Research Article

Ecosystem-based adaptation as a strategy to increase climate resilience of small island communities in Indonesia

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Abstract. *The climate crisis is a global challenge significantly affecting the sustainability of both human system and ecosystem. Due to their geographical circumstances, communities on small islands are more vulnerable to its impacts. This study critically examines the potential of the ecosystem-based*

climate change adaptation model (Ecosystem-Based Adaptation) to increase climate resilience in small island communities, particularly in Indonesia. Through a semi-systematic literature review of 31 key studies, this research analyzes the characteristics of small island climate vulnerability and resilience, then compare the findings to Indonesia context. Ecosystem-Based Adaptation has several advantages compared to other climate adaptation models; however, some challenges and limitations associated with its implementation are also identified. Findings suggest that for Ecosystem-Based Adaptation to be effective, it needs to be community-led alongside empowerment, integrative-collaborative, and adaptive. Furthermore, the literature review identified critical gaps in current research on Ecosystem-Based Adaptation on small islands, offering valuable avenues for further exploration and advancement of this vital adaptation approach.

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1. Introduction

The term "climate crisis" encompasses the issues of global warming and climate change, along with their associated impacts. It emphasizes the threats to humans and Earth's ecosystems, prompting the urgent need for action to address these challenges (Ripple et al., 2019). The Intergovernmental Panel on Climate Change (IPCC, 2021) has officially affirmed that climate change is real, poses a global threat, and is predominantly driven by human activities.

As an archipelagic country, Indonesia faces significant risks due to the climate crisis. The Asia Development Bank/ADB (ADB, 2021) ranks Indonesia among the top three countries most at risk from climate-related disasters, including floods, heat waves, rising sea levels, food production failures, and clean water shortages. Additionally, with 29.36% of its population dependent on agriculture, forestry, and fisheries for their livelihoods (Indonesia Center of Statistics/BPS, in Muhamad, 2023), the ongoing climate crisis poses a critical threat to the country's economic and social sustainability.

As an archipelagic nation consisting of approximately 17,000 islands, of which around 6,000 are inhabited, Indonesia confronts distinct climate risks associated with its smaller islands. These smaller islands, often more isolated and resource-

limited, face heightened vulnerability to the impacts of climate change. Consequently, developing effective climate adaptation solutions for these regions is essential. This study seeks to explore one of the climate adaptation models endorsed by the United Nations Framework Convention on Climate Change/UNFCCC, specifically Ecosystem-Based Adaptation (EBA). It aims to investigate how this model can be effectively implemented to bolster climate resilience in small island communities. To guide this exploration, the study will focus on the following question: considering the small islands unique vulnerabilities, advantages, and challenges, how can EBA strategies effectively enhance climate resilience in small island communities in Indonesia?

2. Theoretical framework

2.1 Climate crisis and adaptation responses

Climate change is a global phenomenon of shifting weather patterns, seasons, and climate, which can occur both naturally and anthropogenically. However, the climate change that has occurred in recent decades has been confirmed to be anthropogenic—since the Industrial Revolution, human activities globally have released millions of tons of greenhouse gases, causing an increase in the average temperature of the Earth's atmosphere. This increase in temperature disrupts the Earth's natural systems, causing changes both in the weather patterns and intensity, and these changes have significantly impacted humanities.

The impacts of climate change are already being suffered worldwide through increased frequency and intensity of hydrometeorological disasters, the spread of infectious diseases, biodiversity loss, and ecosystem degradation. These events, in turn, impact the entire human-made system, threatening critical socio-economic aspects such as food security, water security, health, livelihoods, and peace. All these impacts and/or risks caused by climate change are called the climate crisis (United Nations Development Programme/UNDP, 2023).

To better understand the scope of these challenges, it is important to recognize that although the climate crisis is a global phenomenon, the impacts are not evenly distributed; some regions and communities suffer greater risks than others. Coastal and small island areas have higher risk from the climate crisis, both in terms of the percentage of the population affected and the losses - or potential losses - from the climate crisis (Nurse et al., 2014). Some impacts are already occurring in coastal and small island areas; these are expected to intensify as the average temperature of the Earth atmosphere increases.

Considering the situation in coastal areas and small islands regarding the climate crisis, an adequate response is needed to protect coastal and small island communities from the extreme impacts of climate change. Responses to climate change consist of (1) mitigation - various efforts to stop or reduce further climate change, and (2) adaptation - various efforts to respond to the impacts of climate change. Climate adaptation is "actions that help reduce vulnerability to the current or expected impacts of climate change" (UNDP, 2023, para. 34). This dual-track response underscores the importance of both long-term prevention and immediate adaptation. Denton et al. (2014) emphasized that delaying the response to climate change will reduce the windows of opportunities to develop pathways of climate resilience; therefore, efforts to develop community climate resilience must be carried out as early as possible. It is also recommended that responses to climate change should prioritize those with co-benefits, that is "secondary or unintended benefits of an adaptation action/project, which are additional to the primary purpose of the action but contribute positively to creating community climate resilience" (Jones & Doberstein, 2022, abstract).

Ecosystem-Based Adaptation (EBA), or Nature-Based Adaptation, is a climate adaptation strategy that leverages natural solutions and maximizes ecosystem services to increase resilience and reduce vulnerability (International Union for Conservation of Nature/IUCN, 2024; United Nations Environmental Programme/UNEP, 2025). EBA encompasses a range of ecosystem management activities from forests, grasslands, wetlands, to coastal and marine areas. In contrast to engineered solutions, the primary goal of EBA is to protect communities from the impacts of climate change. However, it is said to provide co-benefits in improving livelihood and mitigating climate change through ecosystem restoration.

2.2 Climate resilience in small island communities

In the context of disasters, risk - including climate change-related risks - is defined as a function of 'exposure to hazards', 'vulnerability', and 'capacity' (United Nations Disaster Risk Reduction/UNDRR, 2025). The presence of a hazard does not necessarily mean disaster will occur. Although 'hazards' might be inevitable, disaster risks can be reduced if 'vulnerability' is balanced with increased 'capacity' (Zakour & Swager, 2018). In this framework, vulnerability and capacity are not fixed, they can be shaped and improved through targeted interventions. Both are influenced by socio-economic circumstances, the capacity of community, and—in terms of climate change—active efforts in adaptation and mitigation. This understanding serves as the foundation for

building community climate resilience. Coastal or small island communities are often more impacted by the climate crisis rather than causing it; in other words, there may be little they can do to stop the global climate change, but by reducing vulnerability and exposure, communities can build resilience and moderate the impacts of climate change on their lives.

Norris et al. (2008, p.130) define community resilience as "the process of linking (a community's) adaptive capacity to positive post-disturbance functioning and adaptation (towards recovery)". The process, as described in the study, can produce a variety of outcomes: *resistance* is the ability to moderate the impact of a disturbance and maintain the initial state/well-being; *resilience* occurs when a community is temporarily affected by a disturbance but able to recover to its original state and well-being; while *vulnerability* means that a community is affected and unable to recover fully, thus reducing its ability to survive. This spectrum highlights how communities may respond differently to disturbances, depending on their preparedness and adaptive capacities. According to de Graaf-van Dinther & Ovink (2021), the climate resilience of a community, especially those in coastal areas, consists of five pillars:

(1) Threshold capacity: the ability to prevent damage by developing thresholds/barriers to moderate potentially catastrophic environmental variations. Some examples are flood-reducing channels and planting trees as a barrier to strong winds.

(2) Coping capacity: the ability of a community to cope with extreme weather caused by climate change and reduce the damage caused by such weather. Examples of capacity building include developing early warning systems and evacuation routes, storing food/water reserves for emergencies, etc.

(3) Recovery capacity: the ability of a community to recover from a problematic/extreme situation and then return to the same or better condition. This capacity can be enhanced through insurance mechanisms and/or emergency reserve funds, the existence of organizations/teams trained in disaster response, agreeing on various recovery schemes, etc.

(4) Adaptive capacity: a community's ability to anticipate uncertain future developments. Strengthening this capacity involves developing alternative scenarios for the community, such as preparing migration locations in anticipation of rising sea levels, developing variations in sources of income/livelihoods, and so on.

(5) Transformative capacity: the ability to proactively change towards climate-resilient communities through the development of environmental support, capacity building, and the identification and implementation of interventions to catalyze the change process. Some examples of activities that can be carried out are increasing multi-stakeholder engagement in the community, developing partnerships with parties outside the community, and developing regenerative development models. Together, these five capacities provide a holistic framework for understanding and strengthening resilience in vulnerable coastal and island communities.

3. Method

The climate crisis is a systemic and cross-sectoral development issue; therefore, literatures related to the issue are not concentrated in one field of science. Instead, they are spread across various fields ranging from science, environment, social, and health to business and economics. Considering this cross-sectoral nature, this study uses a semi-systematic literature review as described in Snyder (2019).

The literature review aims to synthesize findings from previous research, identifying patterns and drawing conclusions on specific research questions. Literature reviews, according to Snyder (2019), are divided into three types based on the rigidity of the procedure: systematic, semi-systematic, and integrative. Each type is said to be more effective in different research contexts. In particular, semi-systematic reviews are helpful when the research topic is cross-disciplinary and conceptualized differently. Hence, a fully systematic review is difficult to conduct—emerging research topics often have this nature (Zunder, 2021). Semi-systematic reviews can be used to map the common thread of various studies related to a topic, which can then be synthesized into a meta-narrative; therefore, semi-systematic reviews are often referred to as narrative literature reviews or meta-narratives (Snyder, 2019; Wong et al., 2013).

In this study, an initial search was conducted using the Publish or Perish (PoP) tool using Google Scholar as database (Eykelbosh & Fong, 2017). Since preliminary searches yielded few results on this specific topic, Google Scholar is chosen for its wide range of results compared to other databases, and to also include grey literatures. The use of Publish or Perish (PoP) helped enhance the comprehensiveness of the search compared to manual methods. Four key phrases were identified based on the theoretical framework, namely "ecosystem-based adaptation/EBA" (and its synonym nature-based adaptation), "small

island" (or "small island developing states/SIDS"), "community resilience" and "climate change." An initial literature search was conducted on journal articles published between 2014 and 2023, resulting in 500 article titles. The year 2014 was selected due to its significance when climate vulnerability in small islands was acknowledged, as articulated in the IPCC Fifth Assessment Report (Nurse et al., 2014).

The search results were then screened based on number of citations, resulting in 454 articles. These results turned out to be very diverse regarding scientific fields, theme coverage, and study direction. To refine the focus, further selection was carried out with a personal assessment strategy on the article's title (Zunder, 2021). The selection criteria were the presence of at least two key phrases or their synonyms in the title; for example, an article entitled "Ecosystem-based adaptation in small island developing states" was selected because it contains the key phrases EBA and SIDS. This phase of the review emphasized the semi-systematic nature of the method, where various synonyms of key phrases are identified and accommodated (see figure 1). This title selection stage resulted in 79 selected articles.

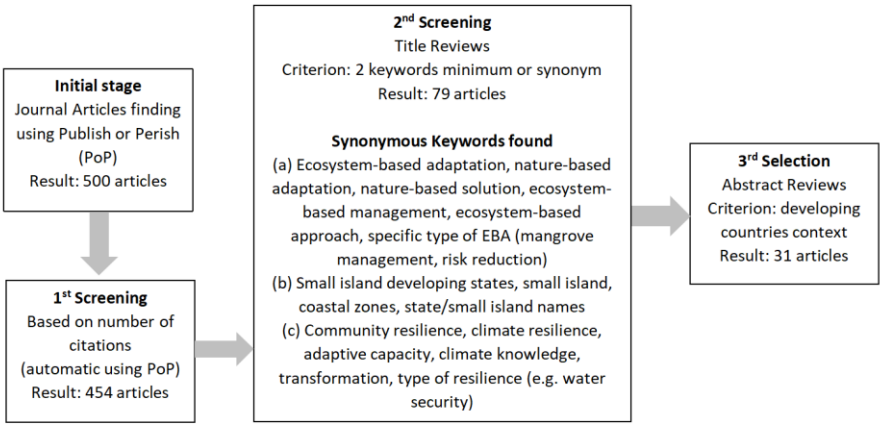

Figure 1. Stages of literature search and screening

Further screening was carried out by reading the abstracts of the 79 articles to identify suitability with the research objectives. This study aims to find EBA implementation strategies for small islands in Indonesia. Therefore, the research loci became a determining factor in inclusion or exclusion: research located in

developing countries' coastal or small islands were included, while research located in developed country and land/terrestrial areas were excluded. The final search results consisted of 31 articles to be analyzed.

To relate the findings more directly to the Indonesian context, results from literature were used as a basis to search similar situations/conditions in Indonesia through web-based mechanism. This involved translating findings into Bahasa Indonesia and conducting searches via Google to locate related references. These are then compared to analyze the relevance of findings to Indonesian context, which resulted in some recommendations for country-specific EBA implementation.

4. Findings and Discussion

The process of literature search and screening provided two notable results. Firstly, literature on the topic of "EBA in small islands" was found in various journal themes ranging from climate change, ecology, marine science, climate science, island studies, social sciences, forestry, social ecology, disaster studies, women studies, and sustainability/sustainable development (Table 1; see Appendix 1). This diversity in publication sources is consistent with the interdisciplinary nature of EBA, especially when narrowed down in the context of small islands and developing countries.

Secondly, among the literatures found through automatic search, only few matched with the theme of EBA in small islands (79 out of 500 articles), and even fewer in developing country settings (31 out of 79 articles). This scarcity of relevant literature highlights a significant research gap. This finding is consistent with existing studies that shows how research on EBA mainly originates from, and is conducted in, developed country settings (Fernandino et al., 2018; Owen, 2020; Robinson, 2018). The reason could be that the issue is relatively recent in recognition; Robinson (2018) mentioned that IPCC Fifth Assessment Report in 2014 as a critical point that raised academic concern about small islands vulnerability to climate change impacts. Following the release of this report, the number of studies on climate adaptation in small islands increased significantly.

4.1 Characteristics of small islands climate vulnerability and resilience

Small islands, despite their diversity in geography, history, culture, and levels of economic development, tend to share a common set of climate-related challenges (Klöck & Nunn, 2019). A significant portion of the literature on climate adaptation in small islands is focused on Small Island Developing States (SIDS),

a group of 39 countries and 18 associate members of the United Nations characterized by similar vulnerabilities. However, recent findings suggests that many of these challenges also affect small islands outside the SIDS category (Petzold & Magnan, 2019). These common challenges include limited natural and financial resources, growing populations within confined land areas, high disaster vulnerability, dependence on external inputs, and fragile ecosystems (Petzold & Magnan, 2019; UN-Habitat, 2015).

In terms of exposure to hazards, small islands are particularly at risk. They experience a higher frequency of natural disasters compared to larger landmasses, and climate change is projected to intensify these events (Gheuens et al., 2019). Typical hazards include sea level rise, heat waves, tropical cyclones, ocean acidification, and high waves (Thomas et al., 2020). These hazards translate into real and increasing threats to human well-being, particularly in the form of: (1) disastrous flood - especially in tropical regions; (2) wind and large waves damage; (3) health risks due to heat and vector-borne diseases; (4) food and water insecurity (Thomas et al., 2020). In Indonesia, many of these impacts are already observable. Data from Ministry of Environment and Forestry (KLHK) confirm instances of rising sea levels leading to the loss of coastal areas and small islands (KLHK, 2019). Meanwhile, the National Board for Disaster Management (BNPB) has reported an upward trend in disaster frequency between 2010-2020 with hydrometeorological events being the most prevalent (BNPB, in Pusparisa, 2021). Projections by the Ministry of National Developmental Planning (Bappenas) further warn of worsening food and water insecurity between 2020 and 2034, especially in the eastern island regions (Bappenas, 2021).

Vulnerability in small islands is multidimensional, shaped by both environmental and socio-economic factors (Filho et al., 2020; Owen, 2020; Robinson, 2018). The main livelihoods of small islands are generally tourism, fisheries, and agriculture (Fernandino et al., 2018; Thomas et al., 2020); all these sectors are highly dependent on ecosystem health, making the livelihoods of small island communities highly vulnerable to the impacts of climate change. Many coastal communities rely on coastal and marine ecosystems as a source of food; the impacts of climate change on these ecosystems - for example, coral bleaching - will potentially contribute to food insecurity (Fernandino et al., 2018). In addition, most small islands have limited water resources. Climate change and ecosystem degradation will exacerbate this water scarcity, increasing pressure on socio-economic situations, especially on marginalized communities (Gheuens et al., 2019; Woroniecki, 2019).

This is especially critical from a gender perspective. In many communities, including those in Indonesia, women are primarily responsible for securing household water. The worsening scarcity of clean water therefore places disproportionate burdens on women, affecting not only domestic workloads but also reproductive health (Nalau, Becken, Schliephack, et al., 2018; Singh et al., 2022; KLHK, 2019). These findings underscore how socio-economic risks from climate change are experienced differently across genders, with women often facing more severe consequences.

Geographic isolation also contributes to small islands' vulnerability. Difficult access due to physical barriers - such as long distances or dangerous seas - limits the delivery of information, social services, external assistance, and overall development (Fernandino et al., 2018; Petzold & Magnan, 2019). Due to these obstacles, communities and local governments on small islands generally have limited coping capacity, both in terms of understanding and technical skills, and funding to anticipate the impacts of the climate crisis (Fernandino et al., 2018; Gheuens et al., 2019; Klöck & Nunn, 2019; Petzold & Magnan, 2019; Robinson, 2018; Silver et al., 2019; Thomas et al., 2020). As the intensity and frequency of climate change impacts increase, these already limited capacities may further decrease over time as losses from climate-related disasters will reduce the capacity of small island governments to protect themselves from climate crisis. These access-related vulnerabilities are also evident in Indonesia. According to Presidential Decree no.63/2020, Indonesia has 62 "least developed" district (Indonesia Financial Audit Board/BPK, 2020); about a third are situated in small islands of archipelago, many of them laid remote from mainland. In the future, the physical obstacle in form of high waves is projected to worsen as a result of climate change, where 90% of Indonesian seas will be "too dangerous for ships under 10 GT (gigatons) capacity" in 2045 (Bappenas, 2021). Without proper adaptation, this increase in physical obstacles will further isolate Indonesia's small islands, potentially increasing vulnerability of communities in these remote and least developed areas.

In addition to this limited capacity, small island communities may become more vulnerable due to lack of sufficient responses to climate-induced threats. This is related to the perception of the government and small island communities towards the climate crisis. With limited access to education, lack of scientific data on islands, and language barriers, the government and small island communities tend to view climate crisis as 'too distant' (Ruckelshaus et al., 2015, in Fernandino et al., 2018) compared to, for instance, poverty or lack of access. Consequently, local government tends to prioritize their budgets for infrastructure development

and short-term economic achievements (Fernandino et al., 2018; Petzold & Magnan, 2019). Although some adaptation actions have been done, they were mostly reactive to urgent challenges, lacking considerations on future or long-term dimensions (Klöck & Nunn, 2019); although the scale continues to increase, these adaptation responses are often inadequate compared to the scale and extremity of the climate change impacts faced by small islands (Mcleod et al., 2019).

According to literature findings, small island communities are often aware of climate change impacts around them because changes are already visible or experienced in their daily life. However, community members often have diverse perspectives as to why these changes occur, and they generally have not allocated many resources to anticipate the dangers of climate crisis. Instead, attention is given more on daily life challenges such as poverty, food sufficiency, and livelihoods (Thomas et al., 2020; Walshe et al., 2018). This could be due to lack of agreement or common perception about the risks of climate crisis (Robinson, 2018; Walshe et al., 2018). Compared to Indonesia settings, one research conducted by Bohensky et al. (2016) on Lombok Island residences have shown similar result where residents from different professional and educational background perceive climate change differently. Another survey by YouGov (Nguyen, 2024) show that even though awareness of the urgency of climate change may be higher now in Indonesia (89%), the urge to act remains relatively low (47%). However, if the impacts of climate change are both experienced and understood by the community, the motivation to act may become higher (Filho et al., 2020; Thomas et al., 2020).

As global urbanization increases, some small islands are experiencing high urbanization rates (UN-Habitat, 2015). In Indonesia, some islands have this similar situation, such as Batam and Bali. It is also worth noted that the trend of urbanization in Indonesia is no longer concentrated in Java island; instead, it tends to be more widespread to less developed regions including some archipelagic provinces, such as Bangka-Belitung, Nusa Tenggara Barat, and Kepulauan Riau (Firman, 2024). Urbanization in small islands poses some other risk factors including the growth of densely populated areas near the coast and/or disaster-prone locations, higher environmental pressures, and lack of government capacity to regulate development. These can increase the vulnerability of small island communities in various ways. Areas with dense population near coastal locations may suffer severe impacts of climate-related disasters, as in the case of Bintan Island flood where 1176 families were impacted (Haka, 2025). Urbanization means more exploitation to water sources, while

Indonesia small islands often already struggle with water scarcity and lack of clean water infrastructures (Ministry of Public Works/PUPR, 2025). Climate change impacts, such as long droughts, will exacerbate this situation.

Small islands are indeed threatened by various exposures to climate-related hazards. However, vulnerability is not the only narrative to frame the issue of climate change in small island communities; in other words, they are not "passive recipients" in climate adaptation. Instead, some capacities have been identified that potentially serve as initial capital for developing climate resilience. Island communities often have high coping capacity and recovery capacity, since coastal areas and small islands often face extreme weather, such as strong winds, large waves, and floods. Therefore, even before climate change, coastal and small island communities often had experience coping with and recovering from disasters (Petzold & Magnan, 2019; Trundle et al., 2019). This recovery capacity is sometimes part of the identity, for instance in Trundle et al. (2019), meaning that communities not only recovered, but also transformed because of the experience. Walshe et al. (2018) shows similar capacity from communities to respond to the impacts of climate change and anticipate the threat of climate crises. The knowledge are sometimes embedded in their indigenous tradition, therefore integration of indigenous knowledge may play an important role in building climate resilience (Petzold & Magnan, 2019; Singh et al., 2022). In Indonesia, an example of indigenous knowledge related to food security is shown by the Bajo coastal community, where the *Tubba dikatutuang* system prohibits destructive fishing in sacred coral zones, while *Parika* institutions regulate harvesting seasons – ensuring long-term marine resource sustainability (Hasrawaty et al., 2017). For instance, the community enforces seasonal bans on fishing in protected areas and imposes fines up to IDR 2 million for violations, which has maintained 62% live coral cover in these zones (Hasrawaty et al., 2017). Another local wisdom for disaster preparedness exists in Simeulue Island, where tsunami indicators (e.g., receding seawater post-earthquake) and evacuation protocols are embedded in *nandong* verses and *nafi-nafi* storytelling, enabling rapid community response during crises (Maru et al., 2023).

In some cases, remoteness can even be an asset. Many small islands, by virtue of being underdeveloped, have maintained pristine ecosystems. This enhances threshold capacity, as healthy ecosystems regulate local climate conditions and support community self-sufficiency (Petzold & Magnan, 2019). Some Indonesian islands still possess such intact ecosystems. However, without legal protection and sustainable management, these areas remain highly vulnerable to degradation from tourism and destructive fishing - such as the coral reef damage in Raja

Ampat caused by a cruise ship (Detikcom, 2019), or reef-bombing incidents in Banggai Laut (Ministry of Marine and Fisheries/KKP, 2024). Despite evidence of adaptive capacity in small islands, they remain highly vulnerable to the long-term impacts of climate change (Nurse et al., 2014). Therefore, adequate adaptation measures are still necessary.

4.2 EBA Implementation in small islands: strengths and good practices

Findings from literature show that the forms of climate change adaptation carried out on small islands are not all ecosystem-based, instead, they are quite diverse in response to specific challenges on each island. This diversity of adaptation approaches is viewed positively, as it demonstrates that island communities possess a relatively high adaptive capacity (Granderson, 2017; Klöck & Nunn, 2019). Examples of adaptation actions on small islands are found in the studies of Fernandino et al. (2018); Filho et al. (2020); Klöck & Nunn (2019); Petzold & Magnan (2019). These actions can generally be grouped into four main categories:

a) Physical/structural. Including building sea walls and canals, also implementation of technology for early warning system, relocating assets, restoring coastal/marine ecosystems, etc.

b) Social. Including education/empowerment, information dissemination, environmental monitoring, migration/relocation, etc.

c) Institutional. Including legal-regulatory development, government policies, community-based decision-making, etc.

d) Resettlement or migration of a community to a new location. Resettlement is carried out in response to immediate climate impacts (e.g., settlements destroyed by strong waves) or long-term (e.g., loss of settlement areas due to sea level rise). However, McLeod et al. (2019) caution that this option should only be considered as a last resort, as relocation can potentially cause new problems, including the loss of traditional lifestyles.

Among the various climate adaptations implemented in small islands, several examples of Ecosystem-Based Adaptation have been identified in developing country settings. These examples illustrate how nature-based strategies can address both immediate and long-term climate risks while delivering additional socio-economic benefits. They include:

(1) Mangrove reforestation (Chow, 2018; Nalau, Becken, Schliephack, et al., 2018; Saroar et al., 2019). In Indonesia, such efforts have been carried out in

several projects, for example the Build With Nature initiative (Ecoshape, 2025), and the project documented in Lahay et al. (2020). It is important to note, however, that both examples were implemented in mainland coastal settings rather than in small islands. According to Chow (2018), the restoration or development of mangrove ecosystems is referred as "unique climate strategy" because it provides co-benefits for both climate change adaptation (e.g., serving as wave and windbreaker, preventing abrasion) and mitigation (e.g., absorbing carbon dioxide, preserving biodiversity). However, the level of mangrove effectiveness depends on the strength of the trees and the quality of their habitat. For this reason, mangrove restoration efforts should be supported by adaptive strategies and integrative approaches that ensure their long-term sustainability.

(2) Protection of coastal areas through the improvement or preservation of coastal protective ecosystems, such as coral reefs and seagrass beds (Chong, 2014; Fernandino et al., 2018). In some cases, coastal area management also aims to reduce drought and flooding risks (Saroar et al., 2019).

(3) Adaptations in the food sector, including rotational agriculture (Nalau, Becken, Schliephack, et al., 2018) and restoration of natural flood canals as irrigation sources for food crops (Saroar et al., 2019).

These practices are sometimes synergized with local wisdoms already present in the community (Buckwell et al., 2020), ensuring that adaptation measures are culturally relevant and more easily adopted. For example, communities may conduct environmental monitoring (Granderson, 2017) or manage coastal and marine resources (Buckwell et al., 2020; Mcleod et al., 2019). In the Indonesian context, Widarmanto (2018) documents a traditional regulation system called *awig-awig* which served as the foundation for successful fishery management in a mainland coastal community.

Some practices of EBA in Indonesia have been found, e.g. Sekolah Lapang Iklim or Climate Field School by the Indonesia Agency of Meteorology, Climatology, and Geophysics (BMKG, 2023) in forest settings, and the initiative described by Lontara (2022) in a riverside setting. However, overall, there is limited literature on EBA practices in Indonesia's small islands. This gap may suggest that the importance of EBA in small islands, or even the specific climate risks unique to small island context, has not yet been fully recognized.

Global mapping of EBA practices shows that most EBA programs are effective in mitigating the extreme impacts of climate change (Chausson et al., 2020), however, these findings are not specific to EBA in small islands. In addition to its benefits for climate adaptation, some EBA implementations show co-benefits

such as the strengthening of traditional knowledge (Nalau, Becken, Schliephack, et al., 2018), improvement of community livelihoods, and the emergence of innovations in resource management (Buckwell et al., 2020; Woroniecki, 2019). EBA, when implemented with community empowerment, may attract the attention of key actors such as government authorities, thus creating opportunities to renegotiate community decision-making powers (Woroniecki, 2019). Furthermore, EBA implemented with an integrative approach, in addition to having a direct impact on the climate resilience of island communities, can provide additional benefits such as strengthening several SDGs (Filho et al., 2020; Mcleod et al., 2019; Nalau, Becken, & Mackey, 2018; Owen, 2020).

Compared to other adaptation strategies, EBA offers several advantages. Firstly, EBA is a relatively low-cost solution; the co-benefit nature of EBA allows several problems to be targeted through a single action, making it more cost-effective (Buckwell et al., 2020; Silver et al., 2019). Secondly, when appropriately implemented, EBA can effectively increase the threshold capacity for small island communities. Analysis of various climate adaptation actions shows that coastal and marine ecosystems are important in protecting coastal and small island communities (Chong, 2014; Mcleod et al., 2019), both physically and socio-economically, since these ecosystems are often the primary source of community livelihoods. EBA is considered a more effective and sustainable solution when compared to the "mechanical" forms of climate adaptations, e.g. the construction of sea walls and other physical structures which, in addition to high maintenance costs, may also have negative impacts on ecosystem health (Klöck & Nunn, 2019; Petzold & Magnan, 2019; Silver et al., 2019). Thirdly, the public and policymakers tend to be more receptive to EBA due to its integrative and pragmatic nature. EBA programs can improve both environmental protection and community welfare, and their benefits are often immediately felt (Buckwell et al., 2020; Chong, 2014; Nalau, Becken, & Mackey, 2018). These advantages make EBA increasingly popular as a sustainable climate solution.

4.3 EBA implementation in small islands: challenges and limitations

EBA has the potentials to create climate resilience in various contexts, including that of small island communities. However, its implementation faces several challenges that potentially reduce its effectiveness. From the literature standpoint, it is clear that political, socio-economic, and institutional situations greatly influence the success of EBA (Chong, 2014; Nalau, Becken, & Mackey, 2018). Conflicts of interest, corruption, and weak government coordination are major inhibiting factors (Fortnam, 2019). In addition, a rigid and overly sectoral

governmental system can complicate implementation because EBA is cross-sectoral in nature (Seddon et al., 2020). If the EBA implementation policy is designed *top-down,* its implementation is often determined by the interests of donors or the government, meaning the results are often not appropriate or effective in the long term (Petzold & Magnan, 2019); furthermore, such approaches often ignore the complexity and internal capacity that the community already has (Walshe et al., 2018). The political succession system in many countries generally operates on a five-year cycle; Indonesia is one of these countries. This is also considered a challenge because building community resilience through EBA may take longer time (Robinson, 2018); potentially resulting in discontinued programs following changes in political leadership.

The next challenge is the implementer's understanding of the scientific aspects of EBA. To be able to implement EBA effectively, a comprehensive understanding of ecosystem structure and mechanisms is required, for example, knowledge of the mechanisms of interaction between ecosystems, climate, and humans, as well as an understanding of the degree of effectiveness and scale of climate adaptation (Filho et al., 2020; Nalau, Becken, & Mackey, 2018). In addition, a deep technical understanding of the area situation is also required, i.e. knowing when and where EBA is most effective to be implemented (Milman & Jagannathan, 2017; Silver et al., 2019). Access to such knowledge tends to be scarce in small island settings. One common misconception is that EBA is simply about "planting trees" (Seddon et al., 2021), while there is also confusion in small island communities about the risks of climate crisis and what kind of actions need to be taken (Walshe et al., 2018). This lack of understanding results in partial and/or out-of-sync implementation of EBA, leading to tradeoffs affecting both natural ecosystems and local communities (Chausson et al., 2020; Saroar et al., 2019; Seddon et al., 2020, 2021).

Some social tradeoffs that arise from the inadequate implementation of EBA are discussed by Woroniecki (2019), where marginalization occurs as a result of EBA implementation that is insensitive to power relations. In this context, marginalization can take different forms and occur at different levels. Marginalization may occur towards island communities by policymakers and/or implementers, or it may happen when community involvement does not represent all demographic groups in a balanced manner, for example, by not involving women (Singh et al., 2022) and other marginal members such as the elderly (Granderson, 2017). Such imbalances in participation can weaken the legitimacy and inclusivity of EBA programs, reducing their long-term effectiveness. Although no reported cases of EBA marginalization have been

found, such marginalization are likely to happen in various contexts of development in Indonesia, particularly since discrimination against vulnerable society members still occurs, despite a significant decrease in the last decade according to the Indonesia Ministry of Women Empowerment and Child Protection/KemenPPPA (KemenPPPA, 2024).

In addition to these two challenges, another key weakness that frequently emerges in the literature is the lack of result measurement, prediction, and long-term evaluation of its effectiveness (Chausson et al., 2020; Milman & Jagannathan, 2017; Seddon et al., 2020). This gap is critical because without proper evaluation, lessons learned cannot be effectively transferred or scaled up. The success of EBA is often only measured directly after program completion, with post-program monitoring typically carried out for 6 months to a maximum of one year. Given the high level of uncertainty in climate change, the results of these short-term measurements may not reflect the effectiveness of EBA in the long term. For instance, while short-term data may suggest immediate benefits, hidden vulnerabilities can emerge years later—such as in the case of mangrove planting, which often uses a hit-and-run approach. According to Chow (2018), mangrove ecosystems are highly vulnerable to climate change, and without continuous monitoring, these adaptation efforts risk wasting resources and damaging already fragile island ecosystems.

Another weakness is the lack of cost-benefit analysis, which means the effectiveness of funding is less certain (Chausson et al., 2020). In the absence of such analyses, policymakers may be hesitant to allocate resources or sustain funding. When this review was done, only one study was found that focused on the cost-benefit analysis of EBA (Buckwell et al., 2020), and it found that EBA has a high level of cost-benefit effectiveness. However, these results are insufficient to scientifically claim that EBA has a high benefit value compared to its costs, especially in the long term.

When analyzed from the perspective of the five pillars of climate resilience, the most significant portion of EBA seems to lie in enhancing threshold capacity, although there may be partial contributions to other pillars (e.g., mangrove restoration enhances adaptive capacity by providing new food sources and livelihood options). This suggests that EBA is an important but incomplete tool in the broader resilience-building toolkit. Restoring or preserving ecosystem services alone is insufficient to fully develop the five pillars of climate resilience. The other four capacities must be developed through strategies that empower small island communities.

4.4 EBA implementation strategy for small island climate resilience

The unique characteristics of small island communities require implementation strategies that are carefully tailored to their vulnerability and resilience profiles. The literature reviewed in this study mentions several potential strategies to increase the effectiveness of EBA on small islands. Across the sources, four main categories of strategies emerge: (1) community-based or self-managed, (2) community empowerment through distribution of access and information, (3) integrative and multi-stakeholder approaches, and (4) adaptive planning. Rather than being applied in isolation, these strategies are most effective when implemented in combination, allowing each to reinforce and complement the others (Owen, 2020).

The first strategy suggests that implementation of EBA should be community-based and self-managed by the community (Nalau, Becken, Schliephack, et al., 2018; Petzold & Magnan, 2019; Woroniecki, 2019). Given the diversity of contexts among islands, a top-down approach generalized across all regions is often inappropriate and/or unsustainable. On the other hand, small island communities have some resilience; they are often experienced in coping with and recovering from complex events, they are also the owners of indigenous knowledge about their areas, and the ones most likely to settle there in the long term. These capacities make island communities well-positioned for self-reliance (Petzold & Magnan, 2019). When designed and led locally, the implementation of community-driven EBA has the potential to be more contextual and sustainable, with local leadership playing a pivotal role in ensuring long-term success (Fernandino et al., 2018).

More specifically, community-based implementation must be carried out inclusively, involving and accommodating the diversity of community members' perceptions (Walshe et al., 2018). This inclusivity ensures that adaptation measures are relevant and supported across different groups. For example, gender-sensitive involvement is important to be emphasized, because culture in a community sometimes differentiates the roles of women and men. Consequently, according to their roles, women have not only specific vulnerabilities and needs, but also specific expertise and skills. Recognizing and integrating these unique contributions increases community resilience, especially in adaptive capacity (Singh et al., 2022).

The second strategy - empowerment through access and information distribution - builds directly on the first. On the one hand, communities need certain capacity building to be able to self-manage (Chow, 2018; Petzold & Magnan, 2019;

Walshe et al., 2018); on the other hand, active involvement in implementation also empowers them (Woroniecki, 2019). Buggy & McNamara (2016) identified factors such as social dynamics, power relations, and changes in social norms as key determinants in successful implementation. Community empowerment can be a strategy to address and positively influence these factors.

Capacity building is particularly needed for community scientific understanding, paired with timely and relevant information on the climate crisis and EBA (Fernandino et al., 2018; Walshe et al., 2018; Woroniecki, 2019). Empowerment can occur through knowledge sharing and learning (Gheuens et al., 2019; Owen, 2020), both at the internal community level and between communities and external parties such as other communities, academics, NGOs, etc. Nalau, Becken, Schliephack, et al. (2018) recommend participatory processes for this knowledge co-production. In addition, Granderson (2017) mentions the need for intergenerational transmission of knowledge and knowledge exchange between marginalized or vulnerable groups in society as strategies for knowledge co-production in the community.

Effective solutions to the climate crisis are sometimes found in local wisdom, so integrating local wisdom can benefit EBA implementation. Nalau, Becken, Schliephack, et al. (2018) further mention examples of good practices of local wisdom integration in EBA implementation: EBA is integrated into the traditional governance system in island communities. This integration fosters local ownership and cultural alignment, and has been shown to increase community commitment, as evidenced by the locals continuing adaptation initiatives even after the project period has ended. However, it is important to note that despite the value of traditional wisdom in creating climate resilience, its application must be critically assessed. Not all traditional lifestyles are relevant to today's small island communities, especially those already exposed to modern/urban lifestyles (Granderson, 2017).

Finally, empowerment also occurs when communities have sovereignty/authority to independently manage certain land/areas (Nalau, Becken, Schliephack, et al., 2018; Petzold & Magnan, 2019; Woroniecki, 2019). Along with adequate capacity, communities can manage, enforce local rules, and continuously monitor the area according to the principles of sustainability and ecosystem preservation. Such arrangements enable communities to achieve transformative capacity within the pillar of climate resilience (de Graaf-van Dinther & Ovink, 2021). To fully realize this potential, however, local authority must often be complemented by external recognition and support. Related to increasing capacity and sovereignty over the territory, there needs to be some

agreement with external stakeholders; this highlights the importance of multi-stakeholder collaboration in implementing community-based EBA.

Therefore, the third strategy is closely related to the integrative and multi-stakeholder approach. This approach not only connects communities with broader support systems but also ensures that efforts are reinforced across different levels of governance. Multi-stakeholder collaboration can overcome problems such as limited resources, while also strengthening various stakeholders' commitment to program sustainability (Klöck & Nunn, 2019; Owen, 2020). The involvement of political or government actors can also be critical so that adaptation can be carried out sustainably and have a broad impact (Butler et al., 2016; Mcleod et al., 2019). However, a common challenge is that the government's understanding of vulnerability or needs in various specific areas is generally limited. In this situation, a bottom-up approach is important: empowered communities can partner with the government to provide indigenous data related to their area so that government resources can be directed and utilized appropriately and on target. In such partnerships, the community is the main actor, and the government plays a supporting role in increasing scale and sustainability (Saroar et al., 2019). Developing this multi-party partnership may require mediation by a third party (Woroniecki, 2019).

An integrative approach means that community well-being, collaborative networks, and environmental sustainability are targeted simultaneously in implementing EBA (Filho et al., 2020; Owen, 2020). An example of integrative implementation is the mangrove reforestation program in Bangladesh (Ahammad et al., 2013). Mangrove planting was integrated with mangrove forest management as a community food source, which produced co-benefits in food security, clean water security, and physical protection against the impacts of climate change. This type of integration shows how EBA can generate multiple layers of resilience when ecological restoration is linked directly to community needs. However, the success of such programs depends on the ability to adapt to changing conditions over time, leading to the fourth strategy: adaptive planning and management.

The fourth recommended strategy is adaptive planning and management (Chow, 2018; Fernandino et al., 2018). Adaptive approach is important because the climate change issue is highly complex and uncertain; there were already some missed scientific predictions on the climate change impacts due to various overlooked factors. Therefore, to be successful in the long term, EBA implementation needs to be monitored and adjusted periodically on an ongoing basis, with the level of climate resilience as an indicator of its success. As a

measure of climate resilience, there is recommendation for community resilience indicators proposed by Donatti et al. (2020), namely (1) Percentage of infrastructure damage due to extreme events, (2) Prevalence of food vulnerability after extreme events, (3) Average income from agricultural, livestock, fisheries, and/or ecotourism activities after extreme events, (4) Percentage of residents who can access clean water when extreme events occur, (5) Percentage of deaths/losses when extreme events occur, and (6) Level of losses and deaths due to infectious diseases, heat waves and heatstroke. These indicators reflect community resistance and resilience. When extreme events such as storms or floods occur, climate-resilient communities should be able to reduce the severity of the event's impact by providing clean water and sufficient food, and while also protecting most residents from losses, illness, and death. In the post-extreme event recovery process, the community's capacity to return to economic activities indicates their high resilience.

Adaptive planning is more likely to be successful when EBA is based on local communities, accommodating multiple perspectives, using multiple data sources, and actively involving communities (Butler et al., 2016; Chausson et al., 2020; Milman & Jagannathan, 2017). These monitoring and adjustment activities can potentially train communities to develop adaptive capacity to climate change-related uncertainties. If structured in a continuous action-reflection cycle, this adaptive process can be a transformative education for communities (Giangrande et al., 2019) and develop their transformative capacities to become climate-resilient societies. While these strategies provide a framework for effective action, their impact ultimately depends on the scale and duration of implementation.

Beyond these four strategies, two studies recommend calculating the scale of implementation to make EBA efforts adequate in moderating the threat of climate crisis. This could mean expanding the scope of adaptation actions, extending the duration of the program by at least five years (Butler et al., 2016), or replicating and mainstreaming the program through policy.

5. Conclusions

The small island communities worldwide, including those in Indonesia, share similar characteristics in terms of climate vulnerability and capacity. They face disproportionately high risks from the climate crisis, making urgent and effective adaptation actions essential to safeguard them from extreme climate impacts. Compared to other forms of climate adaptation, EBA has higher potential to strengthen the climate resilience of small island communities if implemented

appropriately. However, key challenges persist, particularly in the form of limited human resource capacity, limited information and the absence of measurable, long-term evaluation.

To maximize EBA's effectiveness, it is recommended that implementation of EBA should be grounded in the specific contexts of each community and designed for self-management, while prioritizing empowerment and avoiding the marginalization of vulnerable groups. Complementary strategies such as integrative approaches, multi-stakeholder collaboration, and adaptive planning can be effective to overcome resource constraints and better address the uncertainties of climate change.

This study also highlights a critical gap that scientific information and data on small islands, both in Indonesia and other developing nations, remain scarce despite their urgency for informed adaptation planning. Therefore, it is important to conduct more research on this topic. It should also be noted that due to review's search terms, the literature analyzed are all written in English. Considering many developing countries and small island states are non-English speakers, there may be more literatures on this research topic that were missed in the search. Further studies on non-English language research are recommended to confirm or address any biases that may have arisen from the literature selection.

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