Original Paper

Public perception on the role of Artificial Intelligence in the sustainable management of tree and forest resources in Kenya

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Abstract. *There is a scarcity of information on the role of Artificial Intelligence (AI) in enhancing sustainable forest management worldwide. Using a literature review, this study explores the case of Kenya, with the aim of contributing to a better understanding of the strategies needed to promote the role of AI in the development and sustainability of forests. Results reveal that AI deployment in forestry is still in the infancy stages. The country has some AI technologies in use to promote forest management. Moreover, both public and private, local, and international organizations are actively involved in developing AI applications for forestry to consider the social, economic, and environmental facets of sustainable forest management. Additionally, no studies have been conducted on the public perception and opinions regarding the use and role of AI in sustainable forest management in Kenya. These study findings pose the risk of limited progress, technological gaps, and uncertain impacts on key green infrastructure development priorities; for example, the achievement of 30% tree cover by 2032 and a host of international development obligations, as well as the continued misunderstanding regarding public perceptions of AI deployment in forestry. There is thus an urgent need for accelerating AI research and development in forestry, fostering collaboration between public and private sectors, conducting studies on public perceptions, and ensuring ethical and sustainable AI implementation.*

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1. Introduction

With the continuous decline in biodiversity and ecosystems worldwide, safeguarding and revitalizing natural habitats, including forests, through technology deployment are becoming crucial for the survival of humanity (Chen et al., 2023; IPBES, 2019; Walder, 2018). Trees and forested ecosystems constitute a significant land-cover category worldwide. They play a crucial role in offering numerous ecosystem services to billions of people (Çolak et al., 2018;

Hua et al., 2022; Pan et al., 2013; Brockerhoff et al., 2017). In response, the United Nations has declared the "Decade on Restoration" from 2021 to 2030 (United Nations Environment Agency (UNEA), 2019). However, the global forest cover and ecosystems continues to diminish (Curtis et al., 2018; Estoque et al., 2022). Among other reasons, forest decline is driven by shifts in land use toward agriculture, unsustainable forest management practices, urbanization, mining activities, climate change, and wildfires (Taubert et al., 2018; Zerbe, 2022 & 2023; Keenan, 2015). To address these challenges, many countries have initiated ambitious ecological restoration efforts, with the overall objective of rehabilitating and restoring the structure and function of degraded trees and forest ecosystems. Unfortunately, there is limited monitoring of restored trees and forested landscapes, resulting in a limited understanding of the benefits, impacts, and successes of restoration activities (DeLuca et al., 2010). Consequently, there are mixed perceptions of the impact of tree and forest conservation and management interventions towards sustainable forest management (DeLuca et al., 2010).

Artificial Intelligence (AI) is becoming increasingly important in forest management. AI facilitates the real-time monitoring of forest health, helps predict and prevent threats such as wildfires and illegal logging, optimizes resource allocation, and enhances data-driven decision-making for conservation efforts. The application of AI contributes to sustainable forest management by preserving and effectively utilizing forest ecosystems. However, few studies have explored people's perceptions of the role of AI in sustainable forest management in many developing countries. Public perceptions can evolve as new developments occur. Moreover, public opinion can vary significantly depending on the region, cultural context, and the specific applications of AI in forest management. As AI continues to advance and become more integrated into various industries, ongoing dialogue and education regarding its benefits and challenges will be crucial in shaping its role in sustainable tree and forest resource management.

In Kenya, the forestry sector has evolved over the years, with increasing conservation activities. Efforts towards afforestation, reforestation, and restoration have been tremendously amplified as various forest sector actors take the lead in landscape and ecosystem restoration activities. Although these efforts have been effective in ensuring sustainable forest management, the use of technology is rapidly gaining global attention. The country has drafted a 10-year strategy that seeks to accelerate actions towards achieving 30% national tree cover by 2032, with the aim of enhancing climate-reliant national economic growth and development goals within the context of Vision 2030 and contributing toward Kenya's commitments to regional and global conventions. To augment this strategic focus, recent technological developments have created new opportunities for forestry value chain development and the transformation of productivity and efficiency. However, there is a limited understanding of the public perception of AI's role in enhancing sustainable forest management. Limited public awareness of AI's potential benefits in forest management has led to missing opportunities for conservation. In literature, it is speculated that resistance, lack of support, ethical concerns, and misunderstandings hinder sustainable development and slow the adoption of AI solutions (Galaz et al. 2021) .

This study aims to address the lack of research on the perception of AI in Kenya using a literature review from the perspective of sustainable development by answering the following question: What are Kenyan citizens' attitudes and opinions towards the integration of AI technologies in the sustainable management of tree and forest resources? To effectively respond to the research question, unlike other studies, this paper will first review the global literature on the public's perceptions of the role of AI in sustainable forest management and then apply the lessons learned in Kenya's context for sustainable forest management and the application of AI to generate the policy implications of this study.

Kenya is an appropriate study site for investigating people's perceptions of AI in sustainable tree and forest management because of its rich biodiversity, ongoing challenges in conservation, and diverse socioeconomic contexts. Understanding public attitudes in this context can inform tailored strategies for effectively implementing AI technologies for sustainable forest management and community engagement.

2. Sustainable Forest Management and AI

Sustainable forest management involves balancing ecological, social, and economic factors of forest management in order to meet current needs without compromising the needs of future generations. In this regard, sustainable forest management requires careful data handling and monitoring, considering the diverse aspects of long-term viability, and resolving conflicting interests (Empig et al., 2023). The use of AI in forest conservation and management is emerging as a feasible way of offering a transformative solution for managing the complex data and procedures involved in sustainable forest management (Costa et al., 2023). AI refers to the simulation of human intelligence in machines, enabling them to perform tasks that typically require human intelligence, such as problem-solving, learning, reasoning, and decision-making. AI can be broadly categorized into narrow AI, which is designed for specific tasks, such as voice recognition or recommendation systems (e.g., Siri and Alexa), and general AI, which aims to possess human-like intelligence and handle a wide range of tasks, although still largely theoretical (Leal Filho et al., 2023). Machine learning is a prominent subset of AI in which algorithms learn patterns from data and improve performance over time. Examples of AI applications in other sectors include self-driving cars, natural language processing, virtual assistants, image and speech recognition, and personalized content recommendations on platforms such as Netflix and Spotify (Leal Filho et al., 2023).

AI is widely used in sustainable forest management, employing drones with remote sensing to monitor and map forests, assess tree health, detect deforestation risks, and estimate the carbon sequestration potential. Additionally, AI enhances carbon dioxide trapping processes and oversees storage locations, thereby ensuring secure underground carbon sequestration (Chen et al., 2023; Karmaoui, 2023). AI drones are employed with remote sensing to monitor and map forests, assess tree health, detect deforestation risks, and estimate the carbon sequestration potential(Liu et al. 2022b; Osman et al. 2022; Yang et al. 2022 & 2023). The use of AI in forestry can substantially enhance the efficiency and effectiveness (Cheong et al., 2022; Kaack et al., 2022). For example, AI has been used to develop ecological models to predict forest dynamics and climate impacts,monitor and predict forest fires for early mitigation,addressing climate change by enhancing the forecasting of severe weather occurrences (McGovern et al., 2017). Smart logging using AI optimizes sustainable harvesting and minimizes environmental impact. Furthermore, AI assists in selecting the appropriate tree species for reforestation. Moreover, public engagement and education benefit from interactive AI platforms and fosters collaboration and data-sharing among stakeholders to ensure effective forest management.

Costa et al. (2023) while measuring forest biomass found that by combining artificial neural networks with Landsat-5 imagery, accurate predictions with an estimation error of approximately 20% for AGB in tropical forests could be achieved. This methodological approach shows great promise and can be applied to assess ecosystem services related to carbon stock in tropical regions.

Through advanced algorithms and machine learning, AI can analyze vast amounts of ecological, social, and economic data in real time. It enables accurate and timely decision-making and the optimization of resource allocation and conservation efforts. AI-powered automation streamlines data collection, processing, and analysis, enhances efficiency, and reduces manual errors (Schmoldt, 2001; Amaral et al., 2021). AI-driven predictive models aid in proactive planning against threats such as deforestation and climate change. Nevertheless, integrating AI in sustainable forest management ensures the holistic preservation and cost-effective protection of global forests.

Utilizing AI-driven automation has several benefits over conventional forest management methods, such as enhanced effectiveness, greater precision, and decreased expenses (Kourtz, 1990; Peng & Wen, 1999; Imada, 2014; Kimsey et al., 2021; Jahani and Rayegani, 2020).

Benefit	AI Automated Forest Management	Conventional Forest Management
Efficiency	AI can rapidly process vast amounts of data, leading to quicker and more informed decision-making.	Manual data collection and analysis can be time-consuming and labor-intensive.
Accuracy	AI-powered algorithms can provide precise analyses, minimizing errors and improving accuracy.	Human errors in data collection and analysis can lead to inaccuracies in decision-making.
Cost	Long-term cost savings can be achieved due to optimized resource allocation and reduced manual work.	
Proactivity	AI enables proactive monitoring and prediction of potential threats, helping prevent issues in advance.	Reactive approaches may result in delayed response to potential threats such as deforestation.
Data management	AI can efficiently handle and analyze large datasets, improving data-driven decision-making.	Managing and analyzing complex data manually can be overwhelming and prone to errors.
Sustainability	AI can assist in optimizing forest use to maintain ecological balance and preserve biodiversity.	May face challenges in finding the right balance between ecological, social, and economic needs.

Table 1. AI automated forest management versus conventional forest management. Source: Author's compilation from Multiple sources

In recent years, empirical studies have shown that AI has revolutionized many sectors, including forestry. AI-driven advancements are reshaping forestry methods byenhancing their effectiveness, reducing costs, and promoting sustainability (Linares-Palomino and Alvarez, 2005; Bojorquez et al., 2020; Chave et al., 2014; Koukal et al., 2014; Asner et al., 2010). Unmanned Aerial Vehicle (UAV) technology has become prevalent in ecological and environmental monitoring (Casazza et al., 2019; Jiang et al., 2021; Johansen et al., 2019; Zhang et al., 2020). AI application has expanded notably in forest resource inventories, mainly because of the increased accessibility and availability of compact sensors (Ma et al., 2015; Qiu et al., 2018b; Hao et al., 2021; Hu et al., 2021b). Additionally, UAV photogrammetry has been widely applied in forest surveys in tropical regions (Popescu, 2007; Lechner et al., 2020; Dalla Corte et al., 2020; Ge et al., 2020; Rahman et al., 2020). Based on this review, AI application is particularly prominent in forest management.

2.1. Public Perception on the Role of AI in Sustainable Forest Management

As AI technologies proliferate, public perception of the role of AI in sustainable forest management is rapidly emerging as a topic of interest and debate. On the one hand, there is a growing sense of optimism regarding the potential of AI technologies to revolutionize forest conservation efforts. Many people believe that AI's data processing capabilities can lead to more informed decision-making, enhanced forest monitoring, and proactive measures to combat deforestation and other environmental threats.

On the other hand,public concerns about AI in environmental and forestry decision-making include ethical implications and fear of job displacement. There are also concerns regarding data privacy and the concentration of power in technology companies developing AI solutions. These concerns arise from recent studies, such as that by Wach et al. (2023), which explored the dark side of generative AI by highlighting its ethical implications, job displacement, data privacy, and concentration of power in AI technology companies.

A survey of registered foresters in five U.S. states revealed that 50% of non-industrial private landowners do not use digital forestry tools, whereas approximately 80% of organization-employed foresters do. Geographic information systems technology was the most crucial tool, followed by inventory systems, databases, and field-ready smartphone applications. Foresters who did not use digital tools cited perceived usefulness for property management and a lack of awareness of available options as reasons for not adopting them (Bettinger et al., 2023). Therefore, analyzing the public perception of AI systems in the forestry sector across different countries or continents provides valuable insights into how technology is embraced, accepted, or resisted in various cultural and environmental contexts. In North America, public perception of AI in forestry is generally positive. AI-powered tools for monitoring and managing forests, such as drones and remote sensing, are crucial for efficient forest management and wildfire prevention. Public-private partnerships often play a role in advancing AI adoption in the sector. In Finland and Sweden there is a strong tradition of forestry but public perception on forestry AI is mixed (McQueen 2019). In China, AI is increasingly being used for forest monitoring and wildlife conservation. Public perception varies; some view it as a tool for environmental protection, while others worry about privacy and data security issues. In Japan has a strong tradition of forestry, and AI is being employed to enhance forest management and detect diseases. Public perception is generally positive, with a focus on preserving traditional practices while incorporating technology. In Australia, AI is used for fire management and forest monitoring, given the country's susceptibility to wildfires. Public perception is positive, with a focus on safety and environmental conservation (Silvestro et al. 2022; Liu et al. 20189; Shivaprakash et al. 2022). Vizard (2020) efound that dspite the perception that AI is more hype than reality right now, a wide majority of companies, including forestry companies are looking to more aggressive adoption of AI. The survey identified the biggest inhibitors of AI adoption to be a lack of understanding of capabilities (46%), lack of training (36%) and lack of initial investment funding (32%).From a general environmental security perspective, Francisco (2023) has found that a national discussion on climate security should focus on military applications of AI and its role in spreading propaganda and misinformation. Internationally, organizations and transnational companies use AI to achieve their goals; however, this has implications for consumption and resource extraction. Military AI collaboration may hinder environmental movements. Furthermore, AI can aid sustainable development but may lead to power imbalances. Ecologically, AI's impact on our perception of the environment and the potential alienation from other cosmologies and environmental effects is concerning. This analysis encourages further exploration of the interplay between AI, geopolitics, and environmental protection, including forest management.

While reviewing the literature on geo-technologies and AI as a tool for riparian forest management, da Silva Leite and Amorim (2021) established that AI-based geo-technologies play a vital role in managing natural resources and addressing society's urgent questions and demands. They offer various techniques and scientific approaches, enabling an understanding using location, dimensions, acquisition, and the processing of data. The findings revealed limited publications related to AI use, particularly in Portuguese. However, AI has demonstrated its significance in research along with remote sensing and GIS (Geographic Information System) software. Notably, the study revealed a research gap concerning the application of AI in studying riparian forest PPAs (Permanent Protection Areas) with geo-technologies, suggesting the need for future research in this area.

This paper advocates for the use of AI in forest management, but emphasizes the need for transparent communication, stakeholder collaboration, and proving conservation benefits for increased AI acceptance. Nonetheless, responsible and inclusive AI in forestry requires further research and regulations.

2.2. The general development context for AI in Kenya

Over the past decade, Kenya has implemented significant political and economic reforms that have contributed to sustained economic growth, social development, and political stability. From 2015 to 2019, Kenya's economy achieved broad-based growth, averaging 4.8% per year and significantly reducing poverty to 34.4% in 2019 (World Bank 2022). Kenya's economy is highly dependent on the country's natural resources. With over 84% of its land area classified as arid or semiarid, Kenya is exposed and highly vulnerable to extreme weather conditions. An average drought results in a 20–30% food deficit, slashes GDP growth by 3–5%, and affects the livelihoods of over 80% of the population (ADB, 2022). According to the Global Climate Change Risk Index (GCRI) of 2021, Kenya is ranked 25th and is most affected by extreme weather conditions and weather-related losses (ADB, 2022).

Youth unemployment and high poverty rates are the key challenges to Kenya's economic growth and development. The youth unemployment rate is 38.9%, with an estimated 800,000 young people entering the labor market every year and over 8.9 million in Kenya living below the poverty line. At a population growth rate of 2.7%, Kenya's population is projected to rise to 66.3 million by 2030. The increasing population presents a challenge for the sustainable utilization of forest resources and opportunities to expand farm forests. According to a 2014 study by the GATSBY Charitable Fund, Kenya's national wood deficit was estimated at 12 million M^3 in 2014 and is predicted to rise to as high as 34.4 million M^3 by 2030. Against this background, the new Kenya Kwanza administration's bottom-up economic model has prioritized accelerating the achievement of 30% national tree cover by 2032 for increased employment opportunities, improved livelihoods, climate change reliance, and enhanced Kenya's economic growth within the context of Vision 2030.

2.3. Sustainable forest management in Kenya

Trees and forests are important strategic national assets in Kenya because of their ecological and socioeconomic value. Kenya's forest sector contributes to the livelihood base for over 82% of Kenya's households through direct employment for over 750,000 Kenyans and indirect benefits to over 4 million citizens, accounting for approximately USD 365 million (3.5%) of the GDP (MEF 2018).

However, Kenya is a low forest cover country with less than the recommended minimum global standard of 10%. Over the years, the rapidly expanding population and conversion of forest land to agriculture have been the major drivers of forest cover loss. From 1990 to 2015, approximately 311,000 ha of forestland were converted into other land uses (FAO, 2015b). Weak governance, unsustainable exploitation, overreliance on forest products, forest fires, and the increasing adverse effects of climate change have further exacerbated the deforestation and degradation of forests in Kenya (FAO, 2022a; FAO, 2022b).

The National Forest Resource Assessment conducted in 2021 established Kenya's National Tree Cover at 12.13% and forest cover at 8.83% (KFS, 2022). During the launch of the National Forest Resources Assessment Report 2021, Kenya's President set a new national ambition to achieve 30% tree cover by 2050. However, on October 20, 2022, the President directed the acceleration and attainment of 30% tree cover by 2032. The goal of the strategy is to produce 15.9 billion quality seedlings in Public and Private Tree Nurseries by 2032, which will be achieved through increased high-quality seed production by KEFRI, , the KFS, other MDAs, and the private sector. Additionally, the strategy aims to raise the National Tree Cover by 17.8% (10,579,062.51 ha) by 2032, focusing on protecting, conserving, and restoring Public Natural Forest Reserves. It will enhance forest cover in Natural Forests outside reserves and commercial plantations and promote tree cover on farmlands (agroforestry), ASALs, schools, institutions, urban forests, green spaces, roads, highways, and infrastructure projects. Further, public education and awareness campaigns have intensified. Moreover, improved technologies for wood utilization, sustainable forest management, and strengthened forest governance will be key priorities achieved by enhancing the institutional capacities of the MEF, KFS, KWTA, and CoG for effective coordination and project implementation.

The Ministry of Environment and Forestry should bolster its coordination efforts and strengthen the capacity of relevant stakeholders, including SAGAs, MDAs, and county governments, to effectively implement, monitor, and report strategies. To achieve this, they will establish a National Coordination Committee and multi-institutional Technical Team with a Secretariat at the Ministry of Environment and Forestry, which will include representatives from government agencies, the Council of Governors, NGOs, the private sector, and development partners. Additionally, County Implementation Coordination Committees will be formed, co-chaired by County Commissioners and County Governments, with

Kenya Forest Service serving as the Secretary. Furthermore, sub-county-level coordination committees should be created to enhance coordination and collaboration at the local level.

To reduce its reliance on domestic forest products in key economic sectors, Kenya has positioned itself as a trading nation at the regional and global levels in forest products. Nevertheless, Kenya is committed to contributing to global climate change mitigation and adaptation through Nationally Determined Contributions (NDCs) as part of the UNFCCC, in line with the Paris Climate Change Agreement requirements aimed at lowering GHG emissions by 30% by 2030.

The Kenyan Constitution of 2010 recognizes the need to increase national tree cover by at least 10% by 2030. This development aspiration is also in line with Kenya's commitment to restore 5.1 million hectares of forest and degraded landscapes, which formed part of the African Forest Landscape Restoration Initiative (AFRI100) target and the NDC target of reducing greenhouse gas emissions by 32% by 2030, relative to a business-as-usual scenario.

2.4. AI application in sustainable forest management in Kenya

Forest management in Kenya involves various activities aimed at maintaining and optimizing forest ecosystem functions and processed. These include; planning, inventories, and silviculture practices such as planting and harvesting, fire prevention, pest and disease management, and ecological monitoring. Sustainable management includes community engagement, public education, and conservation efforts for a long-term environmental, social, and economic balance. To improve the execution of these activities, several AI applications for forest management have recently emerged in the country, aiding in promoting sustainable forest management. For example, tree species site matching (SSMT), the creation of Gatsby Africa, aids growers in choosing the most appropriate tree species for their specific location. By analyzing factors such as soil quality, rainfall, altitude, soil type, soil depth, and species performance, SSMT supports tree growers and investors in identifying the optimal tree species for their needs. This information is accessible online through Georeferenced PDF or ArcGIS, presenting the suitability level of a tree species for the chosen site, ranging from very suitable to not suitable (FSK, 2023).

KEFRIApp was introduced as a site-species-matching tool designed to aid tree growers in identifying the most suitable tree species for specific ecological zones. Accessible as a mobile platform, the application offers valuable guidance to users regarding the types of trees suitable for their desired areas. Moreover, the application furnishes tree growers with information on tree nursery locations and facilitate the real-time documentation of tree-planting activities. The app is available for download on the Google Play Store (FSK, 2023).

In collaboration with the National Centre for Earth Observation at the University of Leicester, the Kenya Forest Service (KFS) has jointly developed an advanced AI-based monitoring system to rapidly detect deforestation. This system sends alerts every five days using Copernicus Sentinel-2 images at 10m spatial resolution, enabling the identification of even minor forest cover changes and small-scale logging activities. Known as the Forest 2020 project, this system provides near-real-time alerts to forest rangers and managers, enabling prompt responses to identified regions. Satellite images were compared with previous data to verify changes, making them crucial for the effective monitoring of forest changes at both the regional and national levels. Additionally, the system helps the KFS keep track of tree cover across Kenya, serving as an early warning mechanism to combat threats such as illegal logging, human settlements, and wildfires, thereby halting further forest destruction (FSK, 2023).

Efficiency plays a crucial role in achieving sustainable forest management. One technology driving this effort is the Timbeter App, currently implemented within the Kenya Forest Service, which has the potential to revolutionize public plantation management. Utilizing AI and machine learning, the Timbeter App offers a digital timber measurement solution that ensures accurate log detection and aims to combat illegal logging while enhancing timber monitoring and supply through its unique algorithm. This application streamlines log inventory processes, reduces costs, and expedites round-wood measurements. With its user-friendly mobile platform, Timbeter provides services, such as inventory and measurements, replacing traditional paper-based methods. By adopting Timbeter, the forestry sector can enhance efficiency and transparency, thereby contributing to sustainable practices. The application is readily available for download on both the Google Play Store and Apple Store. The Ministry of Environmental Climate Change and Forestry has also developed the Jaza Miti App to collect and analyze tree-planting data in the country. It is aimed at tracking progress towards achieving 30% tree cover by 2032 (FSK, 2023).

3. Materials and Methods

3.1. Study Area

Kenya is located in East Africa and is known for its diverse wildlife, scenic landscapes, and vibrant culture. Its population is approximately 50 million people, with over 40 ethnic groups, each with unique languages, customs, and traditions. Kenya's capital city, Nairobi, serves as an economic and cultural hub. Kenya's geography is diverse, ranging from savannas to forests, mountain ranges, and coastal plains. It is home to some of the world's most famous wildlife reserves, including the Masai Mara National Reserve, which is known for its annual wildebeest migration, and Amboseli National Park, which is renowned for its large elephant herds. The country's coastline is dotted with pristine beaches, coral reefs, and marine parks, making it a popular destination for beach holidays and water sports enthusiasts. Kenya is one of the most developed countries in East Africa, with a GDP of approximately $100 billion (Macheru, 2023).

3.2. Data Collection

This study aims to address the lack of research on the perception of the role of AI in forest management in Kenya, using a literature review and document content analysis from the perspective of sustainable forest management. To effectively respond to these requirements, a systematic and comprehensive approach to document content analysis was adopted. The primary goal is to bridge the gap in research concerning the perception and understanding of AI technologies in Kenya's unique socioeconomic and cultural context. An extensive literature review was conducted to begin the data collection process, encompassing academic papers, policy documents, reports, and media articles pertaining to AI technologies and sustainable development in Kenya. This comprehensive review serves as a foundation for identifying the key themes, concepts, and patterns surrounding AI perceptions in the country. After identifying relevant documents, data were systematically extracted from the content.

The key documents consulted during the data collection process are listed in Table 2. These documents provide the overall context within which AI has been applied to forest management in Kenya. This research relied solely on document reviews as the source of data, largely because documents are reliable, easily accessible, and abundant, providing comprehensive insights and enabling researchers to efficiently analyze historical, scientific, and social phenomena.

Name of Document	Source	Key information sought
Constitution 2010	Internet	Provisions on the use of AI technology in environmental protection
Vision 2030	Internet	Whether AI technology is important for forests and is enshrined in long-term visions
Draft Forest Policy, 2020	Internet	Information on the use of AI in forest governance
Forest Conservation and Management Act, 2016	Internet	The institutions responsible for developing and applying AI in forest management
National Strategy for Achieving and Maintaining 10% Tree cover	Internet	Whether urban forests are enshrined in long-term visions
Kenya Information and Communications Act, 1998	Internet	Whether the Act supports the application of AI in various resource sectors
Kenya Science, Technology, and Innovation Act, 2013	Internet	Whether the Act supports the application of AI in various resource sectors

Table 2. Key documents Consulted

3.3. Data Analysis

The document content analysis data captured various dimensions of the role of AI in sustainable forest management, such as public attitudes towards AI, perceptions of AI's impact and role in sustainable development, potential ethical concerns, and policy recommendations. Figure 1 summarizes the analytical framework developed as a result of emerging themes from a literature review on public opinion on the role of AI in forest management, which was applied to Kenya to generate the policy implications of this study. As shown in Figure 1, AI plays a crucial role in sustainable forest management by enabling efficient data analysis, predictive modeling, and real-time monitoring. It aids in optimizing resource allocation, assessing biodiversity, detecting deforestation, supporting informed decision-making, and contributing to forest ecosystem preservation and responsible use for a sustainable future.

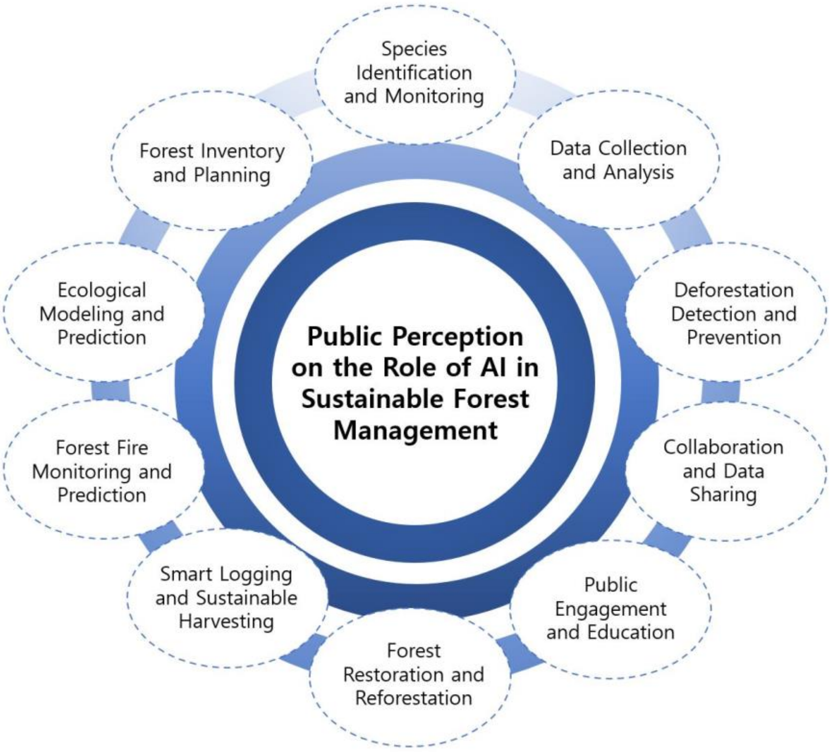

Figure 1. Analytical framework for public perception on the role of AI in forest management in Kenya

4. Results

4.1. The current status of AI applications in forest management

When the analytical framework for public opinion on AI technologies in Kenya's forest management is applied to the Kenyan context, the results show that the country has few AI technologies that are applied to promote sustainable forest management. Table 3 outlines the broad areas of sustainable forest management, the AI technology used, and the benefits achieved as a result of AI application. Both public and private, local, and international organizations are involved in the development of AI applications for forest management. The benefits and impacts of AI applications have affected the social, economic, and environmental aspects of sustainable forest management.

Broad Area of Sustainable Forest Management	AI Technology	Developer(s)	Benefits/role
Data Collection and Analysis	Jaza Miti App	Ministry of Environment Climate Change and Forestry	Collects and analyses tree planting data, tree species-site matching
Species Identification and Monitoring	Project 2020	National Centre for Earth Observation at the University of Leicester, Kenya Forest Service	Effective monitoring of forest changes, combat threats like illegal logging, human settlements, and wildfires,
Deforestation Detection and Prevention	Project 2020	National Centre for Earth Observation at the University of Leicester, Kenya Forest Service	Effective monitoring of forest changes, combat threats like illegal logging, human settlements, and wildfires,
Forest Inventory and Planning	Timbeter App	Kenya Forest Service	Improved efficiency, transparency, combat illegal logging, enhancing timber monitoring and supply
Ecological Modeling and Prediction	Project 2020	National Centre for Earth Observation at the University of Leicester, Kenya Forest Service	Effective monitoring of forest changes, combat threats like illegal logging, human settlements, and wildfires,
Forest Fire Monitoring and Prediction	Project 2020	National Centre for Earth Observation at the University of Leicester, Kenya Forest Service	Effective monitoring of forest changes, combat threats like illegal logging, human settlements, and wildfires,
Smart Logging and Sustainable Harvesting	Timbeter App	Kenya Forest Service	Improved efficiency, transparency, combat illegal logging, enhancing timber monitoring and supply
Forest Restoration and Reforestation	KEFRIApp, SSMT	Kenya Forestry Research Institute, Gatsby Africa	site-species matching, furnish information on tree nursery

Broad Area of Sustainable Forest Management	AI Technology	Developer(s)	Benefits/role
			locations and facilitate real-time documentation of tree planting activities
Public Engagement and Education	KEFRIApp, SSMT	Gatsby Africa and	site-species matching, furnish information on tree nursery locations and facilitate real-time documentation of tree planting activities
Collaboration and Data Sharing	Project 2020	National Centre for Earth Observation at the University of Leicester, Kenya Forest Service	Effective monitoring of forest changes, combat threats like illegal logging, human settlements, and wildfires,

Table 3: AI technologies for forest management in Kenya

4.2. The attitudes toward the integration of AI technologies in forest management

Studies on people's attitudes toward the integration of AI technologies in forest management are limited. Nevertheless, these attitudes in Kenya are gradually evolving, with a mix of optimism and cautiousness. While some stakeholders view AI as a potential game-changer for enhancing data-driven decision-making, optimizing resource allocation, and combating deforestation, others express concerns about its potential socioeconomic impacts and ethical implications. Education and awareness of the benefits and risks of AI play a vital role in shaping these attitudes. As more successful AI-driven initiatives are showcased, and tangible benefits become evident, the acceptance and adoption of AI in forest management is likely to increase, fostering sustainable practices and conservation efforts.

5. Discussion

Sustainable forest management requires a balance between the ecological, social, and economic factors of forestry development (Empig et al., 2023). However, in view of the complex and intricate data and processes involved, the use of technology, particularly AI, is emerging as a solution to this challenge (Costa et al., 2023). This study sought to explore the public perception of the use of AI in enhancing sustainable forest management by examining the Kenyan context against global studies using a literature review and document content analysis.

The results of applying the analytical framework to public opinion on AI technologies in Kenya's forest management (Figure 1) reveal that AI deployment in forestry is still in its infancy. The country has few AI technologies to promote sustainable forest management (Table 3). The few AI applications in place have functions that cross-cut various facets of the analytical framework developed in Figure 1. For instance, in the realm of data collection and analysis, the Jaza Miti App, developed by the Ministry of Environment, Climate Change, and Forestry, collects and analyzes tree-planting data, facilitating tree species-site matching, and also plays a role in public engagement and education. For species identification and monitoring, Project 2020, a collaboration between the National Centre for Earth Observation at the University of Leicester and the Kenya Forest Service, enables the effective monitoring of forest changes and helps combat threats such as illegal logging, human settlements, and wildfires. Similarly, Project 2020 was utilized for deforestation detection and prevention, ecological modeling and prediction, and forest fire monitoring and prediction, providing valuable insights for forest management and protection.

In the analytical thematic area of forest inventory and planning, the Timbeter application developed by the Kenya Forest Service seeks to enhance efficiency and transparency and combat illegal logging while improving timber monitoring and supply. For forest restoration and reforestation efforts, KEFRIApp and SSMT, developed by the Kenya Forestry Research Institute and Gatsby Africa, aid in site-species matching, furnish information on tree nursery locations and facilitate the real-time documentation of tree-planting activities. Moreover, these applications support public engagement and education, encourage citizen participation in sustainable forest management efforts, and are supported by forestry development policies (Table 2). The results from Kenya are largely consistent with findings from global literature that appear to acknowledge the positive role of AI in forest management. AI-driven advancements hold great promise for transforming forestry practices and making them more efficient and environmentally sustainable. By incorporating AI, particularly through machine learning algorithms and UAV (Unmanned Aerial Vehicle) technology, forest management and resource inventory can be significantly improved (Chen et al., 2023; Karmaoui, 2023; Liu et al., 2022b; Costa et al., 2023; Osman et al., 2022; Yang et al., 2022 & 2023; Cheong et al., 2022; Kaack et al., 2022). AI technologies enhance forest management by improving effectiveness, sustainability, precision, and expenses (Table 1; Kourtz, 1990; Peng and Wen, 1999; Imada, 2014; Kimsey et al., 2021; Jahani and Rayegani, 2020). AI technology applications in forestry are enhancing data collection on forest biomass changes in areas greatly affected by accessibility challenges, areas with diverse and complex forest structures, and areas with complex topography and unfavorable climatic conditions (Linares-Palomino and Alvarez, 2005; Bojorquez et al., 2020; Chave et al., 2014). UAVs are used increasingly in ecological monitoring, particularly in forest resource inventories and tropical forest surveys (Casazza et al., 2019; Jiang et al., 2021; Johansen et al., 2019; Zhang et al., 2020; Ma et al., 2015; Qiu et al., 2018b; Hao et al., 2021; Hu et al., 2021b; Popescu, 2007; Lechner et al., 2020).

From the foregoing discussion, there are potential benefits of implementing AI technologies in Kenya's efforts to achieve 30% national tree cover by 2032 under the new Kenyan Kwanza administration's bottom-up economic model. AI-driven tools can improve forest monitoring and resource inventory through satellite imagery and UAVs with advanced sensors, thereby providing real-time data on forest cover, tree health, and growth rates. Predictive modeling using AI can anticipate threats, such as illegal logging and wildfires, enabling proactive measures for forest protection. AI can optimize tree-planting strategies based on factors such as soil type and climate conditions, ensuring successful afforestation and reforestation. It can also support community engagement through social media analytics and sentiment analysis, tailoring awareness campaigns, and encouraging citizen science projects for active participation in tree care. Additionally, AI aids in resource allocation and funding optimization, helping Kenya meet global climate change mitigation and adaptation commitments as part of the UNFCCC's NDC and the Paris Climate Change Agreement. However, as the proliferation of AI in forestry continues, there are emerging criticisms and opinions that demand a cautious approach to its application in forestry and other sectors. Skeptics demand AI market regulation and improving the quality of AI in the market; they fear of job losses, deep fake content, and general technostress (Wach et al., (2023). This study acknowledges the fear of AI's role in spreading propaganda related to climate change security. Although concerns about risks and job displacement are valid, dismissing AI's transformative benefits hinders progress. Responsible development, regulations, and proactive measures can mitigate risks and ensure positive impacts on society through efficiency, innovation, and improved quality of life. Education and awareness can reshape criticisms, leading to increased acceptance and adoption of AI in forest management and fostering sustainable practices and conservation efforts.

The results from Kenya have also revealed that there are currently no studies on the public perception of the role of AI in forestry. This study recognizes this as a major shortcoming in promoting the role of AI in forestry development. Without comprehensive research, missed opportunities to leverage AI's potential for accurate data analysis, early forest fire detection, biodiversity monitoring, and sustainable resource management could occur. This would hinder efforts to address critical environmental challenges and optimize conservation initiatives for future generations. Therefore, there is an urgent need for research on this topic in Kenya and beyond. Reviewed literature on geo-technologies and AI as tools for riparian forest management, da Silva Leite and Amorim (2021) have established that AI-based geo-technologies play a vital role in managing natural resources, addressing society's urgent questions and demands; however, there is a research gap concerning the application of AI in studying riparian forest PPAs with geo-technologies, suggesting the need for future research in forest management. In addition, owing to the current challenges facing AI deployments, such as limited resolution and high costs, more research is required.

6. Conclusion and Recommendations

The application of AI technologies in sustainable forest management in Kenya is in its infancy, but the initiatives in place demonstrate the potential for significant positive growth and impact on the forest industry development. The integration of AI tools such as the Timbeter App, Project 2020, and the KEFRI App in sustainable forest management has the potential to facilitate efficient data analysis, real-time monitoring, and informed decision-making, thereby enhancing forest protection and resource management in the country.

With continued awareness and successful AI implementation, the country is poised to harness the full potential of AI as a more sustainable and environmentally conscious approach to forest management. This development trajectory will help Kenya achieve its development aspirations outlined in the Constitution 2010, Vision 2030, and the government's Bottom-up Economic Transformation Agenda (BETA), among other international commitments ratified by Kenya.

Addressing the public perception of AI in forest management requires education, transparency, stakeholder engagement, and showcasing its benefits. Targeted campaigns familiarize people with AI advantages and involve local communities, organizations, and policymakers. Transparency, data privacy, and responsible usage build trust. Public-private collaboration fosters innovative AI solutions and overcomes financial constraints for successful deployment. The demonstration of AI benefits in forest management garners public support. Efficient resource allocation, biodiversity preservation, the detection of deforestation, and local engagement have created positive perceptions. Capacity building and addressing cultural factors enhance acceptance. Long-term sustainability indicates AI's value. Future studies should analyze the cost benefits and use diverse data sources for a comprehensive analysis.

The research limitation of this study is that it solely relied on a bibliographic review and did not include a direct analysis of public perception through interviews with stakeholders and subjects involved in Kenya's sustainable forest management. This omission results 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. This could be addressed by cross-referencing and using diverse data collection methods.

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