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Article

The role of highland bamboo species (*Oldeania alpina*) non-timber forest products in household income and house construction in Masha district, Southern Ethiopia

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Abstract: Bamboo is one of the noble plant species in Ethiopia. Household (HH) income and construction role of highland bamboo (*Oldeania alpina* (K. Schum.) Stapleto) stands were assessed at Masha district, Southern Ethiopia. Three peasant associations (PAs), Yepo, Yina and Gada, 7–15 key informants and 68, 46, 31 households, respectively were interviewed about the cost and income of bamboo to compare with woody climbers, honey, and mushroom in 2021. Bamboo was one of the main sources of income in all PAs, at least for fencing or house construction. In Yepo, Yina and Gada bamboo accounts 0.7%, 28.1%, 16.3% of the HH NTFP income, respectively. The local people responded that bamboo constructed houses and fences were durable for 15–30 and 2–10 years, respectively. In constructing a 2.44–4.27 m radius local house in Yepo, Yina and Gada 2.4–6 m^3, 4.1–5.82 m^3 and 3.1–4.3 m^3 bamboo culms were harvested at 15, 20, and 30 years interval, respectively by each HH. Bamboo young shoots were also seasonally used for food. Although bamboo provides multiple uses, like substitute for wood and environmental services, it was facing different problems of deforestation. Therefore, policy attention is highly important for bamboo sustainable utilization.

Keywords: construction; challenges; household income; non-timber; bamboo; plantation; policy

1. Introduction

Bamboos are perennial woody grasses belonging to the Poaceae (Gramineae) family and Bambuseae subfamily [1,2]. Since most bamboos have tree morphology and attain tree size at maturity they are named tree-grasses [3]. In the world, there are about 1250 species of bamboo belonging to 75 genera [4] divided into two "groups": woody and herbaceous. Bamboo covers over 36 million ha of world total area [5]. Woody bamboo are large diameter ones that can be used for construction, although they are categorized under non-timber forest product. Woody bamboos can be broadly divided into two clumping and running. Woody bamboo diameters vary from 10 mm to 200 mm, wall thicknesses from <10% of the external diameter to completely solid, and culm heights can exceed 30 m^3 [6]. Bamboo can grow up to 25 m in six months [7]. Once fully grown, culms typically take three to five years to mature to full strength, during which they experience silicification and lignification. After a period of five to six years, the culm's strength begins to deteriorate. Bamboo has a complex system of branching; and flowers that typically have three perianth-like structures (lodicules) and 3–6 stamens [8]. The geographical distribution of bamboo is governed largely by climate and soil conditions [9]. Bamboo grows inside forests and it is also widely spread outside forests, including farmlands, riverbanks,

roadsides and urban areas [5]. Bamboo is one of the important popular plant species widely used in the world. Bamboo meets a rising and diverse consumer demands, generates income and contribute to reforestation and climate change mitigation due to its rapid growth and environmentally friendly character [10,11]. Globally, 2.5 billion people earn incomes from bamboo-related activities. Global annual trade earns 5–7 billion USD from bamboo, compared with the 8 billion USD return from tropical timber trade [12].

In Africa, there are about 43 species and 11 genera bamboo occupying an area over 1.5 million ha [13]. Of these, 40 are mainly found in Madagascar while the remaining 3 are in mainland Africa. In Africa, *Oldeania alpina* (K.Schum.) Stapleto species of bamboo is distributed in Cameroon (Mt. Cameroon), Zaire (Kivu), Rwanda, Burundi, the Sudan and the mountains of Uganda, Kenya, Tanzania and Malawi [14].

Ethiopia has only two species of bamboo namely highland (*Oldeania alpina* (K. Schum.) Stapleto), and lowland bamboo *Oxytenanthera abyssinica* (A. Rich. Munro). Ethiopia has about 1 million ha of the two species of bamboo [15], the lowland being more dominant (850,000 ha). *O. alpina* ("Kerekeha" in local Amharic language) is a highland bamboo species growing in altitudes between 2200 m and 3500 m above sea level. *O. abyssinica* ("Shimel" in local Amharic language) is a lowland bamboo growing within altitude between 700 m and 1800 m above sea level. The highland bamboo grows in mountain gorges and tops forming the bamboo zone, usually in Moist and Wet Dega agro-climatic zones in Gojam, Shoa, Kefa, Gamo Gofa, Sidamo and Bale regions in dense stands with a leafy canopy and stems. About 20% of Ethiopia's total bamboo area occurs in between Bale Mountain, Bonga and Metu in South West part of Ethiopia and up to Dangla in the North [16]. Many of the endemic bamboo species of Africa are found in Ethiopia. Thus, 67% of African bamboo resources and more than 7% of the world total are found in Ethiopia [17]. Bamboo is one of the noble plant and highest yielding renewable resource that has huge economic and development potential as an alternate "cash crop". The development of bamboo helps to solve problems of housing, furniture shortage and job opportunities. It is widely used in mixed farming societies of Ethiopian as supplement to other non-timber forest products such as honeybee, spices, climber and mushroom. Although it is grouped under non-timber forest product (NTFP), bamboo plays an important role as a supplement to satisfy ever-increasing demands of woody biomass materials.

The scarcity of construction materials is necessitated the use of bamboo for many purposes. NTFP's are all the biological materials, products both from fauna and flora, (other than industrial round wood and derived sawn timber, woodchips, wood-based panels and pulp) that may be extracted from natural ecosystems, managed plantations, etc. and utilized within the household, be marketed or have social, cultural or religious significance [18,19]. Bamboo pulp is high grade, and the chemical recovery problems arising from high silica content have now been solved by desilication [20]. It also produces good quality activated carbon [21]. It also plays a vital role in environmental amelioration, biodiversity preservation, soil conservation and waste purification [3,22,23]. There are over 1500 distinct uses of bamboo have been recorded around the world, which are growing in number due to

innovation. Bamboo forests are likely to sequester carbon at a similar level to fast-growing trees and, hence, significantly contribute to the efforts being made to mitigate climate change. Bamboo can be used for bamboo floorboards, fabricated panels, handicrafts, curtains, modern ceilings, bioenergy, charcoal, paper, clothes, medicine, edible bamboo shoots, bamboo beer, bamboo soft drinks, etc. [24].

In Ethiopia, nearly 750,000 people are engaged in bamboo cultivation, management and utilization to support their livelihoods [25]. Bamboo utilization in Ethiopia is basically rudimentary, and bamboo product import exceeds export, in contrast to the resource base of the country. Bamboo is becoming increasingly important commodity because of its potential as wood substitute which includes cheap, efficient, and fast growth, its role in environmental protection; wide ecological adaptation; and the fact that the state of forest is shrinking globally [26]. When mature the culm of the Ethiopian highland bamboo is hollow, while that of the lowland bamboo is solid. The lack of awareness about multiple use of bamboo and scarcity of scientific knowledge about their production and main properties were challenges for conservation and utilization in 2010s. However, in 2020s better informative knowledge were emerged from different research centers of Ethiopia and elsewhere. In the past, bamboo forests were located in the more inaccessible areas, which protected them from destruction. The highland bamboo forest at Masha, south western Ethiopia, and the lowland bamboo forests at Assosa, Metekel, and Manbuk in western Ethiopia are preserved because of inaccessibility. Currently, the construction of roads has aggravated the destruction of the bamboo forest. Therefore, wiser utilization, and sustainable management plantation development are highly needed.

The Ethiopian Forestry Development was responsible for the development and utilization of bamboo and its product. Ethiopia mapped 3 million ha of suitable land for bamboo restoration with the foreseeable support of research centers. Ethiopia plans to increase its bamboo cover from the current 1.5 million hectares to 3.5 million in the coming few years as there are many suitable sites [27]. There were few modern industries for processing bamboo in addition the age old bamboo cottage industries [28].

In Ethiopia, many people have been using bamboo in their everyday life for thousands of years in rural communities. In spite of its multiple use and environmental services, bamboo is poorly managed and given less attention is in the country [29]. Bamboo is regarded as multipurpose plant in Asia and Latin America where it has thousands uses ranging from food to house construction, mainly to replace many of the timber products traditionally derived from forest tree species. Domestic market for bamboo products like furniture, baskets, utensils, mats, beehives, house construction and others are quite substantial. However, there is no formal market procedures adopted in the sales of these items since the production is at the small-scale level over many places. For the poorer households, bamboo provides a safety net, especially through the open access condition for harvesting. However, the seasonal markets and the poor quality determinately affected the income amount [30]. Therefore, informed decision by public and policy requires studies on household income contribution of bamboo and its comparative advantage with other similar products. Within many households, manufacturing of bamboo

products is something extra to increase the household income, next to the basic agriculture activities, which provide their basic income. There are limited quantitative studies with regard to the contribution of bamboo to the rural household income, except general description of its use. Accordingly, a household survey was conducted at Masha, one of the highland natural bamboo growing area, to quantify the household income and house construction role derived from bamboo, and to compare it with other farming products of rural households and to investigate its challenges.

2. Material and methods

2.1. Description of the study area

The studied area consisted of most bamboo growing and utilizing three peasant associations (PA) which are within Masha district, Sheka zone of Southern Nations and Nationalities People Regional State (SNNPRS). These were Gada, Yina and Yepo peasant associations (PAs). Yepo PA located at 7°46′/35°34′, Yina PA at 7°38′/35°30′ and Gada PA at 7°38′/35°33′ (**Figure 1**). The mean annual temperature varies from 10 ℃ at higher altitudes to 19 ℃ at lower altitudes. The mean annual rainfall varies from 1100 mm to 2200 mm and the mean annual potential evapotranspiration (PET) from 1350 mm to 1500 mm, hence the length of the growing period (LGP) of the area is above 300 days per annum [31,32]. According to the local farmers practice, the study area had rain fall period from April to November and a relatively dry season from December to February. The dominant land use/land cover in Yepo, Yina and Gada PA, respectively are primary forest, bamboo and enset. Especially, in Yina and Gada most of the area is covered by bamboo. In general, Masha forests are parts of the Tropical Afromontane Rainforests [33]. Non-bamboo forests are characteristically made up of a mixture of *Afrocarpus* and broad-leaved species like *Croton macrostachyus*, *Ilex mitis*, *Olea welwitschii*, *Afrocarpus falcatus*, *Pouteria adolfi-friederici*, and *Schefflera abyssinica.* Shrubs and climbers are very common and include *Landolphia buchananii*, *Jasminium abyssinicum*, *Hippocratea goetzei, Oxyanthus speciosus*, *Oncinotis tenuiloba*, *Tiliacora troupinii*, and *Hippocratea africana.* Natural forest products such as spices, and mushrooms, under bamboo are well distributed throughout the forest. The soils of the area are characterized by red to reddish-brown colours and have limited available phosphorus [34]. The soils are made up of different taxonomic groups such as Nitosols, Orthic Acrisols and Chromic Luvisols [31]. The total human population in Yepo, Yina and Gada are 6400, 2310 and 1572, respectively, which are in 570, 385, and 259 households [35]. The Masha natural bamboo forest was stocked with 8840 trees ha^{-1}, uniformly distributed with a mean height of 16.8 m, and diameter of 7.6 cm [17].

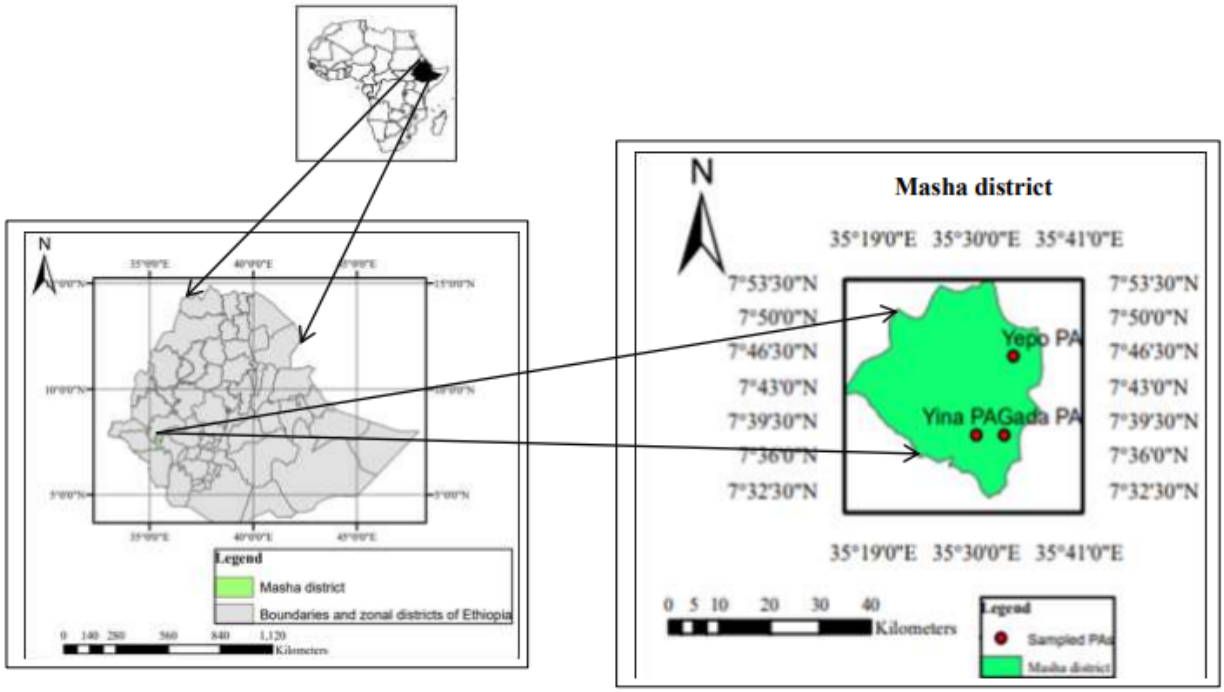


Figure 1. Location of the study area.

2.2. Data collection and analysis

In each peasant association the total household number, total human population and households that effectively practice the major farm activities were obtained from the district (woreda) agricultural and natural resources bureau. Households were stratified based on farmers practicing major mixed farming activities like livestock, annual agricultural crops, enset, NTFP, coffee, and wood products and others doing none or one of these activities. From the major practitioners of mixed farming activities on the same plot of land, from each PA, 12% was interviewed (to interview at least statistically valid 30 households) about the uses of bamboo, the income and house construction role obtained from bamboo in comparison with other farming activities and the threats to the existing bamboo forest. The households interviewed randomly in Yepo, Yina and Gada were 68, 46, 31 households, respectively. Number of people interviewed (sampled) was 15, 7, and 10, respectively in Yepo, Yina and Gada PA as key informants. During the interview bamboo was treated as NTFP for comparison and then again as a single product. The income data was based on the cultivation, management of farming product and their selling at farm gate prices of 2021. A 25 years data was predicted first and then discounted at assumed 3% interest rate (Equation (1)) as assumed to be used by national bank of Ethiopia for cash deposit by using Microsoft excel-spread sheet 2010 software. The study set a time prediction of 25 years as the relevant and rotation period for the computation of costs and benefits from the forest plantation, such as timber for lumber production of the local plantations of Cupressus tree species and Pinus tree species, although these plantations were not sampled.

In traditional grass house construction, the quantity of bamboo as a compliment to wood, and climber was obtained by taking three newly built houses in each PA. In each PA house sizes are measured by local units called feet (1 foot equals ca. 0.3048

m). Usually 2.44–4.27 m (8–15 feet) radius houses were built in the district. The volume of round and split wood used in construction was calculated by volume formula (Equations (2)–(4)). The quantity of climber required was determined by adult man or woman load (pack). The volume of bamboo required was calculated by volume formula (Equation (5)). The wood components of local house are single and thick central support "Miseso", wall "gidgida", and rings of walls "gigida mager". All cost and incomes were in US dollar ($USD). The cylindrical correction factor or form factor was determined by the ratio of sum the volume of cut pieces to the total cylindrical volume calculated by diameter at breast height (DBH). Commonly, the form factors, a ratio of actual volume to cylindrical volume, of bamboo are found to be 0.45.

$$Net\ income\ at\ NPV\ terms = (Bo - Co) + \sum_{t=1}^{n} \frac{[(B - C)_n]}{[(1 + i)^n]} \quad (1)$$

$$Volume\ of\ Miseso = solid\ wood = \pi/4(DBH2) \times H \quad (2)$$

$$Volume\ of\ gidgida = split\ wood = mid\ diameter \times L \times H \quad (3)$$

$$Volume\ of\ gidgida\ mager = round\ wood = \pi/4(DBH2) \times H \quad (4)$$

$$Volume\ of\ bamboo = \pi/4(DBH2) \times ff \times H \quad (5)$$

where: B_0 = the benefit at initial year zero; C_0 = the cost at initial year zero; B = the benefit from the end of year 1 to year 25; C = the cost from the end of year 1 to year 25; n = the year number; i = the assumed interest rate of 3%; DBH = diameter at breast height; H = total height of round above the ground after felling a tree or bamboo stem; L = length of cut wood; ff = form factor; π = 3.142.

3. Result

3.1. Incomes of different NTFP

Bamboo was the main non-timber forest product that was used in combination and as a supplement of other non-timber forest products including cardamom, woody climbers, honey, medicinal plants, and mushroom that are more or less daily utilized either as cash source or for household consumption in Masha forest (**Figure 2**).

Bamboo and honeybee production were the main source of income of NTFP in all PAs. In Yepo PA the availability of bamboo was lower as compared to the other two PAs and most of bamboo demanding activities were satisfied by purchasing from nearby markets of Yina and Gada PA. In terms of profit, the contribution of honey to NTFP income of households is 82.9%, 92.1% and 69.9%, respectively in Gada, Yepo and Yina PA, while the contribution of bamboo is 16.3%, 0.7% and 28.1%, respectively in the Gada, Yepo and Yina PA (**Table 1**). Although the profit obtained from honey is higher than bamboo, all households use bamboo at least for one household activity such as house making and fence construction, but there are households that does not use honey. Honey is profitable in limited area while bamboo is considered as a basic requirement for household activity.

Figure 2. Traditional beehive, bamboo forest and korerima natural forest in natural bamboo forest.

Table 1. The share of different NTFP profit in households.

Peasant association	Type of NTFP	Net income (profit) (%)
Gada	Bamboo	16.3
	Woody climbers for house construction	0.2
	Honey from bamboo hive	82.9
	Medicinal plants	0.7
Yepo	Bamboo	0.7
	Spices such as cardamom (from natural forest)	6.2
	Woody climbers	0.4
	Honey	92.1
	Medicinal plants	0.3
	Mushroom	0.2
Yina	Bamboo	28.1
	Woody climbers	0.7
	Honey	69.9
	Medicinal plants	0.2
	Mushroom	1.1

Bamboo plays a role as direct food source from young shoot that approximate a net present profit of $189.43 (**Table 2**) in Gada PA, and $119.4 in Yina PA, although the total food obtained from NTFP, mushroom and bamboo shoot were very low, because they were rarely available in few months of the year and they had no management. Bamboo shoots were available only in April to May months and mushroom was available in September to October months during the observation period. These two products become part of the diet only for few months. They are cooked with vegetable and used to prepare a delicious dish locally called "wat" which is served with "injera" or bread or "kotcho" local bread from enset.

The local people responded that harvesting of culms had been starting from 2–4 year-old bamboo after shoot sprouting, depending on the end use of culms.

Table 2. Household cost and income distribution of bamboo.

Peasant association	Uses of bamboo	NPV (cost) ($)	NPV (income) ($)	NPV (profit) ($)
Gada	Bamboo-fencing	103.21	154.71	51.43
	Bamboo-house construction	1.57	5.50	3.93
	Bamboo hive & container making	17.71	64.00	46.29
	Bamboo shoot for food	11.79	201.21	189.43
Yepo	Bamboo for fencing	0.14	0.43	0.29
	Bamboo for house construction	12.07	37.43	25.36
Yina	Bamboo for fencing	17.21	36.07	18.86
	Bamboo for fire wood	46.00	227.79	181.79
	Bamboo shoot for food	48.36	167.71	119.36
	Bamboo for house construction	7.57	15.00	7.43
	Bamboo sheath as cover hive and house	30.50	51.64	21.14

3.2. Household income of bamboo

At households' level, bamboo was used for multiple uses such as constructing houses, producing honey beehive; making local containers, and making fence. In processing enset products called "kotcho", bamboo is used as instrument or knife. **Table 2** shows the numerous benefits of bamboo and its being parts of many of the household utensils and ingredients of materials. In income generation, the highest net present present profit, $189.43, was obtained from bamboo shoot for food in Gada PA followed by $181.79 from bamboo for fire wood in Yina PA (**Table 2**). Moreover, the local people responded that the underneath of bamboo is a good media for the growth of palatable grasses and different varieties of mushroom.

3.3. The prediction of the amount of cost and income of households from bamboo products

In Gada PA, the highest income source, about $10.93 annually was obtained from bamboo shoot food, followed by bamboo for fencing, about $8.4 annually (**Figure 3**). The other income sources of bamboo products were for house construction, and beehive making (**Figure 3**).

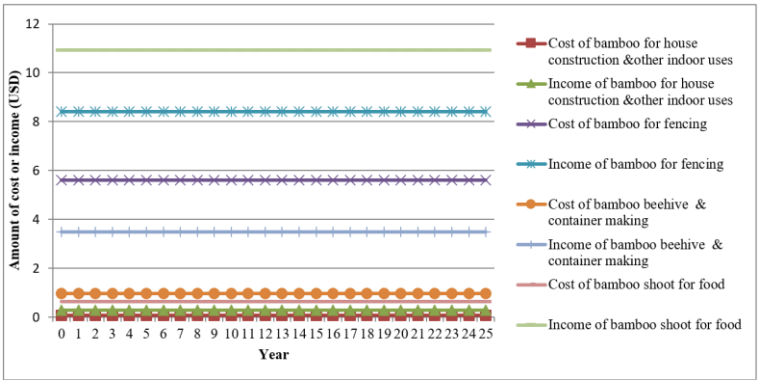


Figure 3. The amount of cost and income in Gada PA.

In Yepo PA, the highest income source, about $2.03 annually was obtained from bamboo for house construction & other indoor uses, followed by bamboo for fencing, about $0.02 annually (**Figure 4**).

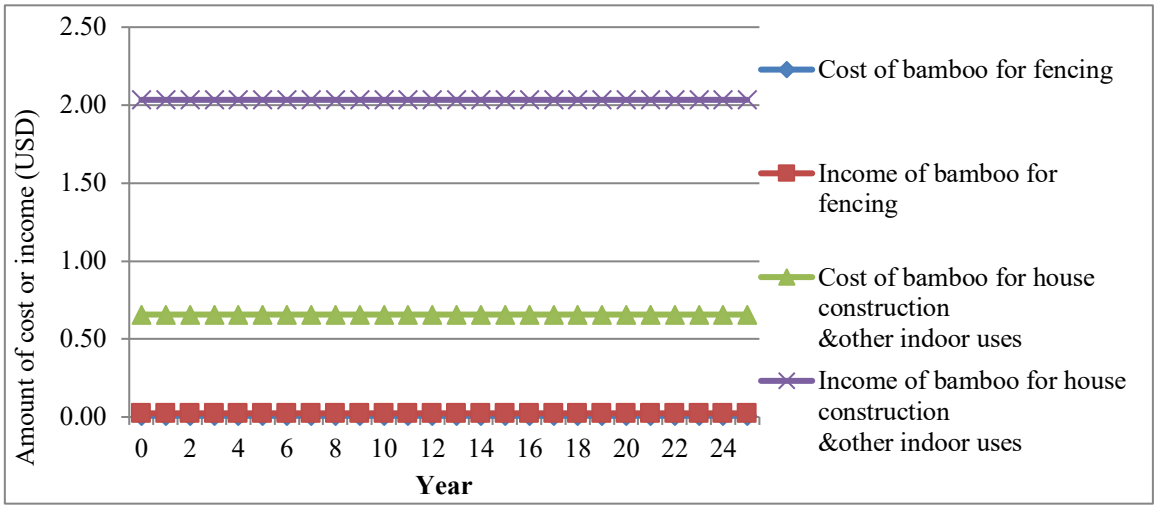


Figure 4. The amount of cost and income in Yepo PA.

In Yina PA, the highest income source, about $12.37 annually was obtained from bamboo for fire wood, followed by bamboo sheath as cover for beehive and house, about $2.8 annually (**Figure 5**). The other income sources of bamboo products were for house construction, and beehive making (**Figure 5**).

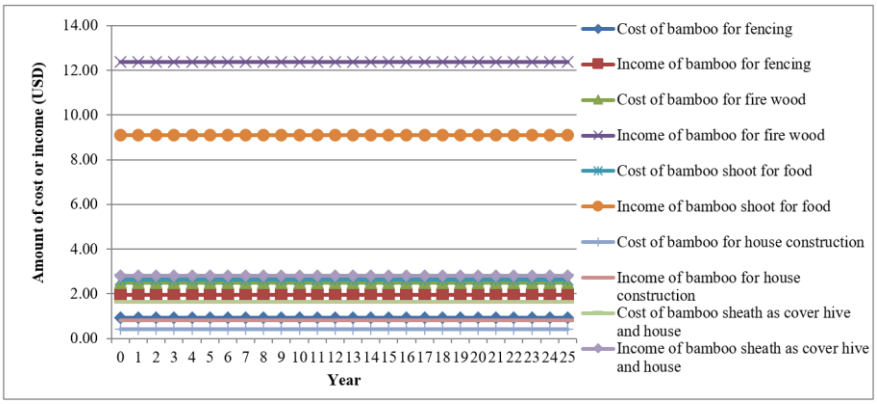


Figure 5. The amount of cost and income in Yina PA.

3.4. Construction role of bamboo

As can be seen from **Table 2**, most of the bamboo is used for construction and beehive making. In using bamboo as construction material, climbers are used instead of nail. Climbers grow usually not in the same place as bamboo and only selected species of liana are used in house construction and fencing. Some households use rope from enset, however the durability of climbers is preferred, except the fiber from enset which is stronger than climber.

The local people in the three PAs have similar experience towards the uses of bamboo. In construction aspect it is used for house construction, for fencing, container (local cereal store "Gotera") making, fire wood, honey bee hive making

and cover of hive (bamboo sheath). In natural forest so far bamboo is available in promising quality and quantity (**Figure 6**). The fences from bamboo are used up to 10 years in cold areas like Yina PA and up to 2 years in relatively warm areas like Yepo PA. Houses constructed from bamboo were serving up to 30 years in cold areas at Gada, for 20 years at Yina, and 15 years at Yepo. Moreover, in Yina and Gada where bamboo is available in abundance quantity more number of bamboo stems are used. Bigger solid stems of bamboo >7 cm DBH and 15–20 m height are used usually for fencing (**Figure 6**) and smaller solid stems of bamboo nearly 6 cm DBH and 10–13 m length are used for house construction. In all PAs bamboo is used for construction of roofs and walls of houses (**Figure 7**).

Figure 6. Natural stands of bamboo **(a)** left for housing; **(b)** right for fencing and for instrument.

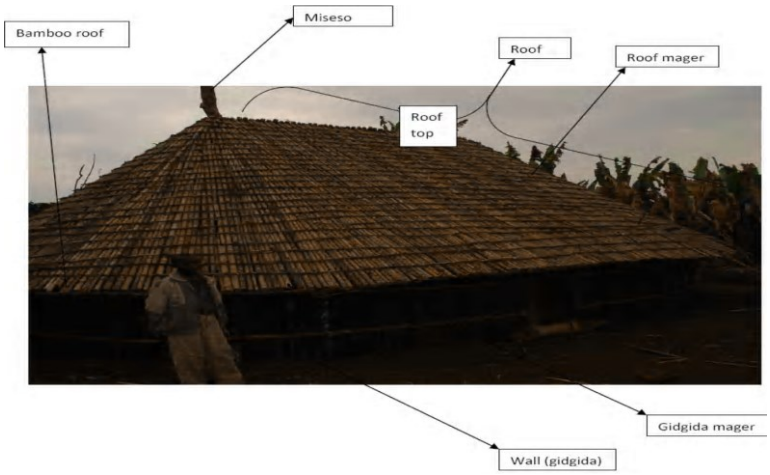
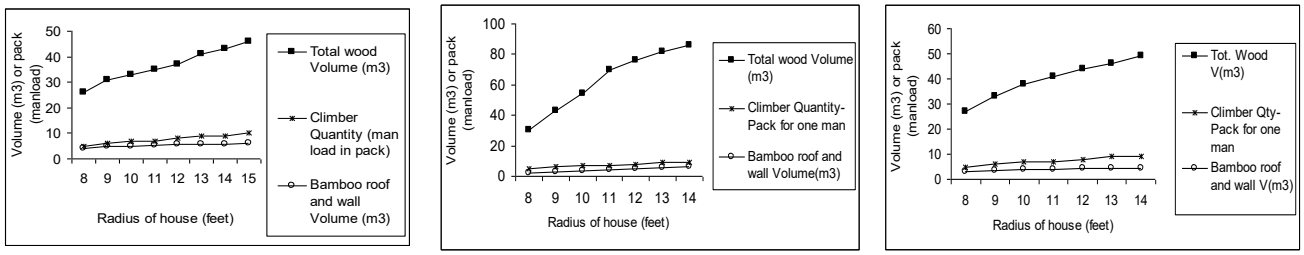


Figure 7. Rural bamboo roof house.

A rural house shown in **Figure 7** was constructed from wood, climbers and bamboo. The climbers are serving the purpose of nail. Usually, the climbers are sold in the market as pack measured in man load or woman load. On average, a man or woman load is 36 kg. In all parts of the house: roof and wall there was a utilization of wood, climbers and bamboo components. The measurement of radius was from the central post in local Amharic language called "Miseso" (**Figure 7**) to the walls of the house at the periphery. The amount of the three components used in peasant association (**Figures 8** and **9**) and the average life span of houses and contracting new ones was different from PA to PA. The volume of bamboo required to construct rural traditional house accounts 13%–16% of the wood volume in Yina, 6%–8% in Yepo and 9%–11% in Gada PA (**Figures 8** and **9**). According to the local people's

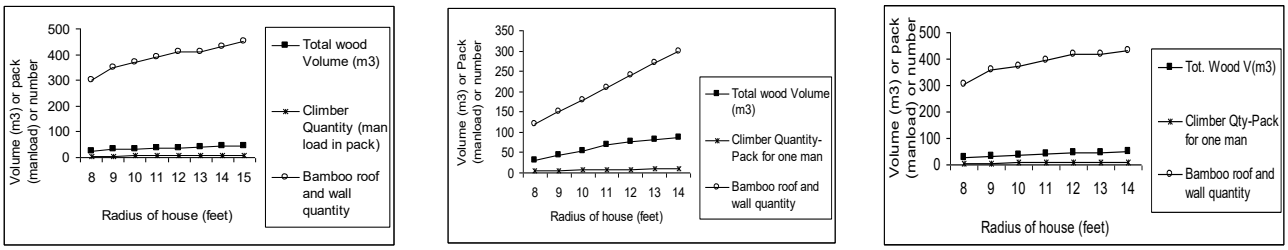
response, in 8–15 feet radius house construction, 4.1–5.82 m^3 volume of bamboo in Yina, 2.4–6 m^3 in Yepo, and 3.1–4.3 m^3 in Gada are exploited from the bamboo forest at intervals of 15, 20 and 30 years by each household, respectively.

On the other hand, the number of bamboo stems used to construct house ranges from 300–430 in Yina, 120–300 in Yepo and 306–434 in Gada PA, respectively for 8–15 feet radius house (**Figure 9**).



(a) **(b)** **(c)**

Figure 8. Volume of bamboo used as component for house construction at **(a)** Yina PA; **(b)** Yepo PA; and **(c)** Gada PA.



(a) **(b)** **(c)**

Figure 9. Quantity of bamboo used as component for house construction at **(a)** Yina PA; **(b)** Yepo PA; and **(c)** Gada PA.

4. Discussion

Bamboo was the basic material used for house making and fence construction in Masha district. The local people stated that all households were gaining income directly or indirectly from bamboo in the district. Although the district was endowed with different non-timber forest products, other studies revealed that the surrounding of Masha district had over 500 different NTFPs such as bamboo, honey, spices and etc. Most of these were only used locally used, but some including bamboo have regional and even international markets [30]. In the present study, the net profit value of bamboo in comparison to the contribution of 4 to 6 NTFP was 16.3%, 0.7% and 28.1%, respectively in the Gada, Yepo and Yina PA (**Table 1**), as stated in Liese and Wiener [36] and EEFCCC [25]. In Masha district, households had the potential of earning net present profit of $189.43 in Gada PA and $119.4 in Yina PA from bamboo shoot food (**Table 2**). This was also globally confirmed as over two million tons of edible bamboo shoots consumed every year that worth $214 million in 2010 [37], which is showing the potential of natural bamboo stands and if there was a management effort, the profit would have increased. INBAR [38] also stated that the Ethiopian two indigenous bamboo species namely high land and lowland bamboo

can generate over $1.2 billion every year if the country's bamboo resource base is properly utilized. Different studies showed that, bamboo is a source of employment in labor market. A survey in six countries, in Southern and Eastern Africa, showed that about 763,000 persons were employed in small-scale production or trading of four types of forests, respectively: grasses, cane and bamboo products (42%), wood working (27%), other wood products (11%), and other forest products trade (20%) [39]. A study conducted in northern Ethiopia, on highland bamboo showed that on average producers supply 374.79 bamboo culms and earns revenue of $149.5. On average local traders, retailers and wholesalers earn 7.52%, 9.51% and 9.23% of profit Margin and these traders earn average revenue of $1302.4, $2536.5 and $5496.9, respectively. Traditional bamboo product processors produce 687 traditional bamboo chairs on average per year. Higher value was added at bamboo furniture enterprise level and lower value is added at producer and trader level [40]. The contribution of bamboo to the household income was the highest in Ethiopia in comparison to other non-timber forest products as confirmed by Mekonnen [28]. However, the local people sell mostly bamboo culms in roadside markets and the value addition and value chains were inefficient. These lower profits to the local people or producers were not incentivizing them to manage bamboo and therefore, the government should give attention to create the awareness of local people to manage and add value to bamboo products. On the other hand, in 2023, the approximate price range for Ethiopia Bamboo was between $0 and $0.2 per kilogram, which was lower than the other countries because of the lack of value addition to bamboo products in Ethiopia [41].

In the present study, the number of bamboo stems used to construct house ranges from 300–430 in Yina, 120–300 in Yepo and 306–434 in Gada PA, respectively for 8–15 feet radius house (**Figure 9**). This was confirmed by Kibwage and Misreave [42] who stated that in construction sector, bamboo accounts for 2%–3% at the Ethiopian national level and more than 50% in rural areas of Southern Nation, Nationalities and People (SNNP) and Benshangul Gumuz National Regional States in Ethiopia.

Major challenges of bamboo at Masha district: There were different problems that had been damaging the natural bamboo forest of Masha district including encroachment by the local people, lack of regeneration, expansion of grass lands, expansion of agriculture and resettlement and inefficient utilization.

Encroachment by local people: The bamboo forest at Masha is accessible to residential local people and traders travelling from Tepi to Masha towns. There are a number of residents inside and close to the forest as the bamboo forest was owned by individual households in private lands and by the public on communal lands. Accordingly, the encroachment rate was very high. Since activities were illegal and the cutting of bamboo was inconsiderable of size and location of bamboo stems, the damage created during illegal cutting was devastating. Greater proportions of stems were damaged as compared to proper utilization. Especially people travelling in public transport were randomly cutting bamboo stems from bamboo forests located near to road sides. This illegal cutting is very uncontrollable because those who cut are appearing in unusual time where local guards are not at the spot. The best way of controlling is fencing the bamboo especially along the borders of public road.

Similarly, the local residents need to take responsibility in managing and utilizing the forest.

Lack of regeneration: There was no management plan for bamboo forests of Masha neither in private or communal lands. The stocking was not uniform, in some places was highly dense and in others is scattered. Overstocking, and over maturity and old age were resulting in falling and death of many bamboo stems. No promising regeneration and no appropriate gaps were created for regeneration. In some points, there was haphazard falling of stems and there was no selective cutting to remove matured stems. There was a need to remove matured stems selectively; however, this recommendation of selective was not put into practice. The people interviewed responded that getting bamboo shoot and regeneration of other woody plant species some ten years ago was much better than today. The lack of bamboo shoot currently was attributed to climate change and mismanagement or random cutting of bamboo population. Similarly gregarious flowering may have a detrimental effect (loss of regeneration from suckers) and need a closer protection of the area. The gregarious flowing resulted in death of stems, and only seeds fallen on the ground had the chance of regeneration but the absence of gaps that allow the transmission of solar radiation could hinder regeneration from seed. Therefore, creating gap for natural regeneration from seed and mass seed collection for seed storage are highly needed.

Expansion of grass land: The bamboo forest was adjoined with marshy grassland. Probably because of climate change and frequent disturbance by nearby grazing, and lack of proper diversion of seasonal water flow, the grassland was expanding towards to the bamboo forest. There were some bamboo stems dried due to water logging. This requires proper drainage.

Expansion of agricultural land and settlement: There were many settlers and new immigrates near to the bamboo forest. Although there were government controls over the expansion of agricultural land, there was a slight move towards the bamboo forest by the local settlers. Moreover, the settlers were cutting bamboo for fire wood and fencing. No enrichment planting of bamboo was observed in the studied peasant associations. The residents were not willing to plant because of the availability of natural stands of bamboo. Investors were not in need to manage and utilize bamboo instead they were interested to clear bamboo and want to plant other monoculture plantation. The local people would like to plant eucalypt and investors want to plant tea as many areas of the nearby natural forests were cleared for tea plantation in the highland. The possible way to halt devastation of bamboo stands is prohibiting settlement close to the natural bamboo stand. The local people should be trained to conserve and sustainably utilize this natural bamboo endowed to the area. There should be management plan on annual and seasonal cutting of the forest and clearing of bamboo should be banned. Investors should be initiated on the proper utilization of bamboo and value addition to its various products.

Inefficient utilization of bamboo stems: There was wastage of bamboo culms during harvesting from natural stands and during utilization. It was observed that, to get a single stem, usually 4 to 6 other stems were damaged and wasted in the bamboo forest stand. Similarly, to cut a 1 m long bamboo stem a 4 m long stems was cut and left unused as responded from local people. This was because of lack of knowledge on using bamboo. There were few activities undergoing by different non-

governmental organizations in training the utilization of bamboo (personal communication). Such activities should be strengthened to create responsibility, sustainable management and utilization. Therefore, training on the utilization and security of ownership of the communally owned bamboo forests are highly important.

There were many losses in harvesting bamboo also as stated by the Masha district officials as 1 m bamboo culm claims a 4 m bamboo a stem because of the lack of awareness on proper utilization of bamboo as required in Darabant et al. [43]. Efforts were made to develop bamboo resources by East Africa bamboo project mainly in Ethiopia and Kenya that aimed at promoting the development of sustainable production of bamboo in East African countries with focus on marketing [44]. However, UNIDO project has included few bamboo growing areas namely Asosa, Injibara and Hagere Selam by forgetting Masha bamboo. UNIDO's remark that Masha bamboo forest is one of bamboo flowering area for the collection seed for research and dissemination to other parts of Ethiopia, appropriate intervention is important as stated in EEFCCC [25]. Management approaches were suggested to improve the productivity and product quality of the remnant bamboo forest of Masha, however; diagnostic information was not practiced [17], but the present study emphasize the need for additional efforts to the proper management and sustainable utilization of bamboo forest in smallholders of Mash district.

The limitations of the current study include lack of sufficient literature on Ethiopian and Masha district bamboo to compare the results. The bamboo sector in Ethiopia was not well developed and there was no strong institution that management and utilize the bamboo resources except the African bamboo sector which was at the beginning stage. Therefore, it is highly important to establish bamboo institute, conduct research on the sustainable management and utilization of bamboo, the house construction roles of bamboo and the establishment of indigenous bamboo farms.

5. Conclusion and recommendation

The wood substitute and non-timber forest product uses of bamboo in the Masha district of Gada and Yina peasant association were non replaceable within the mixed farming system of the society. Income, food value, and local fence and house construction uses were the main benefits that urge the conservation of the bamboo forest land. Bamboo had direct food source from young shoot that approximate a net present profit of $189.43 in Gada PA, and $119.4 in Yina PA and a firewood net present profit of $181.79 in Yina PA in addition to other benefits including house and fence construction. Bamboo has the potential to reduce deforestation because it was used for house construction by replacing the slow growing natural forest species. In 2.44–4.27 m feet radius house construction, 4.1–5.82 m^3 volume of bamboo in Yina, 2.4–6 m^3 in Yepo, and 3.1–4.3 m^3 in Gada were harvested from the bamboo forest at intervals of 15, 20 and 30 years by each household, respectively. However, the bamboo forest was declining both by natural and manmade threats of overexploitation, lack of management, and lack of regeneration. Therefore, the local government and forest department of the area should put collective efforts to save

the devastation of bamboo forest and possible sustainable utilization. Preparation and practicing of management plan of the bamboo forest, opening gaps for natural regeneration, establishment of propagation site and enrichment planting, training on management and utilization are crucial activities that should be done urgently in the bamboo forest of Masha district. There was limited information the bamboo young shoots of the highland bamboo, and there should be further research for wider production and utilization.

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