 4. Perceptions of impact on operational efficiency. The table 4 shows respondents' perceptions of the impact on operational efficiency, with 33.3% strongly agreeing and 36.1% disagreeing. 13.9% remain neutral, 13.9% lack strong opinion, and 16.7% disagree. The cumulative percent represents all respondents' views within the four categories.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Agree	5	13.9	13.9	13.9
	Neutral	2	5.6	5.6	19.4
	Disagree	18	50.0	50.0	69.4
	Strongly Disagree	11	30.6	30.6	100.0
	Total	36	100.0	100.0	

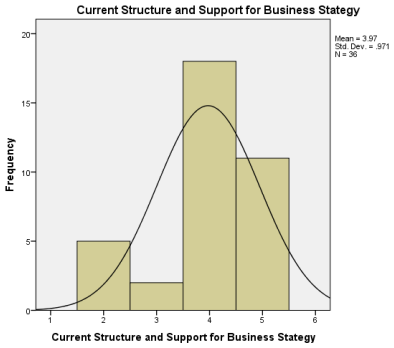

Table 5. Perceptions of current structure and support for business strategy. The table 5 shows respondents' perceptions of the current structure and support for business strategy. 13.9% agree, while 5.6% remain neutral. 50.0% disagree with the effectiveness, and 30.6% strongly disagree. The cumulative percent indicates all responses fall within the provided categories, leaving no unaccounted data.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	5	13.9	13.9	13.9
	Agree	9	25.0	25.0	38.9
	Neutral	20	55.6	55.6	94.4
	Disagree	2	5.6	5.6	100.0
	Total	36	100.0	100.0	

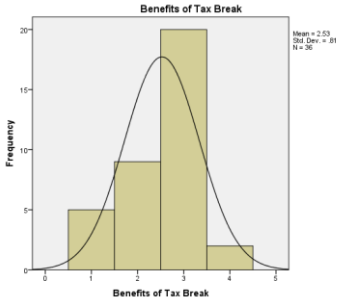

Table 6. Perceptions of current structure and support for business Strategy. The table shows 6 respondents' views on the benefits of a tax break, with 13.9% strongly agreeing and 25.0% agreeing. The majority, 55.6%, remain neutral, and only 5.6% disagree. The cumulative percent indicates all responses fall within the provided categories, leaving no unaccounted data.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	5	13.9	13.9	13.9
	Agree	9	25.0	25.0	38.9
	Neutral	20	55.6	55.6	94.4
	Disagree	2	5.6	5.6	100.0
	Total	36	100.0	100.0	

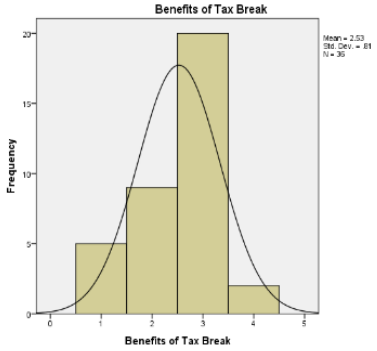

Table 7. Perceptions of benefits of tax break. The table 7 shows respondents' views on the benefits of a tax break, with 13.9% strongly agreeing and 25.0% agreeing. The majority, 55.6%, remain neutral, and only 5.6% disagree. The cumulative percent indicates all responses fall within the provided categories, leaving no unaccounted data.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	7	19.4	19.4	19.4
	Agree	20	55.6	55.6	75.0
	Neutral	7	19.4	19.4	94.4
	Disagree	2	5.6	5.6	100.0
	Total	36	100.0	100.0	

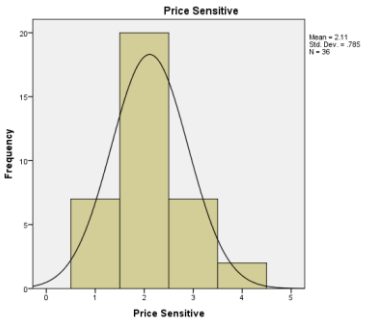

Table 8. Perceptions of price sensitivity. The table 8 shows that 19.4% strongly agree with being price sensitive, while 55.6% agree, 19.4% remain neutral, and 5.6% disagree. The cumulative percent indicates all responses fall within the provided categories, with no unaccounted data.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	12	33.3	33.3	33.3
	Agree	16	44.4	44.4	77.8
	Neutral	8	22.2	22.2	100.0
	Total	36	100.0	100.0	

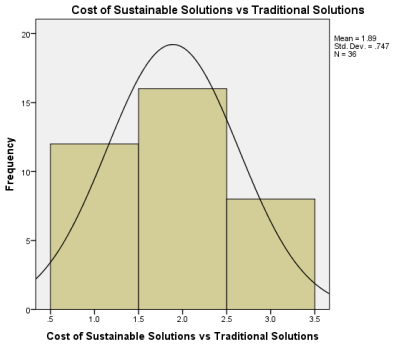

Table 9. Perceptions of the cost of sustainable solutions vs traditional solutions. The table 9 shows respondents' views on cost comparison between sustainable and traditional solutions. 33.3% strongly agree, 44.4% agree, and 22.2% remain neutral. All responses fall within the provided categories, leaving no unaccounted data.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	5	13.9	13.9	13.9
	Agree	19	52.8	52.8	66.7
	Neutral	8	22.2	22.2	88.9
	Disagree	4	11.1	11.1	100.0
	Total	36	100.0	100.0	

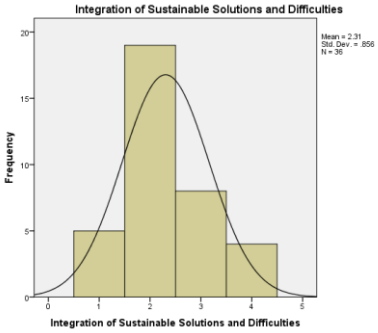

Table 10. Perceptions of integration of sustainable solutions and difficulties. The table 10 shows respondents' views on the integration of sustainable solutions, with 13.9% strongly agreeing and 52.8% agreeing. 22.2% remain neutral, while 11.1% disagree. The cumulative percent indicates all responses fall within the provided categories, leaving no unaccounted data.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	7	19.4	19.4	19.4
	Agree	2	5.6	5.6	25.0
	Neutral	6	16.7	16.7	41.7
	Disagree	8	22.2	22.2	63.9
	Strongly Disagree	13	36.1	36.1	100.0
	Total	36	100.0	100.0	

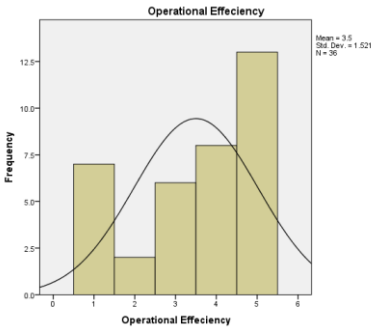

Table 11. Perceptions of operational efficiency. The table 11 shows that 19.4% of respondents strongly agree that operational efficiency is achieved, while only 5.6% agree. 16.7% remain neutral, 22.2% disagree, and 36.1% strongly disagree. All responses fall within the provided categories, leaving no unaccounted data.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	8	22.2	22.2	22.2
	Agree	17	47.2	47.2	69.4
	Neutral	7	19.4	19.4	88.9
	Disagree	4	11.1	11.1	100.0
	Total	36	100.0	100.0	

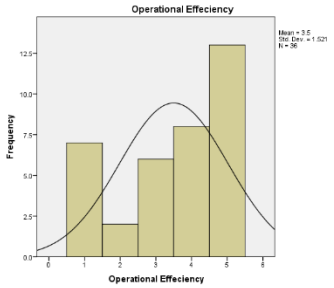

Table 12. Perceptions of foreigners and local market ratio. The table 12 shows that 22.2% of respondents strongly agree on the significant presence of foreigners in the local market, while 47.2% agree. 19.4% remain neutral, while 11.1% disagree. The cumulative percent indicates that all responses fall within the provided categories, leaving no unaccounted data.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly Agree	2	5.6	5.6	5.6
	Agree	6	16.7	16.7	22.2
	Disagree	18	50.0	50.0	72.2
	Strongly Disagree	10	27.8	27.8	100.0
	Total	36	100.0	100.0	

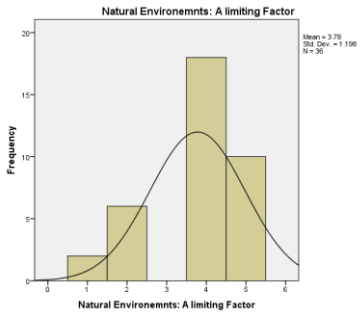

Table 13. Perceptions of natural environments as a limiting factor. The table 13 shows respondents' views on whether natural environments are limiting factors. 5.6% strongly agree, 16.7% agree, while 50.0% disagree and 27.8% strongly disagree. All responses fall within the provided categories, leaving no unaccounted data.

2) Correlation Analysis

Correlations									
		A	B	C	D	E	F	G	H
A	Pearson Corr.	1	.692**	-.059	.149	.176	-.064	.060	-.112
	Sig. (2-tailed)		.000	.734	.386	.304	.710	.727	.515
B	Pearson Corr.	.692**	1	-.147	.258	.304	-.111	.010	-.194
	Sig. (2-tailed)	.000		.392	.129	.071	.519	.952	.257
C	Pearson Corr.	-.059	-.147	1	.481**	-.664**	.728**	.832**	.738**
	Sig. (2-tailed)	.734	.392		.003	.000	.000	.000	.000
	N	36	36	36	36	36	36	36	36
D	Pearson Corr.	.149	.258	.481**	1	-.313	.527**	.512**	.418*
	Sig. (2-tailed)	.386	.129	.003		.063	.001	.001	.011
E	Pearson Corr.	.176	.304	-.664**	-.313	1	-.413*	-.875**	-.688**
	Sig. (2-tailed)	.304	.071	.000	.063		.012	.000	.000
F	Pearson Corr.	-.064	-.111	.728**	.527**	-.413*	1	.576**	.369*
	Sig. (2-tailed)	.710	.519	.000	.001	.012		.000	.027
G	Pearson Corr.	.060	.010	.832**	.512**	-.875**	.576**	1	.733**
	Sig. (2-tailed)	.727	.952	.000	.001	.000	.000		.000
H	Pearson Corr.	-.112	-.194	.738**	.418*	-.688**	.369*	.733**	1
	Sig. (2-tailed)	.515	.257	.000	.011	.000	.027	.000	
	N	36	36	36	36	36	36	36	36

Table 14. Correlations between various factors in the context of sustainability in the business industry. The table 14 displays the relationships between sustainability variables in the business sector. It is evident that "Operational Efficiency" and "Judging Level of Sustainability" have a substantial positive association, as does "Judging Level of Sustainability" and "Spreading the Word." On the other hand, a few variables exhibit negative correlations, which shed light on how sustainability and corporate operations interact. A = Office location; B = Complex rules and regulations for business entering sustainable products industry; C = Impact on operational efficiency; D = Operational efficiency; E = Judging level of efficiency; F = Price sensitivity; G = Spreading the word; H = Collaborating with regulatory agencies.

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

		A	B	C	D	E	F	G	H	I	J	K	L
A	Pearson Corr.	1	.055	.399*	.235	-.297	.073	.329*	.420*	-.321	-.005	.152	.061
	Sig. (2-tailed)		.748	.016	.168	.079	.673	.050	.011	.056	.978	.378	.725
	N	36	36	36	36	36	36	36	36	36	36	36	36
B	Pearson Corr.	.055	1	-.127	-.062	.346*	.704**	.006	.011	-.153	.688**	.242	.114
	Sig. (2-tailed)	.748		.461	.719	.039	.000	.971	.951	.373	.000	.155	.509
	N	36	36	36	36	36	36	36	36	36	36	36	36
C	Pearson Corr.	.399*	-.127	1	.848**	-.522**	.085	.715**	.786**	-.595**	.112	.494**	.527**
	Sig. (2-tailed)	.016	.461		.000	.001	.621	.000	.000	.000	.516	.002	.001
	N	36	36	36	36	36	36	36	36	36	36	36	36
D	Pearson Corr.	.235	-.062	.848**	1	-.441**	.095	.749**	.814**	-.542**	.167	.460**	.526**
	Sig. (2-tailed)	.168	.719	.000		.007	.580	.000	.000	.001	.329	.005	.001
	N	36	36	36	36	36	36	36	36	36	36	36	36
E	Pearson Corr.	-.297	.346*	-.522**	-.441**	1	.290	-.218	-.239	.124	.216	.024	-.136
	Sig. (2-tailed)	.079	.039	.001	.007		.087	.201	.160	.470	.205	.887	.428
	N	36	36	36	36	36	36	36	36	36	36	36	36
F	Pearson Corr.	.073	.704**	.085	.095	.290	1	.338*	.280	-.494**	.964**	.582**	.464**
	Sig. (2-tailed)	.673	.000	.621	.580	.087		.044	.098	.002	.000	.000	.004
	N	36	36	36	36	36	36	36	36	36	36	36	36
G	Pearson Corr.	.329*	.006	.715**	.749**	-.218	.338*	1	.902**	-.789**	.260	.760**	.738**
	Sig. (2-tailed)	.050	.971	.000	.000	.201	.044		.000	.000	.125	.000	.000
	N	36	36	36	36	36	36	36	36	36	36	36	36
H	Pearson Corr.	.420*	.011	.786**	.814**	-.239	.280	.902**	1	-.740**	.199	.672**	.635**
	Sig. (2-tailed)	.011	.951	.000	.000	.160	.098	.000		.000	.246	.000	.000
	N	36	36	36	36	36	36	36	36	36	36	36	36
I	Pearson Corr.	-.321	-.153	-.595**	-.542**	.124	-.494**	-.789**	-.740**	1	-.407*	-.927**	-.922**
	Sig. (2-tailed)	.056	.373	.000	.001	.470	.002	.000	.000		.014	.000	.000
	N	36	36	36	36	36	36	36	36	36	36	36	36
J	Pearson Corr.	-.005	.688**	.112	.167	.216	.964**	.260	.199	-.407*	1	.492**	.415*
	Sig. (2-tailed)	.978	.000	.516	.329	.205	.000	.125	.246	.014		.002	.012
	N	36	36	36	36	36	36	36	36	36	36	36	36
K	Pearson Corr.	.152	.242	.494**	.460**	.024	.582**	.760**	.672**	-.927**	.492**	1	.939**
	Sig. (2-tailed)	.378	.155	.002	.005	.887	.000	.000	.000	.000	.002		.000
	N	36	36	36	36	36	36	36	36	36	36	36	36
L	Pearson Corr.	.061	.114	.527**	.526**	-.136	.464**	.738**	.635**	-.922**	.415*	.939**	1
	Sig. (2-tailed)	.725	.509	.001	.001	.428	.004	.000	.000	.000	.012	.000	
	N	36	36	36	36	36	36	36	36	36	36	36	36

Table 15. Correlations between various factors related to sustainability and business operations. The table 15 shows correlations between sustainability and business operations, with strong correlations between factors like marketing efforts, high electricity prices, foreigners and local market ratio, and sustainable solutions integration. Negative correlations exist for natural environments and national awareness campaigns. These findings provide insights into sustainability and business strategies. A Experience; B Current structure and support for business; C Hindrance for marketing efforts; D High electricity prices; E Benefits of tax break; F Traditional perspective about sustainability; G Foreigners and local market ration; H Integration of sustainable solutions and difficulties; I Natural environments: a limiting factor; J Need for national awareness campaigns; K Certain marketing symbols; L Cost of sustainable vs traditional solutions.

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

4. Discussion

Our first hypothesis (H1) posited that businesses venturing into the 'sustainable market' sector would perceive the legal climate in the UAE as favorable. Surprisingly, our findings contradicted this hypothesis. Participants in our study expressed the belief that other jurisdictions offered a more conducive legal environment than the UAE for sustainable business endeavors. Despite the UAE government's emphasis on sustainability in national development, as evidenced by the adoption of legal guidelines at both federal and emirate levels, businesses offering sustainable solutions perceived existing legal restrictions as substantial impediments. This suggests a misalignment between the government's sustainability objectives and the regulatory framework in place. Further research is needed to pinpoint the specific legal challenges faced by businesses across different industries. A potential avenue for resolution lies in educational marketing communication, which could bridge the gap between business and government stakeholders. Collaborative efforts between businesses and government administrative departments, possibly through 'Chambers of Commerce and Industry,' may help create a more favorable legal environment for sustainable businesses.

Our second hypothesis (H2) posited that businesses regard economic, sociocultural, and environmental aspects as pivotal for the long-term sustainability of the UAE market. Our findings provided partial support for this hypothesis. While economic factors were identified as hindrances to the development of sustainable alternatives, sociocultural considerations, local and regional culture, and the demographic structure emerged as influential factors shaping the market for sustainable solutions. This underscores the significance of societal issues in influencing the sale of sustainable goods and services within the UAE market.

Our third hypothesis (H3) suggested that psychological barriers impede the adoption of sustainable solutions in the UAE. Our study confirmed the presence of psychological obstacles, inhibiting the UAE's ability to promote sustainable goods. These obstacles stem from consumption behaviors among the affluent class, which tends to utilize more resources and favor products aligned with the status quo. This phenomenon is driven by a psychological aversion to long-term thinking and the prevalence of non-sustainable resources in the market. Our fourth hypothesis (H4) proposed that the UAE faces challenges in adopting effective sustainable solutions due to its conventional marketing strategy. Our findings validated this hypothesis, indicating that traditional marketing practices

indeed hinder the adoption of sustainable solutions. The success of a company in this context is closely linked to the level of awareness about sustainability among its clientele and the broader business community. However, our study also revealed that implementing innovative marketing strategies, such as Sustainable Marketing, can yield positive outcomes for many companies. This implies that both market stakeholders and businesses need to shift their perspectives when implementing new marketing strategies in the sustainable sector to navigate these challenges effectively.

Our findings suggest that an efficient marketing plan is essential for addressing the root causes for the success of companies that deal in 'sustainable solutions. A revision of the legal framework is also recommended. Environmental psychologists debate what factors are most crucial to creating a responsible and sustainable society. It is important to note that people will not experience a sense of urgency unless they can connect it to their quality of life. Businesses should fit their products and marketing strategies to the mindset of the public and status symbols. Products and marketing tactics must match the status symbol and the public's thinking, and sustainable solutions must be created with competitive pricing. Technology can be used to create cost-effective solutions. Collaboration between business and education is essential for adopting a sustainable attitude, creating new opportunities for influencing the future and implementing policies that will provide wealth to future generations. Our study aims to alter the psychological perspective of society toward sustainable resources and help motivate businesses to develop consumer-friendly motivating techniques to break down societal resistance to delaying action until the environment suffers irreparable harm. This involves promoting knowledge/education about governmental activities and programs and transforming the traditional marketing strategy into ethical marketing techniques by putting in place educational programs at all grade levels and in higher education.

Researchers seek to understand and address the causes of events. Sustainable marketing plays a crucial role in this process, as it has the potential to alter ingrained beliefs and behaviors that have contributed to the current sustainability problem. Future generations must be educated in sustainable marketing development to understand complex environmental, social, and economic issues. Conversations about ethical ramifications, alternate worldviews, the place of humans in ecosystems, and future visions should be included in teaching programs. A sustainability curriculum aims to create a community prepared to contribute to more sustainable opportunities. All levels of education should be included in sustainability education initiatives, from kindergarten education

through doctoral programs. Decision-makers, to be successful, must prioritize sustainability education, but due to lack of commitment at operational and educational levels. Young marketers must learn about sustainability marketing challenges in kindergarten, and education policymakers must play a major role in integrating sustainability into the curriculum. Future marketers must develop goods and services that benefit the social, cultural, and economic context while protecting the environment. Implementing a sustainable attitude requires collaboration between business and education, between individual businesses, research organizations, and academic institutions.

5. Conclusion

Projects in research and development are essential for connecting academic institutions with industry to spread and manage knowledge. Collaboration between academic institutions and businesses can inspire new ideas, boost academic research initiatives, and address commercial problems. The university-business relationship should be expanded to the "Triple Helix Model" to promote economic and social growth. Industry clusters offer the opportunity to expand R&D in intellectual property. Knowledge management, conferences and meetings, entrepreneurship centres, and personnel enhancement programs facilitate the exchange in the triple perspective between university staff and the business community. Relationships between academia and industry are important for innovation.

The research focused on sustainability, marketing, and psychology in the UAE, but its findings may not be universally applicable due to regional disparities, constraints in data collection, and lack of longitudinal dimension. The findings may not be applicable across all industries or businesses in the UAE's sustainable market. These limitations mean that future research endeavors should aim to expand our understanding by conducting more extensive and diverse surveys, employing longitudinal research designs, exploring the applicability of findings to other regions, delving deeper into the complexities of psychological factors, and investigating strategies to address identified barriers. These efforts will contribute to a more comprehensive understanding of sustainable marketing and psychology, fostering effective practices in the UAE and beyond.

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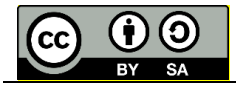

Original Paper

Comparison of environmental Kuznet Curve testing before and during the implementation of Sustainable Development Goals

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Abstract. *This research aims to analyse comparative environmental Kuznet Curve (EKC) testing before and during the implementation of Sustainable Development Goals (SDGS). Our study uses a quantitative approach. The sampling technique used is purposive sampling, involving countries that are included in the categories of 10 high, upper middle and lower middle-income*

countries on the Asian continent during the 2011-2020 period. The data analysis method used is panel data regression analysis by combining cross section and time series data in order to analyse the variables Gross Domestic Product, Population Density, Foreign Direct Investment, Human Development Index, Agricultural Land, and Industrialization and their influence on CO_2 emissions in the countries studied.

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1. Introduction

Economic development is a process with a declared aim of increasing economic growth and improving community welfare. Generally, efforts that have been made so far are still too focused on the goal of economic growth and ignore social and environmental aspects. The economic development process is still largely concerned with efforts to increase productivity in order to meet public consumption. Increasing the production of goods and services cannot be separated from the utilization of existing natural resources (Chiu 2012; Dietz et al., 2012; Suki et al., 2020), which tends to be exploitative and ignores environmental sustainability (Choumert et al., 2013; Cole & McCoskey, 2013; Lau et al., 2014). Production activities that continuously exploit natural resources have a negative impact on the environment, (Sarkodie & Ozturk 2020; Murshed et al., 2021) and issues of environmental damage, global warming and climate change have reached the world's attention in recent years because they are detrimental to human life. Excessive exploitation of natural resources, without thinking about the impacts that will result in economic, social, and other crises, pose an increasing threat to people's lives in the future (Xu 2018; Ridzuan et al., 2020). During the 2011-2020 period, carbon dioxide pollution in Asia for high income countries has tended to decrease, while upper middle and lower middle-income countries has tended to experience an increase. The environmental pollution that has occurred is due to several factors.

The first factor that can increase environmental pollution is Gross Domestic Product (GDP). Efforts to increase economic growth as indicated by an increase in GDP are also one of the causes of increasing environmental pollution. High industrial activity that produces waste and combustion smoke certainly contributes to environmental pollution. In fact, several previous studies explained that GDP growth was also offset by an increase in environmental

pollution (Al-Mulali et al, 2015; Jebli & Youssef, 2015; Inglesi-Lotz and Bohlman, 2014). The second factor is population. The higher the population density, the more housing will be built, and the more household waste will be produced. The increasing population can also increase the demand for goods and services which requires greater production of these goods and services. The third factor that can increase environmental pollution is foreign investment. Foreign Direct Investment (FDI). This can boost economic activity which will certainly increase the amount of waste and pollution particles which will further worsen environmental damage (Aung 2017). The fourth factor that can increase environmental pollution is the quality of human resources. The better the quality of existing human resources, the better the quality of the environment should be because the level of public awareness of the importance of environmental sustainability becomes higher. The fifth factor that can increase environmental pollution is the availability of agricultural land. Agricultural land is becoming increasingly depleted and changing its function, which can have a negative impact if the land is used for housing and industry. The decrease in agricultural land results in a decrease in plants that can absorb carbon. The sixth factor that can influence environmental pollution is industrialization. A country's effort to improve its economy through industrialization in order to provide needed goods and services and absorb labour has a negative impact on the environment, in particular through the production of waste that pollutes the environment (Katircioglu et al., 2018; Olale et al., 2018).

Efforts to improve people's welfare are not enough if only seen from an economic development perspective. Achieving economic growth and environmental sustainability are apparently conflicting goals, even though the 2000 Millennium Development Goals (MDGs) and the 2016 Sustainable Development Goals endeavour to reconcile them. The purpose of this paper is to analyse the relationship between economic growth and environmental quality by employing the Environmental Kuznets Curve (EKC) Hypothesis. The EKC Hypothesis examines the relationship between economic development and environmental damage (Farhani 2014, Lacheheb 2015, Ahmad 2017, Aziz 2020) and posits that increasing economic development activities will initially be accompanied by increased environmental damage. However, Grossman & Krueger (1995) proposed the model of an inverted U-curve where at the beginning of economic growth environmental degradation increases, but environmental degradation will decrease as economic growth increases (Altintas, 2020), because economic growth is accompanied by an increasing demand for environmental quality, thereby leading to measures that decrease environmental

deterioration. Since then, this hypothesis has become an interesting subject for researchers.

Thus far, research has provided mixed results. Some studies in diverse countries - in Pakistan (Ali et al., 2015), in Ethiopia (Endeg, 2015), and in countries with high income (Camci et al., 2018) have produced findings that the EKC hypothesis is in the long term demonstrated as an inverted U-shaped curve. However, other research actually provides contradictory findings, whereby EKC does not fully occur in the Gulf Cooperation Council (GCC) countries (Basarir and Arman, 2013), in South Africa (Inglesi-Lotz & Bohlmann, 2014), and in countries with middle and low income (Camci et al., 2018). Moreover, ECK with an N form, which suggests that the hypothesis will not hold in the long run, is found both in OECD and non-OECD countries in Latin America, Asia, and Africa (Beck & Joshi, 2015). Our aim is to conduct comparative analysis of EKC testing before and during the implementation of SDGS on the Asian continent.

2. Research methods

Our study uses a quantitative approach. We use secondary data in the form of panel data which combines time series data for the period 2011-2020 and cross-section data on 30 countries on the Asian continent consisting of high-income countries, upper middle-income countries, and lower middle-income countries. This is obtained from documents published the World Bank (2022a; 2022b; 2022c; 2022d; 2022e; 2022f) and the Asian Development Bank (2022). The sampling technique used is purposive sampling, i.e., countries that are included in the categories of 10 high, upper middle and lower middle-income countries on the Asian continent. The high-income countries include Bahrain, Brunei Darussalam, Qatar, Israel, Japan, South Korea, Oman, Saudi Arabia, Singapore, United Arab Emirates. The upper middle-income countries include Armenia, China, Fiji, Iraq, Jordan, Lebanon, Malaysia, Maldives, Thailand, and Turkmenistan. The lower-middle income countries include Bangladesh, the Philippines, India, Indonesia, Cambodia, Morocco, Mongolia, Myanmar, Sri Lanka, and Vietnam.

The data analysis method used is panel data regression analysis by combining cross section data and time series data. This data analysis is used to reduce obstacles that arise due to limited data so that the expected goals can be achieved. The cross-section data used in this research consists of 10 high income countries, 10 upper middle-income countries and 10 lower middle-income countries for a total of 30 countries. The time span for the data is from 2011-2020. Our research

also compares the testing of the Environmental Kuznets Curve Hypothesis before and after the implementation of the SDGs using dummy variables. Data obtained is tabulated, processed, and interpreted using the Eviews 11 program. Several variables in this research model are converted into natural logarithm (logn) form to make the model linear so that the data can be distributed normally. To obtain an inverted-U pattern formed from the relationship between GDP and CO_2 emissions, we use a quadratic equation.

$$CO_2\ it=\alpha+\beta1\ GDP\ it+\beta2\ POP\ it+\beta3\ FDI\ it+\beta4\ HDI\ it+\beta5\ TO\ it+\beta6\ UB\ it+\beta7\ LP\ it+\beta8\ ID\ it+\beta9\ D00*PDBit+\beta10\ D00*POP\ it+\beta11\ D00*FDI\ it+\beta12\ D00*HDI\ it+\beta13\ D00*TO\ it+\beta14\ D00*UB\ it+\beta15\ D00*LP\ it+\beta16\ D00*ID\ it+\varepsilon it \quad (3.1)$$

The Kuznets environmental curve hypothesis created by Grossman & Krueger (1995) shows a non-linear relationship between emissions and economic growth. So, to test the validity of the Kuznets environmental curve hypothesis in this equation a variable (squared) as an explanatory variable was added. The expanded Kuznets environmental curve equation in this research is written based on country income criteria, namely high-income countries, upper middle-income countries, and lower middle-income countries. The regression equation used for each criterion is as follows:

High income countries (high income):

$$CO_2\ it=\alpha+\beta1\ GDP\ it+\beta2\ GDP2\ it+\beta3\ POP\ it+\beta4\ FDI\ it+\beta5\ HDI\ it+\beta6\ LP\ it+\beta7\ ID\ it+\beta8\ D00*PDBit+\beta9\ D00*POP\ it+\beta10\ D00*FDI\ it+\beta11\ D00*HDI\ it+\beta12\ D00*LP\ it+\beta13\ D00*ID\ it+\varepsilon it \quad (3.2)$$

Upper middle-income countries:

$$CO_2\ it=\alpha+\beta1\ GDP\ it+\beta2\ GDP2\ it+\beta3\ POP\ it+\beta4\ FDI\ it+\beta5\ HDI\ it+\beta6\ LP\ it+\beta7\ ID\ it+\beta8\ D00*PDBit+\beta9\ D00*POP\ it+\beta10\ D00*FDI\ it+\beta11\ D00*HDI\ it+\beta12\ D00*LP\ it+\beta13\ D00*ID\ it+\varepsilon it \quad (3.3)$$

Lower middle-income countries:

CO_2 it=α+β1 GDP it +β2 GDP2 it +β3 POP it +β4 FDI it +β5 HDI it+β6 LP it +β7 ID it +β8 D00*PDBit +β9 D00*POP it +β10 D00*FDI it +β11 D00*HDI it +β12 D00*LP it +β13 D00*ID it +εit (3.4)

Legend:

CO_2 it = CO_2 gas emissions for country i in year t

GDP it = GDP per capita for country i in year t

GDP2 it = GDP per squared capita for country i in year t

POP it = Density for country i in year t

FDI it = Foreign investment to country i in year t

HDI it = Human development index for country i in year t

LP it = Land agriculture for country i in year t

ID it = Industrialization for country i in year t

D00 it = SDGs program dummy for country i in year t

(0= Before SDGs, namely 2011-2015, 1=During the implementation of SDGs, namely 2016-2020)

α = constant

β1,β2,β17= coefficient

ε = residual (error term)

Our research estimates the existence of EKC as applied by Dong et al. (2018) using the model specifications in equation (3.5). The existence of EKC in a country can be determined by looking at the coefficientβ1 andβ2.

a) Ifβ2 < 0, an inverted U-shaped relationship occurs.

b) Ifβ2 > 0, there is no inverted U-shaped relationship.

After ascertaining the existence of EKC in a group of countries, the next stage is to calculate the Turning Point (TP) and Turning Year (Y) for each country using the following formula (Shuai et al., 2017):

$$TP = -\frac{\beta 1}{2\beta 2} \quad (3.5)$$

Legend:

TP = turning point, defined as the GDP per capita at which the EKC will reach its peak

β1, β2 = equation coefficients

Based on the conditions above, it can be posited that the EKC hypothesis occurs if the GDP per capita variable is significantly positive and the square of GDP per capita is negative. Furthermore, changes in the influence of economic growth, population density, FDI, HDI, trade openness, urbanization, agricultural land, and industrialization on CO_2 emissions between before and after the implementation of the SDGs program can be determined from the dummy value of each independent variable. If the dummy is significant, it means that there are changes that occurred in that variable after the SDGs came into force.

Panel data regression analysis methods can be based on three approaches.

1) Common Effect Model (CEM)

According to Baltagi (2005), a model without individual influence (common effect) is an estimate that combines all-time series and cross section data using the Ordinary Least Square (OLS) approach to estimate the parameters. This model assumes that the intercept and slope values between individuals remain constant over various periods of time, so that the estimation results do not correspond to actual reality. In general, the model equation can be written as follows:

$$Yiy = \alpha + \beta Xit + \varepsilon it \quad (3.6)$$

Legend:

Yiy = Response variable at the ith observation unit and time t

Xit = Predictor variable at the ith observation unit and time t

β = Slope coefficient or direction coefficient

α = Intercept of the regression model

εit = error

2) Fixed Effect Model (FEM)

The FEM approach or fixed effects model assumes that there are different effects according to the relationship between individuals and time, which are shown through differences in the intercept or constant for each individual. In other words, in this model the intercept or constant value between individuals is different but has a constant slope between individuals in various time periods because the characteristics of each individual are different (Basuki & Prawoto, 2016).

3) Random Effect Model (REM)

This model estimates panel data where disturbance variables may be interconnected over time and between individuals. In this model the difference between individuals and time is shown by the intercept through error. The specification effect of each individual is needed as part of the error component which is random and uncorrelated with the observed explanatory variables. Models with this approach can minimize the use of degrees of freedom but do not reduce the number as is done with fixed effects. The advantage of using this approach model is that it eliminates heteroscedasticity problems. This model is also called the Error Component Model (ECM) or Generalized Least Square (GLS) technique.

3. Results

The results of our research emerge from panel data regression analysis techniques used on secondary data related to CO_2 Emission Demand (Y), Gross Domestic Product (X1), Population Density (X2), Foreign Direct Investment (X3), Human Development Index (X4), Agricultural Land (X5), Industrialization (X6). There are three model choices in panel data regression analysis, including the common effect model, fixed effect model, and random effect model. Model selection in panel data regression analysis is carried out using specification tests. Based on the specification test, the results obtained show that the model chosen in this research is the FEM model. The panel data regression results using FEM are presented in Table 1.

Sample	Dependent Variable	Independent Variable	Coefficient	Prob. T-statistics	Prob. F-statistics	Adj-R2
High income countries	CO_2	D00*GDP	-1,206	0,000***	0,000	0.872
		D00*POP	0.842	0,000***		
		D00*FDI	3,516	0,000***		
		D00*HDI	1,034	0,000***		
		D00*LP	0.563	0,000***		
		D00*ID	6,781	0,000***		
		GDP	2,476	0,000***		
		GDP2	-1,036	0,000***		
		POP	0.568	0.325		
		FDI	4,798	0.015***		
		HDI	2,367	0,000***		
		L.P	1,876	0.124		
		ID	8,345	0.009***		
Upper middle-income countries	CO_2	D00*GDP	4,714	0,000***	0,000	0.798
		D00*POP	1,453	0,000***		
		D00*FDI	6,873	0.014***		
		D00*HDI	1,357	0.005***		
		D00*LP	1,985	0,000***		
		D00*ID	4,834	0,000***		
		GDP	23,897	0,000***		
		GDP2	-1,004	0.003***		
		POP	2,673	0.013***		
		FDI	7,352	0,000***		
		HDI	2,146	0.186		
		L.P	4,645	0.231		
		ID	6,354	0,000***		
Lower middle-income countries	CO_2	D00*GDP	3,785	0,000***	0,000	0.697
		D00*POP	2,053	0,000***		
		D00*FDI	7,342	0.007***		
		D00*HDI	1,093	0.012***		
		D00*LP	1,257	0.006***		
		D00*ID	5,893	0,000***		
		GDP	11,456	0.003***		
		GDP2	1,102	0.002***		
		POP	4,653	0.041***		
		FDI	9,065	0.217		
		HDI	1,763	0.162		
		L.P	2,356	0,000***		
		ID	8,365	0.001***		

Table 1. Summary of Hypothesis Test Results and Determination Coefficient Analysis

a. Panel Data Regression Analysis in High Income Countries

Based on the results of the regression analysis above, the result is that the GDP variable has a probability of <αnamely 0.000 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The population density variable has a probability >αnamely 0.325 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The foreign investment variable has a probability <αnamely 0.015 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The human development index variable has a probability <αnamely 0.000 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The agricultural land availability index variable has a probability of >αnamely 0.124 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The industrialization variable has a probability <αnamely 0.009 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. Based on the regression results, the Prob F-statistic value is 0.000, which means <0.05 so that Ha is accepted, and it can be concluded that the variables Gross Domestic Product (X1), Population Density (X2), Foreign Direct Investment (X3), Human Development Index (X4), Agricultural Land (X5), Industrialization (X6) together influence CO_2 emissions in high-income countries.

b. Panel Data Regression Analysis in Upper Middle-Income Countries

Based on the results of the regression analysis above, the results show that the GDP variable has a probability of <αnamely 0.000 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The population density variable has a probability <αnamely 0.013 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The foreign investment variable has a probability <αnamely 0.015 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The human development index variable has a probability of >αnamely 0.186 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The agricultural land availability index variable has a probability of >αnamely 0.231 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The industrialization variable has a probability <αnamely 0.000 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. Based on the regression results, the Prob F-statistic value is 0.000, which means <0.05 so that Ha is accepted, and it can be concluded that the variables Gross Domestic Product (X1), Population Density (X2), Foreign Direct Investment (X3), Human Development Index (X4), Agricultural Land (X5), Industrialization (X6) together influence CO_2 emissions in upper middle-income countries.

c. Panel Data Regression Analysis in Lower Middle-Income Countries

Based on the results of the regression analysis above, the results show that the GDP variable has a probability of <αnamely 0.003 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The population density variable has a probability <αnamely 0.041 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The foreign investment variable has a probability of >αnamely 0.217 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The human development index variable has a probability of >αnamely 0.162 > 0.05 (alpha 5%), so H0 is accepted, and Ha is rejected. The agricultural land availability index variable has a probability <αnamely 0.000 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. The industrialization variable has a probability <αnamely 0.001 < 0.05 (alpha 5%), so H0 is rejected, and Ha is accepted. Based on the regression results, the Prob F-statistic value is 0.000, which means <0.05 so that Ha is accepted, and it can be concluded that the variables Gross Domestic Product (X1), Population Density (X2), Foreign Direct Investment (X3), Human Development Index (X4), Agricultural Land (X5), Industrialization (X6) together influence CO_2 emissions in lower middle-income countries.

Country Category	**Variable**	**Independent Variable Coefficient**	**Variable**	**Independent Variable Coefficient** (with dummy)
High income countries	*GDP*	6,703	*D00*GDP*	-2,013
	POP	4,378	*D00*POP*	1,561
	FDI	19,763	*D00*FDI*	9,672
	HDI	6,723	*D00*HDI*	2,987
	LP	4,098	*D00*LP*	0.968
	ID	23,567	*D00*ID*	11,675
Upper middle-income Countries	*GDP*	3,067	*D00*GDP*	1,097
	POP	2,984	*D00*POP*	1,007
	FDI	10,013	*D00*FDI*	5,467
	HDI	7,876	*D00*HDI*	6,978
	LP	2,876	*D00*LP*	1,076
	ID	16,457	*D00*ID*	9,054
Lower middle-income countries	*GDP*	5,908	*D00*GDP*	2,876
	POP	8,765	*D00*POP*	2,986
	FDI	18,092	*D00*FDI*	10,761
	HDI	7,356	*D00*HDI*	3,254
	LP	6,987	*D00*LP*	2,096
	ID	24,765	*D00*ID*	12.54

Table 2. Results of EKC Hypothesis testing before and during SDGs implementation.

Based on Table 2, it can be argued that before the implementation of SDGS, almost all variables in high, upper middle and lower middle-income countries had a positive influence on CO_2 emissions. However, after the implementation of the SDGs, in high income countries, the increase in GDP has a negative effect on CO_2 emissions. This shows that a number of developed countries have carried out development with low emission principles. For upper and lower middle-income countries, however, after implementing the SDGs all variables have a positive impact in increasing CO_2 emissions, while the coefficient values are lower.

Sample	Coefficient Value		Turning Point	Occurrence of EKC
	GDP	GDP2		
High income countries	2,476	-1,036	USD 11.94 thousand	Will happen in the future
Upper middle-income countries	23,897	-2,008	USD 47.98 thousand	Will happen in the future
Lower middle-income countries	11,456	1,102	USD 93.98 thousand	Will not occur

Table 3. Turning Point Test

Table 3 is a summary of the test results, which shows that there are differences in the results of testing the EKC hypothesis in Asia, both in high income countries, upper middle-income countries or in lower middle-income countries. The EKC hypothesis is declared valid if the GDP per capita variable has a positive coefficient value and the squared GDP2 per capita variable has a negative coefficient value. Based on the results of testing the EKC hypothesis, in high income and upper middle-income countries this will happen in the future because they have negative GDP2 coefficient values. The hypothesis that EKC will occur is at a GDP value of USD 11.94 thousand and USD 47.98 thousand. Meanwhile, in lower middle-income countries there is no EKC because the GDP2 value is positive.

4. Discussion and conclusions

The results of our analysis show the extent to which the six variables studied have a positive and significant or insignificant influence on CO_2 emissions. As regards the effect of per capita income on CO_2 emissions, the results of our analysis in high income countries show that the coefficient value of the GDP variable is 2,476, in upper middle-income countries, the coefficient value of the

GDP variable is 23,897, and in lower middle-income countries, the coefficient value of the GDP variable is 11,456. These values indicate that in all cases GDP has a *positive* and *significant* influence on CO_2 emissions.

The results of the analysis in high income countries show that the coefficient value of the population density variable is 0.568, indicating that population density has a *positive* and *insignificant* effect on CO_2 emissions. On the other hand, in upper middle-income countries, the coefficient value of the population density variable is 2.673, and in lower income countries, the coefficient value of the population density variable is 4,653, indicating that in both cases population density has a *positive* and *significant* influence on CO_2 emissions.

The results of the analysis in high income countries show that the coefficient value of the foreign investment variable is 4,798, and in upper middle-income countries the coefficient value of the foreign investment variable is 7.352, indicating that in both cases foreign investment has a *positive* and *significant* influence on carbon dioxide CO_2 emissions. In lower middle-income countries, the coefficient value of the foreign investment variable is 9.065, indicating that foreign investment has a *positive* and *insignificant* effect on carbon dioxide CO_2 emissions.

The results of the analysis in high income countries show that the coefficient value of the human development index variable is 2.367, indicating that the human development index has a *positive* and *significant* influence on CO_2 emissions. In upper middle-income countries the coefficient value of the human development index variable is 2.146, and in lower middle-income countries, the coefficient value of the human development index variable is 1.763, indicating that in both cases the human development index has a *positive* and *insignificant* influence on CO_2 emissions.

The results of the analysis in high income countries show that the coefficient value of the agricultural land availability variable is 1.876, and in upper middle-income countries, the coefficient value of the agricultural land availability variable is 4,645, indicating that the availability of agricultural land has a *positive* and *insignificant* influence on CO_2 emissions. On the other hand, in lower middle-income countries, the coefficient value of the agricultural land availability variable is 2.356, indicating that the availability of agricultural land has a *positive* and *significant* influence on CO_2 emissions.

The results of the analysis in high income countries show that the coefficient value of the industrialization variable is 8.345, in upper middle-income countries the coefficient value of the industrialization variable is 6.354, and in lower

middle-income countries, the coefficient value of the industrialization variable is 8.365, indicating that in all cases industrialization has a *positive* and *significant* influence on CO_2 emissions.

The results of dummy variable analysis show that before the implementation of SDGS, almost all variables in high-income, upper-middle, and lower-middle-income countries had a positive influence on CO_2 emissions. However, after the implementation of the SDGs, in high-income countries the increase in GDP has a negative effect on CO_2 emissions. This shows that in developed countries, many have implemented development policies with low emission principles. For upper and lower middle-income countries, although after implementing the SDGs all variables have a positive impact in increasing CO_2 emissions, the coefficient values are lower. This suggests that implementation of SDG policies can contribute to results in line with the EKC hypothesis.

In terms of overall EKC hypothesis testing our research has limitations in the form of a research model that only focuses on the dependent variable CO_2 emissions. A further limitation is that it does not include countries in the lower income category. The research methodology uses only panel data analysis techniques. Future further research should complete the model by adding environmental quality index variables to the model and using more comprehensive analysis techniques. Moreover, while our research uses a uniquely quantitative approach, future research should add a qualitative dimension.

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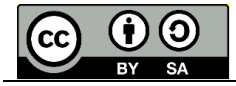

Original Paper

Enhancing energy justice through solar power proliferation in Kenya's devolved units.

Insights from Makueni and Nyeri

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Abstract. *In response to escalating human needs and the worsening impacts of climate change attributed to fossil fuel use, the concept of energy justice, especially in relation to solar power, has emerged as a solution to ensure sustainable energy access, security, and affordability universally. Despite efforts to promote solar power in many developing countries, energy injustices persist, exacerbated by limited scientific information on promoting energy justice within the solar power context. Addressing this challenge in Kenya, this study aimed to explore Makueni and Nyeri counties better to understand strategies for universal energy provision through solar power. The study examined the socio-cultural, economic, and environmental contexts relevant to energy justice and solar power usage. Information was gathered from online sources through literature and official documents to analyze qualitatively for insights employing a case study research design and literature review. The examination revealed contrasting scenarios in Nyeri and Makueni counties: Makueni demonstrated robust leadership with community-driven projects and proactive financing, while Nyeri faced challenges with regulatory transparency. Nonetheless, both counties sought equitable solar distribution, with Nyeri prioritizing affordability and Makueni emphasizing public participation and long-term community involvement. The study underscores the influence of contextual factors and governance on energy justice outcomes in solar power expansion, urging solar power stakeholders to prioritize inclusive approaches and regulatory enhancements for sustainable energy justice initiatives.*

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1. Introduction

There is widespread concurrence that providing energy for all through the proliferation of renewable energy sources such as solar energy is one of the most feasible interventions for limiting global warming to 1.5^{o}c in efforts to avoid catastrophic climate change (IPCC, 2018; IEA, 2019; Sustainable Energy for All, 2024). This realization originates from the fact that traditional energy production and distribution systems based on fossil fuels have propagated energy injustice for a long time. Fossil fuel extraction pollutes the environment, demands substantial resources, and exploitation requires monopolized technology, which

may not be available for most developing countries. Promoting energy justice through solar photovoltaics (PV) has become cost-effective and accessible, challenging fossil fuels. In 2019, up to 119 GW of solar power installed capacity was achieved globally, reflecting its versatility across market segments. In addition, many governments actively pursue solar power exploitation in their quest for sustainable development (IEA, 2020; Aklin, 2018; UN, 2018). However, solar PV's affordability and modularity have not completely eradicated energy poverty, reflecting socio-material injustice where households struggle to access adequate energy services (Horta et al., 2019).

Consequently, the concept of energy justice in solar power proliferation has emerged to strive for fairness in social and economic involvement, addressing the disproportionate impacts on marginalized groups such as frontline, working class, and indigenous communities. Energy justice aims for accessible, affordable, clean, and democratically community-managed energy for all (Initiative for Energy Justice, 2024). However, existing literature reveals there are still gaps in clearly defining renewable energy and marginalized communities across various jurisdictions (Initiative for Energy Justice, 2023). Contrary to policy goals, this creates a substantial opportunity for energy sources backed by the fossil fuel industry to remain a part of the grid. Moreover, various approaches are used to define marginalized communities without carefully examining the perspective of outcomes and benefits for frontline communities. As a result, energy poverty tied to inadequate infrastructure for energy services can endure even with widespread infrastructure rooted in deep-seated inequalities. Energy access related to energy justice is integral to energy rights, citizenship, facilitating cleanliness, good health, political participation, and comfortable living temperatures (Day et al., 2016; Brand-Correa & Steinberger, 2017). However, the concept of a right to energy is intricate, with diverse interpretations and contestations over its implications necessitating the need for more context-specific studies in various jurisdictions (Sareen & Haarstad, 2018; Day et al., 2016). Nevertheless, enhancing energy justice in solar power exploitation requires new strategies that intertwine renewable energy justice, energy equity, and energy democracy to enhance benefits that can accrue to local populations through remedying injustices of the fossil-fuel energy system and extractive economy (Behrens et al., 2016; Mitchell, 2009).

In Kenya, solar energy is recognized through key policies such as the Energy Act No. 1 of 2019 as essential for achieving energy justice and sustainable development. This realization has seen massive government investment being channeled into promoting its proliferation. The Kenyan government has

removed import duty and zero-rated value-added tax (VAT) for renewable energy equipment and accessories. Furthermore, Kenya is devising and revising renewable energy plans to ensure dependable solar energy provision at optimal costs by creating a favorable atmosphere encouraging investments in energy infrastructure at national and county government levels. Despite these efforts, energy injustices are still prevalent in access to energy, energy costs, and energy governance, particularly in rural and underserved areas. Using a literature review through document content analysis with case study insights from Makueni and Nyeri counties, this study investigates the current status of solar energy justice in the two counties in Kenya and devises strategies for improving solar energy access for all. To respond to this study objective, two research questions were asked. First, from the perspective of energy justice and sustainable development, what is the current status of solar proliferation in Makueni and Nyeri counties? How can solar energy justice be improved for sustainable development in Nyeri and Makueni counties? To execute this study, the concept of energy justice in solar power proliferation was first reviewed from the theoretical and empirical background of sustainable development. Later, the findings were synthesized with results from the case studies in order to draw the policy implications of this paper.

2. Energy Justice, Solar Power, and Sustainable Development

2.1. Theoretical analysis

Energy justice addresses inequalities in the energy sector by advocating for a global energy system that distributes benefits and costs fairly. It emphasizes representative and impartial decision-making, applying principles of justice to availability, affordability, sustainability, and due process (Sovacool & Dworkin, 2014). This approach aims to integrate justice and ethics into energy sector decisions, recognizing the potential impact on citizens' lives while ensuring fairness among paying consumers (Heffron & McCauley, 2017; Heffron, 2022). Energy justice addresses the ethical distribution of energy resources, aligning with sustainable development principles and the Rio Declaration's equity standards. Prioritizing affordability, sustainability, and availability, it fosters human and economic development through distributional, recognition, and procedural justice principles (Jenkins et al., 2016). Distributional justice tackles energy access disparities, recognizing uneven resource distribution. Recognition justice rectifies overlooked populations. Procedural justice ensures inclusive decision-making, employing methods like public participation and EIAs. Implementing these

principles in energy policies enhances availability, affordability, sustainability, and due process, fostering acceptance, conservation, and development (Jenkins et al., 2016). The concept of energy justice holds significant importance for Kenya as it navigates defining its energy future, including the future of solar power. Kenya is confronted with the task of facilitating a 'just transition' to a lower carbon economy, balancing poverty reduction and climate change resilience objectives.

2.2. Empirical studies

The global recognition of energy's importance is underscored by the dimensions of Sustainable Development, which aims to ensure access to affordable, reliable, sustainable, and modern energy for all (Muigua, 2020; Heffron & Heffron, 2021). Renewable energy sources, especially solar power is increasingly being promoted as the preferred modern energy for all. Consequently, there is an emerging body of knowledge that seeks to explore energy justice and find ways in how to improve the proliferation of solar power (Chapman et al., 2018). Energy justice literature has gained substantial academic and practical traction, yet lacks systematic reflection on its scope and contributions. A review of 155 articles from 2008 to 2019 reveals gaps in author diversity and research design. While conceptual frameworks are expanding, there's a need for more diverse research methods. Energy justice serves as a powerful tool, encouraging researchers to remain normative and proactive in identifying injustices while fostering new research methods and themes (Jenkins et al., 2021).

In Australia, a study that delved into the equitable distribution of energy production benefits and costs explored the tension between urban consolidation and solar photovoltaic (PV) promotion in Australia's capital cities. Using dynamic panel data analysis from 2001 to 2015, it finds that denser built environments initially impede solar PV installations, mitigated by feed-in tariffs (FiTs) (Poruschi & Ambrey, 2019).

In two Western Indian states, a study explored the political-economic dynamics influencing solar energy development, focusing on Rajasthan and Gujarat. It investigated how regional factors and path dependence shaped solar growth, often diverging from expectations. Energy justice was introduced to assess alignment with climate justice, economic development, and social equity goals. Through a political economy lens, the study contributed to understanding solar power's intersection with development. Another study in India indicated that large-scale deployment of solar photovoltaic (PV) systems might overshadow social and environmental justice concerns. It examined procedural justice in solar energy implementation, using the Charanaka Solar Park case study. It highlighted

impacts on rural communities and marginalized groups due to procedural justice failures, suggesting policy and governance improvements (Yeneti & Day, 2015). Yeneti et al. (2016) delved into spatial justice aspects concerning land acquisition for large-scale solar energy projects within India's developmental framework, focusing on the Charanka Solar Park in Gujarat, one of the world's largest solar park projects. It exposes discrepancies between official rhetoric and ground realities. Despite claims of inclusive renewable energy initiatives, the research uncovers contentious land and power dynamics. Vulnerable communities face increased precariousness, risking livelihoods due to common land enclosure and questionable land acquisition practices. This case illustrates how mega solar projects may perpetuate a regime of accumulation, benefiting coalitions of interests while disenfranchising vulnerable social groups from their vital assets.

Bedi (2019) studied solar energy as an alternative to fossil fuels to meet India's energy needs, particularly in Kerala. It examined the Kasaragod solar park project and the associated green corridor transmission line, promoted as climate-friendly infrastructure development. While government officials touted benefits, including development for local stakeholders, indigenous Adivasis and others without land titles opposed land acquisition. Local political opposition reduced the solar park's size, but some Adivasis lost land and livelihoods. The case highlighted how achieving renewable energy goals must address socio-environmental injustices and recognize historical land disparities, underscoring the importance of local political power in shaping large-scale projects.

Other studies show that renewable energy, including wind and solar power, is vital for sustainable development. However, challenges like unequal benefits distribution, cultural disrespect, and limited participation in decision-making persist. Addressing these issues is crucial for integrating energy justice into policies and ensuring an equitable transition to sustainable energy systems (Villavicencio Calzadilla & Mauger, 2018). Heffron et al. (2021) found that global solar energy development is crucial for meeting energy and climate goals, leveraging untapped solar potential. It transforms energy mixes, aligning with Paris Agreement targets. Research highlights solar's overlooked benefits and justice implications. Analyzing legislation across 72 countries emphasizes the need for robust legal frameworks to ensure investment certainty and flexibility. Combining law and economics, flexible justice can enhance economic welfare through market reforms, accommodating technological advancements, cost changes, and ownership structures in solar energy systems (Heffron et al., 2021).

In the African context, access to clean and affordable energy remains a significant challenge due to economic constraints and inadequate institutional support

(Njiru & Letema, 2018). However, renewable energy adoption policy is advancing in Africa with the hope of exploiting the benefits of energy justice. Comparative mapping of renewable energy policies in 34 African countries reveals varying policy frameworks' contributions to energy justice (Müller et al., 2021).

In summary, scholarly reviews emphasize global efforts to promote solar energy justice for Sustainable Development. Studies across the world highlight disparities in contextual practicalities, while in Africa, there is still low energy access despite solar power adoption. This calls for comparative solar energy policy mapping, integrating socio-ecological justice and development goals.

2.3. Solar energy and just transition in Kenya

Kenya has seen remarkable strides in energy transition, with 89% of electricity sourced from renewables in 2021, including a 1% contribution from solar power. The country's solar potential, estimated at 15,000 MW, is promising due to its equatorial location and ample sunshine hours. Major solar projects like the Garissa Solar power (55 MW), Malindi solar plant (52 MW), and others aim to mitigate carbon emissions and provide energy access. Corporate giants like East African Breweries Limited (EABL) and Bamburi Cement are investing significantly in solar energy to reduce costs and reliance on the national grid, signaling a broader trend toward sustainability and clean energy adoption in Kenya. Additionally, local companies such as the London Distillers Kenya (LDK) has successfully cut power costs by 50% through solar power utilization, demonstrating the economic and environmental benefits of renewable energy integration (KIPPRA Website, 2024). Kenya faces significant challenges regarding the cost, source, and quality of electricity. Compared to neighboring countries, Kenyan manufacturers pay up to four times more for electricity, impacting their competitiveness. Solar energy presents a cost-effective solution, with costs decreasing globally by 86% since 2009. However, solar energy usage remains low in Kenya, despite its abundant potential and environmental benefits. The country heavily relies on hydroelectric and geothermal power, leading to power outages and losses for manufacturing firms. Drought exacerbates electricity generation issues, prompting increased reliance on costly diesel generators. Efforts to improve energy access and reduce costs include tariff reductions and subsidies by the government. Plans for renewable energy expansion and initiatives like the National Energy Efficiency and Conservation Strategy aim to enhance energy supply and promote solar energy utilization. Recent interventions, such as VAT exemptions on solar equipment and solar

electrification programs for schools and health facilities, demonstrate progress in solar energy adoption (KIPPRA, 2024).

Despite these efforts, Challenges persist in the solar market due to substandard products, necessitating regulatory measures and consumer awareness for quality and affordability assurance. Policy recommendations include subsidies for commercial projects, restructuring Feed-In Tariffs, promoting mini-grids, net metering, domestic manufacturing, and quality control measures (KIPPRA, 2024). Solar energy systems benefit manufacturers by stabilizing power bills, improving energy reliability, and reducing grid dependency. Collaboration between the solar industry and regulators ensures quality standards enforcement (KIPPRA, 2024).

Moreover, Kenya has experienced rapid growth in electrification, reaching 75% of the population with access to electricity by 2018 (International Energy Agency [IEA], 2019). The National Electrification Strategy aims for universal access by 2022, emphasizing renewable energy deployment. Despite progress, a significant urban-rural disparity persists, with 84% of rural populations lacking electricity. Nairobi households are 36 times more likely to have electricity compared to those in Turkana or Tana River Counties, raising concerns about energy justice (Muigua, 2020). Such disparities underscore the need for equitable energy access, especially for vulnerable populations. Ensuring fairness in energy provision is essential, given its fundamental importance as a human need (Moner-Girona et al., 2019).

Energy costs encompass both connection expenses and energy consumption fees. Sub-Saharan African countries face significant affordability challenges due to high power costs relative to income levels. In Kenya, electricity prices surpass global averages, with households paying $0.224 per kWh and businesses $0.192 per kWh. Alternative sources like kerosene, influenced by international prices, are unpredictable and unreliable for low-income households (Avila et al., 2017). The Constitution of Kenya 2010 guarantees access to information, but some energy providers withhold crucial details, hindering informed decisions on tariffs, pollution, and affordability. Additionally, stakeholders often disregard public participation principles during energy projects, undermining democratic decision-making and potentially neglecting the interests of affected communities (Muigua et al., 2015). In summary, even though adoption rates are still low due to a myriad of challenges, Kenya has made significant strides in energy transition, with renewables contributing 89% of electricity, including a 1% share from solar power.

3. Materials and Methods

3.1. Case study research design

The case study research design for the study on Enhancing Solar Energy Justice in Devolved Units in Kenya, which focused on Makueni and Nyeri Counties, involved an in-depth investigation into the unique contexts, challenges, and opportunities surrounding solar energy access and distribution within these regions. By examining specific cases within Makueni and Nyeri Counties, researchers identified best practices, barriers, and potential interventions to promote equitable solar energy access and address underlying socio-economic and environmental concerns. The case study approach enabled a comprehensive examination of real-world experiences, providing insights that informed policy formulation, community engagement strategies, and sustainable energy development initiatives at both local and national levels.

3.2. Case studies

3.2.1. Nyeri County

Nyeri County, located in Kenya, boasts a diverse landscape characterized by its administrative boundaries, topographical features, hydrological networks, vegetation, national parks, human settlements, transportation corridors, and social infrastructural facilities. Covering an area of 3337 km^2, the county comprises eight sub-counties and 30 wards. Its topographical diversity ranges from the majestic heights of Mount Kenya, the highest point at 5199m above sea level, to the lowlands of Mukurweini Central ward along the Sagana River, which sits at 1192m above sea level. Slopes within the county vary from 2% to 90%. Hydrologically, rivers, wetlands, and dams cover 0.05% of the total land area, with the River Sagana boasting the highest average discharge of 13m^3/s. Nyeri County's rich vegetation includes forests covering 38% of the land area, notably the Mount Kenya Forest and Aberdare Forest. The county is also home to significant conservation areas, including Mount Kenya National Park (107 km^2) and Aberdare National Park (466 km^2). Human settlements are marked by two principal towns—Nyeri and Karatina—along with four urban centers and numerous market and rural centers. The transportation infrastructure is well-developed, with a road network spanning 3092 km, a rail network of 77.7 km, and four airstrips. The county has an extensive network of social infrastructural facilities, including 440 public ECDs, 352 public primary schools, 195 public secondary schools, colleges, TVETS, vocational training institutes, polytechnics,

and universities, along with various levels of health facilities catering to the diverse needs of its population.

Hydropower stands as Nyeri's primary grid electricity source, contributing 677 MW to the national grid and comprising over 57% of the country's electricity output. In Nyeri County, Sagana River holds hydropower potential, as indicated by studies from Sogreah Engineering Firm. While wind speeds are generally low, wards in Kieni East display moderate potential for small-scale power generation. The region's cool climate, influenced by Aberdare Ranges and Mt. Kenya, contrasts with hotter, drier areas in Kieni East and West, where solar energy potential thrives due to high insolation, particularly during dry seasons. These renewable resources offer promising energy alternatives in the county (Two Ems Associates, 2019).

Up to 68% of residents rely on electricity for lighting, with over 80.78% of households connected to the national grid as of August 2018. Firewood serves as the primary cooking fuel for 61% of households, particularly in Rugi and Gikondi wards, highlighting the demand for alternative energy sources like solar power, especially in Kieni East and West sub-counties.

The Nyeri solar PV plant in Kenya is poised to become the country's first privately owned project of its kind to achieve commercial operation, following a significant US$355,000 equity investment from the Renewable Energy Performance Platform (REPP, 2024). Developer Marco Borero anticipates reaching financial close on the 1.5MW project in Nyeri County imminently, targeting commercial operation by year-end. REPP's equity injection has facilitated completion of the financing required for the project, complementing earlier senior debt offers. Astonfield Solar, the sub-Saharan Africa solar EPC contractor, is set to accelerate construction with REPP's support. The project's location just north of Nyeri town aims to harness natural solar energy, contributing to Kenya's clean energy goals and reducing reliance on fossil fuels (REPP, 2024).

The Kiamariga solar project, initially envisioned as a remedy to the energy poverty plaguing Kagati, Mathira Constituency, encountered formidable obstacles that ultimately led to its downfall. Primarily, the absence of comprehensive community consultation regarding land use profoundly undermined the project's legitimacy, fostering skepticism and resistance, particularly among figures like James Kabarita (Standard Newspaper, 2020). Moreover, the opaque process of awarding the project to Kumar and Associates triggered concerns regarding transparency and potential misappropriation of

public funds, voiced notably by members of the Nyeri County Assembly. Regulatory challenges, including the failure to secure a Power Purchase Agreement with Kenya Power, compounded the project's difficulties, while doubts about Kumar and Associates' expertise in solar energy development further eroded confidence in its feasibility. Environmental apprehensions and disputes over land usage rights added to the project's complexities, prompting appeals to the National Land Commission. Despite these setbacks, the county government remains intent on revitalizing the project, highlighting the need to address community grievances, enhance transparency in procurement, and navigate regulatory frameworks meticulously to ensure its potential success upon revival (Standard Newspaper, 2020).

3.2.2. Makueni County

Makueni County, spanning 8,034.7 sq km, is home to over 0.9 million people. It shares borders with Kajiado, Taita Taveta, Kitui, and Machakos Counties, lying within Kenya's arid and semi-arid Eastern region. Notable physical features include the Volcanic Chyulu hills, Mbooni hills, and Kilungu hills. The county comprises six sub-counties: Makueni, Mbooni, Kaiti, Kibwezi East, Kibwezi West, and Kilome. Renowned for horticulture, Makueni boasts water management projects like dams and irrigation schemes, bolstering agriculture and prosperity. With a focus on service delivery and continuous investment, the county emphasizes transparency through web portals, social media, and maps, aiming to serve as a model for development locally and nationally. Makueni County, located in Kenya's arid and semi-arid southeastern region, confronts significant climate challenges, notably frequent droughts. Its population, primarily dependent on rain-fed agriculture and estimated at 987,653 in 2019, faces heightened vulnerability to climate change due to limited adaptation resources (GoK, 2019c). In response, Makueni County has enacted the Makueni County Climate Change Act of 2022, a robust framework for climate resilience and adaptation. This legislation establishes the County Climate Change Fund (CCCF), mandating 1% of the annual county development budget for climate change initiatives. Operationalized in 2015, the CCCF, with investments totaling KES 28.9 million by April 2017, aims to enhance the adaptive capacity of local communities (GoK, 2015c; BRACED, 2020).

Energy consumption in the county is rising, yet the adoption of renewable energy sources beyond hydro-electricity remains limited. Most residents depend on charcoal and firewood, undermining environmental conservation efforts in the county (Makueni County Environment and Climate Change Policy, 2021). In Makueni County, strategies are being pursued to promote the adoption of

renewable sources of energy and identify mechanisms for subsidizing alternative energy sources as a way of reducing environmental pollution. The county and REREC have signed a collaboration to enhance rural electricity accessibility, renewable energy, and clean cooking (Makueni County Government Website, 2024). With a Kshs. 30 Million matching grants from the County Government, the initiative aims to benefit approximately 624 households, promising improved living standards and economic growth. The Department of Infrastructure, Transport, Public Works, Housing, and Energy, in collaboration with Strathmore University and WRI, organized a 3-day County Energy Plan Validation workshop focused on Energy Access to affordable, sustainable, and clean energy, productive use of energy, clean cooking technologies, and sustainable bioenergy (Makueni County Government, 2024).

The County Government of Makueni (GoM) emphasizes power and resource redistribution through robust Public Participation (Gathii and Otieno, 2018; Wesangula, 2018; Omolo et al., 2018). Public participation involves five layers: village, cluster, sub-ward, ward, and county levels, fostering community decision-making and civic education on governance and household involvement. The policy acknowledges the interconnectedness of institutions, systems, and individuals. An interview conducted in the county in a region that had been installed with solar power the benefit of public participation in the county (Acts, 2024). All 32 interviewees concurred that public participation is pivotal for the success of solar initiatives, including mini-grids, home systems, or grid-connected projects. They emphasized that excluding stakeholders from the process undermines a project's sustainability and effectiveness in the long run. The prevalence of non-state actors in Makueni has facilitated the government's introduction of a robust policy of public participation, creating an environment conducive to the adoption of solar technologies at the household level. Community groups, such as the women's group selling M-KOPA solar products, play a significant role in promoting and distributing these solutions through various channels like churches, markets, and community gatherings. Their partnership with M-KOPA, incentivized by bonus payments, underscores the effectiveness of organized groups as a value chain for solar products. This collaborative approach not only fosters solar uptake but also empowers women economically and socially, granting them decision-making authority over products that directly impact their lives and community. Thus, Makueni's emphasis on public participation not only supports the private sector in solar production but also fosters socio-economic empowerment at the grassroots level (Acts, 2024). The study recommended that the deployment of solar energy should be integrated into broader decision-making frameworks within any given

context. Inclusive decision-making processes are essential for the successful uptake of solar energy, necessitating targeted efforts to include historically marginalized groups such as women and young people. Moreover, solar power initiatives should align with broader efforts aimed at empowering citizens both at the individual and collective levels. This holistic approach ensures that solar energy projects contribute not only to sustainable energy access but also to broader societal empowerment and inclusion agendas (Acts, 2024). The map (Figure 1) shows the geographical location of Nyeri and Makueni counties in Kenya.

Figure 1. Location of the study sites

3.3. Data sources and collection process

In conducting the study, a meticulous approach to data collection via textual analysis was adopted. Initially, inclusion and exclusion criteria were established to ensure the relevance of the gathered literature, focusing on solar energy justice, devolution in Kenya, and studies specific to Makueni and Nyeri Counties. Keywords such as "solar energy justice," "devolution," "Kenya," "Makueni County," and "Nyeri County" were defined to facilitate comprehensive searches across academic databases like PubMed, Google Scholar, JSTOR, and Scopus.

Through systematic screening, texts were evaluated based on their alignment with the research objectives, and only those meeting the inclusion criteria were selected for detailed analysis. These selected texts underwent thorough textual scrutiny, concentrating on identifying key themes regarding solar energy justice, devolution policies, challenges, and opportunities within the context of the two counties. Pertinent data points were extracted from the analyzed texts to inform the study's conclusions and recommendations. Ultimately, through synthesis and interpretation, the findings derived from the textual analysis aimed to offer meaningful insights into solar energy justice within the framework of devolved governance in Makueni and Nyeri Counties, thus contributing to informed decision-making and policy formulation in the region.

Document	**Key findings**	**Source**
Government of Makueni County Vision 2025	Provides for the need of clean energy sources, including solar power for sustainable development in the county.	Website
Makueni County Environment and Climate Change Policy 2021	Promotes the use of renewable energy sources including solar power as a way of curbing environmental pollution	Website
Makueni County Forest and Landscape Restoration Implementation Plan (FOLAREP), 2023-2030	Identifies solar power fencing as one of the ways of promoting innovative community-based and cost-efficient approaches for protection of restored and/ or areas under restoration	Website
Nyeri County Spatial Development Plan, (2019- 2029)	Identifies the potential for solar energy in the county in the drier and hotter areas of Kieni East and West sub-counties due to the high insolation, especially during dry seasons.	Website
Nyeri County Integrated Development Plan, (2023-2027)	Emphasizes the need to tap solar energy resources in the county	Website
Kareithi, (2017)	The study examined factors influencing the implementation of rural electrification programs in Kieni East Sub County, Nyeri County, Kenya. It employed a descriptive survey research design targeting 4289 households and 10 Rural Electrification Authority Team members. The findings highlighted funding, electricity costs, alternative power sources, and demand as critical factors affecting program implementation, suggesting the need for subsidies and policy adjustments to enhance success.	Google Scholar
Nyaga et al., (2020)	Explored the fuel preferences and reasons among households in urban areas of Nyeri town, Kenya, aiming to understand domestic energy transition. It	Google Scholar

Document	Key findings	Source
	was established that factors such as convenience, affordability, accessibility, and cultural beliefs significantly influence fuel choices among urban residents.	
Mwangi, (2013)	The study investigated energy consumption patterns in rural households in Mukaro location, Nyeri County, focusing on wood fuel usage and its influencing factors. Findings emphasized the significance of wood fuel, household income, and distance traveled in fuel consumption, proposing recommendations for policy recognition and support for alternative energy sources.	Google Scholar
Waita & Aduda, (2017)	The study established that unclear module specifications, poorly matched batteries, and undersized cables, emphasizing the need for training in PV system design and maintenance.	Google Scholar
MacEwen & Evensen, (2021)	The study demonstrated that processes of women's empowerment contribute to democratizing energy structures in the Makueni county. It emphasizes the importance of examining winners and losers in the energy transition and proposes integrating feminist epistemologies into energy democracy theorizing to analyze self-constructions and social hierarchies.	Google Scholar
Kazungu, (2020)	The study revealed that in Machakos county, firewood was extensively used for cooking across all schools, followed by charcoal, LPG gas, and paraffin. Electricity was seldom used due to its high cost and unreliability. Lighting mainly relied on electricity and solar energy. Energy-saving stoves, solar power, and energy-saving bulbs were preferred due to their affordability and environmental benefits. Challenges included the scarcity of firewood and charcoal, the high installation cost of solar power, and electricity's unreliability. The study recommended government interventions to make modern energy technologies more accessible, establishment of school-based woodlots, and increased adoption of solar power to mitigate overreliance on firewood.	Google Scholar
Ngetha, (2015)	The paper examined energy source trends in Kenya's central highlands rural community over three decades, from firewood to solar home systems. While industries and urban areas rely on petroleum and hydroelectric power, rural areas mainly use firewood. This reliance impacts ecosystems and nutrient cycling, especially considering over 80% of Kenya's regions are arid or semi-arid.	Google Scholar
Standard Newspaper, (2020)	The Newspaper reported that an existing solar power project, the Kiamariga solar project in Kagati, Mathira Constituency in Nyeri county, initially proposed as a	Website

Document	Key findings	Source
	solution to the energy poverty in the region, faced significant challenges and ultimately floundered. The failure of the Kiamariga solar project stemmed from: insufficient community consultation leading to skepticism and resistance, transparency concerns, regulatory hurdles, doubts over developer expertise, and environmental and land use issues.	
Nation Newspaper, (2020)	Reported that Nyeri residents opposed a Kshs. 6 billion solar power plant funded by international investors, citing irregularities in the contract. The residents complained that they had not been consulted. They noted that the public participation conducted over the handling over of their 134 Ha community land to the investor was biased. The plant was aimed at producing 40 megawatts to be fed to the national grid.	Website

Table 1. Documents reviewed

3.4. Data analysis

This study sought to explore ways of enhancing solar energy justice in Kenya's devolved units by using the lens of energy justice as an analytical framework. Energy justice encapsulates the foundational principles of equitable distribution, affordability, and universal access to clean and reliable energy sources for all individuals and communities. It serves as a conceptual framework for advancing solar energy justice, ensuring that the benefits of renewable energy technologies are shared equitably among diverse populations. Equitable distribution emphasizes the fair allocation of solar energy resources across regions, demographics, and socio-economic groups, striving to address historical disparities in energy access and promote inclusive development. Affordability is paramount within the realm of energy justice, as it entails making solar power financially accessible to households, businesses, and institutions, regardless of their income levels or economic status. By reducing barriers to entry and implementing innovative financing mechanisms, such as subsidies and microfinance initiatives, affordability can be enhanced, enabling more individuals to transition to clean energy solutions. Access to clean and reliable energy sources is foundational to achieving energy justice, as it underpins various aspects of human well-being, including health, education, and economic productivity. By prioritizing equitable distribution, affordability, and access to clean energy,

stakeholders can foster a more sustainable and inclusive energy transition, empowering communities and advancing social equity on a global scale.

4. Results

4.1. Current status of solar power in Nyeri and Makueni counties

Nyeri County lacks research on solar power and energy justice, contrasting with Makueni's thriving community solar projects driven by public participation and collaborations. Makueni's proactive financing, including partnerships with REREC and academia, showcases commitment to solar development. Challenges persist in Nyeri, marked by regulatory hurdles and transparency issues despite investments (Table 2).

Thematic Area	Makueni	Nyeri
Community solar projects	Community solar projects in Makueni County reflect a concerted effort towards sustainable energy adoption. Leveraging public participation initiatives, including multi-layered engagement from village to county levels, Makueni promotes solar energy uptake. Collaborations with non-state actors, exemplified by women's groups selling M-KOPA solar products, demonstrate effective community-driven distribution networks. This holistic approach empowers marginalized groups, aligning with broader socio-economic and environmental goals.	Community solar projects in Nyeri County face significant challenges despite its diverse landscape and rich renewable energy potential. The Nyeri solar PV plant represents a promising initiative, with substantial investment from REPP aiming to achieve commercial operation soon. However, the failure of the Kiamariga solar project underscores the importance of comprehensive community consultation and transparency in procurement processes. Regulatory hurdles and environmental concerns further complicate solar energy initiatives in the region.
Policy environment	Makueni County fosters sustainable energy through community-driven solar projects. Public participation initiatives, collaborations with non-state actors, and multi-layered engagement promote solar energy uptake, empowering marginalized groups and aligning	Nyeri County faces challenges in its solar power policy environment. The Nyeri solar PV plant represents progress, attracting substantial investment for commercial operation. However, the failed Kiamariga solar project highlights transparency and regulatory hurdles that impede solar energy initiatives.

Thematic Area	Makueni	Nyeri
	with socio-economic and environmental objectives.	
Financing initiatives and investments	In Makueni, financing initiatives and investments for solar power are gaining momentum as the county prioritizes sustainable energy solutions. The collaboration between the county government and the Rural Electrification and Renewable Energy Corporation exemplifies this commitment, aiming to enhance rural electricity accessibility and promote clean cooking through renewable energy sources. With a significant matching grant from the County Government, initiatives seek to benefit hundreds of households, promising improved living standards and economic growth. Additionally, partnerships with academic institutions like Strathmore University and organizations such as the World Resources Institute (WRI) underscore Makueni's proactive stance toward securing financing and investments for solar power. These efforts signify a pivotal shift towards leveraging financial resources to drive solar energy adoption and bolster the county's sustainable development agenda.	In Nyeri County, solar power initiatives receive substantial financing and investments, exemplified by the Nyeri solar PV plant. With a significant equity injection from the Renewable Energy Performance Platform, the project aims to achieve commercial operation soon, contributing to Kenya's clean energy goals.

Table 2. Status of solar power

4.2. Status of solar power justice

Both Nyeri and Makueni counties prioritize equitable distribution of solar power. Nyeri promotes affordability through initiatives like Solibrium, while Makueni's Public Participation policy and 40 MW solar project enhance energy access for off-grid communities. Makueni's structured governance approach suggests a

more comprehensive commitment to inclusive and sustainable energy distribution (Table 3).

Energy Justice Thematic Area	Nyeri	Makueni
equitable distribution	Solibrium, provides solar panels, solar systems, and solar lamps to communities through women's groups, offering loans or a subsidized price system. Residents have access to the solar systems and can pay in installments	The County Government of Makueni is committed to a redistribution of power and resources through a strong policy of Public Participation and investment in development projects. One such project is the 40 MW solar project. that aims to provide cheap, reliable, and clean energy to power public installations and later markets and villages not connected to the national power grid. The project is expected to bridge the energy supply gap in the county and contribute to Kenya's Nationally Determined Contribution (NDC) by reducing the country's greenhouse gas emissions by 30% by 2030.
affordability	Solar power is becoming increasingly affordable in Nyeri County, Kenya. The County Government of Nyeri has been committed to promoting the use of solar power to provide affordable and sustainable energy to the region.	The 40 MW solar project that aims to provide cheap, reliable, and clean energy to power public installations and later markets and villages not connected to the national power grid
access to clean and reliable energy sources	The county government of Kenya is prioritizing access to clean and reliable solar energy, particularly through solar-powered boreholes. Davis and Shirtliff Limited has been contracted to install solar power to 16 boreholes within six months, aiming for completion by March next year. Additionally, various solar energy companies in Kenya, such as Sunraserg Energy Experts and Eco Renewables Felicity Solar Energy Company, offer diverse solar products and services, including power generation and backup solutions.	The County Government of Makueni has a policy of Public Participation that subdivides the county into five layers of governance: (1) village level, (2) cluster level, made up of 5 villages grouped together, (3) the sub-ward level, (4) ward level, made up of 7 geographical regions that divide that county, and finally (5) the county level.

Table 3. Solar power justice

4.3. Strategies for promoting solar justice

Both Nyeri and Makueni counties employ innovative strategies to enhance energy justice through solar power. In Nyeri, geospatial tools identify areas

lacking electricity access, informing prioritized electrification and renewable energy strategies. Integrated energy access plans combine grid expansion and off-grid solar systems, aligning with Kenya's successful National Electrification Strategy. Meanwhile, Makueni emphasizes public participation and community empowerment, recognizing their role in achieving Sustainable Development Goals. Leveraging geospatial tools aids in identifying electricity-deprived areas, optimizing grid extension, and renewable energy strategies. Integrated energy access plans prioritize grid expansion and off-grid solar systems, reflecting a comprehensive approach to increase electricity access and foster sustainable development. Solar companies' contributions further bolster Kenya's transition to sustainable energy solutions, promoting economic growth in both counties.

5. Discussion

Energy is a fundamental driver of human development, yet global energy sectors face significant disparities in access, costs, and decision-making processes (Behrens et al., 2016). The imperative to address climate change has underscored the urgency of transitioning away from fossil fuels toward renewable energy sources (IPCC, 2018; IEA, 2019). Energy justice has emerged as a critical framework to tackle these disparities by advocating for distributional, recognition, and procedural fairness in energy provision (Sovacool & Dworkin 2014; Heffron & McCauley 2017; Heffron 2022; Jenkins et al., 2016).

In Kenya, achieving the country's development goals through the proliferation of solar power is closely linked to energy justice. Kenya's energy transition has made notable progress, with renewables contributing 89% of electricity in 2021, including a 1% share from solar power. Major solar projects aim to mitigate carbon emissions and improve energy access, highlighting the potential for collaboration among stakeholders to drive sustainable progress in the energy sector and broader development efforts (KIPPRA, 2024). Corporate entities like East African Breweries Limited (EABL) and Bamburi Cement are actively investing in solar energy to reduce costs and dependency on the national grid, reflecting Kenya's growing sustainability trend. Local firms like London Distillers Kenya (LDK) have also embraced solar energy, reducing power costs by 50% and demonstrating the economic and environmental benefits of solar adoption. However, Kenya still faces challenges related to electricity costs, sources, and quality, despite the significant potential and declining global costs of solar energy (KIPPRA, 2024).

Analyzing the application of energy justice principles to solar power proliferation in Nyeri and Makueni counties reveals contrasting realities. Makueni County has shown strong leadership in implementing community-driven solar projects through robust public participation and partnerships with non-state actors, supported by proactive financing initiatives. In contrast, Nyeri County faces challenges related to regulatory transparency and policy environments, despite investments in solar projects (Table 2). The comparison between Nyeri and Makueni counties underscores the implications for sustainable development. Makueni's proactive approach and community engagement highlight the potential for successful solar projects through transparent governance structures. Conversely, Nyeri's challenges underscore the need for improvements to foster equitable access to solar energy. The disparity between the counties emphasizes the importance of comprehensive frameworks and collaborative efforts to address barriers and promote energy justice.

Efforts to ensure equitable distribution of solar power are underway in both Nyeri and Makueni counties. While Nyeri focuses on affordability initiatives like Solibrium, Makueni's Public Participation policy stands out for facilitating access through large-scale solar projects. However, Makueni's structured governance approach suggests a more enduring commitment to community involvement, potentially leading to more inclusive and sustainable energy distribution over time compared to Nyeri (Table 3). Various documents and studies highlight the importance of promoting energy justice through solar power across Kenyan counties, advocating for clean energy sources to ensure sustainable development and environmental preservation. The Energy Act of 2019 defines renewable energy comprehensively, underlining its significance in guaranteeing energy security, a fundamental aspect of energy justice. Despite the prevalence of biomass, promoting other renewable sources is crucial for enhancing energy security and advancing energy justice in Kenya.

Studies from other regions, such as Australia and India, provide insights into the political-economic dynamics and procedural justice involved in solar energy development, highlighting disparities and obstacles in land acquisition and community involvement (Poruschi & Ambrey, 2019). In Africa, energy poverty remains a challenge, despite gradual progress in renewable energy uptake. Comparative analysis of policies underscores the necessity of justice considerations to ensure fair and sustainable energy transitions, emphasizing comprehensive strategies aligned with socio-ecological justice and development objectives. Several countries have made significant strides in implementing fair and sustainable energy transitions in solar power, aligning comprehensive

strategies with socio-ecological justice and development objectives to achieve sustainable outcomes. One notable example is India, where the government has launched ambitious solar energy programs like the Jawaharlal Nehru National Solar Mission. Through policy incentives, subsidies, and capacity-building initiatives, India has rapidly expanded its solar power capacity, making significant contributions to energy access and environmental sustainability while fostering socio-economic development. Another example is Rwanda, which has implemented innovative policies and partnerships to promote solar energy adoption, particularly in rural areas (Bedi, 2019). Through the Scaling Solar program, Rwanda has facilitated private sector investment in solar projects, improving energy access, creating jobs, and reducing carbon emissions. Additionally, countries such as Chile and Morocco have capitalized on their abundant solar resources to drive sustainable energy transitions. Chile has leveraged solar power to diversify its energy mix and reduce dependence on fossil fuels. At the same time, Morocco has invested in large-scale solar projects such as the Noor Ouarzazate Solar Complex, contributing to energy security and economic growth. These examples highlight the importance of comprehensive approaches that integrate social, economic, and environmental considerations to achieve sustainable outcomes in solar power deployment, advancing socio-ecological justice and development objectives on a global scale (Sustainable Energy for All, 2024).

In summary, promoting inclusive approaches ensures equitable access to clean energy. Kenya's Nyeri and Makueni counties exemplify collaborative efforts toward energy justice through solar power expansion. Partnerships between government, private sector, communities, and NGOs drive solutions, including community-driven projects, financing options, public awareness, and innovative technologies, fostering social equity and environmental sustainability.

6. Conclusion and Recommendations

Globally, energy disparities persist, magnifying the urgency of transitioning away from fossil fuels to renewable sources. Kenya's commendable progress in renewable energy, particularly solar power, reflects a commitment to mitigate climate change and enhance energy access. The quest for energy justice through solar power proliferation in devolved units in Kenya, exemplified by the case of Makueni and Nyeri counties, underscores the pivotal role of collaborative and innovative efforts in driving equitable and sustainable energy transitions. However, disparities between counties such as Makueni and Nyeri highlight the

need for comprehensive frameworks and collaborative strategies to address regulatory challenges and foster transparent governance. Makueni's proactive approach, marked by community engagement and partnerships, demonstrates a promising model for successful solar projects and enduring energy justice. Conversely, Nyeri's struggles underscore the imperative of improving policy environments to ensure equitable access to solar energy. The global discourse on energy justice underscores the significance of considering socio-ecological justice and development objectives in sustainable energy transitions. Examples from India, Rwanda, Chile, and Morocco illustrate the transformative potential of comprehensive strategies aligned with energy justice principles, driving socio-economic development while mitigating environmental impacts. Collaboration among government, private sector, and communities is crucial for overcoming solar energy barriers, improving financing, and raising awareness. Equitable access through innovation and inclusive policies fosters social and environmental sustainability, demanding commitment and collective action. The study's limitations include the focus on only two counties, which may not fully represent Kenya's diverse energy landscape. Additionally, the analysis primarily examines policy frameworks, potentially overlooking grassroots perspectives and implementation challenges. Future studies could explore broader geographical areas in Kenya to capture the diversity of energy justice initiatives and enrich the understanding of solar power proliferation and energy justice.

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Competing Interests

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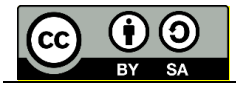

Original Paper

Future directions for solar energy in a global context with particular emphasis on Saudi Arabia, the Middle East, and North Africa

Fatimah Alamrani

Received: 5 November 2023 | **Accepted:** 29 December 2023 | **Published:** 31 December 2023

Keywords: Kingdom of Saudi Arabia (KSA), Middle East and North Africa (MENA), photovoltaic (PV), concentrating solar power (CSP)

Abstract. *Solar energy has emerged as a viable and sustainable replacement for conventional energy sources with significant environmental and financial advantages. Photovoltaic (PV) systems and concentrating solar power (CSP) technologies are used to harness the energy of sunlight and have been widely applied, leading to a sharp increase in solar installations across the globe. The use of solar energy has been propelled even further by decreasing solar panel prices, developments in energy storage, and encouraging regulations. This article analyzes future directions for solar energy in a global context, with a*

particular emphasis on the Kingdom of Saudi Arabia (KSA), and the Middle East and North Africa (MENA) region. It proposes a discussion of the challenges and opportunities relating to solar cell adoption in the KSA and MENA region, also in the light of the potential paradox of countries who are among the largest producers of fossil-fuels being in the forefront of the move to carbon-negative technologies.

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1. Introduction

The development of solar energy on a global scale has been driven by the world's rising energy demand and growing concerns about the environmental impacts of continuing use of fossil fuels and climate change. Leaving aside debates concerning the adequacy and efficacy of international agreements on the phasing out of fossil fuels, solar energy is now well-established as a renewable, abundant, and clean energy source capable of making an important contribution to attempts at resolving the global energy dilemma. The solar cell (SC) plays a crucial function in harvesting energy efficiently. The scope and benefits of solar PV technology for societies all over the world are abundant. This article aims to provide a broad discussion of the potential global impact of SCs, then focusing on the KSA and the MENA region, where SCs are particularly promising due to the growing population and abundance of sunlight, with associated challenges that must be overcome. The future of SCs in these regions is discussed, and how technology, supply chains, and economics can drive further adoption if appropriately balanced. The intention is to contribute to existing literature by addressing often-overlooked regions of the globe and examining their unique opportunities and potential when looking at SC development and adoption in a global context.

2. Progress, challenges, and future directions for the KSA and the MENA region in a global context.

Over a period of several decades, the KSA has greatly increased its use of clean energy sources like SCs (Gul, 2016). Solar energy usage started in 1960, and a systematic improvement initiative for the advancement of solar energy was launched by King Abdul-Aziz City for Science and Technology in 1977 (Said et al., 2004). Due to a construction boom and an escalating population, the

country's need for power is continuously growing. Power generation must be adequate and suitable given the current high loads and the hazards of conventional energy production using fossil fuels must be curbed and gradually eliminated.

The KSA is potentially among the largest generators of solar PV energy due to its advantageous location in a sunbelt area, vast expanses of desert land, and year-round clear skies. It is economically advantageous to try to produce renewable energy in the country using PV cells and direct sunlight because the average amount of energy from the sun falling on the country is 2200 thermal kWh/m2 (Alawaji, 2001). On the other hand, there are still many difficulties with solar energy worldwide, including overheating and potential cooling systems, cost issues and a lack of funding, low efficiency, and technical difficulties (Yousif, 2020). However, the lifespan of solar power modules, which is greatly affected by degradation brought on by heat and humidity, has been extended and problems limitations due to processes, such as light reflection off the cell's surface and the collision and recombination of light's created electrons and holes, which prevent them from contributing to the cell's output, have been increasingly successfully addressed. Figure 1 illustrates the technological advances in SCs.

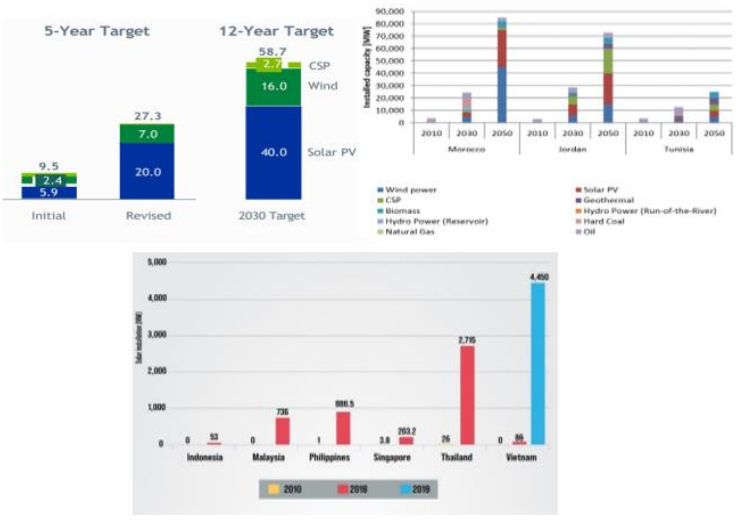

Figure 1. The progress of SC technology in KSA, MENA region, and Asia (Alshehri, 2019; ASEAN Centre for Energy, 2019; Zelt et al., 2019).

The KSA is by now regarded as the highest producer of solar energy per unit of electrical capacity (0.003 GW) compared to other nations (AlOtaibi et. al., 2020). The country's Vision 2030 plan aims to lessen the nation's reliance on oil while increasing private sector involvement in the economy and creating the opportunity for future solar energy deployment to be accelerated. Figure 2 shows the current trends of PV supply chain.

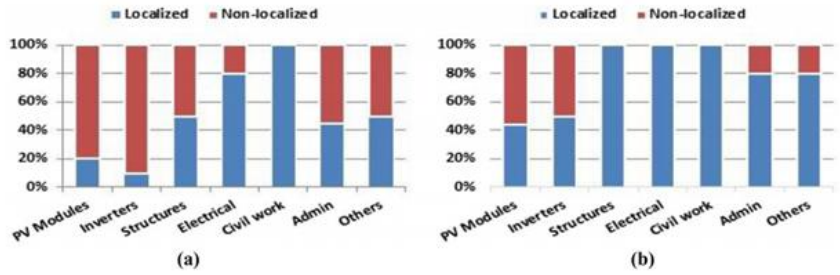

Figure 2. (a) PV chain supplied locally and globally in 2018 (b) the expected values of PV for 2023 (AlOtaibi et al., 2020).

Many other MENA governments are focusing their attention on diversifying solar energy through large-scale projects. In the Middle East, in Abu Dhabi plans are underway to develop several solar energy projects by 2025. In the United Arab Emirates, the Mohammed Bin Rashid Solar Park plans to finish a 5 GW plant by 2030. By 2030, Morocco aims to produce 52% of its energy from renewable sources. In the years up to the end of 2022, growth rates in the use of solar energy in Egypt and Tunisia have been 30% and 20%, respectively and in the same period Oman planned for 1.5 GW of solar power facilities to be online. Jordan is boosting its expenditures on clean energy, and helping people use renewable energy sources to become more self-sufficient and save money by generating their own electricity. Despite political unrest and administrative difficulties, Iraq has included solar energy in its future energy mix plans (News, 2020). Figure 3 illustrate the trends of solar power in MENA region.

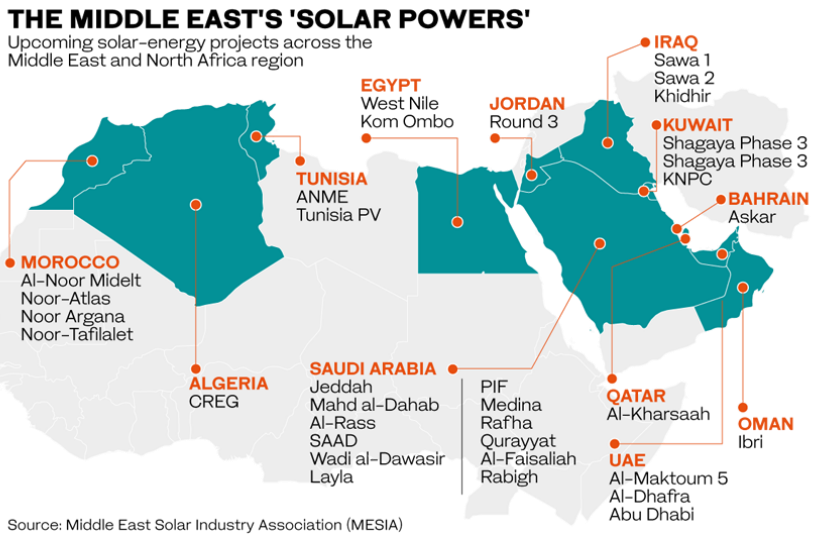

Figure 3. Solar power utilization in MENA (News, 2020).

In global terms, it is projected that solar PV capacity will provide 25% of the world's power needs by 2050, reflecting a tenfold rise in PV's proportion of the generation mix from 2016. By 2050, it is anticipated that solar PV's installed capacity (8519 GW) will need to be expanded substantially more than wind's installed capacity (6044 GW)[2]. Solar PV will also facilitate the transformation of the world's electrical industry. By 2050, as shown in Figure 4, the total installed capacity of solar PV will reach 8,519 GW (IRENA, 2019).

Since many countries such as the KSA and others in the MENA sunbelt have a vast potential for solar energy, they can make an important contribution to the shift whereby renewable energy sources and electrification substitute fossil fuels as these become uncompetitive and unsustainable in a world increasingly moving to carbon-constrained economies and carbon-negative technologies. Such a result can be achieved both in terms of domestic consumption and also of transmitting renewable electricity across continents.

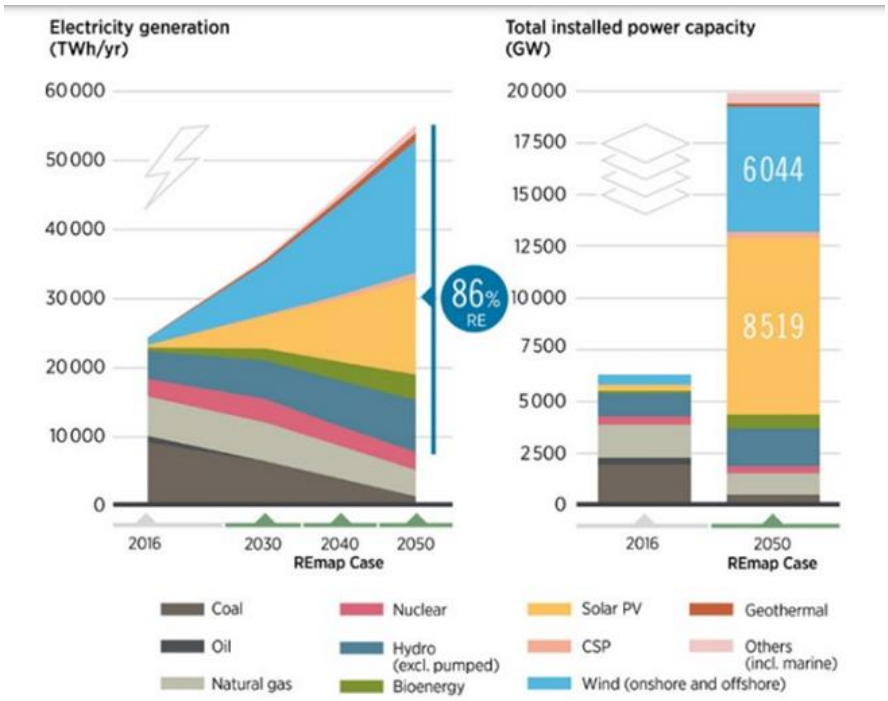

Figure 4. Photovoltaic solar energy expansion by 2050 (IRENA, 2019).

Initiatives well underway advance the sustainable development objectives of the countries in the region and establish them as pioneers in the renewable energy transition. Solar power and photovoltaics have revolutionized the world's energy scenario, but key challenges and opportunities remain. For example, theoretical limits have not been met practically for many SC materials, and further nanomaterials research could discover better SCs (Markvart, 2021). The advent of SCs capable of flexibly being added conformally to different materials should also open new avenues for on-the-go charging. Similarly, SCs capable of capturing a wider range of the electromagnetic spectrum should lead to gains in power generation, even if theoretical efficiencies are not met. Novel developments in biological SCs may take decades to eventuate but research already indicates promising outcomes in the future (Wang, 2020). With their solar energy potential and financial resources available due to fossil-fuel production,

the KSA and other MENA countries can play an important role in such developments.

3. Conclusions

The goal of ongoing research and development in the field of solar energy and photovoltaics is to increase SCs' efficiency and longevity while examining novel performance-improving materials and creating cost-effective manufacturing methods, which has particular importance for the economics of SCs. Areas with abundant sunlight, such as the KSA and the broader MENA region, provide ideal locations for producing, distributing, and researching, thereby making a highly significant contribution to the future of solar energy. Many countries in these areas are already investing heavily in solar power projects and moving towards a scenario in which fossil fuel-producing countries can become protagonists in the transition to sustainable energy sources (Najm, 2019). By embracing solar power, they have the chance to play an important role in lessening local and global environmental impacts of fossil fuels, attaining energy security, and creating more resilient societies for future generations.

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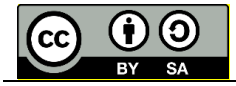

Original Paper

Electric vehicle grid demand:

Potential analysis model and regional architectural planning approach for charging using PVsyst tool

Mahipal Bukya, Swati Sharma, Rajesh Kumar, Akhilesh Mathur, Gowtham N, Pancham Kumar

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Keywords: PVsyst; electric vehicle; solar photovoltaic; demand response; lithium-ion.

Abstract. *Electric transportation is a societal necessity to mitigate the adverse effects of local emissions and global climate change. To reach net zero emissions by 2050, countries have examined many strategies to electrify road transport and deploy electric vehicles (EVs). Due to falling lithium-ion (Li-ion) battery pack costs, global electric vehicle sales have grown consistently*

over the past decade and reached 10 million units in 2022. The safe and steady operation of the regional power grid may be compromised by the connection of a sizable random charging load. Therefore, it is crucial to conduct a pre-emptive analysis of the charging load and its potential impact, ensuring that electric vehicles can seamlessly integrate with the grid upon connection. This study employs PVsyst simulation software to assess the feasibility of a 12800 MWp (9000 MWp plus 3800 MWp) PV grid-tied system in India's Delhi-NCR region. The system's affordability and spatial compatibility are considered. The average electrical loads for the Delhi-NCR region have been estimated. The system achieves a 0.846 performance ratio, generating 1648 KWh/KWp/year. About 52.7% of the load has been utilized by the electric vehicle, while the surplus is fed into the power grid. This study emphasizes PV systems effectiveness in alleviating grid peak loads, their cost-effectiveness, low maintenance, and adaptability to peak-time loads.

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1. Introduction

The global total energy consumption is rising radically because of the expanding population, modernization, and individuals' expectation of a rising quality of life. Sector-wise global energy consumption is shown in Figure 1 (IEA, 2023; Hanni et al., 2023). Transportation plays a vital role in the development of any country. The energy demand from transportation is around 26%. Global warming and an impending energy problem have compelled nations to endeavour to become greener and cleaner. Worldwide, interest in electric vehicles (EVs) is growing because of rising gasoline prices and environmental concerns. Electric vehicles (EVs) have emerged as a potentially viable and environmentally sustainable alternative to traditional internal combustion vehicles (ICVs) by utilizing a clean energy source. Electric mobility is thus seen as a societal necessity to mitigate the adverse effects of local emissions and global climate change. Worldwide, countries have explored several pathways to electrify road transport and the deployment of EVs to reach the net zero emissions target in line with the 2050 scenario. The sale of electric vehicles globally has been rising steadily Y-O-Y over the past decade and crossed 10 million units in 2022 due to a consistent drop in lithium-ion (Li-ion) battery pack costs. In 2022, the proportion of electric

automobiles among all new car sales was 14%. In 2021, the percentage is approximately 9%, while in 2020, it is less than 5% (IEA, 2023; Petrovic et al. 2020). Figure 2 illustrates the global growth of electric vehicle (EV) stocks from 2010 to 2022 (Petrovic et al., 2020; Haghani et al., 2023), encompassing both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) on a global scale. Approximately 66,000 electric buses and 60,000 medium and heavy-duty trucks were purchased globally in 2022, accounting for approximately 4.5% of total bus sales and 1.2% of total truck sales worldwide. The need for electric vehicle batteries is steadily increasing. However, with increased EV sales, there has also been an increase in instances of EV failures (IEA, 2023; Bukya et al., 2023a). The demand for automotive lithium-ion (Li-ion) batteries significantly increased by over 65% and reached 550 GWh in 2022, compared to about 330 GWh in 2021. This development may be attributed mainly to the rise in sales of electric passenger cars, with new registrations showing a 55% increase in 2022 compared to 2021. Fig.3 shows the battery demand scenario and a significant increase in EV global stock in 2022 (IEA, 2023; Bukya et al., 2023b). A deal on climate change was reached in Paris as part of the Ministry of New and Renewable Energy's (MNRE) nationally mandated contributions from the Indian government. As per the agreement, India has committed to generating 40% of its installed power generation capacity from non-fossil fuel sources by 2030. Additionally, India declared that by 2030, the GDP's emission intensity will be 33–35% lower than it was in 2005. Reducing carbon emissions is also pledged for a healthy earth. It was planned at the beginning of 2015 that 175GW of renewable energy installations will be completed by 2022. This 174 GW comes from 10 GW of biomass, 60 GW of wind, 100 GW of solar, and 5 GW of small hydro power (Li et al, 2021; Zhang et al, 2022; Amini et al., 2016).

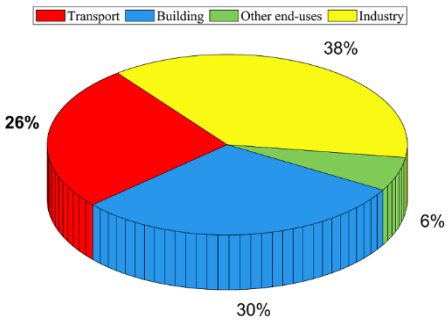

Figure 1. Sector-wise global total energy consumption

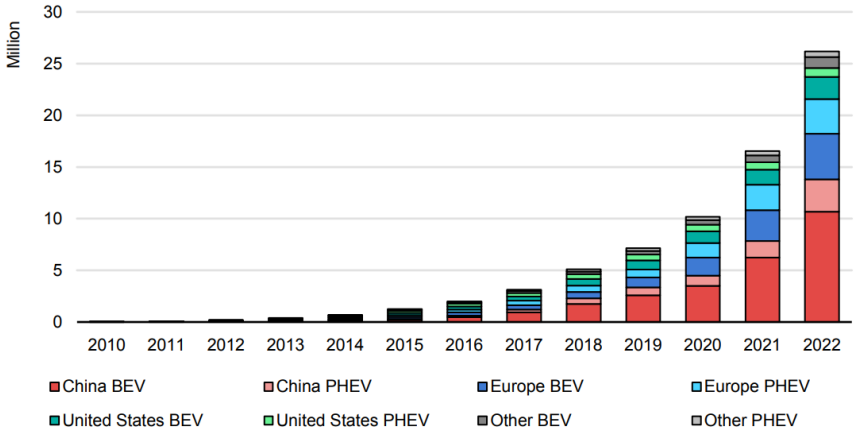

Figure 2. Evolution of the global electric car stock from 2010-2022

The escalating apprehensions regarding global warming and climate change necessitate a heightened focus on the use of clean and sustainable energy sources (Borozan et al., 2022). Renewable energy sources serve as a fundamental basis for planners in formulating a policy framework that effectively addresses energy security and equity, while simultaneously attaining objectives related to the reduction of carbon emissions and mitigation of pollution. Utility size power producers, small power generators, state utilities that include production, transmission, and distribution firms, regulatory and power management organizations, the government, and consumers are major players in the renewable energy (RE) industry (Dominguez-Jimenez et al., 2020; Sharma et al., 2023a; Gao et al., 2021).

Delhi, the National Capital Territory (NCT) of India, is the most populous metropolitan area in the country, receiving a significant influx of individuals from other states, as reported by World Population Review. Rapid urbanization and industrialization have had a negative impact on the environment in recent years. Air pollution in Delhi is a persistent issue that occurs throughout the year (Adaramola, 2014). Significant sources of pollution include Diesel generator sets, car exhaust, road dust, construction dust, open waste burning, light and heavy industries, dust storms and agricultural burning during certain seasons, and

sources outside Delhi's administrative boundaries are some of the major causes of pollution (Alsadi et al., 2018; Amin, 2017; Ahmadi et al., 2018), Bollipo et al., 2021). While Delhi's air quality is the subject of the greatest study, publications, and attention (both nationally and internationally), opinions on its causes and effects are divided. The widespread use of electric vehicles (EVs) of all kinds could be one way to address these issues. There are many potential benefits associated with electric mobility. Among these advantages are improved air quality, less reliance on fuel imports, a drop in greenhouse gas (GHG) emissions, a higher plant load factor for the electrical grid, and the chance to lead a rapidly expanding worldwide industry (Almshari et al., 2022; Garg et al., 2024). The Indian and state governments have made several attempts to promote the use of electric cars (EVs), but the adoption rate of EVs is still quite low (Bukya et al., 2023; Garg et al., 2022; Kumar P. et al., 2023; Kumar B. et al., 2015). The need for electricity has increased over the last few decades, and the state of Delhi NCR has built conventional power generation to meet around 25% of the demand. State utilities and other stakeholders are becoming more interested in and focused on renewable energy because it is becoming commercially viable (Manisha et al., 2022; Kiran et al., 2020).

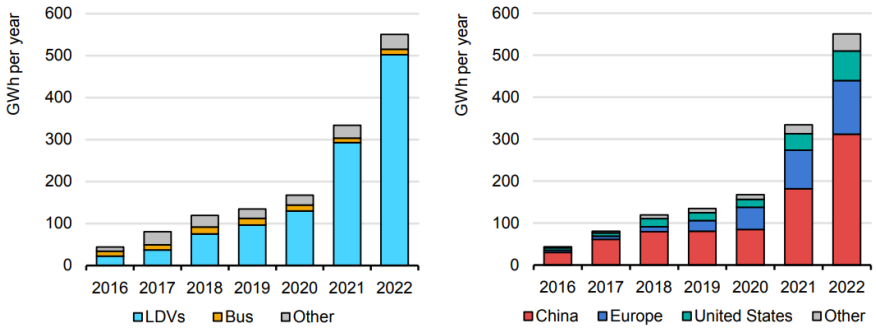

Figure 3. Battery demand by mode and region from 2016-2022

The power is generated at load centres, solar energy can be deployed decentralized, which has the advantage of reducing transmission and distribution losses and saving money on the expense of building additional transmission infrastructure. Efficient methods of utilizing solar energy include decentralized generation via solar rooftop systems, solar electric car charging stations, off-grid

applications, and tiny solar power plants at the consumer's end (Sharma et al., 2018). Day by day the use of electric vehicles increasing in Delhi and NCR regions and the charging stations plays very crucial role in future. Thus, the characteristics of EVs mobility demand encompassing modal split, the proportion of mandatory optional trips, trip frequencies, departure times, distance travelled and travel times which plays a pivotal role the requirements for physical infrastructure and the sizing of support facilities within transportation systems. Modal split refers to the distribution of trips among various transportation modes such as private cars and public transit. The ratio of mandatory trips provides the information for the leisure/aborted trips. These trips will determine the optimum cost for every specific distance travelled by the EVs and the desired SOC required for charging/discharging. The socio demographic features such as cost for each trip and the life of EVs battery plays a crucial role in shaping travel preferences and the driving patterns. Thus, analysing these parameters aids in developing targeted strategies for promoting and integrating EVs into the transportation systems and it is one of the challenges for improving the EVs mobility not only in Delhi NCR but also all over the world. The paper will highlight the simulation study of the solar PVsyst for installation of solar charging stations as per load demand of EVs in the region. The main objective is to replace the conventional energy from the utility with rooftop solar PV system and to meet the load requirements. This system of design is simulated by using PV syst and each component is analysed. Also, the current economic and environmental conditions in the proposed roof top solar PV system will be analysed and the results will be compared considering the solar PV system and the utility supply (Trina solar (2020)). The total distance taken for the EV travelling is 30 km, SOC to be 95% for single trip of 30 km and the travel frequency of EVs in Delhi NCR is about 190 km/day and the annual cost is 9811.90.

The following sections of the paper are structured as follows: the second section analyses and models the charging loads of electric vehicles using solar photovoltaic systems and system modelling; the third section leads to a discussion of the results; and the fifth section wraps up the study with limitations and future research opportunities.

2. Analysis and modelling of electric vehicle charging loads based on solar photovoltaic system

There are many complex elements that affect the charging load of electric cars (EVs) in each region. The EV load is impacted by several factors, including the driving behaviours of EV users, the charging infrastructure and grid environment, the performance characteristics of the EVs themselves, and the overall utilization of EVs. These factors all have varying degrees of influence. As illustrated in Figure 4, factors such as the quantity of EVs, charging power, and available battery capacity, among others, determine the total charging demand on the local power grid. Moreover, as charging times become more concentrated, the overall charging load from regional EVs escalates. Consequently, our approach begins with an examination of the forecasted regional EV ownership and EV charging behaviours, ultimately leading to predictions regarding the future charging load of regional EVs. The electric vehicle's frequencies are highest during the morning, evening, and night. During night-time, heavy-duty vehicles are at their maximum as compared to daytime. The fast-charging infrastructure has been considered for EV charging.

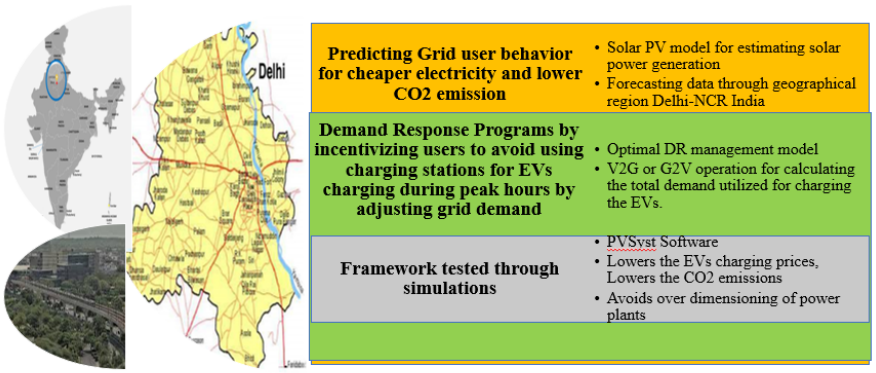

Figure 4. Novel framework for estimating the optimum DR potential)

2.1 Analysis of influencing aspects and EV charging behaviour

A multitude of factors, mostly classified as external and internal value chain factors, impact the forecasting of future ownership of electric vehicles (EVs) within an area. Technical improvements, governmental incentives, and economic conditions are examples of external value chain elements. In contrast, internal value chain factors involve considerations such as charging infrastructure development and consumer behaviours. Detailed analysis of these factors is proposed in the subsequent sections.

2.1.1 Economic Aspects

The automotive industry's progression is intricately linked to economic considerations. A favourable economic climate plays a pivotal role in enhancing the rate of vehicle expenditure. This study has demonstrated that for every 1% increase in per person GDP, or gross domestic product in China, there is a corresponding 0.46% rise in car ownership per one thousand individuals (Shankar et al., 2022; Shankar et al., 2023). Consequently, with China experiencing consistent economic growth, it has regularly held the top position worldwide in terms of electric vehicle (EV) production and sales. While GDP is the customary metric to gauge a region's economic development, it is also influenced by population size (Sher et al., 2015; Weidong et.al, 2007). As a result, this study employs GDP per person as a metric to assess provincial fiscal components.

2.1.2 Policy Supports and Technology developments.

Current study highlights the substantial impact of policy subsidies on the regional electric vehicle (EV) industry. In the nascent stages of EV development in China, the government strongly promoted EVs as an efficient solution to mounting energy and environmental challenges (Sharma et al., 2022, 2023b). This advocacy for EVs materialized through the initiation of the "Automobile Industry Adjustment and Revitalization Plan" in 2009 marked the commencement of the national demonstration initiative for new and energy-efficient vehicles. The central authority allocated assets for subsidization. Concurrently, the Ministry of Finance issued the "Notice on the Pilot Work of Demonstration and Promotion of Energy-Saving and New Energy Vehicles" in same year, by describing the pilot towns' conditions for new energy vehicle subsidies (Sheoran et al., 2023). Bolstered by national policies and surging market demand, various regions introduced their complementary subsidy policies to further incentivize EV development. Consequently, this study examines the average government

subsidy index as a key variable affecting the ownership of electric vehicles in each region.

As financial subsidies gradually diminish, the regional electric vehicle (EV) industry is poised to shift from a reliance on policy support to a more market-driven model, as shown in Figure 5. Technological maturity should emerge as the foundational driver of the EV industry's development, with technological innovation playing a pivotal role in guiding consumer purchasing decisions. Currently, ongoing breakthroughs in science and technology continually enhance EV performance, indicating a rapid upward trajectory in technological maturity (Chen et al., 2020; Shu et al., 2017; Yin et al., 2016). Surveys and analyses reveal that consumers place the highest emphasis on specific technical aspects when considering EV purchases, with vehicle range ranking as their primary concern, closely followed by factors like appearance, price, and interior space. In general, the driving range of EVs has consistently been a crucial determinant of their progress, offering a direct reflection of technological development maturity. Consequently, this paper utilizes sustainable driving range as a proxy for technological development factors.

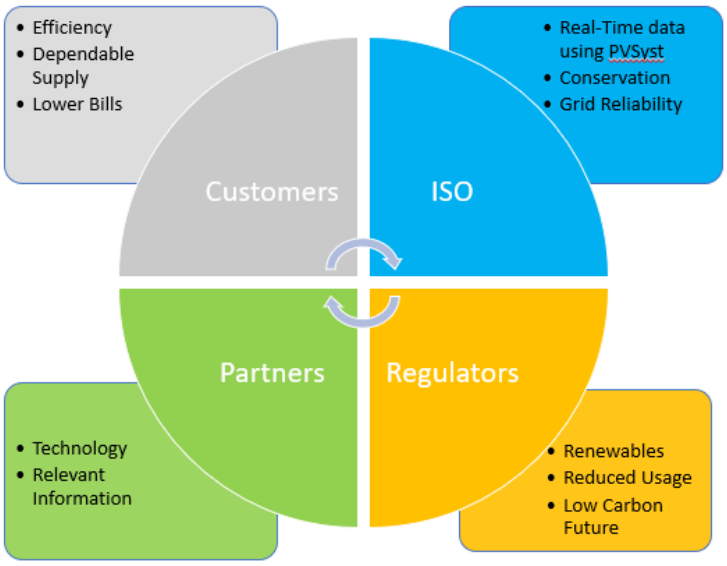

Figure 5. Designed energy strategy with DR and load management

2.1.3 Charging stations and consumers aspects

The advancement of basic charging infrastructure, including regional charging stations and charging piles, makes it feasible to guarantee the efficient operating of electric cars (EVs), improve their convenience, and ultimately increase people's propensity to buy them. Now, China has more EV charging stations overall than any other country in the world, yet there is still a large distribution gap between different regions. Most charging stations can be found in larger, more developed medium and large cities, while they are still relatively rare in certain less developed areas (Ma O et al., 2013; Tushar et al.,2018). Looking ahead, as urban development progresses, the ongoing enhancement of charging infrastructure is expected to encourage a larger populace to embrace and utilize EVs. Consequently, this paper employs the count of public charging piles as a yardstick for assessing charging infrastructure development, deeming it a vital criterion for predicting future EV ownership in a city. The ultimate success of regional electric vehicle (EV) development hinges on consumer attitudes, with consumer acceptance playing a pivotal role in determining the proliferation of EVs on the lane. User acceptance encompasses the willingness of consumers to embrace EVs among various automotive options, influenced by the state of EV technology and the availability of supporting infrastructure. Currently, consumer acceptance of EVs remains constrained. This is largely attributable to the practical challenges, as outlined in this article, such as the intensity of technological advancement and the deployment of charging capabilities. Nonetheless, as these challenges are addressed and knowledge pertaining to EVs becomes more widespread, consumers are expected to enhance their identification of EVs (IEA, 2023), Uzma Dar et al., 2022; Pannala et al., 2020). The proportion of EVs within the overall vehicle population directly reflects consumer acceptance and serves as a vital indicator for forecasting the future prevalence of EVs. Figure 6 describes the various EV service functions based on charging infrastructure and planning.

2.2 System Modelling

A 12,800 MWp grid-connected PV system was used in the study to assess its performance. PVsyst V 7.3.4 is a flexible software tool for designing, analysing, and simulating solar PV systems. This program optimizes PV system designs and predicts energy generation and utilization for charging electric vehicles (EVs) by considering several elements, such as meteorological data, shading, system components, and site-specific information. It is an invaluable tool for solar

industry professionals, helping them make well-informed decisions and maximize project efficiency.

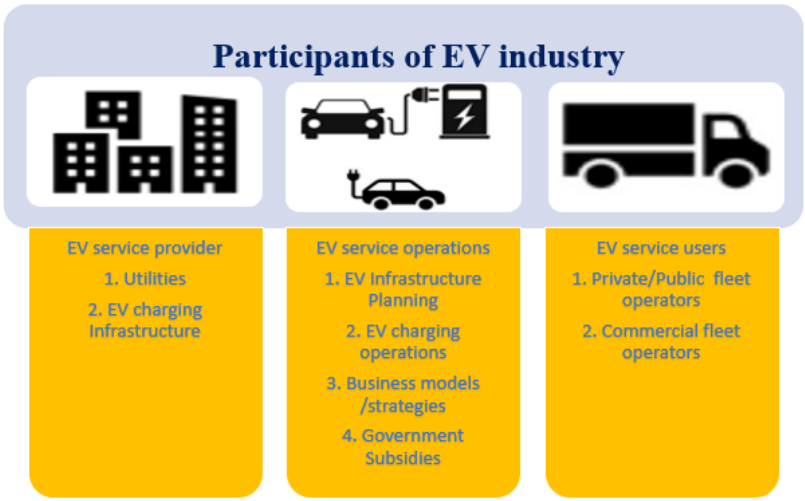

Figure 6. EV service functions

Power losses resulting from radiation, soiling, temperature changes, wiring, inverters, power electronics, interconnections, and grid availability are taken into consideration in the analysis. The system consists of 660 V delta energy inverters and 3,283 Trina Solar photovoltaic modules with an 11,560 MWp capacity. Table 1 shows the technical data of solar panel and Table 2 shows the inverter technical datasheets.

Figure 7 shows the input/output diagram for the energy injected into the grid of 12800 MWp (a) 9000 MWp (b) 3800 MWp.

Model		**TSM-DE 19-550Wp Vertex**	
Pnom STC Power (Manufacturer)	550 Wp	Technology	Si-mono
Module Size (WxL)	1.096x2.384 m²	Rough module area (Amodule)	2.61 m²
Number of cells	2x55	Sensitive area cells (Acells)	2.64 m²
Specifications for the model (Manufacturer or measurement data)			
Reference temperature (Tref)	25°C	Reference irradiance (Gref)	1000 W/m²
Open circuit voltage (Voc)	37.9 V	Short Circuit Current (Isc)	18.52 A
Max. power point voltage (Vmpp)	31.6 V	Max. power point current (Impp)	17.40 A
=> maximum power (Pmpp)	549.8 W	Isc temperature coefficient (mulsc)	7.4 mA/°C
One-diode model parameters			
Shunt Resistance (Rshunt)	200 Ω	Diode saturation current (IoRef)	0.040 nA
Serie Resistance (Rserie)	0.12 Ω	Voc temp. coefficient (MuVoc)	-105 mV/°C
Specified Pmax temper. Coeff. (muPMaxR)	-0.34%/°C	Diode Quality Factor (Gamma)	1.00
		Diode factor temper. Coeff. (mu Gamma)	0.0001/°C
Reverse- Bias Parameters, for use in behavior of PV arrays under partial shadings or mismatch			
Reverse characteristics (dark) (BRev)	3.20 mA/V²	(Quadratic factor (per cell))	
Number of by-pass diodes per module	3	Direct voltage of by-pass diodes	-0.7 V
Model results for standard conditions (STC: T=25°C, G=1000 W/m², AM=1.5)			
Max. power point voltage (Vmpp)	31.3 V	Max. power point current (Impp)	17.58 A
Maximum power (Pmpp)	550.1 Wp	Power temper. Coefficient (mupmpp)	-0.34%/°C
Efficiency (/module area) (Eff_mod)	21.1%	Fill factor (FF)	0.784
Efficiency (/cell area) (Eff_cells)	22.7%		

Table 1. Technical datasheet of 12800 Mega-Watt trina solar panel

Inverter – Solar Inverter DelCEN (3000)			
Model	Solar Inverter DelCEN (3000)		
Commercial Data		**Data Source**	
Protection:	IP65		
Control:	Display operational data	Width	615 mm
		Height	950 mm
		Depth	275 mm
		Weight	84.00 kg
Input characteristics (PV array side)			
Operating mode	MPPT	Pnom ratio (DC:AC)	1.30
Minimum MPP Voltage (Vmin)	610 V	Maximum PV Power (Pmax DC)	7616400 kW
Maximum MPP voltage (Vmax)	800 V	Power Threshold (Pthresh)	3000 KW AC
Absolute max. PV Voltage (Vmax array)	1000 V		
Min. Voltage for PNom (Vmin@Pnom)	640 V		
"String" Inverter with input protections		**Multi MPPT Capability**	
Number of string inputs	36	Number of MPPT inputs	36
Behaviour at Vmin/Vmax	Limitation		
Behaviour at Pnom	Limitation		
Output Characteristics (AC grid side)			
Grid Voltage (Imax)	Triphased 480 V	Nominal AC Power (Pnom AC)	3000 kWac
Grid Frequency	50/60 Hz	Maximum AC Power (Pmax AC)	3300 kWac
Maximum efficiency	98.8 %	Nominal AC current (Inom AC)	5275099 A
European average efficiency	98.4%	Maximum AC current (Imax AC)	12612062 A

Table 2 . Inverter technical datasheet

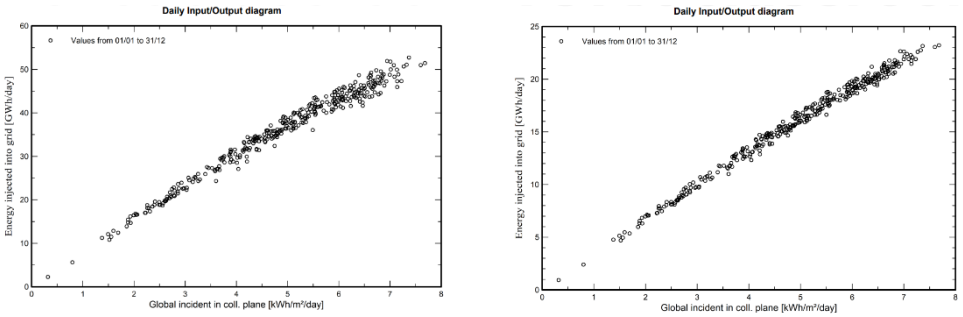

Figure 7 (a) and (b) Diagram showing the energy input and output into the grid of 12800 MWp (a) 9000 MWp (b) 3800 MWp

Thus, 1562500 strings of 36 series modules are constructed using 56250000 solar panels in total. The output of eight 160 KWp inverters with 36 MPPT units is injected into the electrical grid. Fig.8 shows the system output power distribution and the inverter efficiency curve, while Fig.9 shows the various layouts of solar PV arrays. Every module is oriented towards the south at a 0° azimuth and a 15° inclination, devoid of any shading influence.

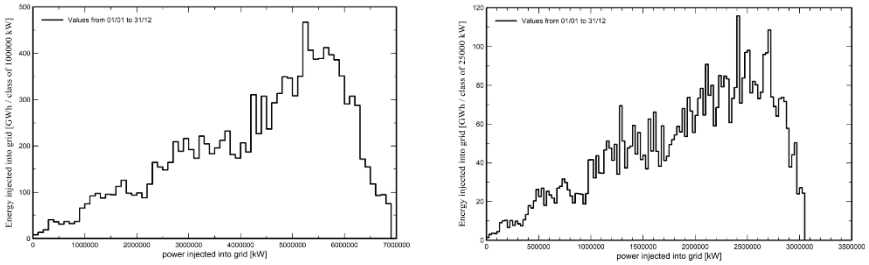

Figure 8 (a) and (b) System output power distribution of 12800 MWp (a) 9000 MWp (b) 3800 MWp.

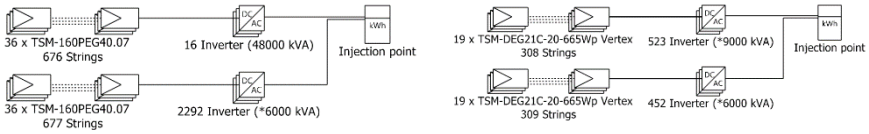

Figure 9 (a) and (b) Single line diagram of Solar PV Array Configuration of 12800 MWp PV grid (a) 9000 MWp (b) 3800 MWp

Figure 10 depicts the demand response variation for 24 hours for 12800MWh solar PV grid. The system shows demand variation for different hours such as 1st hour to 5th hour, 6th hour to 12th hour, 13th hour to 18th hour and 19th hour to 24th hour.

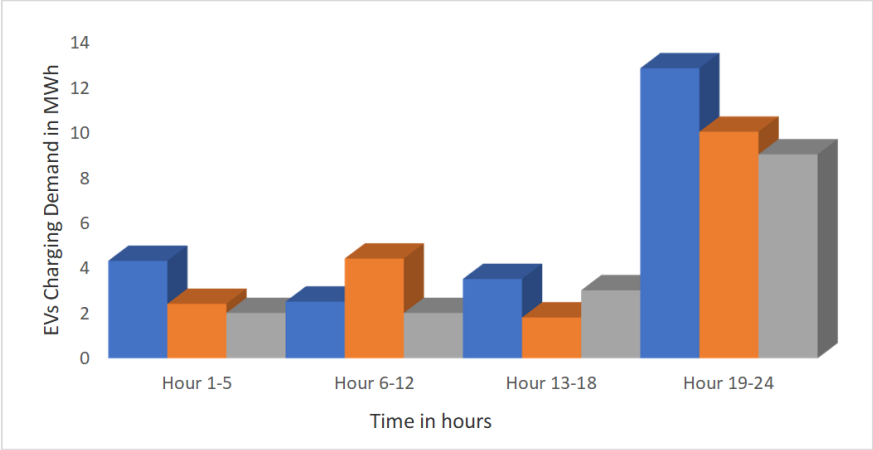

Figure 10 EVs Charging demand for 24-hour scenario using PVSyst

3. Results and Discussion

This study uses a structured charging scenario to anticipate the future charging load of electric cars (EVs) in the Delhi-NCR region of India. This scenario assumes that electric vehicle drivers prioritise their personal driving distance needs and start charging as soon as they get to the charging station. The previous section examined the examination of several variables, such as the length of the charge, the distribution of charging start times, the distribution of the initial state of charge (SOC), and the choice of charging modes for various EV models. In this section, we use the PVSyst tool to simulate the initial charging time and the initial SOC state of electric vehicles, as well as the variation of the demand response due to EV charging loads and the power grid throughout the year. This builds upon the predictions of future EV ownership and a thorough analysis of charging behaviour.

Based on the PVsyst simulation, the highest energy generation happens in March and the lowest energy generation happens in January since the start of the year. The performance ratio and overall assessment of the 12800 MWp based PV load for EV charging are summarised in Figure 11.

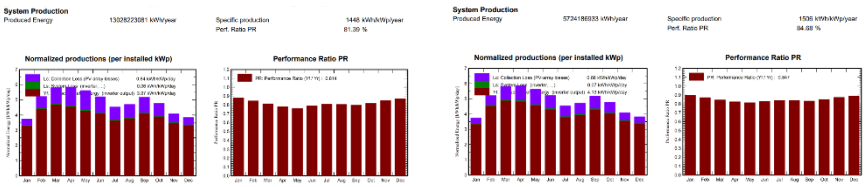

Figure 11 (a) and (b) Performance Evaluation and Performance Ratio of the 12800 MWp Solar PV Plant (a) 9000 MWp (b) 3800 MWp)

Table 3 shows the balances and main results of 9000 MWp. Table 4 shows the balances and main results of 3800 MWp. A power loss diagram for a solar PV plant with a capacity of 12800 MWp is shown in Figure 12. It shows how the power loss varies throughout the year due to various factors such as ambient temperature of 25.43^{0}C, wiring, inverter, power electronics, interconnections, and grid availability. Global horizontal irradiance is 1647.8 KWh /m2, horizontal diffuse irradiation is 891.6 KWh /m2. 1734.6 kWh/m2 is the yearly global efficient value. The grid value is 5724186933 KWh in total. The grid performance ratio is 0.847.

	Glob Hor kWh/m²	**Diff Hor** kWh/m²	**T_Amb** °C	**Glob Inc** kWh/m²	**Glob Eff** kWh/m²	**E Array** kWh	**E_Grid** kWh	**PR** ratio
January	89.58	50.4	13.35	116.0	113.4	932366250	917624802	0.879
February	115.5	50.0	17.69	146.3	143.3	1130978969	1113369353	0.846
March	158.7	70.0	23.72	179.8	175.7	1333569922	1313765104	0.812
April	171.5	82.9	29.76	175.6	171.4	1251906338	1232142073	0.780
May	185.5	97.3	33.62	174.1	169.3	1213984979	1195153040	0.763
June	171.2	99.3	33.25	156.3	151.8	1127976114	1110497310	0.789
July	151.6	100.1	31.45	140.4	136.3	1036717645	1019966362	0.807
August	149.1	92.4	30.43	145.8	141.8	1074264906	1056816869	0.806
September	145.1	74.8	29.18	155.2	151.3	1130874874	1113382935	0.797
October	126.7	72.3	26.74	147.9	144.6	1104921397	1088032495	0.817
November	95.7	55.1	20.52	122.6	119.7	953061904	938823090	0.851
December	87.9	46.8	15.08	118.8	116.2	943253267	928649648	0.869
Year	1647.8	891.6	25.43	1778.6	1734.8	13233876565	13028223081	0.814

Table 3. Balances and main results of 9000 MWp

	Glob Hor kWh/m²	Diff Hor kWh/m²	T_Amb °C	Glob Inc kWh/m²	Glob Eff kWh/m²	E Array kWh	E_Grid kWh	PR ratio
January	89.5	50.4	13.35	115.8	113.9	400816717	394453601	0.897
February	115.5	50.0	17.69	146.0	143.8	490977318	483276989	0.871
March	158.7	70.0	23.72	179.7	176.4	585760029	576966190	0.845
April	171.5	82.9	29.76	175.8	172.3	559651541	550712386	0.825
May	185.5	97.3	33.62	174.5	170.5	548057325	539469577	0.814
June	171.2	99.3	33.25	156.7	153.0	500292054	492528189	0.827
July	151.6	100.1	31.45	140.7	137.3	455095905	447760866	0.837
August	149.1	92.4	30.43	146.0	142.6	472366024	464687519	0.838
September	145.1	74.8	29.18	155.2	152.0	499220773	491437362	0.833
October	126.7	72.3	26.74	147.8	145.2	484136854	476694294	0.849
November	95.7	55.1	20.52	122.3	120.1	412169989	405998827	0.873
December	87.9	46.8	15.08	118.5	116.6	406514729	400201133	0.889
Year	1647.8	891.6	25.43	1779.0	1743.6	5815059260	5724186933	0.847

Table 4. Balances and main results of 3800 MWp

Legend: Glob Hor - Global horizontal irradiation, Diff Hor - Horizontal diffuse irradiation, T_Amb - Ambient Temperature Global, Glob Inc - incident in coll. Plane, Glob Eff - Effective Global, corr. for IAM and shadings E Array - Effective energy at the output of the array, E - Grid - Energy injected into grid PR - Performance Ratio

Furthermore, the potential for demand response by electric vehicles (EVs) integrated into the provincial potential grid is influenced by the response frequency of EV users. In this study, it is presumed that the availability of charging infrastructure is adequate, and various situations with differing response prices were established for comparative analysis. For instance, with effective pricing strategies and policy incentives tailored to a 25% response rate, it is possible to reduce the maximum peak load by 7616.4 MW and achieve each day transfer of 9000 MWh of electrical energy. Alternatively, with a 40% response rate and the same incentives, a reduction of 3000 MW in maximum peak load and a daily transfer of 12800 MWh of electricity can be attained. These measures clearly have the potential to mitigate provincial potential grid load variations and helps in managing the overall utilization of load for charging the EVs.

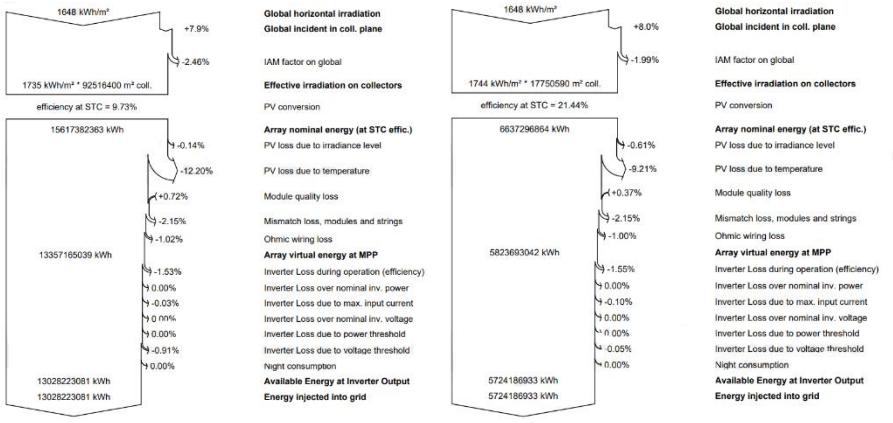

Figure 12 Loss diagram over the whole year for 12800 MWp (a) 9000 MWp (b) 3800 MWp

4. Conclusions

This analysis has laid the groundwork for EV charging load prediction and demand response investigation within the framework of EVs contributing to regional power grids. From this analysis of 12800 MWp solar PV grid, the following inferences can be drawn:

(1) At present, some regional power grids continue to grapple with significant disparities between power supply and demand during specific timeframes. The swift expansion of the electric vehicle industry anticipates a peak electric vehicle charging load in the area projected at 12800 MWp Solar PV system. This electric vehicle charging load is projected to comprise 81.39 % of the provincial potential grid performance ratio at maximum load, considering user charging behaviour without the implementation of optimal load management. The unpredictable fluctuations in this load can pose a detrimental influence on the secure and steady functioning of the energy grid.

(2) The double nature of EVs as both consumers and potential energy sources means they possess significant potential for regulating power loads, enhancing power quality, accommodating renewable energy, and contributing to local power grid demand response through effective

supervision. Moreover, this optimization can play a role in curbing the need for extensive expansion of the provincial energy grid.

(3) The Solar PV-grid tied system 12800 MWp system has been framed by combining the two solar PV grid of 9000 MWp and 3800 MWp solar PV grid as the PVsyst has a drawback that it can form a grid for maximum 9000 MWp in one go. Thus, we combined two grids of different power to obtain a 12800 MWp grid and calculated the demand response and efficiency of the system and obtain better efficiency and low losses.

The next crucial step involves delving deeper into the organized charging and discharging scenarios of electric vehicles, as well as exploring the synchronized communication between electric vehicles and local energy grids for all regions of India. This research builds upon the recent analysis of EV demand response prospective and the established context for EV integration into local energy grid demand response for India Delhi-NCR region. Future work can be extended based on improving the sociodemographic features of EVs like the total distance up to 150 km, calculating the total number of trips travelled by the EVs, aborted trips for the consumers during weekends and the weekdays for obtaining the optimum cost, the travel frequency up to 300 km/day and making it cost effective even for longer distances with the 12800 MWp solar PV grid for EVs charging. This will be a key changer for EV mobility and provides better incentives to the consumers using public transits every day.

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Original Paper

Enhancing citizen participation in local development planning in Nairobi and Makueni Counties in Kenya

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Keywords: inclusivity; transparency; accountability; good governance; citizen participation.

Abstract. *Public participation in development planning is critical for achieving sustainable development outcomes. Even though participation is still evolving, the existing theoretical models indicate that implementing*

public participation enhances responsiveness to community needs, leverages diverse skills, and instills a sense of ownership for sustainable development projects. Although Kenya has made strides in ensuring citizens' participation in local government development processes, local authorities and other stakeholders still find the existing public participation inadequate, marginalizing the needs of the local citizens in development planning. This paper aims to explore the current status and determine the factors that affect the active participation of citizens in development planning by examining the preparation process of the 2023- 2027 County Integrated Development Plans for Nairobi and Makueni Counties in Kenya. The intention was to enhance participation by devising strategies for sustainable participation practices. Based on the case study approach, involving literature review and textual analysis of key documents and county-specific County Integrated Development plans retrieved from official online sources, the results revealed that Nairobi and Makueni counties have distinct approaches and challenges in public participation. Despite budget constraints and perceived citizen apathy, Nairobi addresses historical service delivery issues through diverse mechanisms like social media and town hall meetings. Makueni excels in inclusivity using comprehensive matrices, but low budget allocation hinders participation. Both counties aim to enhance participation, with Makueni emphasizing innovative civic empowerment through citizen schools and promoting inclusive decision-making. Unfortunately, the impacts of participation could not be evaluated in both cases because the plans lack a dedicated section on the approach to public participation used to develop the plans. These results imply the need for more studies on the impacts of participation and the effects of integrating technology, such as AI, in participation to promote efficiency in the use of scarce county resources.

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1. Introduction

With the growing human needs, government institutions across the developed and developing world are increasingly embracing public participation as crucial for development planning. Rooted in humanitarian movements advocating people-centric development (Jennings, 2000), public participation ensures

citizens affected by development decisions actively shape their course (Sinclair & Diduck, 2017; Maurice et al., 2021). However, with ongoing societal change, implementing public participation is becoming increasingly context-specific, and hence, the need for urgent localized studies in order to develop strategies for enhancing it, especially at sub-national levels.

Kenya has also embraced citizen participation in development planning. The country has initiated policy and legislative reforms to improve public participation in development. The 2010 Constitution of Kenya recognizes and institutionalizes public participation in the country. Moreover, the three arms of government established by the 2010 constitution have established standards for public involvement, emphasizing that it must be meaningful and not merely symbolic or procedural. As of 2016, more than fifty cases were filed in Kenyan courts challenging the lack of public participation in appointments, legislation, budgets, development projects, and impeachments.

Consequently, public participation has emerged as an evolving concept whose interpretation, application, and practice vary depending on the context and the issue under discussion. In order to improve public participation at sub-national levels (counties), this paper used the case study research design with a literature review and document content analysis in the case of Nairobi and Makueni Counties to explore the current status of citizen participation in developing the County Integrated Development Plans for the period 2023-2027 and extract valuable lessons for future improvements. To respond to these study aims, this study reviewed the theoretical background of democratic principles grounded in participatory democracy and aspects of constitutional law from the perspective of sustainable development. The findings were then synthesized together with results from empirical reviews in order to determine the policy implications of this study. The study focuses on Makueni County for its established public participation and Nairobi for its urbanization. A comparative analysis aims to draw insights for enhancing public involvement in development planning.

1.1. Participatory governance for local development planning: Theoretical Analysis

In this paper, public participation refers to the active involvement, engagement, and inclusion of public members in decision-making processes, policy development, and implementing projects or initiatives by governments, organizations, or institutions. Public participation in development planning fosters responsiveness to community needs, collaboration, and utilization of diverse skills. It enriches decision-making with local knowledge and enhances project ownership, sustainability, and success through a collective commitment

to initiatives (Wiarda et al., 2023). Participatory governance originated from Ancient Athens revived during the enlightenment period and gained traction in the twentieth century as a response to top-down approaches, bolstered by civil rights movements. It later evolved into an inclusive decision-making model championed by international development organizations and is now a recognized principle for democratic and responsive governance globally (Ergenc, 2023).

Sherry Arnstein's ladder of citizen participation, featuring eight steps that signify varying levels of involvement, is the most used theoretical model for describing citizen participation in development. The ladder serves as a valuable tool for interpreting the meaning of 'participation' in programs and policies. Arnstein's conceptualization of the eight rungs provides a comprehensive understanding of the varying levels of public participation. Rungs one and two, termed as "non-participation," involve manipulation and therapy strategies by those in leadership. This approach circumvents genuine participation by patronizing participants, either through education or curing processes. Progressing to Rungs three and four signifies a shift toward "tokenism," where citizens are informed and consulted, though their input is non-binding. Rung five, known as "Placation," represents a higher form of tokenism, allowing advice without decision-making power. Rung six, "Partnership," enables citizens to negotiate and influence decision-making. The pinnacle, Rungs seven and eight, embodies "Delegate power" and "Citizen control," granting have-not citizens the authority to manage their own affairs. Another significant contribution comes from Sarah White, who outlines four forms of participation: nominal, instrumental, representative, and transformative, each with distinct functions. Actors at different power levels, both at the top and grassroots, perceive and have different interests in each form. These conceptual frameworks contribute to a nuanced understanding of the dynamics of public participation (Gaber, 2020). Sherry Arnstein's ladder of citizen participation was used as the lens for examining Kenya's case studies in order generate study implications.

Empirical reviews on participatory governance reveal worldwide efforts to entrench public participation in development planning, yet challenges hinder its success in many local governments. Studies conducted in Zimbabwe (Nyama & Mukwada, 2023) and China (Qiu et al., 2023) underscore the intricate dynamics influencing public participation, emphasizing the need for context-specific strategies to achieve meaningful engagement in development planning. Moreover, despite legislative guidelines for citizen participation in defining local development agendas in South Africa, studies suggest citizen involvement varies across municipalities. Some municipalities exhibit genuine participatory

processes, while others treat citizens as mere ratifiers of pre-planned development interests (Molale, 2023; Molale, 2021). The study advocates exploring citizen participation through the lens of participatory communication to understand the facilitative nature of participation in local government. The above reviews show persistent difficulties in achieving meaningful public involvement in development planning worldwide. Despite democratic principles advocating inclusivity and transparency, implementation hurdles persist, requiring further research to bridge the gap and enhance community engagement globally.

Various factors affect citizen participation in development planning. In Zimbabwe, top-down approaches that neglect citizens' needs affect citizen participation in development planning (Nyama & Mukwada, 2023). In Tanzania, Income level, cattle ownership, age, awareness, experience, and gender were noted as factors influencing citizen participation in development planning. To address this challenge, the government was urged to enhance community involvement in project development (Fredrick & Ahmad, 2023). In Thailand, where tokenism is rampant in light rain projects that demand citizen participation, socio-demographic factors such as residential location, age, occupation, and income affect participation levels (Panyavaranant et al., 2023). In Indonesia, the complexity of participative development planning requires ongoing assessment of institutionalization through laws and regulations in the context of democratized and decentralized governance (Widianingsih & Morrell, 2007). From these reviews, the complexity of public participation dynamics stresses the importance of targeted strategies for meaningful engagement in development planning.

In the Kenyan context, public participation is defined as an open and accountable process, aligning with constitutional provisions emphasizing its fundamental value. The 2010 Constitution mandates the state to facilitate public involvement in policymaking and governance. Several policy and legislative measures prioritize public engagement, such as public finance management, planning, performance management, and the Bill of Rights. The County Integrated Development Plans (CIDPs) are pivotal in shaping individual county development. CIDPs are comprehensive, medium-term strategic plans developed through an inclusive process involving stakeholders, reflecting a holistic approach to development (County Governance Tool Kit Website, 2023). The CIDP development process involves meticulous stages, starting with consultations and data collection, followed by stakeholder engagement, formulation of strategies, and public participation forums. These forums allow

citizens to contribute to the development priorities and goals. The CIDP development culminates in approval by the County Assembly, ensuring transparent and citizen-driven governance at the county level (IGTRC n.d). Various mechanisms facilitate consultations between state organs and the public in Kenya, including community forums, town hall meetings, and media engagement. Challenges to meaningful public participation include limited resources, time constraints, accessibility issues, distrust in leadership, elite capture, absence of enforceable norms, political competition, compensation expectations, inadequate civic education, and insufficient funding. Despite these challenges, public participation remains integral to inclusive governance and sustainable development in Kenya (IGTRC n.d). Exploring cases in different devolved units, such as Makueni and Nairobi, could shed light on unique practices and understanding of diverse contexts, which inform strategies to enhance inclusivity and effectiveness in governance processes across different counties in Kenya.

2. Materials and Methods

2.1. Case study research design

This study uses a case study research design to evaluate the implications of using public participation in developing county-integrated development plans. The choice of this design was informed by the fact that public participation involves complex and context-specific challenges that often require an in-depth understanding of the unique factors at play. A case study design allows for an in-depth examination of a specific case and provides a comprehensive understanding of the complexities and contextual factors, including those involved in county-integrated development plans. The design focuses on understanding the specific contexts, processes, and outcomes in participatory development planning.

2.2. Case studies

2.2.1. Nairobi City County

Nairobi County is one of the forty-seven Counties in the Republic of Kenya. It borders Kiambu County to the North and West, Kajiado to the South, and Machakos to the East. Among the three neighboring counties, Kiambu County shares the longest boundary with Nairobi County. The county has a total area of 696.1 km2 and is located between longitudes thirty-six to forty-five degrees east and latitudes one to eighteen degrees south. It lies at an altitude of 1,798 meters

above sea level. According to Article 220 (2) of the Constitution, the third County Integrated Development Plan (CIDP) for 2023-2027 has been crafted to establish a framework for county planning, budgeting, funding, monitoring, and evaluating programs and projects in the medium term. It is in response to the development issues identified by the county citizens. The plan focuses on economic growth, poverty reduction, income generation, employment creation, improved service delivery, and business development as key drivers of its development agenda (Nairobi County Integrated Development Plan, 2023-2027).

In the implementation of CIDP III, the county is effectively integrating the global Agenda 2030, Africa's Agenda 2063, the fourth Medium Term Plan of Kenya Vision 2030, and the "Big Four" Agenda. Building on the successes and lessons from the first two CIDPs, this plan aims to accelerate socio-economic transformation, achieving a resilient economy through measures such as enhancing city competitiveness, increased infrastructure investment, improved education and skills access, functional health systems, broader water and sanitation supply, expanded market linkages, promotion of entrepreneurship, job creation, and provision of decent and affordable housing (Nairobi County Integrated Development Plan, 2023-2027).

The outcomes will be achieved by strategically focusing on economic, social, environmental, spatial, legal, and institutional aspects of development, with collaboration from stakeholders like the National Government, development partners, private sector investors, and other counties. The ultimate goal is to enhance the quality of life for residents and visitors of Nairobi City County, including improved incomes, life expectancies, and knowledge and skills acquisition, all realized through a resilient economy by 2027 Nairobi County Integrated Development Plan, 2023-2027).

The plan is organized into six chapters, starting with County General Information, which provides background details about the county's position, size, physiographic and natural conditions, administrative and political units, demographic features, and the human development index of its citizens. Chapter six of the plan details the County monitoring and evaluation structure, Outcome indicators, Data Collection, Analysis and Reporting, Dissemination, Feedback Mechanism, Citizen Engagement, and the Evaluation Plan. Information and learning from the monitoring and evaluation system will provide critical input to the appropriate design of future programs and projects (Nairobi County Integrated Development Plan, 2023-2027).

Unfortunately, the plan lacks a dedicated section on public participation in the plan formulation process. Therefore, the extent of public participation in preparing the CIDP could not be thoroughly evaluated. Nonetheless, for the current CIPD, a public participation notice was placed on the county website inviting the general public, development partners, non-state actors, and all stakeholders to Ward-based consultative forums scheduled in seventeen sub-counties that constitute Nairobi County. The two-day process between seventeenth and eighteenth November 2022 was conducted at various centralized locations, and the consultations were planned to start at 9 am. The participation was also to inform the finalization of the 2023/2024 Annual Development Plan. Those willing to participate could submit written memoranda to ward and sub-county administrators' offices, county economic planning office, or send an email or physically deliver the memoranda to the County Secretary's office. Customer care and social media links were also provided to promote citizen interaction (Nairobi County Website, 2023).

In the previous CIDP 2018-2022, the devolution and sub-county administration sector enhanced citizen participation in county Government programs through public participation and civic education. At the end of the plan period, the sector carried out 272 public participation forums against a target of 340 and seventeen Civic Education forums against a target of 204. During the years 2020 and 2021, the sector did not carry out any public participation forums due to the Ministry of Health protocols on public gatherings due to COVID-19. In prioritizing issues for 2023-2027, the low level of public inclusivity in county government issues is noted as a development issue caused by inadequate public participation forums. This is attributed to potential low budgetary allocation for public participation even though there are opportunities where donors can finance such forums. The other cause of low inclusivity is the lack of public participation guidelines constrained by public apathy due to a culture of tokenism. Lack of public participation in land administration and management is noted to be caused by dilapidated city hall infrastructure. Public participation is also affected by the administration's disjointed and ad hoc nature or impromptu nature. The plan proposes the following strategies for enhancing public participation: to enhance civic engagement and foster a more inclusive decision-making process, the establishment of a dedicated Public Participation Directorate is imperative. The Directorate will play a pivotal role in recruiting skilled and passionate individuals, such as County Rapporteurs, who will serve as liaisons between communities and government entities. Additionally, the identification and empowerment of Community Public Participation Champions will be a key focus, ensuring that diverse voices are heard and amplified. The Directorate will work collaboratively

to develop a comprehensive Public Participation Policy, laying the foundation for transparent and participatory governance. In conjunction with this policy, guidelines, and regulations will be crafted to provide a framework for effective public engagement. To further align with best practices and legal frameworks, a thorough review of the National Council for Civic and Governance (NCCG) Public Participation Act will be conducted, ensuring that the Directorate's initiatives align seamlessly with existing legislation and contribute to the overall advancement of democratic values (Nairobi County Integrated Development Plan, 2023-2027).

2.2.2. Makueni County

Makueni County is one of the forty-seven counties in Kenya. It is situated in the southeastern part of the country and borders the following counties: Machakos to the North, Kitui to the East, Taita Taveta to the South, and Kajiado to the West. The county lies between Latitude 1º 35' and 3° 00' South and Longitude 37º10' and 38º30' East with an area of 8,176.7 KM². The county is divided into nine National government administrative sub-counties (Kathonzweni, Kibwezi, Kilungu, Makindu, Makueni, Mbooni East, Mbooni West, Mukaa, and Nzaui) and six county government administrative sub-counties which are also the parliamentary constituencies namely Makueni, Mbooni, Kibwezi East, Kibwezi West, Kaiti and Kilome. The six sub-counties are further subdivided into 30 electoral wards. Makueni County is a South Eastern Kenya Block (SEKEB) member alongside Kitui and Machakos Counties (Makueni County Integrated Development Plan, 2023-2027).

At its core of development planning, public participation is a meticulously structured process of consulting with individuals, groups, and entities before making decisions. It is a mechanism designed to amplify the voices of those who may otherwise go unheard, crystallizing the concept of agency within the County Government. Public participation is intended to generate and confirm decisions rather than being a conduit for decisions already made. Importantly, it transcends political affiliations, representing a non-partisan process where the government becomes the agent seeking instruction and direction from the people. The Government of Makueni County is steadfast in its commitment to employing various participation models, including consultation, placation, partnership, and citizen control. This commitment aligns with the constitutional vision of fostering people-centered and people-driven development. From its inception, the county government has actively strived to create an environment conducive to citizen involvement in policy development. To operationalize this commitment, the government adopts multiple forms of public participation,

from informing and consulting to involving, collaborating, and empowering the public.

A distinctive feature is that participation in all forums, and development committees is entirely voluntary, with no benefits to members based on their engagement. The implementation of public participation unfolds through a comprehensive matrix of forums established at different administrative levels. The Village Peoples Forum, Village Clusters Peoples Forum, Sub-Ward Peoples Forum, Ward Peoples Forum, Sub-County Peoples Forum, and County Peoples Forum form a hierarchical structure, each serving as a conduit for citizen engagement. These forums convene regularly, ensuring broad representation and active citizen involvement in decision-making processes. The Public Participation Matrix delineates the number of forums, participants, development committee representatives, and the working composition of each forum. These forums, from the grassroots to the county level, create a tiered system that reflects the diverse composition and needs of the community. With a total target of 3,488 participants, this matrix outlines a comprehensive and inclusive approach to public participation.

Organized groups, including teachers' unions, head teachers associations, women's organizations, youth councils, faith-based organizations, farmers groups, and others, are crucial contributors to the participatory process. These groups ensure that diverse perspectives and interests are considered in decision-making forums. The overarching goal of this public participation framework is not only to facilitate citizen engagement but also to have a tangible impact on social and economic dimensions. Socially, public participation is seen as a potent tool in mitigating conflicts by bringing together diverse stakeholders and interest groups. By actively involving the public, the framework seeks to reduce the number and magnitude of social conflicts arising while implementing policies, laws, and development plans. Economically, an enlightened citizenry is viewed as a catalyst for effective participation in the development process. Empowered citizens are expected to influence the decision-making process, positively impacting their livelihoods. This dual focus on social and economic impacts underscores the comprehensive and sustainable nature of the public participation framework in Makueni County (Makueni County Integrated Development Plan, 2023-2027).

The 2023-27 County Integrated Development Plan (CIDP) marks the third long-term strategy since the initiation of Devolution in Kenya, a consequence of the 2010 Constitution. Timed alongside the new government regime post the August 2022 elections, the plan, themed 'A resilient economy for sustainable

development,' aims to foster a community capable of withstanding shocks and fostering economic growth. Acknowledging national and international commitments, the CIDP aligns with Africa's Agenda 2063, Paris Agreement, East Africa Community Vision 2050, International Conference on Population and Development (ICPD) 25 Kenya Commitments, Sendai Framework for Disaster Risk Reduction 2015-2030, Kenya Vision 2030, and The Makueni Vision 2025. Structured around eight sectors—Water, Sanitation, Environment, and Natural Resources; Agriculture and Rural Development; Transport, Infrastructure, Energy and ICT; Health Services; Social Protection, Education and Recreation; General Economic and Commercial Affairs; Lands and Urban Development; and Devolution—the CIDP consists of six chapters and an annex. These chapters cover county overview, performance review, spatial development framework, development priorities, implementation framework, and Monitoring, Evaluation, and Learning Framework (MEALF).

Additionally, the CIDP, estimated at Kshs 92.3 billion, will be executed through Annual Development Plans, drawing funding from the national government's equitable share, grants, Own Source Revenue (OSR), and Development Partners (DP) support. A series of Sector Working Reports underpinned the work on the plan prepared by Sector Members at the Sub County and County Level, and the Ward Public Participation reports from the ward and locational public participation (Makueni County Integrated Development Plan, 2023-2027). Unfortunately, the plan lacks a dedicated section on the plan formulation process. Therefore, the extent of public participation in preparing the CIDP could not be thoroughly evaluated. However, from the 2023-2027 CIDP, a public notice was issued on the county website inviting residents and other stakeholders to a sub-ward public participation forum on the 2024/2025 county annual development plan and community feedback on CIDP 2023-2027 in various sub-ward venues between twenty-first and twenty-second August 2023. A PDF report on the participation is also available online (Makueni county, website 2023)

2.3. Data sources and collection process

The study employed a systematic textual analysis procedure to extract and analyze relevant documents, including county-integrated development plans, policy reports, and project reports. The document selection criteria and data extraction steps focused on implementation cases, methodologies, strategies, and key actors. The coding scheme categorized textual data into themes such as "citizen participation," "Policy Framework," and "inclusivity." Contextual analysis

considered broader social, economic, and environmental factors influencing outcomes. The interpretation and synthesis phase drew meaningful conclusions, showcasing implications for future development planning. Validity and reliability checks ensured accuracy through independent coding and cross-verification, leading to a comprehensive report emphasizing the role of public participation in understanding development planning in the Kenyan context. The process involved reading and breaking down the text, coding relevant units, grouping codes into categories, analyzing patterns, and interpreting themes to conclude community participation in development planning. The key documents consulted are shown in Table 1.

Document	Type	Source	Key Findings
Makueni County Integrated Development Plan, 2023- 2027	County planning tool	Internet	The plan marks the third generation of long-term planning. The public is consulted in all the development planning sectors.
Nairobi County Integrated Development Plan, 2023-2027	County planning tool	Internet	The plan incorporates the aspirations and needs of the city's residents, businesses, and stakeholders through a participatory and consultative process.
Nthiga and Moi, (2021)	Research article	Internet	There was active public involvement and overall satisfaction with CDF project execution. However, there was need for exploring further avenues to expand public participation in policy formulation.
Mutisya, (2018)	Research article	Internet	Public participation was insufficient and overshadowed by higher-level technocrats. There was a need for civic education on project monitoring and evaluation.
Waitere, (2022)	Research article	Internet	Challenges to public participation included political obstacles, role conflicts, limited facilitation, and inadequate incentives. The study called for timely civic education.
Mbevi, (2016)	Research article	Internet	Findings showed limited community involvement attributed to economic constraints and lack of understanding. There was the need for more civic education, and involving communities in project planning for better resource identification and contribution.
Kioko, (2018)	Research article	Internet	There was a significant relationship between community participation and the regulatory framework, socio-economic factors, social attitude, and trust. Participation could be strengthened by civic education.
Kisumbi et al., (2017)	Research article	Internet	From the background of the theory of Citizen Participation Ladder, the study found that Citizen Power did not significantly impact

Document	Type	Source	Key Findings
			water project sustainability. The study called for enhanced community participation in all water projects.
Malusha & Njoroge, (2023)	Research article	Internet	The findings revealed that citizen participation practices significantly influence CIDP implementation. The study called for the publishing of public deliberation outcomes.
Kaseya & Kihonge, (2016)	Webpage	Internet	The study found that civic education significantly impacts participation. Further research on the education level's impact on public participation was suggested.
Atieno et al., (2019)	Research Article	Internet	Findings indicated that education level, language use, employment status, trust, and political influence impact public participation. The study called for a change in public attitude towards government project participation.
Mutwiri, (2016)	Research Article	Internet	Findings revealed that community awareness, behavioral factors, and economic considerations significantly impact public participation. It called for enhancing public awareness, tailoring development projects to local economic benefits, and improving public relations and policy communication.
Namano, (2015)	Research Article	Internet	It found a very weak relationship between public awareness and participation, no relationship with accessibility, and a weak positive correlation with the financial situation.
Mbithi et al., (2019)	Research Article	Internet	The study revealed a positive level of citizen participation. Conversely, challenges in influencing decision-making, unresponsive County Assembly Members, difficulty accessing information, and corruption.
Munyao, (2019)	Research Article	Internet	The research identified systemic gaps affecting the effectiveness of public participation, such as issues with civic education, lack of a public participation Act, and communication gaps in public forums. It called for aligning legal reforms for public participation.

Table 1. Documents reviewed.

2.4. Data analysis

The reviewed literature from document content analysis revealed that several pivotal factors that shape the engagement level and overall process efficacy influence effective public participation in development planning. Effective public

participation in development planning requires clear and accessible communication of plans, considering diverse demographics and cultural nuances. Building trust in overseeing institutions is crucial, alongside well-timed and flexible engagement activities. Capacity building through education and training fosters community participation. Supportive legal and policy frameworks and adequate resource allocation enhance inclusive strategies. Establishing accessible feedback mechanisms is vital to assure communities, and learning from past experiences and addressing historical perspectives is crucial for future engagement success. These findings constituted the conceptual lenses of this study and were used to observe the current status of citizen participation in developing CIPD for Nairobi and Makueni Counties and to draw study lessons. In order to explore the current status, five broad thematic areas, namely, participation activities, process, achievements, challenges, and strategies for participation, were analyzed for each county. Document content analysis was used for its cost-effectiveness compared to other research methods, such as surveys or experiments. It avoids direct participant contact, which is beneficial for sensitive topics. Objective and relying on document content sidesteps researcher bias. Though lacking quantitative data, acknowledged limitations in document availability hinder statistical depth, impacting the overall study.

3. Results

3.1. Current status on the role of citizens in development planning

Results show that public participation is beneficial for both Nairobi and Makueni counties. Table 2 shows the current status of citizen participation in CIDP development. Nairobi aspires to use public participation to regain its image after many years of sub-optimal service delivery. Makueni seeks to use public participation for the purpose of improving the quality-of-service delivery.

Thematic Area	Nairobi	Makueni
Participation activities	Long-term development planning (CIDP) and short-term development plan (Annual Development plan)	Long-term development planning (CIDP) and short-term development plan (Annual Development plan)
Mechanism of participation and category of participation	Various mechanisms, including Social media (Facebook, X), town hall meetings at ward level, and written and oral submissions (Nairobi County Website, 2023; Nairobi County Integrated Development Plan, 2023-2027).	Various mechanisms are used for public participation (Makueni County website, 2023). Participation is structured (Makueni County Integrated Development Plan, 2023-2027),

Achievements or benefits	Improved quality of service and county image as the "The Green City in the Sun."	Improved quality of service.
Challenges and causes	Limited budgetary allocation and citizen apathy	Inadequate capacity among the citizens, Inadequate funding.

Table 2. Status of participation in development planning

3.2. Factors affecting citizen role in participation in development planning

Results show that several key factors affect public participation in both Nairobi and Makueni (Table 3).

Key Factor	Nairobi	Makueni
Accessible information	A public participation notice was placed on the county website and social media handles	A public participation notice is displayed on the county website
Inclusivity of outreach strategies	There is a need for inclusive public participation guidelines.	The outreach strategy is highly comprehensive and inclusive.
Cultural sensitivity	Public apathy due to a perceived culture of tokenism may hinder effective public participation.	Citizens are enthusiastic to participate in CIDP and other development matters.
Trust in institutions	Low levels of trust due to bad negative experiences	There is a high level of trust in institutions
Timing and flexibility of engagement	Public participation is conducted in 2 days but has flexible approaches, including emails.	Public participation is conducted in 2 days but has flexible approaches, including petition and complaint forms.
Capacity-building opportunities for the citizens	There are forums for capacity building through civic education	There are forums for capacity building through civic education
Resource allocation	There are limited budgetary resources to facilitate participation	There are limited budgetary resources to facilitate participation
Past experiences and perceptions of participation	Unfavorable perception due to bad negative experiences with participation	Favorable perception due to the presence of feedback mechanisms

Table 3: Factors affecting participation

3.3. Strategies for enhancing the role of citizen participation in development planning

Results show that Nairobi County wishes to ensure citizens are adequately informed, included, heard, served with dignity and order, actively participate in decisions that impact their needs, hold public officers accountable, and have

creative self-expression opportunities. Makueni seeks to transform citizen participation through a raft of proposals, as shown in Table 4.

Nairobi	**Makueni**
Establishing a public participation directorate	To enact implementable laws and and policies, undertake objective oversight, and represent the interests of the public
Recruiting Public Participation personnel, including the County Rapporteur	To empower the citizenry to achieve meaningful participation in development activities.
Identifying Community Public Participation Champions	Improving community knowledge in development matters
Developing a public participation policy;	Improving community participatory and representative decision-making targeting special interest groups involved in participatory development
Developing public participation guidelines and regulations	Establishing participatory development committees
Reviewing the Nairobi City County Government Public Participation Act	Writing social safeguard reports and implement them
Collecting data, classifying data geographically and along other applicable matrices, and building appropriate databases for participation and engagement	Improving civic education resource materials and sharing them with the citizens
Conducting mapping of stakeholders per sector	Developing a civic education curriculum and disseminating it
Undertaking a baseline survey of public participation	Establishing a center for devolution and participatory development (community-led development school)

Table 4. Strategies for improving participation

In summary, Nairobi and Makueni counties demonstrate unique approaches and challenges in citizen participation in development planning. Nairobi tackles historical service delivery problems through social media and town hall meetings, overcoming obstacles amid budget constraints and citizen apathy. In contrast, Makueni excels in inclusivity, using comprehensive matrices and engaging numerous participants. Shared factors influencing participation in both counties

include low budgetary allocation, cultural sensitivity, trust levels, timing, and past experiences. Improvement strategies encompass creating participation directorates, recruiting personnel, implementing laws and policies, emphasizing civic empowerment, and fostering inclusive decision-making.

4. Discussion

Participatory governance as a key strategy for achieving sustainable development outcomes. Public participation enhances responsiveness to community needs, leverages diverse skills, and instills a sense of ownership for sustainable development projects (Jennings, 2000; Sinclair & Diduck, 2017; Maurice et al., 2021; Ergenc, 2023). It is behind this backdrop that in a bid to promote inclusive development, Kenya has deliberately entrenched public participation in key national development policies and legislation. In the context of development planning at the local level, the County Integrated Development Plans (CIDPs) are important in shaping the development trajectory of individual counties. Their development involves a meticulous and participatory process with multiple stages as guided by key policies and legislation outlined in Table 1, especially the County Governments Act of 2012. However, public participation is not uniform across counties. Moreover, the participation outcomes have been largely contextual with the changing socio-economic matrices.

This paper aimed to use document content analysis in the case of Nairobi and Makueni counties to explore and compare the current status of citizen participation in developing the county's integrated development plans for 2023-2027. When the analytical approach developed from the literature review was applied to the two counties, results showed that both Nairobi and Makueni counties showcase distinct approaches and challenges. Citizen participation is sought in both long-term and short-term development planning. Moreover, both counties employ similar strategies, incorporating mechanisms such as social media, town hall meetings, and written/oral submissions. However, Nairobi's approach, though not explicitly stated, is perceived as potentially tokenistic, possibly due to perceived citizen apathy.

In contrast, Makueni adopts a structured matrix for participation at the sub-ward level, documented in a comprehensive PDF report, targeting a diverse group of 3,488 participants. In addition, even though participation in both counties is aimed at improved service quality, Nairobi faces challenges of limited budgetary allocation and negative public perception, while Makueni grapples with citizen capacity and funding inadequacies (Table 2). In relation to Arnstein's

participation ladder, and based on study findings, the current status of the two cases falls in between and including Rungs three and five, signifying a shift between "tokenism," where citizens are informed and consulted. However, their input is non-binding and "Placation," representing a higher form of tokenism, allowing advice without decision-making power (Gaber, 2020). This finding is consistent with the findings from local studies conducted in Makueni county and has called for enhancing public participation in development planning such as Nthiga & Moi (2021), Mutisya (2018), Waitere (2022), Mbevi (2016) and Kioko (2018) and studies such as Atieno et al. (2019), Namano (2015), and Munyao (2019).

Results also reveal that similar factors affect the effectiveness of public participation, for instance, access to information, flexibility, and time in both counties. However, in the considered opinion of this paper, the limited budgetary allocation for facilitating citizen participation has a much greater negative impact on citizen participation. Limited financial resources restrict the implementation of effective outreach, educational initiatives, and feedback mechanisms, creating a more pronounced negative impact on the overall quality and inclusivity of citizen participation processes. Nevertheless, both counties have performed well by incorporating robust and flexible participation mechanisms that promote modern technology. Nairobi employs diverse methods such as social media (Facebook, X), ward-level town hall meetings, and written/oral submissions, detailed in the Nairobi County Website 2023. Makueni adopts diverse approaches to public participation, facilitating the submission of petitions and complaints through dedicated forms. The engagement extends to the sub-ward level, meticulously documented in a PDF report on the Makueni County website 2023 (Table 3). These findings give credence to the facilitative role that local and national government officials provide to encourage public participation in development planning (Nyama & Mukwada, 2023; Wiarda et al., 2023; Mbithi et al., 2019; Munyao, 2019).

While lauding the county officials for the gains registered in promoting participation, this study calls upon the county officials to redouble their efforts and further integrate the use of more modern multi-tasking technology by promoting AI technology in public participation. AI revolutionizes public participation in development planning through data analysis and insights, processing diverse data sources like social media and surveys. It extracts valuable insights from unstructured data, aiding planners in understanding public opinions. Predictive analytics, driven by AI algorithms, anticipates issues and opportunities based on historical data, enabling proactive addressing of public

concerns. Chatbots on websites or social media platforms engage the public instantly, answering queries and gathering feedback efficiently. Natural Language Processing analyzes language, helping planners grasp public sentiment. AI's role extends to Virtual and Augmented Reality, creating immersive simulations for public feedback. Personalized recommendations, automated surveys, collaborative platforms, and inclusive design ensure a dynamic and responsive development planning process accessible to all.

Moreover, even though diverse strategies are adopted to enhance citizen participation, Makueni's strategy of establishing a Centre for Devolution and Participatory Development (community-led development school) should be lauded as a strategy for enhancing the sustainable participation of citizens. Firstly, it serves as a dedicated hub for empowering communities with knowledge and skills essential for effective participation in local development processes. This strategy fosters a culture of informed engagement, enhancing the overall quality of citizen involvement. Moreover, centralizing resources and expertise in a specific institution creates a sustainable platform for continuous learning and capacity building. This approach ensures that communities are well-equipped to actively contribute to decision-making and development initiatives, making them more strategic and impactful. Nairobi County should be encouraged to develop a policy guideline for promoting citizen participation in CIDP development. This policy will provide a structured framework outlining the mechanisms and avenues through which citizens can actively engage in decision-making processes related to their communities. It ensures that the diverse voices and perspectives of the population are considered, contributing to more informed and equitable development plans. Additionally, a well-defined policy promotes transparency, accountability, and trust between the government and its constituents. Ultimately, it strengthens the social fabric by empowering citizens, making them active stakeholders in shaping the trajectory of their own development, and fostering a sense of ownership and pride in community outcomes.

Results in Table 4, comparing the public participation strategies of Nairobi and Makueni, show that both regions exhibit robust approaches, albeit with nuanced differences. Nairobi focuses on institutionalizing participation by establishing a Public Participation Directorate, while Makueni emphasizes enacting laws and policies for objective oversight. Both recruit specialized personnel, such as County Rapporteurs in Nairobi and Community Participation Champions in Makueni, to facilitate engagement. Nairobi prioritizes policy development and regulatory review, ensuring a legal framework for participation, whereas Makueni centers on improving community knowledge in development matters and

establishing participatory development committees. Nairobi's emphasis on data collection, classification, and database creation aligns with a structured approach for participation and engagement. At the same time, Makueni's focus on civic education resource materials and a community-led development school highlights a commitment to enhancing citizen understanding. Both regions share commonalities in conducting stakeholder mapping and baseline surveys, which are essential for informed decision-making. The adequacy of these strategies depends on the specific needs and dynamics of each county. Nairobi's legal and institutional foundation ensures a structured approach, while Makueni's emphasis on community empowerment and education reflects a grassroots-oriented strategy.

However, a major setback in both counties is that CIDPs lack a dedicated section highlighting how public consultations were conducted in their development. Lack of information on the form of public participation used, the impacts of participation, and the challenges incurred have significant implications. First, it hampers the thorough evaluation of public participation in preparing the plan. Public participation is crucial in democratic governance and decision-making processes. Without a clear understanding of how the plan was formulated, assessing the level of involvement and input from the community becomes challenging. This lack of transparency may lead to skepticism and mistrust among the public, as they may question the legitimacy of the plan and whether their voices were truly considered.

Furthermore, a dedicated section on the plan formulation process serves as a valuable resource for stakeholders, policymakers, and researchers. It provides insights into the methodologies, data sources, and criteria used in shaping the plan. This information is vital for accountability and for learning from the successes and challenges of the planning process. In the absence of such a section, there is a risk of overlooking potential flaws or biases in the formulation process. This, in turn, could impact the effectiveness and relevance of the CIDP. Additionally, making informed decisions for future planning initiatives becomes more difficult without clear documentation of the formulation process. To address these implications, it would be advisable to revisit the CIDP and incorporate a dedicated section outlining the steps to formulate the plan. This not only enhances transparency but also strengthens the foundation for future community engagement and participatory planning processes.

Public participation is important in development planning because it enhances more inclusive sustainable development. In the context of county-integrated development plans, different counties are at different levels of implementing

public participation in development planning. Despite robust strategies being applied in Nairobi and Makueni, addressing specific challenges is crucial for enhancing inclusive and effective public participation in development planning.

5. Conclusion and Recommendations

In conclusion, this study has highlighted the critical role of public participation in attaining Sustainable Development outcomes in Kenya, specifically within the context of County Integrated Development Plans (CIDPs) for 2023-2027. Examining Nairobi and Makueni Counties has revealed distinct strategies and challenges in citizen involvement. Despite robust approaches, financial constraints present a notable obstacle, underscoring the urgency for increased budgetary allocation and other innovative funding models. Makueni's innovative establishment of a Center for Devolution and Participatory Development emerges as an exemplary model for fostering sustained citizen engagement. Recommendations to enhance citizen participation include hastening Nairobi's adoption of a citizen participation policy and a collective effort from both counties to address documentation gaps, ensuring transparency and informed decision-making in future planning endeavors. Future studies should focus on assessing the effectiveness of innovative models such as Makueni's Center for Devolution in sustaining citizen engagement. Moreover, exploring the impact of increased budgetary allocation on public participation quality and inclusivity is crucial. The limitation of this study is that there could be some risk related to the subjective nature of interpretation, as different analysts may interpret texts differently, leading to misinterpretations.

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Original Paper

Fostering environmental innovation programs in Madiun Regency, East Java, Indonesia

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Abstract. *Madiun Regency faces numerous challenges in maintaining environmental sustainability amidst economic development in the region. To address these challenges, well-planned collaborative and innovative efforts are required, prioritizing environmental protection and sustainable development. This study examines the implementation of regional innovation programs related to the environmental sector in Madiun Regency. Data collection was conducted through Focus Group Discussions (FGD) and primary source searches from relevant local agencies. The study found that the Madiun Regency Government has implemented several regional innovation programs, including turning waste into gold (Merubah Sampah Menjadi Emas/MERAMBAH EMAS), organic fertilizer processing unit (Unit Pengolahan Pupuk Organik/UPPO), recycling waste into handicrafts and public facilities, biological agent, green public open spaces, and the city without slums (Kota Tanpa Kumuh/KOTAKU). These programs have contributed to the promotion of a smart environment which focuses on utilizing technology to manage resources efficiently, promote sustainability, and mitigate environmental impacts. However, to enhance community participation, the Regional Government should increase efforts in socialization and the formation of environmental cadres. This will facilitate the supervision of environmental protection and management functions in Madiun Regency.*

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1. Introduction

Environmental management has become a crucial issue globally as awareness of the need to preserve and safeguard the environment grows. Countries and regions are developing innovative approaches to address this challenge (Yakthi et al., 2023). As an archipelagic nation rich in diverse natural resources and ecosystems, Indonesia faces unique environmental management challenges and opportunities (Supriyanto, 2017). Regencies and cities across Indonesia are actively working to implement effective environmental measures. The urgency of addressing global climate change and environmental degradation is recognized

due to their significant impacts (Wibowo & Jundiani, 2023). It is essential for the government to work with various stakeholders to adopt cross-sectoral strategies and enhance community involvement, aiming to maintain a balance between economic development, social welfare, and environmental health (Hasan & Syahruddin, 2022; Mahmood et al., 2023; Panuluh & Fitri, 2016).

Madiun Regency, also known as Kabupaten Madiun, as a complex region, faces a series of pressing environmental challenges that demand thorough attention and effective solutions. In this context, the most prominent issue is waste management. The rapid population growth and accelerated urbanization have significantly contributed to the increase in waste generation, including both domestic and industrial waste (Hanifah, 2017). Within the scope of Madiun Regency, waste management issues take centre stage. The main challenges include the solid waste management system, which currently grapples with inadequate capacity and efficiency. Furthermore, medical waste management also comes under scrutiny due to its limited handling capabilities, which could potentially pose serious health risks to the community.

The current waste management infrastructure in Madiun Regency operates on a multi-tiered system that includes collection, transportation, processing, and disposal. However, inefficiencies and capacity issues plague this system, hindering its effectiveness. For example, the implementation of waste banks, intended to promote recycling and reduce landfill use, has not yet achieved the desired outcomes. Cahyani et al. (2022) note that although waste banks have been set up in several localities, the lack of community participation and inadequate support systems limit their effectiveness. Similarly, Zulfawati et al. (2020) highlight that there must be a comprehensive strategy that includes education on waste segregation, incentives for participation, and improved regulatory frameworks to enhance waste bank operations.

Apart from waste-related issues, land use conversion also presents a significant challenge in Madiun Regency. Urban growth and the conversion of agricultural land into residential or industrial areas can disrupt the natural ecosystem and upset the environmental balance. Ignoring principles of land use conversion can lead to negative environmental impacts, such as the deterioration of water quality (Susanti & Miardini, 2017). Waste originating from industrial and domestic activities, when discharged into water bodies, can lead to water contamination and a decline in water quality (Ningrum, 2018). Furthermore, this issue may serve as a principal factor in the diminishing availability of clean water in the future if it is not addressed swiftly (Juniatmoko & Erikania, 2020).

In response to these challenges, Smart Agroforestry (SAF) practices emerge as a viable solution, promising enhanced profitability for farmers alongside sustainable landscape management and climate change mitigation efforts (Octavia et al., 2022). The significance of understanding and finding solutions to these issues reflects the urgency of addressing environmental challenges in Madiun Regency. Achieving harmony between economic development, environmental protection, and social well-being stands as the primary goal in these endeavours.

Madiun Regency serves as a recent example of how a holistic and synergistic approach among various societal and local governmental aspects can yield positive innovations in environmental management. By focusing on proper waste management, planned land use conversion, and the protection of natural ecosystems, the region has made significant contributions to efforts aimed at achieving environmental sustainability (Jazuli, 2015).

This study aims to explore and analyse the diverse innovations in sustainable environmental management undertaken by the Madiun Regency Government and its community. By detailing the approaches, strategies, and outcomes of addressing environmental management challenges, this paper enhances the knowledge of integrated waste management approaches within regional governance structures, showcasing a successful example of environmental innovation that can be adapted and further developed in various regions. Grounded in a conceptual framework that integrates technological, socio-economic, and institutional perspectives, this paper will elucidate the impact of environmental management innovations on community well-being and sustainability in Madiun Regency, providing a comprehensive overview of local-level innovations that support environmental sustainability.

2. Methodology

The research was conducted in Madiun Regency from February to June 2022. The region is located in East Java Province, with coordinates ranging from 111°25'45" to 111°51' East Longitude and 7°12' to 7°48'30" South Latitude. It shares borders with Bojonegoro Regency to the north, Jombang Regency to the east, Ponorogo Regency to the south, as well as the Magetan and Ngawi Regencies to the west as can be seen on Figure 1. Administratively, Madiun Regency covers an area of 1,010.86 km^2, comprising 15 sub-districts and 206 village/kelurahan administrative areas (Pemerintah Kabupaten Madiun, 2022).

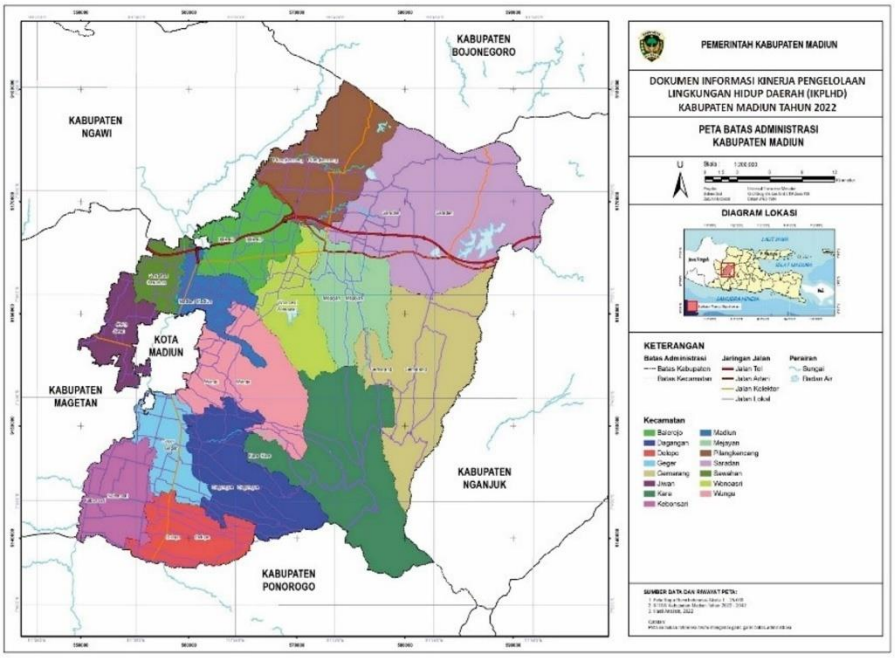

Figure 1. Administrative area of Madiun Regency.

2.1 Research method

The research methodology employed in this study encompasses two primary approaches: Focus Group Discussion (FGD) and the collection of primary sources from relevant agencies. The FGD approach was utilized to gain profound insights from diverse stakeholders. These discussions focused on official data and perspectives regarding environmental management concepts, challenges faced, and contributing factors to the sustainability of environmental management in Madiun Regency. The FGDs were conducted in accordance with ethical guidelines and informed consent was obtained from all participants.

2.2 Collection of primary sources

The primary sources were identified from key departments that have direct involvement and impact on environmental management. These include the Central Statistics Agency, Population and Civil Registry Service, Environmental

Service, Public Works and Spatial Planning Service, Forestry Service, Health Service, Agriculture Service, Regional Disaster Management Agency, and various non-governmental organizations operating within the regency.

The selection of documentation and reports from these departments was based on their relevance to the study's focus on environmental management initiatives. Specific criteria for source selection included:

a. Relevance
   The source must provide data or insights directly related to environmental management practices, challenges, or outcomes.

b. Authenticity
   Only official documents and reports published by the recognized agencies were considered to ensure accuracy and reliability.

c. Recentness
   Documents were chosen from the last three years to ensure the data reflected current conditions and practices.

2.3 Data analysis

Data from the primary sources were analyzed using a combination of qualitative and quantitative methods. Qualitative data, especially from reports on program evaluations and policy outcomes, were analyzed to extract narratives and case studies relevant to the sustainability of environmental management. While quantitative data were used to perform statistical analysis to identify trends and patterns.

In the FGDs, data were collected and then analyzed to identify priority issues in the environmental sector of Madiun Regency using scoring techniques. These priority issues were subsequently used as a basis for identifying and implementing an environmental innovation program tailored to address these specific concerns. The criteria for determining priority issues included: (1) affecting the lives of many people; (2) high relevance to regional interests; (3) potential for cross-sectoral or cross-regional collaboration; (4) likelihood of causing long-term negative impacts if not addressed promptly; (5) potential to cause cumulative impacts and multiple effects; and (6) potential to disrupt the implementation of sustainable development.

2.4 Identification of environmental innovation program

For the development of the environmental innovation program in Madiun Regency, the study incorporated a conceptual framework that integrated various dimensions of environmental management, such as technological, socio-economic, and institutional approaches.

3. Results and Discussion

The vision of the Madiun Regency Government is to realize a safe, independent, prosperous, and ethical region. One of the key missions that elaborates on this vision focuses on enhancing independent economic development through agribusiness, agro-industry, and sustainable tourism (Pemerintah Kabupaten Madiun, 2022).

3.1 Priority issues

Based on the findings from the FGDs, the Madiun District has identified four priority issues in the environmental sector for 2022. These issues include waste management, degradation of water quality, land damage, and land conversion and hold paramount importance for the Madiun Regency Government.

3.1.1 Population growth

The population of Madiun Regency has shown a tendency to increase over the past five years. Figure 2 shows the highest population increase occurred between 2019 and 2020, with a percentage increase of 9.13% (Badan Pusat Statistik Kabupaten Madiun, 2023).

This population growth has led to an increased demand for natural resources, including water, land, and energy. Consequently, there is a risk of over-exploitation of these resources, such as land conversion, excessive water usage, and increased reliance on fossil fuels. These activities can result in environmental degradation, including deforestation, drought, and pollution. Additionally, the growing population often triggers urbanization and infrastructure development, which necessitates more land. As a result, there is a conversion of forested or agricultural land into urban or industrial areas (Weber & Sciubba, 2019).

3.1.2 Increase in economic activity

Economic development in Madiun Regency is frequently accompanied by an increase in the consumption of goods and services, subsequently leading to increased waste generation. The heightened demand for products results in a rise

in both domestic and commercial waste. Inadequate waste management systems can lead to waste accumulation in landfills, causing environmental pollution and posing public health risks.

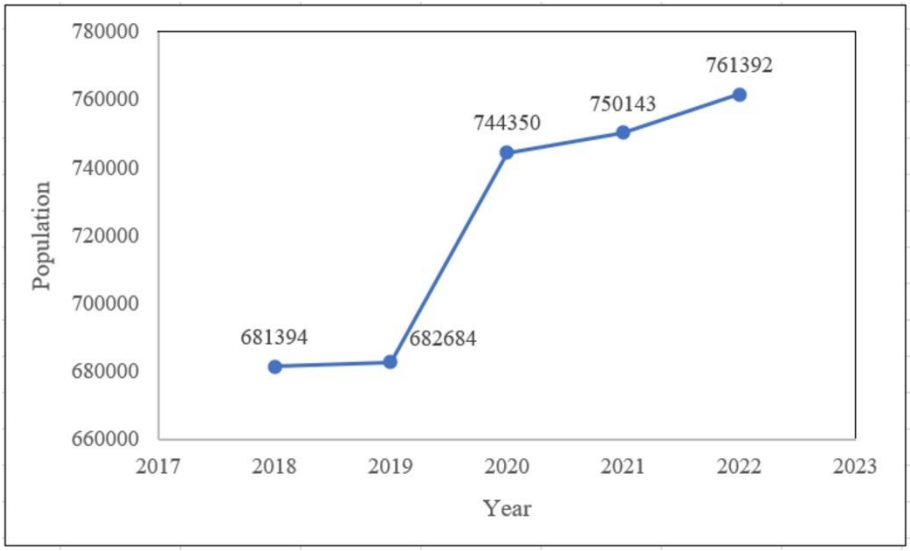

Figure 2. Total population of Madiun Regency 2018-2022.

Furthermore, the escalation of industrial and agricultural activities to meet economic demands can lead to a decline in environmental quality. Industrial activities contribute to air and water pollution, the generation of toxic industrial waste, and greenhouse gas emissions. Intensive agricultural practices involving the use of pesticides and chemical fertilizers can contaminate soil and water sources. Economic progress also frequently triggers changes in land use, with agricultural lands and forests being converted into urban, industrial, or infrastructure areas. This alteration in land use can result in deforestation, the loss of natural habitats, and harm to ecosystems. Additionally, changes in land use can heighten the susceptibility to natural disasters such as floods, landslides, and droughts (Acheampong & Opuku, 2022).

3.1.3 Geographical and topographical conditions of Madiun Regency

Madiun Regency is situated amidst the slopes of Mount Wilis and the Kendeng Zone Mountains in the north, while the western sub-districts of Madiun Regency are still influenced by Mount Lawu. The topography of Madiun Regency exhibits significant diversity, characterized by mountainous terrain in the south, plains in the central region, and hills in the north. This varied topography poses risks such as landslides, floods, and droughts (Afandi et al., 2020). Among the most prevalent natural disasters in Madiun Regency are floods and landslides, which are categorized into three hazard classes: low, medium, and high (Pemerintah Kabupaten Madiun, 2022).

3.1.4 Behaviour of Madiun Regency residents

Madiun Regency is encompassed within the Madiun Watershed, a vast lowland area with residents living near the watershed. The presence of settlements in riparian zones or near rivers, reservoirs, and springs, coupled with the habit of indiscriminately disposing of garbage into these water bodies, exacerbates water quality issues, particularly surface water quality. This issue arises from a lack of public awareness and knowledge regarding the detrimental consequences of such activities. Assessment of water quality using parameters such as biochemical oxygen demand (BOD), chemical oxygen demand (COD), pH, temperature, and ammonia-nitrogen highlights the importance of monitoring these parameters to evaluate the impacts of waste disposal on river water quality (Kasmuri et al., 2021).

Figure 3 provides an example of the findings obtained from monitoring the biochemical oxygen demand (BOD) parameters of river water in Madiun Regency. The dumping of untreated domestic wastewater and solid waste into water bodies accelerates the degradation of water quality, obstructing water flow and causing shallowing of the river. Consequently, this diminishes the river's capacity, leading to stagnant water and subsequent flooding.

3.2 Environmental innovative programs

After identifying the four environmental priority issues in 2022, Madiun Regency has developed and implemented some environmental innovative programs to achieve ecological sustainability. The following are six innovation programs in the environmental sector in Madiun Regency.

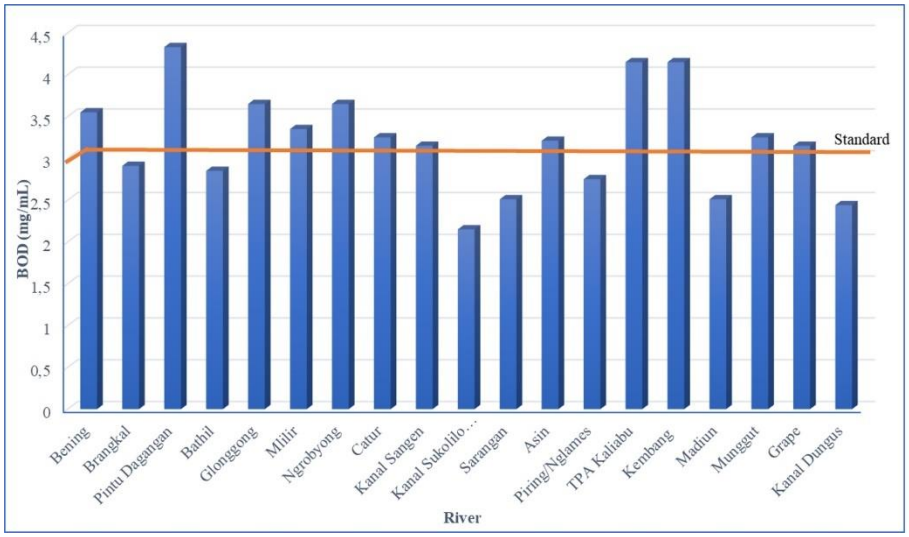

Figure 3. BOD Parameters of river water in Madiun Regency taken in the first semester of 2022.

3.2.1 Merubah Sampah Menjadi Emas (MERAMBAH EMAS)

The Madiun Regency Government currently operates one final waste processing site known as Tempat Pembuangan Akhir (TPA) called Kaliabu TPA, located in Kaliabu Village, Mejayan District. The landfill area spans 5 hectares and has a waste storage capacity of 260,000 m^3 (with two layers of levels). Currently, the Kaliabu TPA contains approximately 174,882.77 m^3 of waste, reaching around 70% of its capacity. It is projected that the landfill will reach its full capacity within the next few years. To prolong the storage period, various measures have been undertaken by the relevant authorities, including optimizing the role of waste banks throughout Madiun Regency. The waste bank operates as a waste management initiative that involves the repurchase of waste through a deposit-based system, similar to the banking concept (Wulandari et al., 2017). Studies show a strong correlation between the number of waste banks and waste reduction, indicating their effectiveness in decreasing landfill waste volumes (Susilowati & Herdiansyah, 2019).

Madiun Regency is home to 220 waste banks, distributed across 15 sub-districts. Among these, 130 waste banks are actively engaged in fostering and supervising waste management, while the remaining banks are still in the developmental

phase, requiring continuous guidance. To enhance the development of waste banks and generate greater community interest, innovative approaches and breakthroughs are necessary. In this regard, the Madiun Regency Government has introduced the "MERAMBAH EMAS" program, which involves exchanging waste for gold savings, as shown in Figure 4 below.

Figure 4. Garbage bank customers receive gold savings.

The "MERAMBAH EMAS" program in Madiun Regency is an innovative initiative that aims to convert waste into gold savings through the operation of waste banks. The program is based on Government Regulation of the Republic of Indonesia Number 81 of 2012, which focuses on waste bank management using the reduce, reuse, recycle system. The objective of this regulation is to enhance coordination and establish a sustainable strategy for managing household waste, while also strengthening the capabilities of waste bank administrators.

The program has been successful in several aspects, including the increase in the number of waste banks, job creation for waste bank administrators, a reduction in waste volume at temporary disposal sites known as Tempat Pembuangan Sampah (TPS), and an increase in the number of waste bank customers. It has also improved the welfare of waste bank management and customers, as well as raised public awareness of organic and inorganic waste management. The program has been particularly impactful for housewives, and it has led to a significant decrease in waste residue at TPS and an increase in community participation as waste bank customers. Waste banks can become economic institutions where waste can be a transaction tool used in their activities, because like conventional banks that use money as the instrument, the waste bank emphasizes its focus on waste management, which is the current environmental problem (Ansyar, 2020).

The implementation of the "MERAMBAH EMAS" innovation involved several stages, including community outreach, the establishment of a Memorandum of Understanding (MoU), and the inclusion of waste banks in the Database and WhatsApp Group of the Madiun Regency Main Waste Bank. The program has been sustained through monthly evaluations, which ensure the ongoing success and sustainability of the initiative.

The Madiun Regency Environmental Service collaborated with the Head of Village, Family Welfare Movement Team, and PT. Pegadaian Madiun Branch to conduct community outreach. Subsequently, a MoU was established between the Department of the Environment, Family Welfare Movement Team, and PT. Pegadaian Madiun Branch. The final stage entailed the establishment of a Waste Bank and its inclusion in the database and WhatsApp Group of the Madiun Regency Main Waste Bank.

The "MERAMBAH EMAS" program is an effort by the Madiun Regency Government to address waste management challenges and promote environmental sustainability. It has not only contributed to waste reduction and job creation but has also provided an innovative way to incentivize and engage the community in waste management practices. The "MERAMBAH EMAS" innovation was initially implemented in Tiron Village and Sendangrejo Village in 2019. Customers' waste savings, originally intended for holiday, education, and social savings, were converted into gold savings. Each month, customers receive a savings book indicating the amount of gold. The proceeds from the sale of waste, valued at IDR 10,000 are converted into gold savings of 0.001 grams (based on an estimated gold price of IDR 800,000 per gram).

The introduction of the "MERAMBAH EMAS" innovation yielded several improvements in environmental management performance, including:

1) An increase in the number of waste banks from 11 units in 2016 to 196 units in 2019.
2) Job creation for Waste Bank administrators, with the number of personnel rising from 376 to 1,176.
3) A reduction in waste volume by approximately 30% at TPS.
4) An increase in the number of Garbage Bank customers.

This program has had a significant impact on society, particularly for housewives. The innovation has successfully improved the welfare of waste bank management and customers, while also raising public awareness of organic and inorganic waste management. Additionally, the program has led to a decrease in waste residue at TPS and an increase in community participation as waste bank customers, with the number of customers rising from 26 to 136.

Figure 5. Waste bank administrative activities.

The activities of the Waste Bank commence with the weighing, recording, and sorting of waste based on its classification. The waste is then collected by the main waste bank. The proceeds obtained from customers' waste sales are coordinated and transferred to PT. Pegadaian Madiun Branch as gold savings. In order to ensure the ongoing sustainability of this innovation, monthly evaluations are conducted. These evaluations take place when the Village Waste Bank sells waste to the Main Waste Bank. Figure 4 and Figure 5 illustrate the activities and

impact of the "MERAMBAH EMAS" program, providing visual support for the program's implementation and outcomes. Following the evaluation, appropriate measures are taken, such as providing guidance to existing waste banks, conducting comparative studies with other waste banks, or rewarding waste banks that demonstrate proper management.

The program's impact and success demonstrate the potential for similar initiatives to be implemented in other regions facing waste management issues. By exchanging waste for gold savings, the "MERAMBAH EMAS" program has effectively transformed the perception of waste from a disposable material to a valuable resource, contributing to both environmental and social benefits. This program also serves as a model for sustainable waste management and community engagement, and its expansion and replication in other areas could further contribute to the advancement of waste management practices and environmental conservation efforts. This program is a notable example of innovative waste management practices, and its success in Madiun Regency holds promise for the broader advancement of sustainable waste management initiatives.

3.2.2 Unit Pengolahan Pupuk Organik (UPPO)

UPPO as the organic fertilizer processing unit program in Madiun Regency is an initiative implemented by the local government to effectively manage organic waste by converting it into organic fertilizer (Herdiansyah et al., 2022). This program aims to mitigate the adverse environmental impacts of organic waste while supporting the advancement of sustainable agriculture. The implementation of the UPPO Program in Madiun Regency involves several key steps:

1) Organic waste collection

This program entails the systematic collection of organic waste from various sources, including agricultural waste, kitchen waste, market waste, and livestock waste. The local government collaborates with the community, farmers, and entrepreneurs to establish an organized system for collecting organic waste.

2) Organic waste treatment

The collected organic waste undergoes composting or fermentation processes. To facilitate this, the local government has established an organic fertilizer processing unit equipped with the necessary equipment and infrastructure. The processing methods employed are environmentally friendly and adhere to organic fertilizer processing standards.

3) Processing and storage

The organic fertilizer produced undergoes further processing to optimize its quality and nutrient content. The processed organic fertilizers are then stored under appropriate conditions to maintain their stability and quality before being distributed to the agricultural and plantation sectors.

4) Farmer empowerment

This program also focuses on empowering farmers in the effective use and management of organic fertilizers. The local government provides training and assistance to farmers, enabling them to understand the benefits, application, and proper management practices associated with organic fertilizers. The objective is to enhance agricultural productivity, reduce reliance on chemical fertilizers, and promote sustainable agricultural practices (Gaina et al., 2021).

5) Distribution of organic fertilizers

The organic fertilizers produced through the program are distributed to farmers and plantations in Madiun Regency. The local government collaborates closely with the Department of Agriculture and relevant institutions to ensure the availability of organic fertilizers in sufficient quantities, at affordable prices, and in a timely manner. This distribution contributes to the development of environmentally friendly agriculture and enhances the yield and quality of crops.

The UPPO program in Madiun Regency plays a crucial role in promoting sustainable organic waste management and supporting organic-based agriculture. Through the conversion of organic waste into organic fertilizer, this program has the potential to reduce the reliance on chemical fertilizers, thereby mitigating their detrimental impact on the environment. Additionally, it aims to enhance the well-being of farmers in the region. Figure 6 serves as proof that the Madiun District Government actively supports community groups in implementing the UPPO program by providing infrastructure and equipment grants.

The Madiun Regency Government has set a target to establish 21 UPPO units, which consists of the following components:

1) Compost houses equipped with fermentation tubs.
2) Cage buildings with drainage channels.
3) Livestock (8 cows/buffaloes).
4) Organic fertilizer processing equipment.
5) Three-wheel vehicles.

Figure 6. Documentation of the UPPO Program at the Margo Utomo Farmer Group, Gandul Village, Pilangkenceng District.

The UPPO program is designed as a community-based empowerment initiative. Therefore, it is essential to increase community participation by forming environmental cadres and fostering community organizations in the environmental sector. These efforts will facilitate the supervision of environmental protection and management functions within Madiun Regency (Kusuma et al., 2023).

3.2.3 Recycling Waste into Crafts and Public Facilities

In 2022, Madiun Regency implemented a waste recycling program that transforms waste into crafts and public facilities as part of its commitment to sustainable and innovative waste management, which can be seen on Figure 7.

This program aims to minimize environmental pollution caused by waste, raise public awareness about the significance of recycling, and generate handicraft products and useful public amenities. The implementation of the program includes the following steps:

1) Waste sorting and collection

The residents of Madiun Regency are educated and encouraged to segregate waste at home and in public areas. The waste is sorted into organic, inorganic, and hazardous categories, and then collected separately by sanitation workers or other relevant parties. A study highlights the importance of efficient waste management systems that balance economic, environmental, and social factors, supporting the initiatives undertaken by Madiun Regency (Harijani et al., 2017).

Figure 7. Recycling waste products into handicrafts and public facilities in Madiun Regency.

2) Recycling centre

The Madiun Regency Government established a recycling centre equipped with the necessary facilities and equipment to process waste into new raw materials. This centre employs a skilled workforce trained in waste processing techniques for creating handicraft products and building materials.

3) Creativity in recycling

The collected waste is processed and transformed into various handicraft products, such as bags, wallets, accessories, and home decorations. Additionally, certain inorganic waste is utilized to construct park benches, fences, and other public facilities. This recycling process involves collaboration with local artists and craftsmen to produce high-quality products from waste materials.

4) Community training and empowerment

This program also includes training and empowering the community in waste management and the conversion of waste into economically valuable products. Community members are provided with opportunities to learn techniques for processing waste into crafts, including the selection process, cleaning methods, and techniques for creating aesthetically pleasing and marketable products.

5) Integration in public facilities

Craft products made from recycled waste are integrated into the construction of public facilities. For instance, park benches, trash cans, and wall decorations are created using recycled materials. This not only enhances the aesthetic appeal of these facilities but also conveys an important message about responsible waste management to the community.

The program to recycle waste into crafts and public facilities in Madiun Regency in 2022 represents a tangible effort to reduce waste, generate economically valuable products, and raise public awareness about the significance of sustainable waste management.

3.2.4 Biological agent program

Excessive use of pesticides is one of the key factors contributing to the decline in water quality, particularly in agricultural areas. The widespread application of synthetic pesticides, which often contain hazardous chemicals, poses risks to environmental health when misapplied or used in incorrect dosages. These chemicals can leach into water bodies, causing pollution. For instance, studies highlight the extensive use of agricultural pesticides affecting downstream water quality and the pervasive impact of these chemicals on ground water and surface water quality (Rad et al., 2022).

To address this issue, the implementation of natural and environmentally friendly pesticides, known as "biological agents", can help mitigate pollution caused by synthetic pesticides (Budiman et al., 2019). Biological agents are a means of controlling plant pests through the use of natural enemies. The introduction of biopesticides, which includes various natural enemies of plant pests, not only helps in mitigating pollution but also enhances sustainability in agriculture. For example, the implementation of biopesticides has demonstrated significant reductions in environmental contamination, providing a viable alternative for managing pest populations in an eco-friendly manner (Swapan et al., 2023).

The objectives of implementing a program for the control of plant pest organisms for food crops, horticulture, and plantation in Madiun Regency are as follows:

1) Enhance farmers' skills and knowledge in integrated pest management techniques using biological agents (natural enemies) for food crops, horticulture, and plantations.
2) Motivate and mobilize farmers and agricultural businesses to achieve self-sufficiency in rice production while maintaining stability in food crop production.
3) Foster the development of independent farmers capable of producing biological agents/natural enemies as alternatives to chemical pesticides.
4) Reduce production costs through cost-effective and affordable pest and plant disease control methods.
5) Minimize environmental damage caused by the use of harmful chemical fertilizers and pesticides, as evidenced by reduced pollutant levels in water from alternative farming practices (Oquist et al., 2007).
6) Improve the welfare of the farmers group known as gabungan kelompok tani (Gapoktan) members by utilizing organic fertilizers with the assistance of biological agents.

By implementing these biological agent activities, Madiun Regency aims to promote sustainable and eco-friendly practices in pest control, reduce environmental pollution, enhance agricultural productivity, and improve the well-being of farmers and agricultural communities by conducting a training session regarding the making of biological control agents as shown on Figure 8.

3.2.5 Green open space/Ruang Terbuka Hijau (RTH)

"Green open space" refers to designated land areas dedicated to greening and improving environmental quality. These spaces include parks, city parks, recreational parks, and urban forests that serve as sources of oxygen, absorb air pollution, and provide natural air conditioning (Zaitunah et al., 2021). Green open spaces also play a crucial role in maintaining ecosystem aesthetics and balance (Harjanti & Anggraini, 2020). In Madiun Regency, green open spaces are designed to provide comfortable and healthy public spaces for local residents, contributing to an enhanced quality of life. These spaces offer green, refreshing environments that serve as places for relaxation, socialization, and activities that

support a healthy and sustainable lifestyle. It is essential to maintain and care for green open spaces to ensure their long-term benefits for the community.

Figure 8. Training on making biological control agents in Ngetrep Village, Jiwan District.

Currently, only four sub-districts in Madiun Regency have public green open spaces: Dolopo, Wungu, Mejayan, and Nglames. These spaces typically take the form of city parks and recreational parks, equipped with facilities such as children's play areas, walking paths, seating areas, and shaded plants. They are designed to accommodate recreational and sports activities, with sports fields, jogging areas, bicycle paths, and spaces for various physical activities. Figure 9 exemplifies the largest green open space in the Caruban District, frequently used for various communal activities. In addition to providing tourism and recreational opportunities, green open spaces also contribute to economic development by creating job opportunities for local residents.

Figure 9. Green open space condition in Caruban Square, Madiun Regency.

In addition to expanding the capacity of green open spaces, the Madiun Regency Government conducts an annual tree seed planting program. This program aims to prevent natural disasters and maintain water availability. For instance, a tree planting event took place on Wednesday (30/03/2022) in the reservoir border area of Sareng Village, Geger District. Tree planting activities also occurred at other locations, including the reservoir in Sareng Village, Geger District, Jegglik Village, Kare Village, and Morang Village, Kare District. A total of 12,500 seeds were planted with the intention of preventing natural disasters. The tree species planted include rambutan, jackfruit, mango, and others.

3.2.6 City without slums/Kota Tanpa Kumuh (KOTAKU)

The KOTAKU program is a government initiative aimed at addressing the issue of slum settlements in Indonesia, including Madiun Regency (Triastuti et al., 2023). This program focuses on improving the quality of settlements, enhancing accessibility, and empowering communities to create better and more sustainable cities. In Madiun Regency, the KOTAKU Program encompasses several activities, including:

1) Slum rehabilitation.

This program aims to rehabilitate and develop slum settlements into habitable and improved settlements. Rehabilitation efforts include enhancing basic infrastructure such as clean water supply, sanitation facilities, electricity, and improving road access to the settlements.

2) Provision of infrastructure and public facilities.

The KOTAKU program also emphasizes the provision of necessary public infrastructure and facilities for the community. This includes constructing and repairing roads, drainage systems, parks, green open spaces, as well as social facilities like places of worship, health service centres, and community activity centres.

3) Community empowerment.

The KOTAKU program promotes community empowerment in the management of settlements. It encourages active participation of residents in the planning, implementation, and maintenance of settlement facilities. Communities are encouraged to form participatory groups that are involved in decision-making and program implementation.

4) Capacity building and education.

The program incorporates an educational approach and capacity building activities to enhance settlement management. Training and outreach programs are conducted to raise public awareness about the importance of hygiene, sanitation, and sustainable practices.

5) Supervision and monitoring.

The KOTAKU program includes continuous supervision and monitoring to ensure the success of the program and the quality of rehabilitated settlements. Effective supervision helps identify and address any issues that may arise during the implementation process.

The KOTAKU program in Madiun Regency aims to create healthy, livable, and sustainable settlements. Its implementation involves collaboration between local and central governments, communities, and other relevant stakeholders. One of the areas in Madiun Regency that has experienced the implementation of the KOTAKU program is Kincang Wetan Village and Sambirejo Village, Jiwan District as can be seen in Figure 10.

KOTAKU activities in these villages include:

1) Construction of a 270-meter-long water canal in RT 13 RW 6, with a budget of IDR 150,000,000.
2) Rehabilitation of Uninhabitable Houses (Rumah Tidak Layak Huni/RTLH) in Phase I, targeting houses belonging to Misran in RT 2, Slamet in RT 12, Simin in RT 8 RW 2, Gunirah, and Sutopo in RT 20 RW 4. Then in Phase II, RTLH rehabilitation was carried out on the Sukiran house.

3) Rehabilitation of Uninhabitable Houses for the houses of Sumadi in Wayut Village, Wiji Riono in Bibrik Village, Riman in Klagen Serut Village, and Cikrak in Kwangsen Village, Jiwan District, with each rehabilitation costing IDR 20,000,000.

Figure 10. Inauguration of the KOTAKU Program in Kincang Wetan Village and Sambirejo, Fiscal Year 2022.

3.2.7 The importance of environmental Cadres' roles

In Indonesia, the establishment of environmental cadres is governed by the Minister of Environment and Forestry Regulation Number 8 of 2022, which addresses Initiating the Development of the Environmental Generation. This regulation emphasizes the advancement of environmental stewardship through a grassroots management approach as a key strategy to achieve sustainable environmental development. The goal is to foster a clean and healthy living environment through consistent and continuous community engagement.

The formation of environmental cadres in Madiun Regency is a strategic step in enhancing community participation and empowerment in environmental

management and protection. Through education, awareness, and sustainable environmental management practices, environmental cadres can play a significant role in ensuring the sustainability of the environment for future generations.

Madiun Regency has initiated the formation of environmental cadres in each village/sub-district, as confirmed by the enactment of Madiun Regent Regulation Number 14 of 2022 on Waste Management in Villages. This regulation stipulates that waste management should ideally be handled at the community level within villages/sub-districts. As such, it is encouraged for every village or smaller community unit to establish environmental cadres and waste banks. The organizational structure of environmental cadres at the village level typically comprises the following positions: Chairman, Secretary, Treasurer, and sub-sectors for Waste Management, Greening, Energy, Health and Hygiene, and Cooperation.

Several recent studies highlight the critical role of community-based empowerment initiatives in environmental protection management. These initiatives focus on establishing environmental cadres and fostering the development of community organizations. Key elements include active stakeholder participation, the implementation of effective environmental law enforcement mechanisms, and the creation of synergy between community engagement and environmental legal awareness. These aspects are vital for integrating environmental interests into the legal framework and securing justice for nature through community-based empowerment programs (Insani & Karimullah, 2023).

In the realm of environmental education and capacity building, the Learning Institute for Environment (LIFE) project at Eastern Visayas State University in the Philippines stands out as a significant example. This project prioritizes training for leadership roles and the cultivation of a culture of excellence in environmental science and rural development. It aims to equip professionals with the necessary skills for effective environmental protection management (Cadiz & Aguirre, 2021).

4. Conclusions

The Madiun Regency Government has implemented numerous innovative programs aimed at environmental preservation, notably transforming waste into valuable resources. This study has highlighted key initiatives such as the

MERAMBAH EMAS program, which focuses on waste conversion, the establishment of organic fertilizer processing units (UPPO), and the creative reuse of waste in crafts and public facilities. Further efforts include promoting biological agents, developing green open spaces (RTH), and executing the KOTAKU program to eradicate slums. These strategies have effectively intertwined economic development with environmental management and social welfare improvements. The establishment of environmental cadres in each village underlines the government's commitment to fostering a prosperous community that values cleanliness, effective waste management, and eco-friendly practices. These cadres play a pivotal role in enhancing air and water quality, boosting public awareness about environmental health, and promoting sustainable consumption. Collectively, these measures underscore a significant advancement in Madiun Regency's approach to environmental stewardship and community engagement. This study contributes to the scientific understanding of integrated waste management strategies within regional governance frameworks, demonstrating a successful model of environmental innovation that could be replicated and further innovated in other regions. Further research is necessary to explore the long-term impacts of these environmental innovation programs on waste management practices, which will help in refining and expanding their application and efficacy across different contexts.

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Original Paper

Sustainable and responsible creation of shared values in the fast fashion industry

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Keywords: Corporate social responsibility (CSR); Creating Shared Value (CSV); fashion industry; sustainability; virtues; value.

Abstract. *The fashion industry is well-known for its negative social and environment impacts and a problematic compliance with criteria related to sustainability, Corporate social responsibility (CSR) and Creating Shared Value (CSV). However, even fast fashion businesses, despite their low-cost approach "at any price", claim to have moved towards sustainability. To examine the extent to which their claims are genuine requires scrutiny*

involving four steps. First, the concepts of sustainability, CSR, and CSV in relation to the fashion industry are determined. Second, the particularities of their measurement for fast fashion businesses are examined with particular reference to the fundamental virtues of respect and no waste. Third, these two virtues are assessed as precursors of the sustainable and responsible creation of shared values regarding a number of well-known fast fashion businesses in the EU, on the basis of their own qualitative content analysis in comparison with that of third-party websites. Fourth, results are critically and comparatively discussed. This leads to conclusions concerning the presence or absence of respect and no waste virtues and the variability in purported sustainable and responsible creation of shared values in the fast fashion industry. Our findings are that what is proclaimed and practiced by fast fashion businesses is thus far highly heterogenous and without regard for the question of measurability and the ability of the public to monitor it. The inherent limitations of our study will need to be offset by future longitudinal studies with a larger sample of businesses involving wider jurisdictions and using more sources.

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1. Introduction

In an editorial published on 16 September 2022, focused on the "staggering environmental impact" of fast fashion, *Nature* stated that "the textiles industry urgently needs input from researchers to help it to embrace the circular economy" (Nature, 2022: 653). The issue is indeed complex, since the fashion industry entails the production, retail and sale of fabrics, clothes and accessories based on evolving preferences (Turečková, 2014). It represents a *sui generis* blend of an intangible drive for an ongoing change involving aesthetic, cultural and other considerations, often unrelated to functionality and conventional value-for-money and its tangible and functional outcomes (MacGregor et al., 2020a; 2020b). The textile sector provides a country's image in the global market (Hussain et al., 2020) and the fashion industry has a revenue of over one trillion USD, most of it generated in China, and with the average revenue per user of over USD 390 (Statista, 2023).

In the last two decades fashion production and consumption has doubled (Shirvanimoghaddam, et al., 2020) and the fashion industry has become the second largest polluter in the world (only just after the oil industry) (Gupta et al., 2019), responsible for about 20% of the planet's water wastage and around 10% of the world's greenhouse gas emissions (MacGregor Pelikánová & Sani, 2023). In addition, the fashion industry is one of the five top-of-land and raw material users and one of the leading causes of social injustice vis-à-vis emerging nations (White et al., 2017). Often, fashion's long product chains begin in jurisdictions with low environmental and social concerns and end up in Europe. The age of keeping individually and locally tailored clothes for life and beyond ended in the 19th century in Europe and the *prêt-à-porter,* along with globalization and outsourcing, turned the fashion industry into an industry generating items with unacceptable environmental and social costs. Currently, after food, housing and transportation, textile consumption has the fourth-highest impact on the environment and on climate change in the EU (Centobelli et al., 2022). The urgent need for change must involve "refocusing on making things that last, and so encouraging reuse; and more rapidly expanding the technologies for sustainable manufacturing processes …" (Nature, 2022: 653).

2. Sustainability and responsibility

We believe that defining sustainable behaviours and manufacturing processes should start from a recognition of how the concept of sustainability has millennial roots and is related to value judgments about justice in the distribution and use of resources (MacGregor Pelikánová et al., 2021a; 2021b). It is linked to Aristotle´s idea of general complete justice, or rightness, and particular justice, which can be either public distributive (appreciative with rewards or vindictive with punishments) or private corrective (restitutive for involuntary behaviour or commutative for voluntary contracts). Such an understanding of justice provides the general direction for a sustainable future (Balcerzak & MacGregor Pelikánová, 2020), which is based on economic (profit), environmental (planet), and social (people) pillars and should reconcile the available resources and needs of the increasing world population (Meadows et al., 1972). Such a vision of sustainability should be an integral part of business strategies and match with Porter´s original trio (cost leadership, differentiation, and focus), added trio (variety-based, needs-based, and access-based strategies) and latest duo (capturing the core and broadening without diluting) (Moon et al., 2014).

Moving beyond the definition of the UN Brundtland Commission report from 1987 as meeting the needs of the present without compromising the ability of future generations to meet their own needs, sustainability can be seen as virtue/values-based, requiring a systemic transformation and a multidisciplinary connection of ideas, theories and methods, involving both individual and collective responsibility, and building bridges between generations and (Fitzpatrick, 2023). It should consider the entire biosphere and also be built upon moral values which go together with a love for life (biophilia) (Barbiero, 2016). Business sustainability cannot be realized without multi-stakeholder models across industries (Van Tulder & Keen, 2018), especially since corporations, particularly large and multinational corporations, are powerful players with vast resources which assume pivotal roles not confined merely to business itself. Although pursuant to the conventional and not necessarily unethical belief that the (primary) social responsibility of a business is to increase its profits (Friedman, 1970; Jahn & Brühl, 2018), sustainability, together with the responsibility for promoting it, is today a question of the factors considered and the criteria employed for the assessment of the operations of a business (Paksiova & Oriskova, 2020; Petera et al., 2019). Its frequently anthropocentric nature, focusing predominantly on humans while disregarding other species, is increasingly subject to criticism (Kopnina et al., 2021). A key feature required within Society 4.0 (Turečková et al., 2023) is thus the union of sustainability and responsibility.

Responsibility means that people must answer to an authority for the effects they cause, and this authority evaluates the eventual damages that derive (Schüz, 2012). Within a legal system where this authority is a judge, we deal with a special type of responsibility called liability (MacGregor Pelikánová & MacGregor, 2020). The modern era of economic, legal, ethical, and other responsibilities of a business towards society (Sroka & Szántó, 2018), called Corporate Social Responsibility (CSR), was launched in 1953 by Howard R. Bowen and consolidated in 1979 with the four-part definition of CSR: "CSR encompasses the economic, legal, ethical and discretionary expectations that society has of organizations at a given point in time" (Carroll, 2016: 2). Subsequently, the pioneering idea of win-win CSR emerged, i.e., that "CSR can be much more than a cost, a constraint, or a charitable deed – it can be a source of opportunity, innovation, and competitive advantage" (Porter & Kramer, 2006: 3) and led to the notion of creating shared values (CSV) (Porter & Kramer, 2011). Currently, it is understood that these four CSR pyramid layers are not strictly separate, and that ethics permeates the entire pyramid (Carroll, 2016), for example, corporate philanthropy goes beyond the category of a mere desire (Eger et al. 2019) and so

paves the way for CSV. CSV should "unlock the next wave of business innovation and growth" and "reconnect company success and community success" (Porter & Kramer, 2011: 77). In this sense it is arguable that CSV is a profitable variation of traditional CSR (MacGregor Pelikánová & Hála, 2021; Salonen & Camilleri, 2020).

To be fully realized, CSR must encompass the incorporation of sustainable and ethical principles and practices (Sroka & Szántó, 2018), the engagement with steps to minimize negative impacts and maximize positive contributions (Ogutu et al., 2023), going beyond mere law compliance to further social goals (Tafuro et al., 2022), re-considering of the importance of social capital (Chmelíková et al., 2019). CSR should consider stakeholders' expectations and the triple bottom line of economic, social, and environmental performance (Pisani et al., 2017). It is also argued that this triple bottom line requires consideration of animal rights and environmental ethics, because the current anthropocentric ideology leads to short-termism (Bansal & DesJardine, 2014). In other words, future generations of humans will profit from a planet that is diverse and biologically abundant (Kopnina et al., 2021). In the words of the European Commission, CSR is "the responsibility of enterprises for their impacts on society", (European Union, 2011: 3.1) i.e., CSR is about setting up a multi-stakeholder dialogue while considering the expectations of stakeholders and advancing a better understanding of the link between the company and society, based upon shared moral values and love for life (Barbiero, 2016).

3. Crises, policies, and legislation

Crises magnify differences and bring forth both challenges and opportunities (D´Adamo & Lupi, 2021). The post-modern, global, and heavily competitive society has witnessed several major crises in recent years (Błaszczyk et al., 2023; Cowling & Dvouletý, 2023), while the common denominators of all of them are issues related to sustainability, values and their balancing and prioritizing (Dyduch et al., 2021; Hála et al., 2022; MacGregor Pelikánová & Rubáček, 2022). Climate change is often considered the greatest immediate problem facing humanity (Jones et al., 2023: 4), closely followed by environmental degradation, loss of biodiversity, natural resource depletion, and water waste (Jepsen et al., 2015; Michalak & Michałowski, 2022). Individual and corporate choices related attempts to survive and prosper can lead both to hedonistic immediate self-gratification and to long-term societal solutions linked to increased confidence and a unique strategic advantage (Porter & Kramer, 2006 et 2011; Petera et al.,

2021). Businesses must address values and sustainability in the time of crises, especially those businesses held to be wasteful, anti-environment and anti-social, such as the fashion industry (MacGregor Pelikánová & Sani, 2023) and both the UN and the EU endeavour to provide guidance for it.

While the 17 Sustainable Development Goals (SDGs) of the UN's 2030 might appear as revolutionary, their key drivers are essentially conventional and traditionalist, viewing cultural heritage largely within the context of urban development (Saleh et al., 2021; Turečková & Nevima, 2019). In many respects, it is, however, a very ambitious plan, and its achievement is far from easy (Bali & Fan, 2019), even in the "developed" countries of the EU (Borchardt et al., 2022). UN Secretary-General António Guterres recently summarized the disappointment regarding the lack of progress regarding the meeting of such targets by stating "Yet today, only 15 per cent of the targets are on track. Many are going in reverse. Instead of leaving no one behind, we risk leaving the SDGs behind" (UN, 2023a). The UN is clearly against any trade-offs or charades regarding SDGs, and exhorts maximizing synergies between environmental and social endeavours, in particular as regards climate action and other pro-SDGs actions.

The EU institutions, in particular the European Commission, also voice alarm and continue proposing measures to address crucial issues, establishing, for example, the six priorities for the period 2019-2024, P1-P6, of which the first one is the European Green Deal (EGD) with its nine sub-strategies, EGD1-EGD9. Despite the clear EU Commission commitment to sustainability and SDGs, as in the EGD and circular economy concerns (Kowalska & Bieniek, 2022), EU member states vary significantly in terms of implementing SDGs and in particular SDG 9 (infrastructure, industrialization, and innovation). Even European businesses ostensibly pro-sustainable, in the same jurisdiction and in the same industry, can vary dramatically in their commitments to sustainability, e.g., some of them engage in sustainability initiatives independently and make them part of their own activities, while others do it with their business partners by forming sustainable supply chains (Małys, 2023).

The EGD explicitly addresses selected industries, such as the fashion industry, as in the EGD3 New circular economy action plan (CEAP), EGD4 Environment action program to 2030, EGD8 Textiles strategy and EGD9 Zero pollution action plan. In addition, these strategies entail Extended Producer Responsibility (EPR). The manufacturing and transport of clothing contributes increasingly to pollution, social injustice and the spreading of unnecessary items causing waste, while a growing number of Europeans are willing to pay more for

clothes with a high sustainability component (Centobelli et al., 2022). Moreover, the EU aims to be the first area in the world to act against fast fashion and its blighting waste (Centobelli et al., 2022) under the motto "fast fashion is not fashionable" (Shirvanimoghaddam et al., 2020). Thus, by 2030 textile goods sold in the EU should be long-lasting, recyclable, and accompanied by their digital product passport taking advantage of modern blockchain technologies and QR-codes, e.g., COM (2022) 142 "Final proposal for a regulation establishing a framework for setting ecodesign requirements for sustainable products" and repealing Directive 2009/125/EC as of 30 March 2022.

Fast fashion businesses are well aware of these policy and legislative initiatives, as well as the growing number of pro-sustainability consumers (MacGregor et al., 2020a). Furthermore, they are aware that the attitude of "low cost at any price" cannot be sufficient and they look for other options to subscribe to, including CSR and CSV (Hála et al., 2022). Consequently, various pro-CSR and pro-CSV genuine or fake declarations and actions by fast fashion businesses operating in the EU have been proliferating and the EU Commission and other EU institutions have moved to change EU policies (Czyżewski et al., 2020) and EU law, building a strategic framework to fight against lies and manipulation in this arena (MacGregor Pelikánová & MacGregor, 2020), as in the EU taxonomy battle against greenwashing (MacGregor Pelikánová & Sani, 2023; Rubáček et al., 2023). Fast fashion businesses continue issuing various sustainability and CSR reports and fill their websites with information about their social and environmental accomplishments. Studies and assessments of such declarations are rare, focusing on the luxury rather than the fast fashion segment (MacGregor et al., 2020b; Di Maria et al., 2023), and do not attempt to verify them or compare policies regarding CSR and CSV (MacGregor Pelikánová & Sani, 2023). This creates a gap to be filled.

4. Trends in fast fashion

The general trends in the fast fashion businesses are very clear. Fast fashion production outside of the EU is constantly expanding and its disastrous environmental and social impact grows, progressing from local over to regional to global. The garments produced, causing pollution and irreversible water wastage, travel extensively, leaving a heavy carbon footprint, and end up in the EU itself, only to be discarded quickly with no regard for ecological consequences. The EU institutions have taken strategic, political, and legislative steps in this respect. At the same time, both European businesses and European

consumers are becoming more aware and sensitive to the question, including the consideration of pro-sustainability behaviours as a competitive advantage and anti-sustainability behaviours as negative or even taboo. Consequently, sustainability has become an important theme for fast fashion businesses. Analysing the extent to which this is bringing about change requires investigation, classification and measurement of pro-SDG, CSR, and CSV compliance of fast fashion businesses.

Fast fashion is accused of promoting reckless and wasteful consumption with the false and manipulative excuse of democratizing, while instead leading to social injustice (worker harassment and exploitation, wage theft, systemic racism, and gender inequality), health threats (diseases due to toxic chemical use), environment destruction (water wasting, increased greenhouse gas emissions, biodiversity loss, and resource and soil depletion) (Bick et al., 2018). All these consequences are largely futile, because less than 10% of fast fashion items is genuinely used for a longer term and only 1% is recycled (Mu, 2023). The waste consisting of fast fashion items, and generated by households in the EU, is growing by 5% annually (Statista, 2024), while the production of these unused or not really needed garments has, for example, directly caused the rapid disappearance of the Aral Sea at an ever-faster rate (Looding, 2020). At the same time over 70% of these garments promptly turn into solid waste, clogging rivers, greenways, and parks, etc. (Bick et al., 2018). Fast fashion practices are becoming incompatible with the EU vision of reconciling competition and sustainability, and the entire fast fashion industry contradicts the EU vision of a greening economy and competition law (Jones et al., 2023:6). In this respect, the EU strives to react via determining priorities and strategies, including the CEAP and EU Strategy for Sustainable and Circular Textiles to create a greener textiles sector.

The fast fashion business model is characterized by speed, novelty, economy, and disposable trends in constant change (Dabija et al., 2022; Powell, 2021) and production in remote low-cost labour jurisdictions (Centobelli et al., 2022). At the same time, fast fashion businesses understand that their operations bring moral and/or legal duties generating costs, at least from the short-time perspective (MacGregor Pelikánová & MacGregor, 2020). Considering the business model and price orientation, fast fashion businesses must explain and convince not only consumers to carry on with them (Gohel et al. 2023), but also investors. Since investors are becoming more socially conscious as well as aware of the negative legal and economic consequences of unsustainable behaviour, Environmental, Social, and Governance (ESG) is becoming increasingly

important. ESG concerns standards for a company's behaviour used by socially conscious investors to screen potential investments. CSR and ESG can be seen as two faces of the same coin. CSR is about the sustainability message generated and broadcast by the fast fashion business, while ESG is about the sustainability message sent back by investors. This dynamic of macro-economic sustainability reflected by the micro-economic interaction of CSR and ESG can be realized via various patterns. The popular pattern "proclaim-claim" via vision and mission statements and/or codes of ethics is not the only option. The "pattern communicate-create" can be employed to seek the intersection between responsibilities and taking advantage of synergies (Ferraro & Beunza, 2018), either only internally between networks of internal stakeholders (Ujwary-Gil, 2023) or externally between networks of external stakeholders (Balcerzak et al., 2023). Therefore, practically almost all fast fashion businesses, at least informally, declare their pro-sustainability and pro-value orientation by Internet postings, typically on their own domains, and a large majority of them issue sustainability or CSR reports. Some of them reflect this in their codes of ethics and in their policies.

Over the last two decades, a myriad of mechanisms has been developed to standardize pro-sustainability and pro-value declarations and to measure and assess the resulting action of fast fashion businesses. Numerous international and national indexes have been created, various scoring agencies and bodies have been ranking, and diverse certification trademark and rewards have been distributed. Certainly, these metric and standardization devices are always speculative and cannot fully overcome the ephemeral and multi-faceted nature and unpredictability of all consequences. It is currently debated about how to describe something, what we know if we only see it (White, 2013), and how to measure something that is may well be immeasurable (Gjølberg, 2009), while fast fashion businesses continue to report it.

Fast fashion businesses use universal standards, such as 17 SDGs and ISO standards. They also refer to indexes, such as the Dow Jones Sustainability World Index[1], the MSCI global environment indexes[2], and the Calvert Social Index (Little, 2008) and CSRHub Consensus ESG Ratings[3]. Moreover, a number of indexes particular to fast fashion and its purported inclination to greenwashing

[1] https://www.spglobal.com/spdji/en/indices/esg/dow-jones-sustainability-world-index/
[2] https://www.msci.com/our-solutions/indexes/index-categories/esg-indexes/global-environment-indexes
[3] Search Sustainability Ratings | CSR Ratings (csrhub.com)

have been developed, such as the Fashion Transparency Index (FTI)[4], and many rankings are provided, based on statistical data[5]. Fast fashion businesses operating in the EU can also take advantage of various EU certification trademarks and labels, e.g., the EU ecolabel, or rely on national labels from individual EU member states. Sustainability competitions are spreading in all EU member states. For example, in the Czech Republic these competitions are organized both by ministries[6] and also by private initiatives[7]. However, each one of these measurements assumes a different vision of sustainability and works with both hard and soft data, involves human subjective assessment elements and is instantaneous and looks more toward the past. The sustainable and responsible creation of shared value must be future oriented. The understanding and measuring of pro-sustainability declarations and actions can only be carried out preliminarily and must be subject to future review.

Ideally, sustainability would be perfectly mirrored by CSR and ESG, which both should lead to CSV in full compliance with their customers and investors. Contemporary strategic management seeks sources of value in order to create and capture these values (Dyduch et al., 2021), to turn threats into opportunities especially in an era of crises (Błaszczyk et al., 2023; Kovoor-Misra, 2009). Companies and businesses should become agents of both social change (Kramer & Pfitzer, 2016) and environmental change, for example, within a vision of affective ecology (Barbiero, 2021). Nevertheless, fast fashion businesses in the EU do not exhibit constant progress in indexes and scores. Indeed, the current scientific literature emphasizes the sustainability failures of fast fashion businesses, both intentional and through negligence (Gohel et al., 2023).

However, during the last decade, almost all fast fashion businesses in the EU have moved towards declaring a change of orientation and business models and inform the public about their various pro-sustainability programs, projects, actions and attempts to progress towards specific goals. Currently, the fast fashion industry offers many examples of vigorous sustainability statements and outstanding scoring and rates posted on the Internet, in particular via their own domains and social media (Michaela & Orna, 2015). At the same time, many recall past positive rankings and laudatory declarations that were followed by actions with subsequent disastrous consequences in the environmental and/or

[4] https://www.fashionrevolution.org/about/transparency/
[5] https://www.statista.com/statistics/1202694/fashion-industry-leading-countries-worldwide/ and https://fashionunited.com/global-fashion-industry-statistics
[6] https://www.mzp.cz/cz/top_odpovedna_firma
[7] https://byznysprospolecnost.cz/

social spheres. One example is the Rana Plaza Factory Complex in Dhaka, Bangladesh, which was celebrated in 2006 as an ideal place to produce garments for many firms. The factory collapsed in 2013, killing over one thousand employees and becoming a "terrible and sad metaphor for fast fashion´s uncontrollable impacts" (Centobelli et al., 2022; Ertekin & Atik, 2015; Huq & Stevenson, 2020). Other cases have been illustrated by Fraser & van der Ven (2022). While for some twenty years fast fashion businesses have been presenting themselves as pro-sustainability and pro-value oriented, quoting various indexes, scores, ratings, and labels, the level of patent manipulation and consequent mistrust is significant. Unsurprisingly, there is public reluctance to believe it and European customers, especially young ones, do not trust it (MacGregor Pelikánová & Hála, 2021).

Clearly, modern fast fashion businesses care more for their reputation then in the days before Rana Plaza (Kannan, 2018) and appreciate that their sustainability should be guided by policies, laws and even private initiatives to common goals reflecting common values while boosting competitiveness (Kiseľáková et al. 2019) and are more than eager to speak about it. However, they are often reluctant to engage with it in a genuine manner for various reasons, including the lack of incentives (Hur & Cassidy, 2019). Avoiding abuses and malpractices, such as the currently extremely popular greenwashing (Balcerzak et al., 2023), requires moving towards establishing four justifications for CSR that create the drive for "the right kind of profits" (Porter & Kramer, 2006) and are complemented by three ways to CSV (Porter & Kramer, 2011). The justifications for CSR are moral obligation (ethical dimension), sustainability (continuity of all three pillars: economic, environmental, social), license to operate (Faustian bargain between the society and the corporation) and reputation (pleasing the public-at-large) (Porter & Kramer, 2006). The ways to CSV are reconceiving products and markets, redefining productivity in the value chain and enabling local cluster development (Porter & Kramer, 2011). Conventionally, seven fundamental virtues are proposed as matching the justifications of CSR (moral obligation - respect, sustainability - (no) waste, license to operate - communication/dialogue, reputation - consciousness) and three ways to CSV (trust/honesty, transparency, collaboration) (MacGregor Pelikánová & Sani, 2023), as in Table 1.

These seven virtues partially overlap with the virtues and vices indicated by Aristotle in his second book of the Nicomachean ethics and conceptually match Aristotle's virtue balancing, as in the pattern "fear and confidence: rashness - courage – cowardice" (Rackham, 1997). Furthermore, it is illustrative to consider them along with the features of the stages of CSR development, as in Table 2.

Four justifications for CSR	**Dimension**	**Virtue description**	**Virtue abbreviation via a key word**
Moral obligation = companies have the duty to be right citizens and to "do the right thing"	Deontological (moral imperative)	Recognizing and following right objects and goals	RESPECT
Sustainability= companies have the duty to operate in ways that secure long-term performance	Consequentialism (utilitarian imperative)	Using resources wisely	NO WASTE
License to operate = companies have the duty to communicate and pragmatically reflect stakeholders	Social contract (request imperative)	Making compromises based on dialogue	COMMUNICATION
Reputation = companies have the duty to satisfy expectations of external audience	Social contract (order imperative)	Recognizing and doing what others might morally expect	CONSCIOUSNESS
Three ways to CSV		**Virtue description**	**Virtue abbreviation via key word**
Reconceiving products and markets = companies have to understand what is good for customers	Deontological pragmatism	Figuring what is good, explain it and be consistent and trustworthy	HONESTY (no lying)
Redefining productivity in the value chain = societal problems can create economic costs	Consequentialism (utilitarian imperative)	Turning challenge/threat into opportunity (courage to be transparent, honest and open-minded)	TRANSPARENCY
Enabling local cluster development by collaborating = no company is self-contained	Social contract (request imperative)	From shared words (communication) to shared acts (collaboration)	COLLABORATION (higher form of COMMUNICATION)

Table 1. Seven fundamental virtues for sustainability. Source: Authors based on 4 justifications for CSR and 3 ways to CSV (Porter & Kramer, 2006 et 2011).

Clearly, both fundamental virtues for sustainability and stages of CSR development are rooted in a genuine and committed awareness and readiness to go ahead with an active and individual responsibility towards others. Such an inclination is hardly measurable and so, before even thinking about measuring fast fashion businesses via indexes and scores and verifying it via empiric observance, it is necessary to explore their standpoint regarding the seven fundamental virtues for sustainability, since, without them, no genuine and mature CSR, CSV and ESG can occur. Of these seven, two appear as especially critical for the fast fashion industry – respect and no waste. Various surveys and studies reveal that these are what customers and investors want the most from

the fast fashion businesses and what is the most challenging for fast fashion businesses (Gohel et al., 2023; Hur & Cassidy, 2019). Since fast fashion garments are intentionally designed with short life cycles via planned obsolescence (Birtwistle & Moore, 2007), then the goals of respect and no waste appear difficult to achieve. Our study aims to investigate the extent to which fast fashion businesses recognize this as a prerequisite for making claims to sustainability.

Development of CSR	**Era**	**Fiduciary duty to**	**License to**	**Description/Features**	**Maturity/nature via a key word**
CSR 1.0 Corporate SELF Responsibility	Business & Society 1960-1994	Primary stakeholders	Exist	Becoming a community-focused business – "do not harm" - Correlation between financial performance and relationship with stakeholder (Freeman stakeholder model)	RECOGNITION
CSR 2.0 Corporate Social RESPONSIVENESS	Business in Society 1995-2006	Secondary stakeholders	Operate	Financial benevolence – "to financially contribute" - Focus only on social welfare, charity and stewardship principle, ethics, (Carroll pyramid)	COMMUNICATION
CSR 3.0 Corporate SOCIAL and STRATEGIC Responsibility	Business-Society 2006-2014	All stakeholders	Better serve needs	Engaging your workforce –" to volunteer" Long term relationship with stakeholders (Porter CSV)	COLLABORATION
CSR 4.0 Corporate SOCIETAL/SUSTAINABLE Responsibility	Sustainable Business 2014-	Future stakeholders	Explore with unmet needs, common goals	Strategic community engagement - Inclusion of SDGs, contributing to a common purpose (Van Tulder Strategic Sustainable Business...)	INCLUSION

Table 2. Review of stages of CSR development. Source: Authors based on strategic and operational principles of sustainable business (Van Tulder & van Mil, 2023:344-353).

5. Research methods and materials

Our research focuses on the genuineness of the self-declaratory endeavours of fast fashion businesses via their own digital setting – their own domains with websites – and other related Internet sources. The study uses data from two types of websites – based on the domains of the fast fashion businesses selected and on other reporting domains. This data is processed through a qualitative thematic

content analysis performed by the simplified manual Delphi method with Likert scale ranking (Jebb et al., 2021). The results of the study are critically discussed and compared, using comparative glossed tables. This leads to conclusions about the existence of sustainable and responsible shared values in the fast fashion industry, related trends, and the need to find carefully balanced, pragmatic, well-communicated and consistent sustainability and value orientation choices based on respect, no waste and transparency.

The underlying research question is addressed through the study of secondary sources and the analysis of websites and the synthetic Fashion Transparency Index (FTI), taking account of the achievement of stages of CSR development. In this way, our purpose is to research and critically analyse the presence or absence of sustainable and responsible shared values in the fast fashion industry via a triangulation of information provided in the digital setting and linked to business virtues (Royo-Vela & Cuevas Lizama, 2022), juxtaposed to the FTI and the stages of CSR development. The study is based on two assumptions implied in prior literature. Firstly, the sustainable and responsible creation of shared values is intimately linked to justifications for CSR and ways to CSV, i.e., these are necessary virtue pillars for building genuine and solid values. A fast fashion business cannot be sustainable and pro-sustainability if it is disrespectful, wasteful, uncommunicative, dishonest, and not transparent. Secondly, these key fundamental virtues are distilled and communicated through the key terms of respect and no waste.

The raw data used was mined from both the internal and external Internet sources (MacGregor Pelikánová, 2021) and complemented by empirical field observations (McLeod, 2015). This data was processed via a content analysis (Krippendorff, 2013; Kuckartz, 2014), while using a qualitative manual Delphi approach (Okoli & Pawlowski, 2004) and critical juxtaposition with glossing and Socratic questioning (Yin, 2008). From the fast fashion arena, we pre-selected ten businesses which are well known in the EU and which, at the same time, are digitally fully present. They have freely accessed Websites with various reports and declarations placed on their own domains (MacGregor Pelikánová & Rubáček, 2022) and are covered by reporting Websites of third parties. The complex individual and thematic content analysis through the manual Delphi approach was carried out by a micro-team of specialists following set guidelines and correction rounds were used (MacGregor Pelikánová et al., 2021a). The micro-team consisted of three experts in the field, in particular in doing CSR and CSV assessments based on Websites and reports (MacGregor Pelikánová, 2021b), who are not the authors of this article. They assessed data on the ten fast

fashion businesses about sustainable and responsible shared values and stages of CSR development using a Likert scale ranking, i.e., for agreement giving + (the strongest agreement being +++), for lack 0 and for disagreement - (the strongest disagreement being ---) (Jebb et al., 2021). They followed guidelines set by the authors and the two rounds of review avoided discrepancies, while the triangulation boosted the accuracy by allowing cross-checking (Royo-Vela & Cuevas Lizama, 2022).

6. Results and Discussion

The results of our study take the form of a qualitative content analysis and comparative glossed tables. Both the scientific literature and business statements, especially if generated by fast fashion businesses themselves, assert that CSR has not been about tensions, trade-offs and preferring something over something else (MacGregor Pelikánová & Hála, 2021). Instead, it is proposed as a vision of the future (White, 2013) entailing an integrated, unified whole which creates a sustainable stakeholder framework (Carroll, 2016) and brings opportunities and a competitive advantage potential. CSR should lead to the creation of shared values, thereby CSV (Salonen & Camilleri, 2020), and subsequent virtues, in particular respect and no waste. These are central for a dynamic exploration of opportunities for innovativeness (Dyduch et al., 2021) and essential for putting together resources and engaging in open transparent dialogue to identify common points supporting economic, environmental, and social sustainability in a collaborative manner (Van Tulder & Keen, 2018), to be pursued during periods of economic upturn and downturn (Cowling & Dvouletý, 2023).

However, pragmatic observation of the classical fast fashion business model leads to a certain amount of scepticism regarding the capacity and potential of fast fashion businesses to "unlock the next wave of business innovation and growth" and "reconnect company success and community success" (Porter & Kramer, 2011: 77). The notion that CSV is a profitable win-win variation of traditional CSR (MacGregor Pelikánová & Hála, 2021; Salonen & Camilleri, 2020) clashes with the basic parameters of fast fashion, which are neither about sustainability nor about values, but instead marked by a "sustainability bias" and bioeconomy and circular economy reluctance (Colasante & D´Adamo, 2021).

Fast fashion is essentially about speedy mass production at a low cost, efficiency over effectiveness, quantity over quality, immediate financial profits regardless of human workforce exploitation and environment pollution. The fast fashion segment grew during the late 20th century as the manufacturing of clothing

became less expensive as the result of more efficient supply chains and new quick response production methods, and greater reliance on low-cost labour from the clothing industries of Asia (Bick et al., 2018). The environmental and social consequences of fast fashion, including massive abuses, have been often underplayed by scientific literature, research, and discussions surrounding environmental and social justice (Bick et al., 2018). Recent legislative and policy trends, along with crises, particularly COVID-19, have created pressure on the textile and clothing value chain and the fashion industry in general (Di Maria et al., 2023 Tafuro et al., 2022), while concerns expressed especially by young consumers have been growing (Hála et al., 2022), referred to the ethical dimension of the fashion industry (Cerchia & Piccolo, 2019) and new sharing and recycling strategies. While there is still a gap between the attitudes and sustainable behaviour of Generation Y (Mason et al., 2022; Pauluzzo & Mason, 2022), there is no doubt that Generation Z supports increasingly a sustainable/circular economic paradigm to combat climate change by adopting responsible consumerism (D´Adamo et al., 2022), increasing readiness to pay the circular premium and acquire second-hand, or even swap clothes (Colasante & Adamo, 2021). This seems to be backed by the EU institutions, law, and policy and to push more fast fashion businesses to decide whether to speak or not to speak about sustainability, to behave or not to behave sustainably, to enact or not enact the sustainable and responsible creation of shared values. The arena for such developments is the Internet.

From the manual Delphi assessment of respect and no waste based on the internal website of these ten fast fashion businesses and its verification based on external websites emerges a heterogeneity closely mirrored by the indications concerning the achievement of stages of CSR development, i.e., – or 0 lead to CSR 1.0 or CSR 2.0, while + leads towards CSR 3.0 and even CSR 4.0, see Table 3 (in Appendix A).

This is then further analysed through comparison with the synthetic Fashion Transparency Index reflecting 246 indicators covering a wide range of social and environmental topics and based upon their public disclosures, as in Table 4.

Table 4 indicates a high rate of confirmation and consistency, while the data and assessment regarding only one fast fashion business reveals a discrepancy. However, a deeper study of the presented data explains, at least partially, the underlying issue. The company in question is very active in announcing information about its various CSR and CSV campaigns and these endeavours are closely watched by the public-at-large, which realizes that the set targets and goals are not fully met.

	CSV assessment RESPECT/No WASTE	Fashion Transparency Index	Comments
1.	+/++	61-70%	Confirmed positive
2.	-/-	0-10%	Confirmed negative
3.	0 /+	41-50%	Confirmed neutral
4.	--/--	61-70%	Discrepancies
5.	++/+++	41-50%	Confirmed positive
6.	+/0	21-30%	Confirmed negative
7.	0/0	41-50%	Confirmed neutral
8.	-/+	31-40%	Confirmed neutral
9.	---/---	0-10%	Confirmed negative
10.	0/0	31-40%	Confirmed neutral

Table 4. CSV by 10 fast fashion businesses – Internal and External data on respect + no waste. Source: Prepared by the authors based on the websites of the selected fast fashion businesses and external websites addressing CSV and https://www.fashionrevolution.org/about/transparency/

Regarding the rest of the fast fashion businesses, the results are consistent. They support the criteria of respect, no waste and transparency. At the same time, they reveal positive and negative aspects related to given companies. One business with a positive rating emphasizes circularity, recycling, and local engagement, while another does not provide full official records for every step of the production process and some of its claimed goals are not fully realized, but when it issues a report, this is detailed and corresponds to reality. At the other end of the spectrum, there are considerable shortcomings regarding CSR and CSV in a number of businesses who report very little about their CSR/CSV and this is subsequently often disconfirmed. Indeed, one business vigorously asserts the circularity, recycling, and respect to people, etc., but 96% of their sustainability claims have been classified as false or misleading.

7. Conclusions

Sustainability is virtue/values-based and requires a systemic transformation and a multidisciplinary connection of ideas, theories and methods while demanding the engagement of both individual and collective responsibility (Fitzpatrick, 2023).

Based on the research conducted through secondary sources and the analysis of the websites, involving stages of CSR development and Fashion Transparency Index of ten well known fast fashion businesses in the EU, there emerges a nuanced answer to the research question whether fast fashion businesses in the EU go for sustainable and responsible creation of shared values, with some key outcomes.

The selection of fundamental virtues for sustainability based on CSR justifications and pathways to CSV, in particular respect and no waste, together with transparency, and their consideration through website declaration by fast fashion businesses and website information from other subjects via a Manual Delphi assessment is consistent with and leads to similar propositions as in the Fashion Transparency Index. This confirmation, which is further boosted by similar field observations, suggests the methodological appropriateness and a sufficient scientific robustness of the design of the study, including the reference to the mentioned fundamental virtues identified.

The study reveals that every fast fashion business engages in declarations about its sustainability and value orientation with digital e-publication of these declarations on their own websites. These declarations use different tenors, target various aspects of sustainability, and propose various priorities regarding virtues and values. Their juxtaposition with information provided by the websites of other subjects often reveals serious inconsistencies and even discrepancies. This heterogeneity matches with the achievement of different stages of CSR development by fast fashion businesses in the EU.

Both existing scientific literature and our study suggest that the public is open to accept various virtues and values preferences and sustainability strategies and does not have a bias per se. However, once the choice is made by the fast fashion business, typically by posting of declarations on its own website, then the public does not hesitate to verify and double-check their reliability. Thus, the issue is not so much about which sustainability aspects and which values are endorsed, but whether this endorsement is genuine. The public is not actively involved in establishing values, but it is increasingly active in monitoring their enforcement and does not readily accept any lies or excuses. Once a fast fashion business proclaims a value, it is expected that it will keep its word. The question is fundamentally one of the culture and preferences of each fast fashion business and the demand and pressure created by its stakeholders. It is about the need to find carefully balanced, pragmatic, well-communicated and consistent choices for sustainability and shared value orientation, based on respect, no waste and transparency. In order to monitor this and contribute to *Nature*'s call for more

research input, we believe that future studies could develop further our research methodology and expand the portfolio of exploration tools and sources, as well as the number of businesses, industries and jurisdictions involved.

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Original Paper

Sustainable performance of bottled water firms in Ethiopia:

The role of green supply chain management

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Keywords: green supply chain management (GSCM); sustainable performance; environmental sustainability; economic performance; bottled water manufacturing; Ethiopia.

Abstract. *Due to growing awareness of the negative environmental effects associated with the bottled water industry, there is increased pressure from customers, the government, and stakeholders for firms to adopt green supply chain management (GSCM) practices. These practices aim to minimize environmental consequences while enhancing social and economic*

performance. However, GSCM and sustainable development are still in their early stages of practice, particularly in Ethiopia where research investigations are limited. This study examines the impact of GSCM practices on environmental, economic, and social performance in the bottled water manufacturing industry in Ethiopia. A survey of 323 managers reveals that GSCM practices have a positive impact on all three dimensions of sustainability performance: environmental, social, and economic. However, the specific impact of each practice varies. All five GSCM practices improve the environmental performance of firms. Some practices also improve other dimensions of sustainability performance. For example, internal environmental management and cooperation with customers significantly improve social performance, but not economic performance. On the other hand, investment recovery improves economic performance. However, eco-design and green purchasing do not have a significant impact on economic or social performance. The findings of this study have theoretical implications and practical insights regarding sustainable performance for managers.

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1. Introduction

The food and beverage industry in Ethiopia plays a significant role in the country's economy, contributing 20.7% to overall manufactured exports, surpassing well-established industries like apparel, leather, and footwear (UNIDO, 2020). The bottled water market is the fastest growing and most dynamic sector within the food and beverage industry. However, despite its growth and contribution to the economy, it is also major source of environmental pollution and deterioration (Ensermu, 2014). To address this issue while achieving economic goals, it is increasingly important to implement environmentally friendly operations (Ghosh et al., 2022a), such as green supply chain management (GSCM), which integrates environmental considerations into supply chain management practices (Assumpçao et al., 2022). In recent decades, GSCM practices have become a top priority for business organizations due to regulatory pressure, market-based pressure, and stakeholder' requirements to address environmental, social, and economic concerns (Huang & Huang, 2021). Numerous studies have investigated the potential outcomes of GSCM practices

and found that they positively affect firms' environmental performance (García Alcaraz et al., 2022; Pinto, 2020), economic performance (Akhtar, 2019; Cousins et al., 2019; Pinto, 2020), and social performance (Han & Huo, 2020; Le, 2020). However, some studies have failed to establish a significant relationship between GSCM practices and firms' economic performance (Abdul-Rashid et al., 2017; Laari et al., 2017; Petljak et al., 2018), leading to inconclusive results. Further research is needed (Nguyen & Adomako, 2021) to determine the conditions under which the relationship can be significant.

The unique environmental challenges faced by the bottled water industry, involving pollution and deterioration, highlight the pressing need for the implementation of sustainable practices. Bottled water firms in Ethiopia face an increasing demand for compliance with GSCM practices from customers, the government, and other stakeholders to prevent environmental impacts and improve social and economic performance. This study contributes to the literature in several ways. First, it provides empirical insights into GSCM practices in developing countries, where they are still not mature. Second, it integrates resource-based views and a triple bottom-line perspective to fill a gap in the research on GSCM in Ethiopia. Third, it examines the relationship between GSCM practices and integrated sustainable performance, including environmental, economic, and social dimensions. The rest of the paper is structured as follows. Section 2 presents the theoretical background and conceptual framework, defining the relationship between GSCM practices and sustainable performance of the firm. Section 3 outlines the research methodology used and section 4 presents the empirical approach used to validate the model and the main results. The final section discusses the key findings and conclusions.

2. Literature review

2.1 Theoretical background

Several theories have been used to study GSCM practices and their relationship to performance, including the resource-based view (RBV) theory, transaction-cost theory, institutional theory, and stakeholder theory (Liu et al., 2018; Touboulic & Walker, 2015). However, as the main aim of this study is to investigate the sustainability performance outcomes of GSCM practices, only the resource-based view (RBV) theory and Triple Bottom Line (TBL) perspective were considered as its theoretical underpinnings. The RBV theory was preferred to explain how firm GSCM practices affect sustainable performance, as opposed to stakeholder theory and institutional theory, which have been widely used to

investigate the motivations and drivers for the adoption of GSCM practices. The TBL approach was used to understand how firms integrate sustainability practices into the entire supply chain, from sourcing raw materials to product disposal, to achieve economic, environmental, and social performance.

The RBV theory suggests that developing and leveraging unique internal resources and capabilities such as GSCM practices, environmental management systems, and green technologies allows a company to achieve a sustainable competitive advantage (Barney, 1991). For this advantage to be sustained, a firm's resources must be valuable, rare, inimitable, and non-substitutable (VRIN) (Barney et al., 2021). For instance, competitors find it difficult to replicate the positive public image a company has built via the proper implementation of GSCM practices (Cankaya & Sezen, 2019). Furthermore, the environmental and economic performance of a company has also been shown to be significantly related to its internal green practices (Raza et al., 2021). Therefore, the RBV is useful for understanding how GSCM practices contribute to firm's sustainable performance.

Although not a theory per se, another relevant concept is the Triple Bottom Line (TBL), which focuses on the need for firms to consider not only economic viability but also environmental and social dimensions when making supply chain decisions such as GSCM practices (Longoni & Cagliano, 2018; Yee et al., 2021). While a staggering number of studies have been conducted to evaluate the performance of sustainable supply chains using the TBL approach (Lopes de Sousa Jabbour et al., 2017), the major emphasis has been on individual TBL dimensions rather than all three integrated TBL dimensions (Touboulic & Walker, 2015; Tseng et al., 2019). Therefore, based on the Triple Bottom Line (TBL) concept, this study argues that the implementation of GSCM practices can be considered to achieve TBL (environmental, economic, and social). For example, GSCM practices that contribute to reducing waste are thought to result in improvements in the environmental bottom line, while GSCM practices that improve working conditions and the welfare of the surrounding community are thought to result in social performance (Saeed & Kersten, 2019; Yee et al., 2021). In general, this study argues that the availability of unique resources and capabilities, as well as the commitment to successfully execute them, are considered crucial to improving the sustainable performance of firms. Additionally, the demand of the firm to maintain a competitive advantage and align their green supply chain practices accordingly would significantly affect their sustainable supply chain performance.

2.2 Conceptual framework and hypothesis development

This study integrates the five most commonly used GSCM practices based on RBV theory and sustainable performance based on the TBL concept to build a comprehensive holistic model in an attempt to address the gap in previous studies. Building on previous studies, Figure 1 shows the conceptual framework of the study, where the arrows moving from the five GSCM practices to each sustainable performance dimension indicate the five specific hypotheses related to each performance outcome.

2.2.1 Green supply chain management (GSCM) practices and firms' environmental performance

GSCM practices have been shown to improve environmental performance (Ma et al., 2022; Vijayvargy & Sahoo, 2021). For instance, Petljak et al. (2018) stated that green purchasing and cooperation with customers are components of GSCM practices that are thought to improve environmental sustainability. Additionally, Micheli et al. (2020) and Pinto (2020) found that companies that cooperate with customers to implement GSCM practices tend to have improved environmental performance, while Cankaya & Sezen (2019) and Younis et al. (2019) argued that investment recovery practices can help companies improve environmental sustainability. Furthermore, eco-design and internal environmental management practices significantly influence the environmental performance of a firm (Namagembe et al., 2019). The available study evidence shows that GSCM practices help companies minimize their environmental impact and perform better in terms of environmental performance. However, it is important to note that the relationship between GSCM practices and environmental impact is not always direct and can be influenced by several contextual factors (Zhu et al., 2008). Therefore, we hypothesized,

H_{1a}: Internal environmental management has a significant positive effect on firm environmental performance.

H_{1b}: Eco-design has a significant positive effect on firm environmental performance.

H_{1c}: Green purchasing has a significant positive effect on firm environmental performance.

H_{1d}: Cooperation with customers has a significant positive effect on firm environmental performance.

H_{1e}: Investment recovery has a significant positive effect on firm environmental performance.

2.2.2 Green supply chain management (GSCM) practices and firms' economic performance

Green supply chain management (GSCM) practices have been linked to improved economic performance for firms (Huang & Huang, 2021)—,reducing costs (e.g., energy, waste, and material inputs), enhancing brand recognition, and increasing market share (Sarwar et al., 2021). For example, green purchasing can help firms save money on energy and waste disposal costs (Taghavi et al., 2021). A study by Ma et al. (2022) also indicates that implementing GSCM practices can improve the environmental and financial performance of pesticide firms in Pakistan and recommends further studies in other countries and sectors to increase the generalizability of the findings. However, some GSCM practices can have a negative effect on economic performance in the short term, such as increased production costs (Cousins et al., 2019). Despite inconclusive findings (Fang & Zhang, 2018), most empirical studies show that effective GSCM practices are imperative for a firm's economic sustainability. Hence, this study aims to evaluate this relationship in different settings—a developing country and an industry with high economic and environmental impact—the bottled water manufacturing industry—to obtain an improved understanding. Therefore, we formulate the following hypotheses:

H_{2a}: Internal environmental management has a significant positive effect on firm economic performance.

H_{2b}: Eco-design has a significant positive effect on firm economic performance.

H_{2c}: Green purchasing has a significant positive effect on firm economic performance.

H_{2d}: Cooperation with customers has a significant positive effect on firm economic performance.

H_{2e}: Investment recovery has a significant positive effect on firm economic performance.

2.2.3 Green supply chain management (GSCM) practices and firm social performance

The concept of social performance pertains to the evaluation of the effects that firm practices have on its customers, employees, and the community at large (Cankaya & Sezen, 2019; Sarwar et al., 2021). Firms with high social performance has the potential to enhance healthcare facilities, employment opportunities, and business opportunities within local communities (Das, 2018). Scholarly literature

indicates that GSCM practices have a positive influence on social performance. For instance, Micheli et al. (2020) found that firms that embraced GSCM practices exhibits improved working conditions, increased wages, and reduced environmental impacts. Awan (2019) also suggests that organisations that effectively adopt GSCM practices have lower staff turnover, increased employee satisfaction, and improved customer satisfaction. Although there is a wealth of research on the relationship between GSCM practices and environmental, economic, and operational performance, few studies have explicitly examined the social dimension of sustainable performance (Baah et al., 2021; Jia et al., 2020; Micheli et al., 2020). Hence, this research posits that an in-depth examination of the influence of GSCM practices necessitates consideration of all three aspects of sustainable performance. Accordingly, the following hypotheses are developed:

H_{3a}: Internal environmental management has a significant positive effect on firm social performance.

H_{3b}: Eco-design has a significant positive effect on firm social performance.

H_{3c}: Green purchasing has a significant positive effect on firm social performance.

H_{3d}: Cooperation with customers has a significant positive effect on firm social performance.

H_{3e}: Investment recovery has a significant positive effect on firm social performance.

3. Material and methods

3.1 Target population and sampling procedure

This study targeted a population of 134 bottled water factories in Ethiopia. The bottled water manufacturing industry in Ethiopia was selected as the focus of this study due to its significant growth and contribution to the country's economy, as well as the environmental challenges it faces. While the specific industry choice may limit the generalizability of the findings, we believe that the adoption of green supply chain management (GSCM) practices and their impact on sustainable performance are relevant topics that can provide insights for other industries and countries. To ensure a representative sample, 99 firms were selected using a non-probability purposive sampling technique. Individual respondents from each company were selected from various relevant

departments, such as operations, purchasing, plant management, quality control, supply chain, and logistics. For the structural equation model (SEM) analysis, a sample size of 177 respondent was suggested. This was based on a 0.3 effect size, a 0.05 probability, a 0.8 statistical power level, eight latent variables, and 32 observed variables (Soper, 2022). However, to minimize bias and subjectivity when assessing multiple interrelated green supply chain management (GSCM) practices and their outcomes, the study aimed to gather responses from five respondents per bottled water manufacturing firm. Consequently, 495 questionnaires were distributed to managers across the participating companies. Through consistent follow-up efforts, 323 complete and usable responses were collected, resulting in a response rate of 65%.

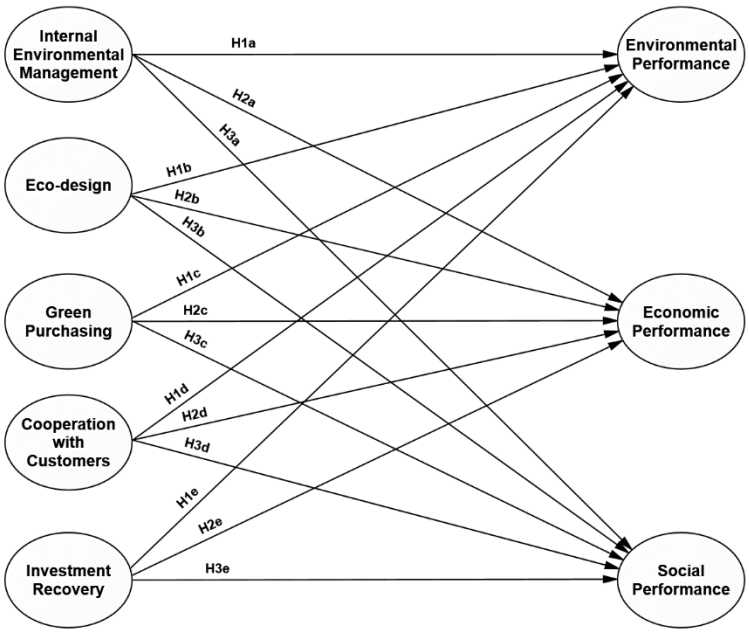

Figure 1. Conceptual framework and hypotheses

3.2 Measurement scale

The firm's GSCM practices were measured using a set of twenty-one items adapted from Zhu et al. (2008), to ensure consistency with established measurement scales widely accepted and used in the literature. Similarly, environmental and economic performance was adapted from Zhu et al. (2008), and social performance was measured using five items adapted from Paulraj (2011). The adaptation process involved careful consideration of the original items and making minor adjustments to the wording or context of some items to ensure their appropriateness for Ethiopian bottled water manufacturing industry context. All constructs were measured using at least three items on a five-point Likert scale (1 = not at all, 2 = to a small extent, 3 = to a moderate extent, 4 = to a great extent, and 5 = to a very great extent).

3.3 Questionnaire validation tests and quality checks

An initial questionnaire draft was refined through pre-testing with academics and practitioners in supply chain management, ensuring accuracy, content validity, and alignment with the study context. A pilot test with 50 potential respondents further improved the questionnaire by aligning it with the specific context of the study. KMO and Bartlett's test confirmed the suitability of the data for factor analysis. Exploratory factor analysis (EFA) identified a clear underlying structure, revealing eight latent factors accounting for 62.12% of the total variance. Five items were excluded due to low factor loadings or cross-loadings. All eight latent constructs demonstrated good reliability, with Cronbach's alpha coefficients ranging from 0.777 to 0.962. Our results further suggest that common method bias is unlikely to have significantly influenced our findings. Overall, the results of the validation tests and quality checks (see Appendix A for detailed technical information) support the sound psychometric properties of the research instrument.

4. Data Analysis

The study used structural equation modelling (SEM) to simultaneously test and estimate statistical relationships among multiple latent constructs as well as the hypotheses put forth in the model (Dash & Paul, 2021; Sarstedt et al., 2022). This study used covariance-based structural equation modelling (CB-SEM), which is more appropriate for theory testing and confirmation of latent construct relationships (Hair Jr. et al., 2017), more robust to SEM assumption violations

(Kline, 2016), and more widely used in studies of GSCM practices (Dash & Paul, 2021). Data analysis was performed using SPSS version 26 and AMOS 24.

4.1 Measurement Model

Confirmatory factor analysis confirmed the well-defined structure of our measurement model, revealing distinct and reliable constructs. For each construct, strong internal consistency (CR and MaxR (H) > 0.7) and convergent validity (AVE > 0.5) were confirmed (see Table 2 of Appendix B for full results). Furthermore, discriminant validity tests ensured the constructs were distinct, with all HTMT values falling below the 0.85 cut-off (refer to Table 3 in Appendix B). The model had a great fit to the data, and it went beyond the recommended criteria for several fit indices (see Table 4 in Appendix B for details). This robust and well-fitting measurement model lays a strong foundation for the exploration of our research hypotheses using the structural equation model.

4.2 Structural model

We used structural equation model (SEM) analyses to find out how statistically significant the links were between GSCM practices, environmental management, economic performance, and social performance. The significance level accepted for this study was set at $p < 0.05$, indicating statistical significance. The results of our analysis, as shown in Table 5 and Figure 2, indicate a significant impact that all five GSCM practices have on environmental performance. Additionally, these practices also have an impact on at least one other performance dimensions like economic or social performance. We found that internal environmental management has an influence on both environmental performance (β =.230 p =.001) and social performance (β =.150 p =.019), supporting hypotheses H_{1a} and H_{3a}. However, it did not have an impact on economic performance (β =.004, p =.950), which refutes hypothesis H_{2a}. Furthermore, our findings reveal that companies' cooperation with customers significantly improve both environmental performance (β =.138, p =.034) and social performance (β =.161, p =.012), providing support for hypotheses H_{1d} and H_{3d}. However, we did not find a significant relationship between companies' cooperation with customers and economic performance; thus, hypothesis H_{2d} was not supported.

The findings of the study indicate that investment recovery had an influence on both environmental performance (β =.169, p =.012) and economic performance (β =.199, p =.005). However, there was no impact observed on social performance (β =.017, p =.794). As a result, these outcomes support hypotheses H_{1e} and H_{2e} while contradicting H_{3e}. Moreover, eco-design and green purchasing

also had significant positive impacts on environmental performance (β =.139, p =.031, and β =.138, p =.020, respectively), but no significant impact on economic (β =.059, p =.366, and β =.058, p =.336, respectively), or social performance (β =-.073, p =.239, and β =.020, p =.725, respectively). Therefore, hypotheses H_{1b} and H_{1c} are supported, while hypotheses H_{2b}, H_{2c}, H_{3b}, and H_{3c} are not supported.

Hypothesized Relationship			Estimate	S.E.	C.R.	P-values
H1c	***Environmental performance***	***<--- Green purchasing***	***.138***	***.044***	***2.319***	***.020***
H2c	Economic performance	<--- Green purchasing	.058	.040	.962	.336
H3c	Social performance	<--- Green purchasing	.020	.043	.352	.725
H1a	***Environmental performance***	***<--- Internal environmental mgmt.***	***.230***	***.048***	***3.388***	***
H2a	Economic performance	<--- Internal environmental mgmt.	-.004	.042	-.063	.950
H3a	***Social performance***	***<--- Internal environmental mgmt.***	***.150***	***.047***	***2.354***	***.019***
H1d	***Environmental performance***	***<--- Cooperation with customers***	***.138***	***.070***	***2.115***	***.034***
H2d	Economic performance	<--- Cooperation with customers	.048	.064	.733	.464
H3d	***Social performance***	***<--- Cooperation with customers***	***.161***	***.070***	***2.522***	***.012***
H1e	***Environmental performance***	***<--- Investment recovery***	***.169***	***.059***	***2.511***	***.012***
H2e	***Economic performance***	***<--- Investment recovery***	***.199***	***.056***	***2.820***	***.005***
H3e	Social performance	<--- Investment recovery	.017	.058	.261	.794
H3b	Social performance	<--- Eco-design	-.073	.062	-1.179	.239
H2b	Economic performance	<--- Eco-design	.059	.058	.904	.366
H1b	***Environmental performance***	***<--- Eco-design***	***.139***	***.063***	***2.151***	***.031***

Table 5. Path estimates for structural model

5 Discussion and Conclusions

This study sheds light on the relationship between GSCM practices and sustainable performance in the context of bottled water manufacturing companies in Ethiopia. The findings indicate that all five GSCM practices have a significant positive effect on environmental performance, which corroborates previous research (Sahoo & Vijayvargy, 2020; Samad et al., 2021; Sarwar et al., 2021). This result supports the theory of Resource-Based View (RBV) which suggests that firms can improve their environmental performance by leveraging their unique internal resources and capabilities related to environmental sustainability. However, except investment recovery practices, none of the GSCM practices have a significant effect on economic performance. This result is inconsistent with some previous studies suggesting that GSCM practices lead to better economic performance (Ahmad et al., 2022; Altaf et al., 2020; Rehman Khan & Yu, 2021). However, a few other researchers have also found a mixed

or non-relationship between GSCM practices and economic performance (Agyabeng-Mensah et al., 2020; Fang & Zhang, 2018; Pinto, 2020; Saeed & Kersten, 2019). These results contradict the RBV theory, which posits that firms' internal unique resources sustain performance (Hart, 1995). The findings of this study indicate that some GSCM practices do not directly determine economic performance (Sahoo and Vijayvargy, 2020). Possible reasons for the inconsistent results may be attributed to different contextual factors, such as the size of the company, market conditions, the regulatory environment, and the characteristics of the industry in which the company operates. For example, according to Saeed & Kersten (2019), the impact of GSCM practices on economic performance varies based on the development level of the country in which the firm operates and the size of the firm, with stronger impact for firms in developed countries and larger firms than for firms in developing countries and smaller firms.

The SEM analysis also showed that only two GSCM practices - cooperation with customers and internal environmental management - have a positive effect on social performance. This corroborates previous research that found GSCM practices can lead to better social performance (Abdullah et al., 2020; Cankaya & Sezen, 2019; Geng et al., 2017). These findings illustrate the potential of GSCM practices to improve customer satisfaction, invest in social projects, enhance relations with community stakeholders, provide employee training and education, and improve employee health and safety. The present study provides additional insights into the positive effects of investment recovery practices on environmental and economic performance. This finding is consistent with prior research (Cankaya & Sezen, 2019; Fang & Zhang, 2018). The findings indicate that investments targeted towards enhancing the environment have the potential to generate economic benefits, hence supporting the case for adopting green practices in business supply chains. Nevertheless, it is important to note that the lack of a significant influence on social performance stands in contrast to findings from prior research (Abdullah et al., 2020; Younis et al., 2016). Further investigation is warranted to explore the complex relationship between investment recovery and social performance.

The implementation of eco-design and green purchasing practices has no significant impact on economic or social performance, which is inconsistent with previous research (Abdullah et al., 2020; Ahmad et al., 2022). Eco-design and green purchasing practices, which often require cooperation and coordination among suppliers and partners in the supply chain may not directly translate into economic and social performance if suppliers are difficult to identify, engage with, or manage. In conclusion, in response to (Liu et al., 2020), who called for

more real-world research on GSCM in developing economies, this study uses all three parts of the triple bottom line framework to measure its effectiveness, similar to Jia et al. (2020), Lis et al. (2020), and Panigrahi et al. (2019). Similar to previous studies, our results indicate that most of the GSCM practices examined had a positive impact on environmental performance (Assumpção et al., 2023; G. Das et al., 2023; Holling & Backhaus, 2023), but their effects on economic and social performance were modest (Das et al., 2023; Vanalle et al., 2017). This suggests that companies in the bottled water manufacturing industry in Ethiopia should adopt a comprehensive approach to sustainability, considering various GSCM practices and their potential impacts on different performance dimensions. It is also essential to consider the specific context and challenges faced by the industry in implementing GSCM practices.

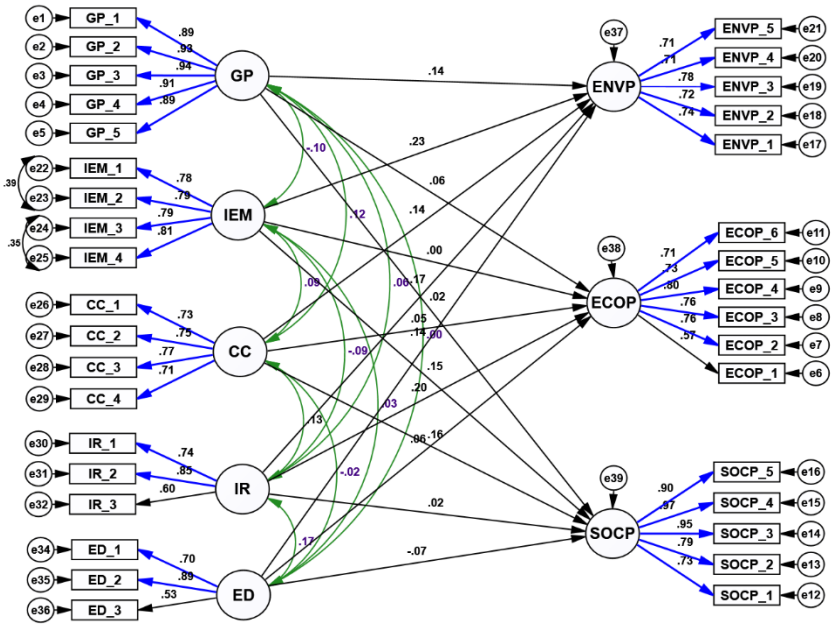

Figure 2. Structural model

5.1 Theoretical implications

The current study makes a significant contribution to the existing literature on GSCM practices and sustainable performance by providing empirical evidence in the context of bottled water manufacturing companies in Ethiopia. First, our study partly supports RBV by showing a link between GSCM practices and competitive advantage through environmental performance. However, the modest effects seen on economic and social dimensions suggest that GSCM's contribution to sustainability might depend on various contextual factors and need specific practices designed to deal with local problems (Nureen et al., 2022). Second, it advances our understanding of how specific GSCM practices can result in a range of positive outcomes, with varying degrees of impact across different performance dimensions. This suggests that for manufacturing organizations, GSCM is a potentially strategic tool for enhancing environmental, economic, and social performance (Awan et al., 2022), although further research is needed to determine the optimal configurations and contexts for its maximum effectiveness. Third, the research findings highlight the importance of considering the specific context in which GSCM practices are implemented and the types of GSCM practices used. This aligns with existing research indicating that factors like industry characteristics, governmental regulations, and consumer demand can influence the efficacy of GSCM practices (Zhu et al., 2008). This suggests that firms need to strategically select and adapt their GSCM practices to their specific circumstances.

5.2 Practical implications

Our findings offer important practical insights for managers of bottled water manufacturing companies in Ethiopia and other similar industries that are considering implementing GSCM practices. First, the practical implications of our study should be considered in light of the modest effects observed in our results, particularly in relation to economic and social performance. Hence, managers can leverage GSCM for its environmental benefits while integrating it with business strategy for its longer-term economic and social performance. Second, firms should implement a holistic GSCM approach that encompasses the whole supply chain, from sourcing raw materials to product disposal, to optimize the benefits of GSCM practices (Ghosh et al., 2022b; Raman et al., 2023; Zhaolei et al., 2023). Using this approach can help businesses become more profitable, enhance their reputation, and lessen their environmental impact. Third, firms should measure and track the implementation of GSCM practices to identify areas for improvement and assess

progress made (Assumpcao et al., 2023; Nureen et al., 2023). By doing so, firms can identify areas where they can reduce their environmental footprint and improve their sustainability performance. Furthermore, by investing in environmental training and education, firms can enhance their employees' understanding of GSCM practices and their importance in achieving environmental, economic, and social performance goals (Nureen et al., 2023; Murad & Zou, 2023).

5.3 Limitations and future research directions

Despite its contributions, this study has several limitations that should be considered. First, we focused solely on the bottled water industry in Ethiopia and relied on self-reported data that may limit the generalizability of our findings to other sectors or countries. Future research should explore other industries and countries, use objective measures or multiple data sources, and employ qualitative methods to enhance the robustness and depth of the findings. Second, this study was cross-sectional, which limits its ability to establish causal relationships between GSCM practices and sustainable performance. Longitudinal or experimental studies could provide further insights into this relationship. Third, future studies should explore additional factors and mechanisms through which GSCM practices influence sustainable performance and explore additional factors that may mediate or moderate these relationships. Fourth, the economic and social impacts of GSCM, beyond environmental benefits, may depend heavily on industry, firm specifics, and context. More research is needed to unlock the mechanisms for optimizing economic and social performance across diverse organizational contexts.

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Original Paper

Investigating wildlife crop pests and farmers' willingness to pay for pest management in the Batang Toru Forest, Indonesia

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Keywords: farmers' strategies; farmers' willingness to pay; pest regulation; sustainable agriculture; wildlife pests.

Abstract. *Effective pest regulation is crucial for sustainable agriculture and livelihoods in agricultural landscapes. This study aims to understand the challenges faced by farmers, the strategies they employ, and their willingness to contribute to managing pest-related issues in the Batang Toru region. A*

quantitative research design was employed, and data were collected through face-to-face interviews with 125 randomly selected respondents from five villages between 2020 and 2022. Descriptive statistical analysis was used to analyze the survey data, and farmers' willingness to pay (WTP) was assessed using a choice experiment method. The findings reveal the diverse range of challenges and strategies associated with pest regulation in various crops, including peanut, paddy, durian, banana, and bitter bean farming. Wildlife pests such as wild boars, non-human primates, and birds were identified as significant contributors to crop damages and losses. Farmers employed physical barriers, scare tactics, repellents and deterrents, traps, and lethal means to mitigate these challenges. Most farmers expressed their readiness to contribute financially, with a preference for in-kind rewards such as paddy and benzoin over cash payments. The findings highlight the complex and context-specific nature of pest management strategies, emphasizing the importance of understanding local ecological dynamics and cultural factors when designing interventions.

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1. Introduction

The sustainable livelihood of farmers and rural communities is greatly influenced by the sustainability of forests due to the valuable ecosystem services they offer. These services encompass a wide range of benefits, from the provision of resources to cultural services (Lele et al., 2013; Sandifer et al., 2015; Velasco-Muñoz et al., 2022), all of which contribute to the overall well-being of these communities and farmers. While there is a growing recognition of the significance of ecosystem services, previous studies have frequently overlooked the assessment and perspective of rural communities regarding the entire spectrum of these services. Instead, emphasis has been placed on regulatory services, with carbon sequestration emerging as the most highly valued among them (Acharya et al., 2019). For instance, the significance of ecosystem services in facilitating agricultural activities has been recognized among farmers in the Batang Toru ecosystem, as highlighted by Harahap et al., (2022) and Harahap & Yonariza (2022). However, certain economically valuable ecosystem services, such as pest control services, have not received sufficient attention and

investigation. Consequently, the assessment of ecosystem services for rural and agricultural economies, particularly with regard to pest control, remains significantly limited. Numerous studies have delved into different aspects of pest regulation and its impact on farmers. In this illustration, Brévault & Clouvel (2019) explores and examines a burgeoning methodology aimed at fostering agroecological pest management. The author emphasizes the essential interconnections among agronomy, ecology, and social sciences, highlighting the need for bridges to facilitate the development of this approach.

In a recent study by Wyckhuys et al. (2023), the complexities of pest management science within farming systems are explored and the need for a nuanced understanding of the multifaceted factors involved. The study emphasizes the importance approaches that consider the intricate interactions between pests, crops, and the farming environment, aiming to enhance pest management effectiveness and promote sustainable farming practices. Furthermore, Lazaridou & Michailidis (2023) conducted a recent study explored the intricate relationship between farmers' perceptions, attitudes, and practices regarding the use of avian species for pest management and the study enhances our understanding of birds' potential role in pest control strategies and emphasizes the significance of incorporating farmers' perspectives into the design of sustainable pest management interventions. However, there is a notable research gap in the field of pest regulation specifically concerning smallholder farmers in agroforestry systems. These farmers face unique challenges as their forests are connected to protected areas for conservation, and they cultivate a diverse range of crops and forest products that are often targeted by wildlife. This includes both protected species like orangutans (Pongo sp.) and non-protected species like wild boars and long-tailed macaques, all of which may be considered as pests by the farmers. Given the scarcity of research in this area, our study aims to delve into the farmers' experiences with pest regulation. We acknowledge that pests can exert a substantial influence on agricultural productivity and sustainability, making effective pest control measures indispensable for farmers in the Batang Toru region. By exploring the firsthand experiences of farmers, we seek to gain insights into the challenges they encounter, the strategies they employ, and their willingness to involve in managing pest-related issues. Building upon the insights garnered from these studies, our research aims to provide a comprehensive understanding of the farmers' experiences with pest regulation in the Batang Toru region. Additionally, our study will explore the willingness to pay of pest regulation and the potential benefits of harnessing ecosystem services for sustainable pest management.

2. Materials and methods

2.1. Study area

Our study focuses on smallholder farmers in the Batang Toru Ecosystem (BTE), encompassing South Tapanuli, Central Tapanuli, and North Tapanuli Regencies (see figure 1). This region's forest serves as a vital resource for the farmers, and it supports a diverse range of wildlife species, including orangutans, tigers, wild boars, and long-tailed macaques.

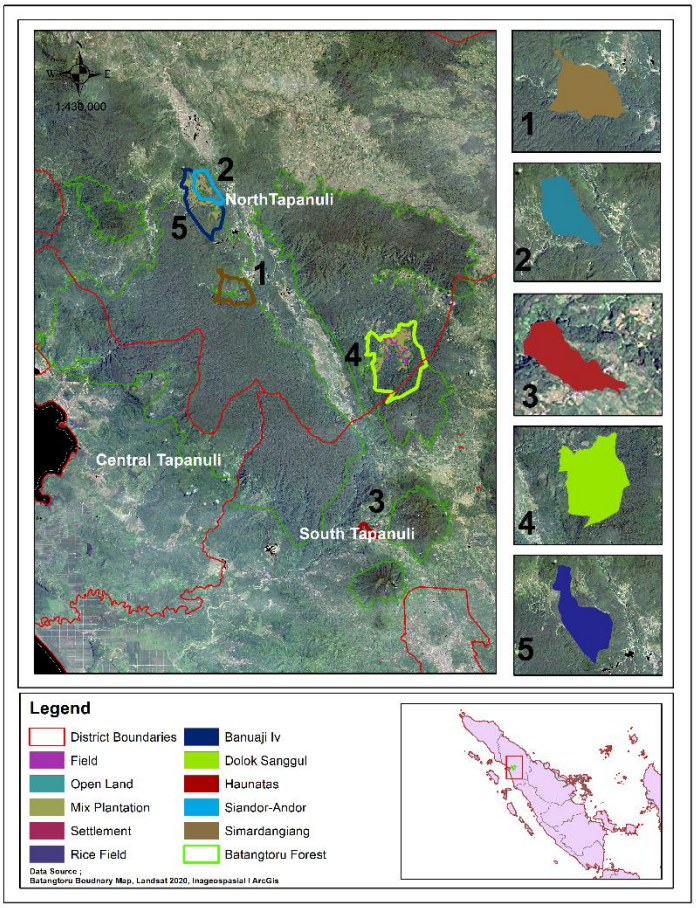

Figure 1. Study Area

The farmers cultivate various crops and forest products such as corn, rice fields, Durian, Petai or bitter bean, and bananas. A purposive sampling technique was utilized to select a representative sample of smallholder farmers for the survey. The study focused on all research village communities benefiting from ecosystem services, totaling approximately 675 household heads across four villages. For the sample selection, we used a formula considering the population of households benefiting from ecosystem services in the Batang Toru forest (675 heads of households). The Slovin Method, with a 95% confidence level and an 8% margin of error, yielded a sample size of 123 respondents, rounded up to 125 agroforestry farmers from 5 villages. The sample size was determined using the Slovin method, selecting farmers based on their agroforestry livelihoods and frequent interactions with wildlife pests in the Batang Toru forest. Interviews were conducted between 2020 and 2022 after obtaining permission from the respondents. Table 1 provides an overview of the sample distribution across districts, villages, and forest blocks.

No	Village	District	Total Household	Total Population
1	Simardangiang	North Tapanuli	188	680
2	Dolok Sanggul	North Tapanuli	140	657
3	Haunatas	South Tapanuli	110	550
4	Siandor-andor	North Tapanuli	130	603
5	Banuaji	North Tapanuli	250	988
Total			675	3478

Table 1. Distribution of samples by district, villages and forest block

Data analysis

A quantitative research design was employed to investigate smallholder farmers' perspectives and experiences regarding pest regulation services, with a focus on the role of wildlife within the Batang Toru forest. A household survey was conducted through face-to-face interviews using a structured questionnaire containing closed-ended questions with multiple-choice options. The interviews were conducted in a respectful and engaging manner, allowing the farmers to express their experiences, perspectives, and strategies in managing pests. The survey data were analyzed using descriptive statistical analysis, including frequencies and percentages. Additionally, farmers' willingness to pay (WTP) was assessed through a choice experiment method, and economic analysis was employed to determine their WTP. Data Analysis Descriptive statistical analysis was employed for the quantitative survey data collected. Frequencies and

percentages were calculated to summarize and analyze the data. Statistical software, such as SPSS and Microsoft Excel, was utilized for data analysis.

3. Results

3.1. Farmers' Profile

In our analysis of the demographic composition of the surveyed group of 125 farmers (refer to table 2), the distribution of age stands out as a significant factor. Notably, 9.6% of these individuals involved in agriculture belong to the 18-30 age group. Conversely, the majority, accounting for 68.8%, falls within the 31-60 age range, indicating a prevalence of middle-aged farmers. Additionally, 21.6% of respondents are aged over 60, emphasizing the presence of experienced and senior members within the farming community. Regarding gender, the agricultural landscape is predominantly male, with 85.6% of respondents identifying as male farmers. In contrast, female farmers constitute a smaller but noteworthy 14.4%, highlighting a distinct gender-based divide in agricultural participation.

Summary of farmer's demographic information		**Total (n=125)**
Age (%)	18-30	9.6
	31-60	68.8
	>60	21.6
Gender (%)	Male	85.6
	Female	14.4
Marriage status (%)	Single	6.4
	Married	85.6
	Widow/ed	8
Religion (%)	Christian	78.4
	Islam	21.6
Education level (%)	No Education	5.6
	Elementary school	33.6
	Junior high school	30.4
	Senior high school	30.4
	University	0
Agriculture training program (%)	Trained	28
	Untrained	72

Table 2. Farmers' demographic information

A thorough examination of marital status reveals a nuanced distribution among these farmers. A minority, constituting 6.4%, are categorized as single, while a significant majority of 85.6% declare themselves as married. Interestingly, 8% are widowed or widowers. In terms of religious affiliations, Christian farmers make up a predominant majority at 78.4%, underscoring the prevalence of Christianity within the surveyed farming community. Simultaneously, Islam represents the religious adherence of 21.6% of the respondents. It is noteworthy that 5.6% have not received any formal education. Furthermore, 33.6% have completed elementary school, indicating a foundational level of education, while 30.4% hold junior high school qualifications, denoting an intermediate level of educational attainment. Another 30.4% have achieved senior high school education, and no farmers reported possessing a university degree. Regarding participation in agricultural training programs, 28% of these farmers have undergone formal training, potentially equipping them with enhanced skills and knowledge. Conversely, 72% have not received such training, suggesting opportunities for capacity-building and skill enhancement in the sector.

3.2. Pest regulation and farmers' strategy

The results of our study reveal nuanced insights into the effects of pest regulation on different crops, focusing on peanuts, paddy, durian, banana, and bitter bean farming (see figure 2). Peanut *(Arachis hypogaea)* farmers in Banuaji reported a decrease in pest regulation, with 32% of farmers experiencing this issue. Similarly, in Siandor-andor, 20% of peanut farmers reported a diminishing of pest regulation. In Simardangiang, 16% of surveyed farmers also experienced a decrease in pest regulation. Notably, the pests most commonly reported by peanut farmers were wild boars *(Sus scrofa domesticus*), non-human primates like long-tailed macaques *(Macaca fascicularis*), and rats (*Rattus argentiventer*). Paddy *(Oryza sativa*) farmers, complaints about diminishing pest regulation were prominent. In Banuaji and Siandor-andor, 68% and 52% of farmers respectively claimed an increase in pests affecting their paddy fields. In Doloksanggul and Simardangiang, the situation was even more severe, with 92% of farmers reporting pest-related problems. Surprisingly, in Haunatas, a staggering 96% of paddy farmers faced challenges related to pest regulation. The pests commonly cited by these farmers included rats, wild boars (*Sus scrofa domesticus*), birds (*Aves sp.*), and rice ear bug *(Leptocorisa oratorius*). Durian *(Durio zibethinus)* farmers in Banuaji and Siandor-andor reported 20% and 28% respectively experiencing an increase in pests targeting their durian crops. In Doloksanggul, this figure rose to 64% of durian farmers, while in Haunatas, 76% faced similar issues. Notably, Simardangiang exhibited the highest percentage, with 84% of durian farmers

complaining about pests, including non-human primates and treeshrew *(Tupaiidae)*. Banana *(Musa sp.)* farmers in Doloksanggul faced significant challenges, with 92% of them reporting a decrease in pest regulation. The pests affecting banana crops in this region included fruit flies *(Nacoleia octasema),* leaf rollers *(Erionota thrax*), and beetles (*Cosmopolites sordidus*), as well as long-tailed macaques. Bitter bean *(Parkia speciosa)* farmers also experienced pest regulation issues although to a lesser extent. In Doloksanggul, approximately 8% of farmers reported this problem, while in Haunatas and Siandor-andor, the figures were around 4%. In Simardangiang, approximately 16% of bitter bean farmers faced challenges related to pests. The pests affecting bitter bean crops include non-human primates, caterpillars, insects, sap-sucking bugs, and ants. These findings highlight the diverse and nuanced nature of pest regulation challenges across different crops around the Batang Toru forest, providing valuable insights for developing targeted pest management strategies and interventions.

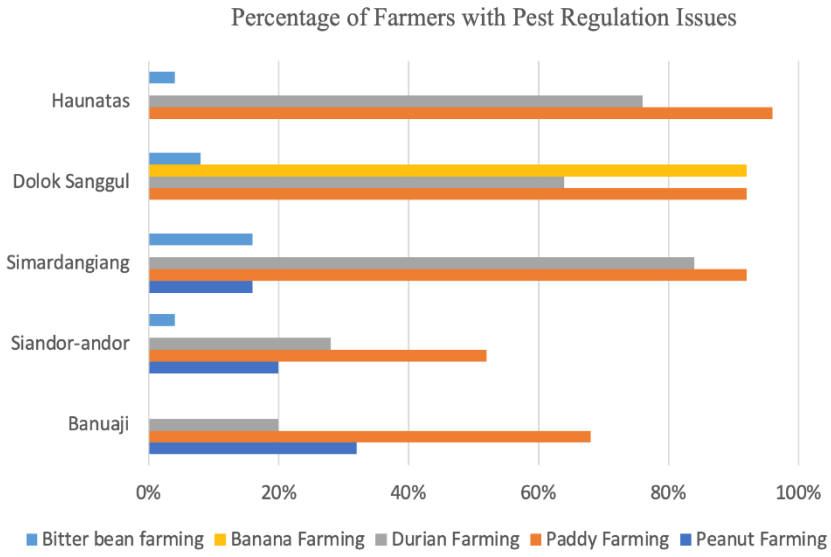

Figure 2. Pest regulation services diminishing for agricultural commodities in study area.

Our study aimed to gain insights into the strategies employed by farmers in addressing specific wildlife pests, namely wild boars, non-human primates, and birds, which were consistently reported as problematic across various agricultural

commodities including paddy, peanut, durian, bitterbean, and banana. We specifically excluded species such as squirrels and caterpillars from our analysis. Our investigation focused on farmers residing in the Batang Toru area and their approaches to managing these wildlife pests. Through our research, we identified several strategies commonly utilized by farmers to tackle wildlife pests (see figure 3). The strategies encompass physical barriers, scare tactics, repellents, and deterrents, as well as traps and scare guns. Farmers in the study area have adopted these diverse methods as part of their pest management practices to mitigate the damage caused by wild boars, non-human primates, and birds.

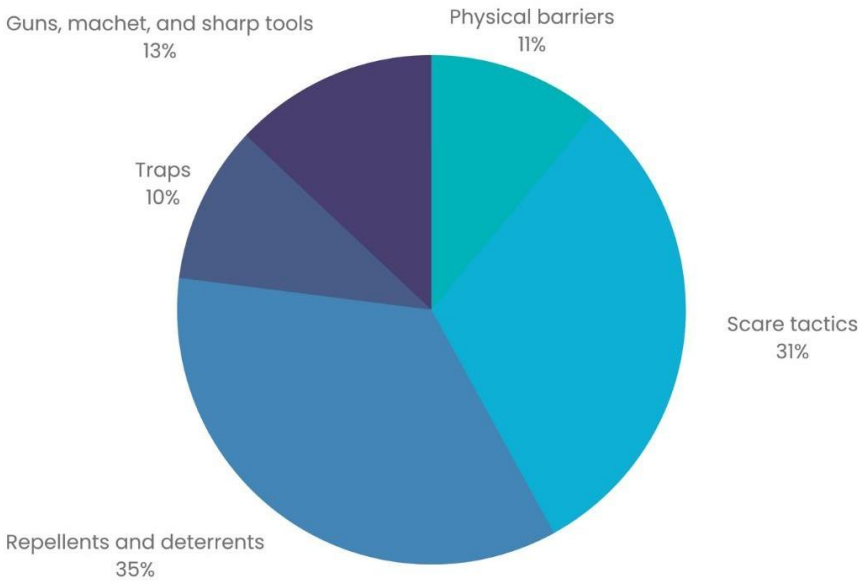

Figure 3. Farmers' strategy to tackle the wildlife pest.

Our study reveals a range of strategies employed by smallholder farmers in addressing wildlife pests within their agricultural practices. Among these strategies, physical barriers, such as the erection of fences around paddy, banana, and peanut fields to prevent access by wild boars, monkeys, and birds, were

commonly observed. However, only a small percentage (11%) of the interviewed farmers reported utilizing physical barriers, suggesting that this approach alone may be insufficient when dealing with wildlife pests. On the other hand, approximately 31% of farmers applied scare tactics as a means to frighten away wildlife pests. These tactics encompassed the creation of loud noises, the use of scarecrows or effigies, and the deployment of reflective materials that produce flashes of light, all intended to deter animals from entering their fields. This approach emerged as a prevalent practice across all studied villages, indicating its widespread use among farmers attempting to expel wildlife pests. A significant portion of farmers (35%) claimed to invest substantial time and effort in repelling and deterring wildlife pests on their own. They described activities such as "mamuro," a local term used to denote the vigilant protection of their crops, particularly paddy fields, from wildlife. This entailed farmers dedicating their time to actively monitor and safeguard their crops, employing their own vocalizations as a means of repelling wildlife. The involvement of children in assisting their parents in the field was also commonly reported across different agricultural commodities in all villages. Among the surveyed farmers, a small percentage (11%) still employed traps to expel wildlife pests, primarily targeting wild boars. This practice was observed in all villages except Dolok Sanggul, where the majority of farmers identified as Muslim. The absence of trap usage among Muslim farmers in Dolok Sanggul suggests that their cultural and dietary preferences may influence their decision not to trap wild boars. Furthermore, approximately 13% of the interviewed farmers claimed to utilize firearms, machetes, and sharp tools such as sticks and stones to repel pest wildlife. They asserted that this strategy was essential for ensuring the safety of their agricultural commodities. These farmers further emphasized that they employed lethal means intentionally, perceiving the wildlife species as a threat to their livelihoods. These findings underscore the diversity of strategies employed by smallholder farmers in addressing the challenges posed by wildlife pests within their agricultural operations.

3.3. Farmers' willingness to pay for pest management

Having gained a comprehensive understanding of the pest issues faced by farmers and their management strategies, our investigation delved into assessing their willingness to pay (WTP) for a pest management program aimed at safeguarding their agricultural commodities from wildlife such as wild boars and non-human primates. The primary objective of our study was to determine the extent to which farmers were willing to financially contribute to the enhancement of pest regulation services (see table 3). To collect data on farmers' WTP, we

conducted personal interviews through household surveys. The results revealed that a substantial proportion of farmers, specifically 82 percent, expressed readiness to pay for an improvement in pest regulation.

Type of payment	Freq.	Biannual WTP	Annual WTP	Transferred to monetary value
Pest regulation (Individual settings).				
Paddy (kg)	32	12	768	IDR 3,840,000
Benzoin (kg)	54	2	216	IDR 25,920,000
Cash (IDR)	16	60,000	IDR 1,920,000	IDR 1,920,000
WTP Median				IDR 148,922
WTP Annually				IDR 297,843
Total WTP Annually				IDR 1,035,898,431

Table 3. Farmers' WTP for pest management

Interestingly, most farmers preferred in-kind rewards, specifically paddy and benzoin, rather than cash payments. These rewards were provided after each harvest, which occurred once every six months. Among the available payment methods, benzoin emerged as the most popular choice among farmers, with 47 percent opting for this in-kind reward. On average, each farmer received a total of 2 kg of benzoin every six months. Paddy was the second most favoured option, chosen by 25 percent of farmers, who received an average of 12 kg of paddy per six-month period. Cash payment was selected by only about 18 percent of farmers, with an average amount of IDR 60,000 disbursed every six months. However, it is noteworthy that 18 percent of respondents cited the belief that pests like the long-tail macaque and wild boar were beyond control as their main reason for being unwilling to pay for pest regulation. Furthermore, farmers had been hearing rumours that the government had relocated these macaques from the forests near Lake Toba to their woodlands, where the species had become more prevalent. To provide an overall estimate of the farmers' WTP for ecosystem regulatory services, we calculated the aggregate value through an individual setting, which amounted to IDR 1,035,898,431 when converting the in-kind rewards to monetary value. This assessment accounts for the preferences expressed by the farmers and underscores their substantial contribution to pest management efforts.

4. Discussion

Our study provides valuable insights into the challenges and strategies associated with pest regulation in different crops, including peanuts, paddy, durian, banana, and bitter bean farming. These findings highlight the diverse and nuanced nature of pest regulation challenges across different crops in the Batang Toru forest region, offering valuable insights for developing targeted pest management strategies and interventions. These results align with previous research that emphasizes the significance of effective pest management practices in ensuring crop productivity and minimizing losses (Wyckhuys et al., 2023). In our study, we focused on addressing specific wildlife pests, namely wild boars, non-human primates, and birds, which were consistently reported as problematic across various agricultural commodities (Linden et al., 2019). This aligns with previous studies that have identified these species as major contributors to crop damages and losses (Harahap et al., 2022; Khattak et al., 2022a; Regmi et al., 2013a, 2013b). The strategies employed by farmers to tackle these wildlife pests included physical barriers, scare tactics, repellents and deterrents, traps, and scare guns. Farmers in the study area have adopted these diverse methods as part of their pest management practices mitigating the damage caused by these pests. While physical barriers, such as fences, were commonly observed among farmers, the low percentage of farmers utilizing this strategy suggests that it may not be sufficient on its own to effectively manage wildlife pests. Scare tactics emerged as a prevalent strategy, with farmers investing significant time and effort in repelling and deterring pests on their own. Our discovery uncovers the intricate practice of "*mamuro*" showcasing the meticulous safeguarding of crops, primarily paddy fields, against wildlife. It underscores the proactive stance adopted by farmers, who diligently employ this traditional method to deter pests. Although time-consuming, this widely practiced technique in the region aligns with our findings, reinforcing the prevalence of traditional practices within agricultural communities (Hussain et al., 2022). Traps were employed by a small percentage of farmers, primarily targeting wild boars, but were absent among Muslim farmers in Dolok Sanggul, likely influenced by cultural and dietary preferences. Additionally, some farmers resorted to using lethal means, such as firearms, machetes, and sharp tools, to repel pest wildlife, perceiving these species as threats to their livelihoods. These findings emphasize the diversity of strategies employed by smallholder farmers in addressing the challenges posed by wildlife pests within their agricultural operations. The strategies identified in our study align with previous research that has highlighted the range of methods used by farmers to mitigate wildlife-related crop damage (Khattak et al., 2022b; Kross et al., 2018; Micaelo et al., 2023). They underscore the complexity and context-

specific nature of pest management strategies, highlighting the importance of understanding local ecological dynamics and cultural factors when designing effective interventions (Hussain et al., 2022).

Understanding farmers' willingness to pay (WTP) for pest management programs is crucial for the development and implementation of sustainable pest regulation services. In our investigation, we assessed farmers' WTP for a pest management program aimed at safeguarding their agricultural commodities from wildlife such as wild boars and non-human primates. Our study found that a substantial proportion of farmers (82 percent) expressed readiness to financially contribute to an improvement in pest regulation. This aligns with previous research that has shown farmers' willingness to invest in pest management to protect their crops (Gitahi et al., 2019). Interestingly, most farmers preferred in-kind rewards, specifically paddy and benzoin, over cash payments. These rewards were provided after each harvest, which occurred once every six months. Benzoin emerged as the most popular choice among farmers for this in-kind reward, followed by paddy. Cash payment was selected by only a small number of farmers. The preference for in-kind rewards can be attributed to several factors. Firstly, it may be influenced by cultural and traditional practices, where agricultural commodities hold intrinsic value beyond monetary compensation. Secondly, in-kind rewards like paddy and benzoin provide tangible benefits directly related to farming activities, serving as inputs for future agricultural production or as valuable products that can be used or traded within local communities. This preference for in-kind rewards aligns with studies that have highlighted the importance of considering non-monetary incentives and local contexts when designing payment schemes for ecosystem services (Bottazzi et al., 2018; Grillos, 2017). It is noteworthy that a small percentage of respondents cited the belief that pests like the long-tailed macaque and wild boar were beyond control as their main reason for being unwilling to pay for pest regulation. This perception could stem from previous experiences or information circulating among farmers, such as rumours about the relocation of macaques from nearby forests to their woodlands, leading to an increase in their prevalence. This highlights the need for effective communication and outreach programs to address farmers' concerns and provide accurate information about pest management strategies and the potential benefits of collective efforts. Our findings on farmers' willingness to pay for pest management indicate that farmers recognize the value of effective pest regulation in safeguarding their agricultural commodities and livelihoods. This aligns with previous studies emphasizing the economic significance of pest management investments in enhancing crop productivity and reducing losses (Kpadé et al., 2017; Lazaridou & Michailidis,

2023; Parry, 2022; Tapsuwan et al., 2020; Wanger et al., 2014). Moreover, it highlights the potential for establishing financial mechanisms, such as payment for ecosystem services or community-based funding schemes, to support and sustain pest management initiatives in the study area. In conclusion, our study provides nuanced insights into the effects of pest regulation on different crops and the strategies employed by farmers to address wildlife pests. The diverse range of strategies, including physical barriers, scare tactics, repellents and deterrents, traps, and lethal means, underscores the complexity of pest management in agricultural landscapes. Furthermore, farmers' readiness to financially contribute to pest management programs, with a preference for in-kind rewards, highlights their active engagement and potential for collaboration in sustaining effective pest regulation services. These findings contribute to the development of targeted pest management strategies and interventions that consider local ecological dynamics, cultural factors, and farmers' perspectives, ultimately fostering sustainable agriculture and biodiversity conservation in the Batang Toru region.

5. Conclusions

Our study examines the intricate challenges and strategies involved in pest regulation across Batang Toru's diverse crops. The nuanced findings form the basis for targeted pest management, emphasizing specific wildlife pests such as wild boars, non-human primates, and birds, recognized contributors to crop damages. Farmers utilize diverse strategies, ranging from physical barriers to lethal means, exposing the complex and context-specific nature of pest management.

We propose practical initiatives, including the initiation of a comprehensive Integrated Pest Management (IPM) training program for farmers. This program emphasizes a holistic approach tailored to address wildlife challenges. Additionally, we recommend community-based outreach to address concerns, dispel misconceptions, and enhance effective pest control. Recognizing cultural influences, we suggest customizing incentive schemes to align with farmers' preferences for in-kind rewards.

Further research should investigate the long-term effectiveness of pest management strategies, considering ecological dynamics and evolving agricultural practices. Crucial research directions include exploring socio-economic impacts on local communities and assessing scalability for neighbouring regions.

Our findings underscore farmers' recognition of the value of effective pest regulation, proposing financial mechanisms like payment for ecosystem services to support sustainable pest management. This study offers insights for developing tailored strategies aligned with local dynamics, culture, and farmers' perspectives, fostering sustainable agriculture and biodiversity conservation in Batang Toru.

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Original Paper

Optimizing environmental education and awareness strategies for sustainable forest management in Kenya.

Lessons from Cherangany, Mt. Kenya, Aberdares, and Kakamega forest ecosystems

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Keywords: Sustainable forest management; conservation; biodiversity; resource management; stakeholder collaboration.

Abstract. *Forests and allied environmental resources are important for environmental and socio-economic development. However, information is scarce on the ways of optimizing the strategies for forestry and environmental education and awareness in many developing countries. Using a literature review and document content analysis, this study explores the case of four forested ecosystems in Kenya with the aim of contributing to a better understanding of the strategies to achieve sustainable forest management. Results show that the key ingredients of effective forestry and environmental education are formal education infrastructure, community engagement panels, digital platforms, corporate responsibility initiatives, media, arts, policy advocacy, and research with feedback loops on initiatives. Kenya is desirous of establishing robust mechanisms for effective environmental education and awareness, as demonstrated by policy and legal actions. Case studies of Cherangany, Mt. Kenya, Aberdares, and Kakamega forest ecosystems demonstrate these commendable efforts by embedding the ingredients of effective strategy optimization within their forest ecosystem management plans. However, there is a need to revise the expired Kakamega, Mt. Kenya, and Aberdare ecosystem management plans and optimize awareness strategies by leveraging the existing educational infrastructure and increasing stakeholder engagement, especially activating the role of county governments and addressing outstanding challenges currently inhibiting sustainable forest management.*

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1. Introduction

Forests are important strategic assets that contribute to sustainable development across the globe (Korosuo et al 2023). They are a source of livelihood for millions of people around the world (Wang & Tian 2023). They provide food, timber,

energy, shelter, and medicine for many local communities (Wang & Tian, 2023; Berlyn, 2023). According to the World Resources Institute, the world had 4.02 billion hectares of tree cover in 2020, which is approximately 30% of the Earth's land. This estimate includes unmanaged and managed natural forests and planted forests (Berlyn 2023). However, with the growing human needs, deforestation and forest degradation are threatening the survival of forests and the species that depend on them (Berlyn 2023). It is, therefore, important to protect and conserve forests to ensure their sustainability and the well-being of the planet.

Environmental education and awareness are increasingly emerging as vital tools for promoting the sustainable management of forests for maximum social and economic benefits (Stefanakis 2022). Environmental education and awareness contribute to an enhanced understanding of the role of forested ecological systems among individuals and stakeholders. Whereas in developed countries, the systems for environmental education and awareness are well-established (Stefanakis, 2022; Breiting & Wickenberg, 2010), many developing countries face challenges in establishing comprehensive environmental education and awareness programs. Forestry awareness initiatives in many developing countries are mainly limited by contextual factors, impacting their effectiveness (Mutia et al., 2023; Hakamada, 2023). In recent times, there have been growing policy initiatives and a tendency to incorporate diverse environmental and awareness strategies in long-term forest ecosystem management plans. These tools are instrumental in achieving a harmonious balance between environmental conservation, economic development, and community well-being (Reid et al. 2019). Limited studies have explored and compared environmental and education awareness strategies in sustainable forest management in developing countries, posing risks like missed opportunities, ineffective community engagement, and inefficient resource allocation.

In Kenya, forests are important for socioeconomic development (Habel et al., 2023; Chepkemoi & Musya, 2023). As such, key forestry policies and programs have been formulated to promote sustainable forest management. Currently, efforts are underway to achieve a 30% national tree cover by 2032, aligning with climate-reliant economic growth goals and Vision 2030. Forestry education and awareness will catalyze positive attitudes toward sustainable forest management (Kinyili 2023). However, following the adoption of forest management plans as the key tools for enhancing sustainability, there is a scarcity of scientific information on comparative studies that relate the forestry education and awareness strategies adopted in forest management plans and their implications for sustainable forest management. This paper seeks to address this challenge by

identifying and comparing the forestry and environmental awareness and education strategies in the case of Cherangany, Aberdare, Kakamega, and Mt. Kenya forest ecosystems and draw the policy implications of the findings on sustainable forest management in Kenya. The Cherangany, Aberdare, Kakamega, and Mt. Kenya forest ecosystems hold vital importance for biodiversity, water regulation, climate resilience, and cultural significance. Conducting studies on their environmental conservation through education and awareness strategies is critical for their sustainability.

In order to achieve the study aims, this paper uses the case study research design with literature review and document content analysis to explore the theoretical and empirical connections between environmental education, awareness, and sustainable forest management. The reviewed global-level lessons were then applied to Kenya's cases in order to derive the policy implications of this study. This study provides crucial information for empowering stakeholders, individuals, and communities, aligns with forest policy goals, and fosters a collective responsibility for the preservation of Kenya's invaluable forest resources.

1.1. Environmental education, awareness, and sustainable forest management: theoretical analysis

Forests and allied natural resources provide ecosystem services needed for human well-being. Despite, employing over 18.12 million and supporting 45.15 million jobs, the sector faces a global call for sustainable management (Yanshu et al., 2019; UN, 2019). Sustainable forest management ensures long-term ecosystem health by balancing conservation, socio-economic needs, and responsible resource use. However, global socio-economic changes, driven by challenges like climate change, pose threats to forest ecosystems by exacerbating biodiversity loss, deforestation, and pollution with effects on human health and the environment.

Interestingly, in the midst of these challenges, environmental education and awareness is fast emerging as a feasible response to these global environmental challenges. Environmental education serves as a crucial tool in natural resource management by enhancing people's comprehension of ecological systems. Ndifon (2015) defines it as a process that transmits environmental awareness to instigate a shift in values and attitudes, promoting sustainable use and proper management of the immediate environment. It empowers individuals to explore environmental issues, participate in problem-solving, and take proactive measures to enhance the environment. According to Smith (2010),

environmental education aims to inform people about how ecosystems function and how humans can manage them sustainably. It addresses environmental issues using methods that promote positive attitudes toward conservation, ensuring the sustainable provision of goods and services from vital resources like forest ecosystems. It can occur formally in classrooms or informally through community-based organizations, participation, mass media campaigns, workshops, and conferences. Understanding the impact of individual actions on the environment, known as environmental awareness, is widely acknowledged as a crucial initial step in addressing environmental issues (Alam, 2023). Therefore, assessing the environmental awareness of individuals becomes essential in tackling environmental challenges and fostering a sustainable society (Alam 2023; Gurbuz et al. 2021), hence the need for this study in the context of Kenya. Bülbül et al. (2020) argue that societies with high environmental awareness find it easier to design and implement policies to counter environmental degradation. Environmental awareness plays a vital role in cultivating an informed society regarding environmental issues, shaping responsible citizens who prioritize environmental care (Mkumbachi et al., 2020; Al Yaqubi, 2020). It is recognized as a significant component in environmental management and the preservation of biodiversity (Hanisch et al., 2014). Research also indicates that cultivating environmental awareness is crucial for fostering environmentally conscious behaviors (Conrad & Hilchey, 2011; Giudici et al., 2019) and has the potential to shape individuals' lifestyles toward greater environmental friendliness (von Borgstede et al., 2013). Fu et al. (2020) emphasize the significant role of environmental awareness in promoting the adoption of pro-environmental behavior.

From the above review, Sustainable forest management and environmental education benefit from technology integration, community engagement, and strong legal frameworks for a holistic approach. Environmental education, both formal and informal, is essential for cultivating positive attitudes and awareness, particularly amidst global challenges like climate change.

1.2. Empirical studies on environmental education and sustainability

Empirical studies have demonstrated the highlighted ingredients of effective environmental awareness and education strategies. Yamada et al. (2023), while analyzing trade-offs between timber and non-timber ecosystem services across three municipalities in Japan, reveal that areas with rich forestry history and high awareness of ecosystem services have lower logging ratios. In regions with external foresters, even forests with abundant services face high logging ratios,

emphasizing the need to enhance local awareness for balanced utilization. The study advocates for local governments' role in educating forest enterprises and providing science-based information for responsible forest management.

In Thailand, a study revealed that an increased duration of schooling is associated with a higher likelihood of actively engaging in knowledge-based, environmentally friendly actions. However, this effect is not observed for cost-saving pro-environmental actions. Moreover, the study indicated that formal education does not significantly influence concerns about global warming or the willingness to pay environmental taxes (Chankrajang & Muttarak, 2017).

The government's fiscal and administrative policy decisions have the potential to impact environmental education. In the U.S., environmental education involves various departments and is shaped by the executive and legislative branches. In India, the Centre for Environmental Education receives government support, highlighting a unique partnership between the Ministry of Environment and a non-governmental organization. Forest sustainability goes beyond government, emphasizing individual responsibility for environmental protection through education and awareness across all age groups, fostering initiative and active participation. The Nigerian government has put forth diverse approaches, including abatement measures, legislation, and policies, to enhance awareness among citizens. Yet, it seems that past strategies focused more on controlling and treating environmental issues rather than preventing them (Thathong, 2012). Effective environmental education is crucial in elevating public knowledge and fostering positive attitudes and behaviors toward the environment. Nigeria and other African nations acknowledge its pivotal role in addressing environmental challenges.

Gavilanes Montoya et al. (2023) conducted a literature review to assess the possibilities for enhancing Information and Communication Technology (ICT) and communication processes within the forestry sector and to gauge their practicality and relevance. The study found the diverse communication flows in forestry, influenced by technologies. Furthermore, ICTs contribute to forest conservation by setting standards and policies, enabling monitoring and analysis at various scales. Across the globe, authorities often use surveys to measure environmental awareness (Ham et al., 2016). Using Google search data for an Environmental Awareness Index (EAI) has advantages over surveys, with lower costs and broader coverage. European studies show a strong correlation between EAI and pro-environmental behaviors, emphasizing the dynamic nature of environmental awareness. Timely measures are crucial for policymakers to assess

policy impact and understand behaviors influenced by environmental initiatives. (Dabbous et al., 2023).

The empirical reviews have emphasized the importance of effective environmental education and awareness to tackle forest management challenges. The importance of comprehensive curricula, community engagement, digital platforms, corporate involvement, media, policy advocacy, interdisciplinary research, and feedback loops have been highlighted. However, gaps exist on the context specific lessons and targeted strategies for effective environmental education and awareness, especially in developing countries and hence the need for this study in Kenya.

1.3. The context for forest management in Kenya

Kenya has a total of 5,226,191.79 ha (52,261 Km^2) of forest cover, which translates to 8.83% of the total land area in the country (Chisika & Yeom 2023). Over the past two decades, Kenya's forest sector has undergone a transformative journey driven by comprehensive governmental reforms. The Forest Act of 2005, later succeeded by the Forest Conservation and Management Act of 2016, marked pivotal milestones in this evolution, coinciding with the promulgation of the Constitution in 2010. A standout initiative was the establishment of the Kenya Forest Service (KFS) as a semiautonomous agency governed by an independent board, resulting in improved resource allocation and heightened operational capacity. The introduction of the Participatory Forest Management (PFM) approach revolutionized the stewardship of public and community forest resources, fostering the creation of 250 Community Forest Associations (CFAs) and 290 Charcoal Producer Associations (CPAs). These associations play a vital role in regulating charcoal production from community forests. Furthermore, the decentralization of forest governance through the establishment of Forest Conservation Committees empowered local entities. The devolution of forestry functions to county governments, as outlined in the 2010 Constitution, marked a significant decentralization effort. County governments now hold responsibility for the conservation and management of forest resources on community and private lands, while the Kenya Forest Service focuses on managing public forests and enhancing the capacities of county governments in their devolved forestry functions. The strengthened governance of water towers was another noteworthy achievement, materializing through the creation of the Kenya Water Towers Agency, reinforcing the protection and sustainable management of vital water resources. Collectively, these reforms signify Kenya's commitment to

fostering environmental sustainability and community engagement in the management of its precious forest ecosystems (Mutune et al., 2017).

Strategies for forestry education and awareness play a pivotal role in promoting sustainable forest management and environmental conservation. These strategies involve a multifaceted approach, including formal education initiatives integrated into school curricula to instill a sense of environmental responsibility among the youth. Community-based programs engage local populations in understanding the importance of forests, encouraging active participation in conservation efforts (Mutune et al. 2017; Chisika & Yeom 2021). Public awareness campaigns employ diverse channels, including mass media and community events, to educate about forest value and individual roles in protection. Two annual campaigns coincide with the short and long rains, emphasizing tree planting. Notably, the President launched the National Tree Growing Restoration Campaign in 2022, aiming to plant 15 billion trees by 2032 (Head of Public Service Website, 2024). Successful forestry strategies in Kenya rely on collaboration between government, NGOs, and local communities. These initiatives aim to improve public awareness, knowledge, and engagement in sustainable forest management. (Mutune et al., 2017).

According to the National Forestry Programme 2016 -2030, Forestry education in Kenya faces challenges like a misalignment between institutions and industry, a lack of harmonized curriculum, inadequate practical training, and insufficient resources. The curriculum lacks participatory review, hindering adaptation to emerging issues like climate change. Entrepreneurial training gaps, resource mobilization issues, and weak linkages between institutions, researchers, and industry further compound the challenges. Improved integration, communication, and support are essential for a comprehensive and effective forestry education system.

There are emerging conservation approaches that have proven to be useful in promoting education and awareness."*Adopt a Forest in Kenya*" is a laudable initiative urging individuals and groups to actively engage in conserving the country's diverse forests. Participants in forest adoption contribute to specific areas' conservation through activities like education, tree planting, and sustainable resource management, demonstrating a commitment to environmental stewardship and community involvement (Chisika & Yeom, 2021). From this review, Kenya is taking a leading role in promoting sustainable forest management.

2. Materials and Methods

2.1. Case study research design

The comparative case study research approach was utilized in the study. It focused on understanding the specific context, processes, and outcomes related to the various strategies adopted to promote environmental education and awareness in each case being examined. The case study design was chosen because it allowed for an in-depth examination of the specific case thus providing a comprehensive understanding of the complexities and contextual factors in each case.

2.2. Case studies

2.2.1. Cherangani forest ecosystem

The Cherangani Forest Ecosystem, vital for local communities and the Lake Victoria and Lake Turkana basins, faces threats from population growth and unchecked settlements. A strategic management plan aims to guide conservation efforts, involving diverse stakeholders in its development from 2011 to 2013. The plan outlines five forest management zones, detailing objectives and actions for restoration and sustainable use. Local communities are recognized as crucial stakeholders in management and conservation. The educational landscape in the Cherangani ecosystem indicates significant education levels, with numerous schools and conservation organizations actively involved. Despite existing legislation, awareness about conservation remains low, leading to proposed activities to address this gap. Challenges include a lack of awareness, commitment, and technical capacity, along with resistance to change and erosion of indigenous knowledge. The plan addresses these issues through training workshops, seminars, media engagement, and participation in environmental events. Stakeholder capacity enhancement involves exchange visits, institution development support, incentives for farmers, and educational opportunities. Environmental education dissemination is planned through harmonized extension packages and resource center construction by key organizations. The overall goal is to enhance stakeholder commitment, awareness, and capacity for sustainable environmental practices in the Cherangani ecosystem. Empirical studies conducted in the ecosystem to evaluate the status of environmental awareness indicate that the ecosystem is still experiencing challenges. Pressing issues in the ecosystem include unlawful grazing, unauthorized logging, charcoal production, forest fires, population growth, policy and institutional failures, and forest intrusion. A call is made for full implementation of the Cherangani Hills

Forest Strategic Management Plan (2015-2040) and involving indigenous communities in political processes, especially in land use and forest management (Rotich, 2019; Ongugo et al., 2017; Rotich & Ojwang, 2021).

2.2.2. Mt. Kenya forest ecosystem

The Mt. Kenya Ecosystem, encompassing various reserves and conservancies, faces persistent threats despite significant conservation efforts. Challenges arise from resource depletion near populated areas due to unsustainable practices driven by poverty, rapid population growth, and weak institutions. A 10-year management plan (2010-2020) was collaboratively developed to address these issues, focusing on participatory implementation and collective management actions. Key threats include wildlife poaching, illegal logging, forest fires, invasive species, illegal water abstraction, and human-wildlife conflicts. The community partnership and education management program within the plan aims to strengthen conservation education, reduce conflicts, and enhance community benefits. Initiatives involve promoting educational programs by organizations like the William Holden Education Center and Wildlife Clubs of Kenya, utilizing mass media and the Internet, and participating in conservation awareness events to raise awareness about the Mt. Kenya Ecosystem. Despite challenges, the plan emphasizes the importance of inclusive and collective efforts to mitigate threats and sustain the natural resources of the Mt. Kenya Ecosystem. Studies in the ecosystem reveal ongoing challenges, including forest fires, limited environmental awareness, population growth, policy and institutional failures, and forest intrusion (Nyongesa & Vacik, 2018; Njeru & Fundi, 2023).

2.2.3. Aberdares forest ecosystem

The Aberdare Ecosystem (AE), covering about 2,162 km^2, faces threats like illegal logging, excessive grazing, poaching, water abstraction, and habitat loss. The actual area may exceed 3,000 km^2 due to rugged terrain. A 10-year management plan (2010-2020) involves extensive stakeholder engagement and aims for community involvement in conservation. Four management objectives focus on reducing human-wildlife conflict, enhancing community benefits, and improving awareness and communication. Key actions include maintaining the electric fence, supporting tourism-related projects, forming associations, generating employment, promoting carbon credits, establishing wind farms, and creating an education center. The electric fence has successfully mitigated conflicts, but some communities resist it, leading to vandalism. Ongoing awareness efforts aim to secure community support. Limited awareness of protected area regulations and values contributes to rule violations,

dissatisfaction, ecological consequences, revenue loss, and insufficient community support. The plan emphasizes continuous awareness-building to address these challenges and foster a future where adjacent communities actively contribute to conservation and benefit from sustainable resource use in the Aberdare Ecosystem. Studies on environmental awareness in the ecosystem reveal persistent challenges, including limited awareness, population growth, policy failures, institutional issues, and forest intrusion (Njeru & Fundi, 2023).

2.2.4. Kakamega forest ecosystem

Kakamega Forest in Western Kenya, an eastern remnant of the Guineo-Congolian lowland rainforest, boasts unique biodiversity, serving as a watershed and resource for the local community. A 10-year ecosystem management plan (2012-2022) involves joint efforts from the Kenya Wildlife Service (KWS) and Kenya Forest Service (KFS), with stakeholder engagement as a priority. Threats like illegal activities and community pressures necessitated the plan. The Community Outreach and Education Program aims to enhance community involvement in conservation and sustainable resource use, addressing human-wildlife conflict and improving livelihoods. Objectives focus on community participation, environmental education, conflict reduction, and enhancing livelihoods. Educational initiatives, including the KEEP Education Centre and the Biodiversity Information Center, involve collaboration with institutions within the Kakamega Forest Ecosystem. Despite challenges like forest degradation and community reliance on resources, the plan aims to foster community support for conservation through education, awareness, and sustainable practices, recognizing the vital role Kakamega Forest plays in national and international biodiversity conservation efforts. Studies in the ecosystem show improved forest management under participatory forest management, but limited awareness persists. Addressing this requires enhancing stakeholder capabilities, reforming institutions, providing financial support, and ensuring proper implementation (Mbuvi et al., 2022; Nyang'au et al., 2020). The four ecosystems studied are shown in Figure 1.

2.3. Data sources and collection process

Researchers developed a systematic content analysis procedure to extract and analyze relevant documents for a study on forest ecosystem management in Kenya. They identified specific plans, policy reports, and project reports in the document selection phase. The data extraction step involved isolating sections related to implementation, methodologies, strategies, and key actors. A coding scheme categorized textual data into themes like "environmental education" and

"forest conservation awareness." The contextual analysis considered broader social, economic, and environmental factors. The interpretation and synthesis phase drew meaningful conclusions, emphasizing implications for future environmental education planning. Validity and reliability checks ensured accurate representation, and the reporting phase presented key findings on how environmental education contributes to sustainable forest management in Kenya. The key documents consulted are shown in Table 1.

Figure 1. Location of the four ecosystems in Kenya

Document	Type	Source	Key findings
Constitution of Kenya, 2010	Policy	Internet	Article 10 d makes sustainable development a national value, while Article 55 makes education a human right. Articles 1, 10, and 118 outline the foundation for this engagement, emphasizing the sovereign power of the people, the values of public service, and the need for openness and accountability in government. Devolved some forestry educational roles to county governments.
Forest Policy, 1968	Policy	Internet	The policy emphasizes forest conservation and sustainable practices, highlighting the critical link between healthy forests and environmental well-being. It promotes environmental education, emphasizing an understanding of ecosystems, biodiversity, and forest balance. The policy encourages grassroots community involvement in environmental education and raises awareness about forests' crucial role in maintaining ecological equilibrium.
Forest Conservation and Management Act, 2016	Policy	Internet	Establishes Kenya Forest Service, the state agency responsible for promoting sustainable forest management through various means, including the provision of environmental education and awareness. The Act establishes Kenya Forestry College, which offers training in forestry. Moreover, the Act provides for programs for community empowerment, including environmental education through participatory forest management.
Basic Education Act, 2013	Policy	Internet	Section 42 mandates the Cabinet Secretary of Education to promote environmental protection education for sustainable development. By making education free and compulsory, standardizing the curriculum, and prioritizing quality, inclusivity, and teacher development, the Act has transformed the education landscape in the country.
Draft National Landscape and Ecosystem Restoration Strategy 2022-2032	Policy	Internet	The strategy aims to improve forestry through education, research, and training, addressing environmental challenges with initiatives like community engagement, digital platforms, and partnerships.
National Forest Programme 2016–2030	Policy	Internet	The program enhances forestry education, quality, and stakeholder capacity through training, research, and innovation, addressing

Document	Type	Source	Key findings
			challenges in forestry education and awareness.
Aberdare Ecosystem Management Plan 2010-2020	Management tool	Internet	The participatory plan involved stakeholders in ecosystem forums, including core planning teams, workshops, expert groups, village-level meetings, and individual consultations.
Mt. Kenya Ecosystem Management Plan 2010-2020	Management tool	Internet	Stakeholders actively shaped the ecosystem plan through forums, including core planning teams, workshops, expert groups, community meetings, and consultations..
Kakamega Forest Ecosystem Management Plan 2012-2022	Management tool	Internet	Stakeholders in the ecosystem actively crafted a participatory plan through forums, including core teams, workshops, expert groups, community meetings, and consultations.
Cherangani Hills Forest Strategic Ecosystem Management Plan 2015 - 2040	Management tool	Internet	The highly participatory plan was formulated by stakeholders around the ecosystem through forums, including participation in the core planning team, stakeholder planning workshops, expert working groups, village-level community consultative meetings, and individual consultations.
Rotich (2019)	Research article	Internet	The study in the Embobut forest in the Cherangany ecosystem focused on forest utilization and conservation, revealing the need to implement the Cherangani Hills Forest Management Plan. Additionally, 14.3% of respondents were illiterate, emphasizing the importance of environmental education and integrating indigenous communities into political processes.
Ongugo et al. (2017)	Research article	Internet	The study detected forest degradation in Mt. Elgon and Cherangany Hills using remote sensing, identifying hotspots. Rehabilitation efforts recommended included establishing demonstration plots and promoting tree planting.
Rotich & Ojwang (2021)	Research article	Internet	The study analyzed forest cover change in Cherangany Hills from 1985-2020, identifying drivers such as land conversion, resource exploitation, fires, and more. It urged a re-

Document	Type	Source	Key findings
			evaluation of conservation strategies for sustainability.
Nyongesa & Vacik (2018)	Research article	Internet	The study on fire management in Mount Kenya's Gathiuru Forest proposed an Integrated Fire Management framework, emphasizing education, research, and mutual exchange between trainers and communities for effective training.
Njeru & Fundi (2023)	Research article	Internet	The study evaluated local community knowledge and attitudes toward conserving the critically endangered Mountain bongo in Mt Kenya Wildlife Conservancy. Results revealed that while 71.8% recognized the bongo, only 18.3% knew its vernacular name, indicating limited ecological knowledge.
Mbuvi et al. (2022)	Research article	Internet	The study examined governance's impact on land cover and forest structure in Kakamega and Loita forests, finding that stakeholder capacity, institutional reform, and financial support enhance each regime's effectiveness.
Nyang'au et al. (2020)	Research article	Internet	This study conducted in Kakamega Forest assessed the impact of participating in a medicinal plants commercialization program on farm income, highlighting the importance of factors like age, literacy, and forest distance.
Rhino Ark Website (2024)	Webpage	Internet	Over 170 schools near key water towers in Kenya, including Mt. Kenya forest and Aberdares ecosystems, have implement a custom conservation curriculum in 2018, enriching the standard syllabus. This was made possible by a partnership between the government and non-state actors.
Pham et al. (2023)	Research Article	Internet	This working paper examines forest-food linkages in Kenya and found that forests contribute to local food supplies and support sustainable food production. Despite policy emphasis, challenges like deforestation persist, requiring effective implementation and further research such as the role of environmental education.

Table 1. Documents reviewed

2.4. Data analysis

This study sought to investigate the strategies for sustainable environmental education and awareness in selected case studies and design recommended ways for optimizing them. A conceptual framework (Figure 2) was developed based on findings from theoretical and empirical literature reviewed at global and local levels. From the analysis, the central pillar of formal education serves as the cornerstone for environmental education and awareness.

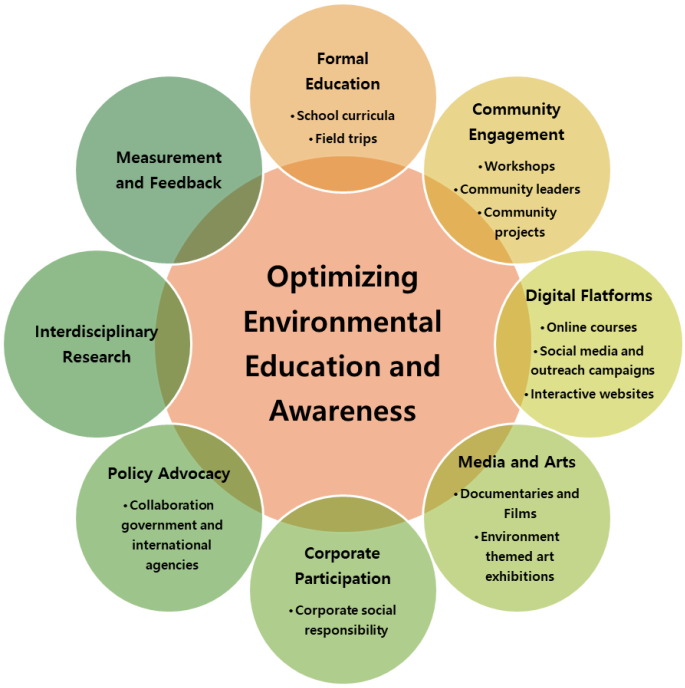

Figure 2. Conceptual diagram for optimizing strategies for environmental education and awareness in selected forest ecosystems in Kenya

This is complemented by experiential learning through field trips, allowing stakeholders to connect theory with real-world scenarios. Collaborative efforts and partnerships with environmental NGOs enhance education through workshops and hands-on activities. Community engagement, with community

leaders as ambassadors, fosters grassroots initiatives and tangible impacts. Embracing the digital era, online courses, webinars, and social media campaigns amplify global accessibility. Interactive websites cater to self-learners, ensuring a dynamic educational experience. Corporate participation through CSR programs and green initiatives enhances environmental education. Media and arts contribute to ecological consciousness through documentaries and exhibitions. Policy advocacy collaborates with government agencies, promoting sustainable policies and engaging in international conventions. Cross-disciplinary education inspires research projects. A robust feedback loop ensures continuous improvement, aiming to nurture an environmentally conscious generation actively involved in sustainable development.

3. Results

3.1. Current status of environmental education and awareness

The four forest ecosystems provide many environmental, social, and economic benefits for local communities and the global economy. The current status of environmental education and awareness is shown in Table 2.

Thematic Area	Findings
Formal education	Cherangani ecosystem has an appreciable educational infrastructure. There are 691 primary schools, 109 secondary schools, and 3 tertiary colleges. There are 90 CBOs, 5 NGOs, 9 CFAs, 7 WRUAs, and a number of government agencies involved in awareness creation.
Community engagement	Across all the ecosystems, a review of the ecosystem management plans shows that communities are engaged in environmental education through the participatory forest management process. However, currently, the process is experiencing challenges, including inadequate capacity, lack of incentives, and high costs for PFMP development. User groups struggle with resource mobilization, and poor advocacy skills hinder effective causes. Environmental conservation interest is weak, focused on benefit sharing, lacking a shared vision, leading to low participation and hindered PFM implementation. Governance issues persist due to weak regulations and non-adherence to rights, emphasizing the need for a comprehensive approach to sustainable community development.
Digital platforms	There are no specific digital platforms for the ecosystems, but there are plans to establish information databases in each of the four ecosystems. Currently, the ecosystems utilize digital platforms developed at the national level to promote environmental education

Thematic Area	Findings
	and awareness, for instance, the Jaza Miti App, which is used to provide awareness on tree species site matching and reporting tree planting progress.
Media and arts	The media plays a critical role in promoting environmental education in the four ecosystems. The media is used to mobilize stakeholders for forest conservation. The Media Council of Kenya has promised to collaborate with journalists to increase public awareness of forest conservation and management and mobilize public support for tree-growing initiatives (Impact Hub media website 2024).
Corporate participation	In the four cases, corporates participate in environmental education and awareness through the "adopt-a-forest" framework. For example, Her Excellency, the First Lady of the Republic of Kenya, has adopted 200 ha of Kakamega forest and has committed to growing 500 million trees across the country by 2032 (Citizen digital website, 2024).
Policy Advocacy	Diverse interest groups are involved in promoting environmental education and awareness. The focus areas include building grassroots capacity and networks for nature conservation, promoting participation and equity in natural resource management, mobilizing public and political support for nature, educating young people about nature, and fostering effective conservation partnerships at local, national, and international levels by Laikipia Wildlife Forum, Nature Kenya, especially in Mt. Kenya ecosystem. Nature Kenya works with a number of site support groups, including, Chebororwa Sekemiat Self-help Group – Cherangany, Kakamega Environmental Education Programme (KEEP), Mt. Kenya Biodiversity Conservation Group (Mt. Kebio), Mukurweini Environmental Volunteers Organization (MEVO) -Aberdares (Nature Kenya Website 2024).
Interdisciplinary research	Even though there are limited studies that focus on environmental education and awareness in the four ecosystems, research studies have been conducted on drivers and trends of deforestation, mostly using satellite technology. The researchers have mentioned the importance of enhancing education and awareness as a strategy for promoting sustainable forest management.
Measurement and feedback	All four ecosystems have multi-stakeholder structures for promoting environmental education and awareness as outlined in the respective ecosystem management plans (Table 1). There are also national-level efforts to complement the ecosystem measurement and feedback mechanisms, such as the Jaza Miti App, which monitors and reports on tree planting activities.

Table 2. Status of environmental education and awareness

3.2. Strategies for environmental education and awareness

Forest ecosystem management plans are playing a pivotal role in promoting sustainable forest management of the four forest ecosystems. Results in Table 3 show that diverse strategies are being employed to promote environmental education and awareness.

Thematic Area	Findings
Formal education	According to the ecosystem management plans, in the Cherangany ecosystem, efforts to strengthen formal education include enhancing the capacity of stakeholders and disseminating environmental messages. In Kakamega attention is given to mobilizing the surrounding schools to register with Wildlife Clubs of Kenya for wildlife conservation awareness creation. In Mt. Kenya, the focus is to ensure that adjacent communities are supporting conservation efforts and livelihoods are improving through the sustainable use of natural resources
Community engagement	In all four study sites, the focus is to strengthen the community structures to be effective in PFM.
Digital platforms	In Mt. Kenya, there are plans to establish a management information database to integrate research and monitoring information in the planning, management, and decision-making. These resource centers will consist of published and unpublished research reports both in analog and digital media for easy access to ecosystem managers. A similar approach is suggested for the Aberdares ecosystem. Cherangany and Kakamega do not mention their efforts using digital platforms.
Media and arts	There are plans to escalate the use of media to promote environmental education and awareness in all four ecosystems. In ecosystems with wildlife, Kenya Park's In Focus program is dedicated to connecting youth with nature through photography, environmental education, outdoor recreation, and creative expression. The initiative aims to support youth groups near protected areas, fostering an appreciation for Kenya National Parks' natural beauty. In collaboration with the parks and reserves, the six-day program enhances participants' photography skills, imparts knowledge about nature, and allows exploration of the park with interactions with park rangers, artists, and professional photographers (Tonywild website 2024).
Corporate participation	All four ecosystems plan to leverage corporate participation through CSR to contribute to economic development while improving the quality of life in the ecosystems. In Kakamega, the focus is to encourage corporates to establish trusts or foundations, through which funds from willing clients (donations) can be channelled or their own profit.
Policy Advocacy	All four ecosystem management plans encourage promoting the advocacy role of nongovernmental organizations and other agencies

Thematic Area	Findings
	as well as promoting advocacy through the PFM process. The specific actions include encouraging advocacy on good governance and leadership, electing leaders with the right skills, undertaking capacity building of stakeholders, developing a code of conduct for community groups, and establishing mechanisms for benefit-sharing amongst stakeholders.
Interdisciplinary research	All the ecosystems emphasize the importance of research to promote environmental education and awareness. There are plans to improve the infrastructure of the existing research facilities in order to improve their educational and awareness roles. The management programs in the management plans, including education and awareness are to be implemented based on continuous research, education, monitoring, and information sharing among the stakeholders
Measurement and feedback	Improving multi-stakeholder structures for promoting environmental education and awareness is envisaged in all the ecosystems.

Table 3. Strategies for enhancing environmental education and awareness

In summary, the results showed that the current status of environmental education and awareness in the four cases highlights their significance for sustainable development. Participatory Forest Management, which is the main avenue for environmental education and awareness, faces obstacles hindering effective education. However, media, arts, and corporate initiatives, such as the "adopt-a-forest" framework, are recognized for their critical role.

4. Discussion

Forests are important for sustainable development (Korosuo et al., 2023; Wang & Tian, 2023; Berlyn, 2023; Yanshu et al., 2019; UN, 2019). Hence, many countries have devised strategies for harnessing educational and awareness initiatives to achieve sustainable forest management (Stefanakis, 2022; Breiting & Wickenberg, 2010; Ndifon, 2015; Smith, 2010; Alam, 2023). However, reviewed literature shows that the effectiveness of awareness programs is influenced by various contextual factors (Mutia et al., 2023; Hakamada, 2023), but there are limited studies in developing countries. Therefore, this study sought to evaluate ways of optimizing environmental education and awareness strategies toward sustainable forest management in Kenya using the case of four forested ecosystems. Results from reviewed global literature show that environmental education and awareness are vital tools in the sustainable management of

forested ecosystems (Reid et al., 2019; Alam, 2023; Gurbuz et al., 2021; Bülbül et al., 2020; Mkumbachi et al., 2020; Al Yaqubi, 2020; Conrad and Hilchey, 2011; Giudici et al., 2019; von Borgstede et al., 2013; Fu et al., 2020).

When the conceptual framework with key ingredients for understanding the strategies for optimizing environmental education (Figure 2) was applied in the context of Kenya, results show that just like at the global level, forests are strategic national assets and the country is desirous of promoting environmental education and awareness for their sustainable management (Habel et al., 2023; Chepkemoi & Musya, 2023). The country has developed policies and legislation to promote sustainable forest management through educational programs (Table 1; Kinyili, 2023). In particular, the constitution of Kenya (Table 1) recognizes education, including environmental education as a fundamental right for every Kenyan and calls upon all public officials to uphold it. In addition, the constitution devolved some forestry functions to county governments, especially the role of educating individual citizens on forestry and environmental matters. Counties in Kenya are supposed to play a multifaceted role in promoting environmental education and awareness. Their efforts span establishing education systems, facilitating community engagement through digital communication and media collaborations, firming up corporate partnerships for conservation, policy advocacy, and overall sustainable development, and contributing significantly to the nation's environmental conservation goals. However, counties have been slow in taking up their forestry and environmental awareness functions.

Other policy documents, for instance, the Forest Policy 1968, emphasize the link between environmental education and high quality of life. Moreover, the Forest Conservation and Management Act, 2016, section 8 (g) establishes the Kenya Forest Service whose mandate partly is to promote forestry education and training across the coutry. The law also established Kenya Forestry College for formal technical training in forestry and environmental matters. However, and perhaps most important is the provision of Participatory Forest Management as an avenue for partnership between the government and forest-adjacent communities. This partnership offers scientific and educational activities as one of the user rights to benefit forest-adjacent communities. Environmental education and awareness activities under the participatory relationship, including forest adoption, have revolutionized public and community forest resource stewardship. Collaborative forestry has fostered the creation of 250 Community Forest Associations (CFAs), 290 Charcoal Producer Associations (CPAs), and the decentralization of forest governance through the establishment of Forest

Conservation Committees, which are currently empowering local communities by involving them in higher conservation decision-making processes. As a result, the cumulative impact of these educational and conservation efforts have improved the country's forest cover which currently stands at 8.83 of the total land area in Kenya (Mutune et al., 2017; Chisika & Yeom, 2021).

However, according to the National Forestry Programme 2016 -2030, there are various financial, institutional, technical, and social challenges facing forestry education and awareness, and they need to be addressed by re-evaluating the current location-specific strategies in order to foster the achievement of sustainable forest management in the country. In this connection, when the conceptual framework in Figure 2 was applied to cases, results showed the forest ecosystems were vital for local communities and the nation at large in view of the social, economic, and environmental benefits (Kakamega Forest Ecosystem Management Plan 2012-2022; Cherangani Hills Forest Strategic Ecosystem Management Plan 2015 – 2040; Mt. Kenya Ecosystem Management Plan 2010-2020 & Aberdare Ecosystem Management Plan 2010-2020). Therefore, preserving them through environmental education and awareness is important. Results show that currently, all four ecosystems portray similar status across the key ingredients of effective environmental education and awareness, as outlined in Figure 2 (Table 2). Moreover, in all the cases, diverse environmental education and awareness strategies are embedded in the forest ecosystem management plans following the amendments to incorporate the forest management law in 2005 (Table 1). Strategies are pursued in the four forest ecosystems with the aim of seeking to enhance the commitment and awareness of environmental issues and conservation by organizing training workshops and seminars involving state and non-state actors, building stakeholder capacity through exchange visits, and disseminating environmental education through the construction of resource centers.

However, in this paper, the authors assert that currently, in view of the elements of Figure 2, the Participatory Forest Management strategy serves as the key avenue for promoting environmental education and awareness in the study cases because it incorporates integrating all the suggested elements in Figure 2. By actively involving local communities in the management and conservation of the case forests, PFM fosters a deep understanding of the ecological importance of these ecosystems. Through hands-on involvement, communities gain practical knowledge, sharpen environmental awareness, and develop a sense of ownership. Participatory forestry initiatives, even though still government-led, to some extent, provide a platform for education and awareness on sustainable resource

use, biodiversity conservation, and the interdependence of ecosystems, contributing to a culture of responsible environmental stewardship. Ultimately, it empowers communities to actively safeguard their natural heritage for current and future generations.

The participatory forest management plans developed to guide the participatory process outline guidelines for resource utilization, biodiversity conservation, and community involvement in decision-making processes, thus strengthening their education and awareness of environmental matters. This paper lauds the participatory practice of integrating robust educational programs in management plans because it fosters a harmonious balance between conservation efforts community engagement and other ingredients of effective awareness programs. Such educational programs play a pivotal role in enlightening stakeholders about the ecological significance of forests, instilling a deep understanding of sustainable practices, and promoting a sense of shared responsibility. By integrating education initiatives into management plans, there is an opportunity to empower local communities, policymakers, and other stakeholders with the knowledge needed to make informed decisions. This proactive approach enhances awareness of environmental challenges and also encourages active participation in conservation activities. Robust education and awareness programs serve as catalysts for building a cadre of informed advocates who can champion the cause of sustainable forest management, ensuring the longevity and vitality of these essential ecosystems.

However, results in Table 2 showed that there are significant social, financial, institutional, and technical challenges affecting the effectiveness of education and awareness programs in the Participatory Forest Management Process. Whereas this study supports participatory ecosystem planning and the inclusion of strategies and actions for promoting education and awareness that cut across the key ingredients of effective educational and awareness programs identified in Figure 2, there is a need to optimize the strategies by leveraging on the opportunities presented by the existing education infrastructure. For example, in the Cherangani forest ecosystem, leveraging the existing educational infrastructure comprising 691 primary schools, 109 secondary schools, and three tertiary colleges in the region would promote formal education and awareness. In addition, across all cases, the policy framework for the country allows for this approach. For instance, the Basic Education Act, 2013, section 42 mandates the Cabinet Secretary of Education to promote environmental protection education for sustainable development. Moreover, across all the cases studied, corporate engagement could be explored to further promote formal education on

environmental conservation. For instance, Rhino Ark, which has a network of over 170 schools near water towers in Kenya, has implemented a customized curriculum that seamlessly integrates conservation awareness into the standard school syllabus in schools near Mau Eburu, South West Mau forest, Aberdares, and Mt Kenya forests. Various topics such as soil conservation, water management, pollution control, tourism, and environmental studies are taught alongside the existing Competency-Based Curriculum (CBC). These laudable efforts have been made possible because of a collaboration between Rhino Ark and the Ministries of Environment, Education, Science, and Technology in a public-private partnership arrangement (Rhino Ark Website 2024). Promoting such educational partnerships is crucial in easing forestry policy design and implementation, as observed by Bülbül et al. (2020), Mkumbachi et al. (2020), and Al Yaqubi (2020). However, caution should be exercised when administering these environmental education programs as they should be culturally and socially acceptable and appropriate (Nyongesa & Vacik 2018; Njeru & Fundi 2023; Mbuvi et al. 2022). Caution is important because sometimes strategies have unintended consequences, as in the case of Nigeria, where past strategies focused more on controlling and treating environmental issues rather than preventing them (Thathong, 2012).

Figure 2 also highlights the role of informal education avenues in promoting environmental education and awareness; this can be exploited to promote sustainable forest management in the ecosystems under study. For example, the Cherangany ecosystem has various conservation organizations implementing programs and projects to raise awareness. This includes 90 Community-Based Organizations (CBOs), 5 Non-Governmental Organizations (NGOs), 9 Community Forest Associations (CFAs), 7 Water Resource Users Associations (WRUAs), and several government agencies. Community engagement through improving participatory forest management and corporate participation can be fostered through the provisions of the existing "adopt-a-forest" framework for maximum environmental education, awareness, and sustainable forest management. For instance, in Kakamega, community efforts have been bolstered by the adoption of 200 ha by Her Excellency, the First Lady of the Republic of Kenya. Greater focus in such an arrangement should be aligned in a manner that ensures community livelihoods are secured. Therefore, the strategy for Kakamega to encourage the establishment of trusts or foundations where funds from willing corporates can be channeled for the benefit of engaged communities can have a beneficial impact on promoting environmental education and awareness in the four cases. Reviewed literature from the works of other scholars such as Rotich (2019), Rotich & Ojwang (2021), and Ongugo et al. (2017) in the

case of Cherangany all support the need for promoting partnerships for education and awareness. Moreover, reviewed empirical studies from other countries' cases support these strategies (Yamada et al., 2023; Chankrajang & Muttarak, 2017; Thathong, 2012). Besides addressing livelihood issues, corporates can also be at the forefront of promoting policy advocacy. For instance, case results indicate that corporations engage in activities aimed at building grassroots capacity and networks for nature conservation, promoting participation and equity in natural resource management, mobilizing public and political support for nature, educating young people about nature, and fostering effective conservation partnerships at local, national, and international levels as shown in the cases of Laikipia Wildlife Forum and Nature Kenya in Mt. Kenya ecosystem. Moreover, Nature Kenya works with a number of site support groups in the four case studies (Nature Kenya Website 2024).

Measuring the impact of educational and awareness programs is one of the requirements of an effective educational program. Results from the four cases show there are limited empirical studies on the measurement of environmental awareness and education impacts in the selected ecosystems. However, an awareness study conducted in the Kakamega forest ecosystem indicates that participatory forest management has improved forest management in forested sites. It is, therefore, urgent and important to conduct studies of the effectiveness of awareness efforts in the ecosystems. Conducting forestry educational and awareness studies within a forest ecosystem is crucial for cultivating a well-informed and environmentally conscious community. These studies provide valuable insights into the intricacies of the ecosystem, offering a deeper understanding of its biodiversity, ecological processes, and the delicate balance that sustains it. By disseminating this knowledge through educational programs and awareness campaigns, communities gain the tools to appreciate the significance of responsible forest management. Such initiatives empower individuals to make informed decisions and also foster a collective sense of stewardship. Forestry studies contribute to the identification of potential threats and challenges faced by the ecosystem, enabling proactive measures to mitigate them. Ultimately, a well-educated and aware community becomes a formidable force in advocating for sustainable practices, ensuring the long-term health and resilience of the forest ecosystem.

Moreover, results from the four study sites indicate a low integration of technology and innovative approaches in forestry education and awareness programs. With advancements in digital tools and platforms, leveraging technology can enhance the effectiveness of educational materials and outreach

campaigns. Digital technologies play a pivotal role in optimizing forestry education and awareness strategies, revolutionizing how information is disseminated and absorbed. Incorporating digital platforms, such as online courses, interactive applications, and virtual reality experiences, enhances accessibility and engagement. These technologies enable the creation of dynamic educational content, allowing learners to explore the intricacies of forestry in immersive and innovative ways. Additionally, digital platforms facilitate real-time communication, fostering a global community of individuals enthusiastic about forestry and environmental conservation. Social media has become a powerful tool for spreading awareness, while data analytics offer insights into the effectiveness of education campaigns. The integration of digital technologies broadens the reach of forestry education and also ensures that strategies are adaptive, interactive, and aligned with the evolving needs of a technologically advancing society, thus maximizing the impact of education and awareness efforts in the realm of forestry. Reviews from global literature have also supported this approach, and besides the use of national-level technologies such as the Jaza miti App, other alternatives such as the use of an Environmental Awareness Index (EAI) formulated using Google search data sourced from Google Trends can be explored (Dabbous et al., 2023).

In summary, this study advocates for a comprehensive, collaborative, and technology-driven approach to environmental education and awareness as a way to achieve sustainable forest management and conservation goals.

5. Conclusion and Recommendations

This study has highlighted the crucial role of environmental education and awareness in achieving sustainable forest management by cultivating values and promoting responsible environmental practices. Effective strategies encompass formal education, community engagement, digital platforms, corporate responsibility, media, arts, policy advocacy, and research with feedback loops. The examined cases have demonstrated commendable efforts in integrating these ingredients into the strategies within their management plans, enlightening stakeholders, and promoting sustainability. The study emphasized the need for measuring the effectiveness of educational approaches adopted in the ecosystems, revealing a lack of empirical studies and suggesting the need to leverage digital technology to enhance education and outreach and encourage county governments to take up a more active role in promoting environmental awareness. The limitation of this study is that it solely relied on a bibliographic

review and did not include a direct analysis of public opinions through interviews with stakeholders involved in managing the ecosystems. This omission resulted in a lack of qualitative and quantitative data that could have enhanced the discussion and allowed for a more direct response to the research's stated objective. It could be addressed by cross-referencing and using diverse data collection methods in future studies.

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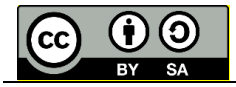

Original Paper

The challenges of private sector engagement in forest landscape and ecosystem restoration in Kenya

The case of Makueni and Elgeyo Marakwet Counties

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Keywords: inclusivity; sustainable forest management; private sector; participation.

List of Abbreviations: ADSE: Anglican Development Services Eastern; AFR100: African Forest Landscape Restoration Initiative; AUDA: African Union Development Agency; CBD: Convention on Biological Diversity; CI: Conservation International;

COP 21: Conference of Parties; FLR: Forest Landscape Restoration; FOLAREP: Forest Landscape Restoration Implementation Action Plan; HDI: Human Development Index; IUCN: International Union for Conservation of Nature; KFS: Kenya Forest Service; LDN: Land Degradation Nuetrality; NDMA: National Drought Management Authority; P4F: Partnerships for Forests; SDGs: Sustainable Development Goals; SDL: State Department of Livestock; TWENDE: Towards Ending Drought Emergencies; UNCCD: United Nations Convention to Combat Desertification; UNFCCC: United Nations Framework Convention on Climate Change; WRI: World Resource Institute; WWF: Wildwide Fund for Nature.

Abstract. *Private sector participation in forest landscape restoration is critical for sustainable development. Even though the role of the private sector in landscape restoration is still evolving, the existing theoretical models indicate that involving the private sector effectively in forest restoration drives financial, technological, and innovative solutions, forging a collaborative approach that benefits both forest ecosystems and businesses. Although Kenya has made strides in ensuring private sector participation in local forest restoration, private sector participation is still inadequate even though there is interest in landscape restoration. This paper aims to explore the current status of private sector engagement in forest restoration to identify the key challenges facing private actors by examining the cases of Elgeyo Marakwet and Makueni Counties in Kenya. The intention was to enhance participation by devising strategies for sustainable participation practices. Based on the case study approach, involving literature review and textual analysis of key documents and county-specific County Integrated Development plans retrieved from official online sources, the results revealed that Elgeyo Marakwet and Makueni counties have distinct statuses and challenges affecting private sector participation. In Makueni County, private sector involvement in landscape restoration is centered on agroforestry, silvopastoral, and plantation forests, comprising 95% of available options. The focus is on enhancing rangeland resilience against climate-induced drought in targeted project wards, with the TWENDE Project collaborating with various private sector partners. Even though limited information on incentives exists, WRI,*

backed by the Mastercard Foundation, funded the planting of 1,200,000 seedlings. In Elgeyo Marakwet, the United Nations Development Programme leads private sector engagement, aiming to increase forest cover. Challenges include invasive species, population pressure, limited youth participation, legal framework gaps, and unclear incentives. These results imply the need for a collaborative and well-coordinated approach to restoration, policy reviews, and conducting a total economic valuation of forest landscapes to sustain private sector interest and engagement in the restoration efforts.

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1. Introduction

Restoration of the world's depleted forests and landscapes is crucial for preserving ecological processes and ensuring the well-being of current and future generations. Moreover, restoration provides a vital nature-based solution to combat climate change. Recent years have witnessed a surge in global and national policy focus on restoration, with various commitments and pledges like the Bonn Challenge, the 1 Trillion Trees Initiative, and the United Nations Decade of Ecosystem Restoration. Despite these initiatives, only a fraction of the pledged land for restoration by 2020 had undergone the process, and countries are currently falling short of meeting their 2030 restoration targets (Forest declaration website 2021). Currently, most restoration projects in Africa rely on traditional funding sources such as government budgets and philanthropic funds, with limited participation from the private sector. Involving the private sector has the potential to mitigate environmental and social risks associated with these initiatives. The private sector's involvement drives financial, technological, and innovative solutions, forging a collaborative approach that benefits forest ecosystems and businesses. Consequently, many countries are devising more robust strategies and re-evaluating the existing strategies for hastening private sector engagement in forest landscape restoration.

Kenya has also embraced promoting the private sector in forest landscape restoration efforts. The country has developed key forestry development policies and initiatives that recognize the role of the private sector in landscape restoration. Kenya's Forest Conservation and Management Act (2016) shapes sustainable forest management, prioritizing community involvement and private sector engagement. Encouraging public-private partnerships establishes

mechanisms for collaborative forest management. The National Forest Programme outlines strategic goals involving diverse stakeholders, including the private sector. In addition, the Climate Change Act (2016) and the National Strategy for Landscape and Ecosystem Restoration 2023-2032 highlight the private sector's pivotal role in forestry landscape restoration. However, with the changing socio-economic matrices, the level of private sector participation in restoration efforts remains insufficient despite significant interest in participating in forest restoration. To understand why participation remains low despite the growing conservation interest, this article explores the current status of private sector participation in forest landscape restoration in the case of Elgeyo Marakwet and Makueni counties to identify the barriers in restoration, aiming to understand the persistent gap between ambition and reality in forest restoration actions.

The study focuses on recognizing their distinct objectives and approaches. Key questions examined include the current status of private sector involvement in forest restoration, alignment of restoration projects with the key ingredients of forest landscape restoration, barriers faced by private actors, and strategies to overcome these barriers. The investigation involved textual analysis of key documents analyzed through thematic analysis to identify inductive themes. In order to holistically respond to the research aims, the concept of forest landscape and ecosystem restoration will be reviewed from the theoretical background of sustainable forest management. The key theoretical and empirical findings were then applied to the Kenyan cases to generate the policy implications of this study. Makueni County and Elgeyo Marakwet are selected for their distinct characteristics, providing insights into challenges in private forestry sector engagement for restoration in Kenya. The diverse ecological zones and land uses offer a nuanced understanding of complexities in restoration initiatives. Makueni's commitment to sustainable development and Elgeyo Marakwet's emphasis on indigenous knowledge integration present unique cases for studying private sector involvement. It allows for a comprehensive examination of challenges and opportunities in private forestry sector engagement across Kenya's varied environmental and socio-cultural contexts.

2. Forest landscape and ecosystem restoration: Theoretical Analysis

Forest landscape and ecosystem restoration is a mutually beneficial strategy, positively impacting the environment by addressing climate change and preserving biodiversity. It enhances human welfare by creating eco-friendly

employment, improved food security nutrition, and increased income prospects. Forest landscape restoration is pivotal in advancing sustainable forest management by fostering a holistic and long-term approach to environmental conservation. Through targeted restoration efforts, the approach mitigates the adverse effects of deforestation and promotes the regeneration of diverse ecosystems. It contributes to forests' overall health and resilience, ensuring their sustained productivity. Moreover, forest landscape restoration initiatives incorporate community engagement and participatory approaches, aligning with sustainable forest management principles. By balancing ecological integrity and human needs, forest landscape restoration becomes a cornerstone in maintaining forests as vibrant, self-sustaining ecosystems for present and future generations.

The imperative drives forest landscape restoration (FLR) to enhance landscape resilience and optimize ecosystem goods and services in anticipation of future changes (IUCN Website 2024). The approach is guided by principles emphasizing a holistic, landscape-focused perspective over isolated sites. Acknowledging the intricate mix of land uses and management practices, FLR operates within entire landscapes, integrating diverse tenures and governance systems. This comprehensive approach allows for harmonizing ecological, social, and economic priorities. Central to FLR is the commitment to maintain and enhance natural ecosystems within landscapes, avoiding the conversion or destruction of natural forests. Instead, FLR champions the conservation, recovery, and sustainable management of these crucial environments, recognizing their intrinsic value and ecological significance. Stakeholder engagement and participatory governance are pivotal, involving diverse groups in decision-making processes related to land use, restoration goals, and ongoing monitoring. FLR's adaptability is evident in its tailored strategies for each unique local context (IUCN Website 2024). Using scientific insights, best practices, and traditional knowledge, FLR integrates information into the local context, considering social, cultural, economic, and ecological values. The restoration efforts aim at multiple functions across landscapes, generating diverse ecosystem goods and services to meet varied stakeholder needs. A crucial aspect of FLR is adaptive management for long-term resilience. Recognizing the dynamic nature of ecosystems and societal needs, restoration approaches evolve, enhancing species diversity and adjusting strategies based on changes in climate, knowledge, and stakeholder needs. Monitoring activities, ongoing research, and stakeholder input are vital in shaping adaptive management plans, ensuring FLR remains responsive and effective throughout its implementation (IUCN Website 2024).

Examining the challenges facing the private sector in forest landscape restoration is inherently linked to sustainable forest management principles. Both concepts share a common objective of balancing ecological preservation with economic interests. Sustainable forest management emphasizes the responsible use of forest resources, aligning with the private sector's long-term viability needs. Forest landscape restoration, as a subset, specifically addresses the rehabilitation of degraded areas, creating opportunities for private enterprises involved in afforestation and reforestation. Investigating the hurdles the private sector faces in this context provides valuable insights into optimizing the integration of environmental and economic goals. It highlights potential barriers, such as financial constraints or regulatory complexities. It informs strategies to enhance the collaboration between private entities and conservation efforts, fostering a more effective and sustainable approach to forest landscape restoration.

2.1 Global reviews on private sector engagement in forest landscape restoration: Empirical Analyses

In this paper, the private sector refers to entities and businesses that operate independently from government or public ownership. These can include corporations, companies, and individuals engaged in activities related to forestry, land management, and environmental services. Private sector involvement in FLR often encompasses initiatives, investments, and collaborations that contribute to the restoration and sustainable management of forest landscapes. This involvement may range from corporations participating in reforestation projects to businesses offering environmental services and products that align with FLR goals. The private sector's engagement in FLR can play a crucial role in providing resources, expertise, and innovation to enhance the effectiveness and scalability of restoration efforts.

Forest Landscape Restoration (FLR) represents a proactive collection of strategies to effectively realize various international policy objectives related to global forests. The Sustainable Development Goal (SDG) 15, the Convention on Biological Diversity (CBD) Aichi Target 15 which aims to restore a minimum of 15 percent of degraded ecosystems, the United Nations Framework Convention on Climate Change (UNFCCC) concerning Reducing Emissions from Deforestation and Forest Degradation in Developing Countries and the United Nations Convention to Combat Desertification (UNCCD) Land Degradation Neutrality (LDN) Project can be realized through the FLR approach (Partnership for Forests 2022). Forest landscape restoration (FLR) encompasses diverse strategies for revitalizing degraded or deforested areas. Options include

afforestation, planting trees in barren regions to establish new forests; reforestation, replanting in areas where forests were removed; and agroforestry, integrating trees into agricultural landscapes for ecological and economic benefits. Natural regeneration allows forests to regrow organically, while assisted natural regeneration involves human interventions to facilitate the process. Sustainable land management practices, like rotational grazing and fire management, maintain ecological balance. Creating buffer zones and wildlife corridors also connects fragmented habitats, emphasizing FLR's adaptability to diverse contexts for a holistic and sustainable approach to restoring forest landscapes (Partnership for Forests, 2022).

This paper will use the illustration of FLR initiatives to explore the challenges facing the private sector when involved in large-scale restoration efforts. In the African context, there is concurrence that FLR has the potential to contribute to sustainable development. Studies show that 60% of Africa's population relies on forests for a significant portion of their food, goods, and services. The standing forests and mangroves play a crucial role in mitigating the impact of climate change by absorbing greenhouse gases, regulating water flows, and protecting coastal communities against extreme events and rising sea levels. However, the challenges of increasing urbanization, conflict, the expansion of refugee settlements, and inadequate soil management practices have resulted in Africa experiencing a loss of 4.4 million hectares (ha) of forest annually between 2015 and 2020 (Partnership for Forests 2022). It highlights the urgent need for sustainable forest management practices and conservation efforts to safeguard the essential resources provided by forests and ensure the well-being of the dependent population. Various Forest Landscape Restoration (FLR) initiatives have been established in Africa to tackle these challenges, such as the Pan African Ecosystem Restoration Action, the Great Green Wall, and the African Forest Landscape Restoration Initiative (AFR100). These initiatives represent long-term, collaborative efforts involving multiple partners to restore ecosystems and enhance human well-being in areas that have been deforested or degraded (Partnership for Forests 2022). The focus is on sustainable, multi-faceted approaches to rejuvenate landscapes and create positive impacts for the environment and the communities dependent on these ecosystems (Partnership for Forests 2022).

The African Forest Landscape Restoration Initiative (AFR100) was inaugurated in 2015 during the 21st session of the Conference of Parties (COP21) in Paris. AFR100, a country-driven initiative, aims to restore 100 million hectares (ha) of land across Africa by 2030. Aligned with the Bonn Challenge, African Resilient

Landscapes Initiative, African Union Agenda 2063, Sustainable Development Goals, and other targets, AFR100 is spearheaded by the AFR100 Secretariat within the African Union Development Agency (AUDA). Supported by a Management Team, including representatives from Partnerships for Forests (P4F), Federal Ministry of Economic Cooperation and Development of Germany (BMZ), International Union for the Conservation of Nature (IUCN), World Bank, World Resources Institute (WRI), and Food and Agriculture Organization (FAO) (Partnership for Forests 2022). AFR100 unites various partners, including participating African nations, civil society, and private sectors, to collaboratively pursue shared restoration goals. These goals encompass food security, climate change resilience, and poverty alleviation. At the multinational level, AFR100 facilitates political engagement and knowledge sharing. It enhances restoration endeavors for signatory countries by providing a platform for communication, exchange, coordination, and access to technical and financial support. With over 32 African countries pledging their commitment to the initiative, AFR100 signifies a concerted effort to address environmental challenges and promote sustainable land restoration. In implementing the highlighted global and regional forest restoration efforts, the core function of the FLR approach is to shift the focus from merely maximizing tree cover to considering the broader functions of forests within landscapes crucial for human dependence. This shift has turned FLR into a unified framework for various international actors to expand forest restoration initiatives through an integrated landscape approach, aligning with national priorities and voluntary commitments (Partnership for Forests, 2022). However, the implementation of FLR in Africa faces challenges, and hence, establishing partnerships between public, private, and non-profit entities is crucial for the economic viability and long-term success of Forest Landscape Restoration (FLR) initiatives. Currently, most restoration projects in Africa rely on traditional funding sources such as government budgets and philanthropic funds, with limited participation from the private sector. Involving the private sector has the potential to mitigate environmental and social risks associated with these initiatives. However, the assessment highlighted that engaging all relevant stakeholders at the national level is a significant challenge in implementing restoration activities. Forest Landscape Restoration (FLR) platforms serve as diverse forums engaging stakeholders from government bodies, international communities, the private sector, civil society, and local communities. These groups often diverge in values, interests, and approaches despite their potential. The initiatives of regional coordinators to unite these various actors faced challenges due to a lack of alignment in vision and a common language within and between ministries and countries. This misalignment

hindered effective collaboration and coordination efforts, emphasizing the need for enhanced communication and shared understanding to foster successful restoration implementation (Partnership for Forests 2022). Limited coordination among various entities has resulted in challenges for regional coordinators, including the duplication of efforts in setting up national stakeholder platforms and monitoring systems within restoration initiatives. Furthermore, infrastructure is absent to facilitate private sector involvement in restoration efforts. The lack of incentives, such as access to funds, poses a barrier to aligning private sector interests with national pledges and government objectives, particularly in areas like improving gender equality in accessing landscape restoration services. Financing remains a significant challenge for initiatives like AFR100, with funders, including private sector actors, often deterred by the long-term nature and perceived lack of a business proposition in these projects. The AFR100 Secretariat identified the urgent need to enhance systems for tracking and reporting on the progress of AFR100 restoration efforts in member countries. The assessment revealed a fragmented and duplicative reporting system due to the absence of a continent-wide AFR100 monitoring framework, making it challenging to comprehensively assess progress as restoration data are scattered across institutions and ministries. This lack of communication and advocacy impedes replicability and knowledge sharing among member countries, diminishing the effectiveness of meeting AFR100 pledges on time and creating an information gap between stakeholders (Partnership for Forests 2022). Three main funding gaps were identified: a lack of funding for restoration actors on the ground, insufficient funds for stakeholder engagement, and a deficit in supporting the private sector—especially female and young entrepreneurs—due to a lack of innovative restoration business models. Addressing these challenges necessitates capacity building and increased collaboration between stakeholders. The Secretariat's assessment emphasized that establishing a transparent and verifiable AFR100 monitoring platform would attract investment into restoration by providing clear information on changes in land cover. This tracking mechanism helps ministries and countries demonstrate progress and encourages donors to continue investing in successful projects (Partnership for Forests 2022).

Oh et al., (2020) scrutinized the divergence, trajectory, and attributes of North Korean forest restoration policy vis-à-vis analogous strategies in South Korea. South Korea's Forest Conservation and Afforestation Project's triumph factors were segmented into four policy spheres: policy and system enhancement, assessment and skill augmentation, populace engagement stimulation, and restoration infrastructure establishment. These facets bore resemblance to North

Korea's Forest Restoration Battle. South Korea crafted the 1st and 2nd Forest Conservation and Afforestation Plans, shifting Korea Forest Service governance to its Ministry of Home Affairs, akin to North Korea's forest development plan and command unit for the Forest Restoration Battle. While South Korea relied on tree monitoring and forestry associations, North Korea embraced socialist competition and agroforestry. South Korea fostered participation through nursery projects, tree planting drives, and responsible afforestation systems, while North Korea pursued agroforestry, a patriotic forest campaign, and a responsible forest regime. South Korea's substitution of forest fuels with fossil fuels, slash-and-burn field clearance, and erosion mitigation contrasted with North Korea's emphasis on ultra-high-grade anthracite coal and dedicated firewood forests. North Korea toughened penalties for deforestation like anthropogenic forest fires, replacing erosion control with agroforestry for slope management. Restoration foundation creation delineated the most significant disparity, implying potential guidance for future inter-Korean forest collaboration.

In their review of global restoration initiatives, Castro et al., (2021) posits that global environmental policies prioritize forest restoration, launching billion-tree initiatives. However, resources are limited, emphasizing the need for effective restoration. Precision Forest Restoration (PFR) focuses on individual plant success, ensuring adult tree establishment with functional ecosystems, utilizing ecological knowledge and diverse technologies. Though costly per plant, PFR promises long-term cost-effectiveness and resilient forests.

In Europe, Cortina-Segarra et al., (2021) established that ecological restoration stands as a crucial measure against human-induced biodiversity decline and disaster vulnerability. Despite political prioritization, Europe's ecological restoration progress falls short, failing international agreements and EU directives. Through a Delphi process, on surveyed restoration experts, revealing 33 barriers primarily rooted in socio-economic challenges rather than environmental concerns. Insufficient funding, stakeholder conflicts, and low political prioritization emerged as key hurdles. Findings underscored the imperative of heightened political dedication, legal compliance, and optimized financial allocation towards ecological restoration, urging integration into land-use planning and enhanced stakeholder collaboration. This study informs strategies to realize the European Biodiversity Strategy for 2030 and the EU 2030 Restoration Plan.

Other large-scale forest restoration initiatives dating back to the 19th century have been implemented worldwide. Some examples are the successful restoration

of degraded heathlands in Denmark and southern Sweden and the establishing of the Tijuca Forest and Paineiras conservation area in Brazil in the 1860s. In the 20th century, significant forest restoration projects include the extensive reforestation efforts in South Korea after the Korean War, the Green Belt Movement founded by Nobel Prize laureate Wangari Maathai in Kenya in 1977, and natural regeneration programs in Costa Rica and Tanzania during the 1980s (Carrapatoso & Geck 2018). Throughout much of the 20th century, the international forest agenda primarily focused on conservation and sustainable management. The concept of Forest Landscape Restoration and its vision of achieving multiple benefits emerged in 2000 during a workshop organized by the IUCN and the WWF in Spain. However, it was not until the launch of the Bonn Challenge in 2011, calling for the restoration of 150 million hectares by 2020, that forest restoration gained global momentum. This momentum was further amplified by the New York Declaration on Forests in 2014, which extended the target to an additional 200 million hectares by 2030, solidifying FLR as a prominent and influential global movement (Carrapatoso and Geck 2018).

Despite the scarcity of literature on the participation of the private sector in FLR, the few available studies show that in many landscapes, the intricacies of land ownership patterns necessitate the active engagement of the private sector in restoration efforts. Some landowners may willingly participate in Forest Landscape Restoration due to the expectation of direct benefits, anticipating profits from the sale of forest products or environmental services for themselves and their families. Alternatively, landowners may engage in FLR driven by indirect benefits, such as safeguarding commercial crops from erosion and promoting sustainable production practices. Large corporate landowners may find FLR appealing as natural regrowth or planted forests act as effective erosion prevention measures on steeper terrains or serve as crucial firebreaks. Participating in FLR demonstrates a commitment to biodiversity conservation and enhances local livelihoods, providing corporations with positive reputational benefits. The level of private-sector involvement hinges on the policy and institutional frameworks established by governments, including the legal obligations imposed on landowners. Research funded by government initiatives, which mitigates silvicultural and economic risks, often serves as a prerequisite for private-sector involvement, rendering investments more attractive and feasible.

Nonetheless, there is a growing interest among asset managers in sustainable investments. Currently, 128 banks from 41 countries, holding a total of US$74 trillion (approximately 40% of global banking assets), have pledged to the industry-led and UN-supported Net-Zero Banking Alliance. This initiative aims

to align investments with carbon neutrality by 2050. Furthermore, the Principles of Responsible Investment, which outline commitments to environmental, social, and governance standards (consistent with fiduciary duty), boast over 3,000 signatories. These signatories collectively manage assets valued at over US$103 trillion, highlighting a significant global commitment to integrating sustainable practices into investment strategies. Financial instruments like green bonds can potentially mobilize investments for environmentally sustainable assets. However, the impact on restoration funding has been limited. Currently, only 5% of green bonds are allocated to investments in land restoration. It contrasts with more established sustainable asset classes, where allocations are higher: renewable energy receives 35%, sustainable buildings receive 30%, and sustainable transport receives 18%. The disparity in funding distribution highlights the need for increased attention and investment in land restoration through financial instruments like green bonds to address environmental challenges effectively.

Corporations increasingly turn to restoration to address carbon emissions and achieve net-zero emission reduction goals. Over 4,000 corporations have committed to Science-Based Targets, aligning their emission reduction efforts with the Paris Agreement. Restoration plays a crucial role in achieving these targets, with carbon offsets gaining recognition as a viable means. In 2021, carbon credits traded in the voluntary market surpassed US$1 billion, with Forestry and Land Use credits accounting for 61% of this total. Additionally, there is a growing acknowledgment that unsustainable corporate practices pose reputation risks, particularly for consumer-facing brands. With heightened public concern for environmental issues, adopting sustainable actions becomes essential for corporate responsibility and advantageous for marketing purposes.

Despite the increasing interest in restoration, funding from private actors remains limited. In 2019, it was estimated that global funding for biodiversity conservation needs to increase by over US$700 billion annually to combat and reverse land degradation, biodiversity loss, and climate change effectively. A stark contrast is observed in the financial support for agriculture, which was 15 times higher than that allocated for forestry objectives in countries with high deforestation rates in 2019. This substantial financial gap underscores the challenges faced by restoration interventions in attracting sufficient funding despite the growing enthusiasm from private actors. Surprisingly, there is a lack of studies exploring the reasons behind these persistent funding shortfalls.

Increased engagement from private funders holds the potential to scale global restoration efforts significantly. While some barriers hinder corporate finance,

corporations often perceive existing market-driven incentives to participate in agroforestry, regenerative agriculture, and active restoration (Löfqvist et al. 2023). This engagement is driven by a desire to meet emission reduction commitments, enhance the sustainability of supply chains, make a positive impact, and improve branding. A clear business presence in the target region plays a pivotal role. Conversely, asset managers encounter barriers, viewing restoration as a nascent, high-risk asset class with insufficient return on investment (ROI) to justify the associated risks (Löfqvist et al. 2023). Asset managers typically favor low-risk projects with commercial products and find that few restoration projects meet these criteria. Notably, there is limited interest in natural regeneration due to a lack of storytelling potential, and quantification systems for benefits were a barrier to financing restoration approaches, such as natural regeneration, which did not have easily communicated pathways linking intervention to outcomes (Löfqvist et al. 2023; Kedward et al. 2022; Begemann et al. 2023). Overcoming these barriers requires three strands of public intervention: expanding markets for restoration benefits, developing green finance mechanisms with public support, and implementing regulations and subsidies for restoration investments. Public and civil society involvement can facilitate leveraging private finance for equitable and ecologically sound restoration initiatives (Löfqvist et al. 2023; Löfqvist and Ghazoul 2019). However, financial instruments designed to attract substantial private finance into conservation often face challenges related to high transaction costs, which are necessary to ensure ecological effectiveness. These costs may conflict with the preferences of institutional investors seeking competitive returns, market efficiency, and scalable investments. Market-led environmental governance approaches often encounter conflicts of interest, undermining their ability to address this trade-off effectively. Strategies involving investors using public funds to reduce risks in natural investments may not be as promising as assumed. The substantial costs involved in making nature markets conventionally 'investible' can limit the success of such approaches (Flammer et al. 2023; Ding et al. 2017).

From this review, forest landscape restoration represents a dual benefit strategy, enhancing the environment while uplifting human well-being through green jobs, food security, and income opportunities. Seed funding is crucial for effective implementation of national FLR platforms. Challenges facing the private sector in FLR, such as limited funding and regulatory barriers, differ between developed and developing nations, demanding tailored solutions and incentivized partnerships to ensure sustainable restoration efforts.

2.2. Private sector participation in forest landscape restoration in Kenya

Kenya has a total forest cover of 5,226,191.79 hectares, accounting for 8.83% of the country's land area (Chisika & Yeom 2023). The last two decades have witnessed a transformative change in Kenya's forest sector, driven by governmental reforms. Key milestones include the Forest Act of 2005 and the Forest Conservation and Management Act of 2016, coinciding with the 2010 Constitution. Establishing the Kenya Forest Service (KFS) as a semiautonomous agency enhanced resource allocation and operational capacity. The Participatory Forest Management approach led to 250 Community Forest Associations and 290 Charcoal Producer Associations regulating charcoal production. Devolution of some forestry functions to county governments, decentralization of governance, and strengthened water tower management exemplify Kenya's commitment to environmental sustainability and community engagement (Mutune et al. 2017).

Unfortunately, approximately 22% of the entire land area in Kenya is degraded, resulting in an annual economic loss of around USD 1.3 billion. It emphasizes the critical requirement for landscape restoration. Kenya has established ambitious Forest and Landscape Restoration (FLR) objectives to raise and sustain a 30% tree cover and rejuvenate 10.6 million hectares of deteriorated lands by planting 15 billion trees before 2032. On the global stage, the country has pledged to decrease its greenhouse gas emissions by 32% by 2030 (Muthuri et al. 2022; Muthuri et al. 2023).

To address the above challenges, the Ministry of Environment, Climate Change and Forestry (MoECCF) developed the Forest Landscape Restoration Implementation Action Plan 2023-2027 (FOLAREP) through the Kenya Forest Service. Recognizing the pivotal role of FLR, the plan is aligned with efforts with Kenya's broader goals of achieving food and water security, sustainable energy, low-carbon resilience, and economic empowerment. Given the collaborative nature of FLR, county governments hold a crucial role, and the Ministry facilitates cooperation between national and county entities. Additionally, efforts underway to foster partnerships with development partners, research institutions, and grassroots networks are also entrenched in the plan.

Recently, the FOLAREP was merged with other forestry development plans in the country to generate the National Landscape and Ecosystem Restoration Strategy 2023-2032, which seeks to accelerate actions towards the achievement of the 30% national tree cover by 2032 to enhance climate-reliant national economic growth and development goals within the context of the Vision 2030

and contribute toward Kenya's commitments to regional and global conventions. Strategy implementation is geared toward supporting a whole-government and whole-society approach to fully rehabilitate and restore 10.6 million hectares through constituency-based nerve centers covering 290 constituencies and some specially selected ecosystems and water towers threatened by deforestation and degradation.

In the context of climate change, numerous private sector stakeholders in the Kenyan forestry sector are actively involved in primary and secondary forest production (Makanji & Oeba 2019). At the grassroots level, individual farmers, driven by personal initiative or encouraged by incentives from entities like the Kenya Forest Service (KFS), partake in tree planting on their farms or engage in participatory forest management. The primary motivation for these farmers is to cultivate trees for personal use, such as constructing houses, obtaining firewood, or generating income through selling tree products to support their households. TIST stands out in Kenya as a distinctive program involving farmers in tree cultivation for climate change mitigation and adaptation. Its primary objectives include increasing biomass and carbon sequestration, ensuring a sustainable fuel wood supply, generating revenue through carbon credit sales, providing crucial training on social and health-related topics, and enhancing area biodiversity with canopy and indigenous trees. Over 54,000 farmers participate in TIST, consciously contributing to climate change mitigation. TIST has successfully validated and verified Voluntary Carbon Standard (VCS) projects, achieving gold-level certification under the Climate Community and Biodiversity Standard (CCBA). Forest carbon credits are obtained and shared with participating farmers (Makanji & Oeba 2019).

In contrast, secondary forest production involves actors like charcoal producers, loggers, and millers, who are less consciously engaged in climate activities and emphasize profit margins over environmental sustainability. However, the potential exists to inform and encourage these actors to shift towards climate-friendly practices. Noteworthy organizations consciously engaged in climate change mitigation and adaptation include Mikoko Pamoja, VI Agroforestry WWF, Kenya Airways, Bamburi Cement Company, and British American Tobacco (BAT). These entities actively participate in tree planting, land rehabilitation, and capacity building to enhance resilience and adaptive capacity, offsetting their emissions through increased carbon stock. Vi Agroforestry, Mikoko Pamoja, and WWF engage in carbon credit trading based on their afforestation, reforestation, and rehabilitation initiatives, showcasing the private sector's potential in forestry to combat climate change. However, these projects

heavily rely on external funding and carbon credit sales are affected by fluctuating prices in compliance and voluntary markets, posing a sustainability challenge. To address this, promoting and expanding such successful practices across the forestry sector is crucial. Sustainable solutions demand collaborative efforts between the government and private sector in forestry, necessitating the development of appropriate institutional and legal frameworks to support enduring climate change and adaptation activities across devolved governance units (Makanji and Oeba 2019). From this review, even though the engagement of the private sector in forest landscape restoration is commonly viewed as a financing mechanism, their involvement is crucial for realizing the Government of Kenya's commitment to raise tree cover to 30% and restore 5.1 million hectares of deforested and degraded landscapes by 2030, aligning with the Bonn Challenge and AFR100 targets.

2. Materials and Methods

3.1. Case study research design

This study used a case study research design to evaluate the implications of private sector participation in forest landscape restoration. This method was characterized by its in-depth exploration of two cases, allowing researchers to gain a nuanced understanding of the complexities and dynamics at play. Unlike quantitative research, which focuses on statistical trends across a large sample, case study design prioritizes the richness of detailed information. Moreover, the strength of case study research lies in its ability to provide insights into real-world situations, offering a contextually rich narrative beyond mere statistical analysis. Researchers employing this design aimed to uncover patterns, relationships, and underlying mechanisms that contributed to a more profound comprehension of the specific case, making it a valuable tool in fields where a comprehensive exploration of unique and intricate phenomena was essential.

2.1. Case studies

2.1.1. Makueni County

Makueni County, located in the southeastern part of Kenya, shares borders with Machakos, Kitui, Taita Taveta, and Kajiado. Encompassing an area of 8,176.7 km², it has a population of 987,653, with a growth rate of 1.1%. The county's monetary poverty rate is 34.5%, slightly below the national average of 35.7%, indicating around 341,197 people experiencing monetary poverty. However, the multidimensional poverty rate in Makueni is 59.7%, significantly higher than the

monetary poverty rate, affecting 589,618 individuals. The projections estimate the population will reach 1,065,482 and 1,087,776 by 2025 and 2027, respectively, highlighting the challenges of multidimensional poverty in the region. Makueni County aspires to build a resilient economy and community, emphasizing forest landscape restoration within the Environment, Natural Resources, and Climate sub-sector. Initiatives include afforestation at household and institutional levels, greening school programs, and law enforcement against deforestation. The county also implements an enhanced climate information system to provide timely and relevant data, empowering communities in decision-making processes.

In forest and landscape restoration, the county government collaborated with the World Resources Institute in 2018 to conduct a Restoration Opportunities Assessment Methodology study (ROAM). The primary objective of this assessment was to pinpoint the challenges and opportunities related to land use for restoration within the county. The findings of this study served as the foundational framework for subsequent forest and landscape restoration initiatives. The assessment identified seven restoration options, including afforestation and reforestation of natural forests, agroforestry, riparian land restoration, road buffer zone restoration, rangeland rehabilitation, plantation forests, and the rehabilitation of natural forests. Subsequently, the government implemented the recommendations outlined in the ROAM report, fostering the practical application of restoration strategies in the county. The key outputs and outcomes from implementing the ROAM process in the county are discussed hereunder.

Makuli- Nzaui Landscape restoration: In collaboration with WRI, a Restoration Action Plan 2021-2026 was prepared. WRI, through the Mastercard Foundation, is financing the planting of 1,200,000 seedlings in five (5) years. So far, 87,500 seedlings have been planted in forest areas and farmland. On afforestation, the government, in partnership with Kenya Forest Service (KFS), rehabilitated degraded natural forest through enrichment planting of 100 Ha in Makuli, Nthangu, Mbooni, and Kilungu Forests; production of four million seedlings in KFS tree nurseries in Makuli, Kibwezi, Mbooni, Kilungu, Nthangu, and Makueni central nursery; establishment of 100 Ha woodlots on farms; restocking of 50 Ha of industrial forest plantations; rehabilitation of 10 Ha in riverine areas and establishment of 10 km firebreaks. One hundred thirty thousand eight hundred seedlings were also planted in institutions, market areas, water project sites, and an additional 58 tree nurseries. A devolution forest was established at Kwa Kathoka ATC during the devolution conference, where 1,000 indigenous tree

species were planted in collaboration with the Council of Governors. On degraded Land rehabilitation, the government rehabilitated the Matwikani watershed by planting 3,000 tree seedlings, 200 stalks of Napier grass, 400 giant bamboo seedlings, and 100 stalks of live materials (Sisal). Nine farm ponds were excavated, one water pan was de-silted, and 59 household farms were provided with 1 kg of grass for grass reseeding. They were also trained in water harvesting technologies.

Additionally, nine gully sites were rehabilitated across the county. For water catchment protection, 17 km of terraces were excavated as soil-water conservation structures in Muuni-Maatha Hill, Mbui Nzau Hills, and Yekanga forest to enhance the hydro-ecological function of county forests. The government Rehabilitated Kiboko and Kiu in Kibwezi West, Mangelete, Kwa Mukonza, and Umani in Kibwezi East, and Kinyongo wetlands in Mbooni sub-county by planting seedlings in 40 hectares of land, constructing and rehabilitating weirs, sand dams, and grass reseeding. One thousand five hundred tree seedlings were also planted along the river banks of the Kanyonga and Kambu rivers. Kenya Forest Service (KFS) protected and conserved 15,004.5 Ha of gazetted forest against all threats and degradation activities on forest conservation.

On environmental governance, the sub-sector developed the Makueni Environment and Climate Change Policy (ECCP), 2021, amended Makueni County Sand Conservation and Utilization Act 2015, revised in 2022; 19 Ward Sand Conservation and Utilization Committees (WSCUC) were established to oversee the sustainable sand harvesting and enhanced participatory natural resource management; County Environment Committee (CEC) was established and gazetted in 2018; Community Forest Associations (CFA) were established, that is Mbooni Community Forest Association (MBOCOFOA).

2.1.2. Elgeyo Maraakwet County

Elgeyo Marakwet County covers an area of 3029.6 km², constituting 0.4% of Kenya's total landmass. Positioned between latitude 0o 10' and 1o 20' North and longitude 35° 10' to 35° 44' East, it shares borders with West Pokot County to the North, Baringo County to the East, Trans Nzoia County to the Northwest, and Uasin Gishu County to the West. With an elongated shape, the county lies between the Uasin Gishu Plateau in the West and the Kerio River in the East. Originating in the Southern highlands of the county, the Kerio River flows into Lake Turkana. The sub-counties in Elgeyo Marakwet exhibit a balanced distribution of gender. Marakwet West has a higher population of both males

(68,948) and females (68,560), as well as Keiyo South with males (60,919) and females (59,827).

In contrast, Keiyo North has a slightly lower population, with males at 49,601 and females at 49,574. Similarly, Marakwet East has a population of 47,849 males and 49,190 females. Elgeyo Marakwet County's HDI is 0.53, lower than the national HDI of 0.60. It can be partly attributed to the ecological zones of the county, with the Kerio Valley region having a high poverty index. In pursuit of its vision, the county aims to be a beacon of progress, advocating for citizen-centric development that places the well-being and aspirations of its residents at the forefront. With a mission focused on transformative actions, the county is committed to empowering its community members, fostering active participation, implementing innovative sustainable development practices, and bolstering climate resilience. Through these concerted efforts, the county envisions a future where livelihoods are elevated and its residents' overall quality of life is enhanced.

In forest landscape restoration, the county government had set a target to mitigate climate change impacts by increasing forest cover from 37.04% to 40.6%. However, by the end of the planned period, the forest cover had decreased to 29.95%. This decline was attributed to technological advancements that refined measurement standards, transitioning from assessing land under cover to precise tree counting. The negative impact of this measurement shift, coupled with deforestation, forest encroachment, charcoal burning, soil erosion, forest fires, and illegal logging, could have had severe consequences. Fortunately, various interventions were implemented, including establishing 47 tree nursery beds, planting 537,411 assorted exotic tree seedlings, and introducing 10,077 bamboo and other environmentally friendly trees.

Furthermore, upon realizing that indigenous forests in Elgeyo Marakwet County face depletion due to human activities, impacting the environment and exacerbating climatic challenges. The county recognizes the importance of integrating indigenous principles into forest conservation to address adverse weather conditions. Traditional practices, such as respecting riverbanks, were crucial in maintaining water sources. However, contemporary farming practices contribute to environmental degradation and health issues. The United Nations Development Programme (UNDP) supports the county in incorporating indigenous knowledge into climate adaptation strategies. The Sustainable Forest Management and Tree Growing Bill establishes a Conservation Council involving indigenous communities to promote community-driven development

priorities through public participation and citizen conservation groups, ensuring ownership and sustainability (Maarifa Centre Website 2024).

Moreover, to promote sustainable tree utilization, the county enacted the Charcoal Act 2017, designed to apply to all forests and woodlands within the county and private lands within the county. Its primary focus is the regulation of charcoal production. Its objectives are poverty reduction, employment creation, and improved livelihoods by encouraging the sustainable use, conservation, and management of forests and trees. The Act also aims to promote soil and water conservation, tree planting, engage communities, the private sector, and other stakeholders in forest management to generate employment, foster dry land forestry for wood fuel, charcoal, and non-wood forest products, and support adaptation and mitigation efforts in climate change. The legislation establishes the County Environmental Committee, which is responsible for vetting and approving applications from Charcoal Producer Associations, reviewing and recommending licensing, monitoring restoration plans, and overseeing tree planting events, with comprehensive powers to execute its functions (UNEP-LEAP Website 2024).

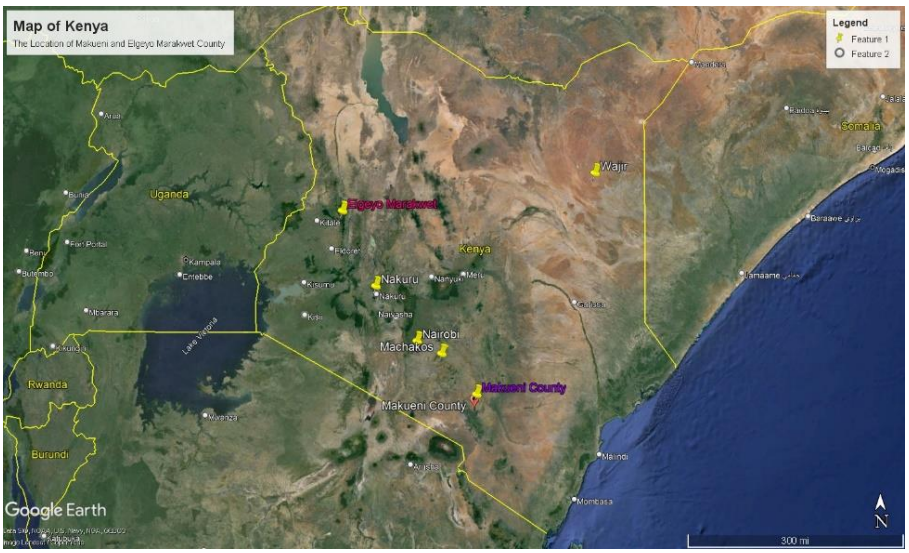

Figure 1. The location of Elgeyo Marakwet County

2.2. Data sources and collection process

The textual analysis process was used to explore the current status of private sector participation in forest landscape restoration in Elgeyo Marakwet and Makueni counties. Five broad areas, namely, participation activities, process, impacts, challenges, and achievements of private sector participation, were analyzed for the current status of each county. The process of data evaluation involved several steps. First, the text was read and reread to gain a general understanding of the content. Second, the text was broken down into smaller units of meaning, such as words, phrases, and sentences. Third, the units of meaning were coded based on their relevance to the three thematic areas. Fourth, the codes were categorized based on their similarities and differences. Fifth, the categories were analyzed to identify patterns and themes related to each of the three key thematic areas of sustainability, which include social, economic, and environmental. Finally, the themes were interpreted and used to conclude the current status of community participation in development planning. The key documents consulted, including the type, source, and key findings during the study, are shown in Table 1.

No.	Name of document	Type	Source	Key Findings
1.	Constitution of Kenya, 2010	Policy	Internet	Encourages private sector participation in forest restoration by recognizing environmental rights, promoting public participation, and emphasizing collaborative approaches to forest management.
2.	Public Private Partnership Act, 2013	Policy	Internet	Provides a legal framework that encourages private sector participation in forest restoration by facilitating collaboration, sharing risks, promoting innovation and efficiency, attracting financial resources, and ensuring timely project implementation.
3.	Sessional Paper on Devolved Government Under the Constitution of Kenya, 2010	Policy	Internet	Indirectly promotes private sector participation in forest restoration by empowering county governments, encouraging partnerships, mobilizing resources, creating economic opportunities, and fostering inclusive planning processes at the local level.
4.	County Governments Act, 2012	Policy	Internet	Indirectly promotes private sector participation in forest restoration by decentralizing decision-making, encouraging the development of CIDPs, allowing for partnerships, facilitating resource mobilization, mandating environmental

No.	Name of document	Type	Source	Key Findings
				management, and promoting local economic development at the county level.
5.	Makueni County Integrated Development Plan 2023- 2027	Action plan	Internet	Provides opportunities for private sector involvement in the environment sub-sector.
6.	Makueni County Forest and Landscape Restoration Implementation Plan (FOLAREP) 2023-2030	Action Plan	Internet	Provides opportunities for private sector involvement in the environment sub-sector.
7.	Elgeyo Marakwet County Integrated Development Plan 2023-2027	Action plan	Internet	Provides opportunities for private sector involvement in the environment sub-sector.
8.	Chepsiror (2020)	Research article	University of Nairobi Research Archive	The study examined the impacts of Chebara Dam on a local community in Elgeyo-Marakwet county, Kenya, using qualitative and quantitative methods. While 68% reported social and economic benefits, 81% were unaware of conservation efforts by ELDOWAS, causing dissatisfaction. Only 3% were employed directly, and 6% received irregular water supply. The study suggests a need for continuous community-based plans to share benefits from the dam.
9.	Cherop et al. (2023)	Research article	Google Scholar	The pre-colonial history of Elgeyo Marakwet reveals an agro-pastoral society closely linked to the environment. The introduction of the shamba system in 1941 aimed to utilize local knowledge for sustainable forest resource management. However, the system failed due to mismanagement and abuse. Local communities desire its reintroduction, emphasizing the need for improved governance, transparency, and rules for successful and sustainable operation.
10.	Kibet (2021)	Research article	University of Nairobi Research Archive	This study, conducted in Marakwet East Escarpment, Elgeyo-Marakwet County, explores the impact of forest cover on landslide risk reduction. Analyzing data from 2000 to 2020 reveals a loss of 390.53 ha of forest cover, correlating with increased landslide frequencies. The local community knows the importance of forest cover, but poverty drives deforestation. Recommendations include policy development for forest protection, conservation, and sustainable management.

No.	Name of document	Type	Source	Key Findings
11.	Abuya (2021)	Research article	Maseno University Institutional Repository	This study in Kalawani Location, Makueni County, examines the impact of the Resilience Livelihoods (RELI) program on community response to climate-related shocks. Focusing on drought, the research finds that RELI interventions, including addressing agriculture risks and providing financial services, increased the community's capacity to respond to climate-related challenges. The study emphasizes the need to overcome barriers for sustained resilience building.
12.	Wanjira & Muriuki (2020)	Research article	Status report	The study highlights the evolution of agroforestry research and development in Kenya, emphasizing investments in research, extension services, education, and certification of tree nurseries. It stresses the need for central coordination, education programs, certification of nurseries, institutional frameworks, farmer associations, and climate finance to scale up agroforestry practices for environmental and economic benefits. The collaboration between government ministries, research institutions, universities, and farmers is crucial for the successful implementation and widespread adoption of agroforestry in the country.
13.	Kenya Water Towers Status Report for Elgeyo Hills (2019-2020)	Status report	Internet	The Elgeyo Hills Water Tower, vital for Elgeyo Marakwet County, faces challenges threatening its ecosystem services like water provision, climate regulation, and cultural significance. Increased degradation endangers its capacity to provide essential goods and services. Conservation initiatives and campaigns are crucial for restoration, involving collaborative efforts and implementing recommended measures such as reclaiming encroached areas, rehabilitating degraded zones, promoting alternative livelihoods, and sustainable land management practices. These actions aim to safeguard this critical water source for Lake Victoria and Turkana, drained by Nzoia and Kerio Rivers.

Table 1. Documents reviewed

2.3. Data analysis

The study evaluated the challenges facing the private sector in landscape restoration using the Triple Bottom Line Approach by textual analysis. This approach evaluates challenges across three key dimensions: economic, social, and environmental impacts. A holistic assessment is achieved by scrutinizing the economic viability, social responsibility, and environmental stewardship of private sector initiatives. The analysis goes beyond mere financial considerations, incorporates the broader implications of restoration efforts on communities and ecosystems, and underscores the importance of a balanced and sustainable approach, ensuring that economic gains are achieved without compromising social well-being or environmental integrity. Figure 1 summarizes the conceptual framework developed after the synthesis of the theoretical and empirical findings. Engaging the private sector in landscape restoration encounters multiple challenges. Short-term profit priorities often overshadow a commitment to long-term environmental benefits, while the prolonged timeframe for restoration results conflicts with businesses' preference for quicker returns. Uncertain regulatory environments, marked by ambiguous policies and frequent changes, add hesitancy. Lack of expertise in ecosystems, biodiversity, and sustainable practices hampers participation. Collaboration hurdles with government bodies, NGOs, and local communities hinder effective teamwork. Perceived high risks from climate change uncertainties and market fluctuations discourage involvement. High investment costs and limited understanding of long-term benefits contribute to the private sector's reluctance to embrace landscape restoration initiatives.

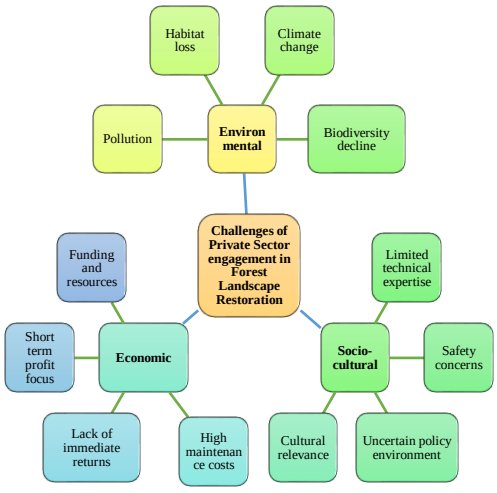

Figure 2. Conceptual framework for challenges facing private sector involvement in forest landscape restoration

3. Results

3.1. Current status of private forestry sector engagement in landscape restoration

3.1.1. Makueni county

Private sector involvement in County landscape restoration focuses on agroforestry, silvopastoral, and plantation forests, comprising 95% of options (Table 2). The emphasis is on enhancing rangeland resilience against climate-induced drought. Key project wards include Nguumo, Makindu, Thange, Ivingoni/Nzambani, and Nguu/Masumba. Private actors, seen as resource mobilizers, operate through the county environment committee. The TWENDE Project, with partners like NDMA, ADSE, IUCN, CI, and SDL, drives involvement. Limited information on participation incentives exists. WRI, with Mastercard Foundation support, funds the planting of 1,200,000 seedlings, with 200,000 already planted.

Broad area	Description
Participation options	The largest opportunity for landscape restoration in the county lies in Agroforestry (44%), Silvopastoral and Rangeland rehabilitation (32%), and Plantation forests (19%); collectively, it accounts for 95% of the restoration options in the county.
Activities	Reducing the cost of climate change-induced drought on the national economy by increasing resilience of the livestock and other land use sectors in restored and effectively governed rangeland ecosystems (FOLAREP 2023-2027).
Restoration sites	The project wards in Makueni are Nguumo, Makindu, Thange, Ivingoni/Nzambani, Nguu/Masumba.
Process	Private sector players are viewed as the resource mobilization actors. Forest landscape restoration is implemented through the county environment committee. Its membership includes six representatives from Private Sector, Development Partners, and PBOs, and representatives from County Departments and Lead Government agencies.
Private actors	The TWENDE Project implemented by the county in collaboration with partners
Incentives for participation	Information on incentives for promoting forest landscape restoration is scarce.
Impacts	WRI, through the Mastercard Foundation, is financing the planting of three and growing 1,200,000 seedlings in five (5) years. So far, more than 200,000 seedlings have been planted in both forestland and farmland.

Table 2. Current status of forest landscape restoration in Makueni County

Private sector involvement in restoring the Elgeyo Hills Water Tower is marked by the United Nations Development Programme (UNDP) engagement. The county government targets climate change by increasing forest cover. Activities include afforestation, reforestation, and community support. The strategy

emphasizes community awareness, education, law enforcement, and rehabilitation, pushing for public-private partnerships to engage wood-dependent companies. Despite progress, specific incentives for private involvement lack clarity in the Sustainable Forest Management and Tree Growing Bill. Implemented interventions include establishing tree nursery beds, planting various seedlings, introducing eco-friendly trees, and showcasing restoration progress.

Broad area	Description
Participation options	The county government had set a target to mitigate climate change impacts by increasing forest cover from 37.04% to 40.6%.
Activities	Afforestation and reforestation and community livelihood support
Restoration sites	Elgeyo-Cherangany Hills ecosystem traverses Elgeyo Marakwet, West Pokot, Trans-Nzoia, and Uasin Gishu Counties. Elgeyo Hills Water Tower is located in Elgeyo Marakwet County and covers an area of 108,194 ha. It encompasses eight (8) gazetted forest blocks: Kaptagat, Kipkabus, Kessup, Kapchorua IV, Tingwa Hills, Tumeiyo, Kapchorua I, and Metkei.
Process	A comprehensive strategy is proposed to address the challenges facing the Elgeyo Hills Water Tower. Firstly, community sensitization and awareness campaigns will be conducted, emphasizing the importance of the Water Tower. Education and training programs will be implemented to empower local communities with the knowledge needed for sustainable practices. Secondly, strict enforcement of laws, enhanced surveillance, and patrols will be employed to curb illegal activities within the Water Tower and ensure proper management of the PELIS program. The reclamation of encroached areas within the gazetted forest is paramount, followed by rehabilitation and reforestation efforts in these restored zones, including planting indigenous trees. Public-private partnerships will be promoted, engaging companies reliant on wood products through initiatives like payment for ecosystem services. Agroforestry will be encouraged to boost tree cover within the Water Tower, providing an alternative income source and mitigating illegal logging. Additionally, alternative livelihood programs such as bamboo farming, beekeeping and adopting alternative energy sources like solar, energy-saving stoves, and micro-hydro-dam power units will be promoted, reducing dependency on forest products. This comprehensive approach aims to ensure the sustainable management and conservation of the Elgeyo Hills Water Tower.
Private actors	United Nations Development Programme (UNDP)
Incentives for participation	The Sustainable Forest Management and Tree Growing Bill establishes a Conservation Council involving indigenous communities to promote community-driven development priorities through public participation. However, the bill does not explicitly state the specific incentives for private sector involvement in restoration.
Impacts	Various interventions were implemented, including establishing 47 tree nursery beds, planting 537,411 assorted exotic tree seedlings, and introducing 10,077 bamboo and other environmentally friendly trees.

Table 1. Current status of forest landscape restoration in Elgeyo Marakwet County

3.2. Key challenges and strategies for landscape restoration

3.2.1. Makueni County

From Table 4, Elgeyo Marakwet's forest landscape restoration faces environmental challenges like low FLR awareness and prolonged droughts, with social issues including limited awareness, political prioritization, poverty, and gender inequalities. Economic hurdles encompass low prioritization, insufficient funds, high costs, corruption, market fluctuations, and unclear benefit-sharing structures. Addressing these requires a comprehensive, collaborative approach to sustainability.

Thematic Area	Challenge
Environmental	▪ Limited/low uptake of information on FLR; ▪ Prolonged droughts; ▪ Uncontrolled land use changes and settlement in sloppy areas disturb the soil structure (Infrastructure that interferes with the hydrology); ▪ Pollution; ▪ Encroachment
Social	▪ Limited awareness of FLR and its benefits that can influence accurate decision-making ▪ The political inclination of most leaders towards prioritization of FLR projects in hotspots ▪ Negative political incitement towards conservation initiatives ▪ High poverty levels lead to high dependency on the land-based sector; ▪ Insufficient information on degradation status and value of forest resources to support proper planning; ▪ Gender inequalities and lack of inclusivity in decision-making ▪ Inequalities in benefit sharing from proceeds of FLR; ▪ Inadequate knowledge of the importance and impacts of FLR among the communities;
Economic	▪ Low prioritization and inadequate budget allocation for FLR; ▪ Insufficient financial resources for restoration of degraded lands; ▪ High cost of FLR activities implementation; ▪ Unpredictable exchange rates ▪ Corruption; ▪ Market fluctuation and failure – unclear valuation for ecosystem services and nature-based products ▪ Lack of clear structures in benefit-sharing

Table 2. Key challenges affecting private sector participation in forest landscape restoration in Makueni County.

3.2.2. Elgeyo Marakwet County

Private sector involvement in forest landscape restoration in Elgeyo Marakwet County encounters challenges in invasive species spread, population pressure causing land degradation, limited youth participation, gaps in legal frameworks, and public knowledge on conservation (Table 5). Inadequate staffing and monitoring systems, communal land tenure issues, funding delays, and a lack of value addition exacerbate the hurdles.

Thematic Area	Challenge
Environmental	▪ The spread of invasive species such as *Prosopis juliflora* (Sw.) DC., Prodr. [A. P. de Candolle] 2: 447 (1825). ▪ Deforestation, forest encroachment, charcoal burning, soil erosion, forest fires, and illegal logging; ▪ The forest cover had decreased to 29.95%. This decline was attributed to technological advancements that refined measurement standards, transitioning from assessing land under cover to precise tree counting.
Social	▪ Population pressure is contributing to land degradation. ▪ Limited youth participation in forest and landscape restoration ▪ Gaps in some existing legal and policy frameworks for the environment sector that lack provisions on forest and landscape restoration ▪ Limited community/public knowledge on environmental protection/conservation. ▪ Inadequate staffing in county government departments, including departments in charge of the environment ▪ Inadequate monitoring and evaluation systems for restoration initiatives at the county level ▪ Communal land tenure systems may be problematic as county governments cannot initiate restoration initiatives or restrict activities on them.
Economic	▪ Limited funding to the environment sector is aggravated by the slow transfer of funds from the exchequer to various county governments. It delays the implementation of programs aligned with landscape restoration. ▪ Limited value addition and product diversification for forest products resulting in more forest destruction

Table 3. Key challenges facing forest landscape restoration in Elgeyo Marakwet County

4. Discussion

Forest landscape restoration through effective private-sector engagement is a key strategy for achieving sustainable forest management outcomes in both developed and developing countries. The private sector drives financial, technological, and innovative solutions, forging a collaborative approach that benefits forest ecosystems and businesses (IUCN Website 2024; Partnership for Forests, 2022; Carrapatoso & Geck 2018). However, the challenges facing

landscape restoration differ between developed and developing countries calling for differentiated initiatives (Cortina-Segarra et al., 2021; Oh et al., 2020). It is behind this backdrop that in a bid to promote forest landscape restoration through private sector involvement, Kenya has deliberately entrenched the private sector's voice in key national development policies and legislation, such as the Forest Conservation and Management Act of 2016, coinciding with the 2010 Constitution (Chisika & Yeom 2023). Recently, the private sector's role has also been recognized in the National Landscape and Ecosystem Restoration Strategy 2023-2032, which seeks to accelerate actions towards the achievement of the 30% national tree cover by 2032 (Chisika & Yeom 2023).

In the quest to promote the private sector's role in forest landscape restoration at the local level, the many devolved units are increasingly developing and adopting forest landscape restoration implementation action plans as the implementation avenues while aligned with Kenya's broader socio-economic development goals. Forest landscape restoration plans are crucial instruments for translating restoration aspirations into tangible, impactful actions that contribute to biodiversity conservation, climate resilience, and sustainable land management. Their development involves a meticulous and participatory process with multiple stages guided by key policies and legislations, especially the County Governments Act of 2012. However, the progress and process of landscape restoration is not uniform across counties. Moreover, with the changing socio-economic matrices, the forest restoration outcomes at county levels have been largely contextual. This paper aimed to use document content analysis in the case of Elgeyo Marakwet and Makueni Counties to explore the current status of private sector involvement in forest restoration and identify challenges to devise strategies for sustainable participation.

When the data analytical approach developed from a literature review was applied to the two case counties, results show that private sector involvement in County landscape restoration primarily focuses on various restoration options. In the case of Makueni, restoration is focused on agroforestry, silvopastoral, and plantation forests, comprising 95% of available options (Table 2). In Makueni, the core objective is enhancing rangeland resilience against climate-induced drought, with targeted project wards including Nguumo, Makindu, Thange, Ivingoni/Nzambani, and Nguu/Masumba. Moreover, private actors, recognized as key resource mobilizers, operate through the county environment committee, with the TWENDE Project playing a prominent role and collaborating with partners like NDMA, ADSE, IUCN, CI, and SDL. While limited information

exists on incentives, WRI, backed by the Mastercard Foundation, funded the planting of 1,200,000 seedlings, with 200,000 already planted.

In contrast, in Elgeyo Marakwet, the private sector involvement engaged the United Nations Development Programme (UNDP), aiming to counter climate change by increasing forest cover through activities like afforestation, reforestation, and community support. The restoration strategy in Elgeyo Marakwet underscores community awareness, education, law enforcement, and rehabilitation, focusing on public-private partnerships engaging wood-dependent companies. However, the Sustainable Forest Management and Tree Growing Bill and other policy documents lack clarity on private-sector incentives that could spur private-sector involvement in forest restoration. Nonetheless, the county has implemented some interventions, including establishing tree nursery beds, planting various seedlings, and introducing eco-friendly trees, showcasing positive strides in forest restoration efforts.

A number of challenges face private sector participation in forest restoration. In Makueni County, forest landscape restoration faces environmental challenges, including low awareness and prolonged droughts, with social issues like limited awareness, political prioritization, poverty, and gender inequalities. Economic hurdles involve low prioritization, insufficient funds, high costs, corruption, market fluctuations, and unclear benefit-sharing structures. Elgeyo Marakwet County encounters challenges in invasive species spread, population pressure, limited youth participation, legal framework gaps, and public knowledge on conservation. Inadequate staffing, communal land tenure issues, funding delays, and a lack of value addition exacerbate the hurdles. These multi-faceted challenges demand a comprehensive and collaborative approach for sustainable solutions in both counties. This finding is consistent with the findings from local studies conducted in Makueni and Elgeyo Marakwet counties and has called for enhancing private sector participation in forest landscape restoration such as and studies such as Chepsiror (2020), Cherop et al. (2023), Kibet (2021) in Elgeyo Marakwet & Abuya (2021) in the case of Makueni County.

However, in this paper's considered opinion, the lack of explicit policy statement on the specific incentives advanced to the private sector, and lack of economic valuation of various forest ecosystems has the greatest impact on their involvement in forest restoration. A clear policy statement delineating specific incentives for private sector involvement and the lack of economic valuation for diverse forest ecosystems pose significant impediments to robust private sector engagement in forest restoration. Private entities may hesitate to invest or actively participate in restoration initiatives without a defined policy framework explicitly

outlining the incentives. Furthermore, the absence of economic valuation mechanisms for different forest ecosystems makes it challenging for the private sector to assess the tangible benefits and potential returns on investment associated with their involvement. These gaps in policy clarity and economic valuation create uncertainties that may hinder the enthusiasm and commitment of the private sector to contribute effectively to forest restoration efforts. Scholars have raised similar concerns in reviewed studies (Flammer et al. 2023; Ding et al. 2017; Löfqvist et al. 2023; Löfqvist & Ghazoul 2019; Cortina-Segarra et al., 2021; Oh et al., 2020).

To successfully embark on the ambitious journey of land restoration and overcome the highlighted challenges, the two county governments require a multi-faceted support system to address the challenges facing the private sector's contribution. Financial and technical resources are paramount, including technical guidance from researchers and national government agencies on restoring diverse degraded areas. Establishing robust legal frameworks is essential for promoting and sustaining restoration initiatives. Given the competing demands on county finances, exploring alternative funding sources, such as collaborations with Civil Society Organizations (CSOs), becomes imperative. Institutional strengthening, through the adequate staffing of environmental management departments, forms a foundational element for effective implementation.

Moreover, conducting Restoration Opportunities Assessment Methodology (ROAM) assessments in counties that have not prepared such restoration opportunities reports, such as Elgeyo Marakwet, will aid in identifying priority areas for restoration, demanding coordinated efforts for addressing these restoration needs together with the private sector. Strengthening private sector participation in forest landscape restoration from the outset in developing County Integrated Development Plans (CIDPs) ensures a collective and inclusive approach. Community awareness and sensitization, coupled with support for Income Generating Activities (IGAs), serve as vital alternatives to land-degrading practices, which could also promote the role of the private sector. In addition, establishing a joint County-level monitoring and evaluation could necessitate the creation of robust legal frameworks and monitoring tools, ensuring the growth and survival of restoration efforts. Additional support includes mapping tree cover baselines at the ward level and establishing a collaborative platform for shared insights and initiatives. This comprehensive backing lays the foundation for successful and sustainable land restoration efforts.

Moreover, facilitating effective knowledge sharing, experience, and learning forms a crucial pillar for the success of land restoration endeavors, fostering a collaborative environment among stakeholders, including the private sector and county governments. Developing and enforcing spatial plans, delineating specific zones for various land uses, contributing to organized and sustainable land management, and harmonizing stakeholder activities in alignment with County Integrated Development Plans (CIDPs), ensuring a cohesive and synergistic approach towards inclusive restoration goals. Furthermore, enhancing research and knowledge management addresses specific gaps and needs identified in counties, providing an informed foundation for targeted and effective restoration strategies. This collaborative and well-coordinated approach sets the stage for a comprehensive and successful land restoration framework.

Various avenues for private sector involvement in agroforestry in Kenya are apparent across different domains. They could be leveraged by Makueni County, which has identified agroforestry as a key restoration intervention in its forest landscape restoration plan. Firstly, private sector entities can collaborate with esteemed research institutions and universities in research and extension, including KEFRI, KALRO, ICRAF, Vi Agroforestry, KFS, and others. This collaboration can span funding research initiatives, providing expertise, and implementing cutting-edge agroforestry practices. In education and training, private sector companies can also engage with universities offering Agroforestry degree programs, supporting research, development, and practical training initiatives. This collaboration has the potential to foster contextually relevant agroforestry innovations and gender-sensitive extension models, aligning with the interests of the private sector.

Moreover, private sector involvement in the certification of tree nurseries is facilitated through partnerships with KEPHIS, KALRO, and KEFRI, allowing companies to invest in certified nurseries and ensure the availability of high-quality germplasm for tree planting. The absence of a specific instrument in the institutional framework for scaling up agroforestry within the government presents a distinct opportunity for private-sector engagement. Companies can advocate for policies and incentives that promote agroforestry, aligning their interests with the national agenda. Collaborating with agroforestry-related associations, particularly those in agriculture, enables private sector entities to contribute to agroforestry extension, value chain development, and financing, aligning with corporate social responsibility goals. Studies scuh as Cortina-Segarra et al., (2021) have called for similar collaborative schemes in the context of Europe. Lastly, private sector involvement in climate finance mechanisms,

such as the Green Climate Fund and Carbon Credit schemes, allows businesses to invest in agroforestry projects, supporting farmers in adopting sustainable practices and contributing to environmental resilience. Moreover, there is a need for an aggressive campaign targeting corporations to implore them to invest in forest landscape restoration. Castro et al., (2021) calls for precision forest restoration which focuses on individual trees success by utilizing ecological knowledge and diverse technologies.

In summary, private sector involvement in forest landscape restoration in Elgeyo Marakwet and Makueni Counties, Kenya, faces diverse challenges including environmental, social, and economic barriers. Overcoming these hurdles requires targeted holistic approaches and collaboration with various stakeholders.

5. Conclusion and Recommendations

In conclusion, this study has highlighted the critical role of the private sector in sustainable forest landscape restoration in Kenya, specifically within the context of County Integrated Development Plans (CIDPs) for 2023-2027. Examining Elgeyo Marakwet and Makueni Counties has revealed distinct status and challenges in private sector engagement in landscape restoration. Despite robust approaches, the lack of explicit policy statements on incentives for the private sector and the lack of total economic valuation of most forest landscapes present a notable obstacle, underscoring the urgency for increased policy re-examination and economic valuation of forest landscapes. Makueni's county emerges with best practices and has developed the county forest landscape restoration plan for fostering sustainable landscape restoration. Recommendations to enhance private sector participation across the two counties include a collaborative and well-coordinated approach to set the stage for a comprehensive and successful land restoration framework targeting policy reviews and conducting the total economic valuation of forest landscapes. Future studies should focus on assessing the effectiveness and impacts of innovative models such as Makueni's FOLAREP in sustaining private sector engagement. The limitation of this study is that there could be some risk related to the subjective nature of interpretation, as different analysts may interpret texts differently, leading to misinterpretations.

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Original Paper

Thermal performance study of traditional slate roofed mud houses in the sub-tropical sub montane and low hills of Himachal Pradesh

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Keywords: vernacular architecture; thermal performance; sustainability; slate roof; adobe houses.

Abstract. *The indoor environment of an area affects its overall functionality and sustainability. Vernacular architecture is noted for its use of sustainable solar passive strategies that result in improved thermal performance. The current study looks at the thermal performance of slate-roofed mud huts, which are common in Himachal Pradesh. The field study, which is based on the adaptive approach, entails both qualitative and quantitative components of thermal comfort via a questionnaire-based thermal comfort survey and onsite measurements of environmental attributes of 130 vernacular dwellings in the sub-tropical submontane and low hills of the north Indian state Himachal Pradesh. A thermal comfort survey about physical and psychological parameters of thermal comfort was done for July, and October of the year 2022 symbolizing the summer and autumn seasons in the region. The parameters were also correlated to the thermal sensation votes of the residents of vernacular houses in the area on the ASHRAE thermal sensation scale. The findings revealed that these traditional dwellings work admirably in the study area's comparably hotter summer season and that the majority of the inhabitants are content in a wider range of temperatures.*

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1. Introduction

Vernacular architecture can be referred to as a captivating and culturally rich image of human society, which showcases the evolution of human society through the ages. It is an integral part of the built environment and has helped a lot to shape it in its current modern form. It comes out as a reflection of the local traditions, materials, and practices that have organically developed within specific geographical conditions and communities. It can be referred to as a need-based indigenous style of architecture, which effectively responds to the daily needs of the inhabitants (Oliver, 1997; Singh et al., 2010a). This particular architectural style has aged with human civilization and embodies the wisdom and knowledge of generations, adapting to the unique social, climatic, and cultural needs of its inhabitants. From the mud-brick houses of the African continents to the stilted houses in southeast Asia, vernacular architecture remarkably showcases the diversity of residential arrangements based on the culture and geography of a

place. These houses are often seen as a harmonious part of the natural environment, well integrated with the local landscape.

By understanding the concepts and principles of vernacular architecture one can learn how communities have thrived while honouring their unique identities through their habitats.

1.2 Vernacular architecture of Himachal Pradesh

Himachal Pradesh is the northernmost state of India, nested in the Indian Himalayan region with a difficult terrain and breathtaking natural landscapes. Himachal Pradesh's traditional architecture, developed as a result of centuries of adaptation to the challenging mountainous terrain and climatic conditions reflects a profound understanding of the local environment, culture, and lifestyle.

The vernacular architecture in Himachal Pradesh is characterized by its distinct architectural features, construction techniques, and use of indigenous materials. The structures seamlessly integrate with the topography, benefitting from the natural resources available in the region to the fullest (R. Sharma & Sharma, 2023). Ranging from the mud houses in the ancient hilltop villages to the intricately designed wooden temples and monasteries, each architectural marvel tells a story of resilience, sustainability, and a deep connection to the land. Himachal witnesses a diverse type of climatic regions from the cold deserts in Kinnor and Spiti regions to the green valleys of the Kangra region and the flatter terrain of the Una region each area hosts a distinctive style of climate-responsive architecture (R. Sharma & Tanwar, 2018). Unique building styles like that of Kathkuni, Dhajji Dewari, adobe, and Taq construction showcase the local craftsmanship and the utilization of available resources like wood and stone (Gadi et al., 2019; Heritage Management Team, n.d.). The vernacular architecture of Himachal Pradesh replicates the region's response to the challenges posed by its varied climatic conditions, including heavy snowfall in winter and monsoon rains in the summer. The buildings often incorporate features like steep-sloped roofs to shed snow, and wide eaves to protect against the elements.

1.2 Thermal Performance

Thermal performance can be termed as a resultant of a building's energy exchange with its surrounding thermal environment. Many active and passive strategies are used to keep the internal environment in line with the desires of occupants and boosting the ability of the building exterior to fulfil inhabitants'

Figure 1: A typical vernacular house in the study area

thermal comfort needs (Joshima et al., 2021). The desired indoor circumstances, the prevalent outdoor climatic conditions, and the type of construction materials and techniques employed, as well as their insulation capabilities, all influence thermally efficient building design. Thermal performance of different building components results in the overall experience of an individual in the indoor surroundings in terms of comfort levels and thermal sensations. Thermal properties of the building components along with user's thermal preference majorly govern the overall performance of any building envelope (Joshima et al., 2021). Analysing both the thermal comfort and thermal properties of a building component is required to judge the overall thermal performance of that component.

Henson defines the concept of thermal comfort as "a situation in which the person lacks the impulses to alter the existing interior environment through behavioural changes" (Djongyang et al., 2010). The American society of heating,

refrigerating and air-conditioning engineers (ASHRAE) delineates it as "the state of mind in which an individual expresses satisfaction with the existing thermal conditions" (Chaulagain et al., 2020). It can be seen in the above definitions that thermal comfort largely depends on one's frame of mind, philosophy and culture along with the prevailing environmental conditions (Du et al., 2014). Different individuals in a same indoor environment can have different thermal sensations and can give different opinions on thermal comfort (Kuchen & Scientific, 2018). Lifestyle changes such as change of clothing, position, heating, cooling mechanisms or windows also affect the thermal comfort of individuals in an area. Ecological factors such as outdoor and indoor temperatures and humidity combine with personal factors i.e., clothing or the physical nature of work of the individuals to impact the 'thermal comfort'. The most generally used indicator of thermal well-being is air temperature influenced by other climatic factors like humidity and wind velocity (Singh et al., 2010b). Thus two types of variables affecting thermal comfort were identified as physical parameters namely air temperature, wind velocity, relative humidity, mean radiant temperature, and personal parameters viz levels of clothing insulation and activity performed (metabolic rate) (Mamani et al., 2022).

Indoor thermal conditions of a place majorly govern the energy utilization in a building and therefore hampers the overall sustainability (Barrios et al., 2012; Toe & Kubota, 2015). Different authors have undertaken different approaches to study the concept of thermal comfort like establishing thermal comfort indices (Cardinale et al., 2013) and adaptive thermal comfort models (Dear et al., 1998; Indraganti et al., 2014; Mishra & Ramgopal, 2015; Singh et al., 2015), onsite field surveys (Fernandes et al., 2020; Madhumathi et al., 2014; Priya, 2019; Singh et al., 2010b). International comfort standards like ASHRAE are majorly based on theoretic investigations of heat exchange in the human body. Research show that thermal comfort of a building is a resultant of the thermal performance and material properties of the building envelope (Cardinale et al., 2013).

1.3 Thermal comfort in vernacular houses

Vernacular houses are more climate responsive with better solar passive features as compared to modern style of construction. Studies have shown that vernacular structure has better indoor microclimate when compared to conventional houses in the areas with similar climatic conditions (Madhumathi et al., 2014; Priya, 2019; Sarkar & Bose, 2015; Soleymanpour et al., 2015). Different studies undertaken in Nepal, China and Tibet show that traditional architecture there is very well adapted to the local climate conditions (Bajracharya, 2014; Bodach et al., 2014;

Chaulagain et al., 2020; Gautam et al., 2019) (Borong et al., 2004; Du et al., 2014; Huang et al., 2016; Huang & Liu, 2010). Traditional residential buildings were relatively 1 to 2°c cooler in summer & 1 to 2°c warmer in winters when compared to current residential buildings. Further there are studies focused on adaptive model of thermal comfort showing the effect of quantitative studies along with those of qualitative data analysis. Researchers took onsite measurements of environmental factors like indoor- outdoor temperatures, relative humidity and wind velocity to account for indoor thermal conditions of the buildings. Their interrelationship was further studied to understand the overall behaviour of the area (Chandel & Sarkar, 2015; Jayasudha et al., 2014; Radhakrishnan et al., 2011; Shanthi Priya, Sundarraja, & Radhakrishnan, 2012c; Shanthi Priya, Sundarraja, Radhakrishnan, et al., 2012). Additional factors like clothing were also considered in certain cases (Indraganti et al., 2014).

Another study highlighted the role of solar passive architecture in achieving indoor thermal comfort for south Portugal which further affirms the climate responsive nature of vernacular architecture (Fernandes et al., 2020). The study involved the use of adaptive thermal comfort model, the case-study building showed good indoor thermal comfort conditions for the whole year except winter where heating systems were required. A lot of studies undertake the qualitative method of heat balance suggested by ASHRAE taking predicted mean vote of the residents into consideration (Dili, Naseer, & Varghese, 2010c; Dong et al., 2014; Nematchoua et al., 2014).

In India also similar studies were undertaken to understand the concept of thermal comfort in the local architecture styles of the country. Comparison of vernacular and modern architecture was drawn on the basis of various architectural factors in terms of the thermal comfort of their residents (CV et al., 2016; Madhumathi et al., 2014; Priya, 2019; Shanthi Priya, Sundarraja, & Radhakrishnan, 2012a; Shanthi Priya & Radhakrishnan, 2019). The studies involved use of linear regression analysis of thermal sensation vote (TSV) to acquire the neutral temperature and comfort range. Authors have evaluated the contribution of vernacular features like the presence of internal courtyard and optimum window openings resulting in a constant air movement, highly insulated building envelop, verandas to guard the external walls from solar radiation and the pitched roof to protect from heavy rain, in a passive environment control system resulting in better indoor conditions (Chandel et al., 2016; Dili, Naseer, & Zacharia Varghese, 2010c; Indraganti, 2010; Rajasekar et al., 2020; V. Sharma et al., 2014). More studies in similar context have evaluated the behavioural

adaptation of people in the analysis & gave guidelines as per Mahoney's tables (Sarkar, 2013; Shanthi Priya et al., 2012b).

One similar study for Kerala involved the field measurements, qualitative and quantitative data analysis and use of predicted mean vote analysis based on Fanger's comfort theory for prediction of maximum and minimum indoor temperature in different seasons (Dili et al., 2011; Dili, Naseer, & Varghese, 2010a, 2010c). Mean radiant temperature of traditional house is very low due to the presence of effective air flow and cooler surfaces in the interiors providing evaporative cooling. Use of bioclimatic chart showed that the traditional building is more thermally comfortable. Summer discomfort is marked by both an increase in humidity and a rise in the minimum temperature. Presence of the internal courtyard, optimum number & size of windows on the external walls, walls made of thick laterite blocks and pitched timber roof covered with Mangalore pattern clay tiles prevents the conductive heat flow into the interiors (Dili et al., 2011; Dili, Naseer, & Varghese, 2010b, 2010a; Dili, Naseer, & Zacharia Varghese, 2010a, 2010b).

Yet another study regarding research on thermal performance of vernacular houses in north east India was done for winter, pre-summer, summer/monsoon, and pre-winter months for various climate zones (Singh et al., 2009, 2011b, 2011a). The study showed different styles of architecture practiced in three climate zones was studied specifically in relation to their individual climate responsive features. It was seen that temperature readings for warm - humid and cold - cloudy climates display permissible limits for indoor temperature swing. In cool - humid climates, the indoor temperature variation is much higher due to low insulation level and thermal inertia of walls. Based on the observations a new Assam type of house was introduced which was an amalgamation of both sustainable practices from the past and present. Solar passive measures were suggested for all the three climate zones ensuring better thermal comfort of the residents (Singh et al., 2009, 2010b, 2010a, 2011b).

2. Thermal comfort analysis of slate roof houses of Himachal Pradesh

The main objective of the study was to understand the concept of thermal comfort in the slate-roofed vernacular houses of the hill areas in the summer season through a qualitative and quantitative approach. From the census of India 2011, it was observed that houses with adobe-style wall construction and stone slate roofs are predominantly seen in the state. And most of them were seen in the Kangra region. amounting to a total of 1,28,160 residential units (*Census of*

India 2011, 2011; *District Census HandBook - Himachal Pradesh*, 2011). Further Kangra district has three major bio-climatic zones namely: 1) Sub Tropical sub montane and low hills. 2)Sub humid Mid hills, and 3) wet temperate high hills as shown in figure 2 (Department of Agriculture, n.d.). Most of the region lies in zone 1, subtropical sub-montane and low hills Sub humid Mid hills, henceforth the "study area", which covers areas of Jawali, Nurpur, Shahpur, etc., and has an elevation of 240-1000 meters above sea level, and a mean annual temperature of 15°C to 21.9°C. Zone 1 is further characterized by hotter summers as compared to zones 2 and 3 and therefore ideal for the study.

The thermal comfort study was undertaken in summers and a transition towards a cooler period of autumn season was considered. Data was collected in the month of July & October, 2022, representing the Summer and Autumn seasons of the year. A sample size of 385 houses was obtained from Yamane's formula (Yamane, 1967). However, due to certain constraints like unoccupancy and inaccessibility throughout the year a 30% of the total sample size was considered. A total of 130 slate roofed mud houses, were undertaken for further study.

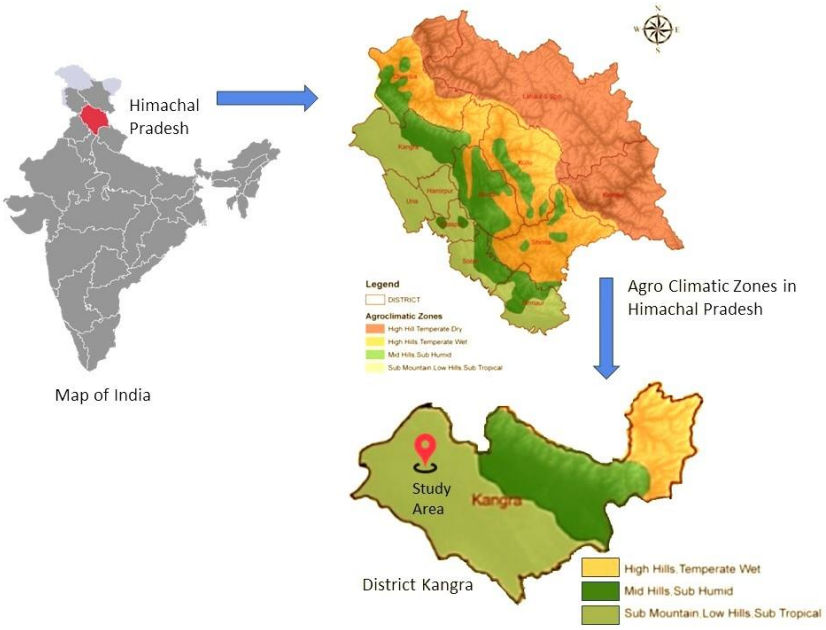

Figure 2: Overview of the study area

2.1 Architecture style of the studied area

Vernacular architecture mostly is characterised by locally available materials and construction techniques. In the study area vernacular houses are mostly two storied structures characterised by verandas as sun shades and smaller wooden doors and windows. Houses were mostly made up of thick mud wall built with the help of unbaked mud bricks or rammed earth mixed with grass and cow dung. Roofs were made up of bamboo layered on with overlapping slates. The roof structure consisted of wooden or bamboo rafters and purlins framework with an overlay of slate nailed together.

Figure 3: A typical vernacular house in the study area

The roof structure lacked any kind of ceiling or insulation below. Typical houses and living rooms on the ground floor with kitchen mostly on the first floor. Front yard or angan is normally present for day today gatherings and other activities. Staircases are generally narrow (2'6"- 3'wide) and straight flights & that is also

made up of completely wood with treads plastered in mud or cow dung and husk. Additional bathing and toilet facility is given at a small distance outside the main house. The houses with hipped or gable type of roof were considered for the analysis. The roofs were mostly rectangular in shape with a few L and U-shaped structures. A ceiling height of 7'-8'6" with an attic space of 4'-5' was mostly observed.

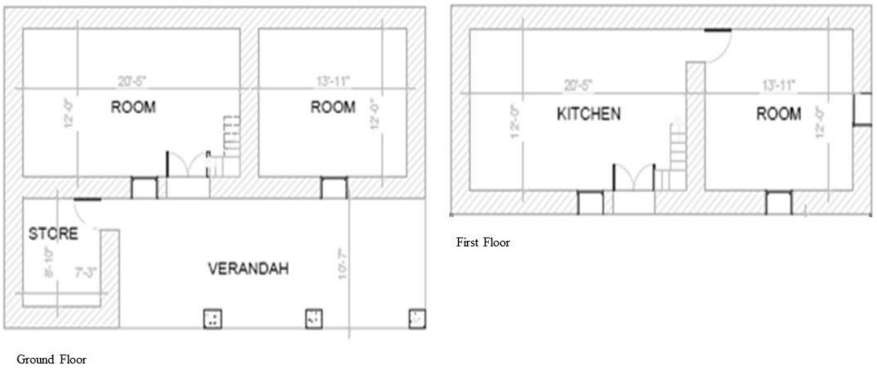

Figure 4: Typical planning layout of vernacular houses in the study area)

2.2 Thermal comfort survey

The lifestyle of a village is deeply rooted in the area's natural beauty, agricultural practices, and traditional values. It reflects a harmonious relationship between the residents and their environment. The residents of the vernacular houses in the study area are mostly farmers or retired government service personals, who opted for agriculture and cattle for their livelihood. The area reflects a strong sense of community, and the people mostly have close ties with their neighbors and extended families. Social interactions are a major part of their daily life. Most daytime activities are outdoor in the common angans (front yards), where the people spend most of the day. Indoor activities in these houses during morning and evening are mostly sedentary and no major metabolic activity was recorded thus, the value of metabolism was taken as 1 for the analysis (Gangrade & Sharma, 2022). Further because of the high thermal insulation of the mud walls the temperature indoors was slightly lower as compared to the outdoors in peak summer season. No active thermal cooling was seen in the area, however people

opted for light colored cotton cloths along with opening of doors and windows in the summer season resulting in less clothing insulation levels. In peak winters warm woolen cloths, quilts and blankets were used along with fireplaces to keep the indoors comfortable. Four tangible parameters, namely indoor-outdoor temperature, relative humidity, and wind velocity were considered to quantify the attributes of thermal comfort. Two intangible parameters viz clothing pattern and body metabolism/activity were considered along with thermal sensation votes of the residents were used for an onsite evaluation of the existing thermal conditions and lifestyle of the people through a detailed questionnaire-based thermal comfort survey. The thermal sensation of the occupants was quantified through thermal sensation votes (TSV) based on a seven-point thermal sensation scale specified by ASHRAE (American Society of Heating, 2017; Priya, 2019). The thermal sensation scale ranged from -3 (very cold) to -1 (slightly cold), 0 being (neutral) and +1(slightly warm) to + 3 (very hot). Values of -2 and +2 symbolized cold and warm respectively. Clothing insulation levels were quantified in terms of Clo values along with metabolism as 1 because of the resting state of the occupants during the survey. A correlation analysis was undertaken between the tangible onsite measurements and the thermal sensation votes and clothing patterns to understand their interrelationship. Further multiple regressions were undertaken to quantify these relationships individually as equations. Lastly, thermal comfort range and neutral temperatures were established for two seasons.

3. Result and Discussion

3.1 Summer Season

Field measurements were done for physical attributes like indoor-outdoor temperature, humidity, wind velocity and psychological attributes like clothing pattern and body metabolism in the month of July 2022, for the summer season as shown in figure 5. The body metabolism can be considered constant as all the occupants were in sedentary state with no physical activity. An outdoor temperature variation of 25.3^{0}C -40.2^{0}C.

The indoor areas were comparatively colder, a temperature difference of 0.7-3.5^{o}C was seen. When compared to ground floor the first floor was comparatively warmer because of the heat gain through the slate roofs during the day. The relative humidity was observed between 20%-78% with a wind velocity

ranging between 1-4v7m/s which helped in making the indoor environment comfortable. The occupants voted the thermal sensation in a range of slightly warm (+01) to very hot (+03) as shown in figure 6.

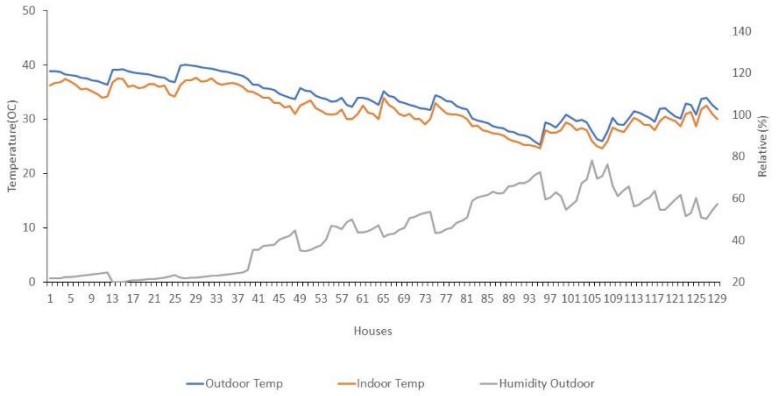

Figure 5: Physical attributes of thermal comfort in Summer

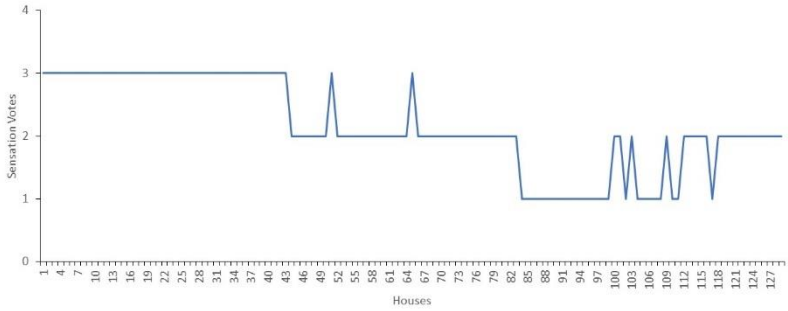

Figure 6: Thermal sensation votes in Summer

A correlation of the different factors was also analyzed as shown in table 1. It was seen that thermal sensation votes are very much related to the indoor and outdoor temperature, about 93%. A correlation of around 33% was seen between thermal sensation votes and relative humidity however their dependence on that of wind speed was negligible.

	Outdoor Temp	Indoor Temp	Humidity Outdoor	Wind Velocity	TSV
Outdoor Temp	1				
Indoor Temp	0.991713	1			
Humidity Outdoor	-0.977	-0.96962	1		
Wind Velocity	0.360203	0.368887	-0.36927	1	
TSV	0.931072	0.936542	-0.91201	0.360719	1

Table 1: Correlation between physical attributes of thermal comfort and TSV in Summer

A relation between outdoor- indoor temperature was established as shown in equation 01, achieving a R^2 value of 0.98 as seen in figure 7.

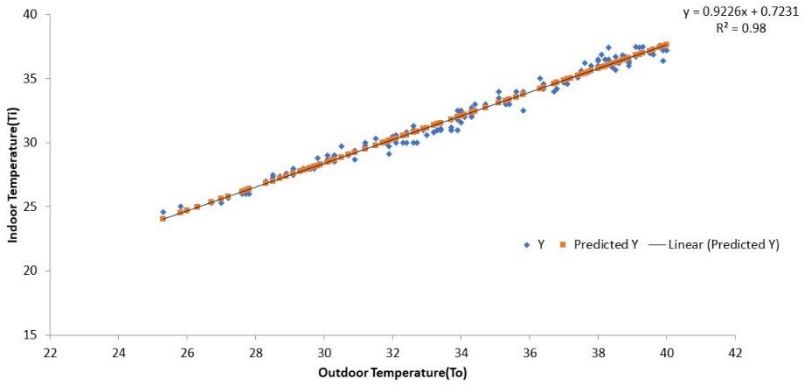

Figure 7: Relationship between indoor and outdoor temperature in Summer

$T_i = 0.9226T_o + 0.7231$……... (1)

Further dependance of thermal sensation votes on that of parameters of thermal comfort was also considered as seen in figure 8. The relation of thermal sensation votes to that of outdoor temperature, indoor temperature and relative humidity is as shown in equation 2-4 respectively. The R^2 value achieved is around 0.87, 0.87 and 0.84 in the three cases which shows a strong impact of the indoor, outdoor temperatures and humidity on the votes. The R^2 value for that of wind velocity is only 0.1, which shows a negligible impact of wind velocity on the thermal sensations.

$TSV = 0.1724T_o - 3.6431$……... (2)

$TSV = 0.1864\ T_i - 3.7636$ ……..……. (3)

$TSV = -0.0389Rh - 3.8424$ ……..……. (4)

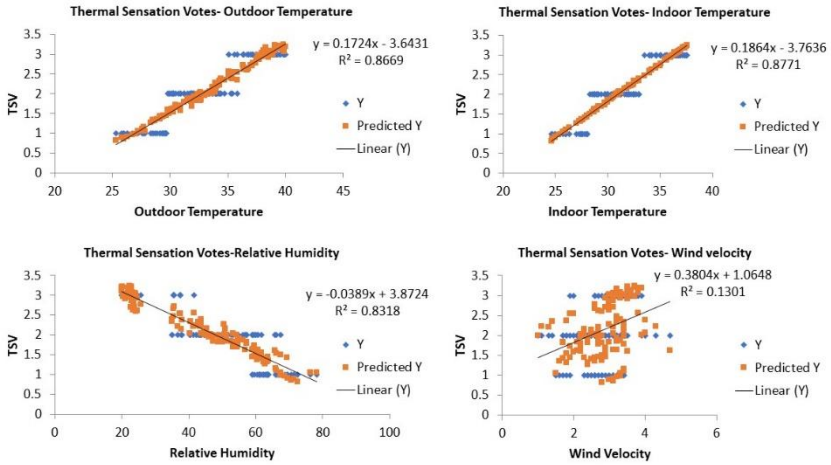

Figure 8: Relationship between thermal sensation votes and physical attributes of thermal comfort in Summer

On hotter days residents in some houses used cooling mechanism like fans, opening of windows etc. During the noon. Lighter cotton cloths were mostly donned in the region. The insulation levels (Clo Values) of clothing ranged between 0.5-0.57 (ASHRAE Standard, 2004; Gangrade & Sharma, 2022). It is seen in figure 9 that clothing levels majorly depend on the indoor-outdoor temperatures and relative humidity, with very less correlation with wind velocity. The relation of clothing insulation with that of indoor-outdoor temperature, relative humidity and wind velocity is as established in equation 05-08.

$$Clo = -0.0064To + 0.7473 \quad (5)$$

$$Clo = -0.0069Ti + 0.7505 \quad (6)$$

$$Clo = 0.0015Rh + 0.4666 \quad (7)$$

$$Clo = -0.0137v + 0.5706 \quad (8)$$

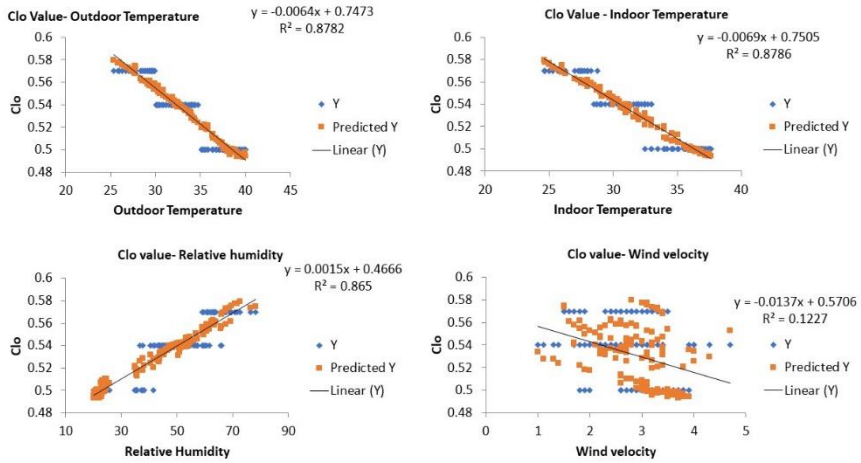

Figure 9: Relationship between clothing insulation levels and physical attributes of thermal comfort in Summer

3.2 Autumn season

An outdoor temperature variation of 22.2°C -37.8°C was seen in the area with a slightly varying range of indoor temperatures as shown in figure 10.

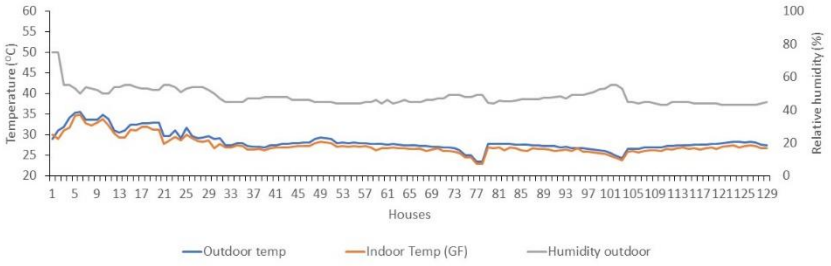

Figure 10: Physical attributes of thermal comfort in Autumn

Due to the insulation properties of thick walls and high thermal mass. The indoors were slightly colder on days when the outdoors are comparatively hotter and vice versa. When compared to ground floor a trivial variation in the temperature of the first floor was seen. The first floor was slightly hotter than the ground floor in higher outdoor temperatures, but slightly colder than the ground floor when the outdoors is colder because of the less thermal lag of the slate tiles in addition to the absence of a proper ceiling material. The relative humidity was observed between 34%-75% but the wind velocity ranged between 0-2m/s which was quite negligible in this scenario.

Thermal sensation votes were taken from the residents in the month of October, which ranged from 0 (neutral) to +3 (hot) in certain cases, but majority of the votes lied in the neutral zone showing that the respondents were very much comfortable in the given conditions.

Figure 11: Thermal sensation votes in Autumn

A correlation of the different factors was also analyzed as shown in table 2. It was seen that thermal sensation votes are very much related to the indoor and outdoor temperature, about 90%. Their dependence on that of wind speed and relative humidity was negligible. The relative humidity measured was in a very comfortable range of that of 25-50%. No extremities were seen which could have led to a discomfort amongst the residents.

	Outdoor temp	Indoor Temp	Humidity outdoor	Wind Velocity	TSV
Out Door Temperature	1				
Indoor Temp	0.986484	1			
Humidity outdoor	-0.07922	-0.09954	1		
Wind Velocity	0.457899	0.466278	-0.29412	1	
TSV	0.897773	0.908092	-0.10212	0.464108	1

Table 2: Correlation between physical attributes of thermal comfort and TSV in Autumn

A linear regression was undertaken to analyze the dependence of indoor temperature to that of outdoor temperature. The relationship can be established

through equation number 9 and figure 12, Where Ti = indoor temperature & To = outdoor temperature.

$T_i = 0.9212\ T_o + 1.3315$ …….. (9)

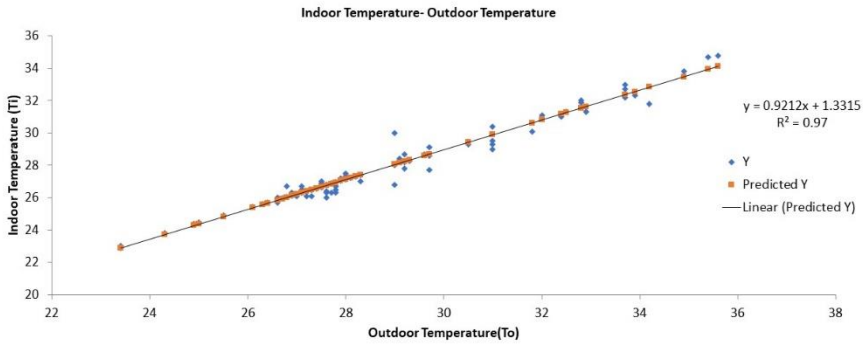

Figure 12: Relationship between indoor and outdoor temperature in Spring

Further dependance of thermal sensation votes on that of parameters of thermal comfort was also considered as seen in figure 13. The relation of thermal sensation votes to that of outdoor temperature and indoor temperature is as shown in equation 10 and 11 respectively. The R^2 value achieved is around 0.97 and 0.82 respectively which shows a strong impact of the indoor & outdoor temperatures on the votes.

$TSV = 0.222\ T_o - 5.0862$ …….. (10)

$TSV = 0.2407\ Ti - 5.393$ …….…….. (11)

A R^2 value of 0.2 is scene in the relationship of thermal sensation votes to that of relative humidity which implies that a strong impact of the same is not clearly observed similarly a R^2 value of 0.01 shows a negligible impact of wind velocity on thermal sensation votes. The relation can be established as seen in figure 13

& equation 12 & 13. Where Ti = indoor temperature, To = outdoor temperature, v= wind velocity, Rh= relative humidity and TSV = thermal sensation vote

TSV = 0.0663Rh – 1.9602…….…….. (12)

TSV = -0.1099v + 1.259…….……. (13)

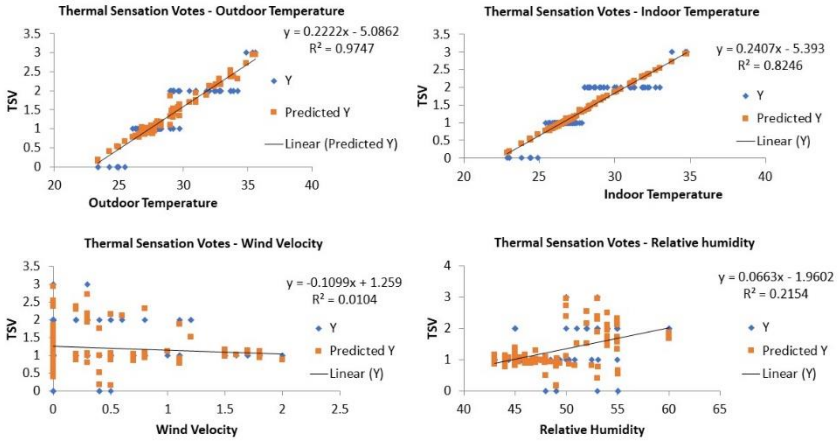

Figure 13: Relationship between thermal sensation votes and physical attributes of thermal comfort in Autumn

No artificial heating or cooling was undertaken as adaptive measures, only a shift towards slightly warmer cloths was seen in certain areas. The residents were majorly using full sleave flannel shirts, trousers, on normal days and light shirt with long sleeves on hotter days. Similarly, women were using thick fabric suits on slightly colder days, n normal full sleaves cotton ones in hotter conditions. The insulation levels of clothing ranged between 0.54-0.67. It is seen in figure 14 that clothing levels majorly depend on the indoor and outdoor temperatures, with very less correlation with the relative humidity and wind velocity.

The relation of clothing insulation with that of indoor-outdoor temperature, relative humidity and wind velocity is as established in equation 14 -17, where Clo = clothing insulation, Ti = indoor temperature, T_o = outdoor temperature, v= wind velocity and Rh= relative humidity

$$Clo = -0.0232T_o + 1.271 \quad (14)$$

$$Clo = -0.0242T_i + 1.2793 \quad (15)$$

$$Clo = -0.0067Rh + 0.9386 \quad (16)$$

$$Clo = 0.0499v + 0.5949 \quad (17)$$

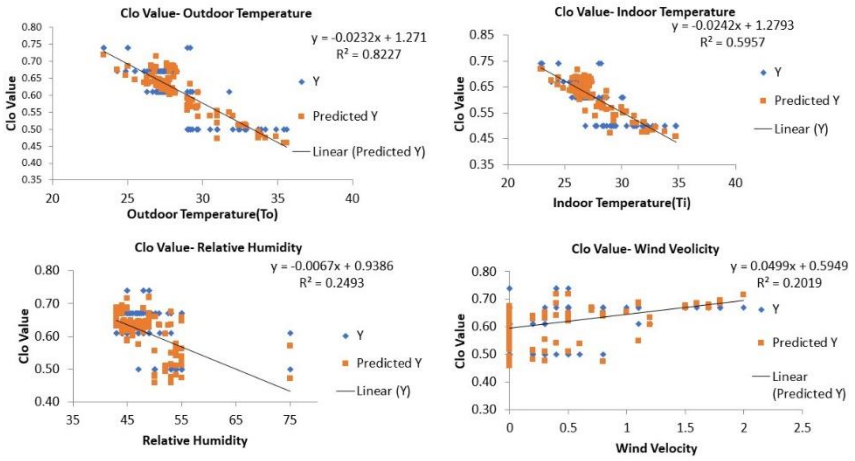

Figure 14: Relationship between clothing insulation levels and physical attributes of thermal comfort in Autumn

3.3 Thermal comfort range and neutral temperature

The field measurements were taken in the July and October months representing the peak of summer and autumn season. which resulted in comparatively hotter summers and colder winters as seen in table 3, based on the thermal sensation votes, a temperature range of was identified in which the residents were mostly comfortable throughout the year. A temperature range pertaining to -1(slightly cold) to 0 (neutral) to +1(slightly warm) were considered as comfortable. A temperature range of 22.9^{O}C – 28^{O}C with a neutral temperature of 23.7^{O}C was attained as thermal comfort range for the two seasons the year.

Season	Outdoor Temperature (°C)		Indoor Temperature (°C)		Relative Humidity (%)		Wind velocity (m/s)		TSV		Thermal Comfort Zone (°C)	Neutral Temperature (°C)
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
Summer	25.3	40	24.6	37.6	20	78	1	4.7	1	3	24.6-28	-
Autumn	23.4	35.6	22.9	34.8	43	60	0	2	0	3	22.9-27.8	23.7

Table 3: Physical attributes of the study area throughout the year

The majority of the indoor temperature was inside the thermal comfort zone, showing that the vernacular slate roof houses were much more climate responsive. If we take into consideration the overall satisfaction of the residents with respect to their vernacular style of house they are very much satisfied with the thermal behavior of the houses when compared to their modern counterparts. As seen in figure 15, satisfaction levels of 70-95% despite their maintenance and other materialistic issues were observed among the residents for the vernacular style of houses representing their livelihood and comfort.

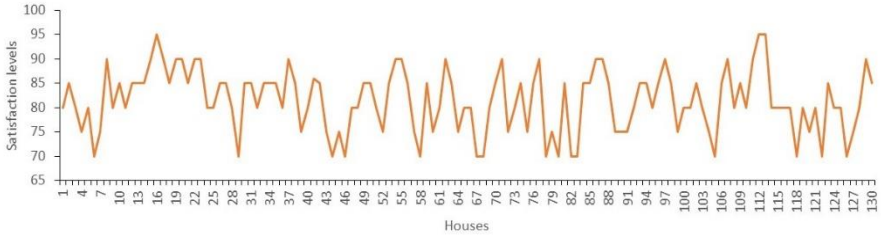

Figure 15: Overall satisfaction levels of the residents

4. Conclusions

Vernacular architecture is decidedly sustainable when it comes to climate responsiveness and ease of construction. Previous studies in the field of thermal comfort were referred to and evaluated to identify the various thermal comfort settings and criteria. Studies have shown that vernacular architecture very efficiently responds to the harsh chilly winters of the hills. To evaluate their thermal performance in comparatively warmer summer season a study was

carried out in the warmer areas of sub-tropical sub montane & low hills of Himachal Pradesh. A field survey was conducted in the months of July and October to understand the thermal perception of the individuals and the thermal efficiency of their houses. Based on the analysis following conclusions were drawn.

- Despite being a hill area sub-tropical sub montane & low hills of Himachal Pradesh witness a comparatively warmer summer. Thermal sensation of the individuals ranged from warm to very hot in the month of July. The residents were comfortable in the temperature range of 24.6^{o}C to 28^{o}C without using any active cooling technique.
- October month being the representative of autumn season was very comfortable compared to summer. a neutral temperature of 23.7^{o}C was observed. an overall comfort range of 22.9^{o}C to 28^{o}C was seen for the two seasons.
- During peak summer season passive architecture features like thick walls, ventilated slate roofs without ceiling (with air gaps) and adaptive measures like change of clothing patterns help to enhance the thermal comfort of the individuals.
- A strong correlation of the thermal sensation of the individuals and the factors of thermal comfort like indoor outdoor temperature was seen. The study showed R^2 values of around 0.9 establishing the strong dependence of the thermal sensation votes and clothing patterns of the individuals on the indoor - outdoor temperature. R^2 values for TSV vs wind velocity and relative humidity were considerably lesser showing a lesser interdependence.
- People continued to lead highly contented, sustainable traditional lives. Residents' overall satisfaction levels ranged from 70% to 90%, demonstrating that it was in line with the climate, way of life, and culture of the area. Locals still consider that traditional mud homes are more climate-responsible and thermally viable than their contemporary counterparts.

Finally, it can be concluded that viable design interventions can therefore be done in the vernacular slate roof systems to make vernacular houses more sustainable and comfortable which later can be adopted in the modern houses to increase the quality of life and be thermally more responsive to the indoor conditions. further elaborate studies can be done considering all the 12 months of the year and using simulations etc. to look into the effects of passive design features on the thermal performance of vernacular architecture of the state.

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Original Paper

Sustainable practices in Keylong's vernacular architecture.

A detailed study of construction and thermal efficiency in the Himalayas

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Keywords: vernacular architecture; traditional wisdom; sustainable practices; construction and thermal efficiency.

Abstract. *This study meticulously investigates the resilience and sustainable attributes of vernacular architecture in Keylong, a paradigmatic region located in the Himalayan highlands. The research primarily concentrates on elucidating the indigenous construction techniques, materials, and their concomitant impact on thermal performance, underscoring the intersection between traditional wisdom and sustainable practices. The principal aim of this inquiry is to unravel the intricate relationship between vernacular architectural practices and their inherent sustainability, particularly in the context of the harsh climatic conditions prevalent in the Himalayan region. The objectives encompass a comprehensive analysis of the construction methodologies, material utilization, and the thermal efficiency inherent in these traditional dwellings, juxtaposed against contemporary building practices. Methodologically, the study employs a multifaceted approach, incorporating empirical data collection through state-of-the-art Tempnote TH32 dataloggers, coupled with qualitative assessments derived from local narratives and historical perspectives. This dual approach facilitates a holistic understanding of the vernacular architecture's performance and its adaptive strategies in the face of climatic adversities. The findings reveal a profound congruence between the vernacular architecture of Keylong and the principles of sustainability. The traditional constructions demonstrate remarkable thermal efficiency, primarily attributable to the judicious use of locally sourced materials and time-honored construction techniques. Moreover, these structures exhibit a remarkable resilience to the region's extreme weather conditions, embodying a sustainable architectural paradigm that harmonizes with the natural environment. The study's outcomes underscore the significance of reviving and integrating traditional architectural wisdom into contemporary sustainable building practices. It posits that such integration could offer viable solutions to the challenges posed by climate change, especially in ecologically sensitive and high-altitude regions. This research not only contributes to the academic discourse on sustainable architecture but also provides practical insights for architects,*

planners, and policymakers engaged in the development of resilient and sustainable habitats in the Himalayas and similar contexts.

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1. Introduction

Vernacular architecture in Keylong, reflecting indigenous wisdom and environmental adaptability, is a sustainable design paradigm (Bothara et al., 2022; Mazraeh and Pazhouhanfar, 2018; Motealleh et al., 2018; Singh et al., 2010). These structures, dating back to 1960 and depicted in Figures 1 and 2, embody cultural and climatic responsiveness. Utilizing local materials like stone, wood, and mud soil, these buildings exemplify thermal insulation properties essential for the region's extreme winters (Chkeir et al., 2023; Rijal, 2021; Elert et al., 2021; Mendis et al., 2024). The varied spatial layouts address local needs and environmental nuances (Anna-Maria, 2009; Foruzanmehr, 2015; Zune et al., 2020). Additionally, the orientation of these structures, aligned with sunlight and topography, illustrates an effective use of solar energy. This introduction explores Keylong's vernacular architecture's multi-layered relationship with its environmental and cultural context, offering insights for modern sustainable design and cultural preservation amidst climate change challenges.

Figure 1. Vernacular architecture of Keylong Region (Source: Author)

Figure 2. Vernacular Architecture of Keylong Region (Source: Author)

2. Region: Lahaul and Spiti

The Lahaul and Spiti valleys, situated in the northern Indian state of Himachal Pradesh, encompass approximately 13,841 square kilometers and house a population of 31,564, as per the latest census data. These valleys, ensconced within the Himalayan Mountain range, exhibit a wide array of geographical and ecological diversities, contributing to their rich natural and cultural heritage. Distinct yet interconnected, Lahaul and Spiti present unique characteristics and challenges. Lahaul, positioned to the south, is distinguished by its verdant flora, fertile terrain, and clustered villages along the Chandra and Bhaga rivers. The primary economic activity in Lahaul revolves around agronomy, specifically the cultivation of barley and potatoes. This region also boasts of scenic monastic sites, notably the Key Monastery, and traditional wooden architecture with intricate carvings, symbolizing its rich cultural ethos.

Conversely, Spiti, the northern counterpart, is a high-altitude desert valley, characterized by its arid, barren landscape and mesmerizing vistas. It houses ancient monasteries, such as the renowned Tabo Monastery, colloquially referred to as the "Ajanta of the Himalayas." The inhabitants of Spiti have acclimatized to their rigorous environment through agro-pastoral practices, encompassing livestock herding and cultivation of hardy crops like barley and peas. The vernacular architecture across Lahaul and Spiti is a testament to the region's

adaptation to the severe mountainous climate. Traditional dwellings, characterized by thick stone walls, flat roofs, and diminutive windows, epitomize the necessity to conserve thermal energy during prolonged winters. This architectural form illustrates the symbiotic relationship between the indigenous culture and environmental conditions. Tourism in Lahaul and Spiti has seen an upsurge, drawing visitors with its unspoiled landscapes, snow-capped peaks, and distinctive Buddhist monasteries. The region's allure lies in its untouched natural beauty and rich cultural tapestry, making it a destination of significant interest for a diverse array of tourists.

3. Study area - Keylong Region

Keylong, a picturesque township nestled in the Himalayas, serves as the administrative hub of the Lahaul and Spiti district in Himachal Pradesh. Accessible via the Manali-Leh Highway or the Atal Tunnel, Keylong's strategic geographic position is marked by a confluence of diverse climatic conditions and a rich cultural heritage. Flanked by the towering Great Himalayas and the Pir Panjal Range, it presents breathtaking vistas of snow-clad peaks and verdant valleys, as depicted in Figures 3 and 4. Perched at an elevation of approximately 3,080 meters (10,100 feet) above sea level and spanning an area of 1200 square kilometers, Keylong has a population of around 1,150, as indicated by the 2011 Census. This demographic data underscores the unique challenges and opportunities inherent in its remote and lofty location. Situated within the extensive Lahaul and Spiti district, Keylong exhibits distinct yet interconnected attributes. The local populace engages in a variety of livelihoods, including agriculture, animal husbandry, commerce, and tourism. Such diverse economic activities reflect the town's multifaceted character. While the current study delves into Keylong's specific architectural and environmental dynamics, future research endeavors could amplify these findings through comparative analyses with similar high-altitude Himalayan regions. This broader perspective would enrich the understanding of vernacular architecture's role across varying environmental and cultural landscapes. Keylong experiences a cold desert climate, characterized by prolonged, severe winters marked by frequent snowfalls and sub-zero temperatures. Conversely, the summers, albeit warmer, offer a brief window for agricultural activities. The cultivation of crops like barley and peas, integral to local farming practices, aligns with the brief growing season. Additionally, the region's robust livestock, including cows, yaks, and sheep, are well-adapted to these harsh conditions, bolstering the community's longstanding animal husbandry traditions.

Keylong, strategically positioned along the Himalayan trade routes, functions as a pivotal commercial hub, facilitating the exchange of goods with adjacent areas. Its geographical advantage has rendered it a critical nexus for commerce and the distribution of essential supplies. This aspect of Keylong underscores its significance in regional trade dynamics. Beyond its economic role, Keylong is a vibrant cultural epicenter, epitomizing the traditional lifestyle and heritage of its inhabitants. The town is home to several notable monasteries, including the Kardang and Shashur Monasteries. These establishments are not merely religious sanctuaries; they stand as architectural wonders, as illustrated in Figure 5. These monastic sites provide a window into the profound Buddhist culture and historical tapestry of the region, offering insights into the spiritual and aesthetic dimensions of Keylong's community life.

Figure 3. Location map - Keylong Region (Source- Author)

Figure 4. Keylong Village (Source- Author)

Figure 5. Local Buddhist monastery (Source- Author)

Keylong's bustling markets, adorned with vibrant Tibetan prayer flags and animated by local traders, present an authentic snapshot of the region's traditional lifestyle, as captured in Figure 6. These vibrant marketplaces not only offer a visual feast but also serve as cultural intersections where visitors can immerse themselves in the local ethos. Patrons have the opportunity to explore an array of indigenous handicrafts and savor regional cuisine, facilitating a deeper engagement with the community's customs and practices. This interaction between visitors and locals fosters a rich cultural exchange, allowing for a genuine experience of Keylong's unique cultural identity.

Figure 6. Keylong local market (Source- Author)

3.1 Climatic data

Keylong is a high-altitude town in the Himalayas, with diverse and extreme climatic conditions. The town has a unique geographic location in the western Himalayas of India, at an elevation of about 3,080 meters (10,100 feet). The town has a cold desert climate, which causes wide variations in temperature, humidity, precipitation, cloud cover, and wind speed throughout the year.

As per data from Metablue from Figure 7, Keylong witnesses temperature fluctuations ranging from approximately -20°C (-4°F) in January to around 30°C (86°F) in June and July. The coldest months with average minimum temperatures of -9.0°C (15.8°F) and -5.9°C (21.38°F) are January and February, while the July

is the warmest month with average maximum temperatures of 18.2°C (64.76°F). Relative humidity spans from 40% to 80%, peaking in July and August.

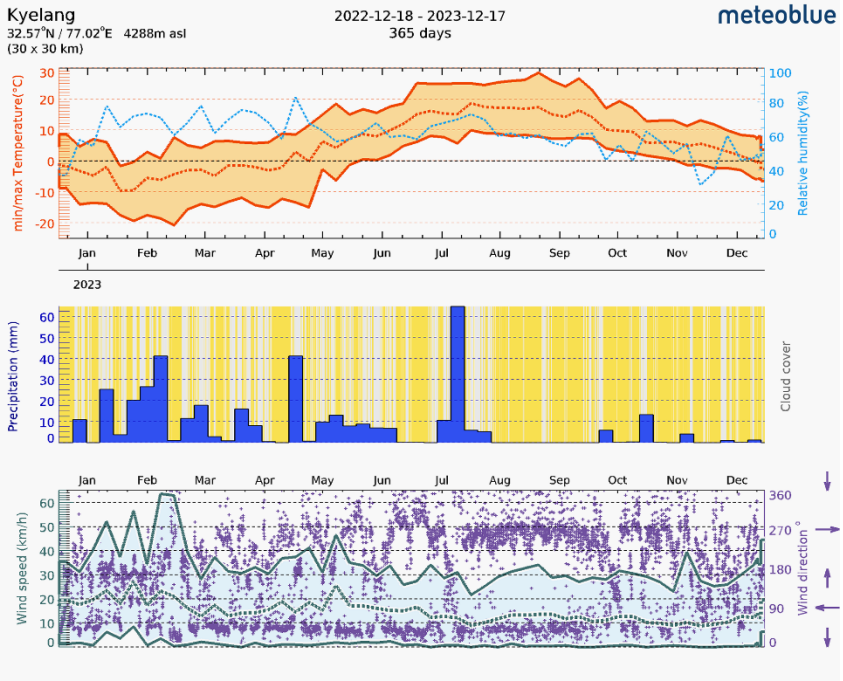

Figure 7. Climatic data of Keylong Region for year 2023 (Source: Metablue)

The precipitation pattern in Keylong is predominantly influenced by the monsoon season prevailing from June to September. July is the wettest month registering an average rainfall of 60 mm (2.4 in). Conversely November and December are the driest months experiencing an average rainfall of 6 mm (0.2 in) and 7 mm (0.3 in) respectively. The annual precipitation accumulates to 323 mm (12.7 in) while cloud cover ranges from 10% to 90%, reaching its highest in July and August.

Keylong encounters variable wind speeds throughout the year with peak speeds reaching up to 64 km/h (39.76 mph) between March and May. In contrast, the lowest wind speeds falling below 10 km/h (6 mph) are observed in July to

December. The prevailing wind direction is predominantly from the northeast, with slight variations corresponding to seasonal changes.

The climatic conditions in the Keylong region significantly impact the lifestyle, culture, and architectural practices of its residents. Navigating through extreme cold, low oxygen levels and scarce resources, the local populace predominantly engages in agriculture, animal husbandry, and trade. This pilot study sheds light on the intricate relationship between the climate and the multifaceted aspects of life in the Keylong region, emphasizing its far-reaching effects on various facets of the local community.

3.2 Climatic adaptive design

The vernacular architecture of Keylong exemplifies a profound understanding of the climatic challenges inherent to the region. Local builders and inhabitants have developed construction techniques that support local regionally available materials such as stone, mud and timber to create structures that withstand the extreme cold and limited resources. The Vernacular Architecture incorporates features like thick stone walls and insulated roofs to provide thermal mass, aiding in temperature regulation and offering protection against the harsh winter conditions (Aranguren et al., 2020; Hamard et al., 2013; Mangeli et al., 2023).

Furthermore, the design of vernacular buildings in Keylong showcases a keen awareness of the need for natural ventilation, passive cooling, and protection from intense sunlight. (Farouq et al., 2020; Mangeli et al., 2023; Zune et al., 2020). Traditional dwellings often feature small windows to minimize heat loss and maximize thermal efficiency. The spatial layout and orientation of these structures are intricately planned to capitalize on natural elements, promoting airflow for cooling during the warmer months (Zhao et al., 2020).

The climatic adaptive Vernacular Architecture of Keylong not only addresses the immediate challenges posed by its environment but also serves as a repository of local wisdom, cultural identity and sustainable living practices. In a research context an in-depth analysis of these architectural strategies would yield valuable insights applicable to contemporary design practices particularly in the face of evolving climate patterns and the imperative for sustainable construction in mountainous regions.

3.3 Pilot case study

In response to the challenging harsh climatic conditions of Keylong, the vernacular architecture style in the region has undergone a gradual evolution

mirroring the demands of its environment. This architectural style bears resemblances to the Kath kuni architecture style. Our research methodology involved an extensive examination of various vernacular architecture types in Keylong with a specific focus on structures dating back to the 1960s. Through on-site visits to different locations, we meticulously selected a representative structure that was built in 1960 and owned by Mr. Soman for detailed analysis.

Figure 8. Local Vernacular Architecture Example (Source - Author)

Our comprehensive investigation delved into the construction techniques, methodologies, strategies, and the procurement and availability of building construction materials associated with the vernacular architecture of Keylong. To assess the relative performance of vernacular architecture compared to contemporary structures, we compared our findings with a modern building erected in the year 2000 by Mr. Jagan Nath. A critical aspect of our research involved conducting a month-long analysis of indoor temperature and humidity during the winter season, providing empirical data for a comparative evaluation.

This research design allows for a nuanced exploration of the effectiveness and adaptability of Keylong's vernacular architecture in the face of its harsh climate, offering valuable insights into construction practices and performance benchmarks for both traditional and contemporary structures.

3.4 Village settlement pattern

In the village settlement planning of Keylong, a distinctive amalgamation of linear and scattered planning principles is evident, reflecting a thoughtful adaptation to the unique topography and cultural dynamics of the region. The central framework of the village is structured around a linear plan, primarily manifested through the road network that serves as a vital artery for movement and commerce as shown in Figure 10. As shown in Figure 9 this linear arrangement strategically situates most shops along the main roads, fostering accessibility and facilitating daily transactions for both residents and passersby.

Figure 9. Keylong linear village settlement view (Source - Author)

However, woven within this linear fabric, elements of scattered planning come to the forefront, introducing a nuanced complexity to the overall settlement design. Notably, certain houses deviate from the linear alignment and find their place on elevated contours. This departure from the linear layout is indicative of a scattered planning approach, possibly influenced by factors such as land ownership patterns or a deliberate choice to reside at higher elevations as seen in Figure 10.

The scattered planning aspect gains prominence in the elevated houses, revealing a deliberate decision to occupy specific locations. This could stem from a desire for panoramic views, environmental considerations, or cultural preferences associated with certain elevations.

Figure 10. Keylong linear village settlement view (Source - Author)

This hybrid approach to settlement planning underscores a pragmatic response to the challenging mountainous terrain of Keylong. By interweaving linear and scattered elements, the planning not only addresses the practicalities of transportation and daily life but also respects the diverse needs and preferences of the community.

4. Building Form and Orientation

4.1 Building Planning

In the Keylong area, building planning intricately aligns with the functional purpose of each room, a design approach intricately tied to the number of wooden columns (Kaaju) employed, ranging from one to six as detailed in Figure 11,12 and 13. This nuanced system of wooden column usage is historically rooted, with the vernacular architecture of Keylong evolving in response to the region's formidable climatic challenges.

Figure 11. Four Pillar (Kabzi) layout in planning (Source - Author)

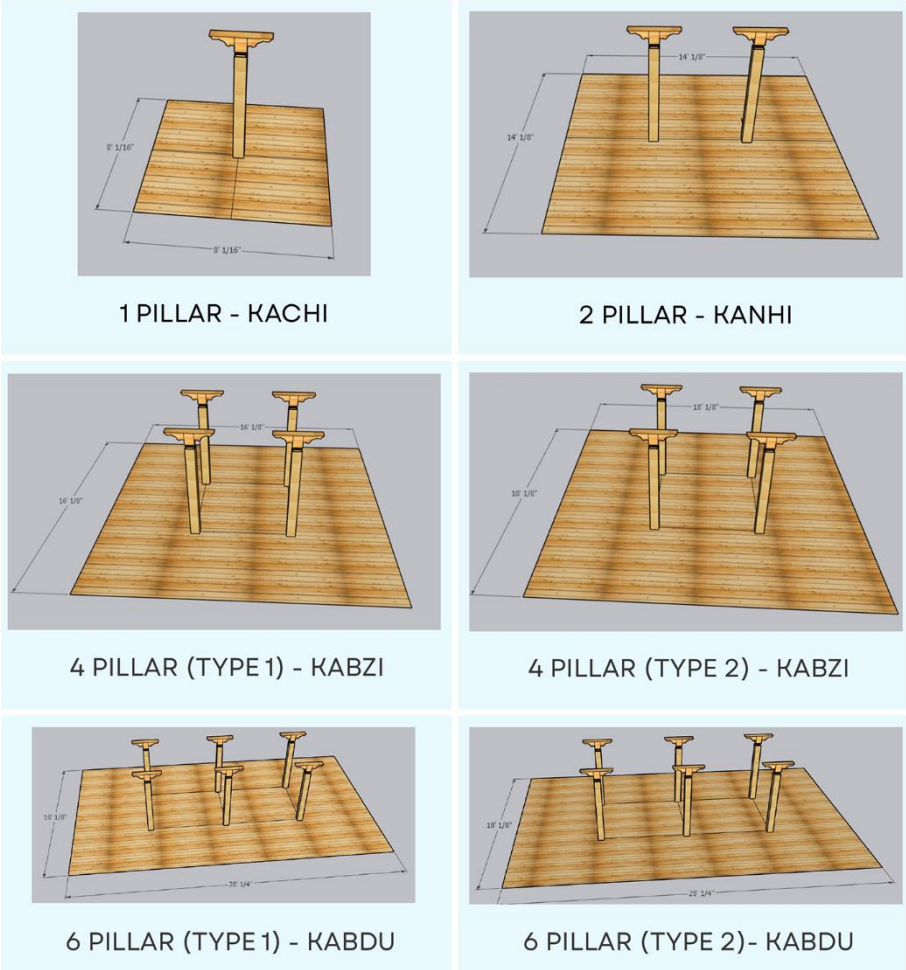

Figure 12. Types of Pillars used in indoor planning (Source - Author)

The architectural planning of structures in Keylong unfolds across three distinctive levels. The basement primarily accommodates cattle and also serves as a storage space for food and grains, a strategic response to the harsh winter climate that necessitates prolonged freshness of stored provisions as shown in Figure 14. The first floor is designated as the living area for occupants, segmented

into various functional zones as shown in Figure 15. The second floor holds a pivotal role, dedicated to the deity area as shown in Figure 16. This space becomes a focal point for prayers, local gatherings, and various cultural activities.

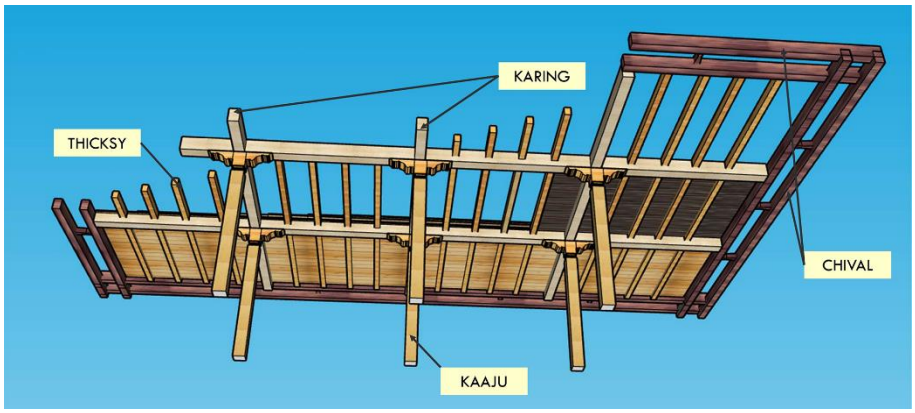

Figure 13. Structural details (Source - Author)

Figure 14. Building basement - For food storage (Source - Author)

Figure 15. Building living space (Source - Author)

Figure 16. Deity area and space for local gathering (Source - Author)

The orientation of these buildings strategically considers the movement of sunlight, a response to the topography of the hills. Larger sides of the structures are deliberately exposed to sunlight, creating a thermal effect that warms the interiors during both winter and summer seasons.

4.2 Foundation

In response to the substantial structural requirements, the building's foundation in the Keylong area entails a meticulous process. The excavation involves digging

a foundation that extends 4 feet in width and 5 feet in depth into the earth. Subsequently, solid blocks of stones are strategically placed at the base, forming a sturdy foundation. The construction process continues with the addition of layers: initially, a layer of mud is applied, followed by the placement of more stone blocks until reaching ground level height. This method employs large stones in conjunction with mud, which functions as a natural mortar, effectively binding the materials together. This amalgamation of large stones and mud not only ensures structural stability but also forms a robust foundation capable of withstanding the substantial load imposed by the building. This meticulous foundation construction process, rooted in the local vernacular architecture of Keylong, epitomizes an adaptation to the challenging terrain and the need for structural resilience. By employing locally sourced materials and leveraging traditional construction techniques, this approach exemplifies the integration of indigenous wisdom and practicality to address the specific structural demands imposed by the region's environmental and climatic conditions.

4.3 Walls

In response to the challenging climate conditions of the Keylong region, local masons have embraced a construction approach characterized by thick walls utilizing stone and wood as primary materials. Various research underscores the thermal insulation properties inherent in stone and wood, revealing their capacity to maintain favourable indoor temperatures as shown in Figure 17 (Alqadi et al., 2023; Farouq et al., 2023; Mangeli et al., 2023; Raju & Ravindhar, 2020). In Keylong's construction practices, walls typically range from 1 foot 6 inches to 2 feet in width with floor height lie between 6 feet to 8 feet, incorporating a combination of stone and mud as foundational materials as shown in Figure 17 and 18. The stacking of larger and smaller stones, interspersed with mud, enhances structural stability.

Figure 17. Outer Building wall facade (Source - Author)

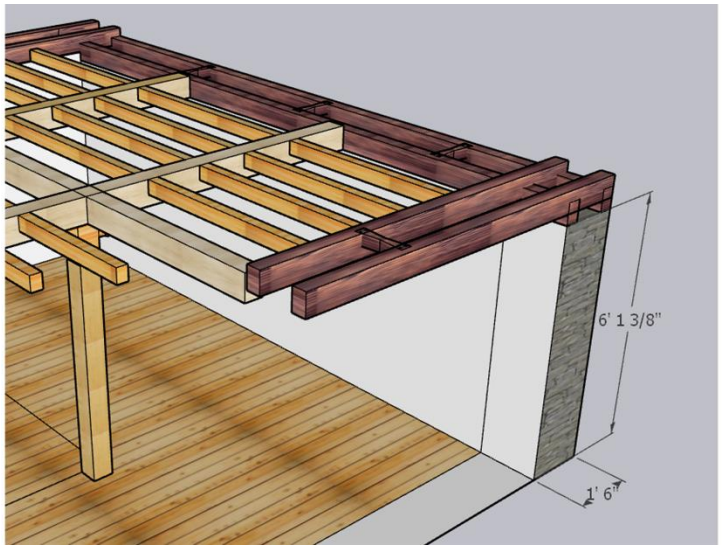

Figure 18. Wall detail (Source - Author)

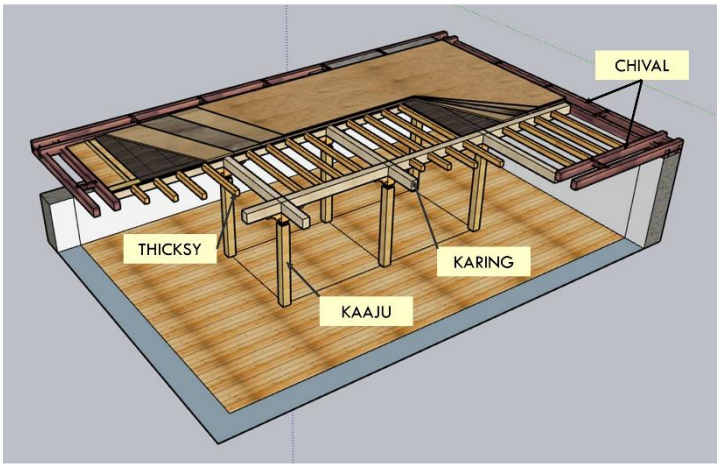

Figure 19. Structural details (Source - Author))

For both functional and aesthetic considerations, mud plaster is applied to the interior and exterior sides of the walls. This not only adds an extra layer of insulation but also contributes to the visual appeal of the structure. Interior partitions are crafted using the wattle and daub construction technique as shown in Figure 20 employing a wall width of 4 inches (Hema et al., 2021; Mendonca & Vieira, 2022). Over windows, wooden log members with a consistent width serve as lintel beams, providing additional structural support to the overall edifice. Crucially, all construction materials are locally sourced, a practice that not only aligns with sustainable principles but also ensures enhanced thermal comfort for occupants during winter months when temperatures plummet to negative degrees Celsius (Goodhew et al., 2021; Hema et al., 2021).

Figure 20. Wattle and daub detail (Source - Author)

4.4 Flooring

Flooring stands out as a pivotal element within vernacular building structures playing a crucial role in heat retention for occupants. The flooring system is stratified into several layers with the placement of columns at the base corresponding to different room spaces. The central beam (Karing) measuring 6 inches by 6 inches traverses horizontally and vertically between walls as shown in Figure 20 and 21. Situated between these central beams are secondary beams (Thicksy) measuring 4 inches by 3 inches, spaced at 1 foot 6 inches intervals. Atop these beams, a 2-inch layer of sun-dried branches from the Salix daphnoides plant as shown in Figure 22 locally abundant in the area is incorporated. Alternatively, wooden planks may be used in place of branches,

dependent on the family's financial resources to enhance interior aesthetics as shown in Figure 13.

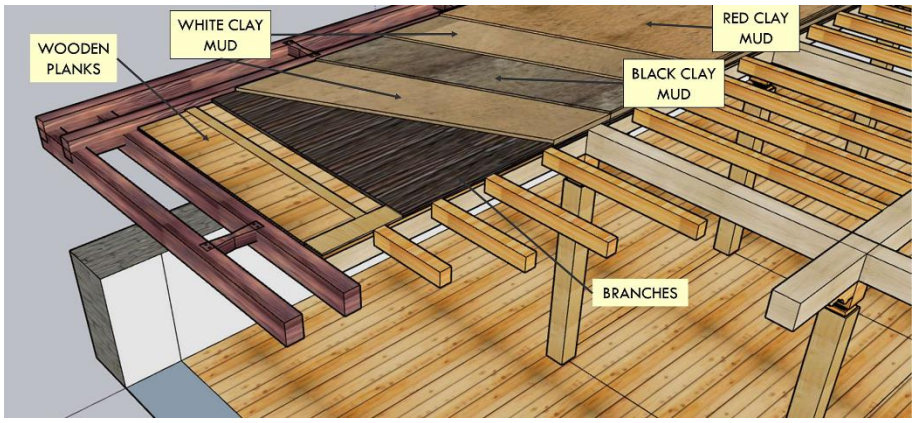

Figure 21. Flooring details (Source - Author)

Above this layer, three successive clay soil layers, each approx. 1 inch thick are employed which can be seen in Figure 21. This multi-layered soil composition acts as an effective insulator, preventing the loss of indoor heat. To complete the flooring structure a final layer is added offering a choice between a thin stone slab, Mud coating or wooden flooring. This topmost layer provides a refined surface for walking while contributing to the overall thermal efficiency of the building.

4.5 Roofing

The Keylong region experiences a formidable climate, marked by abundant snowfall, with snow layers reaching heights of 3 to 6 feet during peak conditions. Vernacular buildings in this area feature flat rooftops, employing a similar principle to the flooring structure. The construction involves layers of central and secondary beams, sun-dried branches or wooden planks, and multiple soil layers, with the addition of a final 1 to 2 inches of clay soil on the roof's surface as elaborated in Figure 23, 24 and 25. This design consideration, observed in response to the harsh winter conditions, enables the accumulation of snow layers on the rooftop (Zune et al., 2020).

Figure 22. Salix daphnoides tree (Source - Author)

Figure 23. Basement ceiling (Source - Author)

Figure 24. Roofing design (Source - Author)

Figure 25. Roofing details (Source - Author)

Research studies highlight the efficacy of snow as a natural insulator of heat. Comprising tiny ice crystals with entrapped air, snow forms a thermal barrier on the roof (Chandel et al., 2016; Singh et al., 2010; Zune et al., 2020. The air pockets within the snow layer act as effective barriers, preventing the escape of heat to the outdoor environment. This insulating effect contributes significantly to maintaining a warmer indoor environment during the severe winter months.

4.6 Building openings

The design of building openings stands as a critical element in vernacular building structures, profoundly influencing the creation of a conducive indoor environment for occupants. A strategic consideration in window placement aligns with the sun's direction, ensuring an optimal influx of sunlight into the building. Varied areas within the building are equipped with different numbers of windows, carefully calibrated to cater to the specific needs of each space. Each window is constructed with a standardized size of 4 feet by 3 feet, utilizing wood and glass, as depicted in Figure 25. Complementing this window configuration, a wooden beam is strategically positioned over each window, providing enhanced structural support, as illustrated in Figure 17.

This architectural approach exemplifies a refined integration of environmental considerations into building design, facilitating the creation of well-lit and appropriately ventilated interior spaces. (Vijayan et al., 2021). The deliberate alignment of window placement with solar orientation not only harnesses natural

light effectively but also contributes to energy efficiency and the overall thermal performance of the structure.

Figure 26. Building openings (Source - Author)

5 Data collection

5.1 Indoor temperature and humidity

In Keylong, a Pilot case study was undertaken to explore the distinctive vernacular architecture prevalent in the region. The investigation revealed that vernacular buildings outperformed contemporary counterparts, attributed to the compatibility of building materials with the local environment. Various study emphasized that structures crafted from stone, wood, and soil contributed to a superior indoor environment for occupants. To ensure a comprehensive understanding of our methodology, we used Tempnote TH32 dataloggers with a systematic data collection process spanning different seasons. We conducted a statistical analysis using [specific software/method], allowing for a more robust interpretation of the thermal performance data.

The contemporary building incorporated materials such as baked red brick, cement, sand, aggregate, wood, and stone. The data collection spanned one month during the peak winter season in January 2023, offering a comprehensive snapshot of environmental conditions within both buildings. This research design facilitated a meticulous exploration of the thermal and humidity

performance of vernacular and contemporary structures, providing empirical data to ascertain the effectiveness of traditional building practices in Keylong.

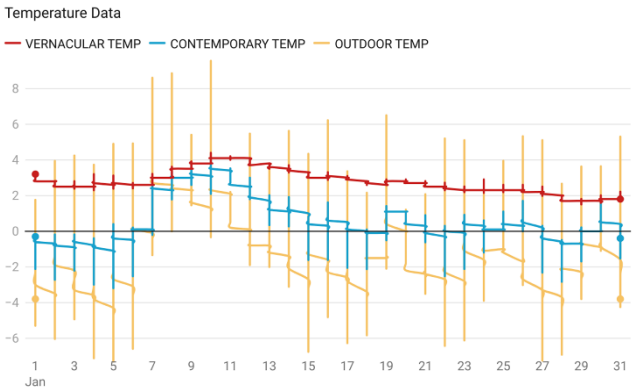

Figure 27. Temperature data (Source - Author)

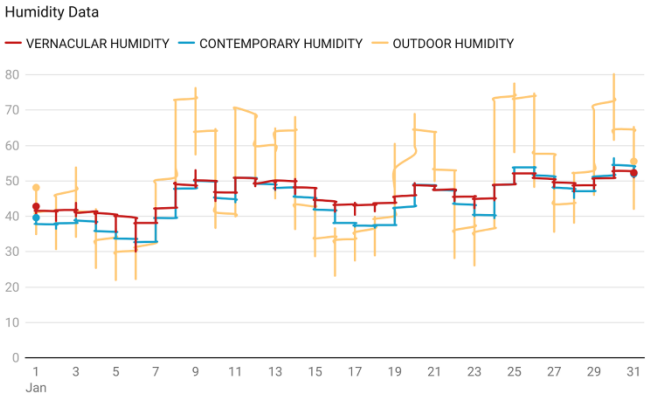

Figure 28. Humidity data (Source - Author)

6. Results and discussion

This investigation delves into the vernacular architecture of the Keylong region, with a primary focus on its construction patterns, materials and thermal performance in comparison to contemporary buildings. The vernacular buildings under study dating back to 1960, exemplify the utilization of locally sourced materials such as stone, wood and mud soil known for their commendable thermal insulative properties. The construction layout, based on various sizes, reflects a meticulous consideration of spatial needs within the local context. To assess the thermal performance of both vernacular and contemporary buildings, Tempnote TH32 dataloggers were employed during the peak winter season from January 1, 2023, to January 31, 2023.

As shown in Figure 27 and 28 the data revealed distinctive thermal profiles for vernacular and contemporary buildings. The contemporary building exhibited suboptimal performance, experiencing the lowest recorded temperature of -3.2 degrees Celsius and a high humidity level of 57 percent. Conversely, the vernacular architecture maintained a significantly more favourable temperature range from of 2.1 to 4.3 degrees Celsius, providing enhanced thermal comfort compared to its contemporary counterpart. A detailed analysis of the climatic data reveals significant patterns in temperature and humidity, correlating these with the architectural features unique to Keylong. This deeper analysis helps in understanding how traditional designs adapt to and mitigate climatic challenges.

The superior performance of vernacular buildings can be attributed to the inherent thermal properties of locally sourced materials namely stone, wood and mud which possess excellent insulation capabilities. This characteristic ensures better temperature regulation within the building mitigating the extremes of external climatic conditions. The vernacular architecture's reliance on various sizes for building areas reflects an intrinsic understanding of spatial requirements tailored to local needs. This flexibility in design caters to the functional demands of the occupants while aligning with the climatic nuances of the Keylong region. The empirical data collected underscores the thermal superiority of vernacular buildings and carries significant implications for contemporary architectural practices. Incorporating locally sourced materials and adopting construction strategies aligned with indigenous wisdom can enhance the energy efficiency and overall comfort of modern buildings, especially in regions with similar climate profiles.

7. Conclusion

In unravelling the intricacies of vernacular architecture in the Keylong region, our present study underscores the profound impact of indigenous design and construction practices on the thermal performance of buildings. The vernacular structures, dating back to 1960 and crafted from locally sourced materials such as stone, wood and mud showcase a remarkable synergy between traditional wisdom and environmental responsiveness. The spatial considerations, reflected in the various sizes of building areas, underscore a nuanced understanding of local needs and climatic nuances. As we conclude this exploration, the study not only reaffirms the thermal superiority of vernacular buildings in Keylong but also advocates for a re-evaluation of contemporary design approaches. The integration of locally sourced materials and construction strategies aligned with indigenous wisdom emerges as a crucial pathway toward creating resilient, energy-efficient and comfortable built environments in the face of evolving climate challenges. Looking ahead, future research endeavours can build upon these findings with a concentrated focus on the indoor environment. A crucial avenue for exploration involves conducting a yearly longitudinal study focused on the thermal comfort within vernacular buildings. This approach would offer a detailed understanding of how these structures perform across different seasons, allowing for an examination of temperature variations and occupant satisfaction over time. Another pivotal aspect for future investigation involves integrating advanced sensors to monitor indoor air quality parameters. This includes tracking humidity levels, air circulation, and particulate matter to gain a comprehensive understanding of the indoor environment's health. Such insights can be correlated with seasonal changes, and the data obtained can be instrumental in designing strategies to maintain optimal air quality within these vernacular spaces.

Furthermore, future research can delve into the energy efficiency of vernacular buildings by closely analysing the performance of traditional heating and cooling mechanisms. This exploration aims to understand how these structures naturally regulate indoor temperatures without excessive reliance on external energy sources, providing valuable insights for the development of sustainable design practices. By focusing on these key aspects, future research can contribute significantly to our understanding of the indoor environment in vernacular buildings, facilitating the development of sustainable and climate-responsive design principles tailored to the unique climatic conditions of Keylong.

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Original Paper

Enhancing cognitive performance and emotional well-being via Nature-induced learning environments.

Insights from neuro-architecture research

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Keywords: neuro-architecture; neuropsychology; built environment; environmental psychology; cognitive architecture; learning environments.

List of Abbreviations: ADHD: Attention-Deficit / Hyperactivity Disorder; ANOVA: Analysis of Variance; ART: Attention Restoration Theory; BDST: Backward Digit Span Test; BVRT: Benton Visual Retention Test; DSM-V: Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition; DSST: Digit Symbol Substitution Test; DST: Digit Span Test; EEG: Electroencephalogram; FAA: Frontal Alpha Asymmetry; NASA-TLX: NASA Task Load Index; PRS: Perceived Restorativeness Scale; PRT: Prospect Refuge Theory; SRT: Stress Reduction Theory; ST: Stroop Test.

Abstract. *This study, involving 22 participants, explored the impact of nature-induced design on cognitive performance and emotional well-being in educational settings. Key metrics included EEG-based Frontal Alpha Asymmetry (FAA), Normalized Alpha brainwave activity, the Perceived Restorativeness Scale (PRS), and the NASA Task Load Index (NASA-TLX). In 'more biophilic' learning environment, i.e., Studio, PRS scores significantly increased, indicating higher perceived restorativeness, while NASA-TLX scores (56.65 in the Studio versus 50.65 in the Seminar Hall, i.e., 'lesser biophilic' learning environment) indicated greater cognitive engagement in the Studio. Notably, the Studio exhibited higher left-aligned FAA outcomes, revealing a significant relationship between FAA and the built environment ($\chi^2 = 12.239$, $p < 0.001$). The study identified substantial effects, with a significant variance for PRS-11 ($F = 12.134$, $p = 0.001$) and moderate influence for NASA-TLX ($F = 4.374$, $p = 0.043$). ANOVA analysis revealed significant differences in cognitive performance across various tests: BVRT ($F = 9.195$, $p = .004$), DST ($F = 20.230$, $p < .001$), BDST ($F = 19.563$, $p < .001$), ST ($F = 4.319$, $p = .044$), DSST ($F = 15.400$, $p < .001$), and the overall Cognitive Score ($F = 27.508$, $p < .001$), indicating a robust effect of the built environment on cognitive functions. This research demonstrates that nature-infused educational environments significantly enhance critical cognitive processes essential for learning, suggesting their potential in environmental design for cognitive and emotional development. However, it*

acknowledges limitations, such as sample variation and experimental settings, and encourages further investigation in diverse contexts and long-term effects.

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1. Introduction

In contemporary society, where individuals spend the majority of their time within or around built environments, the symbiotic relationship between architectural design and human psychology emerges as a focal point of scholarly investigation. The repercussions of architectural composition on involuntary attention, behavioural patterns, and cognitive functions have garnered significant attention, underscoring the imperative to align built environments with the intricacies of human psychological well-being (Kassarning et al., 2018). Within educational contexts globally, students grapple with pervasive academic stress and anxiety, phenomena intricately interwoven with mental health concerns. A burgeoning body of research posits that prolonged exposure to suboptimal educational environments may catalyse the development of psychological challenges, affecting mood and potentially leading to severe mental disorders (Margraf et al., 2020). The multifaceted impact of built environments on mental health spans direct considerations such as illumination levels, background noise, indoor conditions, and pollution, as well as indirect factors including classroom congestion, furniture design, and aesthetic elements (Asim et al., 2021). Critical considerations in the design of learning spaces extend to the cognitive implications of inadequate illumination and ambient noise, the discomfort induced by suboptimal temperature control and ventilation, and the potential hindrance to cognitive performance resulting from distractions and elevated stress levels in crowded educational settings (Castilla et al., 2023). Ergonomic challenges posed by uncomfortable furniture further impede students' concentration and participation. Monotony in design elements may contribute to reduced engagement and cognitive function, while limited access to outdoor spaces may deprive students of the benefits associated with biophilic design, impacting both cognitive and mental well-being (Ko et al., 2020). Challenges stemming from inefficient floor plans, unclear navigation aids, and complex layouts within learning environments present additional stressors that can contribute to tension and anxiety, ultimately impairing cognitive abilities (Maxim et al., 2023). Environmental factors such as unpleasant smells, visual distractions, and clutter introduce further complexities, disrupting students' focus and concentration in academic pursuits. Moreover, the absence of personalization

options within learning spaces and non-accessible buildings pose potential obstacles for students with disabilities, impacting engagement and social and cognitive growth (Klatte et al., 2010). This intricate interplay between architectural design, environmental variables, and cognitive well-being underscores the urgency and significance of investigating the impact of learning-built environments on students' cognitive functions within the scope of this research endeavour (Aries et al., 2015).

1.1. Cognition: attention, memory, perception and executive function

Cognitive functions, encompassing attention, memory, perception, and executive function, form the bedrock of essential mental processes, facilitating the reception, interpretation, and response to environmental stimuli. These cognitive processes are integral to the execution of daily tasks, problem-solving, decision-making, and overall cognitive performance (Demetriou et al., 2020; Weinstein et al., 1977). Attention, a foundational cognitive ability, involves the focused concentration on specific stimuli while concurrently disregarding others. It manifests in various forms, including alternate, divided, sustained, or selective attention, contingent upon situational demands and task requirements (Marchand et al., 2014; Bodenhausen & Hugenberg, 2011). Memory, another pivotal cognitive process, encompasses the encoding, storage, and retrieval of information for subsequent utilization. This multifaceted process involves the conversion of sensory information into a storable format, the retention of encoded information over time, and the retrieval of stored data as needed. Memory is further categorized into long-term memory, working memory, and sensory memory (Ashcraft, 1989; Dolcos et al., 2020). Perception, an intricate cognitive function, pertains to the construction of meaningful interpretations from sensory data acquired from the environment. This process involves the integration of diverse sensory inputs, such as visual, auditory, tactile, and olfactory cues, to form a coherent representation of the surroundings, enabling recognition of objects and events (Bruner & Postman, 1949; Bodenhausen & Hugenberg, 2011; Cahen & Tacca, 2013). Executive function, comprising sophisticated cognitive processes, serves to manage and coordinate other cognitive skills. It encompasses planning, organizing, initiating and ceasing actions, monitoring performance, and adapting to changing circumstances (Miller & Wallis, 2009; Roebers, 2017). Essential components of executive function include controlling impulsive behaviour, exercising cognitive flexibility through task-switching, and proficiently strategizing and organizing tasks for goal-directed behaviour, problem-solving, self-control, and decision-making (Gilbert & Burgess, 2008; Benedek et al., 2014).

The synergistic operation of these cognitive processes significantly influences how individuals perceive and interact with their environment. To optimize learning, daily functioning, and overall cognitive performance, these cognitive domains necessitate peak functionality (Choi et al., 2014; Ward et al., 2016). Factors such as age, health, environment, and training can modulate the efficacy of specific cognitive processes, highlighting the multifaceted nature of cognitive function within the context of this investigation (Cassrino & Setti, 2015).

1.2. ART, SRT, PRT and Arousal Theory

The psychologists Rachel and Stephen Kaplan developed the Attention Restoration Theory (ART) in the 1980s. According to the hypothesis, exposure to Restorative Environments (often natural settings) helps replenish one's mental capacities and cognitive abilities, especially directed attention, which can become depleted or worn out after repeated use (Kaplan & Kaplan, 1989). To combine elements of nature and encourage mental repair, ART has been applied to a variety of fields, including urban planning, architecture, healthcare, education, and workplace design (Ohly et al., 2016; Neilson et al., 2019). Exposure to restorative environments has been linked to a better mood, less stress, better cognitive function, more creativity, and general wellbeing (Pasanen et al., 2018; Felsten, 2009; Asim et al., 2023; Moreno et al., 2018; Asim & Shree, 2019). The ART states that it is crucial to incorporate natural components into environments and design spaces that promote effortless attention to replenish mental resources, which will lead to better cognitive performance and psychological health in general (Kaplan & Kaplan, 1989; Kaplan et al., 1993).

According to ART, exposure to places with particular restorative features i.e., Restorative Environments, such as natural environments, can aid in the recovery of mental resources like attention. It emphasises how relaxing being in nature is and how easily it attracts attention (Joye & Dewitte, 2018). Improved cognitive function and lessened mental weariness are benefits of the restoration of attention. As stated by Ulrich (1991) and others, who support the Stress Reduction Theory (SRT), being exposed to natural settings can lower stress levels and accelerate the recovery process after stress. It emphasises how nature can have a good impact on emotions and bodily reactions, which can reduce stress and increase wellbeing (Ulrich et al., 1983; Luo & Jiang, 2022). The Prospect Refuge Theory (PRT), put forth by Appleton, focuses on how humans have evolved to choose locations that provide both prospects—views of their immediate surroundings—and refuges—areas of protection and camouflage. According to this theory, being in an environment with beautiful views and a

sense of security or sanctuary can evoke pleasant emotional reactions, support attention restoration, and lower stress levels (Appleton et al.,1975; Dosen & Ostwald, 2016; Gatersleben & Andrews, 2013).

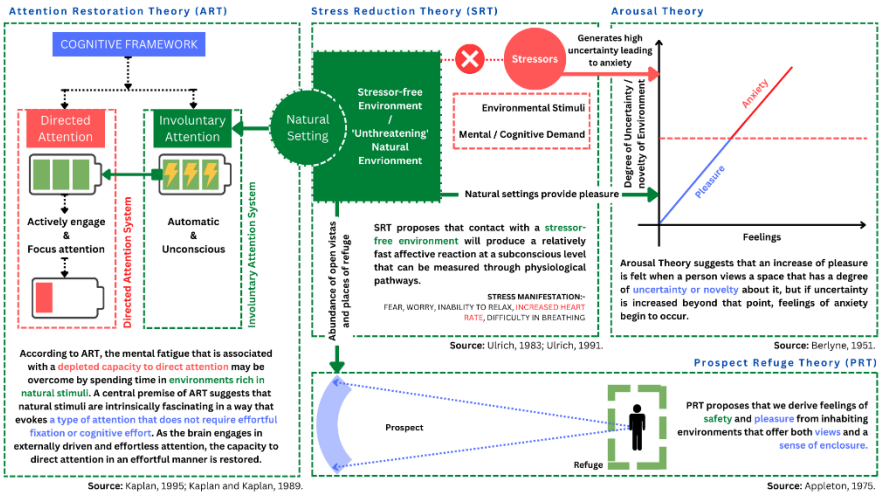

Figure 1. Theoretical frameworks of recovery from stress, and emotional satisfaction with respect to the built environment: attention restoration, stress reduction, arousal, and prospect & refuge (Source: Asim et al., 2023). HR is in https://ojs.unito.it/index.php/visions/article/view/9265/8309

According to the psychology-based Arousal theory, people look for the right amount of motivation or arousal in their surroundings. Both insufficient or excessive stimulation might cause discomfort or stress (Berlyne, 1963; Russell et al., 1980). Natural settings frequently offer the right amount of stimulation, bringing about a state of calm and lowering tension, which is consistent with the ART and SRT principles for decreasing stress. Asim et al. (2023) conducted a comprehensive analysis of various theoretical frameworks (shown in Fig.1), underscoring a common theme across each: the significant benefits of natural environments for enhancing human well-being, alleviating stress, and aiding in attention recovery. Their research highlights the multifaceted impact of natural elements, reinforcing the notion that, despite the distinct focus of each theory, they collectively affirm the importance of integrating natural materials and restorative factors into our surroundings to improve mental health and overall quality of life.

1.3. PRS and NASA TLX

Within the realm of environmental psychology, the Perceived Restorativeness Scale (PRS) is frequently employed as a measurement instrument, assessing an environment's potential for promoting psychological restoration. This scale is intricately linked with the Attention Restoration Theory (ART), positing that specific environmental settings have the capacity to alleviate mental fatigue and contribute to the replenishment of cognitive resources, particularly attention (Pasini et al., 2014; Korpela & Hartig, 1996). The PRS encompasses factors associated with environmental attributes conducive to restorative experiences, including fascination, being away, coherence, and compatibility with individual preferences. Respondents evaluate these characteristics based on their perceptions and interactions with the environment (Rai et al., 2019). PRS has become an important tool in environmental behaviour studies in recent years with urban design and architecture being one of the PRS's main fields of application. The scale is being used by researchers on a wider scale to assess the restorative potential of urban green areas, such as parks and gardens (Stragà et al., 2023; Hooyberg et al., 2022; Rai et al., 2020). This assessment is essential for creating cities that not only have a beautiful appearance but also exhibited residents' mental health and stress relief. Studies on workplace environments have another important use for the PRS. Here, the scale assists in analysing how various workplace layouts and the inclusion of natural features, in particular, might enhance worker productivity and well-being (Pasini et al., 2021; Craig et al., 2022). Research in educational establishments use PRS as a measure to evaluate how their surroundings affect the mental health of their students. Through the assessment of aspects like natural light, vegetation, and layout in educational institutions, the PRS facilitates comprehension of how these features improve cognition and lower stress levels in students (Asim & Shree, 2019; Stragà et al., 2023). When taken as a whole, these various uses of the PRS reflect how crucial it is to design spaces that are both functional and psychologically restorative.

Concurrently, the NASA Task Load Index (NASA-TLX), a multidimensional tool originally devised for assessing the workload of NASA pilots, serves as a comprehensive measure of the mental and emotional demands inherent in a given task (Hart & Staveland, 1988; Hart, 2006; Alaimo et al., 2020). This tool, adapted for application across various disciplines, involves users assigning numerical scores to each dimension while concurrently rating the perceived burden on individual subscales. The derivation of an overall workload score involves the weighted summation of these individual scores (Noyes et al., 2007).

1.4. EEG and its application in learning-built environment

Utilizing the non-invasive technique of electroencephalography (EEG), this study examines the electrical activity within the brain, providing valuable insights into various cognitive processes. EEG allows researchers to observe brainwave oscillations and event-related potentials, which serve as indicators of cognitive functions such as memory acquisition and retrieval, attentional allocation, and other related processes (Gotlib, 1998; Klimesch, 1999; Ball et al., 2009). Notably, the high temporal resolution of EEG renders it ideal for the real-time recording of cognitive changes. Across diverse learning-built environments, EEG serves as a proficient tool for monitoring student participation and attention during learning activities. This capability empowers educators and architects to optimize spatial layouts and configurations, strategically aligning with periods of heightened or diminished attention (Ramírez-Moreno, 2021; Azazzy et al., 2021; Cruz-Garza et al., 2022). Furthermore, EEG recordings have the capacity to capture emotional reactions and affective states, unveiling pivotal details regarding the influence of the built environment on students' emotional experiences. Incorporating positive design elements have further shown to enhance learning processes and contribute to improved memory retention (Arsalidou et al., 2016; Li et al., 2020; Hu et al., 2021). Moreover, EEG facilitates the identification of cognitively challenging or confusing spaces within a specific environment, thereby enabling potential design enhancements for enhanced navigation and spatial comprehension (Lin et al., 2021; Bower et al., 2022; Mavros et al., 2022).

In the study of brainwave oscillations, certain frequency bands have been linked to specific neuronal functions and states of consciousness. Delta waves, which have a frequency range of 1-4 Hz, are often connected with profound relaxation and the unconscious mind and are frequently seen during dreamless sleep. Theta waves, which occur between 4 and 8 Hz, represent a state that is close to consciousness, similar to that experienced during light sleep or intense meditation. Alpha waves, which range from 8 to 13 Hz, indicate a calm yet aware state, and are frequently present throughout restful wakefulness, and serve as a link between sensory and cognitive processes (Bhatti et al., 2016; Horlings et al., 2008). Beta waves, which range from 13 to 32 Hz, are indicative of an active, engaged mind and usually increase during periods of heightened attention or stress. Finally, gamma waves, which have frequencies more than 32 Hz, are indicators of high-level cognitive functioning and complicated information processing, since they represent intricate brain activity. These bands provide a spectral framework for comprehending the brain's changing physiological states

as it interacts with and responds to its surroundings (Dziembowska et al., 2016). By measuring tension and relaxation responses to various environmental stimuli, EEG offers valuable insights for designing tranquil and stress-relieving zones within educational settings (Chen et al., 2020; Asim et al., 2023). This knowledge, in turn, informs the creation of environments that positively influence stress levels, ultimately contributing to enhanced learning outcomes (Hou et al., 2015).

Another important metric arising from within EEG studies is Frontal Alpha Asymmetry (FAA). It conveys information regarding the differences in alpha wave activity between the brain's left and right frontal regions. As mentioned earlier, alpha waves are a type of brain waves found in EEG recordings that are often connected to a relaxed wakefulness state (Smith et al., 2017; Mennella et al., 2017). Alpha power, or the frequency and intensity of alpha waves, in the brain's frontal lobes, is compared to determine FAA. According to the notion, psychological processes and emotions may be related to fluctuations in alpha power between the left and right sides of the frontal cortex (Javorska et al., 2012; Gollan et al., 2014). Studies have shown a potential link between FAA and an individual's ability to regulate and direct their attention. Greater asymmetry favouring the left frontal region, for instance, may be linked to improved attention and the capacity to restrict out unimportant distractions. The relationship between FAA patterns and sustained attention throughout extended activities is also of interest since it may have an impact on performance in professional or educational environments (Pérez-Edgar et al., 2013; Bagherzadeh et al., 2020). It has also been reflected in the studies that approach or avoidance motivation, which can impact decision-making processes, is associated with the FAA. Approach behaviours are frequently linked to left-frontal activity dominance, which may result in more proactive decision-making approaches (Kaur et al., 2020; Deng et al., 2023).

2. Material and Methods

2.1. Methods

The primary objective of this research article was to discern and analyse the different cognitive behaviours exhibited by students within two distinct learning-built environments—namely, a biophilic setting represented by 'the architecture studio' and a less biophilic counterpart represented by 'the seminar hall'. By undertaking a distinct investigation of cognitive functioning, restorativeness and perceived mental workload in these environments, the study aspires to provide

empirical insights into the differential impact of presence of biophilic elements on the cognitive processes of students within educational settings.

2.2. Hypothesis

Grounded in the theoretical frameworks of Attention Restoration Theory (ART), Stress Reduction Theory (SRT), Perceived Restorativeness Theory (PRT), and Arousal Theory, the study posits that the learning-built environment exerts a significant influence on students' cognitive functions, including attention, memory, perception, and executive function. The investigation formulates four hypotheses to systematically examine these cognitive and restorative dimensions, as outlined in Table 1 and illustrated in Figure 2.

Hypotheses	Explanation
H1a	*The presence of the biophilic built environment will generate a positive approach i.e., Left aligned FAA.*
H1b	*The presence of the biophilic built environment will generate a higher Normalized Alpha i.e., induce feeling of calm or restoration or relaxation.*
H2a	*The presence of the biophilic built environment will generate a higher Perception of Restorativeness.*
H3a	*The presence of the biophilic built environment will generate a lower perceived workload score.*
H4a	*The presence of the biophilic built environment will generate a higher Cognitive Score.*

Table 1. Hypothesis being tested in the study with their explanation

These hypotheses collectively serve as a structured framework for the empirical investigation, guiding the analysis and interpretation of data collected within the study. The variables outlined in each hypothesis are strategically selected to capture distinct facets of the cognitive experience within different environmental conditions, providing a comprehensive understanding of the impact of biophilic elements on students' cognitive functions. The subsequent sections detail the methodology employed to test and validate these hypotheses rigorously.

2.3. Location and participants

The study was conducted at an institute of National importance, located between 870 and 900 meters above sea level in the Shivalik hills of the Himalayas, within the Himachal Pradesh region of India. This study aimed to discern the impact of learning environments characterized by variation in presence of biophilia on the cognitive functions, specifically attention, memory, perception, and executive function, among students, with a focus on their cognitive performance. A cohort of 22 participants, maintaining an equitable gender distribution i.e., 1:1 for Male: Female (calculation shown in Table 2) (Faul et al., 2007), enrolled in both bachelor's and master's programs, participated in the study, adhering to an age

bracket of 18 to 26 years. The decision on the sample size was informed by a power analysis, underscoring the study's commitment to statistical reliability and validity. Adherence to Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V) criteria guided the inclusion of individuals, who were screened for adult Attention-Deficit/Hyperactivity Disorder (Adult-ADHD), depression, and anxiety. Screening instruments such as the CES-D (Center for Epidemiologic Studies Depression Scale), GAD-7 (Generalized Anxiety Disorder 7), and ASRS-5 (Adult ADHD Self-Report Scale) were employed for this purpose (Ustun et al., 2017; Lolk, 2013). The utilization of these assessments aimed to pre-emptively identify and mitigate potential confounding influences arising from mental health issues, ensuring the participants' cognitive stability. Participants were additionally required to disclose any history of addictive behaviours, mental disorders, neurological conditions, or a combination thereof. This comprehensive screening process was integral to ensuring the study's integrity and the accurate interpretation of cognitive data by minimizing the influence of external factors on participants' cognitive functioning.

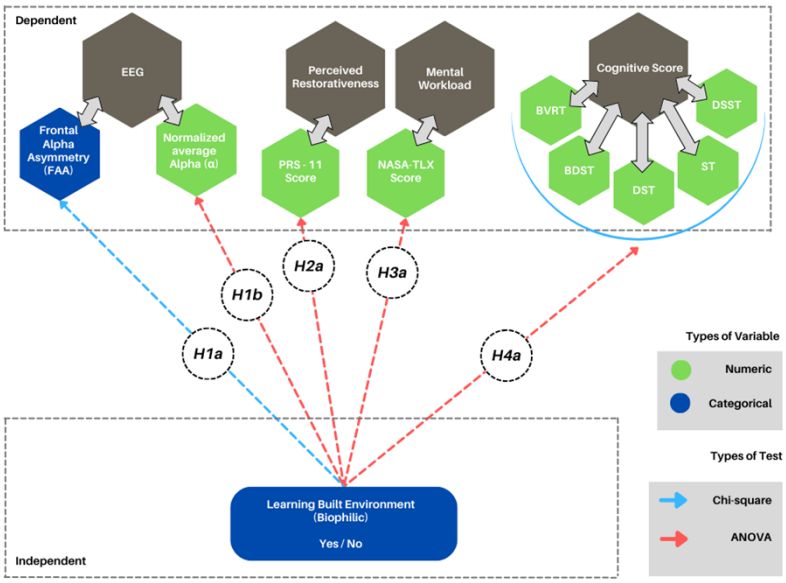

Figure 2. Demonstration of variable associations being tested with ideal statistical tests *(Source: Author)*.

Test Family	Statistical Test	Effect Size	α	power (1-β)	Computed Sample Size
f-test	ANOVA: One way	0.8	0.05	0.95	22
chi square	Goodness of fit tests - Contingency Tables	0.8	0.05	0.95	21
	Adopted Sample Size				**22**

Table 2. Participant sample size calculation using G Power 3.1.

2.4. Learning environments

For this investigation, two distinct learning-centric environments were chosen within the campus setting, specifically denoted as a) Studio and b) Seminar Hall. The layout plan of both the learning environments is shown in Figure 3 and interior views in Fig. 4. The learning environment Studio is a significantly more biophilic in terms of its inherent access to nature from a ribbon window at lintel level on one side and a rear window running from sill to lintel level which offers views of dense pine forest and snow-clad mountains (as shown in Fig. 4-d). Whereas the learning environment Seminar Hall is significantly less biophilic in terms of its access to nature from only a rear window running from sill level to lintel level which offers outdoor views of a small, enclosed garden.

Figure 3. Layout plan of a) Studio: a more biophilic learning environment (left) and b) Seminar Hall: a less biophilic learning environment (right) (Source: Author).

Unlike majority of previous studies where the biophilic element (window or green wall in most cases) is kept in clear sight of the participant, this study adopts an indirect approach and brings the biophilic element as a passive visual element. These elements were positioned outside the direct focus zone of participants, who were aware of their presence without engaging in continuous visual contact. This setup aimed to explore the restorative effects of biophilic features on participants' cognitive states, even in the absence of direct interaction, positing that the mere awareness of these elements could positively influence the learning experience.

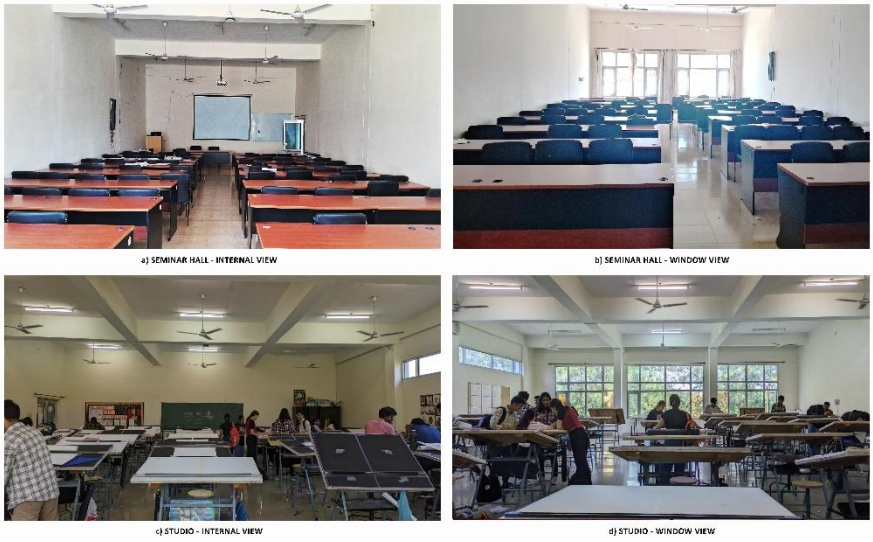

Figure 4. Built Environments: Interior of Seminar Hall and Studio (Source: Author).

2.5. Brainwave and cognitive data acquisition and processing

To facilitate the experimental protocol, each participant had to wear a mobile electroencephalography (mEEG) device namely the InterAxon Muse S, while sitting in the designated learning environment. The Muse S, an EEG device of research-grade quality developed by Interaxon, serves as the apparatus employed for the acquisition of brainwave data in this study.

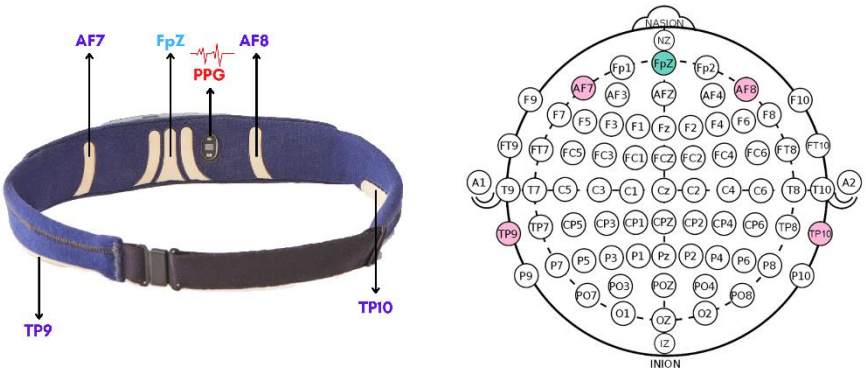

Figure 5. Interaxon Muse S EEG device with electrodes marked (left) and their location as per EEG 10–20 international system (right) (Source: Author).

This device is equipped with four dry electrodes strategically positioned at AF7, AF8, TP9, and TP10 locations as per the EEG 10-20 system, facilitating the collection of brainwave signals encompassing alpha, beta, gamma, theta, and delta frequencies from the frontal and temporal nodes of the brain. The Muse S through its distinctive use in various multidisciplinary studies, thus stands as a reliable instrument for the precise and comprehensive recording of electroencephalographic activity for the course of this study (Domjan et al., 2023; Mansi et al., 2022; Cannard et al., 2021; Mehmood et al., 2023; Asim et al., 2023).

Using a sample rate of 256 Hz, EEG data were captured using the Muse Monitor application and underwent a complex procession through advanced software tools including the extensive EEGLAB toolbox developed by the Swartz Centre for Computational Neuroscience (Delorme & Makeig, 2004). Using MATLAB, we were able to precisely compute the Power Spectral Density (PSD) in each of the standard frequency bands: beta, gamma, alpha, theta, and delta. These bands provide information on different cerebral rhythms. A bandpass filter was used to filter through individual brain waves, keeping just the most pertinent frequencies. After this filtration, the complicated multivariate EEG signals were broken down into their independent components using the Independent Component Analysis (ICA) technique. The last step in this data curation process was a careful cleaning, where any segments that were contaminated by electrical noise or poor electrode

performance were removed. This ensured that the EEG data would remain clear and intact for further analysis. Topographic maps, often known as headplots or topoplots, were created for each participant's EEG data to allow for a visual evaluation of the FAA conditions.

The Frontal Alpha Asymmetry (FAA) indices were calculated by taking the natural logarithm of the alpha power at the right frontal electrode (AF8) and subtracting the natural logarithm of the alpha power at the left frontal electrode (AF7) as shown in the following equation (Koslov et al., 2011; Reznik & Allen, 2018; Zhang et al., 2018):

$$FAA = \ln(AF8) - \ln(AF7)$$

The experimental procedure was conducted with individual participants, ensuring that each subject experienced both learning environments—studio and seminar hall—in a randomized order. This approach allowed for the repeated application of the protocol depicted in figure 6 for each environment, aiming to minimize order effects and ensure unbiased comparisons between the two settings.

As depicted in Fig. 6 showcasing graphical protocol of the study, to assess the initial mood and cognitive state of participants, the valence arousal test was employed before the experimental baseline and cognitive sessions began. This step was crucial for identifying mood outliers and ensuring the reliability of subsequent cognitive test results. Baseline measurements were then established, serving as a reference point for normalizing data collected during the study. This methodological sequence was designed to provide clean, normalized data for analysis, reflecting the study's meticulous approach to examining the impact of biophilic design elements on learning environments. In a structured sequence, participants were directed to maintain an open-eyed observation of the spatial surroundings for an initial duration of one and a half minutes. The duration of 180 seconds (3 minutes) for environmental stimuli has been previously established as valid in an EEG study conducted by Herman et al., 2021. This period was preceded by an equivalent timeframe during which participants closed their eyes, allowing for an introspective phase. This cyclical process was instrumental in the development of individual baseline brainwave patterns over the cumulative span of three minutes.

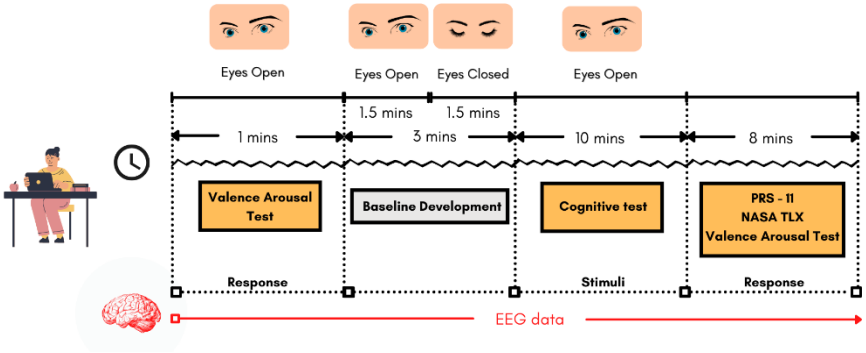

Figure 6. Graphical protocol of the study (Source: Author).

The study commenced with the administration of a combination of cognitive assessments to the participants. These assessments include the Benton Visual Retention Test (BVRT), Digit Span and Backward Digit Span Test (DST/BDST), Stroop Test (ST), and Digit Symbol Substitution Test (DSST) (Lim et al., 2013). The BVRT involved presenting participants with an image for a duration of 10 seconds, after which they were provided with four response options. This test specifically evaluated the visual perception and visual memory capabilities of the participants (Benton at el., 1946). The Digit Span and Backward Digit Span Test focused on assessing the attention and memory functions of the participants. A series of numbers appeared sequentially on the screen, requiring participants to memorize and subsequently reproduce the sequence in both forward (Digit Span) and reverse (Backward Digit Span Test) orders (Jones et al., 2015). The Stroop Test targeted executive function and attention where the participants were tasked with 'speaking' the ink colour of words presented on the screen, aiming to minimize the influence of the actual word on their responses. The imperative was to respond swiftly while maintaining accuracy (Stroop et al., 1935). The Digit Symbol Substitution Test was conducted in a pen-and-paper format where the participants were allocated a symbol corresponding to each digit and were instructed to transcribe the symbols beneath their respective digits within a stipulated time limit of one and a half minutes. This particular test gauged the perceptual abilities of the participants (McLeod et al., 1982). The participants were familiarised with the cognitive tests prior to the experiment. The scores from all cognitive tests were

normalized as it ensures scale consistency across different parameters, enhancing the precision and effectiveness of the computations that follow (Hancock et al., 1988; Singh & Singh, 2020).

In the current study, both the PRS and NASA-TLX instruments have been employed to gauge the restorative experiences and cognitive load experienced by participants within the learning-built environment while engaging in cognitive tests. This integrated approach allows for a nuanced understanding of the interplay between the environmental attributes, cognitive demands, and the subjective experiences of individuals within the educational context. Additionally, they engaged in the assessment of emotional states using the valence-arousal model of emotions. Fig. 7 depicts the entire EEG data acquisition, processing, and feature extraction along with cognitive, perception and environmental data collection procedure.

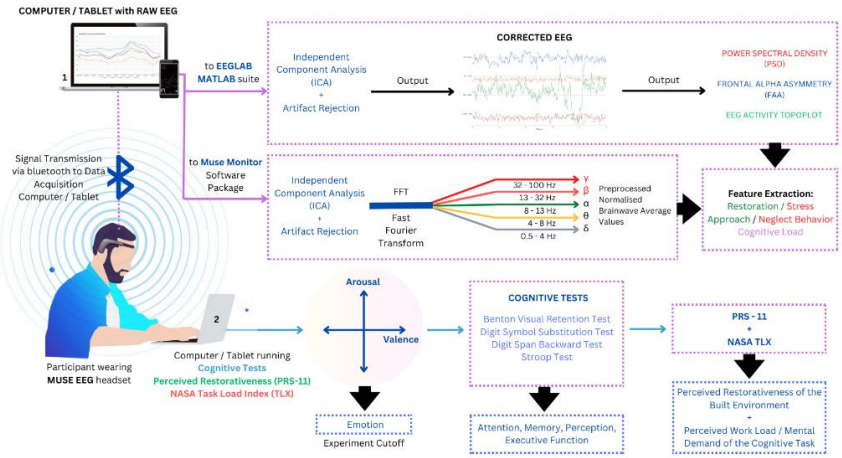

Figure 7. EEG data acquisition, processing, and feature extraction along with cognitive, perception and environmental data collection (Source: Author).
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2.6. Statistical analysis

The statistical analysis was conducted utilizing IBM® SPSS® Statistics Version Amos 27.0. Descriptive statistics, such as frequencies and percentages,

characterized categorical variables, while continuous variables, accounting for psychophysiological traits, were summarized using means and standard deviations. A suite of analytical techniques, comprising Chi-square and ANOVA were deployed to investigate varied combinations of continuous and categorical variables within the analytical framework. The visual representation of the diverse associations under examination, inclusive of appropriate statistical methodologies, is delineated in Fig. 2.

3. Results

The comparison of data from the Seminar Hall and Studio learning environments which is tabulated in Table 3 reveal how different surroundings might affect brainwave activity and cognitive ability. As shown in Fig. 8, Delta, Theta, and Gamma waves had somewhat higher mean values in Seminar Hall. This pattern suggests that the Seminar Hall setting promotes relaxation and meditation, as seen by the presence of Delta and Theta waves, which are frequently linked with profound relaxation and the early stages of sleep. Results from Studio revealed a significant increase in Alpha wave activity and a little increase in Beta wave activity. This might suggest that the Studio atmosphere promotes a state of relaxed alertness, which is ideal for creative and cognitive pursuits, as Alpha waves relate to relaxed mental states and Beta waves with active, engaged thinking.

The Studio environment outperformed the Seminar Hall on all cognitive tests (nBVRT, nDST, nBDST, nST, and nDSST), as indicated by far better mean scores as depicted in Fig. 9. This shows a direct link between the environment and cognitive capabilities such as memory, attention, and problem-solving skills. The cognitive score, which is a cumulative score of all five cognitive tests, was much higher in the Studio (as shown in Table 3), supporting the theory that the Studio's biophilic-influenced spatial and environmental qualities are more conducive to cognitive activities and mental agility.

In the Studio, the mean PRS-11 score is higher (46.32) than in the Seminar Hall (36.18). This implies that participants thought the Studio was typically more reviving or restorative than the Seminar Hall. Compared to the Seminar Hall (26-61, Std. Dev. = 7.48), the Studio has a larger range and standard deviation (21-60, Std. Dev. = 11.42). This suggests that participants' perceptions of the Studio's restorative qualities varied more than expected, with some perceiving it as very restorative and others as less so. In the Studio, the mean NASA-TLX score is higher (56.65) than in the Seminar Hall (50.65). This suggests that people

perceived that the tasks completed in the Studio were more difficult or stressful. The NASA-TLX score's range and standard deviation are also larger in the Studio (42 to 80, Std. Dev. = 10.48) than in the Seminar Hall (40 to 75, Std. Dev. = 8.44), indicating that there was greater variation in the Studio about how difficult the tasks were viewed to be. Interestingly, the Studio had a greater perceived workload (NASA-TLX) even though it was thought to be more restorative (PRS-11). This might mean that even while the Studio setting is better for restoration, the work done there may be more difficult or need a higher level of cognitive involvement.

		SEMINAR HALL – less biophilic				***STUDIO – more biophilic***			
		Mean	***Min.***	***Max.***	***Std. Dev.***	***Mean***	***Min.***	***Max.***	***Std. Dev.***
Brainwaves	***Delta***	*.252*	*.160*	*.390*	*.062*	*.218*	*.080*	*.320*	*.062*
	Theta	*.174*	*.127*	*.220*	*.025*	*.164*	*.129*	*.230*	*.029*
	Alpha	*.217*	*.170*	*.280*	*.024*	*.274*	*.189*	*.370*	*.050*
	Beta	*.222*	*.144*	*.310*	*.042*	*.217*	*.130*	*.300*	*.044*
	Gamma	*.135*	*.064*	*.210*	*.036*	*.128*	*.060*	*.220*	*.036*
Cognitive Tests	***nBVRT***	*.364*	*.000*	*1.000*	*.289*	*.636*	*.000*	*1.000*	*.307*
	nDST	*.318*	*.000*	*0.750*	*.221*	*.648*	*.000*	*1.000*	*.263*
	nBDST	*.273*	*.000*	*1.000*	*.266*	*.648*	*.250*	*1.000*	*.295*
	nST	*.568*	*.000*	*0.950*	*.231*	*.426*	*.000*	*1.000*	*.221*
	nDSST	*.487*	*.000*	*0.900*	*.246*	*.732*	*.500*	*1.000*	*.157*
	Cognitive Score	*2.010*	*.754*	*3.342*	*.655*	*3.090*	*1.736*	*4.052*	*.710*
	PRS-11	*36.18*	*26*	*61*	*7.48*	*46.32*	*21*	*60*	*11.42*
	NASA-TLX	*50.65*	*40*	*75*	*8.44*	*56.65*	*42*	*80*	*10.48*
FAA	***Right***	*12*				*3*			
	Left	*11*				*19*			

Table 3. Descriptive statistics of the Brainwave and Cognitive Tests in different learning environments.

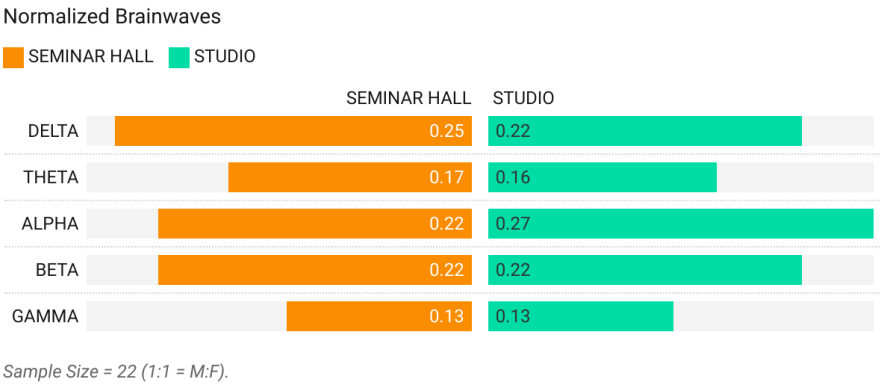

Figure 8. Comparative Analysis of Normalized Brainwave in Seminar Hall and Studio: This chart presents the mean values of different brainwave types (Delta, Theta, Alpha, Beta, Gamma) measured in the Seminar Hall and Studio (Source: Author).

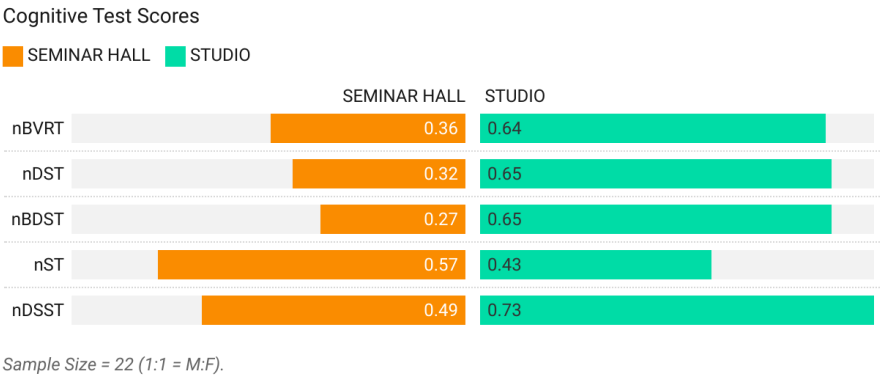

Figure 9. Comparative Analysis of normalized Cognitive Test Scores in Seminar Hall and Studio: This chart illustrates the mean scores of various cognitive tests (nBVRT, nDST, nBDST, nST, nDSST) conducted in the Seminar Hall and the Studio (Source: Author).

Comparative EEG Alpha Band (~10Hz) Topoplots for Participants 1-11 (Female) and 12-22 (Male) in Non-Biophilic (Seminar Hall) and Biophilic (Studio) Environments are shown in Fig. 10. Topoplots employ a colour scale of -4 μV to +4 μV. Cooler colours (blues) imply lower electrical potential, but warmer colours (reds and yellows) suggest greater electrical potential. Certain

parts of the brain show more activity (warmer colours) in one setting compared to another, indicating a persistent pattern. This shows that the two contexts differ in terms of brain activation or relaxation. The brain activity is not seen to be distributed evenly throughout the scalp. There are localized fluctuations in activity, which might imply that specific cognitive processes or emotional states are more prominent in one context than the other. Different patterns of brain activity might indicate different cognitive and emotional states. For example, more frontal activity is frequently connected with engagement and attention, but higher occipital activity may be related to visual processing. Hypothesis H1a and H1b in the next segment will analyze the influence of different built environments on the electrical activity in the brain.

3.1. Frontal Alpha Asymmetry (FAA)

H1a

The analysis involved a Chi-square test to examine the association between Frontal Alpha Asymmetry (FAA) and the type of built environment (Seminar Hall vs. Studio). The results of the Chi-square test demonstrate a significant association between Frontal Alpha Asymmetry (FAA) and the type of built environment ($\chi^2 = 12.239$, $df = 1$, $p < 0.001$). Putting both hypothesis H1a and Fig. 10 comparative topoplots of the participants into consideration, out of the total 30 left aligned FAA (detailed in Table 3), studio learning environment exhibited more left aligned FAA results (19/30) as compared to seminar hall (11/30). This finding suggests that there is a relationship between the asymmetry in frontal brain activity and the specific architectural setting, indicating potential cognitive variations based on the biophilic presence in the learning built environment.

3.2. Normalized Alpha (a) Brainwave

H1b

The null hypothesis, positing no difference between groups, is emphatically rejected based on the results of the ANOVA and a statistically significant difference between groups is observed, predicated on the alpha. The F-statistic, registering at 23.010, signifies a substantial effect. This implies that the variability between groups far exceeds the variability within groups. The p-value, being less than 0.001, furnishes robust evidence against the null hypothesis, bolstering the case for a significant difference between groups. The sum of squares between groups (0.036) is comparatively modest in relation to the total sum of squares (0.102). This implies that the groups elucidate a substantial proportion of the

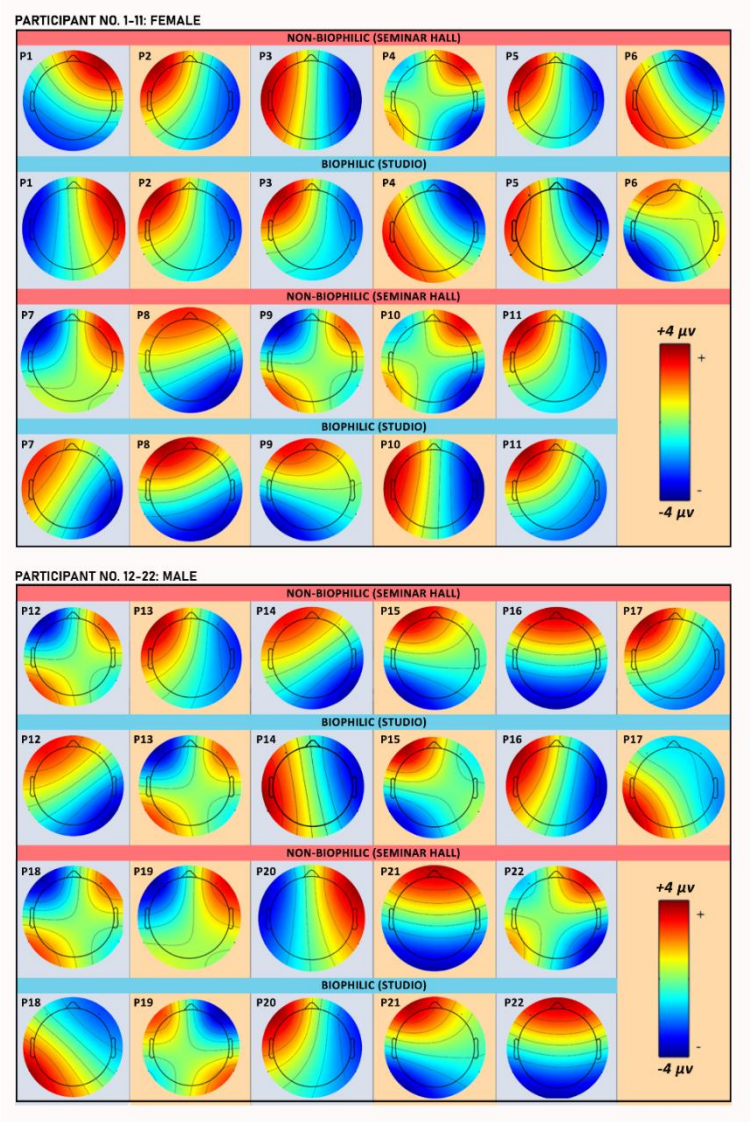

Figure 10. Comparative EEG Alpha Band (~10Hz) Topoplots for Participants 1-11 (Female) and 12-22 (Male) in Non-Biophilic (Seminar Hall) and Biophilic (Studio) Environments. (Each topoplot represents the mean alpha power distribution, measured in microvolts (µV), across the scalp with +4 µV indicating higher alpha activity and -4 µV indicating lower alpha activity. This visualization captures the contrast in brainwave patterns between the two different environmental contexts for each participant) (Source: Author).

variance in alpha. Thus, the results of the ANOVA underscore a statistically significant dissimilarity between groups, as evidenced by alpha. The effect size is considerable, suggesting that the observed differences are not mere chance occurrences. These findings contribute to a nuanced understanding of the impact of group variations on alpha, reinforcing the empirical robustness of the study outcomes.

3.3. PRS-11 and NASA-TLX

H2a

The null hypothesis, positing no difference between groups, is decisively rejected and a statistically significant difference between groups is affirmed based on the PRS-11 variable ($p = 0.001$). The F-statistic, measuring at 12.134, denotes a moderate to large effect size. This implies that the observed variability between groups is considerable. The sum of squares between groups (1130.205) is substantially relative to the total sum of squares (5042.250). This indicates that the groups elucidate a significant proportion of the variance in the PRS-11 variable.

H3a

The null hypothesis of no difference between groups is rejected for the NASA-TLX variable. A statistically significant difference between groups is identified based on the NASA-TLX variable ($p = 0.043$). The F-statistic stands at 4.374, suggesting a moderate effect size. This implies that the variability observed between groups is of moderate magnitude. The sum of squares between groups (396.020) is moderate compared to the total sum of squares (4199.103). This suggests that the groups explain a moderate proportion of the variance in the NASA-TLX variable.

The ANOVA results for both PRS-11 and NASA-TLX variables reveal statistically significant differences between groups, underscoring the impact of the built environment on participants' experiences. Effect sizes further indicate the magnitude of these differences, with PRS-11 exhibiting a moderate to large effect, and NASA-TLX reflecting a moderate effect. The substantial proportions of variance explained emphasize the influential role of the built environment in shaping participants' perceptions and workload.

3.4. Cognitive Score

H4a

The ANOVA results shown in Table 4 underscore the substantial impact of the built environment on participants' cognitive performance across various tests. All p-values ($p < 0.05$) indicate statistically significant differences, emphasizing the influence of the built environment on cognitive outcomes. Notably, the Cognitive Score exhibits a substantial F-statistic of 27.508, underscoring the robust effect size and highlighting the pronounced impact of the built environment on overall cognitive performance.

ANOVA						
		Sum of Squares	***df***	***Mean Square***	***F***	***Sig.***
BVRT	Between Groups	.818	1	.818	9.195	.004**
	Within Groups	3.737	42	.089		
	Total	4.556	43			
DST	Between Groups	1.195	1	1.195	20.230	.000**
	Within Groups	2.480	42	.059		
	Total	3.675	43			
BDST	Between Groups	1.547	1	1.547	19.563	.000**
	Within Groups	3.321	42	.079		
	Total	4.868	43			
ST	Between Groups	.220	1	.220	4.319	.044*
	Within Groups	2.142	42	.051		
	Total	2.362	43			
DSST	Between Groups	.658	1	.658	15.400	.000**
	Within Groups	1.795	42	.043		
	Total	2.453	43			
Cognitive Score	Between Groups	12.839	1	12.839	27.508	.000**
	Within Groups	19.603	42	.467		
	Total	32.442	43			

*p<0.05, **p<0.01

Table 4. ANOVA results of Cognitive Tests and Built Environment.

4. Discussion

This study presents an innovative analysis into the cognitive benefits of biophilic learning settings using an EEG-based approach, adding to a more nuanced understanding of the relationship between architecture and cognitive performance (Jung et al., 2023). These findings support the idea that biophilic

features in educational settings improve cognitive performance significantly, which is consistent with the theoretical frameworks of Attention Restoration Theory (ART) and Stress Reduction Theory (SRT).

First, the observed improvements in FAA in 'more biophilic' learning environment supports the notion that natural elements in learning spaces positively influence emotional well-being and cognitive preparedness. This is consistent with prior research indicating that exposure to natural environments promotes a state of mental restoration, which is important for cognitive processes like attention and memory (Kaplan et al., 1989). The results of this study align with and strengthen existing research findings, underlining the importance of biophilic design in establishing ideal learning environments. More importantly, the enhanced Normalised Alpha brainwave activity reported in 'more biophilic' learning settings supports the restorative effect of these environments. This is in accordance with the findings of Ulrich et al., 1991, who hypothesised that natural surroundings reduce stress and increase psychological well-being. This study adds to this understanding by quantifying the cognitive benefits using EEG measures, providing empirical data to justify the use of biophilic components in educational architecture.

The results of the NASA Task Load Index (NASA-TLX) and the Perceived Restorativeness Scale (PRS-11) reinforce the cognitive benefits of biophilic surroundings. Higher levels of perceived restorativeness are shown by the substantial difference in PRS-11 scores between biophilic and non-biophilic situations. This is important since sustained cognitive engagement and performance depend on these levels. Additionally, the study's methodology—which uses EEG to detect cognitive responses directly—represents a substantial leap in the fields of both built environment and environmental psychology research. It provides a more thorough knowledge of the influence of built environments on cognitive processes by bridging the gap between subjective impressions and objective cognitive performance indicators. This research concludes by highlighting how crucial it is to use biophilic design components in learning environments in order to promote the best possible cognitive functioning. It gives architectural decisions a scientific foundation and emphasises the requirement of designing learning settings that are not only practical but also advantageous to the brain.

4.1. Scope and limitations

This study on the cognitive benefits of biophilic learning environments, while insightful, has certain limitations that warrant consideration for future research.

The restricted number of participants in this study may have an impact on how broadly applicable the results are. Furthermore, the uniform demographic and educational background of the sample may restrict the generalizability of the findings to other groups. Expanding and diversifying the participant groups in future research endeavours will improve the external validity of the results. Additionally, a 4 electrode EEG system was chosen for its portability and suitability for non-laboratory research. While this system facilitates the study of cognitive responses in real-world environments, it inherently provides EEG data with reduced spatial resolution. This limitation is significant, as it impacts the level of detail in the acquired brain activity data. Despite this, we have employed robust statistical methods to ensure that the insights derived from our analysis remain meaningful. Our methodology section elaborates on how the study's design compensates for these limitations, aiming to balance ecological validity with the depth of cognitive insights obtained. Because this study is cross-sectional, it only provides a fleeting image of how biophilic situations affect people. Research with a longitudinal design is required to comprehend the long-term effects. The study's learning environments differed in several aspects beyond the intended "biophilic" level, including variations in desk arrangements, room dimensions, and available equipment. This recognition highlights the complexity of isolating biophilic elements as the sole factor influencing the observed outcomes. These environmental differences could potentially affect the study's findings, making it challenging to attribute observed differences in participant responses directly and solely to the biophilic design elements. This acknowledgment serves to underline the multifaceted nature of learning environments and their impact on cognitive and emotional responses, stressing the necessity for further research aimed at isolating and assessing the specific contributions of individual design elements within educational settings.

5. Conclusions

The present research represents a significant progression in comprehending the cognitive effects of nature induced / biophilic learning environments. We have experimentally shown that the integration of natural components in educational settings may improve cognitive function, as indicated by changes in Frontal Alpha Asymmetry and Normalised Alpha brainwave activity. This has been accomplished through innovative utilisation of EEG equipment along with a set of perception-based questionnaires. These results demonstrate that biophilic design is not only an aesthetic decision but an essential element in creating the best possible learning environment. They also support and expand upon the

theoretical foundations of Attention Restoration Theory and Stress Reduction Theory.

According to our study, biophilic spaces can facilitate better emotional health and cognitive preparedness, both of which are essential in learning environments. The NASA Task Load Index indicates a considerable reduction in cognitive load and a significant increase in Perceived Restorativeness Scale scores. These findings highlight the tangible benefits of these settings in terms of stress reduction and improved ability to participate in sustained cognitive activity. Still, this study's implications are not limited to academic environments. The results have wider implications for environmental and architectural design, since they imply that biophilic design components may be intentionally used to improve cognitive performance in a variety of settings, including public spaces and workplaces. Given these results, it is advised that biophilic design components be included into educational and other spaces by educators, architects, and policymakers in order to support cognitive and emotional well-being. It is important that future studies build on these findings by investigating a range of contexts and long-term effects. In conclusion, this study adds an essential component to our understanding of the intersection between environment and cognitive performance. It emphasises how advanced techniques like EEG can be used in tandem with biophilic design to further understand and develop settings that are not only helpful for learning but also play a key role in improving cognitive functions that are essential for academic achievement.

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Ethics statement

The study protocol was approved by the institutional review board at NIT Hamirpur (NIT/HMR/Acad./Ph.D./05/Sup./2023/234–235), and informed consent was obtained from each participant prior to the start of study.

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Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Original Paper

The transcendence of the Roman Catholic Church's Holy Bread.

Bearer and usher of cultural sustainability

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Keywords: culture; Sustainability; cultural sustainability; Holy Bread; Roman Catholic Church.

Abstract. *Culture is less considered a part of the pillars of sustainability which is usually composed of social, economic, and environmental pillars. However, this paper argues that it should be permanently designated as a pillar in its own right. Through the analysis of the Holy Bread and the spiritual values and attached meanings by the Roman Catholic Church, this study illustrates a two-pronged argument that: (1) the bread, by the process towards and state of transcendence as a Holy Bread, is a bearer and proof of the essentiality of sustainability's cultural pillar; and (2) through this bearing of cultural sustainability, this pillar becomes essential together with the other three pillars of sustainability. Utilizing official texts and sources from the Church itself, this study provides evidence for its argument leading to a conclusion that the concept of sustainability finds the cultural pillar a necessity. Further recommendations for future studies and policy making are provided.*

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1. Introduction

The concept of sustainability as well as Sustainable Development (SD) are the contemporarily accepted method of development and are evident across industries and international fora (Ruggerio, 2021). Its three pillars, economic, social, and environmental, have been guiding its practitioners as considered variables. However, an emerging interrelated fourth pillar has been reflected in several related literatures on SD: the cultural pillar (Hidalgo-Giralt et al., 2021; Harkonen & Stockell, 2019; & Grant, 2019). This pillar of sustainability, which mainly focuses on ideals and practices of people that has a particular meaning to them, reflects various intangible and tangible aspects. One aspect within the discussion of culture is religion (Aranoff, 2020). Each religion has a particular set of valuable elements for its believers which includes food. In the case of the Roman Catholic Church, it is the Holy Bread, given in every celebration of the Holy Eucharist that symbolizes the body of Jesus Christ (Ryan, 2015). Some literature included the Holy Bread as a concept or variable but within the confines of religion and doctrines as well as cultural studies (Sparre & Galal, 2018; & Lipiec, 2022). However, its relation to sustainability, particularly cultural sustainability, has not been explored yet.

With this research gap in mind, this paper argues that bread, by the process towards and state of transcendence as a Holy Bread, is a bearer and proof of the essentiality of sustainability's cultural pillar. This study also advances the argument that through its bearing of cultural pillar, it becomes essential together with the other three pillars of sustainability. In the context of this study, this is demonstrated through the teachings and practices of the Roman Catholic Church and through two sub-points; (1) the guided process of creating and consuming the Holy Bread, and (2) the attached spiritual values and meanings on the Holy Bread.

2. Methods

2.1. Research questions

This paper proposes that the Roman Catholic Church's Holy Bread, its process and state of being such, bears cultural sustainability and proves its essentiality with the rest of the pillars. Specifically, this is supported by answering the following questions.

1. What are the attached spiritual values and meanings on the Holy Bread by the Roman Catholic Church?
2. What are the sustainable ways of living according to the teachings of the Roman Catholic Church?
3. How do the attached spiritual values and meanings of the Holy Bread relate to such ways of living in terms of sustainability?

2.2. Research methodology

The study utilizes a qualitative approach as the non-numerical information and explanation of different texts is analyzed and interpreted. The texts are taken from primary and secondary sources, specifically through the process of collecting and categorizing themes in providing answers for the research questions and advancing the main argument. The documents are from the Roman Catholic Church as a general basis as well as related credible supporting literature from external sources.

2.3. Research limitations

This study is generalist in nature in terms of analyzing the official rules and laws of the Roman Catholic Church and the utilization of the Four Pillars of

Sustainability. The study utilizes the term "Holy Bread" over the "Holy Host" in emphasize the sacred bread received by Catholics during the celebration of the Eucharist. This is to highlight the focus on food in the overall aspect of culture which is being attempted in the study. Nonetheless, both terms in the context of this research remain the same while recognizing that the latter is the official terminology utilized by the Roman Catholic Church.

The study does not consider the meaning and values of the Holy Bread from the common practitioners of the Roman Catholic faith nor any specific practices regarding the Eucharist across the world. The research focuses on generalist official doctrines, writings, related articles on, and recommendations of the Roman Catholic Church as well as on other journal articles and book chapters. The study does not include the Holy Wine since, in practice, it is not conventionally shared for mass attendees as the Roman Catholic Church find the Holy Bread already sufficient to symbolize the body of Christ.

The study does not include the actual practicing of teachings of the Roman Catholic Church as well as the creation, consumption, and the transcendent meanings of the Holy Bread. The study focuses only on what cultural sustainability could possibly usher, by the teachings of the Church alone, through its interrelation with the environmental, economic, and social pillars. This is because such a focus would require a narrowing of scope, reliance on facts of the ground since the study requires how it is practiced, as well as direct data collection from participants and key informants. This limitation of focusing only on concepts does not, however, render the arguments of this paper unprovable.

3. Review of related literature

3.1. Culture and cultural sustainability

Culture as a phenomenon and concept to define is unsettled (Lysgard, 2013; Mironenko & Sorokin, 2018). Its loose structures suggest the encompassing consideration on external objects and internal humanity of the person. These may refer to attitudes, values, languages, moral norms, behaviors, traditions, artifacts, and tangibly produced materials (Allen, 2003; Tuleja, 2017). It is in this scope that most studies and this research shall bank the parameters of the variable. Despite the argument for consolidation towards an empirical and objective meaning, culture's current state suggests its applicability for interrelations with other concepts. One of these is its interrelation with the concept of sustainability which also has no fixed definition (Moore et al., 2017).

Nonetheless, Johnston et al. (2007) points out the basic inclusion of the traditional pillars of sustainability upon analysis of different definitions rendered for the concept. It is on these generalizations in which the study anchors its combination of culture and sustainability substantiated by further studies that utilized both.

The literature is scattered with different narrow scopes. The focus ranges from tourism to entrepreneurship (Tan et al., 2018; Davari & Jang, 2023; Tu et al., 2019; Kraus et al. 2020). Such studies could be noted for their emphasis on tangible and intangible characteristics of culture as well as how it is interrelated with the other three traditional pillars of sustainability. With the growing literature relating culture to the discussion on the pillars of sustainability (Thimm, 2019; Bergan et al., 2021), cultural sustainability can be shown to be connected with the social, economic, and environmental pillars.

Hawkes (2001) points out that culture is an "expression and manifestation" of every individual that is evident in different institutions. These institutions include environmental facilities, community interactions and activities, as well as economic-related actions. Such values, behaviors and traditions are vital if an action, policy, phenomenon and/or idea constitutes development today without compromising the future. In relation to this point, Loach & Griffiths (2017) state that culture contributes on how to approach economics, environment, and society through material outcomes produced and ideas. Despite being closely related to social sustainability, Soini & Birkeland (2014) emphasize that there is a case for emphasis on preservation of; heritage, diversity, locality, eco-cultural resilience, eco-cultural civilization, economic viability, and vitality which potentially merit culture's separation as its own pillar.

Through these arguments, food can be a physical existing cultural product to focus on. Literature highlights foods' relation to social, economic, and environmental sustainability (Bohm, 2023; Hoogland et al., 2007; Moustafa, 2016; Darmody, 2022). As a further contribution, this paper argues for the advancement of culture as a pillar of sustainability through food.

3.2. Bread as a harbor of culture

Food reflects the ideals and actions of a group of people through the process of its creation, provided meaning, and interaction with and through it. Primarily, several studies already included food and philosophies or ideas as variables (Christensen, 2017; Schosler et al., 2013; Heldke, 2002). Aside from the intangible part of culture as a focus, other studies have focused on food and specific cultural

localities and local economy (Welz, 2013; Olson, 2019; Magat, 2020). The existence of such relations generally ushers in the process of making the food within the realm of the environment, the management of resources, the people's assertion on its meaning as well as the process of their consumption and its implications.

Amongst all types and varieties of food throughout existing cultures in history, bread is common and a table staple (Nature Publishing Group, 2018). Locations such as France, Central Asia, the Mediterranean, as well as Middle Eastern countries all do have bread as notable part of their cultural backgrounds (Tripathi, 2023; Zocchi et al., 2022). Several evidence provides explanations on why bread is a common part of human consciousness. One hypothetical reason is the universal registration of the word "bread" in political, social, and economic set-up (Costello et al., 2015; Packham, 2014). Another probable reason for its prevalence is the abundance of its ingredients like wheat and water to most places and the ease of its basic creation.

Aside from geographically situated cultures, religions often associate bread with religious ceremonies and their traditions (Bennett, 2014). It is on this aspect that this study would like to focus on. Bread within religious set-up can be shown to bear all four concepted pillars of sustainability including cultural sustainability.

3.3. Bread, sustainability, and religions

Religion and sustainability have been the focus of different analysis (Jenkins, 2008; Ives & Kidwell, 2019; Berry, 2023). Several studies, such as from Berry (2014) and Chapple (2008) suggest that religious institutions and their rituals often contribute to the concepts and practices of sustainability. Different religious groups have incorporated bread in their worshipping rites. For the Jewish and Muslim people, bread is an important part of Shabbat and Ramadan (Bharath, 2016). These breads are known in different terms and have served as a cultural symbol in many ways. For the Jews celebrating Shabbat, it is called *challah* which is traditionally baked as plain round but can be served braided in contemporary times (Ron, 2022). In the case of Muslims states that bread is a staple food during Ramadan for satiety and appetite. With this, it could be inferred that food, specifically bread, plays an integral role in the practice of various religious ideals and teachings across different beliefs.

For this research, the focus shall be on the Roman Catholic Holy Bread. Anyfantakis (2020) points out that this bread is vital as it is a part of the Eucharistic elements particularly in the Holy Communion. Although other forms

of religious ideals and practices regarding food and eating exists, it is the Holy Bread in which Catholicism anchored its highest regards. This study argues that the process of making and the Holy Bread itself is a bearer of cultural sustainability and that it ushers overall sustainability through the teachings of the Roman Catholic Church.

4. Results and discussion

4.1. What are the attached spiritual values and meanings on the Holy Bread by the Roman Catholic Church?

The spiritual value of the Holy Bread for the Roman Catholic Church is first and foremost reflected on the Code of Canon Law (1983) is the official guidelines that the Roman Catholic Church currently follows that consists of a compendium of rules, norms, practices, and ideas to adhere on as a religious institution. In terms of the Holy Bread, it emphasized that the Holy Eucharist and Holy Communion must be celebrated with such, and it should be made with wheat and must be unleavened (Book IV, Part I, Title III, Chapter I, Art. 3, Can. 924 § 1-2; & Can. 926). Furthermore, the act of Holy Communion should be done "under the form of the bread alone" (Can. 925). The bread can be considered as holy and worthy of the sacrament upon the consecration of a priest (Can. 927).

There have been no official guidelines rendered in buying and/or selling the bread. However, it is important to note that as the Holy Eucharist is a part of the official sacraments of the Roman Catholic Church, the Holy Bread is considered as a "sacred object" and no longer an ordinary matter (Book IV, Part II, Title I, Can. 1171). Therefore, buying or selling a bread to be utilized in the celebration of the Holy Eucharist is acceptable but prohibited if it is already a Holy Bread upon consecration. In general, utmost reverence to the Holy Bread should be observed (Instruction Redemptionis Sacramentum, 2004).

In terms of consuming or receiving, only baptized Catholics that have undergone the Sacrament of Communion, dying children, a person who committed a grave sin but with an acceptable reason not to confess, and/or anyone who is generally nearing death (Book IV, Part I, Title II, Chapter I, Art. 2, Can. 912; Can. 913 § 1 & 2; Can. 916; & Can. 921 § 1 & 2). On the other hand, people who are excommunicated are not allowed to receive the Holy Bread (Can. 915).

With these rendered facts, we can infer that the Holy Bread is of utmost importance and value to the Roman Catholic Church. As a religious institution, it created a formal and systematic process of creation and consumption of the

Holy Bread rendering it as an important part of its religious functions. Nonetheless, the general spiritual value and meaning of the Holy Bread also lies on the concept of transubstantiation. This concept explains that the Holy Bread, through its consecration, is Jesus Christ itself (Francis, 2021). By its transubstantiation, the unleavened bread transitions into a sacred object. As the bread becomes Christ itself in the tradition of the Roman Catholic Church, every ideal, practical as well as identical attributions to Christ, is also attributed to the Holy Bread.

The Holy Bread from being an unleavened bread is a consecrated and integral part of the celebration of the Holy Eucharist and received during the Holy Communion. The Holy Eucharist "is the action of Christ himself and the Church" in which Jesus Christ offers himself to God the Father and for believers spiritually (Can. 899 § 1). Part of this is the Holy Communion in which Catholics accept Jesus Christ through the Holy Bread symbolizing communion with him, the forgiveness of sins, being charitable to the poor and union with the Church (Catechism of the Catholic Church, 1992, CCC 1391-1398; & The Roman Catholic Archdiocese of Atlanta, 2015).

These attributions are reflected in other writings of the church that corroborate such arguments. Benedict XVI (2010) points out that Jesus Christ is "the Bread of Life" providing "eternal and spiritual nourishment". This is corroborated by Hammes (2005) elaborating out that if the bread nourishes us from physical hunger, the Holy Bread therefore replenishes lives. Moreover, Susin (2005) emphasized the further importance of God's word attached on the bread than the bread itself. From here, it can be concluded that spirituality, life, and health supersede the physical one.

Another provided meaning is that the Holy Bread is God's reality and a way to communicate his love (Pieper, 1991). The believer receives God's love and provides him/her with other attributes such as "hope" "light", "joy", and "salvation" for eternal life (Fortin, 2005) as we accept the Holy Bread. By this act of receiving the bread, the Roman Catholic Church suggests that Jesus Christ is within every faithful, and therefore the people within the church are bounded with the identification of being a Christian and affirming Catholic affiliation (CCC 1395) as such. This would entail being empathic, generous, and of service to fellow brothers and sisters (Cavanaugh, 2005; Dodaro, 2005; Muller, 2005).

Overall, these values and meanings of the Holy Bread attached to the culture of the Roman Catholic Church highlight the acceptance and emulation of Jesus Christ's wholeness by the followers. It can be inferred that these set of ideas and

actions are part of its cultural sustainability. As the Holy Bread becomes Jesus Christ, taking it during the celebration of the Holy Eucharist also meant being with Jesus Christ (Mendez, 2005) and following his teachings on how to lead a life. The food itself becomes an integral part of the culture as it embodies the transcendent within the Roman Catholic Church, which in this case is the existence of Jesus Christ.

From the rendered spiritual values and meanings, we could already see that the culture imposed through the Holy Bread has manifesting interrelations with social, economic, and environmental aspects. One example of this is charity and being of empathy with brothers and sisters. This culture manifesting invites the followers of the Church towards acts of sustainability. Values such as empathy for others can be contextualized into possible forms of social care, economic help, or environmental care. With the initiation of the idea and actions upheld upon the acceptance of the Holy Bread, there will be a spillover in the social, economic, and environmental realms. Furthermore, there are heightened and provided concrete examples from the act of accepting the Holy Bread further into the other specified teachings of the Roman Catholic Church.

4.2. What are the sustainable ways of living according to the teachings of the Roman Catholic Church?

The teachings of the Roman Catholic Church as a part of its culture are with the overall sustainable ways of living for the followers, particularly the three traditional pillars of social, economic, and environmental. Christie et al. (2019) mention the concept of Catholic Social Teaching (CST) and its relations to sustainability. This is the official teachings of the Roman Catholic Church in terms varying social issues from various official sources (Sison et al., 2016). Notable among these sources are writings or documents attributed to the pontifical. Leo XIII (1891) was noted for creating the encyclical *Rerum Novarum* that pioneered contribution to CST. The mentioned encyclical focused on the rights and duties of capital and labor, specifically about supporting workers in their labor rights and wages as well as facilitating self-efficiency from resources for them (Davis, 2021). It could be inferred that economic and social sustainability is directly evident from the idea of the encyclical.

Other documents have reflected more themes depending on contemporary issues at the time of their writing. John Paul II (1987) tackled economic inequality, international debt, underdevelopment, unemployment, and arms production across the world. In this encyclical, the Pope presented a form of development that is "more human" rather than focusing on its economic aspects

alone and the use of resources for human vocation (Par. 28-29). Furthermore, human rights should be upheld as well as the morality of development's character (Par. 33 & 35). Traces, on the other hand, of similarities between the genesis of the concept of sustainability (Renoldner, 2013) and the Roman Catholic Church's conceptualization of development at this time can be inferred.

Benedict XVI (2009) focused on charity in justice and the concept of common good (Par. 6). Framing charity as a vocation, emphasis on the concepts of integral human development is stated (Par. 17-18) pointing on providing for everyone and for every need of every individual. In line with the thought of John Paul II (1987), the economic focus of development is not sufficient (Par. 23). Social welfare, peace, infrastructures, agriculture, religious freedom, value for different cultures, justice in economic activities, the environment must also be given priority to usher common development for all (Par. 27, 29, 26, 37, & 48).

Moreover, almost all similar themes are reflected in the Apostolic Exhortation of Francis (2013). Notable emphasis on the poor, scientific progress, and interreligious dialogue (Par. 186-201, 242-243, & 250-254) are differing points from the previous encyclicals. However, as climate change continues to be a dominant contemporary global issue, Francis (2015) provided an encyclical entitled *Laudato Si* which focuses on proper environmental stewardship.

As the following guidelines within CST settle the ideas, values, and actions the Roman Catholic Church wants to instill to its followers as an institution, it can be derived that these can affect the society, economy, and environment in general. Upon the initiation of the Church to settle norms and morals that needs to be followed, an adherence to ushering holistic sustainability is evident. Referring to the four pillars of sustainability, it is with the settlement of the cultural pillar that the other three traditional pillars coexist with it.

4.3 How do the attached spiritual values and meanings of the Holy Bread relate to such ways of living in terms of sustainability?

The acceptance of Jesus Christ through the Holy Bread is the commencing prerequisite of following all his teachings and ideas regarding Christian living and adherence with the Roman Catholic Church (The Roman Catholic Archdiocese of Atlanta, 2015; & CCC 1396). The Holy Bread is metaphorically an opening door to the specific teachings of the Church which would include the Holy Eucharist and CST. Through the celebration of the Holy Eucharist together with what is further taught for the members of the church as they accept Jesus Christ

by the Holy Bread, these comprised the cultural sustainability that is interrelated with the social, environmental, and economic pillars.

5. Conclusions and Recommendations

Food is a vehicle of cultural meaning and importance as well as a proof of the existence of cultural sustainability with the traditional three pillars (economic, social, environmental). This is through the ideas and actions of groups and institutions towards and from the food itself. Furthermore, this paper concludes and therefore emphasizes a recognized pattern, that the three traditional pillars of sustainability coexist with the cultural pillar. Future studies are also recommended to explore other focal points aside from food that can advance this conclusion whether tangible or intangible. This is a pattern that could possibly exist in other contexts or sustainability phenomenon. In the case of religions, the element of transcendence is evident on the value and meaning of food as the purpose of creating such is an integral part of the metaphysical. Thus, the sustainability it ushers depends on the latter.

However, the nature of this relationship should be further analyzed through future studies of other religions and beliefs. In general, such anchoring on religion and transcendence further advances the case of food as a bearer of cultural sustainability. Specifically for the Catholics, it is through eating/acceptance of the Holy Bread that symbolizes following and acceptance of Jesus Christ which in turn promoted overall sustainable teachings for their faith. The concept of "transubstantiation" built by the Roman Catholic Church as an institution is an act that transcends its significance. Moreover, upon its acceptance, it symbolizes the believer's adherence to a multitude of CSTs which provides a cultural framework with economic, social, and environmental sustainability.

Lastly, this study defends the argument that there is a need to emphasize culture – the ideas, actions, and behaviors of groups of people – as a sustainability pillar together with the social, economic, and environmental pillars. No sustainability can be without the initiative of a group of people with their thinking and practices towards social, economic, and environmental structures. In this case, it is justified by the Roman Catholic Church as a group with their creation and provided significance on the Holy Bread.

As a recommendation, future studies should be created that observe specific practices and idea interpretations regarding the creation and consumption of the

Holy Bread. Geographical or parochial differences, as well as other independent variables like cultural variations, environmental and economic phenomenon, socio-political situations etc. are worthy of being explored. In this way the overall sustainability of this focus can be contextualized and better analyzed. Moreover, the potential of food as a justification for and advancement of cultural sustainability's recognition should be further investigated. Food within religious contexts should be the specific focus of future studies, including major religions and spiritualities such as other denominations of Christianity, Islam, Judaism, Hinduism, Buddhism, Sikhism, Shintoism etc. Specific points about cultural heritage and diversity can be emphasized through this endeavor.

Meanwhile, policy making and analysis in sustainability and even SD should include cultural sustainability for further effectiveness and credibility. The development planning and conceptualizing under such principles must then include people's ideas and actions. In this way, social structures, economic ways, and environmental set-up can be approached in a proper and sustainable manner.

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Ethical Considerations

This study, in consideration of inclusivity and multiculturalism, does not employ any means or consider any information that can be discriminating and damaging to any culture, religion or belief.

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