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Ecosystem-Based Adaptation Practices as a Nature-Based Solution to Promote Water-Energy-Food Nexus Balance

Kennedy Muthee *, Lalisa Duguma, Judith Nzyoka and Peter Minang

World Agroforestry (ICRAF), UN Avenue, Gigiri, P.O. Box 30677, Nairobi 00100, Kenya; l.a.duguma@cgiar.org (L.D.); j.nzyoka@cgiar.org (J.N.); a.minang@cgiar.org (P.M.)
* Correspondence: k.muthee@cgiar.org

Abstract: The objective of this study is to evaluate the contributions of ecosystem-based adaptation (EbA) practices to the water–energy–food (WEF) nexus balance, design practical pathways, and analyze barriers towards achievement of EbA-WEF balance. An area case study and descriptive methods were used to analyze data collected from 50 community forests (CFs) spread across three regions in The Gambia. Extensive information from relevant literature sources was also referred to in this study. Fourteen priority EbA practices were established and categorized into four major groups based on their application similarities. Among the anticipated ecosystem services were enhanced water resource conservation, food and feed production, enhanced energy supply, and improved community livelihoods to enhance their resilience. Pathways on how each practice under the broad category contributes to water, energy, and food were developed to demonstrate how they individually and collectively contribute towards the nexus balance. Key enablers identified included a conducive policy framework, institutional support, diverse incentives, information, knowledge, and technology transfer, and climate and non-climate barriers were cited as impediments. The paper concludes by outlining recommendations to overcome the established barriers.

Keywords: ecosystem-based adaptation; ecosystem services; livelihood; resilience; restoration; The Gambia; water-energy-food nexus

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Citation: Muthee, K.; Duguma, L.; Nzyoka, J.; Minang, P. Ecosystem-Based Adaptation Practices as a Nature-Based Solution to Promote Water-Energy-Food Nexus Balance. *Sustainability* **2021**, *13*, 1142. https://doi.org/10.3390/su13031142

Academic Editor: Nathanial Matthews

Received: 4 January 2021
Accepted: 19 January 2021
Published: 22 January 2021

1. Introduction

1.1. Study Background

Ecosystem-based adaptation (EbA) is among the fastest-growing adaptation concepts around the world [1], based on its cost-effectiveness, multiple benefits, and a wide range of applications in different landscapes [2]. The EbA approach entails incorporating biodiversity and ecosystem services into the broader adaptation strategy [3]. Further, Duguma et al. [4] presented evidence that EbA is a system-wide process that considers the interplay between people, policies, institutions, and broader ecosystems with the potential to promote landscape restoration and livelihoods if well harnessed. It has the immense potential to contribute to the developmental and environmental goals at local, national, and global levels, as noted by [5,6]. Over the years, different communities have established various EbA practices depending on their socioeconomic needs, ecological conditions, and desired adaptation outcomes. According to Hoff [7], EbA practices aim to achieve balanced and secure systems that maximize potential synergies and reduce potential conflicts. Reinhard et al. [8] and Rasul and Sharma [9] noted that the security of these practices is defined in terms of their safety, reliability, accessibility, and affordability, at the same time taking into consideration environmental concerns. These options have worked better and are more sustainable compared to other options, such as engineering-based options. This is due to their ease of application in different levels and scales, cost-effectiveness, inclusivity of local and scientific and indigenous knowledge, and reduced social and environmental externalities, among other factors, as Phoju et al. [10] established. However, different practices to promote ecosystem restoration, such as ecosystem-based adaptation, are challenged by the unsustainable usage of ecosystems and biodiversity to supply water, energy, and food to support livelihoods [11,12].

There is increasing research interest in investigating how the interplay between water, energy, and food in a nexus context can play a role in restoring degraded ecosystems and simultaneously support livelihoods that are dependent on them. Studies such as Thomas-Hope's [13] have explored how the three systems' interactions could promote the security and sustainability of ecosystems at global scales. The sustainable livelihood framework looks broadly at poverty reduction through building livelihood assets. The concept was introduced to the world first through the World Commission on Environment and Development (WCED) in 1987 through the "Our Common Future Report" [14] and developed further during the 1992 United Nations Conference on Environment and Development (UNCED) under Agenda 21 [15]. The four livelihood assets analyzed through the framework are social capital (e.g., connections, networks, and shared values and behaviors, among others), human capital (including capacity building, skills development, and awareness, among others), natural capital (for example, biodiversity, land, water, food, forests, and wildlife), and financial/economic capital (e.g., savings, credits, or other remittances). Integrating EbA and WEF concepts can play a crucial role in achieving wider ecosystem restoration and livelihood goals that a single system cannot reach. Furthermore, placing ecosystem-based adaptation in the middle of the nexus could help policy planners and decision-makers design intervention pathways that could lead to multiple environmental and livelihood benefits. This study aims to contribute to this growing discipline by establishing the paths through which the preferred EbA practices in The Gambia could contribute to the nexus balance and support livelihoods through income generation. In particular, the paper seeks to (1) characterize EbA practices in the 50 community forests studied, (2) analyze the contribution of prioritized EbA practices to the WEF nexus and livelihood assets, and (3) assess the existing barriers and enablers to promoting synergies and reducing trade-offs in the development of WEF nexus and livelihood assets through different EbA practices. It also gives practical insights to decision-makers and policy planners, such as intersectoral collaborations, incentivizing the communities towards EbA practice implementation based on current and future scenarios, and enhanced knowledge and technology transfer at low levels.

1.2. Scenario Description

Most ecosystem restoration, livelihood interventions, natural resource use, management, and decision-making strategies are sectoral from theoretical and practical perspectives. They have minimal consideration of the interlinkages among different sectors and the existing cross-cutting relationships among the three domains [5]. Consequently, the net effect has been the promotion of one system (such as agriculture for food) at the expense of the other interlinked segments such as water, energy, and livelihoods, as Muthee et al. [16] argued. At the resource use and decision-making level, Karnib [17] noted that water, energy, and food are viewed independently in most countries, with minimal cross-cutting policies and strategies. This has yielded conflicting laws and policies at national levels that have hindered the ecosystem restoration and livelihood promotion agenda. As a result, planning, management, and political decisions are conducted as a collection of individual parts and not as a whole interdependent and integrated system. Over the years, this approach has proven unsustainable and incapable of meeting local, national, and global resource use and management goals. This has necessitated more inclusive solutions such as the water-energy-food nexus to produce cross-cutting solutions with minimal trade-offs and maximum synergies among the three sectors [18]. One of the suggested solutions is integrating different ecosystem-based adaptation practices within the WEF nexus to achieve multiple benefits related to ecosystem restoration such as water, energy, food, and biodiversity conservation while promoting livelihood asset development at local and national levels if well implemented.

1.3. Water-Energy-Food Nexus in Land-Based Activities

The water-energy-food (WEF) nexus, though an old concept, gained international prominence during the Bonn2011 Conference: The Water Energy and Food Security Nexus—Solutions for the Green Economy held between 16 and 18 November 2011 in Bonn, Germany that visualized the interdependence between the three components [7]. One of the conference outcomes was the consensus that integrating the three aspects could improve the water, energy, and food balance when enabling policy and governance frameworks at different scales. The water-energy-food (WEF) nexus continues to gain research and practice prominence globally due to the interlinkages among these systems. It aims to help decision-makers and policy planners make cross-cutting decisions when managing these interlinked resources from a system-wide perspective instead of the traditional silo approach [9]. Furthermore, the interplay among water, food, and energy is essential for restoring the degraded ecosystems and supporting the livelihoods that are dependent on them, as [8,11] argued. Interactions and interdependence among the three systems are critical determinants of how societies can achieve sustainability and security [13,19] and move the globe closer to attaining targets set through the Sustainable Development Goals (SDGs), as argued by van Noordwijk et al. [20]. Furthermore, there is a need for stakeholder engagement, policy considerations, and the development of institutional capacity at different scales and levels of nexus interactions, using strategies such as ecosystem-based adaptation, which are system wide and multidisciplinary in approach [4,9,19]. This argument is supported by Boas et al. [21], who established that different domains cannot operate effectively unless they take a broader approach considering the trade-offs and complementarity of adopting a nexus approach for positive impacts to be realized at the landscape level.

A study by Pardoe et al. [22] established that mainstreaming the water–energy–and food nexus within the climate change discourse can enhance adaptation potential for the communities. The study cited the lack of clear policy and plan integration and coordination of actions within these sectors as constraints in achieving the sustainable adaptation goal. In agreement, Mpandeli et al. [23] noted that cross-cutting issues such as climate change require cross-cutting interventions such as the WEF nexus, which addresses sector-specific challenges and broader adaptation and mitigation challenges towards more resilient economies, livelihoods, and landscapes. From a policy perspective, Vasileios et al. [24] and Zhang et al. [25] argued that the WEF nexus can create an optimal environment where resources can be used and managed optimally and at the same analyze policy trade-offs and synergies in different sectors to promote sustainable development. WEF can also positively contribute to a sustainable global socioeconomic agenda such as SDG if well integrated within the national level, as Mpandeli et al. [23] noted, and further promote synergies within the set goal targets, as argued by [26,27]. Despite these potentials, research has pointed out that most developed frameworks have limited potential to address water, energy, and food simultaneously. To address these gaps, the study proposes developing an integrated theoretical framework that incorporates both EbA and WEF systems, as discussed in the section below.

2. Methodology

2.1. Proposed Theoretical Framework

The proposed theoretical framework aims to address the gaps identified in the WEF nexus by integrating both WEF and EbA in the same framework to address the shortfalls and synergizing potentials of each system. In so doing, drivers beyond WEF sectors, including social, economic, and political dynamics, to address multisectoral resource use and planning [28] are addressed. Two interlinkage levels are proposed in this framework. The first level links water, energy, and food, establishing that water is needed for energy and food production, energy is necessary for water supply and to support food production, and food production requires both energy and water. For example, over 70% of freshwater is utilized in food production globally through irrigation, a process that is also energy intensive [29]. Furthermore, there is a clear link between food and energy, in the sense that fluctuations in energy prices directly affect food prices. This is attributed to factors including the cost of preparing farming land, food distribution, and the supply of inputs, as Taghizadeh-Hesary et al. [30] established. The next two levels link the WEF nexus with EbA practices. Notably, different EbA practices, if well harnessed, can contribute to the development of a sustainable WEF nexus. The framework is applied in the next sections to develop practical pathways that can be used to achieve this balance. Placing ecosystem-based adaptation in the middle of the nexus could help policy planners and decision-makers design intervention pathways that could lead to multiple water, energy, and food, and the related ecosystems goods and services. These linkages are summarized in the theoretical framework presented in Figure 1 below.

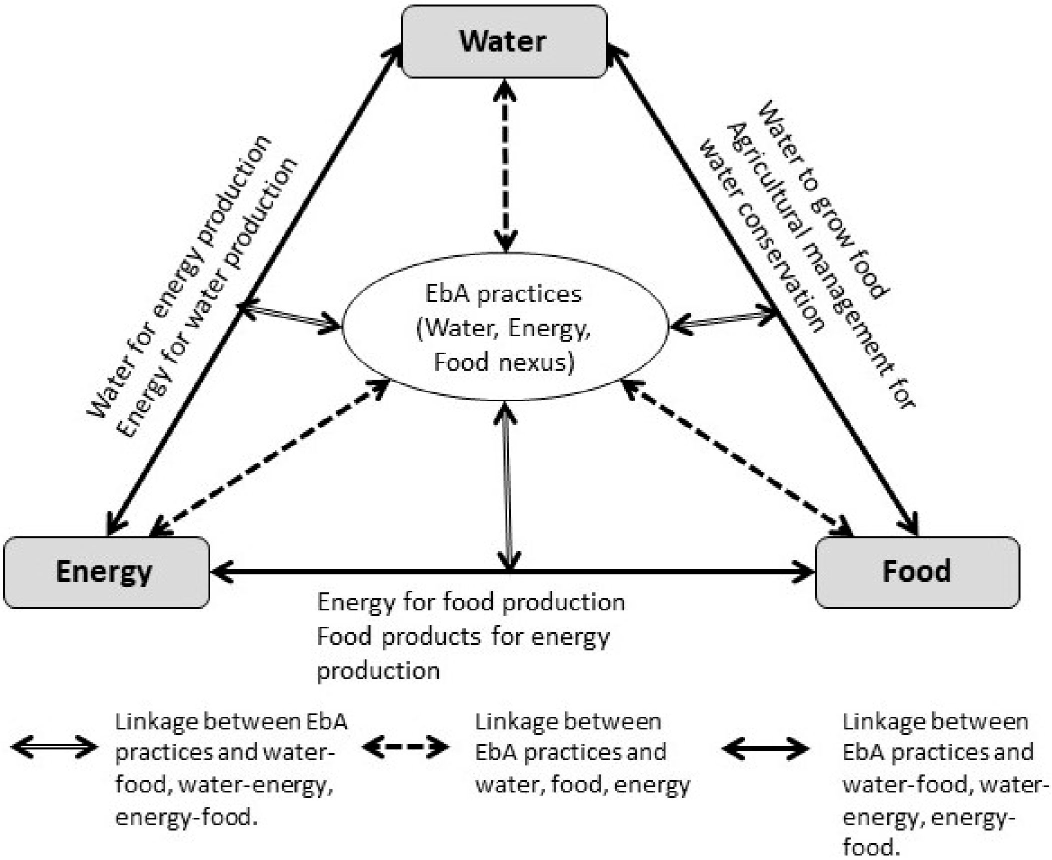

Figure 1. Linkages between ecosystem-based adaptation practices and the water-energy-food nexus (modified from Hoff [7]).

2.2. Case Study: The Gambia

The Gambia is a West African country with a land area of 10,689 km^2 and an estimated population of 2 million [31]. It stretches 320 km inland on both sides of the River Gambia, with the width varying between 24 km and 50 km. The country is located between humid rainforests to the south and arid desert to the north, which largely influences the ecological and biodiversity patterns. The Gambian communities are almost entirely dependent on different ecosystems for their livelihoods, resulting in increased ecosystem degradation and a decreasing ability to sustain their functionality [32,33]. The main livelihood activities are agriculturally based, supporting over 26% of the country's GDP. Farming is dependent mainly on soil groups and climatic conditions. Based on the global soils map classification developed by FAO/UNESCO and further revised by International Union of Soils Science (IUSS) [34], there are four major soil typologies in The Gambia. Ferralitic and ferruginous tropical soils are largely well drained and slightly acidic, dominating the upland areas and supporting the growth of grains. Alluvial soils are highly silted and largely support the growth of rice, and colluvial soils, which support vegetables growth, are widespread countrywide. As evident through precipitation and temperature pattern changes in different regions, climate change has had extensive impacts on different ecological functioning in The Gambia. For example, climate models project an increase in rainfall in Central River Region (CRR) and a marginal decrease in Lower River Region (LRR) of the Gambia within the 2020–2050 period, with a general reduction in the moisture index [35]. The mean onset dates of the rainy season are also projected to change, affecting the length of the growth patterns in The Gambia. On the other hand, the mean surface temperature is projected to increase across the regions, increasing the number of hot days up to 90 annually and temperature levels to over 45 °C. The climatic conditions are characterized by a short rainy season between June and October and a prolonged dry season between October and June, and an annual rainfall range of 850 mm to 1200 mm with a temperature range of 18 °C to 33 °C. The four agroecological zones of The Gambia are summarized in Table 1.

Table 1. Characteristics of different ecological zones in The Gambia (Source: Capacity4food Project [31]).

Agroecological Zone	Average Rainfall (mm)	Length of the Growing Season (Days)	Major Vegetation Types
Sahelian	<600	<79	Open savannah
Sudano-Sahelian	600–900	70–119	Savannah
Sudanian	900–1100	120–139	Woodland savannah
Guinea	>1100	140–150	Woodlands

This study focused on three main regions of The Gambia—the Central River Region (CRR), Upper River Region (URR), and Lower River Region (LRR). These particular areas have experienced high deforestation and forest degradation rates due to extraction of wood for energy use, construction, livestock keeping, and slash-and-burn agriculture, among other pressures [32,33]. Figure 2 below summarizes the three regions studied.

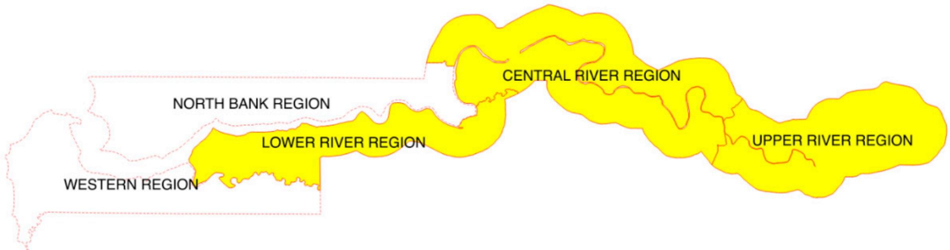

Figure 2. The Gambia administrative areas. The shaded region represents areas where the studies were conducted (Lower River Region—LRR; Central River Region—CRR; and Upper River Region—URR).

2.3. Research Design

The study mainly employed a qualitative research design. A case-study approach was adopted to gain in-depth and contextualized information of the study area and the communities living in it, as recommended by Crowe et al. [36]. Descriptive information related to livelihoods, ecosystems, impacts of climate change, and potential EbA options based on community awareness, gender preferences, and implementation practicalities was obtained through focused group discussion. It involved 15 men and women from the community forest management committee who were engaged separately, after which the results were combined for further analysis. The study also involved expert opinions from different technical persons from The Gambia government to establish the dynamics of EbA practices in the study areas based on the institutional and policy framework. Secondary data were also extensively sought to complement the primary data and establish existing literature gaps. The second part entailed designing pathways on how EbA practices can directly or indirectly contribute to the water-energy-food nexus development, either individually or collectively. The sustainable livelihood framework for poverty reduction was adopted to establish EbA practice contribution to social, natural, human, and economic capital to support livelihoods. The last step involved establishing the barriers and enablers of applying the WEF nexus in EbA practices, which was qualitatively presented based on the community feedback and relevant literature review. Table 2 below summarizes the characteristics of the studied community forests.

Table 2. Summary of the community forests studied.

Region	No. of Community Forests	Total Community Forest Area (ha)	Population	
			No. of Households	Total Population
CRR	23	3949.1	1292	12,163
LRR	11	2419.3	887	8041
URR	16	2235.0	655	8695
Total	**50**	**8603.3**	**2834**	**28,899**

3. Results and Discussions

3.1. Preferred EbA Practices in the Community Forests

The communities mentioned and ranked the preferred practices differently based on their levels of understanding and the implementation practicality. Figure 3 below summarizes the number of mentions of different EbA practices from the 50 community forests studied.

These results were further clustered into four major categories based on their similarities in implementation, associated ecosystem goods and services, and livelihood support benefits. Table 3 below summarizes the four clusters, the related EbA practices under each cluster, a general description of the practices, and associated ecosystem goods and services and livelihood benefits.

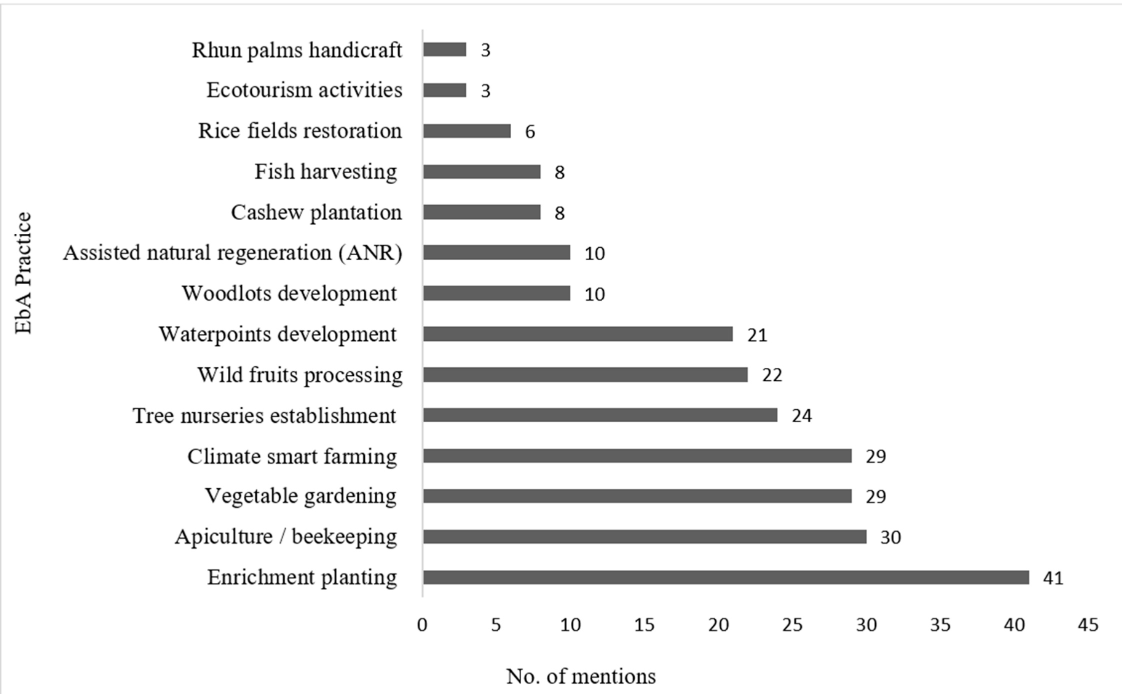

Figure 3. Number of mentions of different EbA practices.

Table 3. Characterization of EbA practices identified.

Broad EbA Cluster	Related EbA Practices	General Description of the Practices	Associated Ecosystem Goods, Ecosystem Services, and Livelihood Benefits
Forest and tree system development	Enrichment planting	Introduction of valuable species to an ecosystem without removing the valuable ones that are already present	Water conservation, wild fruits, fodder, enhanced energy source, soil stabilization, climatic amelioration
	Assisted natural regeneration—ANR	Human-led interventions to accelerate the natural regeneration of trees	Food, shade, habitat protection
	Woodlot development	The development of a portion of land for wood tree growing	Income, fuelwood, timber, and non-timber products
	Cashew plantation establishment	Establishment of cashew (*Anacardium occidentale*) plantations inside the farm or along farm boundary	Firebreak, windbreak, food, shade, income, fencing
Climate-smart farming system	Apiculture (beekeeping)	Process of rearing honeybees	Honey, wax, pollination, enhanced crop production
	Fish harvesting	Harvesting fish for domestic and commercial purposes	Food, income
	Vegetable gardening	Establishing plots for fruit and vegetable growing	Food, income
	Climate-smart farming practices	Diverse agricultural practices that are climate-resilient to increase food production	Food, income, soil stability, water conservation
Nature-based businesses	Rhun palm handicraft development	Planting Rhun palms to support handicraft activities	Income, food, fiber, wood
	Tree nursery development	Developing tree nurseries to propagate seedlings for planting	Seedlings, income
	Wild fruit processing	Collecting, processing, and packaging of wild fruits for human consumption	Income, food
	Ecotourism activities	Socially responsible travels such as nature travels, bird watching, and cultural visits	Income, conservation
Water resource development systems	Water point development	Development and rehabilitation of different water points to conserve and supply water	Water supply, food production, energy production
	Rice field restoration	Process of restoring the functionality of flooded pieces of farmlands used for rice growing	Food, water supply, income

3.1.1. EbA Practices Under the Forest, Tree, and Wood Development System Cluster

The first cluster on forest, tree, and wood development comprises four related EbA practices—enrichment planting, assisted natural regeneration, woodlot development, and establishing cashew (*Anacardium occidentale*) plantations. The most recurrent practice was enrichment planting by introducing high-quality and valuable species in the community forests without removing the species already present. It was mentioned by 82% of the respondents with a high citation in the community forests management plans as a feasible option. Some related enrichment practices mentioned included planting broom grass for soil enrichment and stability; planting pasture and guinea grass, as well as tree and fodder planting. Enrichment planting works well in degraded community forests, though it has a low adoption rate at almost zero, as noted by Duguma et al. [35]. Communities also cited assisted natural regeneration (ANR) activities that entailed applying various human-led interventions or limiting access and using trees to accelerate their natural regeneration. In particular, 20% of the community members identified fire break establishment as feasible ANR (an example of a fire belt is in Scheme 1 below). Fire breaks are created by clearing a 10 m buffer zone (or wider) from the highly probable direction of fire to break its intensity and spread in a given area, thus protecting forests and protected areas from fires, as evident in the photo below. These belts have also yielded numerous social benefits, such as serving as roads to ease movement and connecting different villages such as Bateling, Kwinela, and Tendaba in the LRR, as well as making it easy for children to access schools and other facilities. Other activities mentioned under ANR included supporting the growth of wildings and competitor management around priority trees to support ecosystem goods and service production. The study revealed no existing record of ANR in the studied community forests (CFs) despite the immense potential to contribute towards natural restoration and regeneration.

The establishment of woodlots was identified as a feasible EbA practice by 20% of the respondents to ease pressure related to meeting energy demands in forests, savannahs, and parks. Two levels of woodlots were established: public woodlots in degraded public woodland and private woodlots in private farmlands with 58% and 34% preference rates, respectively. In the private lands, the practice involves setting aside a portion of privately owned land (about 0.1 ha) for fuelwood, timber, charcoal, and non-timber product provision. This approach was cited as feasible in degraded farmlands with a possibility of intercropping vegetables, groundnuts, and other domestic crops for value addition and multiple benefits related to livelihood and ecosystem restoration. Some of the mentioned species that could do well in farm-level woodlots include cashew (*Anacardium occidentale*) and mango (*Mangifera indica*), indicating that several farmers have the practice in place already. However, there is a huge potential to exploit groundnut shells as energy sources since groundnut is already a dominant crop in The Gambia. The establishment of cashew plantations was mentioned by 16% of the respondents as an effective EbA practice to support livelihoods and promote ecosystem restoration. Cashew trees are multi-beneficial to the community regarding food provision, fencing, windbreaking, and fire breaking, and can be planted along farm borders or inside individual farms. The tree is also tolerant of The Gambia climate and would do well in different ecosystems to yield multiple benefits.

3.1.2. EbA Practices under the Climate-Smart Farming System Cluster

Under the climate-smart farming system cluster, apiculture (beekeeping) development, vegetable gardening, different climate-smart farming practices, and fishing activities were chosen as relevant EbA practices. Beekeeping, the process of establishing and maintaining beehives to produce honey and wax for domestic and commercial use, was highly ranked as an EbA strategy applicable to the degraded farmlands at 60%. The Gambia has a long history of beekeeping, as Kent [37] noted, with the anticipated ecosystem goods and services, including enhanced crop pollination, improved farm crop production, and wax and honey production. Despite its vast market potential, the practice remains unprofitable, mainly due to the low adoption of honey harvesting and packaging technologies. Vegetable gardening activities, which included setting aside plots for vegetables and fruit trees for domestic and commercial use, were also identified as a feasible EbA option, with 58% of the respondents mentioning it. These gardens were cited as a possible source of food- and income-generating opportunity, especially for women around their homesteads, with multiple benefits such as meeting nutritional needs at the household level. The option was only applicable in restoring degraded farmlands where the utmost care could be applied to protect the gardens from animal intrusion and theft. A total of 58% of the respondents explicitly mentioned diverse climate-smart farming technologies. These included, among other things, planting early-maturing crops, planting an improved variety of seeds that can endure the harsh climate, mixed farming practices, agroforestry practices, crop rotation, mulching, and compost making. These practices were deemed to have immense potential to transform the degraded farmland ecosystems and meet household livelihood needs.

Scheme 1. Fire belt in Kiang West National Park, a community protected area in the Lower River Region (LRR) of The Gambia. (Photo: Kennedy Muthee/World Agroforestry).

3.1.3. EbA Practices under the Nature-Based Businesses Cluster

Achieving the sustainable sourcing of seeds and seedlings for planting was cited as a significant challenge, hence the need to establish tree nurseries where tree seedlings can be propagated and given special care for later planting in the degraded areas. A total of 48% of the respondents considered tree nursery development a viable EbA practice from both livelihood (enterprise) and restoration perspectives. Wild food processing, a process that involves the collection, processing, and packaging of wild fruits for human consumption, was mentioned as a viable option by 44% of the studied communities. This practice was cited as feasible in restoring degraded landscapes, with additional benefits such as earning the communities an income to support their livelihoods, meeting nutrition needs, and acting as a food source. Despite the considerable potential and variety of different tree species such as baobab, *Ziziphus*, bush mango, tamarind, and hibiscus to provide stock for fruit processing, the practice remains little adopted in The Gambia. Some of the reasons behind the low adoption include the low capacity to process and package fruits for commercial viability as well as poor development of value chains and value addition from the farm to the end consumer. In terms of awareness level, 48.7% of the respondents established that they had been involved in collecting and processing wild fruits for food and income purposes. A total of 6% of respondents mentioned ecotourism-related activities as a feasible EbA option. These included nature travels, bird watching, and cultural visits in the CFs to promote ecosystem functioning and promote local community livelihoods. The community members (6% of the respondents) also cited Rhun palm handicraft development for socioeconomic uses as viable EbA options, with fruits, fiber, wood, roofing, and fencing being additional ecosystem goods. Rhun palm is among the dominant tree species in The Gambia due to its adaptability characteristics such as durability and termite resistance. It remains one of the most highly exploited tree species for its economic benefit. Nature-based businesses go beyond earning income to support community livelihoods and positively contribute to enhancing the water, energy, and food sectors individually and collectively.

3.1.4. EbA Practices within the Water Resources Management Cluster

Water was mainly mentioned as the bottom line for ecosystem restoration and livelihood support. A total of 42% of the studied communities cited water-point establishment and development as essential for feeding livestock, domestic use, and restoring ecosystems. Particular practices identified included enhancing water recharge technologies, water point protection, sinking boreholes, rehabilitating inland water valleys, and water ponds for domestic use, and livestock watering. Rice field rehabilitation through, among other things, development and rehabilitation of dykes to sustainably supply water was cited by 12% of respondents, who considered rice to be their staple food, in agreement with Dibba et al. [38]. Rice fields are flooded pieces of farmlands used for rice growing in addition to supporting other ecological functioning. Water resource development and rice rehabilitation practices are associated with increased food production through rice production, improved livelihoods through rice sale as an economic activity, energy production from rice husks, and enhanced water systems development.

3.2. *Pathways towards WEF Nexus Development through Different EbA Practices*

Different pathways were established to establish how ecosystem-based practices under the four clusters can contribute to WEF nexus development. The arrows establish linkages on how particular EbA practices contribute to enhancing water conservation and security (W), supporting livelihoods and community resilience (L), increasing the supply of food and feed (F), promoting biodiversity conservation and ecosystem service supply (B), and enhancing the supply of energy at different scales (E) in a nexus setting. Figure 4 below develops the pathways through which forest and tree systems development activities such as enrichment planting, assisted natural regeneration, and farm-based agroforestry practices (including woodlot establishment and cashew planting) can contribute to WEF nexus development, in addition to livelihood support and enhancing biodiversity conservation.

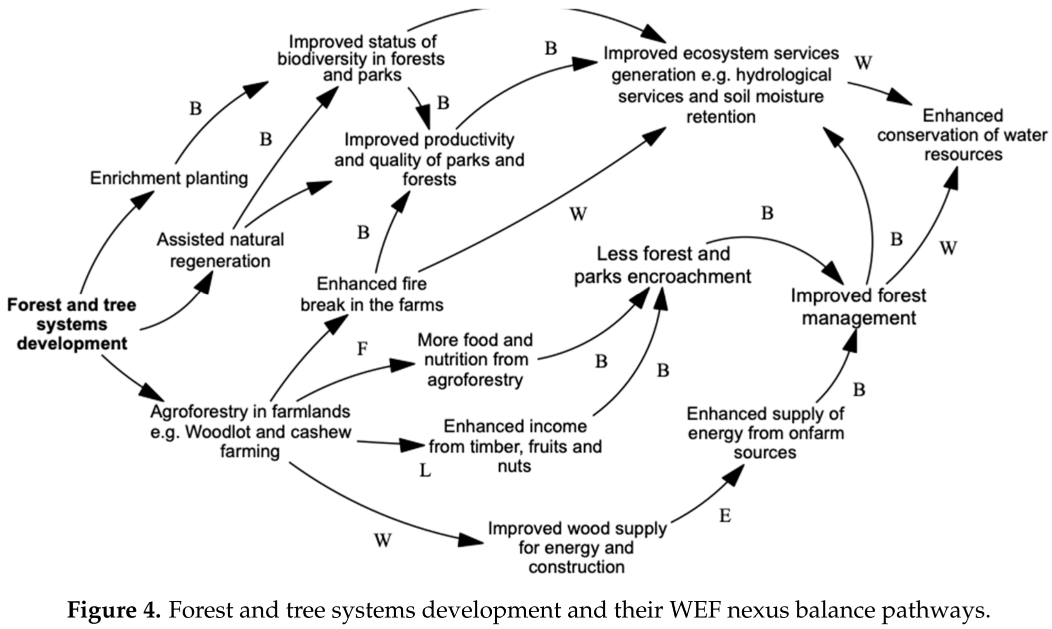

Figure 4. Forest and tree systems development and their WEF nexus balance pathways.

Within the forest and tree systems development cluster, different EbA practices had clear pathways to contribute to the WEF nexus and associated benefits. A quantification figure given by Chu et al. [39], for example, indicated that enrichment planting alone can reduce soil erosion by 20–54%, reduce the annual flow of surface water by 11–43%, and reduce surface water loss by 42–64%, with more preference given to native over exotic tree species. Consequently, this can directly contribute to improving biodiversity and productivity in the CFs and enhancing the regeneration of ecosystem services, as portrayed in Figure 4 above. Agroforestry practices, including cashew and woodlot establishment, directly contribute to food security (through cashew fruits and cashew oil), energy (through increased charcoal and firewood stocks), enhanced groundwater recharge and conservation, as well as reduced surface water evapotranspiration [40]. To illustrate, Njenga et al. [41] estimated that 40% of farmers in Kenya entirely depend on agroforestry systems developed in their lands as a source of firewood. Simultaneously, this system can contribute to income generation by selling timber, fruits, and nuts to support livelihoods and promote biodiversity conservation by protecting habitats. Huges et al. [42] estimated that agroforestry practices can increase household income in Kenya by over USD 43 annually, and Shukla et al. [43] estimated that 65% of India's timber demand is met through on-farm trees. Furthermore, the United Nations Economic Commission for Africa [31] reported that cashew nuts are among The Gambia's highest income earners, accounting for 20.6% of total exports in the agricultural sector. The overall effect of the forest and tree systems development using different EbA practices promotes WEF nexus building with additional benefits related to biodiversity conservation and improved livelihood. This is also replicable in other tracks through activities such as enrichment planting and assisted natural regeneration. However, the development of sustainable forest and tree systems to increase The Gambia's energy stocks requires planting the right tree species at the right time and place for the right purpose [44].

The second pathway summarized in Figure 5 explores how climate-smart farming clusters, including vegetable and fruit gardening, improved fish farming practices, and diverse climate-smart farming technologies, can contribute to balanced WEF nexus building. For example, the proper harnessing of climate-smart farming technologies can increase energy stock through crop residuals [45], and simultaneously increase food stock (through fruits and vegetables) and earn sustainable community livelihoods by selling excess produce [46,47]. A cost-benefit analysis of the economic viability of vegetable and fruit gardening by Langellotto [48] revealed that this activity can produce fruits, nuts, and vegetables worth over USD 677 annually, with the value mainly depending on THE local environmental and socioeconomic context and choice of crops. From the water side, climate-farming systems can improve soil conditions and ground cover that allows better water infiltration and reduces surface water runoff and rates of evaporation experienced in the bare lands [49,50]. Pruning old vegetables and fruit trees from vegetable gardens can supplement energy sources at the household level. Ultimately, this supports the entire WEF nexus system to achieve the required ecosystem restoration, livelihood development, and biodiversity conservation goals.

Figure 6 below shows the links based on nature-based businesses such as Rhun palm handicrafts, ecotourism activities, tree nursery development, wild fruit processing, and marketing. These processes are primarily designed to support community livelihoods and boost their resilience by generating income. Rhun palms, being a dominant tree species across The Gambia, have considerable potential for a sustainable business case. Thoma and Camara [51] estimated a potential gross and net income of GMD 2.6 and 1.7 million, respectively. On the other side, studies have explored the socioeconomic values of tree nurseries, estimated at KES 7.54 million per tree nursery production cycle in Kenya [52], and a net annual profit ranging between ETB 338,377 and 810,183 in Ethiopia [53]. The Gambia's location and accessibility position it as an ideal ecotourism destination. The River Gambia enhances navigation inland to most of the existing parks and protected areas with plausible wildlife and cultural attractions. Lodging and recreation services are the primary services derived from ecotourism centers, which can earn over USD 5000 in profits per center if well developed, according to Duguma et al. [35]. Besides direct earning, different nature-based businesses can reduce the destruction of ecosystems and support ecosystems goods and services related to the water-energy-food nexus. For example, developing ecotourism centers can provide an alternative source of income and livelihood to the communities, thus reducing forest destruction in search of timber and charcoal for sale. Additionally, tree nursery development creates a sustainable source of seeds and seedlings needed to restore degraded forests, ultimately increasing the energy stock and source of wild fruits for biodiversity and human consumption. These cross-cutting benefits promote the water-energy-food nexus balance.

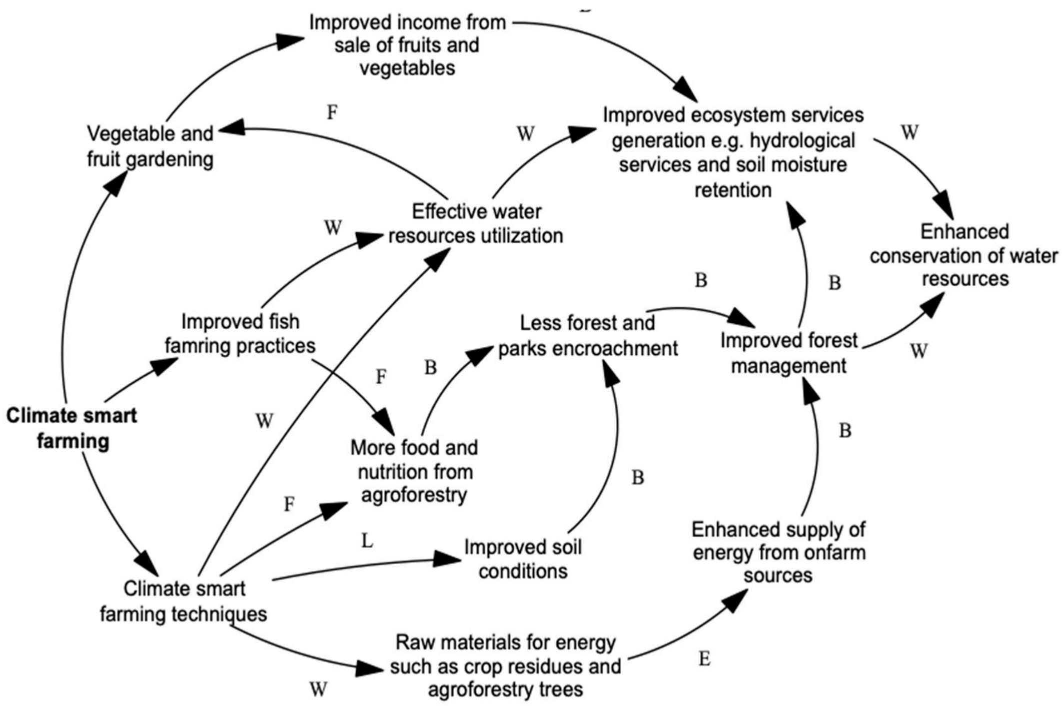

Figure 5. Climate-smart farming practices and their WEF nexus balance pathways.

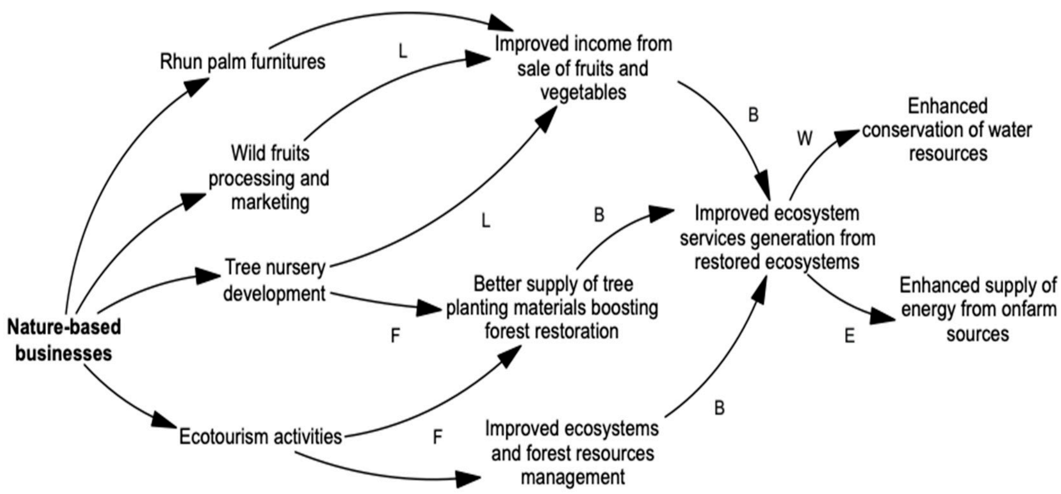

Figure 6. Nature-based businesses and their WEF nexus balance pathways.

Lastly, Figure 7 focuses on water resource management activities such as water point rehabilitation and rice field development. In the water resource management system, related EbA practices include water point development and rice field development. Some of the pathways involve developing water points and rehabilitating rice fields to enhance flow, conservation, and water supply in the entire system. Soullier et al. [54] noted that rice is The Gambia's staple food, with a 117 kg annual per capita consumption and a net import of 83%. As such, developing rice fields can meet sustainable food supply and earn farmers an extra income to meet their livelihood needs. Rehabilitating rice fields and developing water points have additional ecosystem benefits, including enhanced recharging of surface and groundwater, lower water salinization, increased soil nutrients, and water supply stabilization [55,56]. In The Gambia, the intrusion of saline water into farmlands has significantly affected farm productivity and ultimately impacted both farmers' livelihoods and food security [57]. Thus, rehabilitating the rice farms and developing water points can directly lead to reduced water salinity and improved food (rice) productivity. A water rehabilitation suggestion proposed by Bagbohouna et al. [57] is constructing a dam at Sambangalou to limit the amount of saline water from the Atlantic Ocean from entering farmlands through the River Gambia and its tributaries. The same dam can also increase freshwater flows to promote rice farming in inland The Gambia during the prolonged dry season, thus serving multiple ecosystem benefits. From an energy perspective, different studies such as [58–60] have explored the potential of rice straw and rice husks as a potential feedstock for the production of biofuels to produce heat and electricity at household and micro-industry levels. This potential is minimally exploited in The Gambia despite its ability to transform the biofuels sector. In essence, developing water points and rice fields can enhance water conservation and flows, consequently increasing energy and food production in The Gambia.

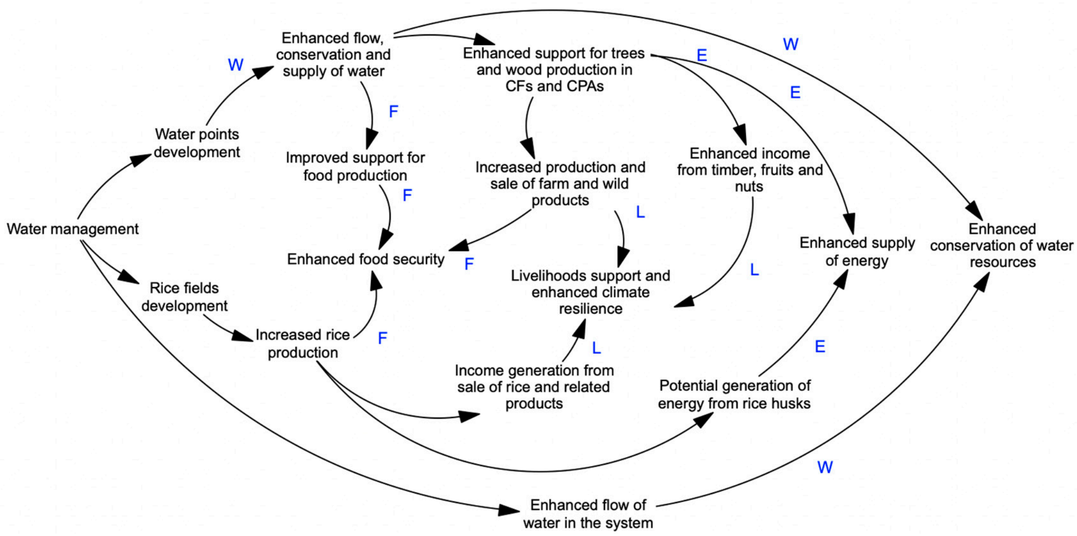

Figure 7. Water resource management practices and their WEF nexus balance pathways.

3.3. EbA Practice Contribution to Livelihood Development through the Sustainable Livelihood Framework Lens

The sustainable livelihood approach framework explores the sustainable livelihood context by, among others, establishing the factors that can improve their livelihoods through increased livelihood assets [15]. Four capital contributions are identified in this framework—natural, human, economic/finance, and social capital—which can be developed through the effective implementation of different EbA practices. Natural capital is the main livelihood asset that the community can use in achieving sustainable livelihoods. According to Tuong [61] and Serrat [15], natural capital refers to natural and environmental stock such as soil, water, biodiversity, and vegetation, from which ecological goods and services are derived to earn a livelihood. All EbA practices are anchored on natural capital—for example, enrichment planting, woodlot establishment, and vegetable gardening—based on the interplay between water, soils, and vegetation operating within a conducive environment. Apiculture activities and fish harvesting are anchored on the availability of biodiversity (bees and fish) and the right environment, both of which are finite resources.

The net synergistic effect can be achieved when the natural resource base is utilized optimally, considering regeneration through natural and human processes. These may include enrichment planting and cashew planting to increase the vegetation cover. Insufficient consideration of the finite nature of natural capital can translate to a net trade-off in the system. For example, EbA activities such as fish harvesting and handicraft activities without clear mechanisms to replenish the extracted resources can decline in the long run. This calls for a precise balance of the usage and regeneration of the natural capital.

Human capital refers to a broad spectrum of knowledge, skills, physical capacity, and the ability to earn a living, thus eradicating poverty [14]. Most EbA practices, such as ecotourism activities, handicraft activities, wild fruit processing, and the development of apicultural activities, directly contribute to human capital development by transferring knowledge, skills, and expertise to implement such actions. This can be further enhanced through a well-organized community and peer-to-peer training to transfer these skills. In so doing, social capital, which includes social networks, relations, associations, and affiliations, can be built within a given locality. For example, EbA practices such as fish harvesting and processing can build strong community involvement in this practice, where they share tools, skills, and knowledge to perfect their art. Social and human capital development directly contributes to building economic or financial capital in terms of accruing cash, savings, and other economic assets [61]. One of the direct pathways towards building economic and financial capital is establishing strong natural resource-based enterprises around ecotourism, tree nursery, vegetable garden, handicraft, wild fruit, and apicultural activities. Packaging and selling the final products such as fruit juice, packaged honey and wax, furniture, seedlings, and vegetables to the already existing market can generate extra income for the communities.

3.4. Enablers and Barriers towards Strengthening the WEF Nexus through Different EbA Practices

A conducive environment is necessary for EbA practice contribution to WEF nexus and capital building. The main climate barriers established within the studied community forests are temperature and rainfall, with a consensus on decreasing and variable rainfall patterns and increasing temperature. This is backed by scientific evidence, with Duguma et al. [35] citing a 0.33 °C increase in temperature in the 1991–2015 period. Furthermore, the 1965–2000 period recorded an increase in areas receiving an average annual rainfall of 800 mm from 36% to 93%. This directly impacts the mentioned EbA practices and their ability to contribute to WEF nexus balance and capital assets development. To illustrate, agricultural production is mostly rain-fed; thus, changes in rainfall patterns are harmful to sustainable water supply and food production and energy provision and, in essence, reduce the capital stock. Changing and varying rainfall and temperature patterns jeopardize over 68% of jobs directly created through the agricultural sector and 40% and 26% of The Gambia's national export and national GDP, respectively. They are also associated with the shrinking of ecosystems and, consequently, reduced ecosystem goods and services, a case in point being the woodland ecosystem that declined from 80% to 42% in the 1940–2001 period [34]. Key enablers cited by the communities included the right policy framework, support from different institutions, different levels, and scales of incentives, technology, and knowledge transfer mechanisms. However, a community-level assessment of the policy understanding revealed a major gap in the knowledge of the existing national policy framework related to the WEF nexus and EbA practices. Some of the mentioned incentives included subsidizing and distributing farm supplies, access to affordable credit and financial support, developing value chains, and markets for the finished products. Putting these measures in place can directly contribute to promoting WEF synergies with minimal trade-offs that directly contribute to the capital stock base.

4. Conclusions and Insights for Practitioners

EbA practices were established as key in promoting water, energy, and food balance; enhancing ecosystem restoration and biodiversity conservation; and supporting livelihoods. Clear pathways were drawn to portray the nexus linkage and address the broader ecosystem and livelihood goals. However, the achievement of this objective is subject to addressing the established barriers, strengthening the enablers, and looking at the interactions and interlinkages from a system as opposed to a singular point of view. Several practical implications for decision-makers and policy planners were made on how EbA practices can promote the WEF nexus and contribute to the development of livelihood assets. These include enhancing intersectoral collaboration across different institutions, policy frameworks, and departments to reduce policy and institutional conflicts in the water, energy, and food/agricultural sectors. Increased incentives through credit facilities, subsidies in farm inputs, enterprise and market development, building capital, and promoting the development of different EbA practices are recommended strategies to strengthen this framework. At the local level, measures such as the transfer of technical knowledge and information through platforms such as extension services and peer-to-peer learning are also crucial for equipping the practitioners with the technical capacity to build their capital and manage available resources effectively. Designing interventions such as EbA practices should be based on current and future climate and adaptation scenarios to promote their sustainability. Notably, climatic change dynamics continue to evolve based on both natural and human influencers; thus, the interventions should be futuristic based on the past and current changes. There is also a need for deliberate efforts from government agencies, development partners, and other stakeholders to raise awareness and build social and human capital among the parties involved in the use and management of natural resources.

Author Contributions: Conceptualization, K.M. and L.D.; methodology and formal analysis, K.M., L.D., and J.N.; writing—original draft preparation, K.M., L.D., J.N., and P.M.; writing—review and editing, K.M., L.D., J.N., and P.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Forests, Trees and Agroforestry (FTA) Research Program of the CGIAR, Grant Number FP 4 and FP 5.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: We appreciate the thoughtful and useful insights from the reviewers that helped in improving the quality of this manuscript. The underlying research was carried out as part of the Forests, Trees and Agroforestry (FTA) Research Program of the CGIAR, specifically Flagship 4 (FP 4) on landscapes dynamics, productivity and resilience, and Flagship 5 (FP 5) on climate change adaptation and mitigation.

Conflicts of Interest: The authors declare no conflict of interest.

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