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Optimizing environmental education and awareness strategies for sustainable forest management in Kenya.

Lessons from Cherangany, Mt. Kenya, Aberdares, and Kakamega forest ecosystems

Sylvester Chisika, Chunho Yeom

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Abstract. *Forests and allied environmental resources are important for environmental and socio-economic development. However, information is scarce on the ways of optimizing the strategies for forestry and environmental education and awareness in many developing countries. Using a literature review and document content analysis, this study explores the case of four forested ecosystems in Kenya with the aim of contributing to a better understanding of the strategies to achieve sustainable forest management. Results show that the key ingredients of effective forestry and environmental education are formal education infrastructure, community engagement panels, digital platforms, corporate responsibility initiatives, media, arts, policy advocacy, and research with feedback loops on initiatives. Kenya is desirous of establishing robust mechanisms for effective environmental education and awareness, as demonstrated by policy and legal actions. Case studies of Cherangany, Mt. Kenya, Aberdares, and Kakamega forest ecosystems demonstrate these commendable efforts by embedding the ingredients of effective strategy optimization within their forest ecosystem management plans. However, there is a need to revise the expired Kakamega, Mt. Kenya, and Aberdare ecosystem management plans and optimize awareness strategies by leveraging the existing educational infrastructure and increasing stakeholder engagement, especially activating the role of county governments and addressing outstanding challenges currently inhibiting sustainable forest management.*

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1. Introduction

Forests are important strategic assets that contribute to sustainable development across the globe (Korosuo et al 2023). They are a source of livelihood for millions of people around the world (Wang & Tian 2023). They provide food, timber,

energy, shelter, and medicine for many local communities (Wang & Tian, 2023; Berlyn, 2023). According to the World Resources Institute, the world had 4.02 billion hectares of tree cover in 2020, which is approximately 30% of the Earth's land. This estimate includes unmanaged and managed natural forests and planted forests (Berlyn 2023). However, with the growing human needs, deforestation and forest degradation are threatening the survival of forests and the species that depend on them (Berlyn 2023). It is, therefore, important to protect and conserve forests to ensure their sustainability and the well-being of the planet.

Environmental education and awareness are increasingly emerging as vital tools for promoting the sustainable management of forests for maximum social and economic benefits (Stefanakis 2022). Environmental education and awareness contribute to an enhanced understanding of the role of forested ecological systems among individuals and stakeholders. Whereas in developed countries, the systems for environmental education and awareness are well-established (Stefanakis, 2022; Breiting & Wickenberg, 2010), many developing countries face challenges in establishing comprehensive environmental education and awareness programs. Forestry awareness initiatives in many developing countries are mainly limited by contextual factors, impacting their effectiveness (Mutia et al., 2023; Hakamada, 2023). In recent times, there have been growing policy initiatives and a tendency to incorporate diverse environmental and awareness strategies in long-term forest ecosystem management plans. These tools are instrumental in achieving a harmonious balance between environmental conservation, economic development, and community well-being (Reid et al. 2019). Limited studies have explored and compared environmental and education awareness strategies in sustainable forest management in developing countries, posing risks like missed opportunities, ineffective community engagement, and inefficient resource allocation.

In Kenya, forests are important for socioeconomic development (Habel et al., 2023; Chepkemoi & Musya, 2023). As such, key forestry policies and programs have been formulated to promote sustainable forest management. Currently, efforts are underway to achieve a 30% national tree cover by 2032, aligning with climate-reliant economic growth goals and Vision 2030. Forestry education and awareness will catalyze positive attitudes toward sustainable forest management (Kinyili 2023). However, following the adoption of forest management plans as the key tools for enhancing sustainability, there is a scarcity of scientific information on comparative studies that relate the forestry education and awareness strategies adopted in forest management plans and their implications for sustainable forest management. This paper seeks to address this challenge by

identifying and comparing the forestry and environmental awareness and education strategies in the case of Cherangany, Aberdare, Kakamega, and Mt. Kenya forest ecosystems and draw the policy implications of the findings on sustainable forest management in Kenya. The Cherangany, Aberdare, Kakamega, and Mt. Kenya forest ecosystems hold vital importance for biodiversity, water regulation, climate resilience, and cultural significance. Conducting studies on their environmental conservation through education and awareness strategies is critical for their sustainability.

In order to achieve the study aims, this paper uses the case study research design with literature review and document content analysis to explore the theoretical and empirical connections between environmental education, awareness, and sustainable forest management. The reviewed global-level lessons were then applied to Kenya's cases in order to derive the policy implications of this study. This study provides crucial information for empowering stakeholders, individuals, and communities, aligns with forest policy goals, and fosters a collective responsibility for the preservation of Kenya's invaluable forest resources.

1.1. Environmental education, awareness, and sustainable forest management: theoretical analysis

Forests and allied natural resources provide ecosystem services needed for human well-being. Despite, employing over 18.12 million and supporting 45.15 million jobs, the sector faces a global call for sustainable management (Yanshu et al., 2019; UN, 2019). Sustainable forest management ensures long-term ecosystem health by balancing conservation, socio-economic needs, and responsible resource use. However, global socio-economic changes, driven by challenges like climate change, pose threats to forest ecosystems by exacerbating biodiversity loss, deforestation, and pollution with effects on human health and the environment.

Interestingly, in the midst of these challenges, environmental education and awareness is fast emerging as a feasible response to these global environmental challenges. Environmental education serves as a crucial tool in natural resource management by enhancing people's comprehension of ecological systems. Ndifon (2015) defines it as a process that transmits environmental awareness to instigate a shift in values and attitudes, promoting sustainable use and proper management of the immediate environment. It empowers individuals to explore environmental issues, participate in problem-solving, and take proactive measures to enhance the environment. According to Smith (2010),

environmental education aims to inform people about how ecosystems function and how humans can manage them sustainably. It addresses environmental issues using methods that promote positive attitudes toward conservation, ensuring the sustainable provision of goods and services from vital resources like forest ecosystems. It can occur formally in classrooms or informally through community-based organizations, participation, mass media campaigns, workshops, and conferences. Understanding the impact of individual actions on the environment, known as environmental awareness, is widely acknowledged as a crucial initial step in addressing environmental issues (Alam, 2023). Therefore, assessing the environmental awareness of individuals becomes essential in tackling environmental challenges and fostering a sustainable society (Alam 2023; Gurbuz et al. 2021), hence the need for this study in the context of Kenya. Bülbül et al. (2020) argue that societies with high environmental awareness find it easier to design and implement policies to counter environmental degradation. Environmental awareness plays a vital role in cultivating an informed society regarding environmental issues, shaping responsible citizens who prioritize environmental care (Mkumbachi et al., 2020; Al Yaqubi, 2020). It is recognized as a significant component in environmental management and the preservation of biodiversity (Hanisch et al., 2014). Research also indicates that cultivating environmental awareness is crucial for fostering environmentally conscious behaviors (Conrad & Hilchey, 2011; Giudici et al., 2019) and has the potential to shape individuals' lifestyles toward greater environmental friendliness (von Borgstede et al., 2013). Fu et al. (2020) emphasize the significant role of environmental awareness in promoting the adoption of pro-environmental behavior.

From the above review, Sustainable forest management and environmental education benefit from technology integration, community engagement, and strong legal frameworks for a holistic approach. Environmental education, both formal and informal, is essential for cultivating positive attitudes and awareness, particularly amidst global challenges like climate change.

1.2. Empirical studies on environmental education and sustainability

Empirical studies have demonstrated the highlighted ingredients of effective environmental awareness and education strategies. Yamada et al. (2023), while analyzing trade-offs between timber and non-timber ecosystem services across three municipalities in Japan, reveal that areas with rich forestry history and high awareness of ecosystem services have lower logging ratios. In regions with external foresters, even forests with abundant services face high logging ratios,

emphasizing the need to enhance local awareness for balanced utilization. The study advocates for local governments' role in educating forest enterprises and providing science-based information for responsible forest management.

In Thailand, a study revealed that an increased duration of schooling is associated with a higher likelihood of actively engaging in knowledge-based, environmentally friendly actions. However, this effect is not observed for cost-saving pro-environmental actions. Moreover, the study indicated that formal education does not significantly influence concerns about global warming or the willingness to pay environmental taxes (Chankrajang & Muttarak, 2017).

The government's fiscal and administrative policy decisions have the potential to impact environmental education. In the U.S., environmental education involves various departments and is shaped by the executive and legislative branches. In India, the Centre for Environmental Education receives government support, highlighting a unique partnership between the Ministry of Environment and a non-governmental organization. Forest sustainability goes beyond government, emphasizing individual responsibility for environmental protection through education and awareness across all age groups, fostering initiative and active participation. The Nigerian government has put forth diverse approaches, including abatement measures, legislation, and policies, to enhance awareness among citizens. Yet, it seems that past strategies focused more on controlling and treating environmental issues rather than preventing them (Thathong, 2012). Effective environmental education is crucial in elevating public knowledge and fostering positive attitudes and behaviors toward the environment. Nigeria and other African nations acknowledge its pivotal role in addressing environmental challenges.

Gavilanes Montoya et al. (2023) conducted a literature review to assess the possibilities for enhancing Information and Communication Technology (ICT) and communication processes within the forestry sector and to gauge their practicality and relevance. The study found the diverse communication flows in forestry, influenced by technologies. Furthermore, ICTs contribute to forest conservation by setting standards and policies, enabling monitoring and analysis at various scales. Across the globe, authorities often use surveys to measure environmental awareness (Ham et al., 2016). Using Google search data for an Environmental Awareness Index (EAI) has advantages over surveys, with lower costs and broader coverage. European studies show a strong correlation between EAI and pro-environmental behaviors, emphasizing the dynamic nature of environmental awareness. Timely measures are crucial for policymakers to assess

policy impact and understand behaviors influenced by environmental initiatives. (Dabbous et al., 2023).

The empirical reviews have emphasized the importance of effective environmental education and awareness to tackle forest management challenges. The importance of comprehensive curricula, community engagement, digital platforms, corporate involvement, media, policy advocacy, interdisciplinary research, and feedback loops have been highlighted. However, gaps exist on the context specific lessons and targeted strategies for effective environmental education and awareness, especially in developing countries and hence the need for this study in Kenya.

1.3. The context for forest management in Kenya

Kenya has a total of 5,226,191.79 ha (52,261 Km^2) of forest cover, which translates to 8.83% of the total land area in the country (Chisika & Yeom 2023). Over the past two decades, Kenya's forest sector has undergone a transformative journey driven by comprehensive governmental reforms. The Forest Act of 2005, later succeeded by the Forest Conservation and Management Act of 2016, marked pivotal milestones in this evolution, coinciding with the promulgation of the Constitution in 2010. A standout initiative was the establishment of the Kenya Forest Service (KFS) as a semiautonomous agency governed by an independent board, resulting in improved resource allocation and heightened operational capacity. The introduction of the Participatory Forest Management (PFM) approach revolutionized the stewardship of public and community forest resources, fostering the creation of 250 Community Forest Associations (CFAs) and 290 Charcoal Producer Associations (CPAs). These associations play a vital role in regulating charcoal production from community forests. Furthermore, the decentralization of forest governance through the establishment of Forest Conservation Committees empowered local entities. The devolution of forestry functions to county governments, as outlined in the 2010 Constitution, marked a significant decentralization effort. County governments now hold responsibility for the conservation and management of forest resources on community and private lands, while the Kenya Forest Service focuses on managing public forests and enhancing the capacities of county governments in their devolved forestry functions. The strengthened governance of water towers was another noteworthy achievement, materializing through the creation of the Kenya Water Towers Agency, reinforcing the protection and sustainable management of vital water resources. Collectively, these reforms signify Kenya's commitment to

fostering environmental sustainability and community engagement in the management of its precious forest ecosystems (Mutune et al., 2017).

Strategies for forestry education and awareness play a pivotal role in promoting sustainable forest management and environmental conservation. These strategies involve a multifaceted approach, including formal education initiatives integrated into school curricula to instill a sense of environmental responsibility among the youth. Community-based programs engage local populations in understanding the importance of forests, encouraging active participation in conservation efforts (Mutune et al. 2017; Chisika & Yeom 2021). Public awareness campaigns employ diverse channels, including mass media and community events, to educate about forest value and individual roles in protection. Two annual campaigns coincide with the short and long rains, emphasizing tree planting. Notably, the President launched the National Tree Growing Restoration Campaign in 2022, aiming to plant 15 billion trees by 2032 (Head of Public Service Website, 2024). Successful forestry strategies in Kenya rely on collaboration between government, NGOs, and local communities. These initiatives aim to improve public awareness, knowledge, and engagement in sustainable forest management. (Mutune et al., 2017).

According to the National Forestry Programme 2016 -2030, Forestry education in Kenya faces challenges like a misalignment between institutions and industry, a lack of harmonized curriculum, inadequate practical training, and insufficient resources. The curriculum lacks participatory review, hindering adaptation to emerging issues like climate change. Entrepreneurial training gaps, resource mobilization issues, and weak linkages between institutions, researchers, and industry further compound the challenges. Improved integration, communication, and support are essential for a comprehensive and effective forestry education system.

There are emerging conservation approaches that have proven to be useful in promoting education and awareness."*Adopt a Forest in Kenya*" is a laudable initiative urging individuals and groups to actively engage in conserving the country's diverse forests. Participants in forest adoption contribute to specific areas' conservation through activities like education, tree planting, and sustainable resource management, demonstrating a commitment to environmental stewardship and community involvement (Chisika & Yeom, 2021). From this review, Kenya is taking a leading role in promoting sustainable forest management.

2. Materials and Methods

2.1. Case study research design

The comparative case study research approach was utilized in the study. It focused on understanding the specific context, processes, and outcomes related to the various strategies adopted to promote environmental education and awareness in each case being examined. The case study design was chosen because it allowed for an in-depth examination of the specific case thus providing a comprehensive understanding of the complexities and contextual factors in each case.

2.2. Case studies

2.2.1. Cherangani forest ecosystem

The Cherangani Forest Ecosystem, vital for local communities and the Lake Victoria and Lake Turkana basins, faces threats from population growth and unchecked settlements. A strategic management plan aims to guide conservation efforts, involving diverse stakeholders in its development from 2011 to 2013. The plan outlines five forest management zones, detailing objectives and actions for restoration and sustainable use. Local communities are recognized as crucial stakeholders in management and conservation. The educational landscape in the Cherangani ecosystem indicates significant education levels, with numerous schools and conservation organizations actively involved. Despite existing legislation, awareness about conservation remains low, leading to proposed activities to address this gap. Challenges include a lack of awareness, commitment, and technical capacity, along with resistance to change and erosion of indigenous knowledge. The plan addresses these issues through training workshops, seminars, media engagement, and participation in environmental events. Stakeholder capacity enhancement involves exchange visits, institution development support, incentives for farmers, and educational opportunities. Environmental education dissemination is planned through harmonized extension packages and resource center construction by key organizations. The overall goal is to enhance stakeholder commitment, awareness, and capacity for sustainable environmental practices in the Cherangani ecosystem. Empirical studies conducted in the ecosystem to evaluate the status of environmental awareness indicate that the ecosystem is still experiencing challenges. Pressing issues in the ecosystem include unlawful grazing, unauthorized logging, charcoal production, forest fires, population growth, policy and institutional failures, and forest intrusion. A call is made for full implementation of the Cherangani Hills

Forest Strategic Management Plan (2015-2040) and involving indigenous communities in political processes, especially in land use and forest management (Rotich, 2019; Ongugo et al., 2017; Rotich & Ojwang, 2021).

2.2.2. Mt. Kenya forest ecosystem

The Mt. Kenya Ecosystem, encompassing various reserves and conservancies, faces persistent threats despite significant conservation efforts. Challenges arise from resource depletion near populated areas due to unsustainable practices driven by poverty, rapid population growth, and weak institutions. A 10-year management plan (2010-2020) was collaboratively developed to address these issues, focusing on participatory implementation and collective management actions. Key threats include wildlife poaching, illegal logging, forest fires, invasive species, illegal water abstraction, and human-wildlife conflicts. The community partnership and education management program within the plan aims to strengthen conservation education, reduce conflicts, and enhance community benefits. Initiatives involve promoting educational programs by organizations like the William Holden Education Center and Wildlife Clubs of Kenya, utilizing mass media and the Internet, and participating in conservation awareness events to raise awareness about the Mt. Kenya Ecosystem. Despite challenges, the plan emphasizes the importance of inclusive and collective efforts to mitigate threats and sustain the natural resources of the Mt. Kenya Ecosystem. Studies in the ecosystem reveal ongoing challenges, including forest fires, limited environmental awareness, population growth, policy and institutional failures, and forest intrusion (Nyongesa & Vacik, 2018; Njeru & Fundi, 2023).

2.2.3. Aberdares forest ecosystem

The Aberdare Ecosystem (AE), covering about 2,162 km^2, faces threats like illegal logging, excessive grazing, poaching, water abstraction, and habitat loss. The actual area may exceed 3,000 km^2 due to rugged terrain. A 10-year management plan (2010-2020) involves extensive stakeholder engagement and aims for community involvement in conservation. Four management objectives focus on reducing human-wildlife conflict, enhancing community benefits, and improving awareness and communication. Key actions include maintaining the electric fence, supporting tourism-related projects, forming associations, generating employment, promoting carbon credits, establishing wind farms, and creating an education center. The electric fence has successfully mitigated conflicts, but some communities resist it, leading to vandalism. Ongoing awareness efforts aim to secure community support. Limited awareness of protected area regulations and values contributes to rule violations,

dissatisfaction, ecological consequences, revenue loss, and insufficient community support. The plan emphasizes continuous awareness-building to address these challenges and foster a future where adjacent communities actively contribute to conservation and benefit from sustainable resource use in the Aberdare Ecosystem. Studies on environmental awareness in the ecosystem reveal persistent challenges, including limited awareness, population growth, policy failures, institutional issues, and forest intrusion (Njeru & Fundi, 2023).

2.2.4. Kakamega forest ecosystem

Kakamega Forest in Western Kenya, an eastern remnant of the Guineo-Congolian lowland rainforest, boasts unique biodiversity, serving as a watershed and resource for the local community. A 10-year ecosystem management plan (2012-2022) involves joint efforts from the Kenya Wildlife Service (KWS) and Kenya Forest Service (KFS), with stakeholder engagement as a priority. Threats like illegal activities and community pressures necessitated the plan. The Community Outreach and Education Program aims to enhance community involvement in conservation and sustainable resource use, addressing human-wildlife conflict and improving livelihoods. Objectives focus on community participation, environmental education, conflict reduction, and enhancing livelihoods. Educational initiatives, including the KEEP Education Centre and the Biodiversity Information Center, involve collaboration with institutions within the Kakamega Forest Ecosystem. Despite challenges like forest degradation and community reliance on resources, the plan aims to foster community support for conservation through education, awareness, and sustainable practices, recognizing the vital role Kakamega Forest plays in national and international biodiversity conservation efforts. Studies in the ecosystem show improved forest management under participatory forest management, but limited awareness persists. Addressing this requires enhancing stakeholder capabilities, reforming institutions, providing financial support, and ensuring proper implementation (Mbuvi et al., 2022; Nyang'au et al., 2020). The four ecosystems studied are shown in Figure 1.

2.3. Data sources and collection process

Researchers developed a systematic content analysis procedure to extract and analyze relevant documents for a study on forest ecosystem management in Kenya. They identified specific plans, policy reports, and project reports in the document selection phase. The data extraction step involved isolating sections related to implementation, methodologies, strategies, and key actors. A coding scheme categorized textual data into themes like "environmental education" and

"forest conservation awareness." The contextual analysis considered broader social, economic, and environmental factors. The interpretation and synthesis phase drew meaningful conclusions, emphasizing implications for future environmental education planning. Validity and reliability checks ensured accurate representation, and the reporting phase presented key findings on how environmental education contributes to sustainable forest management in Kenya. The key documents consulted are shown in Table 1.

Figure 1. Location of the four ecosystems in Kenya

Document	Type	Source	Key findings
Constitution of Kenya, 2010	Policy	Internet	Article 10 d makes sustainable development a national value, while Article 55 makes education a human right. Articles 1, 10, and 118 outline the foundation for this engagement, emphasizing the sovereign power of the people, the values of public service, and the need for openness and accountability in government. Devolved some forestry educational roles to county governments.
Forest Policy, 1968	Policy	Internet	The policy emphasizes forest conservation and sustainable practices, highlighting the critical link between healthy forests and environmental well-being. It promotes environmental education, emphasizing an understanding of ecosystems, biodiversity, and forest balance. The policy encourages grassroots community involvement in environmental education and raises awareness about forests' crucial role in maintaining ecological equilibrium.
Forest Conservation and Management Act, 2016	Policy	Internet	Establishes Kenya Forest Service, the state agency responsible for promoting sustainable forest management through various means, including the provision of environmental education and awareness. The Act establishes Kenya Forestry College, which offers training in forestry. Moreover, the Act provides for programs for community empowerment, including environmental education through participatory forest management.
Basic Education Act, 2013	Policy	Internet	Section 42 mandates the Cabinet Secretary of Education to promote environmental protection education for sustainable development. By making education free and compulsory, standardizing the curriculum, and prioritizing quality, inclusivity, and teacher development, the Act has transformed the education landscape in the country.
Draft National Landscape and Ecosystem Restoration Strategy 2022-2032	Policy	Internet	The strategy aims to improve forestry through education, research, and training, addressing environmental challenges with initiatives like community engagement, digital platforms, and partnerships.
National Forest Programme 2016–2030	Policy	Internet	The program enhances forestry education, quality, and stakeholder capacity through training, research, and innovation, addressing

Document	Type	Source	Key findings
			challenges in forestry education and awareness.
Aberdare Ecosystem Management Plan 2010-2020	Management tool	Internet	The participatory plan involved stakeholders in ecosystem forums, including core planning teams, workshops, expert groups, village-level meetings, and individual consultations.
Mt. Kenya Ecosystem Management Plan 2010-2020	Management tool	Internet	Stakeholders actively shaped the ecosystem plan through forums, including core planning teams, workshops, expert groups, community meetings, and consultations..
Kakamega Forest Ecosystem Management Plan 2012-2022	Management tool	Internet	Stakeholders in the ecosystem actively crafted a participatory plan through forums, including core teams, workshops, expert groups, community meetings, and consultations.
Cherangani Hills Forest Strategic Ecosystem Management Plan 2015 - 2040	Management tool	Internet	The highly participatory plan was formulated by stakeholders around the ecosystem through forums, including participation in the core planning team, stakeholder planning workshops, expert working groups, village-level community consultative meetings, and individual consultations.
Rotich (2019)	Research article	Internet	The study in the Embobut forest in the Cherangany ecosystem focused on forest utilization and conservation, revealing the need to implement the Cherangani Hills Forest Management Plan. Additionally, 14.3% of respondents were illiterate, emphasizing the importance of environmental education and integrating indigenous communities into political processes.
Ongugo et al. (2017)	Research article	Internet	The study detected forest degradation in Mt. Elgon and Cherangany Hills using remote sensing, identifying hotspots. Rehabilitation efforts recommended included establishing demonstration plots and promoting tree planting.
Rotich & Ojwang (2021)	Research article	Internet	The study analyzed forest cover change in Cherangany Hills from 1985-2020, identifying drivers such as land conversion, resource exploitation, fires, and more. It urged a re-

Document	Type	Source	Key findings
			evaluation of conservation strategies for sustainability.
Nyongesa & Vacik (2018)	Research article	Internet	The study on fire management in Mount Kenya's Gathiuru Forest proposed an Integrated Fire Management framework, emphasizing education, research, and mutual exchange between trainers and communities for effective training.
Njeru & Fundi (2023)	Research article	Internet	The study evaluated local community knowledge and attitudes toward conserving the critically endangered Mountain bongo in Mt Kenya Wildlife Conservancy. Results revealed that while 71.8% recognized the bongo, only 18.3% knew its vernacular name, indicating limited ecological knowledge.
Mbuvi et al. (2022)	Research article	Internet	The study examined governance's impact on land cover and forest structure in Kakamega and Loita forests, finding that stakeholder capacity, institutional reform, and financial support enhance each regime's effectiveness.
Nyang'au et al. (2020)	Research article	Internet	This study conducted in Kakamega Forest assessed the impact of participating in a medicinal plants commercialization program on farm income, highlighting the importance of factors like age, literacy, and forest distance.
Rhino Ark Website (2024)	Webpage	Internet	Over 170 schools near key water towers in Kenya, including Mt. Kenya forest and Aberdares ecosystems, have implement a custom conservation curriculum in 2018, enriching the standard syllabus. This was made possible by a partnership between the government and non-state actors.
Pham et al. (2023)	Research Article	Internet	This working paper examines forest-food linkages in Kenya and found that forests contribute to local food supplies and support sustainable food production. Despite policy emphasis, challenges like deforestation persist, requiring effective implementation and further research such as the role of environmental education.

Table 1. Documents reviewed

2.4. Data analysis

This study sought to investigate the strategies for sustainable environmental education and awareness in selected case studies and design recommended ways for optimizing them. A conceptual framework (Figure 2) was developed based on findings from theoretical and empirical literature reviewed at global and local levels. From the analysis, the central pillar of formal education serves as the cornerstone for environmental education and awareness.

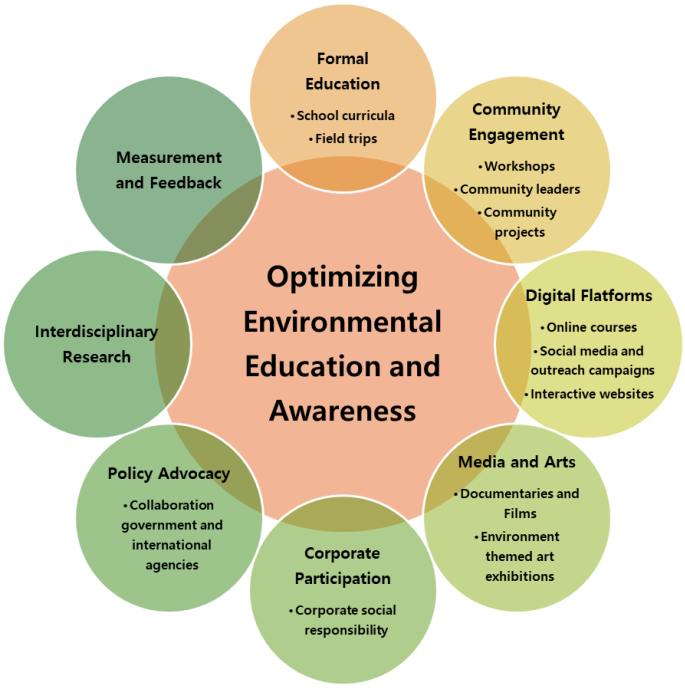

Figure 2. Conceptual diagram for optimizing strategies for environmental education and awareness in selected forest ecosystems in Kenya

This is complemented by experiential learning through field trips, allowing stakeholders to connect theory with real-world scenarios. Collaborative efforts and partnerships with environmental NGOs enhance education through workshops and hands-on activities. Community engagement, with community

leaders as ambassadors, fosters grassroots initiatives and tangible impacts. Embracing the digital era, online courses, webinars, and social media campaigns amplify global accessibility. Interactive websites cater to self-learners, ensuring a dynamic educational experience. Corporate participation through CSR programs and green initiatives enhances environmental education. Media and arts contribute to ecological consciousness through documentaries and exhibitions. Policy advocacy collaborates with government agencies, promoting sustainable policies and engaging in international conventions. Cross-disciplinary education inspires research projects. A robust feedback loop ensures continuous improvement, aiming to nurture an environmentally conscious generation actively involved in sustainable development.

3. Results

3.1. Current status of environmental education and awareness

The four forest ecosystems provide many environmental, social, and economic benefits for local communities and the global economy. The current status of environmental education and awareness is shown in Table 2.

Thematic Area	Findings
Formal education	Cherangani ecosystem has an appreciable educational infrastructure. There are 691 primary schools, 109 secondary schools, and 3 tertiary colleges. There are 90 CBOs, 5 NGOs, 9 CFAs, 7 WRUAs, and a number of government agencies involved in awareness creation.
Community engagement	Across all the ecosystems, a review of the ecosystem management plans shows that communities are engaged in environmental education through the participatory forest management process. However, currently, the process is experiencing challenges, including inadequate capacity, lack of incentives, and high costs for PFMP development. User groups struggle with resource mobilization, and poor advocacy skills hinder effective causes. Environmental conservation interest is weak, focused on benefit sharing, lacking a shared vision, leading to low participation and hindered PFM implementation. Governance issues persist due to weak regulations and non-adherence to rights, emphasizing the need for a comprehensive approach to sustainable community development.
Digital platforms	There are no specific digital platforms for the ecosystems, but there are plans to establish information databases in each of the four ecosystems. Currently, the ecosystems utilize digital platforms developed at the national level to promote environmental education

Thematic Area	Findings
	and awareness, for instance, the Jaza Miti App, which is used to provide awareness on tree species site matching and reporting tree planting progress.
Media and arts	The media plays a critical role in promoting environmental education in the four ecosystems. The media is used to mobilize stakeholders for forest conservation. The Media Council of Kenya has promised to collaborate with journalists to increase public awareness of forest conservation and management and mobilize public support for tree-growing initiatives (Impact Hub media website 2024).
Corporate participation	In the four cases, corporates participate in environmental education and awareness through the "adopt-a-forest" framework. For example, Her Excellency, the First Lady of the Republic of Kenya, has adopted 200 ha of Kakamega forest and has committed to growing 500 million trees across the country by 2032 (Citizen digital website, 2024).
Policy Advocacy	Diverse interest groups are involved in promoting environmental education and awareness. The focus areas include building grassroots capacity and networks for nature conservation, promoting participation and equity in natural resource management, mobilizing public and political support for nature, educating young people about nature, and fostering effective conservation partnerships at local, national, and international levels by Laikipia Wildlife Forum, Nature Kenya, especially in Mt. Kenya ecosystem. Nature Kenya works with a number of site support groups, including, Chebororwa Sekemiat Self-help Group – Cherangany, Kakamega Environmental Education Programme (KEEP), Mt. Kenya Biodiversity Conservation Group (Mt. Kebio), Mukurweini Environmental Volunteers Organization (MEVO) -Aberdares (Nature Kenya Website 2024).
Interdisciplinary research	Even though there are limited studies that focus on environmental education and awareness in the four ecosystems, research studies have been conducted on drivers and trends of deforestation, mostly using satellite technology. The researchers have mentioned the importance of enhancing education and awareness as a strategy for promoting sustainable forest management.
Measurement and feedback	All four ecosystems have multi-stakeholder structures for promoting environmental education and awareness as outlined in the respective ecosystem management plans (Table 1). There are also national-level efforts to complement the ecosystem measurement and feedback mechanisms, such as the Jaza Miti App, which monitors and reports on tree planting activities.

Table 2. Status of environmental education and awareness

3.2. Strategies for environmental education and awareness

Forest ecosystem management plans are playing a pivotal role in promoting sustainable forest management of the four forest ecosystems. Results in Table 3 show that diverse strategies are being employed to promote environmental education and awareness.

Thematic Area	Findings
Formal education	According to the ecosystem management plans, in the Cherangany ecosystem, efforts to strengthen formal education include enhancing the capacity of stakeholders and disseminating environmental messages. In Kakamega attention is given to mobilizing the surrounding schools to register with Wildlife Clubs of Kenya for wildlife conservation awareness creation. In Mt. Kenya, the focus is to ensure that adjacent communities are supporting conservation efforts and livelihoods are improving through the sustainable use of natural resources
Community engagement	In all four study sites, the focus is to strengthen the community structures to be effective in PFM.
Digital platforms	In Mt. Kenya, there are plans to establish a management information database to integrate research and monitoring information in the planning, management, and decision-making. These resource centers will consist of published and unpublished research reports both in analog and digital media for easy access to ecosystem managers. A similar approach is suggested for the Aberdares ecosystem. Cherangany and Kakamega do not mention their efforts using digital platforms.
Media and arts	There are plans to escalate the use of media to promote environmental education and awareness in all four ecosystems. In ecosystems with wildlife, Kenya Park's In Focus program is dedicated to connecting youth with nature through photography, environmental education, outdoor recreation, and creative expression. The initiative aims to support youth groups near protected areas, fostering an appreciation for Kenya National Parks' natural beauty. In collaboration with the parks and reserves, the six-day program enhances participants' photography skills, imparts knowledge about nature, and allows exploration of the park with interactions with park rangers, artists, and professional photographers (Tonywild website 2024).
Corporate participation	All four ecosystems plan to leverage corporate participation through CSR to contribute to economic development while improving the quality of life in the ecosystems. In Kakamega, the focus is to encourage corporates to establish trusts or foundations, through which funds from willing clients (donations) can be channelled or their own profit.
Policy Advocacy	All four ecosystem management plans encourage promoting the advocacy role of nongovernmental organizations and other agencies

Thematic Area	Findings
	as well as promoting advocacy through the PFM process. The specific actions include encouraging advocacy on good governance and leadership, electing leaders with the right skills, undertaking capacity building of stakeholders, developing a code of conduct for community groups, and establishing mechanisms for benefit-sharing amongst stakeholders.
Interdisciplinary research	All the ecosystems emphasize the importance of research to promote environmental education and awareness. There are plans to improve the infrastructure of the existing research facilities in order to improve their educational and awareness roles. The management programs in the management plans, including education and awareness are to be implemented based on continuous research, education, monitoring, and information sharing among the stakeholders
Measurement and feedback	Improving multi-stakeholder structures for promoting environmental education and awareness is envisaged in all the ecosystems.

Table 3. Strategies for enhancing environmental education and awareness

In summary, the results showed that the current status of environmental education and awareness in the four cases highlights their significance for sustainable development. Participatory Forest Management, which is the main avenue for environmental education and awareness, faces obstacles hindering effective education. However, media, arts, and corporate initiatives, such as the "adopt-a-forest" framework, are recognized for their critical role.

4. Discussion

Forests are important for sustainable development (Korosuo et al., 2023; Wang & Tian, 2023; Berlyn, 2023; Yanshu et al., 2019; UN, 2019). Hence, many countries have devised strategies for harnessing educational and awareness initiatives to achieve sustainable forest management (Stefanakis, 2022; Breiting & Wickenberg, 2010; Ndifon, 2015; Smith, 2010; Alam, 2023). However, reviewed literature shows that the effectiveness of awareness programs is influenced by various contextual factors (Mutia et al., 2023; Hakamada, 2023), but there are limited studies in developing countries. Therefore, this study sought to evaluate ways of optimizing environmental education and awareness strategies toward sustainable forest management in Kenya using the case of four forested ecosystems. Results from reviewed global literature show that environmental education and awareness are vital tools in the sustainable management of

forested ecosystems (Reid et al., 2019; Alam, 2023; Gurbuz et al., 2021; Bülbül et al., 2020; Mkumbachi et al., 2020; Al Yaqubi, 2020; Conrad and Hilchey, 2011; Giudici et al., 2019; von Borgstede et al., 2013; Fu et al., 2020).

When the conceptual framework with key ingredients for understanding the strategies for optimizing environmental education (Figure 2) was applied in the context of Kenya, results show that just like at the global level, forests are strategic national assets and the country is desirous of promoting environmental education and awareness for their sustainable management (Habel et al., 2023; Chepkemoi & Musya, 2023). The country has developed policies and legislation to promote sustainable forest management through educational programs (Table 1; Kinyili, 2023). In particular, the constitution of Kenya (Table 1) recognizes education, including environmental education as a fundamental right for every Kenyan and calls upon all public officials to uphold it. In addition, the constitution devolved some forestry functions to county governments, especially the role of educating individual citizens on forestry and environmental matters. Counties in Kenya are supposed to play a multifaceted role in promoting environmental education and awareness. Their efforts span establishing education systems, facilitating community engagement through digital communication and media collaborations, firming up corporate partnerships for conservation, policy advocacy, and overall sustainable development, and contributing significantly to the nation's environmental conservation goals. However, counties have been slow in taking up their forestry and environmental awareness functions.

Other policy documents, for instance, the Forest Policy 1968, emphasize the link between environmental education and high quality of life. Moreover, the Forest Conservation and Management Act, 2016, section 8 (g) establishes the Kenya Forest Service whose mandate partly is to promote forestry education and training across the coutry. The law also established Kenya Forestry College for formal technical training in forestry and environmental matters. However, and perhaps most important is the provision of Participatory Forest Management as an avenue for partnership between the government and forest-adjacent communities. This partnership offers scientific and educational activities as one of the user rights to benefit forest-adjacent communities. Environmental education and awareness activities under the participatory relationship, including forest adoption, have revolutionized public and community forest resource stewardship. Collaborative forestry has fostered the creation of 250 Community Forest Associations (CFAs), 290 Charcoal Producer Associations (CPAs), and the decentralization of forest governance through the establishment of Forest

Conservation Committees, which are currently empowering local communities by involving them in higher conservation decision-making processes. As a result, the cumulative impact of these educational and conservation efforts have improved the country's forest cover which currently stands at 8.83 of the total land area in Kenya (Mutune et al., 2017; Chisika & Yeom, 2021).

However, according to the National Forestry Programme 2016 -2030, there are various financial, institutional, technical, and social challenges facing forestry education and awareness, and they need to be addressed by re-evaluating the current location-specific strategies in order to foster the achievement of sustainable forest management in the country. In this connection, when the conceptual framework in Figure 2 was applied to cases, results showed the forest ecosystems were vital for local communities and the nation at large in view of the social, economic, and environmental benefits (Kakamega Forest Ecosystem Management Plan 2012-2022; Cherangani Hills Forest Strategic Ecosystem Management Plan 2015 – 2040; Mt. Kenya Ecosystem Management Plan 2010-2020 & Aberdare Ecosystem Management Plan 2010-2020). Therefore, preserving them through environmental education and awareness is important. Results show that currently, all four ecosystems portray similar status across the key ingredients of effective environmental education and awareness, as outlined in Figure 2 (Table 2). Moreover, in all the cases, diverse environmental education and awareness strategies are embedded in the forest ecosystem management plans following the amendments to incorporate the forest management law in 2005 (Table 1). Strategies are pursued in the four forest ecosystems with the aim of seeking to enhance the commitment and awareness of environmental issues and conservation by organizing training workshops and seminars involving state and non-state actors, building stakeholder capacity through exchange visits, and disseminating environmental education through the construction of resource centers.

However, in this paper, the authors assert that currently, in view of the elements of Figure 2, the Participatory Forest Management strategy serves as the key avenue for promoting environmental education and awareness in the study cases because it incorporates integrating all the suggested elements in Figure 2. By actively involving local communities in the management and conservation of the case forests, PFM fosters a deep understanding of the ecological importance of these ecosystems. Through hands-on involvement, communities gain practical knowledge, sharpen environmental awareness, and develop a sense of ownership. Participatory forestry initiatives, even though still government-led, to some extent, provide a platform for education and awareness on sustainable resource

use, biodiversity conservation, and the interdependence of ecosystems, contributing to a culture of responsible environmental stewardship. Ultimately, it empowers communities to actively safeguard their natural heritage for current and future generations.

The participatory forest management plans developed to guide the participatory process outline guidelines for resource utilization, biodiversity conservation, and community involvement in decision-making processes, thus strengthening their education and awareness of environmental matters. This paper lauds the participatory practice of integrating robust educational programs in management plans because it fosters a harmonious balance between conservation efforts community engagement and other ingredients of effective awareness programs. Such educational programs play a pivotal role in enlightening stakeholders about the ecological significance of forests, instilling a deep understanding of sustainable practices, and promoting a sense of shared responsibility. By integrating education initiatives into management plans, there is an opportunity to empower local communities, policymakers, and other stakeholders with the knowledge needed to make informed decisions. This proactive approach enhances awareness of environmental challenges and also encourages active participation in conservation activities. Robust education and awareness programs serve as catalysts for building a cadre of informed advocates who can champion the cause of sustainable forest management, ensuring the longevity and vitality of these essential ecosystems.

However, results in Table 2 showed that there are significant social, financial, institutional, and technical challenges affecting the effectiveness of education and awareness programs in the Participatory Forest Management Process. Whereas this study supports participatory ecosystem planning and the inclusion of strategies and actions for promoting education and awareness that cut across the key ingredients of effective educational and awareness programs identified in Figure 2, there is a need to optimize the strategies by leveraging on the opportunities presented by the existing education infrastructure. For example, in the Cherangani forest ecosystem, leveraging the existing educational infrastructure comprising 691 primary schools, 109 secondary schools, and three tertiary colleges in the region would promote formal education and awareness. In addition, across all cases, the policy framework for the country allows for this approach. For instance, the Basic Education Act, 2013, section 42 mandates the Cabinet Secretary of Education to promote environmental protection education for sustainable development. Moreover, across all the cases studied, corporate engagement could be explored to further promote formal education on

environmental conservation. For instance, Rhino Ark, which has a network of over 170 schools near water towers in Kenya, has implemented a customized curriculum that seamlessly integrates conservation awareness into the standard school syllabus in schools near Mau Eburu, South West Mau forest, Aberdares, and Mt Kenya forests. Various topics such as soil conservation, water management, pollution control, tourism, and environmental studies are taught alongside the existing Competency-Based Curriculum (CBC). These laudable efforts have been made possible because of a collaboration between Rhino Ark and the Ministries of Environment, Education, Science, and Technology in a public-private partnership arrangement (Rhino Ark Website 2024). Promoting such educational partnerships is crucial in easing forestry policy design and implementation, as observed by Bülbül et al. (2020), Mkumbachi et al. (2020), and Al Yaqubi (2020). However, caution should be exercised when administering these environmental education programs as they should be culturally and socially acceptable and appropriate (Nyongesa & Vacik 2018; Njeru & Fundi 2023; Mbuvi et al. 2022). Caution is important because sometimes strategies have unintended consequences, as in the case of Nigeria, where past strategies focused more on controlling and treating environmental issues rather than preventing them (Thathong, 2012).

Figure 2 also highlights the role of informal education avenues in promoting environmental education and awareness; this can be exploited to promote sustainable forest management in the ecosystems under study. For example, the Cherangany ecosystem has various conservation organizations implementing programs and projects to raise awareness. This includes 90 Community-Based Organizations (CBOs), 5 Non-Governmental Organizations (NGOs), 9 Community Forest Associations (CFAs), 7 Water Resource Users Associations (WRUAs), and several government agencies. Community engagement through improving participatory forest management and corporate participation can be fostered through the provisions of the existing "adopt-a-forest" framework for maximum environmental education, awareness, and sustainable forest management. For instance, in Kakamega, community efforts have been bolstered by the adoption of 200 ha by Her Excellency, the First Lady of the Republic of Kenya. Greater focus in such an arrangement should be aligned in a manner that ensures community livelihoods are secured. Therefore, the strategy for Kakamega to encourage the establishment of trusts or foundations where funds from willing corporates can be channeled for the benefit of engaged communities can have a beneficial impact on promoting environmental education and awareness in the four cases. Reviewed literature from the works of other scholars such as Rotich (2019), Rotich & Ojwang (2021), and Ongugo et al. (2017) in the

case of Cherangany all support the need for promoting partnerships for education and awareness. Moreover, reviewed empirical studies from other countries' cases support these strategies (Yamada et al., 2023; Chankrajang & Muttarak, 2017; Thathong, 2012). Besides addressing livelihood issues, corporates can also be at the forefront of promoting policy advocacy. For instance, case results indicate that corporations engage in activities aimed at building grassroots capacity and networks for nature conservation, promoting participation and equity in natural resource management, mobilizing public and political support for nature, educating young people about nature, and fostering effective conservation partnerships at local, national, and international levels as shown in the cases of Laikipia Wildlife Forum and Nature Kenya in Mt. Kenya ecosystem. Moreover, Nature Kenya works with a number of site support groups in the four case studies (Nature Kenya Website 2024).

Measuring the impact of educational and awareness programs is one of the requirements of an effective educational program. Results from the four cases show there are limited empirical studies on the measurement of environmental awareness and education impacts in the selected ecosystems. However, an awareness study conducted in the Kakamega forest ecosystem indicates that participatory forest management has improved forest management in forested sites. It is, therefore, urgent and important to conduct studies of the effectiveness of awareness efforts in the ecosystems. Conducting forestry educational and awareness studies within a forest ecosystem is crucial for cultivating a well-informed and environmentally conscious community. These studies provide valuable insights into the intricacies of the ecosystem, offering a deeper understanding of its biodiversity, ecological processes, and the delicate balance that sustains it. By disseminating this knowledge through educational programs and awareness campaigns, communities gain the tools to appreciate the significance of responsible forest management. Such initiatives empower individuals to make informed decisions and also foster a collective sense of stewardship. Forestry studies contribute to the identification of potential threats and challenges faced by the ecosystem, enabling proactive measures to mitigate them. Ultimately, a well-educated and aware community becomes a formidable force in advocating for sustainable practices, ensuring the long-term health and resilience of the forest ecosystem.

Moreover, results from the four study sites indicate a low integration of technology and innovative approaches in forestry education and awareness programs. With advancements in digital tools and platforms, leveraging technology can enhance the effectiveness of educational materials and outreach

campaigns. Digital technologies play a pivotal role in optimizing forestry education and awareness strategies, revolutionizing how information is disseminated and absorbed. Incorporating digital platforms, such as online courses, interactive applications, and virtual reality experiences, enhances accessibility and engagement. These technologies enable the creation of dynamic educational content, allowing learners to explore the intricacies of forestry in immersive and innovative ways. Additionally, digital platforms facilitate real-time communication, fostering a global community of individuals enthusiastic about forestry and environmental conservation. Social media has become a powerful tool for spreading awareness, while data analytics offer insights into the effectiveness of education campaigns. The integration of digital technologies broadens the reach of forestry education and also ensures that strategies are adaptive, interactive, and aligned with the evolving needs of a technologically advancing society, thus maximizing the impact of education and awareness efforts in the realm of forestry. Reviews from global literature have also supported this approach, and besides the use of national-level technologies such as the Jaza miti App, other alternatives such as the use of an Environmental Awareness Index (EAI) formulated using Google search data sourced from Google Trends can be explored (Dabbous et al., 2023).

In summary, this study advocates for a comprehensive, collaborative, and technology-driven approach to environmental education and awareness as a way to achieve sustainable forest management and conservation goals.

5. Conclusion and Recommendations

This study has highlighted the crucial role of environmental education and awareness in achieving sustainable forest management by cultivating values and promoting responsible environmental practices. Effective strategies encompass formal education, community engagement, digital platforms, corporate responsibility, media, arts, policy advocacy, and research with feedback loops. The examined cases have demonstrated commendable efforts in integrating these ingredients into the strategies within their management plans, enlightening stakeholders, and promoting sustainability. The study emphasized the need for measuring the effectiveness of educational approaches adopted in the ecosystems, revealing a lack of empirical studies and suggesting the need to leverage digital technology to enhance education and outreach and encourage county governments to take up a more active role in promoting environmental awareness. The limitation of this study is that it solely relied on a bibliographic

review and did not include a direct analysis of public opinions through interviews with stakeholders involved in managing the ecosystems. This omission resulted in a lack of qualitative and quantitative data that could have enhanced the discussion and allowed for a more direct response to the research's stated objective. It could be addressed by cross-referencing and using diverse data collection methods in future studies.

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Authors

Sylvester Ngome Chisika sylvesterchizika@gmail.com
International School of Urban Sciences, University of Seoul, 02504 Seoul, Korea.

Chunho Yeom (*corresponding author*) chunhoy7@uos.ac.kr
International School of Urban Sciences, University of Seoul, 02504 Seoul, Korea.

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