

**Review Article**

Sustainable Environmental Conservation in East Africa through Agroforestry Systems: A Case of the Eastern Arc Mountains of Tanzania

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Abstract: Sustainable conservation of any ecosystem needs a balance between resource utilization and management. The Eastern Arc Mountains (EAM) of East Africa which covers a large area more particularly in Tanzania needs such kind of balance for its sustainability. With potential biophysical resources such as fluvial, vertisols and xerosols soils with the annual rainfall exceeds 1200 mm per year, may attracts more degradation than conservation. This review aims to assess the influence of agroforestry and related farming systems in the intensification of sustainable conservation in the area. Thereby, we reviewed 39 peer reviewed publications from the data base and some secondary data to attain the goal. It is discernible that agroforestry has increased crop yields for over 50% in the area. However, the ongoing degradation threatens the sustainability of the EAM. Forest degradation will offset over 100 million tons of carbon that is stored in the EAM. Besides, environmental degradation will significantly affect the water sources that feed over 3.5 million people in the downstream. Then, the supply of water for Hydro-Electric Power, environmental requirements and agricultural activities in the downstream will be adequate affected. To curb the authentic and potential degradation, the Eastern Arc Mountains Conservation Endowment Funds (EAMCEF) is operational in the area. Norway is among the great funders of EAMCEF. Therefore, for the robustness of sustainable conservation in EAM, a collective effort from various stakeholders especially donors are needed.

Keywords: Agroforestry Systems, Climate Change, Conservation, Degradation, East Africa

1. Introduction

The Eastern Arc Mountains (EAM) of East Africa are endowed with potential biophysical resources that can allow numerous agricultural systems (e.g. agroforestry systems) to be practiced [18]. The area has a wide range of plant species and can further accommodate the integration of diverse tree crops [22]. Seemingly, a number of large-scale international donors like World Wildlife Fund (WWF) and Alliance for Green Revolution in Africa (AGRA) have earmarked the area to be significant for both human need and environmental requirements. These international donors have a belief that

sustainable conservation is a surest path of elevating adaptation and mitigation in the area.

The increasing food demand due to global population increase, has forced the excessive utilization of available environment resource to produce the needful [8, 23]. This production need not only to be high, but also to be stable and sustainable [30]. In sub-Saharan Africa this sorts of production is urgently needed to feed the under-nourished millions of people [9, 32]. However, this needs good farming systems that can optimally increase yields to curb hunger and famine in the region. Among other things, agroforestry appeared to have significantly increased stable yields in

various areas where adopted [18, 29, 33, 36]. East Africa has some potential ecosystems that can accommodate agroforestry systems to increase yields and food security [2, 3, 33].

Agroforestry is among the conservational practices that can sustain a number of economic, social and ecological significance [18, 29, 36]. In whole, it optimizes crop productivity, restores the degraded environment and improves environmental services in the area. It is a good proposition the as it can curb the problems related to hunger, poverty and environmental stress [5]. Mbwambo et al. [15], showed that the adoption rate of Agroforestry system in Tanzania is not sufficient because only 49% of the small scale farmers (peasants) have adopted alley intercropping (hedgerow), 18% improved fallow, whilst 18% have adopted home garden. Therefore, effective initiatives are to be taken to increases agroforestry adoption [3]. We are proposing agroforestry in the region because most agro-ecological zones in Tanzania and Kenya have already affected by climate change and thus, the people are encroaching the EAM for obtain their livelihoods [11]. The Intergovernmental Panel on Climate Change grouped Tanzania as among the thirteen countries worst affected by the impacts of climate change and vulnerability and has weak adaptive capacities [12]. Basing on that juncture, the country is at risk of failing to feed the increasing population because about 70% of her people depend on rain-fed agriculture and they have weak purchasing power to access the imported food from the market [32]. The report by IPCC, imply that people look for alternative livelihoods including the encroachment in resources areas that are not severely impacted by environmental stress. Tin this aspect, the livestock grazers is the leading group in encroaching the ecosystem to search for water and pasture for their cattle [7, 10, 13]. Therefore, the proposition of sustainable practices than can conserve the ecosystem for a longer time is fairly accorded. This includes the adoption of immediate and long-term remedies that relieves the vulnerable ecosystems and people in the area [11].

This study aims to review the promises of agroforestry systems to sustainable conservation in the Eastern Arc Mountains. It groups agroforestry and allied conservation practices as tool powerful tools for adaptation to the on-going climate change impacts in the study area. The attached socio-ecological benefits of agroforestry would impress other parts of the country to adopt it to benefit the same [5, 6]. The study falls on the interest of researchers, farmers and development partners i.e. The Eastern Arc Mountain Conservation Endowment Fund (EAMCEF). Therefore, agroforestry is considered as a tool that raises the resiliency of the vulnerable communities in most developing countries as a result of climate change impacts as advocated by IPCC and UNFCCC.

2. Materials and Methods

2.1. Profile of the Study Site

The Eastern Arc Mountain (EAM) is comprised of thirteen

separate blocs with their location stretching from South-East Kenya through South-Central Tanzania (Figure 1). They are situated between 3° 20' to 8°45' S latitude and 35° 37' to 38° 48' E longitude covering an area of around 3300 km² of sub-montane, montane, and upper montane forests. The current forested part in the Eastern Arc Mountains is less than 30%, or some 1440 km², of the estimated original forested area. The EAM biophysical characteristics (soil, vegetation and rainfall) are suitable for diverse agricultural systems. They have suitable biophysical characteristics compared to most parts of the country. It covers more than 15 districts in the country.



Source: Adopted from Burgess et al. [2]

Figure 1. Map showing 12 Eastern Arc Mountain blocs in Tanzania and 1 in Kenya.

2.2. Methodology

We selected 39 peer reviewed journal papers, government and international organizations reports to review for this paper. Studies conducted in the area or similar ecosystems and published in international journals were given high consideration in the selection. In whole, we gave priority to authentic journals and reports which were recently published. Similarly, we adhered to all intellectual property rights. Secondary climate data i.e. rainfall and temperature were analyzed through the Mann-Kendall Test [39]. In addition, we designed a conceptual framework to synchronize important aspects of the study (Figure 2).

3. The Conceptual Framework

For sustainable conservation, we need to grasp the socio-economic and ecological significance of agroforestry (Figure 2). It serves the duo function of sustaining the human needs and environmental requirements from [26]. This framework

justifies its sustainable conservation.

In the Eastern Arc Mountains especially in western and eastern Usambara, and Uluru mountains; mangoes, oranges and coconuts trees, maize, cassava, beans and sugarcane are some of the dominant crops produced in the area.

Agrosilviculture, agrosilvopastoral and other forms of agroforestry system are integrated in the study area [26]. This integration offers numerous potentials to both the people and ecology (Figure 2).

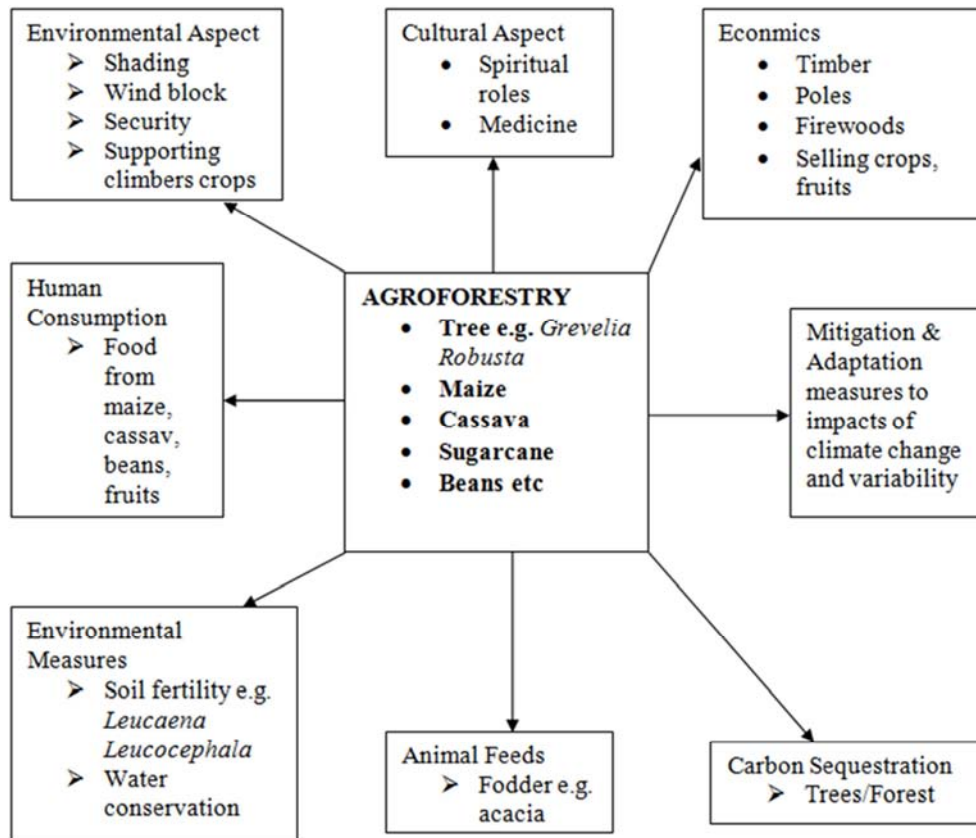


Figure 2. Conceptual framework of agroforestry.

The conceptual framework in figure 2 above convey the information that through agroforestry; a wide range of social, economic, cultural and ecological just to mention a few, can be obtained. This is particular important in areas where the livelihood of most people is limited. Therefore, in the study area where most people are poor, it is advised to adopt agroforestry as among the major livelihoods to get the aforementioned benefits.

4. Potentials of the Area

The mountains are evolutionary and ecologically quite distinct from adjacent highlands, grasslands, savannas, and woodlands in East Africa. They have more affinity to Guineo-Congolian lowland rainforests. The Eastern Arc Mountain has been proposed as one of the several refugia in Africa during geologic periods when the tropical climate was generally adverse for forest development [16]. The EAM has a plenty of biophysical resources ranging from fauna, flora, water resources and soils [4]. It is a source of water supply for over 3.5 million people, storage of over 100 million tons of carbon, habitat of over 800 endemic plant species, 100 endemic vertebrates, 10 endemic mammals, 19 endemic birds,

31 endemic reptiles and 40 endemic amphibians [2, 3, 20].

Their unique characteristic and geological formation of isolation and connectivity played a crucial role in shaping the current distribution of species diversity within and between the mountain blocks. Connectivity is where mountains blocks were formed as sister blocs and were separated by a narrow gap without much difference in forest types. Connected mountain blocks include: North and South Pare, West and East Usambara, North and South Uluguru, and the Udzungwa, all in Tanzania. There are other isolated mountain blocs like Nguu, Nguru, Ukaguru, Rubeho, Mahenge, Malundwe, and Uvidunda in Tanzania. Taita hills in Kenya are the only part of Eastern Arc Mountain with an estimated remnant forested area of 6 km² (Figure 1). These mountains are major sources of water that afterward flows downstream. Big rivers such as Rufiji, Wami, Ruvu, Kilombero and Pangani have their source on these mountains (Figure1). In turn, these rivers provide water for domestic, Hydro-Electric Power, farming and environment requirements [17].

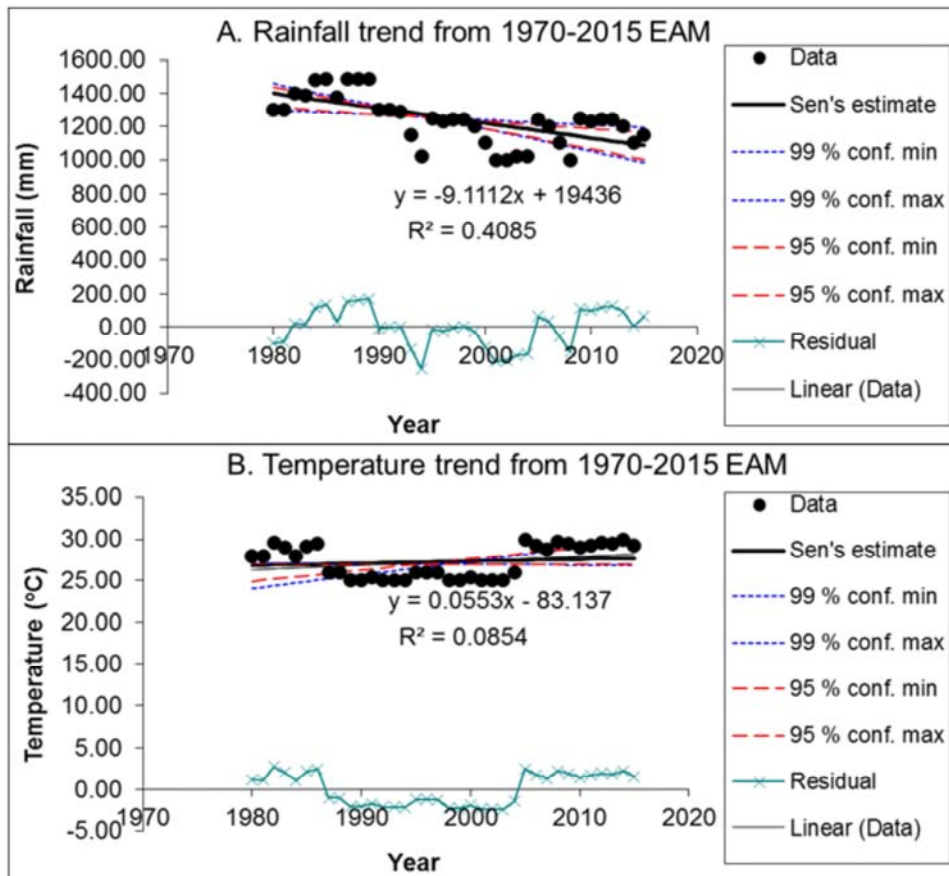
However, the ecosystem is threatened by the increasing degradation due to expansion of anthropogenic livelihoods. Much of these activities happen for livelihoods sustenance.



Figure 3. Part of the EAM with some deforestation.

The mountains have been globally ranked among the top biodiversity ‘rich hotspots’ in the world. However, the findings from Mumbi et al. [2], Charles et al. [3], Mbwambo et al. [15], Reyes [24] and Milledge et al. [16] showed that these potentials are threatened by human induced activities and the global climate change. Table 1 below shows some potential tree species in the area. Some dominant wild Miombo fruit trees in the study area include: Parinari

curatellifolia, Strychnos cocculoides, Vitex mombassae and Flacourtia indica. The block hosts the world’s endemic plant and animal species [2, 25]. Using the biophysical potentials; a wide range of crops are produced for socio-economic and ecological gains. The crops yields provide enough food varieties ranging from vitamin (vegetables), protein (beans), starch (maize) and oil (coconuts). In so doing, it reduces the vulnerability of the local communities as the EAM contribute to 40% the peoples’ livelihoods who lives adjacently [27]. In terms of climate, it appeared that the EAM experience the impact of global climate change. Annual precipitation in the region falls within two seasons, the ‘Long Rains’ (approximately mid-February through June) and the ‘Short Rains’ (approximately mid-October through December) but the overall, the annual rains is amounted to over 1100 mm while temperature varies between 22 and 33°C. The analyses from meteorological data has shown the significant decline of rainfall ($p < 0.05$) and the non-significant increase of temperature ($p > 0.05$). The rainfall has fluctuated at the increasing trend ($R^2 = 0.41$) while temperature so did in the increasing trend ($R^2 = 0.10$) as seen in Figure 4 below. It is seemingly, the decrease in rainfall has affected the ecosystems of the area i.e. water sources, extinctions of flora and fauna species just to list a few. Besides, the increasing temperature above the withstanding capacity has a fairly negative impact to the same.



Source: Data analyses from Tanzania Meteorological Agency (TMA)

Figure 4. Rainfall (A) and Temperature trend (B) in EAM.

Table 1. Potentials of Available Plant Species in the Eastern Arc Mountain.

Species name	Uses/Functions
Acacia species	Firewood, fodder, nitrogen fixation, shade
Albizia schimperiana	Timber, firewood, nitrogen fixation, fodder, rain indicator
Annona muricata	Fruits, shade, live fence
Artocarpus heterophyllus	Fruits, shade, control soil erosion
Balanites aegyptiaca	Timber, firewood, organic matter
Commiphora eminii	Firewood, fodder, shade, organic matter, support climber
Cordia africana	Timber, shade, firewood, soil improvement, fodder
Cordia sinensis	Firewood, organic matter, shade
Croton macrostachyus	Firewood, fodder, nitrogen fixation, shade
Eucalyptus saligna	Poles, firewood, wind break, erosion control
Faidherbia albida	Firewood, nitrogen fixation, fodder, shade
Ficus species	Firewood, shade, windbreak, control soil erosion
Grevillea robusta	Timber, shade, firewood, add organic matter
Kigelia africana	Fruits, shade, nitrogen fixation
Mangifera indica	Fruit, erosion control, windbreak, firewood
Markhamia obtusifolia	Firewood, fodder, nitrogen fixation, shade
Persea americana	Fruits, firewood, shade, soil improvement
Salvadora persica	Firewood, fodder, nitrogen fixation, shade
Syzygium cordatum	Timber, fruits, firewood, organic matter, shade
Tamarindus indica	Timber, fruits, firewood, organic matter

Source: Modified from Charles et al. [3]

5. Degradation of the Area

More than 70% of the area has been deforested through anthropogenic activities such as charcoal making and extensive agriculture. Since 1970's more than 12% of all forest resources in the area have been cleared by small scale farming, charcoal production, and collection of forest resource and extensive grazing i.e. encroachment [27, 37]. These practices set more pressure to the already threatened ecosystems (mountains). The degradation has been optimal at the upstream of Uluguru, Nguru, Usambara and Udzungwa Mountains [31].

This has affected water sources and other land resources [37]. Further, these degradation have increased the threat to endangered species especially in the practices lead to deforestation and disappearance of endangered species. Among these species includes natural vegetation species such as *Mussaenda microdonta*, *Memecylon cogniauxii*, *Syzygium micklethwaitii*, *Coffea mongensis*, *Allanblackia ulugurensis*, *Lasianthus pedunculatus*, *Zenkerella capparidacea* and *Polyscias stuhlmannii*. Apart from anthropogenic factors; the impacts of climate change has significantly increased the threat to resources degradation in the area (Figure 3). Therefore, for sustainable utilization and conservation of the available resources, we need to propose conservation practices in the area [28, 34, 35].

6. Conservational Practices

To retain and improve of the present ecosystem, a couple of sustainable practices should be in place [4, 38]. Among others, agroforestry, afforestation of the degraded areas and setting free (undisturbed) the water sources. It should be understandable that the downstream areas should equally make sustainable utilization of water resources from the upstream. This will reduce the pressure exerted by the great demand of the same.

Fragile ecosystems such as wetlands are readily vulnerable to anthropogenic activities and therefore, they should get conservational attentions from the users [10, 38]. Sustainable conservation of EAM will enhance the supply of water in numerous regions. For example, the Uluguru and Usambara Mountains are sustainable sources of water in Dar es Salam region respectively. They also supply water for Hydro-Electric Power in Kidatu and Nyumba ya Mungu Dams respectively. In the downstream, they also provide water for irrigation agriculture (i.e. Flowers Farming in Arusha), livestock keeping and small scale fishing just to mention some.

Ecologically, agroforestry system facilitate the conservation of the soil fertility particularly in hedgerows. For example; *Grevillea robusta*, *Tamarindus indica* and *Balanites aegyptiaca* are good in forming soil organic matter [30] while some trees are environmental friendly to water sources; therefore, these trees increase the sustainability of water sources [21]. In addition, *Artocarpus heterophyllus*, *Persea americana* and *Mangifera indica* are very good at controlling soil erosion and protecting it from degradation. Besides, shading and wind blocking are among the significant environmental services from agroforestry system that cannot be quantified despite of their contribution to the environment (Table 1). Lastly, it provides building materials especially for houses. Therefore, it brings insight and attention to environmental and socio-economic expertise as it curbs diverse challenges related to the society livelihoods especially from poor and marginalized communities.

7. Mitigation to Climate Change

Forest plays a significant role of carbon sequestration by seizing carbon dioxide from the atmosphere. Reducing emissions from deforestation and forest degradation (REDD) is a mechanism that has been under negotiation by the United Nations Framework Convention on Climate Change

(UNFCCC) to mitigate the impacts of climate change at global level. As a response to the great concern of increasing Green House Gases (GHGs) in the atmosphere; the situation has awakened majority stakeholders to think about the whole issue and its remedies. About 50% of the forest biomass is carbon and thus forest degradation and afforestation have different impacts [3, 19]. Therefore, deforestation will lead to the increase in emission and concentration of carbon dioxide in the atmosphere, whilst afforestation will increase the level of atmospheric carbon sequestration (carbon sink).

Numerous REDD projects related to climate change have been in practice in most of the developing countries like Tanzania as a resolution of the Kyoto Protocol of 1997. They intend to lessen carbon emission by emphasizing the use of clean development mechanism (CDM) as a carbon seizing mechanism. Boehm and Dabhi [1] show that despite the significance of CDM under Kyoto Protocol; there is a need to involve indigenous people prior the establishment of the big project funded under CDM. These authors add that, lack of consent from indigenous people in the establishment of project has brought some problems in some countries. For example, the construction of hydroelectric power (Panama), waste incinerator (India) and palm oil plantation (Indonesia) were opposed by indigenous people.

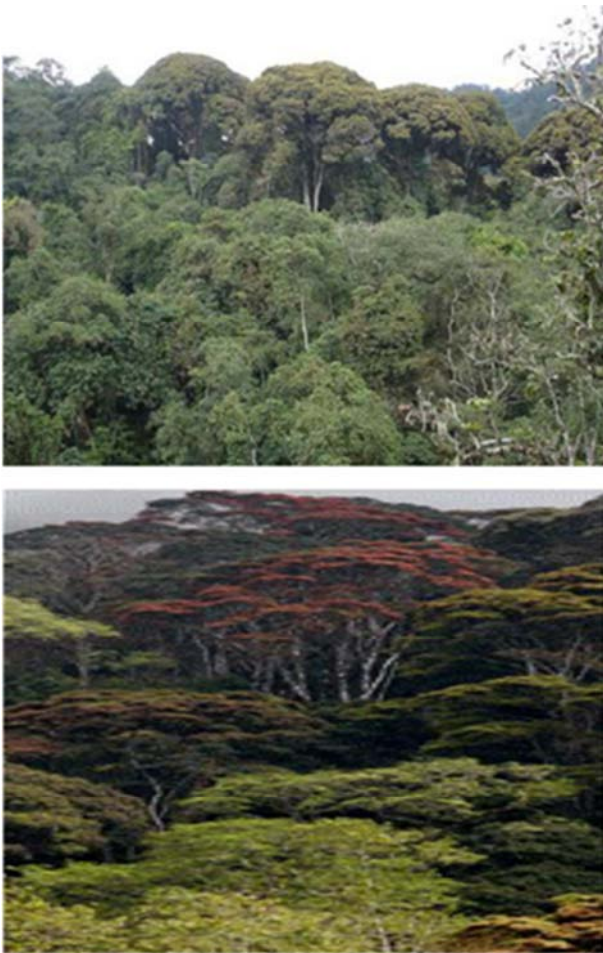


Figure 5. Natural forest relevant for sinking atmospheric carbon in the area.

For sustainable outcomes, the implementation of these projects needs participatory approach from the indigenous people. This approach endorses the consent and a sense of ownership from the people. CDM projects give directives on the prices and procedures on how the people can be compensated for their planted trees through carbon certification. Forest conservation (Figure 5) are good practices as they increase the earth's capacity to sequester atmospheric carbon, and at the same time, they reduce terrestrial carbon emission [13, 14].

The forest in the area sinks and stores more than 100 million tons of carbon. By so doing, they regulates the global climate change. Agroforestry and other conservation practices seize tons of other dangerous greenhouse gases such as methane (CH₄) and nitrous oxide (N₂O). Hence, the adoption of conservational farming systems serve multiple ecological functions. They increase the yields of diverse crops, conserve environment and devise mitigation and adaptation measures to climate change impacts [13, 14].

8. Conclusions

While this study has revealed the significant influence of agroforestry to reduce degradation, it is evident that there is still substantial degradation that is going on in the area. Further degradation threatens more than 40% of peoples' livelihoods who live adjacent to this ecosystem, therefore, there is a need to conserve the EAM and make it sustainable. This can be possible by increasing awareness on the adoption of conservation practices in the area. Increased degradation has brought insight to environmental and development stakeholders such as Norwegian Government who sponsors the implementation of conservation practices in the through EAMCEP.

At local and national, increased participatory approach and enforcement of the set regulation should be adequately adhered to. We recommend that, apart from adopting agroforestry and other conservation farming system, there is a need to make the payment of ecosystems services (PES) and market for ecosystem services (MES) more practical. The former will be done by the communities at the downstream while the latter will be done by those at upstream. This will enhance the equity of resource conservers and users. In addition, the environment related ministries and sectors should work more closely to adhere to sustainable conservation. This entails the Ministries of Agriculture, Water, Land, and Natural Resources and thus, they need to amend some of the conflicting policies, plans and programs on the same.

Besides, the international donors fund food security, sustainable resources and sustainable intensification projects can include agroforestry systems as one of the important components in those projects. For examples World Wildlife Fund (WWF) and Alliance for Green Revolution in Africa (AGRA) have been giving funds for agricultural production, conservation, climate change and sustainability of the environment. These large -scale international donors should increase their advocacy on agroforestry system in the country.

Lastly, this study calls for interventions to rescues deforestation and degradation of forest resources should be done. This is because much of this deforestation has been pronounced in a recent time due to population increase. With that precaution, there is a need to identify the key beneficiaries of the forest ecosystem and how they can benefit from it.

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