

Effectiveness of Ecosystem-based approaches for adaptation: review of the evidence base in Kenya.





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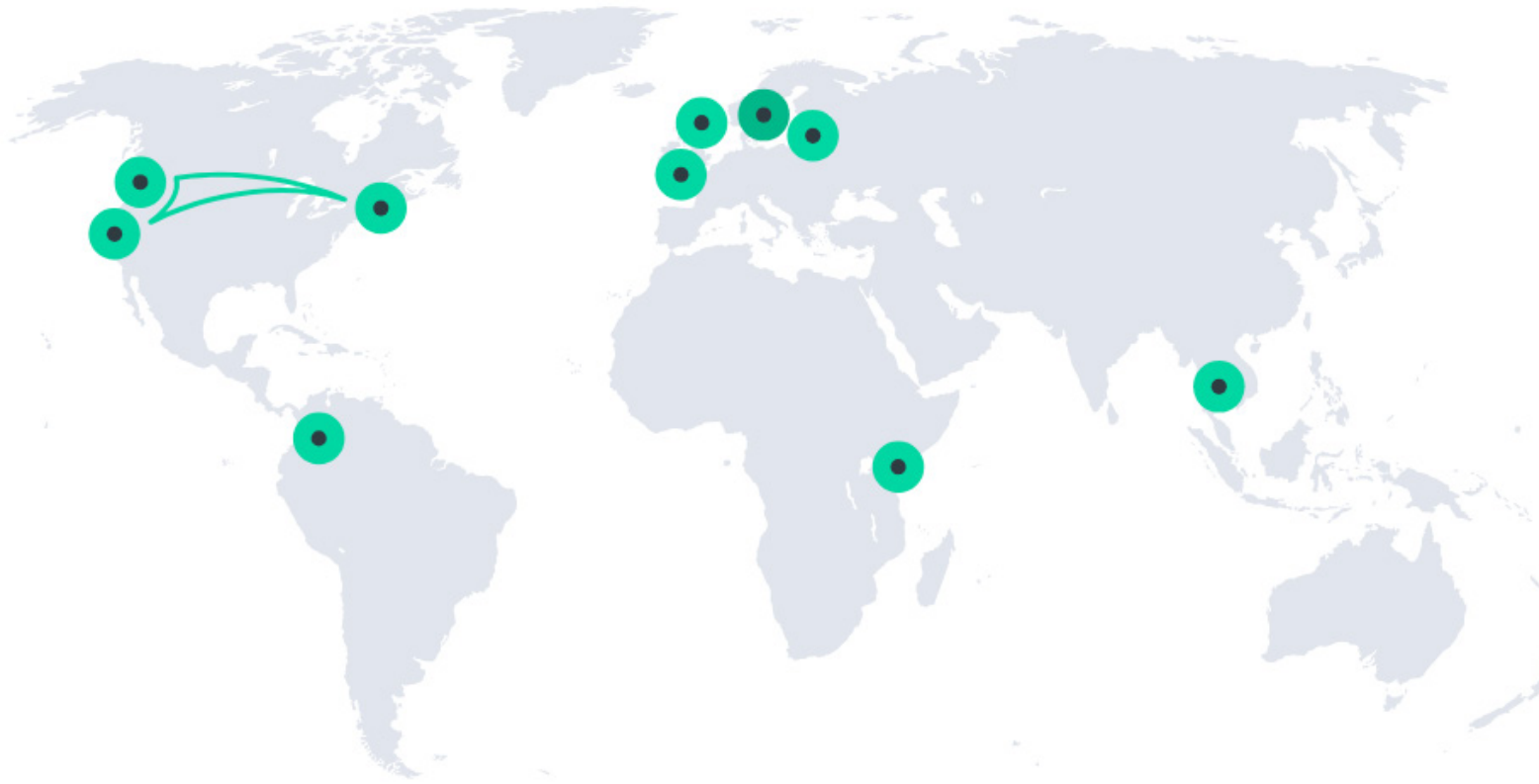
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About the Project

Applying the water-energy-food nexus to promote ecosystem-based adaptation in the Ewaso Ng'iro North Catchment, Kenya

This project seeks to support the Government of Kenya, five county governments (Laikipia, Samburu, Isiolo, Meru and Nyeri), local communities, and agro-based private enterprises to promote ecosystem-based adaptation practices and integrated planning for water, energy, agriculture and land use for resilient livelihoods in the Ewaso Ng'iro North Catchment Area.

The project seeks to apply ecosystem-based adaptation (EbA) and the nexus approaches to facilitate the co-production of resilient water-energy-food (WEF) knowledge with stakeholders (policymakers, local community groups, private sector, and non-governmental organizations) to inform decision and policymaking.

The project will contribute towards several development objectives which are in line with the Kenya Vision 2030 priorities, the Ewaso Ng'iro North Development Area (ENNDA) Integrated Regional Development Plan (2010-2040), the ENNDA catchment management strategy and the reformulation and implementation of CIDPs. These include increasing food security, especially pastoral livestock production; resilience through livelihoods diversification; employment creation through EbA solutions; agricultural growth; the conservation and safeguarding of critical habitats, including wildlife-protected areas and community wildlife conservancies. At the governance level, the nexus approach is expected to promote cooperation among actors and policy coherence across “policy silos”, i.e. sectors, levels and scales and the key added value of the nexus approach is in integrating across the various plans and strategies, promoting synergies and generating co-benefits.

Expected results

- WEF nexus models and development scenarios for Ewaso Ng'iro North Catchment Area (ENNCA)
- Identification, validation, and promotion of innovative Ecosystem-based nexus solutions among key stakeholders in the ENNCA region
- Increased awareness of cross-sectoral interactions (water, energy, agriculture, and land) during the implementation, upscaling, out scaling, and transfer of ecosystem-based nexus solutions at the sub-national and national level





Abstract

Ecosystem-based approaches for adaptation (EbA) integrate biodiversity and ecosystem services into a comprehensive strategy to assist communities in adapting to climate change. Until now, our understanding of these approaches has primarily relied on individual anecdotal case studies. There has been limited systematic effort to gather and analyze this evidence. This study therefore provides a comprehensive review of peer-reviewed and grey literature concerning Ecosystem-based Adaptation (EbA) with the aim of systematically summarizing the current state of evidence regarding the effectiveness of EbA strategies in Kenya. This systematic mapping of the peer-reviewed and grey literature on EbA-relevant interventions has produced a wealth of evidence regarding the use of ecosystem services and biodiversity for human adaptation to climate change, variability, extremes, and natural hazards with multiple social, economic, and environmental co-benefits. The review also revealed the implementation barriers and opportunities that would serve as lessons in scaling up these interventions at the local level.

Keywords: climate change; climate variability; adaptation; ecosystem-based approaches; ecosystem services; ecosystem management; vulnerability.



1.

Introduction

There is scientific consensus that the global climate is warming at unprecedented rates, with manifestations such as increasing surface air temperatures, sea level rise and weather extremes having widespread adverse impacts on both human and natural systems [1]. Weather extremes will become more severe and frequent under global warming levels of 1.50C and 20C [2]. This is an urgent call to action through mitigation and adaptation [3].

As a response, many nations worldwide have created national adaptation plans and programs to integrate effective adaptation into their strategic planning processes through climate adaptation action plans [4], [5] and recognize the important value of natural resources and ecosystems [6], [7]

There are numerous approaches of adapting human and natural systems to climate change. The Convention on Biological Diversity (CBD) Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change defines ecosystem-based approaches for adaptation (EbA) as “the use of biodiversity and ecosystem services to help people adapt to the adverse effects of climate change as part of an overall adaptation strategy” [8]

As part of an overall adaptation strategy that considers the numerous social, economic, and cultural co-benefits for local communities, sustainable management, conservation, and restoration of ecosystems are included in this definition, which was further defined by CBD decision X/33 on Climate Change and Biodiversity [9]. Some examples of EbA practices are illustrated in Munroe et al., [6] and Muthee et al., [10].

EbA can not only produce adaptation outcomes, but also co-benefits in the areas of economy, society, and the environment [11], [12]. It can also help mitigate the effects of climate change [13], [14]. In addition, it is seen as a low-regret and cost-effective choice for climate adaptation [13], [6], [7], [15].

Even though there are many anecdotal case studies of EbA's success worldwide [3], [7], [15], [16], and it being enthusiastically promoted in certain quarters [11], [17], [18], there's a noticeable absence of scientific evidence demonstrating the effectiveness of such approaches, with existing evidence scattered across various fields like natural resource management, disaster risk reduction, and agroecology [6]. There has been limited systematic effort to gather and analyze this evidence [3], [7], [15]. Consequently, the current level of understanding regarding the benefits or limitations of EbA remains uncertain, and identifying key knowledge gaps is challenging, hindering policymakers' ability to compare EbA with other adaptation strategies [6], [7].

Consequently, the goal of this study is to produce a systematic map of peer-reviewed literature and a sampling of the grey literature regarding the current state of the evidence base supporting EbA's success in Kenya.



2.

Materials and Methods

A systematic map methodology following [19], was used to provide state of the evidence-base on how effective EbA interventions are in building community adaptive capacity and resilience to climate change, climate variability and climatic shocks. The primary focus of this methodical approach was scientific literature that clearly draws connections between human adaptation and climate change, climate variability, weather extremes, or other potentially climate-related natural hazards [6], [3].

Only a limited number of adaptation initiatives in Kenya have been documented, and ongoing initiatives won't be able to report on their effectiveness until later. As a result, this research solely presents data on adaptation efforts that have already been carried out. A complete set of search terms used are listed in Munroe et al., (2012). Actions like ecosystem restoration, dryland management, and natural resource management are examples of EbA-relevant interventions [10].

These actions were carried out either to lessen human vulnerability to climate variability and extremes or to assist humans in coping with them. Most of the stated actions have often been carried out outside of a framework for long-term climate change adaptation [6]. Consequently, they have addressed how vulnerable humans are to climatic variability and change, but they have not been pursued as a planned long-term adaptation to climate change. It is not appropriate to disregard the EbA-relevant knowledge base as being unimportant.

Any sensitivity to extremes, such as storm surges, droughts, sea level rise, and flooding that happen more frequently due to climate change, as well as the effects these have, like mudslides, siltation, sedimentation, and soil degradation, will be informed by the EbA-relevant evidence base.

2.1 Review

This section details the review process taken by the study.

2.1.1 Peer reviewed and grey literature.

The study approach follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram developed by [19] (Figure 1) and involved the following six steps:

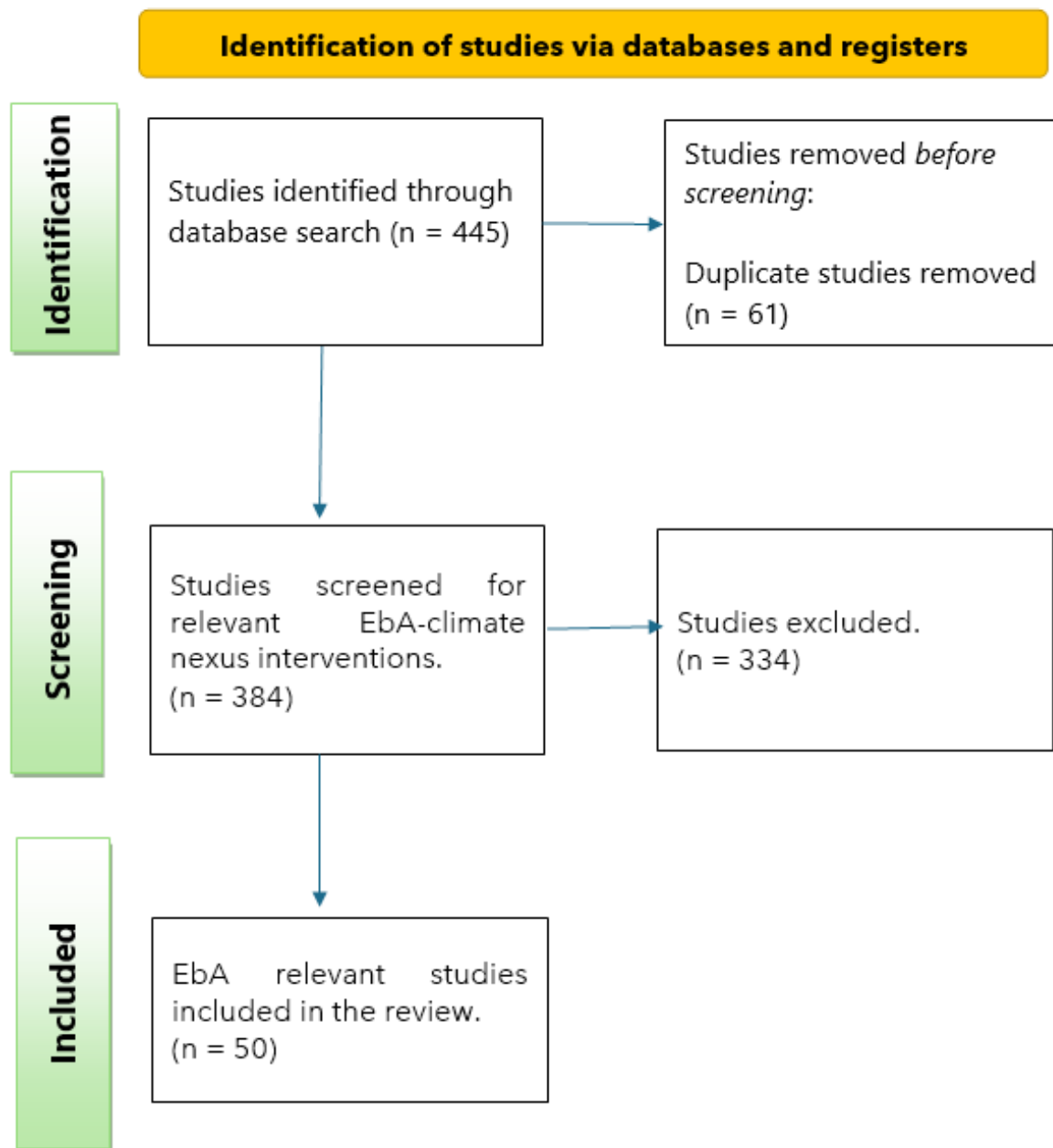


Figure 1: PRISMA flow chart for the systematic review.

Step 1:

Formulating the research questions and defining variables.

The first step involved defining the variables and formulating research questions that would form the basis of the review. The variables for model selection include (i) basic information including the location, ecology, objective for adaptation, (ii) the climate hazard and impact addressed, (iii) description of the evidence, including its type, quality, and the components that make it effective, (iv) measures of success used (results, costs, and benefits), (v) sectors covered by the intervention (iv) barriers and opportunities to implementation. The research questions that guided the review process include: What evidence exists regarding the application of EbA to adapt to the impacts of climate change? What are the critical knowledge gaps in the evidence? How can this study contribute to addressing the identified gaps relevant to EbA-climate nexus in Kenya? These questions guided the search and selection of relevant articles for review.

Step 2:

The search strategy

We used scientific and educational databases including Science Direct, Web of Science, and Scopus, to search for peer-reviewed journal articles with references to the EbA-climate nexus. In addition, Google Scholar was searched for unindexed recent papers. A search criteria was defined to enhance the effectiveness of the search using the following keywords: “ecosystem-based adaptation” OR “ecosystem services” OR “ecosystems” OR “ecosystem approach” OR “biodiversity conservation” OR “biodiversity protection” OR “sustainable forest management” OR “reforestation” OR “afforestation” OR “tree shelter beds” OR “agroforestry” OR “Silvo pastoralism” OR “livelihood diversification” OR “integrated watershed management” OR “managed realignment” OR “integrated coastal zone management”, OR “mangrove restoration” OR “wetland restoration” OR “flood-plain management” OR “rangeland management” OR “conservation agriculture” OR “soil conservation” OR “soil protection” OR “sustainable fishing” OR “sustainable live-stock management” OR “river basin restoration” OR “transboundary water restoration” OR “water conservation” OR “ecosystem restoration” OR “intercropping of adapted species” OR “integrated land-use planning” OR “disaster preparedness” OR “early warning systems” OR “water harvesting” OR “disaster risk reduction” OR “managed protected areas” OR “agroecology” OR “farmer managed natural regeneration” OR “landscape restoration” OR “agroecosystems” AND “climate nexus” OR “climate change adaptation” OR “adaptation.

Step 3:

Screening for inclusion

First, the titles, keywords, abstracts, and study objectives of articles were screened for any mention of ecosystem-based adaptation to identify potentially relevant articles for inclusion in the review. Second, books and book chapters were excluded because they replicated some published journal articles. Third, the methods of selected articles were assessed for their completeness in addressing the EbA-climate nexus, the climate change hazards and impacts addressed, the EbA sectors considered, the co-benefits and effectiveness of the EbA interventions, and the barriers and opportunities for their implementation. The primary researcher reviewed the articles and consulted the rest of the research team to reach a consensus if there was any doubt in deciding on inclusion or exclusion.

Details of the screening process are shown in the flowchart in Figure 1. Initially, 445 studies nationally were obtained from the search of existing databases. In EndNote, the duplicates in these studies were removed, keeping 384 studies. A review and selection of the studies based on the inclusion and exclusion criteria resulted in 85 EbA relevant studies. The findings are presented in the subsequent sections.

Step 4:

Assessing the quality of primary studies

Selected studies were evaluated for their scientific quality, considering the rigor of their research design and methods and their relevance to the research questions. This helped narrow down the choices of which studies to include in the final sample and determine if the quality difference had any effect on the results.

Step 5:

Data extraction and coding

A Microsoft Excel database was created to record the details for each article in the re-view. The variables included encompassed the sectors covered by a EbA relevant intervention (water, energy, and land), (ii) the climatic hazards/impacts addressed (iii) the social, economic, and environmental co-benefits provided, (iv) the results, costs and benefits of the EbA interventions (v) the barriers and opportunities to implementation.

The exclusion criteria included (1) articles not written in English, (2) articles not relating to the primary research question, articles that just address the effects of climate change, those that mitigate it, articles that don't mention the use of ecosystems or biodiversity or provide proof of the effectiveness of intervention and review articles were excluded (Doswald et al., 2014). Following the application of the exclusion criteria for the abstract and full article filtering, 50 studies in total were retained for review.

Step 6:

Analyzing and synthesizing the data.

Finally, the evidence from the selected studies was collated, summarized, aggregated, and systematically presented to highlight novel contributions to the literature.

2.2 Analysis

An Excel spreadsheet was created to collate, summarize, aggregate, and systematically present the evidence from the fifty articles, which were sub-divided into 4 sections. They were:

2.2.1 Basic information

This includes information on the specific climatic hazards and their impacts, location (county), ecosystem type, and the specific beneficiaries of adaptation efforts. While most EbA interventions have primarily targeted individuals or communities, the focus of adaptation can be further segmented into various sectors such as land (agriculture), water resources, and energy.

2.2.2 Description of evidence

This involved examining the nature and reliability of evidence and the different aspects of effectiveness considered, including environmental, social, economic, and institutional factors. The measure of success (whether it was quantifiable or not) and the potential for bias (ranging from experimental control to anecdotal evidence) were considered. According to this framework, articles deemed more reliable are those with measurable indicators of success and are based on experimental research or observational studies [3].

2.2.3 Adaptation outcomes

This measures the direct impact of EbA initiatives in reducing vulnerability to climate change, climatic variability, weather extremes, or other natural hazards associated with climate conditions [6]; the outcomes were categorized as either positive (indicating a decrease in vulnerability or related factors), negative (showing no decrease in vulnerability), or ambiguous (where results vary between positive and negative depending on circumstances); considerations of costs and benefits across social, environmental, and economic domains; the enablers including institutional backing; and pro-EbA policies [3].

2.2.4 Implementation challenges and opportunities

This section provides the challenges/barriers and opportunities or enablers to successful implementation of the identified EbA practices to provide invaluable lessons on the available opportunities to leverage on to maximize the co-benefits of these practices.



3.

Results

3.1. Terminology, type and origin of evidence

3.1.1. Terminology

Only 20% (10 articles) used the term ecosystem-based adaptation. The range of terms used by the rest of the articles to describe the ‘adaptation’ interventions to climate variability, weather extremes, climate change and other climate-related natural hazards is broad and falls in either of these categories: drought early warning systems, livelihood diversification (crop and livestock diversification, improved livestock breeds, drought-resistant crop varieties, honey harvesting), payment for ecosystem services, agroforestry, afforestation, reforestation, grass contour hedges, conservation of indigenous tree species, plantation establishment, soil conservation and fertility improvement, biodiversity conservation, water conservation, policies for water resource management, climate smart irrigation technologies, farm forestry, wetland restoration and protection, community based conservation, eco-tourism, community based rangeland management, holistic grazing management, sustainable land use management, enclosure management, water harvesting, climate resilient enterprises and value chains, community based wildlife conservation, sub-catchment water management, conservation agriculture, climate smart agriculture, grass reseeding, mulching, conservation of woodlands, and farmer managed natural regeneration (FMNR).

3.1.2 Type of evidence

Most articles used qualitative methods (50%) to gather evidence, followed by quantitative methods (28%). Only 22% of the articles used a combination of qualitative and quantitative measures. In these articles, stakeholder consultations and social field surveys were just as common as environmental measures. Most evidence (70%) came from field data studies, 20% from anecdotal studies and 10% from experimental studies.

Table 1: Number of articles per category with a clear measure of the EbA relevant intervention success.

ARTICLE CATEGORY	NUMBER
Experimental studies	5 (10%)
Field data studies	35 (70%)
Anecdotal studies	10 (20%)
Total	50 (100%)

3.1.3 Relevant EbA articles per sector

As shown in figure 2, 100% of the EbA relevant interventions cover the land (agriculture) sector, 90% the water sector, 80% covering both land (agriculture) and water, and 50% spanning the land, water, and energy sectors.

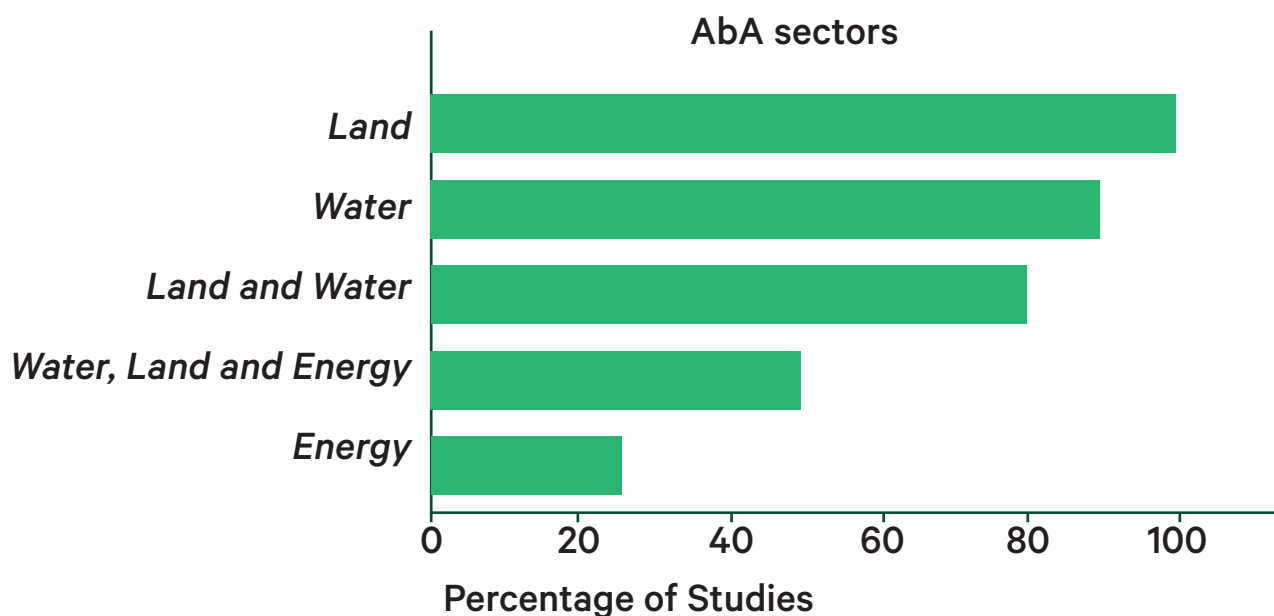


Figure 2: Percentage of EbA relevant articles per sector.

3.1.4 Study counties

Figure 4 shows the distribution of articles by counties. In terms of spread across the counties, the EbA-relevant intervention sites reported in articles in the peer-reviewed literature were evenly distributed, while the share of grey and peer-reviewed literature in this study was 38% and 62% respectively.

3.2 Aim of relevant EbA interventions

3.2.1 Hazards and impacts

The most common climate change hazards addressed through the relevant EbA interventions were related to prolonged droughts, floods, invasive species, and pests and diseases. Additionally, water scarcity, unpredictable rainfall patterns, shifts in season, bi-odiversity loss, soil erosion, land degradation, soil fertility loss and agricultural productivity loss were the main climate change impacts addressed by the EbA interventions. Figure 3 shows the distribution of hazards and impacts addressed. From the analysis of the articles, rainfall variability, and agricultural productivity loss were the most extensively addressed climate change impacts through the EbA interventions.

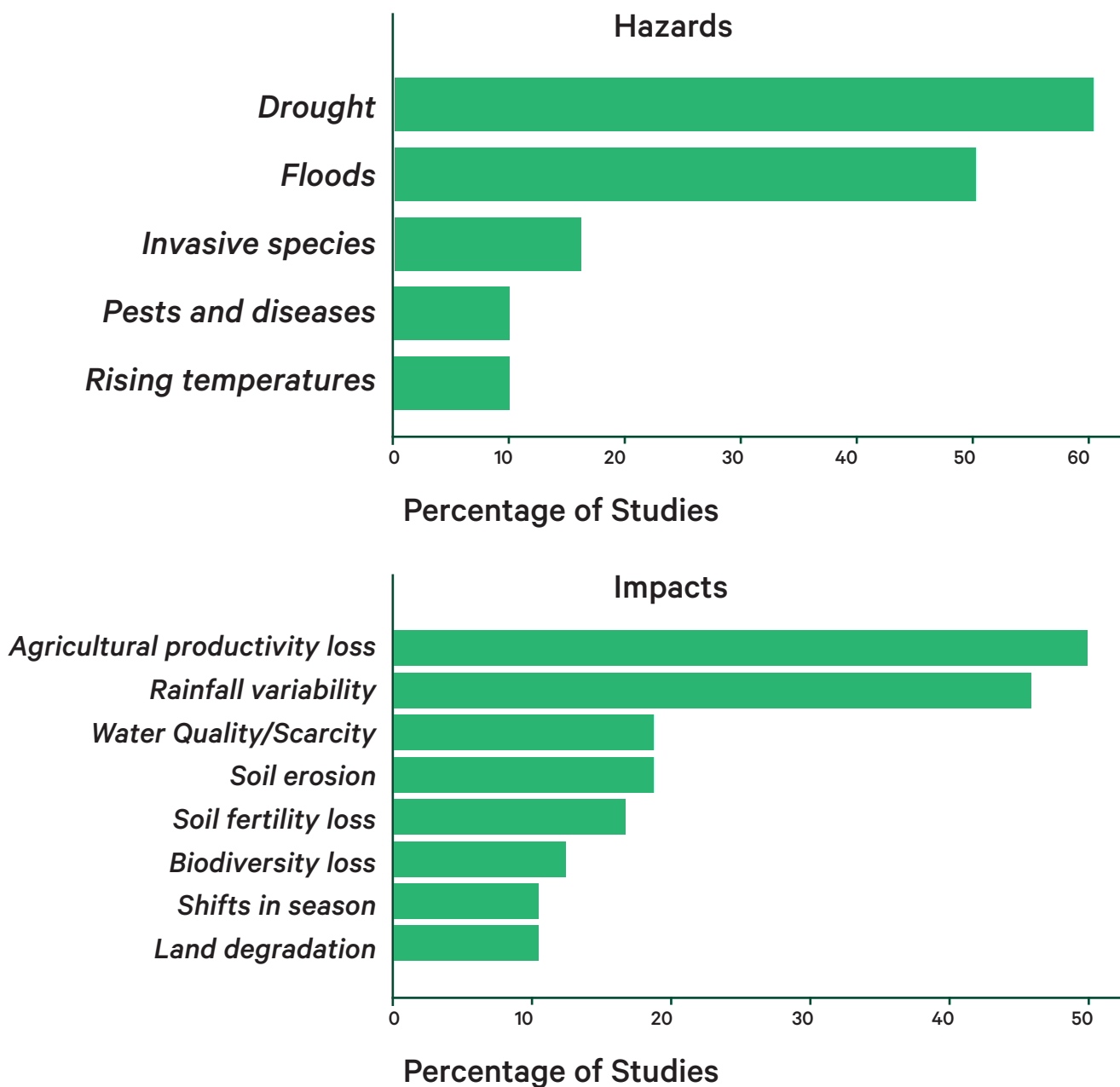


Figure 3: Percentage distribution of climate change hazards and impacts addressed by relevant EbA interventions analysed in the articles (n = 50).

3.2.2 Adaptation targets and co-benefits

From the article results in figure 5, the relevant EbA interventions were in agro-forestry, forest protection, adaptation in agriculture using climate smart interventions, rangeland management, livelihood diversification, soil and water conservation, biodiversity conservation and eco-tourism. The adaptation targets of EbA interventions included: soil erosion regulation and improved soil quality, flood and drought risk regulation, air quality regulation, wetland protection, rangeland management, biodiversity conservation, carbon sequestration, agricultural productivity, and water conservation (figure 6). Table 2 shows examples of climate change hazards and impacts addressed by EbA interventions reviewed from literature.

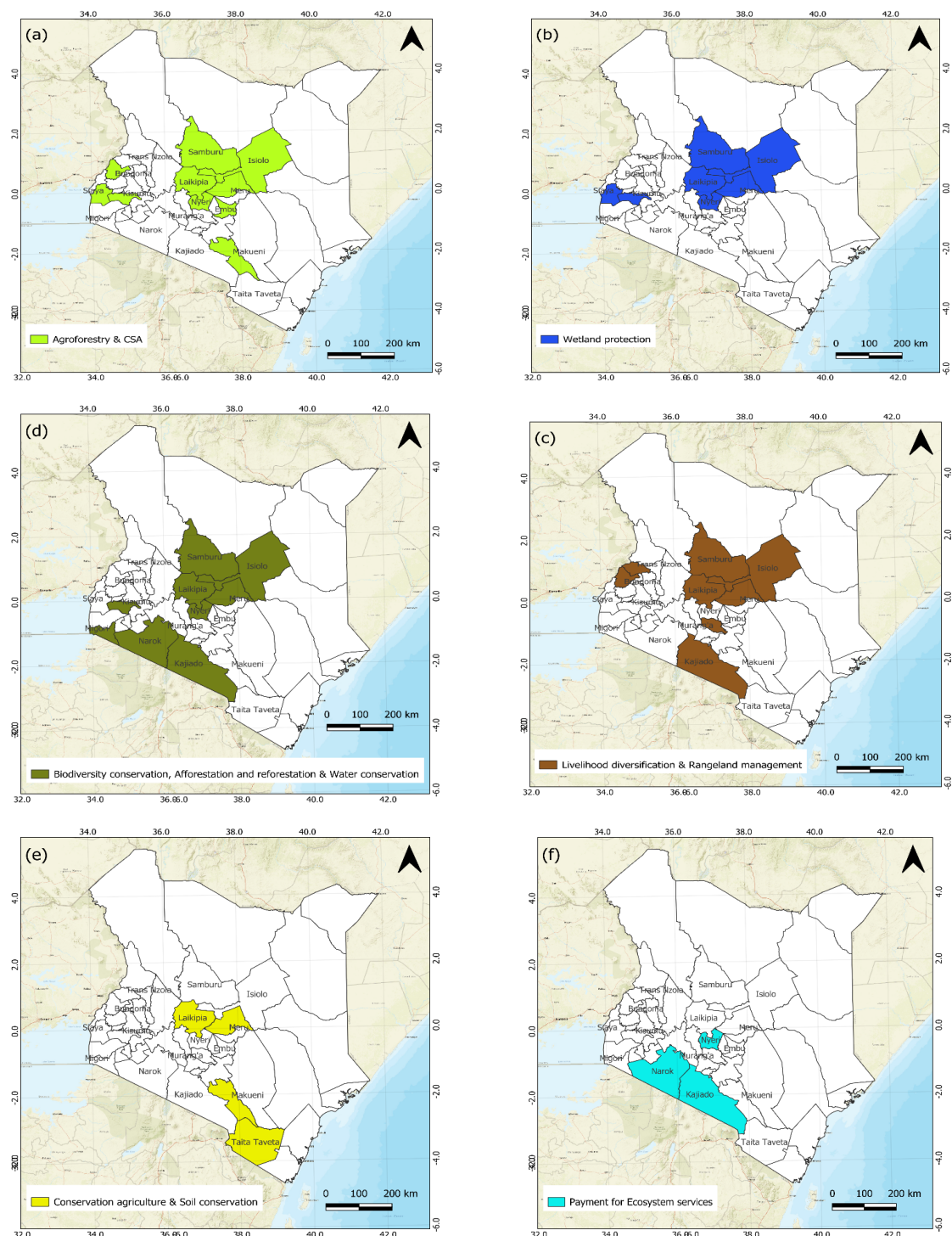


Figure 4: (a) Agroforestry and Climate-smart agriculture; (b) Wetland protection; (c) Livelihood diversification and Rangeland management; (d) Biodiversity conservation, Afforestation and reforestation, & Water conservation; (e) Conservation agriculture and Soil conservation, (f) Payment for ecosystem services

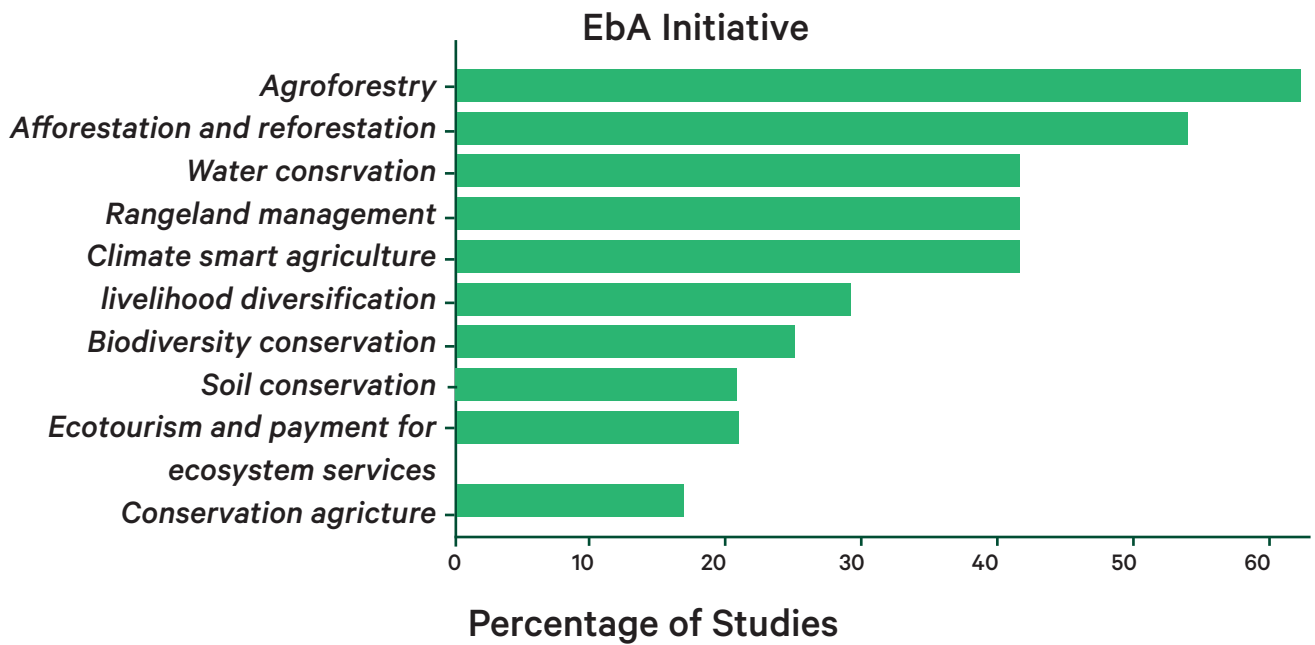


Figure 5: : Examples of EbA interventions (n = 50).

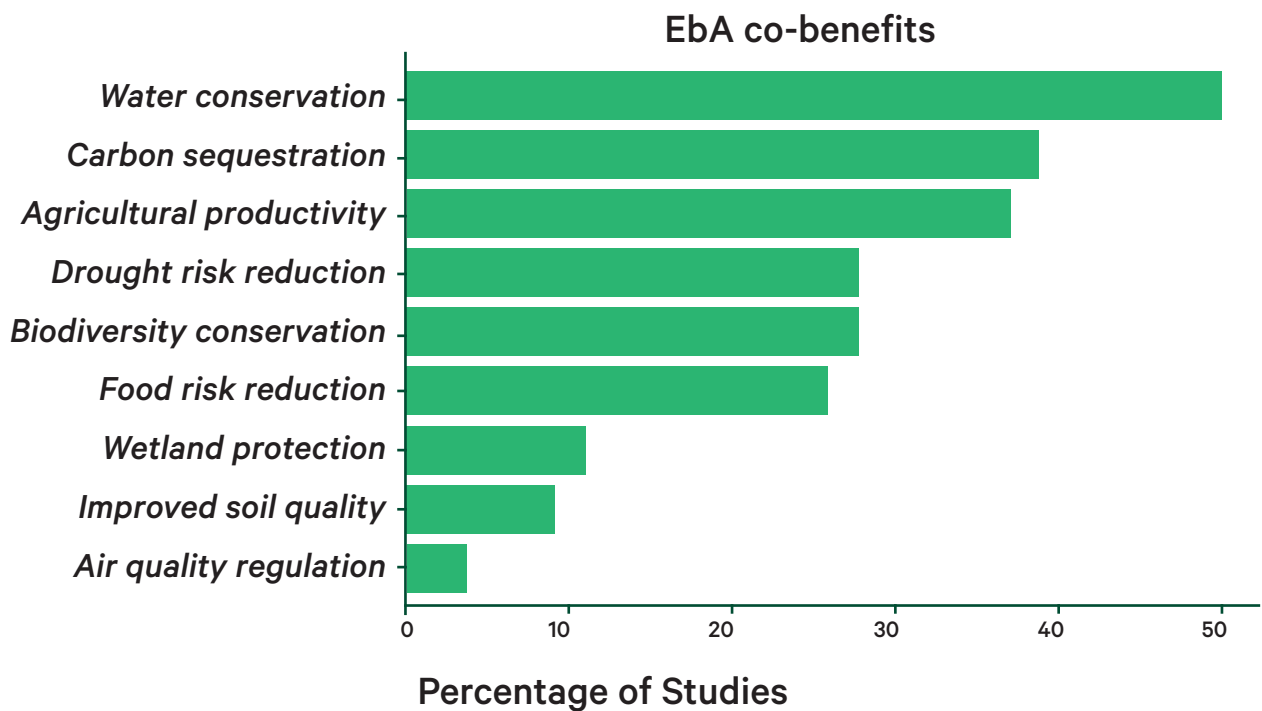


Figure 6: Adaptation targets of relevant EbA interventions addressed in the articles (n = 50).

3.3 Success of EbA interventions

Physical parameters such as changes in water flow and volume, water storage, reduced sediment concentration, community perceptions based on experience such as crop and livestock productivity or failure and improved livelihoods were among the measures used to demonstrate effectiveness of EbA-relevant interventions. Other measures included the results of cost-benefit analyses (the dollar value of the intervention), changes in household incomes, or multi-criteria scoring such as the cost of damage prevented, changes in crop yields, and changes in the number of drought and/or flood events that ended in disasters.

Table 2: Examples of EbA relevant interventions and the impacts/hazards they address.

EbA intervention	Hazard/impact addressed
Afforestation and reforestation	Flooding/water scarcity/soil erosion/biodiversity loss/land degradation/productivity loss
Agroforestry	Flooding/water scarcity/soil erosion/productivity loss/rising temperature/land degradation /biodiversity losses/food insecurity
Climate smart agriculture	Drought/rising temperature/soil erosion/productivity loss
Conservation agriculture	Drought/productivity loss/erosion
Biodiversity conservation	Drought/floods/productivity loss
Livelihood diversification	Drought/floods/productivity loss/increasing temperatures/shifts in season
Rangeland management	Drought/floods/degradation/productivity loss/invasive species
Water conservation	Water scarcity/water quality
Soil conservation	Erosion/productivity loss/floods
Wetland protection	Flood/productivity loss/water quality/water scarcity
Payment for ecosystem services	Flood/drought/productivity loss

3.4 Effectiveness of EbA interventions

Most articles (95%) reported positive results of the identified EbA relevant interventions, with only 5% not reporting results. Positive outcomes covered a wide range of measures such as soil conservation using grass filter strips that was estimated to increase water inflow to the reservoir through a reduction in sediment concentration [20], increase in crop yields under conservation agriculture [21] and agroforestry [22].

3.5 Costs and benefits

3.5.1 Social, environmental, and economic benefits

Most articles discussed environmental and social costs and benefits more than economic benefits. The discussions were more centered on the benefits than the associated costs. Table 3 lists the common costs of EbA-relevant interventions that were identified in the literature. According to most of cost-benefit evaluations from the literature, the EbA-relevant intervention had a net positive benefit when all social, environmental, and economic benefits were considered.

Improved water quality, storage and security, and biodiversity conservation were the top two environmental benefits provided by the EbA interventions (Figure 7). Compared to environmental benefits, the reviewed studies covered less social benefits (Figure 8), these benefits included, better access to social amenities (schools and hospitals) and infrastructure, human safety from reduced flood/drought risks, enhanced community cohesion, improved household adaptive capacity and resilience, women and youth empowerment through seedbanks, tree nurseries and membership to cooperatives, saving on time initially spent in search of water and wood fuel, improved human health, improved and secure livelihoods. Improved household incomes, profits, and savings from sale of surplus production, income from employment, infrastructure development, avoided damage costs from hazards were some of the economic benefits provided by EbA interventions (Figure 9).

Table 3: Environmental, social, and economic costs of EbA interventions identified from literature.

	Environmental	Social	Economic
Cost	invasive species, increasing demand on natural resources, loss of habitats of endemic species (n= 3).	High initial and maintenance costs of these EbA interventions (n= 7), intensive knowledge, and technological capacity required (n = 5).	Prohibitive costs associated with rolling out and maintenance these interventions (n = 12).

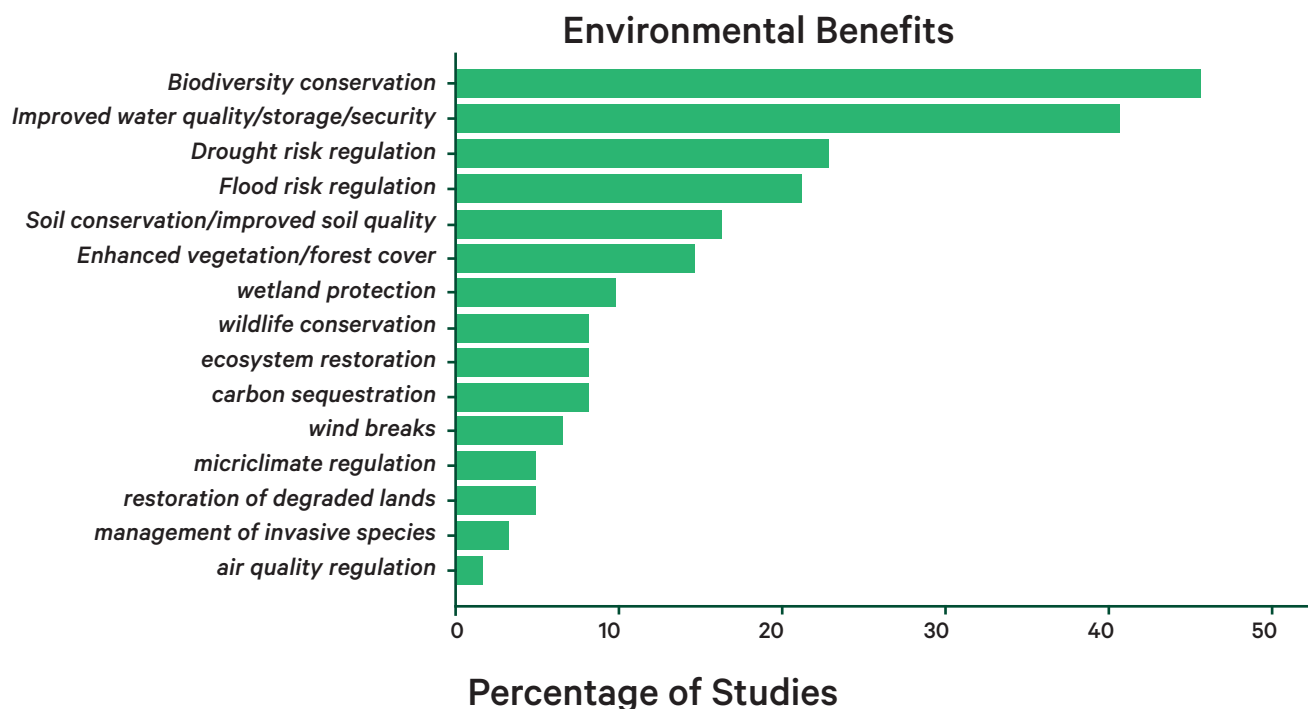


Figure 7: Environmental benefits provided by the EbA interventions identified in literature (n = 50).

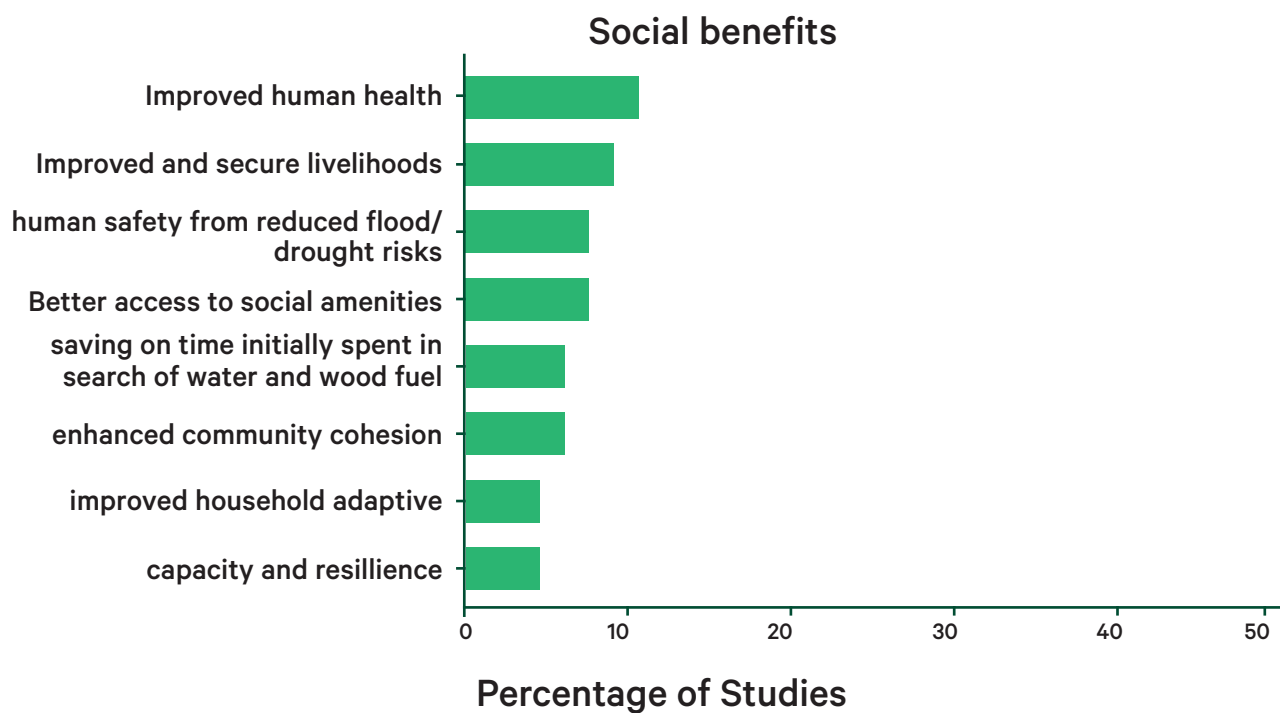


Figure 8: Social benefits of EbA interventions literature (n = 50).

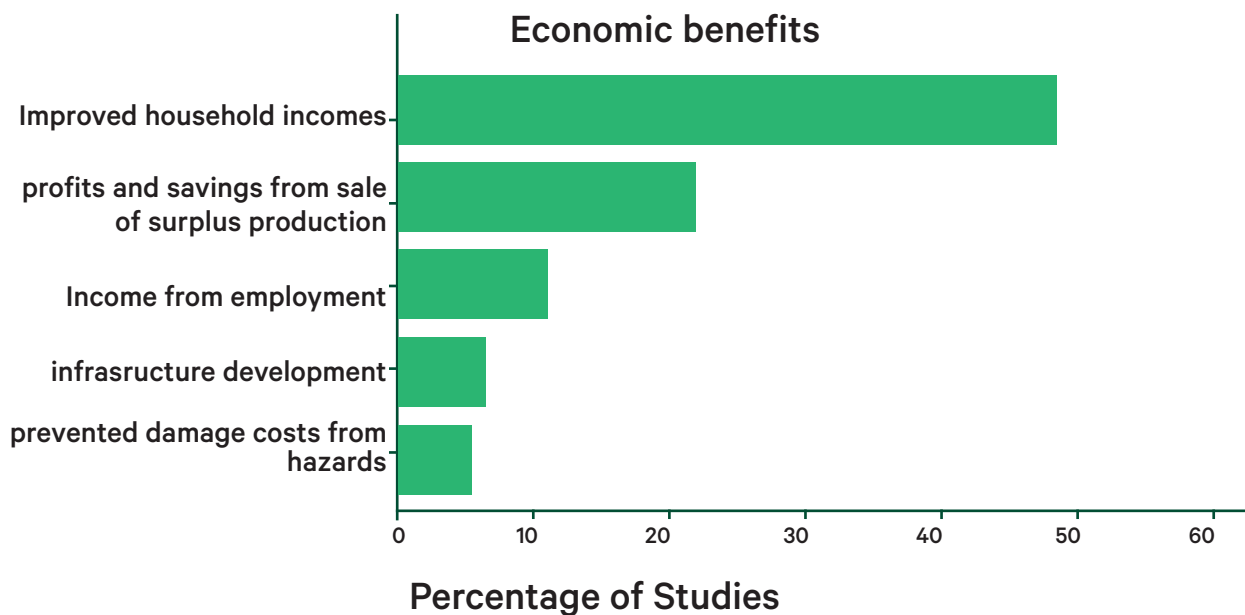


Figure 9: Economic benefits provided by the EbA interventions identified in literature (n = 50).

3.6 Implementation challenges and barriers

Figure 10 shows the implementation challenges/barriers of the identified EbA-relevant interventions. Financial constraints, lack of enabling policies and governance, lack of knowledge, expertise and capacity, prohibitive initial costs, inadequate markets and in-centives, land tenure systems, opportunity costs, inadequate resource mobilization strate-gies, inadequate institutional governance, inadequate partnerships, and collaboration and longer returns on investment periods were identified as the common barriers to implemen-tation of EbA-relevant policies.

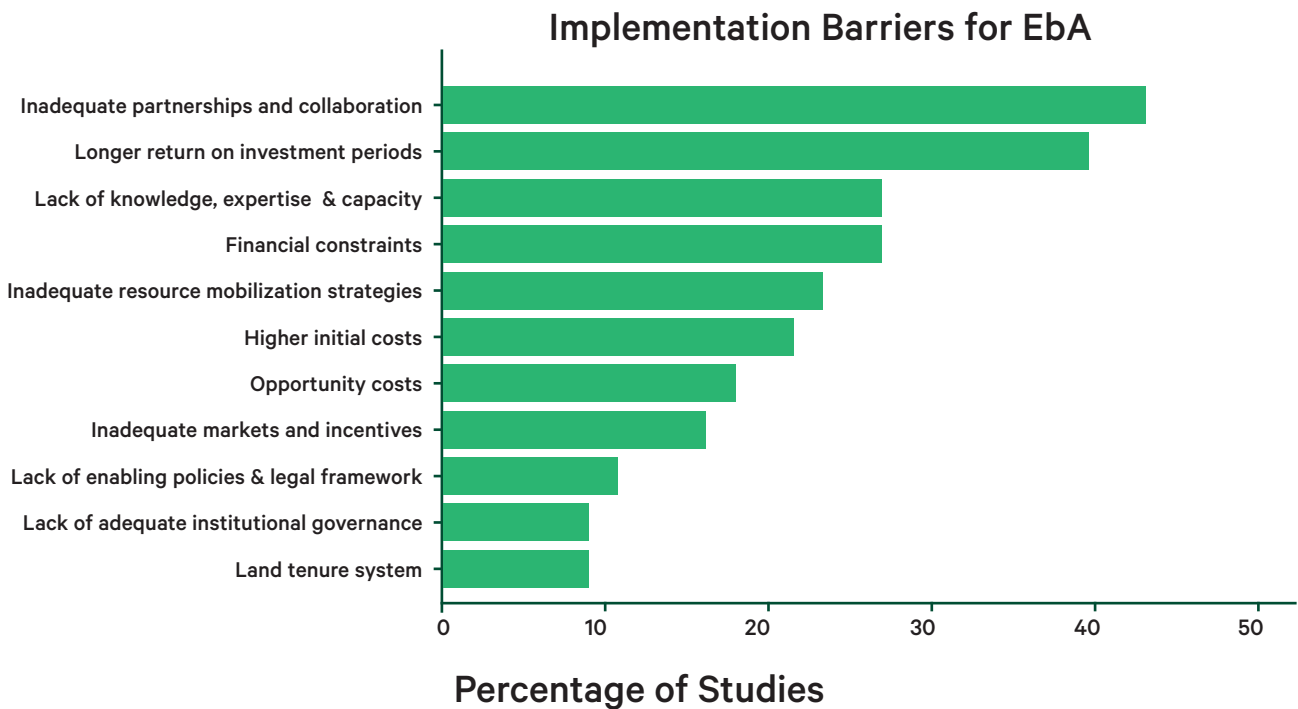


Figure 10: Implementation challenges/barriers of the identified EbA-relevant interventions reported in literature (n= 50).

3.7 Enablers and opportunities for scaling up EbA interventions

Figure 11 presents the common enablers/ opportunities for scaling up EbA-relevant interventions. These include stakeholder engagement, partnership, and collaboration, ca-pacity building trainings, enabling policies and institutional frameworks, enhanced link-ages to markets, access to extensional services, research and development, and technologi-cal transfer.

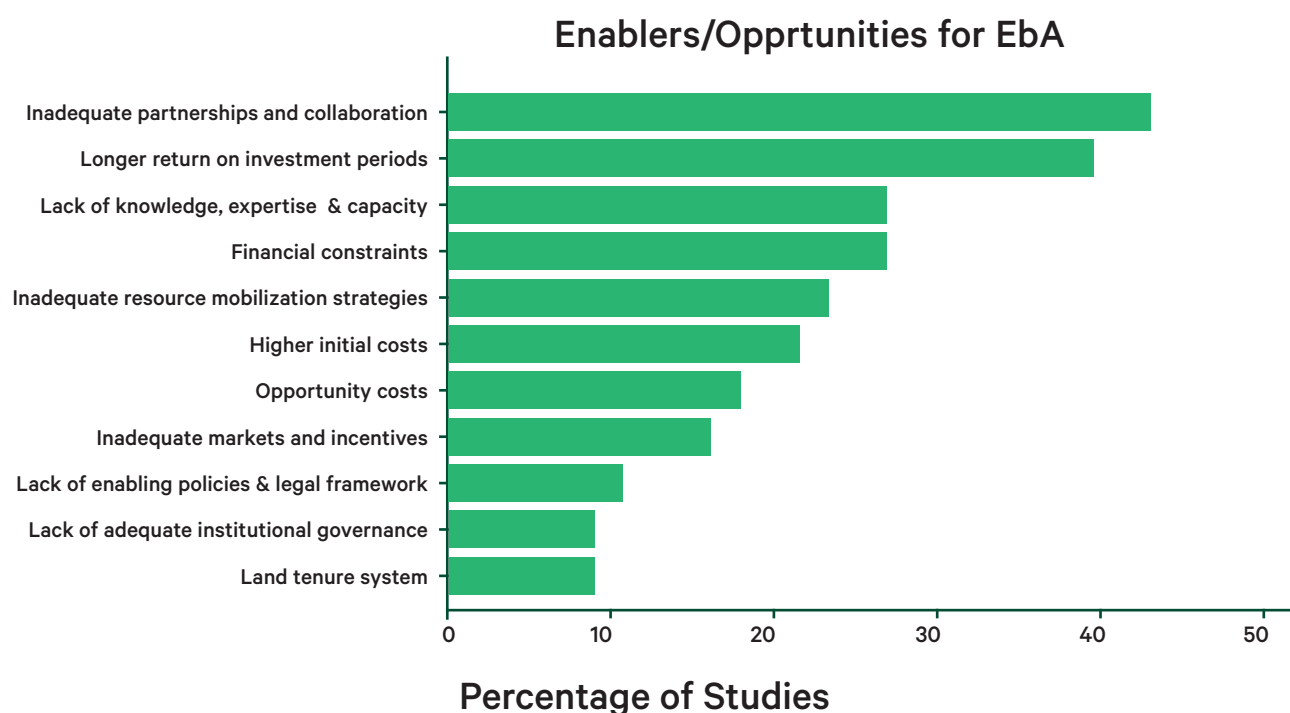


Figure 11: Enablers/opportunities for scaling up EbA-relevant interventions identified in literature (n = 50).



4. Discussion

A significant portion of the reviewed literature focusing on interventions related EbA underscores the numerous social, economic, environmental, and cultural advantages that ecosystems and their services offer to local communities.

For example, Agol et al., (2021) argued that healthy ecosystems provide many products and services such as domestic and industrial water supply, timber and poles for construction purposes, fuelwood, medicinal products, maintenance of biological biodiversity, carbon sequestration, biodiversity protection, flood, drought and soil erosion regulation, nutrient cycling and soil conservation, water storage and drainage, microclimate regulation, medicinal plants, fruits, vegetables, honey production, pasture for livestock and culturally used for recreation, education and eco-tourism.

Cultural services have a smaller impact on resilience and adaptive capacity [7], than other ecosystem services, with provisioning, regulating, and supporting services making up the majority of ecosystem services in the reviewed literature.

Despite the numerous co-benefits provided by the ecosystems and their services, these ecosystems are confronted with multiple natural and climate-induced hazards and associated negative impacts that threaten their sustainability in a changing environment and climate, these hazards include rising temperatures, soil erosion, prolonged droughts, pollution, drought, extreme and unpredictable rainfall patterns, invasive species with significant socio-economic and ecological impacts such as biodiversity losses, decreases in species richness, numbers and composition, production losses, land degradation, air pollution, loss and damage from floods and drought and disruption of the normal function of the ecosystems beyond the capacity and resources of the communities to adapt to these changes (Agol et al., 2021; Lalampaa et al., 2016; Nyberg et al., 2020; Quandt et al., 2017).

Variation of the different EbA interventions across counties

The use of agroforestry, afforestation, reforestation, wetland restoration/protection, and climate smart agriculture (stress tolerant crops and resilient livestock breeds) as an EbA intervention is fairly distributed in most of the counties including Isiolo, Nyeri, Meru, Laikipia, Samburu, Makueni, Siaya, Kisumu and Bungoma. Meru, Taita Taveta and Laikipia were the only counties with literature on the effectiveness of conservation agriculture as an EbA intervention. All the counties in the reviewed literature had water conservation and management, and livelihood diversification as an EbA intervention. Samburu, Laikipia, Isiolo, Meru, and Laikipia promoted eco-tourism as an effective EbA intervention. Nyeri, Narok and Kajiado explored the use of payment for ecosystem services as an EbA intervention [20], [27]. Livelihood diversification was practised in Laikipia, Isiolo, Meru, Nyeri, Isiolo, Samburu and Kisumu counties. Rangeland management/conservation was a common EbA intervention in the Arid and Semi-arid counties of Isiolo, Samburu, Laikipia, and Kajiado. Lastly, soil conservation was practised in the counties of Isiolo, Meru, Samburu, Makueni, Kisumu, Siaya, and Migori.

Research Gaps

Multiple social, economic, and environmental co-benefits can result from EbA-relevant initiatives, as demonstrated by the reviewed literature. Nonetheless, there was less information available in the reviewed literature about the costs of EbA-relevant interventions. The literature often underscores positive outcomes while paying less attention to the costs of interventions on a social, economic, and environmental level. In addition, the information on effectiveness and costs/benefits is crucial for scaling up and implementation of future EbA intervention [3]. Additionally, it is important that future projects report EbA costs and co-benefits and their distribution in time and space.

Most of the articles lack information on the timescales when these costs and benefits may occur after the implementation of an EbA-relevant intervention yet this evidence is important in the long-term planning and decision making to favour their uptake by the local communities [3].

The articles also provide synergies in the EbA interventions as highlighted by the multiple social, economic, and environmental co-benefits spanning different sectors (land, water, energy, tourism), however, they lack information on the associated trade-offs, yet this information is very crucial [7].

Most of the reviewed EbA literature lacks understanding of the governance structures and policy frameworks necessary to support their implementation. As a result, there's need for more research focusing on the institutional arrangements and policy coherence, and governance challenges related to EbA to help identify areas for improvement.

A significant portion of grey literature emphasizes promoting the adoption of EbA but lacks clear indicators of its effectiveness, as highlighted by Munroe et al., (2012). There is a pressing need for more precise measurement of the various additional benefits EbA offers such as disaster risk reduction, food security, and water provision, alongside a deeper understanding of the diverse impacts of various interventions on different demographic groups. This is particularly important because climate change often has a disproportionate effect on the most marginalized and vulnerable groups [15]. Future research should focus on gender-responsive and socially inclusive EbA approaches to ensure that adaptation efforts benefit all members of society equitably.

The reviewed literature also lacks long-term monitoring and evaluation of the implemented interventions. This information is essential for assessing the effectiveness and sustainability of EbA interventions over time. This knowledge gap hinders understanding of the long-term impacts of EbA on ecosystems and communities [7].

Opportunities for implementation

The articles also highlighted the importance of financial access and incentives, access to extensional services, stakeholder collaboration, enhanced linkages to markets, trainings and capacity building, research and development, technological investment and transfer, policies, institutions. and governance as enablers for successful implementation of these interventions in the local case studies.



5.

Conclusions

This systematic mapping of the peer-reviewed and grey literature on EbA-relevant interventions has produced a wealth of evidence regarding the use of ecosystem services and biodiversity for human adaptation to climate change, variability, extremes, and natural hazards. These EbA-relevant interventions are reported to have multiple social, economic, and environmental co-benefits. Additionally, there is promising evidence of the effectiveness of EbA-relevant interventions in reducing vulnerability to climate-induced hazards. However, most of the articles reviewed did not provide any timescales, and the distribution in time and space of the effectiveness of these interventions, it is therefore challenging to draw any conclusions about the effectiveness over the long-term in a changing climate. The review further provides the implementation challenges/barriers for these EbA-relevant interventions and enablers/opportunities for scaling up these interventions at a sub-national scale.

Current tools for monitoring and evaluating adaptation interventions often lack focus on ecosystem aspects and require enhancement. Additionally, there is a need for a deeper comprehension of securing suitable institutional and policy backing to effectively integrate EbA into pertinent national and local adaptation policies and broader national planning frameworks.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure S1: title; Table S1: title; Video S1: title.

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REFERENCES

1. Intergovernmental Panel On Climate Change (Ippc), *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, 1st ed. Cambridge University Press, 2023. doi: 10.1017/9781009325844.
2. Ippc, *Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, 1st ed. Cambridge University Press, 2022. doi: 10.1017/9781009157940.
3. N. Doswald et al., “Effectiveness of ecosystem-based approaches for adaptation: review of the evidence-base,” *Clim. Dev.*, vol. 6, no. 2, pp. 185–201, Apr. 2014, doi: 10.1080/17565529.2013.867247.
4. M. Mullan, N. Kingsmill, A. M. Kramer, and S. Agrawala, “National Adaptation Planning: Lessons from OECD Countries,” OECD, Paris, Apr. 2013. doi: 10.1787/5k483jpfpsq1-en.
5. S. C. Woodruff and P. Regan, “Quality of national adaptation plans and opportunities for improvement,” *Mitig. Adapt. Strateg. Glob. Change*, vol. 24, no. 1, pp. 53–71, Jan. 2019, doi: 10.1007/s11027-018-9794-z.
6. R. Munroe et al., “Review of the evidence base for ecosystem-based approaches for adaptation to climate change,” *Environ. Evid.*, vol. 1, no. 1, p. 13, Nov. 2012, doi: 10.1186/2047-2382-1-13.
7. H. Reid and S. Shafiqul Alam, “Ecosystem-based approaches to adaptation: evidence from two sites in Bangladesh,” *Clim. Dev.*, vol. 9, no. 6, pp. 518–536, Sep. 2017, doi: 10.1080/17565529.2016.1167663.
8. Secretariat of the Convention on Biological Diversity and L. Hughes, *Connecting biodiversity and climate change mitigation and adaptation: report of the second Ad Hoc Technical Expert Group on Biodiversity and Climate Change*. in CBD technical series. Montreal, Quebec, Canada: Secretariat of the Convention on Biological Diversity, 2009. Accessed: Feb. 24, 2024. [Online]. Available: <https://www.cbd.int/climate/copenhagen/>
9. S. of the C. on B. Diversity, “Linking Biodiversity Conservation and Poverty Alleviation: A State of Knowledge Review,” Secretariat of the Convention on Biological Diversity, 2010.
10. K. Muthee, L. Duguma, J. Nzyoka, and P. Minang, “Ecosystem-Based Adaptation Practices as a Nature-Based Solution to Promote Water-Energy-Food Nexus Balance,” *Sustainability*, vol. 13, no. 3, Art. no. 3, Jan. 2021, doi: 10.3390/su13031142.
11. “Convenient Solutions to an Inconvenient Truth. World Bank, 2009,” UNREDD Programme. Accessed: Feb. 24, 2024. [Online]. Available: <https://www.un-redd.org/document-library/convenient-solutions-inconvenient-truth-world-bank-2009>
12. F. Moberg and P. Rönnbäck, “Ecosystem services of the tropical seascape: interactions, substitutions and restoration,” *Ocean Coast. Manag.*, vol. 46, no. 1, pp. 27–46, Jan. 2003, doi: 10.1016/S0964-5691(02)00119-9.
13. [13] H. P. Jones, D. G. Hole, and E. S. Zavaleta, “Harnessing nature to help people adapt to climate change,” *Nat. Clim. Change*, vol. 2, no. 7, Art. no. 7, Jul. 2012, doi: 10.1038/nclimate1463.
14. A. S. Mori, T. A. Spies, K. Sudmeier-Rieux, and A. Andrade, “Reframing ecosystem management in the era of climate change: Issues and knowledge from forests,” *Biol. Conserv.*, vol. 165, pp. 115–127, Sep. 2013, doi: 10.1016/j.biocon.2013.05.020.
15. C. I. Donatti, C. A. Harvey, D. Hole, S. N. Panfil, and H. Schurman, “Indicators to measure the climate change adaptation outcomes of ecosystem-based adaptation,” *Clim. Change*, vol. 158, no. 3, pp. 413–433, Feb. 2020, doi: 10.1007/s10584-019-02565-9.
16. D. Agol, H. Reid, F. Crick, and H. Wendo, “Ecosystem-based adaptation in Lake Victoria Basin; synergies and trade-offs,” *R. Soc. Open Sci.*, vol. 8, no. 6, p. 201847, Jun. 2021, doi: 10.1098/rsos.201847.
17. R. Munang, I. Thiaw, K. Alverson, M. Mumba, J. Liu, and M. Rivington, “Climate change and Ecosystem-based Adaptation: a new pragmatic approach to buffering climate change impacts,” *Curr. Opin. Environ. Sustain.*, vol. 5, no. 1, pp. 67–71, Mar. 2013, doi: 10.1016/j.cosust.2012.12.001.
18. U. N. E. Programme, “Resolutions and Decisions adopted by the United Nations Environment Assembly of the United Nations Environment Programme at Its First Session on 27 June 2014,” Jun. 2014, Accessed: Feb. 24, 2024. [Online]. Available: <https://wedocs.unep.org/xmlui/handle/20.500.11822/34318>
19. D. Moher et al., “Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement,” *Syst. Rev.*, vol. 4, no. 1, p. 1, Jan. 2015, doi: 10.1186/2046-4053-4-1.

20. I. van de Sand, J. K. Mwangi, and S. Namirembe, "Can Payments for Ecosystem Services Contribute to Adaptation to Climate Change? Insights from a Watershed in Kenya," *Ecol. Soc.*, vol. 19, no. 1, 2014, Accessed: Feb. 24, 2024. [Online]. Available: <https://www.jstor.org/stable/26269505>
21. P. Kaumbutho and J. Kienzie, *Conservation agriculture as practised in Kenya: two case studies*. Nairobi, Kenya: African Conservation Tillage Network (ACT); Centre de ..., 2007. Accessed: Feb. 25, 2024. [Online]. Available: https://vtechworks.lib.vt.edu/bitstream/handle/10919/68470/4231_Kenya_casestudy.pdf
22. Y. Nyberg, C. Musee, E. Wachiye, M. Jonsson, J. Wetterlind, and I. Öborn, "Effects of Agroforestry and Other Sustainable Practices in the Kenya Agricultural Carbon Project (KACP)," *Land*, vol. 9, no. 10, Art. no. 10, Oct. 2020, doi: 10.3390/land9100389.
23. S. Carsan and C. Holding, "Growing farm timber: practices, markets and policies," *Meru Timber Mark. Pilot Programme Case Stud. Rev. World Agrofor. Cent.*, Jan. 2006.
24. G. C. Fund, "FP113: TWENDE: Towards Ending Drought Emergencies: Ecosystem Based Adaptation in Kenya's Arid and Semi-Arid Rangelands," *Green Climate Fund*. Accessed: Feb. 24, 2024. [Online]. Available: <https://www.greenclimate.fund/project/fp113>
25. P. K. Lalampaa, O. V. Wasonga, D. I. Rubenstein, and J. T. Njoka, "Effects of holistic grazing management on milk production, weight gain, and visitation to grazing areas by livestock and wildlife in Laikipia County, Kenya," *Ecol. Process.*, vol. 5, no. 1, p. 17, Oct. 2016, doi: 10.1186/s13717-016-0061-5.
26. A. Quandt, H. Neufeldt, and J. T. McCabe, "The role of agroforestry in building livelihood resilience to floods and drought in semiarid Kenya," *Ecol. Soc.*, vol. 22, no. 3, 2017, Accessed: Feb. 24, 2024. [Online]. Available: <https://www.jstor.org/stable/26270151>
27. P. M. Osano et al., "Pastoralism and ecosystem-based adaptation in Kenyan Masailand," *Int. J. Clim. Change Strateg. Manag.*, vol. 5, no. 2, pp. 198–214, Jan. 2013, doi: 10.1108/17568691311327596.

