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Research Article

Market Chain Analysis of Highland Bamboo Poles in Three Districts of the Sidama National Region, Ethiopia

Tsadiku Alemu [1*], Mulugeta Fola[1], Hana Tafesse[1]

Article Info

[1] Southern Agricultural Research Institute, Hawassa Agricultural Research Center, P.O .Box 06

*Corresponding author: tsedekebetsega@gmail.com

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Abstract

Ethiopia is one of the countries well-endowed with bamboo (Arundinaria alpine, and Oxytenanthera abyssinica). As compared to its potential, however, the contribution of bamboo to producers' livelihoods and the national economy is very low. This is partly attributed to limited information on the market chain of standing bamboo its products. This study was, therefore, initiated to analyze the market chain of highland bamboo poles and its determinants in the main production areas of three selected districts of Sidama National Region, Ethiopia. In total, 120 sample households were selected based on a random sampling technique due to the homogeneity of the bamboo producers' population. The two-stage least-square regression model was used to analyze the determinants of the bamboo market supply. The results of the study revealed that primary value chain actors were input suppliers, producers, collectors, wholesalers, retailers, cooperatives, and end-users. Secondary actors were Trade and Industry and Cooperative Bureaus. Bamboo in the study area country used for construction material and household furniture, for firewood and source of income and livelihood. Harvesting of non-mature culm and lack of knowledge on modern silvicultural practices were identified as the main production constraints. While lack of support and training, lack of bamboo-based factories or firms or industries were related to processing constraints. Marketing constraints included a lack of market for bamboo poles and licensing. Measures of market concentration ratio showed that the top four biggest traders controlled 62.43 % of the bamboo market, indicating that the structure of the market was strongly oligopolistic in the study area. According to the survey result, 70.5% of the respondents reported that the bamboo pole's price decision was set by traders. The marketing margin of producers was highest in channel V (42.86%). The number of bamboo culms harvested, sex of the household head, education level of the household head, membership in the farmers-based association, and lagged price were significant determinants of the market supply of bamboo. It was revealed that the market chain of bamboo should consider socioeconomic factors favoring and disfavoring highland bamboo market as well as the knowledge gaps to management of bamboo in the study region.

Keywords: Bamboo, Bamboo Culm, Ethiopia, Market Chain, Oligopolistic

1 Introduction

Ethiopia accounts the largest bamboo resources in Africa, which is estimated to 1.5 million hectares, and sharing approximately 4.2% of the global bamboo resource and 8.3% of the country's total forest area (Sebrala, 2021). Bamboo, as one of the fastest growing, annually regenerating species, is proven to provide climate change mitigation and adaptation benefits. Bamboo (the "green gold") is a perennial woody grass from the family Poaceae under the subfamily Bambusoideae (Zhao et al., 2018). Ethiopia is one of the countries well-endowed with bamboo, mainly, Arundinaria alpine (referred as highland bamboo) and Oxytenanthera abyssinica (lowland bamboo). The Yushania alpine grow naturally in highland agro-ecological zones of 2,200-3,500 meters above sea level. It plays a very essential role socially, economically, and ecologically in areas where it occurs in both naturally and planted. Bamboos play a great role in delivering ecosystem services, biodiversity conservation, soil and water conservation, and socio-economic development (Sebrala, 2021).

Highland bamboo is also grown on farms in small patches or as farm boundaries under cultivation in various regions of Ethiopia (Zhao et al., 2018). Among other services, bamboo plays important role in supporting smallholder households. However, the non-timber forest products trade such as bamboo is often constrained by conditions that typify underdeveloped areas, including isolation, limited local buying power, inadequate infrastructure, poor exposure and access to markets, weak political power, high transportation costs, communication problems, and inadequate education and levels of organization amongst producers and traders (Pérez, 2005 cited in Solomon et al.,2016). Solomon et al. (2016) found that there exists oligopolistic nature of the bamboo market. Moreover, marketing margins also indicate that the producers get much lower benefits than any other market chain actors. The major problems of the production identified by bamboo producers in the study area arise from road infrastructure and market information. The market for bamboo in Ethiopia is not well developed and bamboo marketing as a viable alternative for farmers has become a very challenging issue (Fayera et al., 2017). Due to a lack of machines and tools, the production process relies on manual labor, and bamboo products are perceived as inferior when compared to timber products. The quality of products is inconsistent due to a lack of knowledge on the proper timing of harvesting which is related to little attention given to the cultivation and propagation of bamboo. Lack of proper storage facilities also creates the problem of insect infestation before bamboo culms are processed into desired products (Jessie et al., 2019). Tirusew et al. (2017) found in their study that the major limiting factors for bamboo poles in the present study region were the absence of value-added production and poor market linkage.

The market chain of bamboo in Arbegona, Hula, and Bursa districts of Sidama region is constrained by production not strengthened by modern silviculture, traditional marketing, and not well established or rudimentary level processing which made the sector unused despite the potential of bamboo resources. In addition, the previous studies failed to incorporate major highland bamboo production areas of Arbegona and Bursa, addressed partial areas of bamboo poles marketing route, and failed to address the overall value chain. Therefore, this study aimed to analyze the market chain of highland bamboo in the main production areas of the Sidama region in Arbegona, Hula, and Bursa districts. It was focusing on mapping the market chain of highland bamboo and its functions, identifying the socioeconomic contribution of bamboo and constraints in the production, processing, and marketing of highland bamboo, and analyzing determinants of bamboo market supply.

2 Materials and Methods

2.1 Description of the Study Area

Arbegona district is one of the districts in the Sidama region, which is bordered on the south by Bona Zuria, on the southwest by Bursa, on the northwest by Gorche, on the north by the Oromia Region, and on the east by Bensa. The major town in Arbegona is Yaye. Based on the 2007 Census conducted by the CSA, this district has a total population of 135,862, of which 67,744 are men and 68,118 women; 6,745 or 4.97% of its population are urban dwellers. Hula district is bordered on the south by the Oromia Region, on the west by Dara, on the northwest by AletaWendo, on the north by Bursa, and on the east by Bona Zuria. The major town in Hula is Hageresselam. Districts of Bursa and Bona Zuria boarded with Hula. A survey of the land in this district shows that 59.6% is arable or cultivable, 36.2% pasture, 2.3% forest, and the remaining 1.8% are considered swampy, degraded, or otherwise unusable. Important crops include corn, wheat, barley, local varieties of cabbage, and potatoes. Based on the 2007 Census conducted by the CSA, this district has a total population of 129,263, of whom 64,551 are men and 64,712 women; 6,410 or 4.96% of its population are urban dwellers. Bursa district is bordered on the south by Hula, on the west by Aletawendo, on the northwest by Wensho, on the northeast by Arbegona, and on the southeast by Bona Zuria. Bursa district was separated from Hula district. Based on the 2007 Census conducted by the CSA, this district has a total population of 103,631, of whom 51,731 are men and 51,900 women; 2,304 or 2.22% of its population are urban dwellers.

2.2 Sampling Techniques

A multi-stage sampling technique was employed to draw the sample from the strata of producers, traders and end-users of highland bamboo. First, potential bamboo-producing kebeles were identified purposively from Hula, Arbegona, and Bursa districts on basis of their potential in bamboo production. Secondly, two kebeles were randomly identified from each district. Thirdly, total 120 bamboo producers households were randomly selected owing to the homogeneity of the bamboo pole producers. Head of the household was

communicated for the interview. Owing to lack of an organized list of actors across the market chain of bamboo, key informants were purposively selected including 11 informants from wholesalers, 14 retailers, 10 collectors, 16 processors, and 22 end-users to discuss and triangulate the opportunities and challenges.

2.3 Methods of Data Collection

To collect the primary data, both the household survey and participatory rural appraisal (PRA) tools were employed. The applied PRA techniques included focus group discussions (FGDs), the key informant interviews (KIIs), and observations. While the household survey was conducted using structured questionnaires. The household survey was conducted by trained enumerators. Besides, the household survey questionnaires were pre-tested to check the clarity of the contents, and hence, enabled us to modify the questions. Key informants' interviews were conducted with district experts of natural resources and one focus group discussion was held in each kebele with a group of eight persons.

2.4 Conceptual Framework

The demographic, socio economic and institutional factors affect bamboo market supply in the study area area as indicated in figure 1. It is in this framework that market supply is affected by constraints of production, processing and marketing.

2.4.1 Definition of Variables

Dependent Variable **Market supply of bamboo:** refers to the number of bamboo poles supplied to the market in one year. It is a continuous variable.

Independent Variables **Total harvest:** total number of bamboo poles or culms harvested in one year. It was expected to have a positive relationship with bamboo market supply.

Age of household head: continuous variable measured in years showing how old the household is. It was expected to have a negative relationship to bamboo market supply. It is a continuous variable.

Education level of household head: continuous variable referring to the number of years spent by the household head in formal education. It was expected to have a positive relationship with bamboo market supply.

Membership in associations: refers to membership in any agricultural associations. It is a dummy variable. It was expected to have a positive relationship with bamboo market supply.

Lagged price: It refers to the selling price of bamboo per culm of the previous year before the survey. It was expected to have a positive relationship with bamboo market supply. It is a continuous variable.

Distance to the market: continuous variable measured in kilometres. It was expected to have a negative relationship to bamboo market supply. It is a continuous variable.

Non-bamboo income: It is the total income of the household head in one year excluding income from the sale of bamboo. It was expected to have a negative relationship to bamboo market supply. It is a continuous variable.

Total family: refers to the total number of members of the household. It was expected to have a positive relationship with bamboo market supply. It is a continuous variable.

2.5 Data Analysis

Both descriptive statistics and econometric models were used to analyse the data. Mean, frequency and percentage were used to describe demographic and socioeconomic data. For the econometric analysis, a two-stage least square regression model was employed to analyse determinants of the bamboo market supply. The basic multiple regression model for the econometric part following Greene (2003):

$$Y = \beta X + \epsilon \tag{1}$$

Where Y = the bamboo market supply, β = a vector of estimated coefficient of the explanatory variables X = a vector of explanatory variables, ϵ = disturbance factor

Concentration ratio was used to measure the size of distribution of bamboo pole traders. The market concentration ratio is the common method of measuring market structure.

$$CR = \sum_{i=1}^{n} S_i \tag{2}$$

Where S_i represents the market share of i^{th} firm and n is the number of largest firms for which the ratio is going to be calculated.

Market conduct was evaluated in terms of payment mechanisms and pricing strategy. The market performance or marketing margin was calculated using consumer and producer (in this case bamboo growers) price and marketing cost. Mathematically margins can be calculated as follows:

$$TGMM = \frac{\text{End buyer price} - \text{First seller price}}{\text{End buyer price}} \times 100 \tag{3}$$

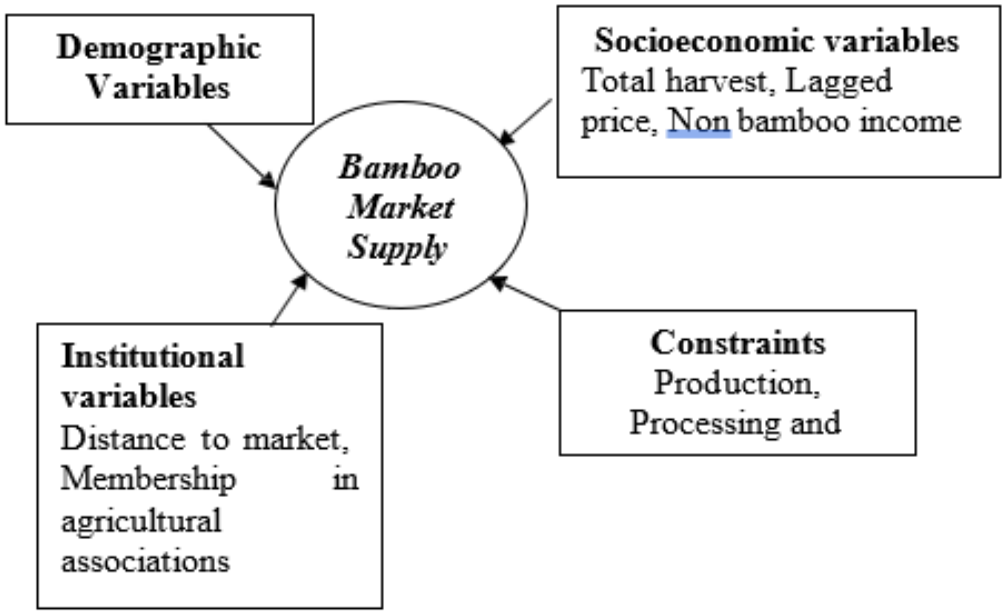

Figure 1: Bamboo market study conceptual framework

Where $TGMM$ = Total gross marketing margin

$$GMMp = \frac{\text{End buyer price} - \text{marketing gross margin}}{\text{End buyer price}} \times 100 \quad (4)$$

Where, $GMMp$ = the producer's gross marketing margins (producers share) from the consumer price

$$NMM = \frac{\text{Gross margin} - \text{Marketing costs}}{\text{End buyer price}} \times 100 \quad (5)$$

Where NMM = Net marketing margin

3 Results and Discussion

3.1 Demographic and Socio-economic Characteristics of Sample Respondents

Out of the total 120 sample respondents, 75% were males and the rest were female household heads. Concerning marital status, 82% were married, 8% were single and 10% were widowed (Table 1). This indicates that the majority of bamboo pole producers in the study area were males and married.

The average quantity of bamboo supplied to the market by sampled households in a year was 579 culms. It is taken as an alternative source of income in times of cash shortage. The average distance to the nearest market center was 4.25 km. The farmers take poles to the market mostly on foot. The average non-bamboo annual income excluding bamboo was estimated to 8715.67 ETB. This non-bamboo income is generated mostly during the agricultural production season. Bamboo harvesting was done twice in a year. The average age of surveyed bamboo producers was estimated to 41.93 years-old. Middle-aged members of households mostly engaged in harvesting. The average family size of households was 8 persons per household. The average year of experience in bamboo cultivation was 24.91 years. Experienced households in bamboo cultivation were better aware of problems related to bamboo value chain study. The average area of land allotted to bamboo cultivation was 0.32 hectares. The average lagged price of bamboo culms was 6.01 ETB per culm (Table 2). The lagged price was important in determining the number of culms or poles to be supplied to the market.

3.1.1 Farmers Based Association Membership

Membership in agricultural associations enabled farmers to engage in the market and supply more of their products to the market. Out of the total respondents, 16.7% were members of bamboo-based cooperatives in the study area (Table 3). These cooperative members were actively engaged in marketing bamboo poles to processors as they were well aware of marketing.

3.1.2 Sources of Major Income Bamboo Producer Households

The average annual income from crop production for the sampled household head was 6321 ETB. This indicates that crop production is a major source of income in the study area. The average annual

Table 2: Marital Status

Marital Status	Frequency	Percent
Married	98	82
Single	10	8
Divorced	-	-
Widowed	12	10
Total	120	100

Table 3: Responses for bamboo producers' cooperative membership status (n=120)

Variables	Response	Percent
Cooperative membership	Yes	20
16.7		
	No	100
83.3		
Total	120	100

income derived from non-farm activities was 580.46 ETB. A household heads obtained 462.27 ETB on average from Off-farm income per annum. The average incomes derived from livestock production and sale of bamboo were 1563.63 ETB and 2413.42 ETB respectively (Table 4). It can be inferred that the sale of bamboo was taken as an additional source of income as it is in the second rank based on average income.

3.2 Highland Bamboo Market Chain Actors and Their Roles

Primary actors were producers, collectors, retailers, and cooperatives. Secondary actors were input suppliers, Trade and Enterprise Development Bureau, and the Cooperative's Development Bureau.

3.2.1 Input Suppliers/Nurseries

Provided seedlings to farmers to enable them to use seedlings instead of vegetative propagation. The district office of agriculture played the role and also thought farmers the importance of applying compost to bamboo farmland.

3.2.2 Producers

Managed bamboo stands, harvested culms, and sold to customers who went the culms for different purposes, which were primarily related to construction purposes, trading, and processing.

3.2.3 Collectors

Sold bamboo after purchased. They came directly to the farm gate of bamboo producer farmers and collected the bamboo. The bamboo was either already cut or made ready by the farmers or the collectors or the collectors bring laborers along with them so that the price was negotiated to take into account the cost the collector incurred for the laborers.

3.2.4 Retailers

Sold bamboo culms after purchase. They attended the local market places at every weekday of the market. They sold bamboo to those who needed it for house construction, wholesaling, or processing purposes.

3.2.5 Wholesalers

Sold bamboo after purchase from retailers or collectors in large amounts to those who wanted it for retail or other purposes.

3.2.6 Cooperatives

Processed different bamboo commodities like a chair, bed, shelf, basket, light bulb embracer, mats. They were primarily organized by the district Trade and Enterprise Development Bureau and Cooperative's Development Bureau.

3.2.7 End Users

Purchased both raw culm and processed commodity.

3.2.8 Trade and Enterprise Development Bureau and Cooperative's Development Bureau

Acted as secondary actors. They organized bamboo-based processors cooperatives and provided licensing.

Table 4: Socio-demographic characteristics of sampled households (n=120)

Variable	Unit	Mean	Std. Dev.	Min	Max
Quantity of bamboo supplied to the market	number	578.5	232.4	300.0	1199.0
Distance to the market center	km	4.3	2.3	1.0	11.0
Non-bamboo income	birr	8715.7	5065.0	3100.0	22001.0
Total harvest	number	1040.2	460.7	400.0	2151.0
Age of household head	years	41.9	10.3	22.0	60.0
Total family size	number	7.5	2.2	3.0	12.0
Education level	year	5.3	2.1	2.0	10.0
Bamboo cultivation experience	year	24.9	7.9	14.0	44.0
Land allotted to bamboo cultivation	ha	0.32	0.15	0.10	0.86
Average lagged price per culm	birr	6.01	2.18	2.13	12.4

3.2.9 Storage

It took place for a maximum of one week because it would dry in a short time and the inconvenience of being flexible in the desired shape for processing. Bamboo needed proper treatment and dried time after harvest to better prevent problems, such as insect infestation. The lack of adequate storage facilities and space exacerbates this problem. These were major challenges that needed attention by organizations that provide merely skills training to the craftsmen.

3.2.10 Transportation

Donkey and horse carts were used in the most manners to transport bamboo culms to local market areas. Human/family labor was also used if the proximity of the marketplace from the household head's house is affordable.

3.2.11 Marketing

Held hand to hand with other retail commodities at the open marketplace on market days at village or woreda market, except wholesalers who take culms to other areas.

3.3 Market Chain Map of Bamboo in the Study Area

Identified market chain functions were described in terms of direct value chain actors and enablers. At the input supply stage, there exist kebele agricultural offices that provided seedlings to substitute the vegetative propagation method of bamboo culms production by producer farmers. At the production stage, farmers are prominent producers. The trading stage comprises wholesalers, retailers, and collectors as major forces linking producers with either local processors or furniture enterprises found in the study area. The processing stage embraced bamboo-based enterprises/cooperatives. Finally, the end-users stage included users who wanedt raw culms for house or fence construction and those who used processed bamboo commodities. Market chain enablers were microfinance institutions, Trade and Industry Bureau, and NGOs (Figure 2).

3.4 Bamboo Marketing Routes

The following figure below shows the marketing route of bamboo in the form of culms. From Hula, Bursa, and Arbegona channelled to major cities such as Hawassa, Shashemene, Adama (Nazareth), Asssa, Dodola, Zway, Meki, and Alentena (Figure 3).

3.5 Product Loss

The total number of culms harvested in 2020 was 124, 827, off which 56% culms were sold, 36% used for home consumption and 8% was lost. The major reasons for the culms loss included cutting in hope of getting purchaser indiscriminate amount, on-farm death of culms because of disease and pests as the culms getting older (Table 5).

3.6 Market Chain Governance

The relationship between producers, traders, and processors not integrated and unorganized. This is manifested by complaints on unlicensed traders who sell bamboo in the unregulated market. The Trade and Industry, and Cooperatives Development Bureaus were in charge of regulating only known cooperatives and traders. Many unlicensed traders become a challenge for licensed cooperatives and traders.

3.7 Socioeconomic Contribution of Bamboo

Owing to their easy workability, strength, straightness, lightness, combined with extraordinary hardness, range of size, abundance, a short period in which they attain maturity, they are suitable for several purposes and uses. The broad category of bamboo benefit is described as follows in the study area.

Table 5: The number of culms harvested, consumed and lost in the study areas

Description	Culms in number	Percent
Sold amount	69,422	55.61
Lost amount	9,944	7.97
Consumed	45,461	36.42
Total	124,827	100

3.7.1 As a Source of Firewood

Dried bamboo poles in the farmland were used as firewood and this slightly decreases the trend of deforestation.

3.7.2 Bamboo as a Source of Income and Livelihood

In comparison with other forms of natural resource utilization, bamboo is highly profitable and requires proportionally little capital investment. In the study area, the average income obtained from the sale of bamboo was 2,413.42 ETB which signifies its visible benefit.

3.7.3 Construction Material and Household Furniture

Rural houses in the study area almost entirely constructed their houses using bamboo poles. Additionally, walls of trade purpose kiosks were constructed using bamboo poles. Chairs, shelves, mats, and toilet walls were also commonly constructed using bamboo poles in Hula, Arbegona, and Bursa districts.

3.8 Constraints in the Bamboo Market Chain

3.8.1 Production Constraints

Cutting of non-mature culm to fulfil cash needs was identified as a constraint. This needs to be corrected by creating awareness to farmers on the age of harvesting the bamboo culms. There is a lack of knowledge on modern silvicultural practices. For example, the timing of the bamboo harvest is crucial in determining the quality of culms. Many farmers harvested the culms in the study areas when they needed income. In addition, without proper storage, especially in the rainy season, culms become prone to insect attacks. The suitability of bamboo to make products, such as furniture, also differs by the age of the culm. For example, younger bamboo contains a higher starch and glucose content than mature bamboo, leading to pest infestations.

3.8.2 Processing Constraints

Lack of bamboo-based factories or firms was taken as a problem since many farmers practiced traditional methods of processing bamboo. The products were primarily traditional furniture, such as benches and stools, and also bamboo mats. Due to the lack of machines and tools required to make the products, the production process relied on largely manual labor. In addition, the quality of bamboo products was inconsistent because of the lack of knowledge on the timing of harvest.

3.8.3 Marketing Constraints

Lack of market for bamboo was a common problem in the study area. The loss of bamboo was customary in the study area and market linkage, allowing the sale of bamboo at a retailer level only. Licensing problem was a challenge since many bamboo traders complained that although they paid taxes, their license was not being renewed while unlicensed traders were conducting illegal trading.

3.9 Existing Bamboo Market Channels

The following seven major bamboo market channels were identified. Of which the first, sixth, and seventh channels were relatively dominant in terms of the volume of bamboo culms. The possible reasons for the dominance of these channels were the involvement of the high number of collectors and the demand of cooperatives to get bamboo poles from producers in a sufficient magnitude.

1. Producer–Retailer–Collector—End User (22%)
2. Producer—Wholesaler—Retailer–Cooperative—End User (3%)
3. Producer—Wholesaler—Retailer—End User (5%)
4. Producer—Collector—Wholesaler—End User (10%)
5. Producer—Cooperative—End User (11%)
6. Producer—Retailer—Cooperative—End User (24%)
7. Producer—Collector—Cooperative—End User (25%)

3.10 Market Structure

The market concentration ratio was calculated to analyze the type of market structure prevailed in the study area. The calculation was conducted by taking the annual or total volume of bamboo purchased by sample traders. As indicated in Table 6, the bamboo

Table 6: Market structure and volume of bamboo in the study area

S.No	Frequency of Traders	Cumulative frequency	% of Cumulative	Total volume of Purchase	% Share of Purchase	Cumu
1	3	3	18.8	38,125	54.9	
2	1	4	25.0	5,213	7.5	
3	1	5	31.3	2,979	4.3	
4	2	7	43.8	2,113	3.0	
5	2	9	56.3	4,156	6.0	
6	3	12	75.0	9,844	14.2	
7	4	16	100	6,992	10.1	
Total	16	16	100	69,422	100	

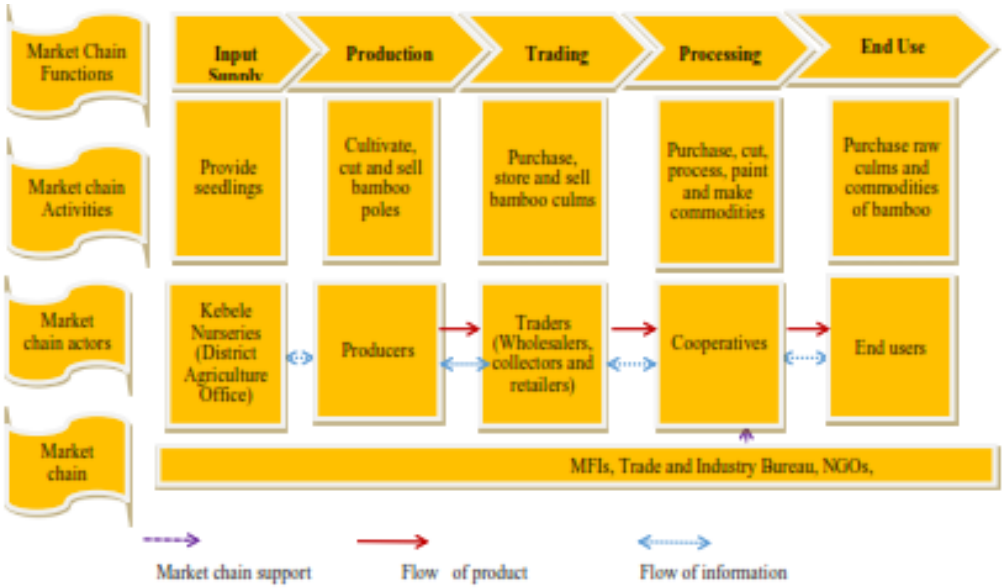

Figure 2: Market chain map of bamboo in the study area

market in the study area was a strong oligopoly. Measures of market concentration ratio showed that the top four biggest traders controlled 62.43 % of the bamboo market, indicating that the structure of the market was strongly oligopolistic in the study area.

3.11 Market Conduct

According to the survey result, 70.5% of the respondents reported that the bamboo pole's price decision was set by traders. About 20.5% of the respondents reported that market price was through the negotiation of producers and traders. The remaining 9% reported that they decide on the price of their product taken to market themselves. This result indicates the lower bargaining power of bamboo producers. All respondents indicated that the payment mechanism was cash hands-based transactions.

3.12 Market Performance

3.12.1 Marketing Margin

The gross marketing margin of actors is summarized in Table 7. The marketing margin of producers was highest in channel V (42.86%). This means they get better when they sell through cooperatives. The highest gross marketing margin (GMM) of wholesalers was 30.04% in channel II. The retailers in this channel give a better price to wholesalers bearing in mind they are going to sell to cooperatives. Retailers derived the highest GMM relative to other actors in Channel I, which was 32.32%. This was because collectors intervene in the middle and sell to users who want the culms badly for construction purposes. The GMM obtained by collectors was highest in channel IV, which was 39.70%. This is because wholesalers pay a high price to collectors than in other channels. Cooperatives share of GMM was highest Channel V (57.14%). This was related to direct access to bamboo culms from producers themselves.

3.13 Econometric Model Results for Determinants of Bamboo Market Supply

Before embarking on the model, different tests were conducted to check the validity of variables. The multicollinearity test of vari-

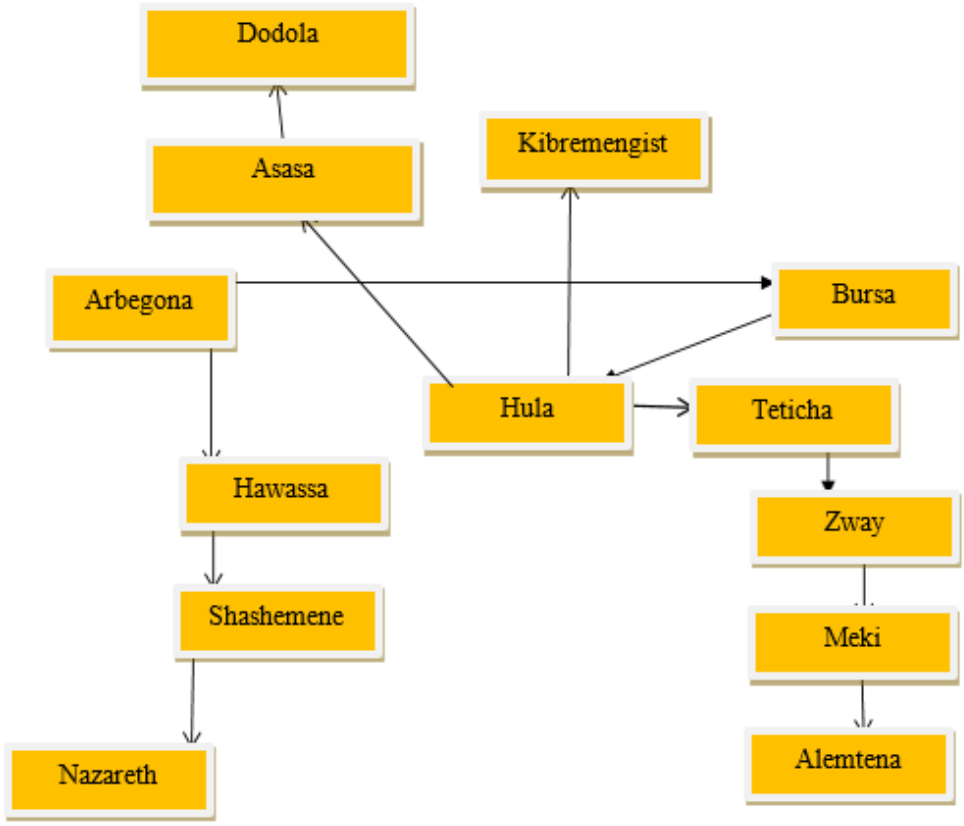

Figure 3: Marketing routes of highland bamboo originated from Sidama region

ance inflation factor result shows that the mean variance inflation factor was 1.42, which suggests no such problem. Also Breusch-Pagan / Cook-Weisberg test for heteroscedasticity showed no problem of such with chi² (1) =0.32, Prob¿chi² = 0.5693. Two-stage least square regression was used because an endogeneity problem was found. The number of bamboo culms harvested when it was tested using cultivation experience of farmers and area allotted to bamboo production with test statistics values: Durbin (score) chi2 (1) =3.27395, (p = 0.0704) and Wu-Hausman F(1,109)= 3.05725, (p = 0.0832). After running two stages least square regression model, the number of bamboo culms harvested, sex of the household head, education level of the household head, membership in farmers based agricultural association, and lagged price were found to be statistically significant.

The number of bamboo culms harvested was positively related to the number of bamboo culms supplied for sale at 1%. This shows that as the number of harvested bamboo increases by one culm, the number of culms supplied for sale increases by 0.18 culms. This indicates the harvest amount increases, more is supplied to the market as a market surplus. This result is in line with the finding of Fayera et al. (2017) who stated that the number of harvested bamboo culms was positively related to the number of bamboo culm supplied for sale.

Sex of the household head had a positive effect on the market supply of bamboo to the market at a 1% significance level. Being a male household increased the number of culms supplied to the market by 146.17 culms per year. The probable reason is males have better access and control over resources than females, and produce and supply more to the market. This result is in line with the research result of Desalegn (2018) who conducted maize value chain analysis in Demebecha district, North West of Ethiopia.

Education level of the household head showed a positive effect on the number of bamboos supplied to market with a significance level of 5%. The survey results revealed that if bamboo producer gets educated, the amount of bamboo supplied to the market increased by 16.12 culms, keeping other factors constant. The probable implication here is those who can read and write stood a better chance of understanding things faster and were well encouraged to produce and market. Amare (2013) also reported that the education level of farmers exhibited a significant and positive effect on the marketed surplus of pepper. Addisu (2016) also found that Education has shown a positive effect on onion quantity supplied to the market.

Membership in farmers-based agricultural association showed a cooperative membership had a significant impact on the market supply of bamboo at 1% significant level. Those who had access to market information increased their yearly bamboo Culm supply

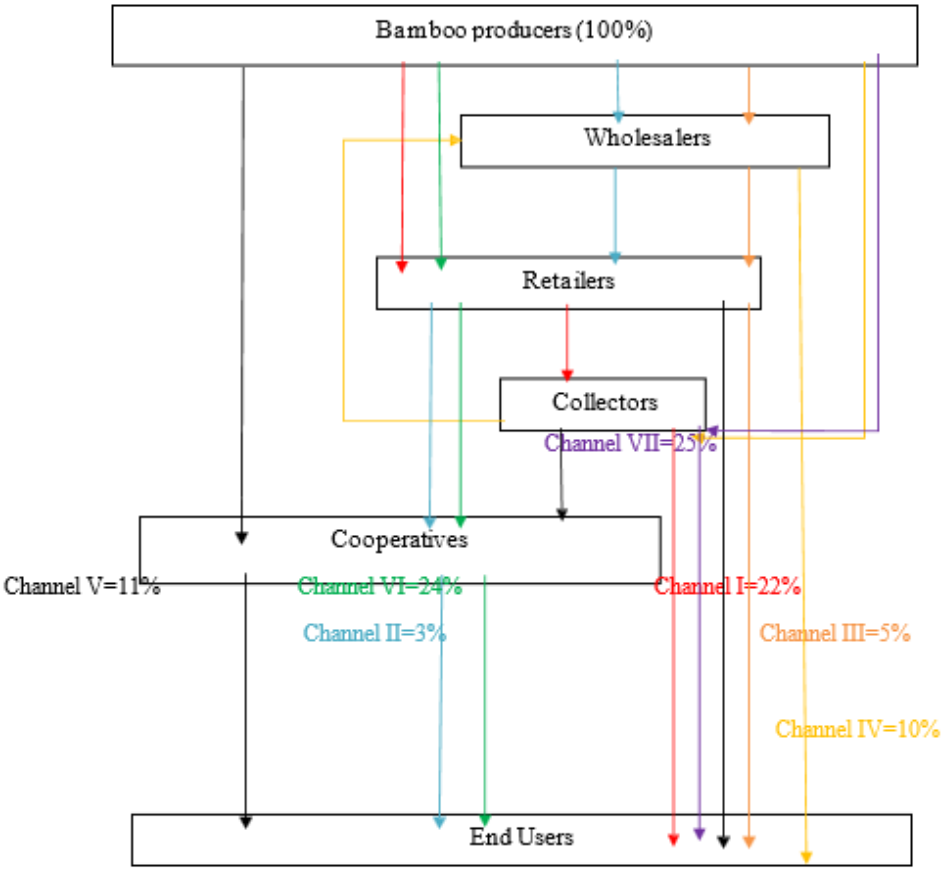

Figure 4: Bamboo Marketing Channels

by 149.61 culms. This finding supports the result in the study of Deepak (2007) who found that cooperatives had a positive impact not only on milk production but also on the marketed surplus of milk.

Lagged price was positively related to the number of bamboo culm supplied for sale at 1%. This shows that as the price of bamboo culm from the previous year increases by one birr, the number of culms supplied for sale increases by 34.19 bundles. The probable reason is the price of agricultural products in the past year/season motivates to produce more commodities in the coming year/season. Tomek and Robinson (1985) cited in Sultan (2016) argued that product price has direct relations with marketable supply in such a way that prices of commodities from the previous year can stimulate the current production of that specific commodity.

4 Conclusion

The market chain of bamboo in the Arbegona, Hula, and Bursa districts of Sidama region is constrained by the lack of modern silvicultural practices and improved seedlings. The primary actors in bamboo market chain were producers, collectors, retailers, and cooperatives. Secondary actors were input suppliers, Trade and Enterprise Development Bureau, and the Cooperative's Development Bureau. Bamboo uses for construction material and household furniture, used as firewood, and source of income and livelihood. Measures of market concentration ratio depicts the structure of the market in the study areas is strongly oligopolistic. The bamboo pole's price decision is largely made by traders. This result indicates the lower bargaining power of bamboo producers. The cash transaction is based on cash hands. Cutting of non-mature culm and lack of knowledge on modern silvicultural practices as well as lack of market for bamboo and licensing are the major challenges identified in bamboo marketing chain. Thus, capacity building on modern bamboo silvicultural practices and processing should be provided to enhance effectiveness and efficiency of bamboo market chain. The margin reaching to producers should be improved by minimizing middlemen as the producers' margin is below 50%. The establishment of bamboo-based associations is required to improve the bargaining power of producers.

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Table 7: Gross marketing margin of actors at different channels

Actors	Indicators	I	II	III	IV	V	VI	VII
Producers	Purchase Price	-	-	-	-	-	-	-
	Marketing Cost	0.95	0.95	0.95	0.95	0.95	0.95	0.95
	Selling Price	7.67	8.33	8.33	7.50	7.50	7.67	7.50
	Gross Profit	6.72	7.38	7.38	6.55	6.55	6.72	6.55
	GMMp	32.28	34.00	39.95	32.89	42.86	31.31	29.53
Wholesalers	Purchase Price	-	7.50	6.65	15.06	-	-	-
	Marketing Cost	-	3.25	3.25	3.25	-	-	-
	Selling Price	-	15.69	14.50	22.80	-	-	-
	Gross Profit	-	4.94	4.60	4.49	-	-	-
	GMMws	-	30.04	29.59	27.41	-	-	-
Retailers	Purchase Price	7.30	13.66	13.66	-	-	7.47	-
	Marketing Cost	0.98	0.98	0.98	-	-	0.98	-
	Selling Price	15.35	20.85	20.85	-	-	15.20	-
	Gross Profit	6.73	6.21	6.21	-	-	6.75	-
	GMMr	32.32	21.06	30.46	-	-	30.73	-
Collectors	Purchase Price	15.20	-	-	7.50	-	-	7.50
	Marketing Cost	1.41	-	-	1.41	-	-	1.41
	Selling Price	23.76	-	-	16.55	-	-	16.60
	Gross Profit	7.15	-	-	7.64	-	-	7.69
	GMMcoll	35.40	-	-	39.70	-	-	35.83
Cooperatives	Purchase Price	-	15.20	-	-	7.50	15.20	16
	Marketing Cost	-	1.49	-	-	1.49	1.49	1.49
	Selling Price	-	24.50	-	-	17.50	24.50	25.40
	Gross Profit	-	7.81	-	-	8.51	7.81	7.91
	GMMcoop	-	14.90	-	-	57.14	37.96	34.64

able time for the study.

Competing interests

The authors declare that they have no competing interests.

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Table 8: Two-Stage Least Square Regression Results for determinants of bamboo market supply

Bamboo market supply	**Coef.**	**Std. Err.**	**P¿z**
Total harvest	0.179***	0.049	0.000
Age	-0.387	1.278	0.762
Sex	146.170***	28.919	0.000
Education level	16.120**	6.698	0.016
Membership in Associations	149.607***	39.668	0.000
Lagged price	34.192***	6.796	0.000
Distance to market	-2.473	5.097	0.628
Non bamboo income	0.002	0.002	0.379
Total family	-3.087	5.499	0.141
_Constant	37.998	95.451	0.691

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Research Article

Variations in Morphometrics of Fruits, Seed and Dendrometric Measurements of Adansonia digitata L. in Sudan

Nasreldin Abdelrahaman Gurashi[1*], Kamal F. Elkhalifa[2]

Article Info

[1] Department of Forestry, Faculty of Natural Resources and Environmental Studies, University of Sinnar, Sudan (P.O. Box 11147, Sinner, Sudan
[2] 2Department of Silvilculture, Faculty of Forestry, University of Khartoum (formerly), Khartoum, Sudan (email:researcherkam@gmail.com)

*Corresponding author: gurashi78@yahoo.com.

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Abstract

Though Baobab (Adansonia digitata L) tree is one of the important multi-purpose species, its fruits characteristics have rarely been researched and hence remain under-utilized or not domesticated yet. With the aim of helping domestication and consequently improvement of baobab fruits, morphological variations in relation to locations of baobab tree have been studied in two genetically isolated different populations, namely Blue Nile and Kordofan states. Each state having three sites were selected where random sampling was carried. For morphometric measurements, 30-78 individual trees were randomly sampled within each baobab population. Baobab fruit traits were correlated with fruit pulp. The Analysis of variance of the parameters was performed following F-variance test. Analysis of variance for different characters showed significant differences in fruit traits between study sites. The dendrometric results were also significantly different ($P \leq 0.05$) between studied population/locations. Trees from ElGerri site were smallest and shortest in DBH and height, respectively. Fruits from Eiroseies site were have the largest values (long; 18.29 cm $\pm$ 5.72, width; 9.40 cm $\pm$ 2.13 and heavy; 264.17g $\pm$ 99.23). There was a trend that the heavier the fruit, the greater the number of seeds. The pulp weight percentage was found to be significantly higher both at El Mansora site and KourTaggat than others study sites. In general, trend at Blue Nile state study sites were found to be superior to others regarding fruit weight, fruit length, pulp percent. The variability in these characters' present valuable information that might be used for choice of close relative for advance baobab high quality planting material.
Keywords: Baobab tree, Dendrometric, Diversity, Fruits traits, Climatic zone

1 Introduction

Africa has rich wild plants and cultivated indigenous species with great commercial and edible fruit species is the African baobab (*Adansonia digitata* L.) belonging to the Family *Malvaceae* (Baum et al. 2004) agronomic potential as food crops. However, many of these species, particularly the fruits and nuts, have not been promoted or researched and thus remain underutilized. Furthermore, many of these species face the danger of loss due to increasing human impact on ecosystems (Gebauer et al. 2002). Worldwide, only about 50 fruit tree species have been highly domesticated so far and are produced on a commercial scale (Leakey and Tomich 1999). Compared to tropical America and Asia, Paull and Duarte (2011) reported that Africa has the highest number of wild edible fruit

species that amount to about 1200 species. One of the African wild Baobab has massive size, the trunk is swollen and stout, Branches are distributed irregularly and large primary, branches are well distributed along the trunk or limited to the apex (Cuni Sanchez 2010). *A. digitata is* a deciduous, massive, royal tree that measures up to 25 m high. It has thick, angular, wide spreading branches and a short, stout trunk, which reaches 10-14 m in girth and often becomes deeply fluted. The form of the trunk varies; in young trees it is conical while in mature trees it may be cylindrical, bottle shaped or tapering with branching near the base.

Baobab is one of the most importance trees of the world (Pakenham 2002, Bynum and Bynum 2014). It is an important indigenous fruit trees (IFTs) throughout the dry lands especially in savanna regions of Africa (Jama et al. 2008). As example, CEC (2008) reported that the European Union acceptance of baobab fruit pulp as a food ingredient in July 2008, and its acceptance in the USA in July 2009 (FDA 2009) have raised concerns in the popular press that baobab commercialization may lead to over- exploitation of natural stands of this species. The baobab tree is being commercialized as a food ingredient due to the high nutritional content of its fruit pulp (Gruenwald and Galizia 2005). According to Diop et al. (2006) baobab fruits are used locally to treat more than 20 diseases. In addition, its roots, bark, wood, leaves, flowers, capsules, gum, seeds, and fruits are used for over 300 different purposes (e. g. Buchmann et al. 2010). Its bark fibers are used for a variety of applications (De Caluwe´ et al. 2009a; Wickens and Lowe 2008).

The Baobab tree is well-known as multipurpose tree species of sub-Saharan Africa, with substantial socioeconomic importance (Sidibe and Williams 2002; Wiehle et al. 2014). Dhillion and Gustad, (2004) reported that the NTFPs of baobab are harvested from different land-use types (e.g., croplands, fallows, forests) and even in protected areas. Although their widely accepted potential and importance, product quality could be greatly improved through more intensive domestication programs. Wickens and Lowe (2008) urged that baobab

trees sustainability is endangered in their natural savannah ecosystem due to cattle overgrazing, intensive agricultural practices, and pronounced drought situations. Before loss of baobab tree domestication, understanding of its morphological characterization and propagation can help to protect the species. The development of management and conservation strategies requires a detailed investigation of morphological variation and genetic resources in the selected populations. Little information is available on baobab tree fruits and dendromeric variation in the study area, that provide information, help towards the effective domestication of this species. As reported by Gebauer *et al*., (2002), within the species there is evidence indicating the existence of a number of local types, differing inhabit, vigour, size, quality of the fruits. Therefore, the present study aimed to analyze variation of baobab tree and fruits traits, in relation to ecological variations between and within locations.

2 Materials and Methods

2.1 Study area

The present study was conducted in two states (Blue Nile and North Kordofan) in the Sudan, across six study sites (Table 1, Fig. 1). Blue Nile state is located in the semi wet zone (Blue Nile Investment Map, 2004) between latitude 10 and 13 North and longitude 33 and 36 East, and occupies a total area of 38500 km². The soil is dominantly characterized by clayey soils while others are sandy. The temperature varies from 14-40 during the rainy season and increasing to 46 in the dry season (April - June). The annual rainfall ranges from 650 - 750 mm and the mean annual rainfall is about 700 mm from May to October. The tree species dominant in the study area include, among others, *A. digitata*, *Anogeissus leiocarpus* DC, *Balanites aegyptiaca* L, *Boswellia papyrifera* Delile ex Caill. and *Terminalia brownii* Fres.

North Kordofan State lies in the semi- arid zone (khairelseid, 1998). It located between latitude 10.5 and 15 North and longitude 27.5 and 32 East. It occupies a total area of 185302 km². The soil where baobab population occurs is characterized by its brown color and more fine particles. This kind of soil may be originated from alluvial sediments deposited by streams which widely varies in particle size and surface characteristics with a hard surface layer when dry (Muneer, 2011). the mean annual temperature ranges from 28-30 with January being the coldest month, and May the hottest. The mean annual rainfall ranges from less than 200 mm in the north to about 450 mm in the southern parts. The dominant trees are *Acacia* spp. such as *Acacia senegal*, *Acacia millefera* and *Acacia orofota*. Other species include *Balanites eagyptiaca*, *Faidherbia albida, Ziziphus spp* and *Tamaridus indica*

2.2 Tree sampling

Trees were sampled at two states from December 2018 to February 2019. At each state, three study sites were selected following a latitudinal and climatic gradient (Cuni, 2010) with the main criterion being the existence of a well-established baobab tree population, and fruit-bearing as well as the abundance of the species (Table 1, Fig.2). Elamin (1990) also used similar approach to collect data on knowledge and distribution of baobab trees. Within baobab population for the morphometric measurements a total 318 individuals were collected. As shown in Table 2 a total of 198 and 120 individual trees were from Blue Nile and Kordofan, respectively. A baobab individual was selected at a minimum distance of 100 m from one another tree in order to avoid the genetically related individuals sampling following approach of (Assogbadjo *et al*. 2006; Kouyate´ 2005). All the trees encountered during the survey were counted and measured for their diameter at breast height (dbh) and total height using a diameter tape and Sunnto clinometer, respectively. The crown diameter was measured depending on the crown boundaries marked on the ground at mid-day.

At each site, from each tree, five ripe fruits without any damage or malformation were collected from different positions in the crown and put in labeled plastic bags. Fruits were harvested by climbing the tree and picking, or by throwing wooden sticks and catching the

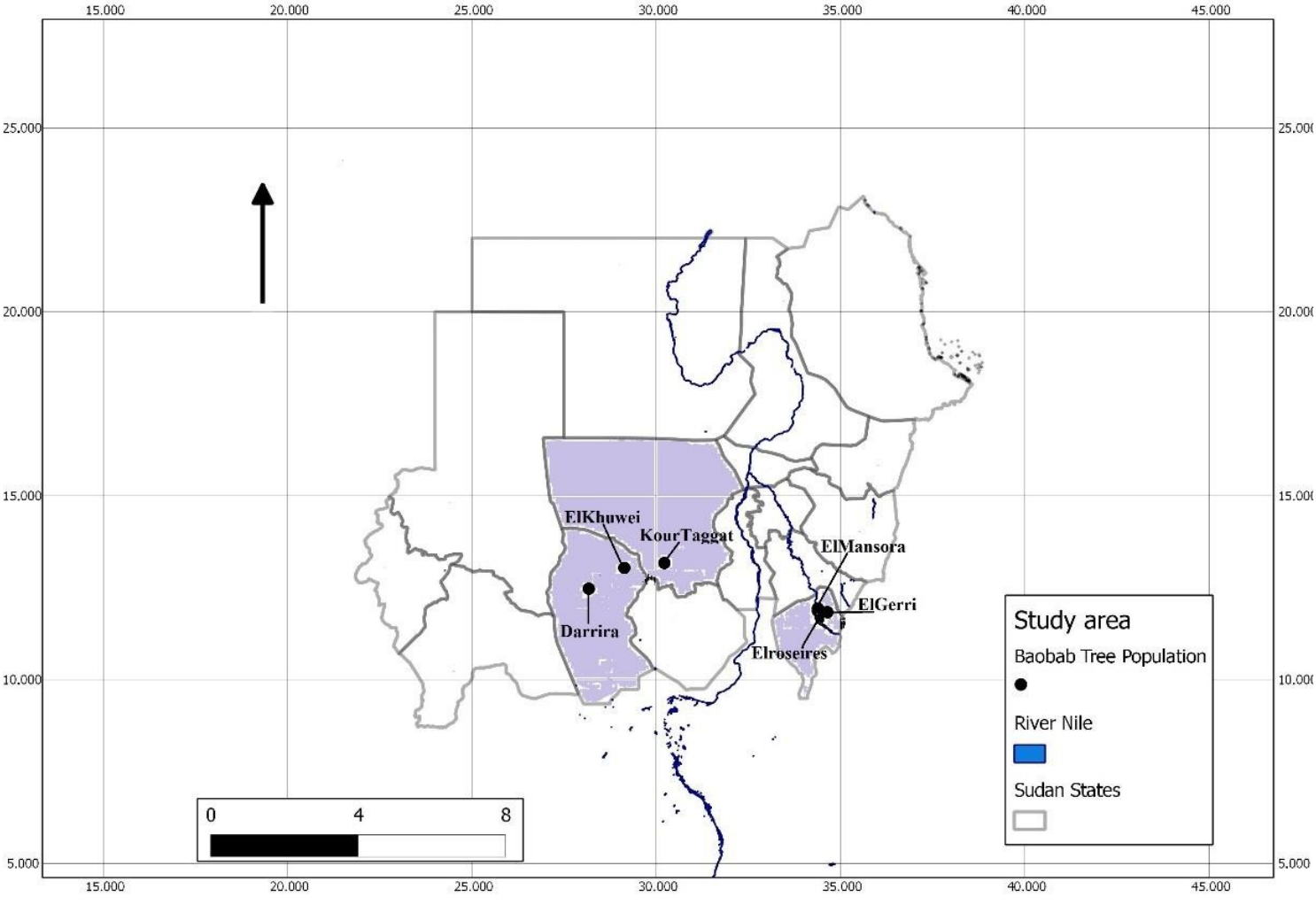

Figure 1: Sudan Map presenting location of six sampled populations of Baobab

falling fruits with a tarpaulin to avoid cracking of the fruit shell (De Smedt et al., 2011). For each fruit capsule length and diameters at the widest part were measured in cm using a measuring tape and then the average was calculated. Capsules shape ratio was calculated by dividing capsule length by capsule diameter which is thickness. Total weights were measured using a Dial Scale to determine the pulp productivity. The capsule shell was opened and separated from shell content (pulp plus seeds) and weighted. Fruits pulp and seeds were separated by dissolving the dry powdery pulp in water for five minutes and then the seeds were weighted and the pulp weight was calculated by subtraction (pulp + seed - seeds weight). The individual seeds were weighted and seed length was measured, according to the method described by De Smedt *et al.* (2011).

Statistical Package for the Social Sciences was used to analysis differences in fruit traits between study sites. Study site was ranked by means of Tukey's. Honest Significance Difference method. Correlations between pulp weight, fruit weight, and other fruit characteristics means were tested using Spearman's rank correlation coefficients. The significance level was 0.05 for the F-ratios and Tukey tests. Throughout this article, the reported values are denoted as means ± SD.

3 Results

The mean diameter at breast height (DBH), Bole height and Crown diameter of the six different baobab stands were similar (Table 2). Mean height of trees at Elroseirs- taloba, El mansora, El khuwei and Darrira were longer ($P < 0.05$) than those at El gerri and Kour Taggat (Table 3). Mean height of trees at Kour Taggat was longer ($P < 0.05$) than mean trees height at El Gerri. The mean diameter at breast height of trees at El Gerri site is shorter ($P < 0.05$) than mean trees DBH of trees from all sites. The diameter at breast height sizes classes based on 0.5 m diameter intervals (Eltahir et al. 2015) was 0.5- 0.99 m; 1 – 1.49 m; 1.5 – 1.99 m. etc...). The overall tree diameter ranges from 0.78 m to 4.55m (Table 3). The largest tree DHH sizes was recorded for Elroseires population (1.75 -4.28 m), while the smaller tree was documented for El Mansora population (0.79-1.64 m). Overall, about 102 trees was recorded within 2.5–2.99 m DBH classes. Only six trees were recorded within DBH class range of 4.5- 4.99 m.

Mean fruit width of tree at Elroseires- taloba, El Mansora and Kour Taggat are larger (P 0.05) than mean width tree at El Gerri.

Table 1: Sampled locations of *A. digitata*: areas, altitudes, geographical locations

Silvicultural Zone	Study sites	Latitude (N)	Longitude (E)	Altitude (m)	Mean annual Precipitation (mm)
Blue Nile	Elroseires-taloba	11°94′0″	34°23′0″	467	700
	El Gerri	11°84′10″	34°63′367″	538	700
	El Mansoura	11°94′00″	34°38′33″	465	700
Kordofan	Elkhuwei	13°04′122″	29°13′098″	530	450
	Kour Taggat	13°18′010″	30°21′272″	560	350
	Darrira	12°47′20″	28°16′99″	565	450

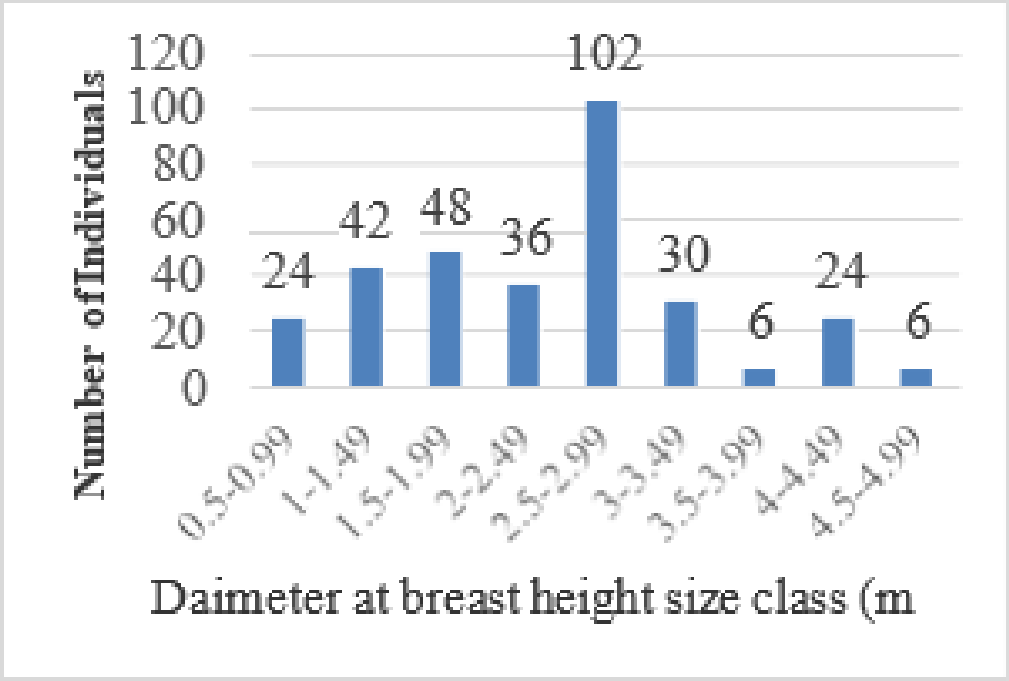

Figure 2: Diameter at breast height range of 318 baobabs (A. digitata) trees of study area, Sudan. Sizes classes are in 0.25 m intervals

ElKhuwei and Darrira (Table 4). In terms of mean fruit length, trees at Kour Taggat and Darrira have shorter length than tree trees from other sites. The least shortest fruit length was recorded at Darrira site. As shown in table 4 there is significant variation (P 0.05) in mean fruit weight in the order of: Elroseires-taloba > El Gerri, El Mansora and Kour Taggat > ElKhuwei > Darrira. The pulp weight percent of trees population at Kour Taggat and El Mansora was higher (P 0.05) than pulp weight percent of trees in other sites. Mean number of seeds per fruit of tree population at Elroseires-taloba, El Gerri and El Mansora higher (P 0.05) than tree population at El Khuwei, Kour Taggat and Darrira. of *Adansonia digitata* population from six study sites is shown in Table 5. Highest (P 0.05) mean seeds weight per fruit was from tree population at Elroseires-taloba and the lowest (P 0.05) mean value was from tree population at Darrira site. In terms of mean dry one seed weight, tree population Elroseires- taloba and Darrira showed higher (P 0.05) values than population at other sites. Tree population at El Gerri and El Khuwei showed shorter (P 0.05) mean seed length than values from tree population at remaining four sites. Mean seed width tree population at Elroseires- taloba, El Gerri and Darrira was higher than values at other tree population at other sites.

As shown in table 6, pulp weight and weight of fruit was positively correlated with most measured fruit characteristics over each study area. For all study sites, correlations between weight of pulp, weight of fruits and other fruit characteristics, except for trees DBH and were found to be similar. In addition, there was no significant correlations between pulp weight and weight fruit with tree height from Kordofan. Pulp weight and weight of fruit was positively correlated with most measured fruit characteristics over each study area.

Mean variation in seeds weight per fruit, dry one seed weight, seed length and seed width

Mean variation in seeds weight per fruit, dry one seed weight, seed length and seed width of *Adansonia digitata* population from six study sites is shown in Table 5. Highest (P 0.05) mean seeds weight per fruit was from tree population at Elroseires- taloba and the lowest (P

0.05) mean value was from tree population at Darrira site. In terms of mean dry one seed weight, tree population Elroseires- taloba and Darrira showed higher (P 0.05) values than population at other sites.

Table 2: Dendrometric tree (mean) of baobab stands of different Baobab stands in study sites of Blue Nile and Kordofan States

Study sites	Dendrometric characters				
	DBH (m)	Girth (m)	Height (m)	Bole height (m)	Crown diameter (r
Elroseires	2.90 ± 0.73	9.11 ± 0.8	21.63 ± 3.55	3.21 ± 1.12	16.09 ± 6.42
El Gerri	1.15 ± 0.23	3.61 ± 0.22	13.05 ± 1.89	3.21 ± 0.75	12.22 ± 2.16
El Mansora	2.61 ± 0.48	8.19 ± 0.51	22.15 ± 1.19	2.95 ± 0.33	13.83 ± 1.60
ElKhuwei	2.90 ± 0.78	9.11 ± 0.65	19.42 ± 3.25	3.53 ± 1.03	13.92 ± 3.63
Kour Taggat	2.27 ± 1.28	7.13 ± 1.33	16.38 ± 5.21	1.66 ± 0.61	14.44 ± 7.33
Darrira	2.18 ± 0.47	6.84 ± 0.35	17.60 ± 3.91	3.50 ± 0.93	10.40 ± 1.67
Total	**2.40**	**7.33**	**18.42**	**3.02**	**13.83**

Means charted by standard deviation. Parameter means charted by a same letter are not significantly different between both sites at P ¡ 0.05 (ANOVA)

Table 3: Diameters at Breast Height class range across Baobab population

States	Sites	Diameter at breast height range	Number of individual
Blue Nile	Elroseirs	1.75 - 4.28	78
	ElGerri	1.6 - 4.55	66
North Kordofan	El Mansora	0.79 - 1.64	54
	ElKhuwei	0.78 - 4.19	54
	Kour Taggat	2.03 - 3.41	36
	Darrira	1.62 - 2.77	30

Tree population at El Gerri and El Khuwei showed shorter (P 0.05) mean seed length than values from tree population at remaining four sites. Mean seed width tree population at Elroseires- taloba, El Gerri and Darrira was higher than values at other tree population at other sites.

As shown in table 6, pulp weight and weight of fruit was positively correlated with most measured fruit characteristics over each study area. For all study sites, correlations between weight of pulp, weight of fruits and other fruit characteristics, except for trees DBH and were found to be similar. In addition, there was no significant correlations between pulp weight and weight fruit with tree height from Kordofan. Pulp weight and weight of fruit was positively correlated with most measured fruit characteristics over each study area.

4 Discussion

The study results contribute to baobab tree conservation and domestication in Sudan as an important resource for the future. Regarding morphological characters. El Amin (1990) stated that the baobab is deciduous trees up to 20 m high, girth up to 13 or more. Gebauer et al. (2002) also reported that baobab is a massive and majestic tree which reaches a maximum height of 25 m. The mean height of the six stands found in this study match up to the height range of earlier work done by El Amin, (1990) and Gebauer et al. (2002). This might probably be due to the fact that the studies were conducted at the same ecological areas or the earlier works might have dealt with similar ages group population.

The diameter (girth values) was also in the range of other observations in western (Assogbadjo et al. 2010; Duvall 2007) and southern Africa (Venter and Witkowski 2010; Cuni Sanchez 2011). Based on assessment 306 baobabs trees in the Nuba Mountains, Sudan, Wiehle et al., (2014) reported that Kordofan baobabs daimeter can reach an impressive size of up to 8.93 m. Patrut et al. (2007) reported the largest DBH (9.74 m) of African baobab from north-eastern Namibia. According to Gebauer *et al.,* (2002) the baobab tree has a short and a stout trunk which attains 3.18 m to 4.45 m or more in DBH. The present findings showed that the DBH of baobab trees at the study sites agree with the earlier studies showed by Baum, (1995) and Gebauer et al. (2002) in Sudan.

The current study reported that fruit size was found to be within the range (13.24-18.29 cm length, 7.27-9.4 cm wide). The result is inconsistent Munthali et al. (2012) fruits from Malawi who reported (11.9 - 16.5 cm length and 6.8 -7.6 cm width) and Assogbadjo et al. (2006) in Benin (16.8-20.7 cm length, 6.2 -8.3 width). Variances in fruit morphology influence be connected to differences in ecological sites between baobabs from Blue Nile and Kordofan states, as suggested by Cuni Sanchez et al. (2010) in Malawi.

Across study sites in the present study, mean seed weight is 77.79 g per fruit, which close to fruit seed weight (71 g per) from Mali (De Smedt et al 2011). As far as seed weight concerned, the finding of study disagrees with the findings of Cuni Sanchez (2010) indicating a value of 87 g in Mali. The means of seed size found in the present study seeds traits (length, 1.15 cm and width of seed, 0.68 cm), is in line with those reported by Msanga (1998) with seed dimensions of 1.2cm in length and 0.8 mm width in Tanzania and by Owen (1999) indicating mean seed size of 0.5 cm width, in Niger. The differences in recorded results showed importance of studying variation at regional scale**,** as seed characteristics may also strongly depict species adaptability Chapman *et al* (2000).

In terms of the correlations between pulp and fruit weight, and measured characters, the study results agreed with those of Assogbadjo

Table 4: Mean (Std. Deviation) morphological characteristics (Fruits width; length; weight, pulp weight and seed weight) of baobab populations in six study sites

Study sites	Fruits width (cm)	Fruit Length (cm)	Fruit weight (g)	Pulp weight % (g)	Number of seeds per fruit
Elroseires-taloba	9.40 ± 2.13	18.29 ± 5.72	264.17 ± 99.23	14.21 ± 2.99	224.71 ± 106.61
El Gerri.	8.27 ± 1.29	17.65 ± 4.96	179.85 ± 58.69	16.88 ± 3.92	184.93 ± 88.79
El Mansora	8.91 ± 1.03	16.11 ± 5.27	206.8 ± 59.87	19.95 ± 5.27	178.97 ± 85.61
ElKhuwei	7.49 ± 1.56	16.17 ± 3.86	158.24 ± 75.5	16.01 ± 3.70	139.65 ± 77.95
Kour Taggat	8.53 ± 1.84	14.78 ± 3.10	178.21 ± 93.16	20.12 ± 8.31	150.68 ± 84.16
Darrira	7.27 ± 1.78	13.24 ± 4.46	125.15 ± 94.52	16.64 ± 4.77	111.80 ± 107.61
Total	**8.33**	**16.33**	**189.43**	**17.00**	**168.51**

Mean numbers with the same letter are not significantly different within column at (P 0.05)

Table 5: Mean (Std. Deviation), variation in seeds weight per fruit and single seed parameters among six study site of *Adansonia digitata* L

Study sites	Seeds weight (g) Per fruit	Dry seed weight (g)	One seed (g)	Seed length (cm)	Seed width (cm)
Elroseires-taloba	117.58 ± 52.38	0.53 ± 0.10	1.22 ± 0.12	0.72 ± 0.05	
El Gerri.	78.22 ± 35.53	0.43 ± 0.08	1.12 ± 0.08	0.68 ± 0.09	
El Mansora	72.87 ± 34.84	0.41 ± 0.11	1.15 ± 0.11	0.65 ± 0.04	
ElKhuwei	63.74 ± 36.94	0.45 ± 0.06	1.11 ± 0.18	0.66 ± 0.07	
Kour Taggat	66.97 ± 43.91	0.42 ± 0.09	1.14 ± 0.11	0.67 ± 0.06	
Darrira	52.71 ± 46.64	0.48 ± 0.05	1.17 ± 0.09	0.69 ± 0.09	
Total	**77.79**	**0.46**	**1.15**	**0.68**	

Mean numbers with the same letter are not significantly different within column at (P ¡ 0.05)

et al. (2005), who reported a similar relationship in Mali, Malawi and Benin. De Smedt *et al*, (2011). commented that it is interesting to mention that the selection of pulp weight according to fruit weight may end up with a large error because some fruits with high weight are not significantly different from fruit pulp that relatively smaller due to heavy shell weight (De Smedt *et al*, 2011). Nevertheless, the study results contrast the argument of Smedt and his colleagues (2011). This may be due to the fact that environmental variables have an important role in phenotypic expression of fruit characteristics in the study areas.

5 Conclusion

The present work revealed that diversity in morphometric traits of baobab fruits and dendrometric tree exist in the six studied baobab population in Blue Nile and Kordofan states, Sudan. The results of this study are useful for great for future domestication and improvement programs of fruits traits. The study recommends further selection of trees with improved fruit characteristics might increase the productivity for getting more variability in respect of desired traits.

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Competing interests

The authors declare that they have no competing interests.

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Table 6: Coefficients of correlation between pulp weight, fruit weight, and other fruit characteristics

Characters	Weight of Pulp		Weight of Fruit	
	Blue Nile	Kordofan	Blue Nile	Kordofan
Weight of Pulp (g)	1.000	1.000	0.829**	0.807**
Weight of Fruit	0.829**	0.807**	1.000	1.000
DBH	0.157	0.068	0.205	0.056
Height	0.418*	0.006	0.449*	0.009
Fruit width	0.781**	0.768**	0.839**	0.882**
Fruit Length	0.030	0.421**	0.220**	0.492**
Fruit shape	-0.267**	-0.260**	-0.139	-0.240**
Fruit thickness	0.431**	0.132	0.452**	0.336**
Weight of seed	0.679**	0.765**	0.925**	0.966**
Number of valves	0.197*	0.461**	0.106	0.453**
Number of Seed/Fruit	0.614**	0.770**	0.794**	0.925**
Weight of seed	0.121	0.144	0.311**	0.322**

** and * Correlation is significant at the 0.01 and 0.05 level, respectively.

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Research Article

Willingness to Pay for the Ecosystem Conservation: The Case of Lake Hora, Bishoftu, Ethiopia

Tesfaye Assefa[1*], Deginet Berhanu[2], Teshale WoldeAmanuel[3]

Article Info

[1] Oromia Environmental Protection Authority, Addis Ababa, Ethiopia
[2] Ethiopian Environment and Forest Research Institute, P.O.Box: 24536 (Code 1000), Addis Ababa, Ethiopia;) [3] Lecturer at Hawassa University, Wondo Genet College of Forestry and Natural Resources, Ethiopia

*Corresponding author: berhanudeginet9@gmail.com

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Abstract

Lakes provide considerable social, economic, and ecological benefits to society. However, they are shrinking and declining due to anthropogenic factors and land use changes, particularly in developing countries. Despite this, information regarding the socio-economic and ecological impacts of the lake level reduction and communities' willingness to pay for its conservation programs is lacking. This study employed a contingent valuation method to estimate willingness to pay for the conservation of Lake Hora, Bishoftu, Ethiopia. The primary data were collected from 203 randomly selected sampled households through face-to-face interviews. A double bounded dichotomous choice format was used to elicit the household's willingness to pay. Descriptive statistics such as mean, standard deviation, and percentages were used to describe sample respondents in terms of some desirable variables. Bivariate probit and probit models were also applied to estimate the mean willingness to pay and to determine factors affecting willingness to pay, respectively. Results of the study showed that most respondents (74.5%) were WTP for the conservation of the ecosystem of the lake. The bivariate probit model result shows that the total willingness to pay was computed at 2,180,706 ETB $(47,811.13)$ per annum. Furthermore, the results of the probit model revealed that age awareness on ecosystem service, occupation, education, marital status, age, and income have positive and significant effects on WTP while the amount of initial bid and satisfaction have a negative and significant effect. Hence, researchers and government should target those socio-economic variables in conserving and restoring lake's ecosystem services at the household level.

Keywords: Bishoftu; Contingent Valuation Method; Double Bounded Dichotomous Choice; Ecosystem services, Willingness to Pay.

1 Introduction

Environment is composed of assets that deliver a variety of services which provide the life support systems to sustain our very existence such as inputs for the production process, waste assimilation, amenity values, and global life support (Folmer and Tietenberg 2003). Principally, environmental resources are the basis of human life playing a crucial role in the survival of people and nations, both for subsistence and economic mainstay, for individuals' welfare and continuing existence entirely depends upon the various attribute of the environment (MEA 2005).

Lake ecosystems have enormous economic and aesthetic values and are largely responsible for positive contributions toward maintaining and supporting overall environmental health. They can serve as a source of food, medicines, and materials as well as for recreational and commercial purposes (Halkos and Matsiori 2014; MEA 2005; Saliba et al. 1987). Though they have such a great role in the welfare of human beings, many ecosystems, and their services are currently under increasing pressure; explicitly, more than 60% of the world's ecosystems are not being used in a sustainable way (MEA 2005). Not only that, the diversity of users who claim rights to obtain different benefits from the lake ecosystems makes it challenging to manage in a sustainable way (Tumer 2020). Many lakes in Ethiopia are located in the Rift Valley and central part of the country where siltation and environmental pollution are common problems (Bamlaku Ayenew et al. 2015; Dagnachew Legesse et al. 2004).

The problem is more serious on the lakes which are in the vicinity of urban areas. In a developing country like Ethiopia, where there are no appropriate urban forest management policies and urban waste management facilities, lakes found in urban centers can be easily polluted by waste (Fasil Kenea et al. 2017). Despite the growing recognition and long-lasting benefits obtained from sustainable lake management, users and decision-makers inappropriately discount when choosing between ecosystem conversion and conservation (Gebrehiwot Mesfin 2020). This is what happens to the lake Hora, which is found in Bishoftu town, Eastern Shewa. Lake Hora is one of the seven lakes found in Bishoftu town (Hora, Babogaya, Cheleleka,Kuriftu, Bishoftu, Kilole, and Green), which took the largest place in the society and is more preferable of its multifunction.

In addition to the recreational services obtained from this lake, it also serves as a host for the great "Irrecha" ceremony celebration of Oromo peoples for a long period. These increase the socio-cultural, economic, and ecological importance of the town too. However, different pressures that arise from liquid waste leakages or discharge from resorts, hotels, and lodges surrounding the lakes, soil erosion from lake side constructions, solid wastes, degradation of forests surrounding the lake, and high pumping of water from the lakes

by different private and governmental institutes speed up its degradation. The information regarding the ecological and economic impacts of Lake Ecosystem degradation on local farmers has not been clearly defined. Hence, due consideration from both the government and community sides is required to keep sustain the ecological as well as the economic value of the lake. The contingent valuation method (CVM) is an important economic technique for the valuation of such anon-marketed goods and services in developing countries (David et al. 2006), which helps to address the environmental issues by eliciting the respondent's willingness to pay through the hypothetical market. Thus, this study was initiated to evaluate the communities' demand for the Lakes' ecosystem conservation by estimating their willingness to pay and examining factors affecting their decision to pay for the ecosystem services.

Payment for Environmental Services (PES) has recently received a great deal of attention as a new, innovative, and promising approach to natural resources management. The approach is considered a paradigm shift from the predominant use of command-and-control mechanisms and conventional approaches to more flexible and efficient ecosystem protection (De Grott et al. 2002). Unlike the conventional approach, PES offers conditional payments to motivate private landowners to invest in land-use practices that lead to conservation or production of ecosystem services (Ferraro and Kiss 2002; Wunder 2005). Payments are usually made in cash, in kind, or, in a mix of both. Accordingly, in this study, PES is defined as a contractual agreement between at least an environmental service (ES) beneficiary and an ES producer, by which the former transfers resources to the latter, providing the ES producer adopts specific practices on the land or resource he controls or possesses, to enhance the production of a specific ES.

2 Materials and methods

2.1 Description of the study area

Bishoftu town was established in 1925 following the Ethio-Djibouti railway line. Geographically the town is located between 8º 43 and 8º 45 North Latitude; 38º 56 and 39º 01 East Longitude, (Genet Abera and Engdawork Assefa 2021), and 47km southeast of Addis Ababa, Ethiopia (Figure.1).

2.2 Sampling design and sample size

This study employs multistage sampling techniques. In the first stage, Bishoftu Lakes werepurposively selected due to having seven natural lakes that need attention for the conservation of the ecosystem in the town. Out of the seven lakes, Hora lake was purposively selected due to the presence of a large area of forest coverage conservation and its multifunctional purpose for the local community. In the third stage, three surrounding kebeles (Cheleleka, Filtu, and Birbirsa foka) were selected randomly from the nine urban kebeles found near the lake. Finally, the required

numbers of respondents (203 households) were sampled by using simple random sampling techniques. The sample size was determined following the method explained by Yamane (1967).

$$n = \frac{N}{1 + N(e^2)} \tag{1}$$

n=N/1+N (e) ^{2} Equation 1

Where n is the sample size, N is the population size, and e is the level of precision (with 7%).

Thus, according to this formula, the sample size of 203 households was randomly sampled and distributed to the three kebeles proportional to their population size.

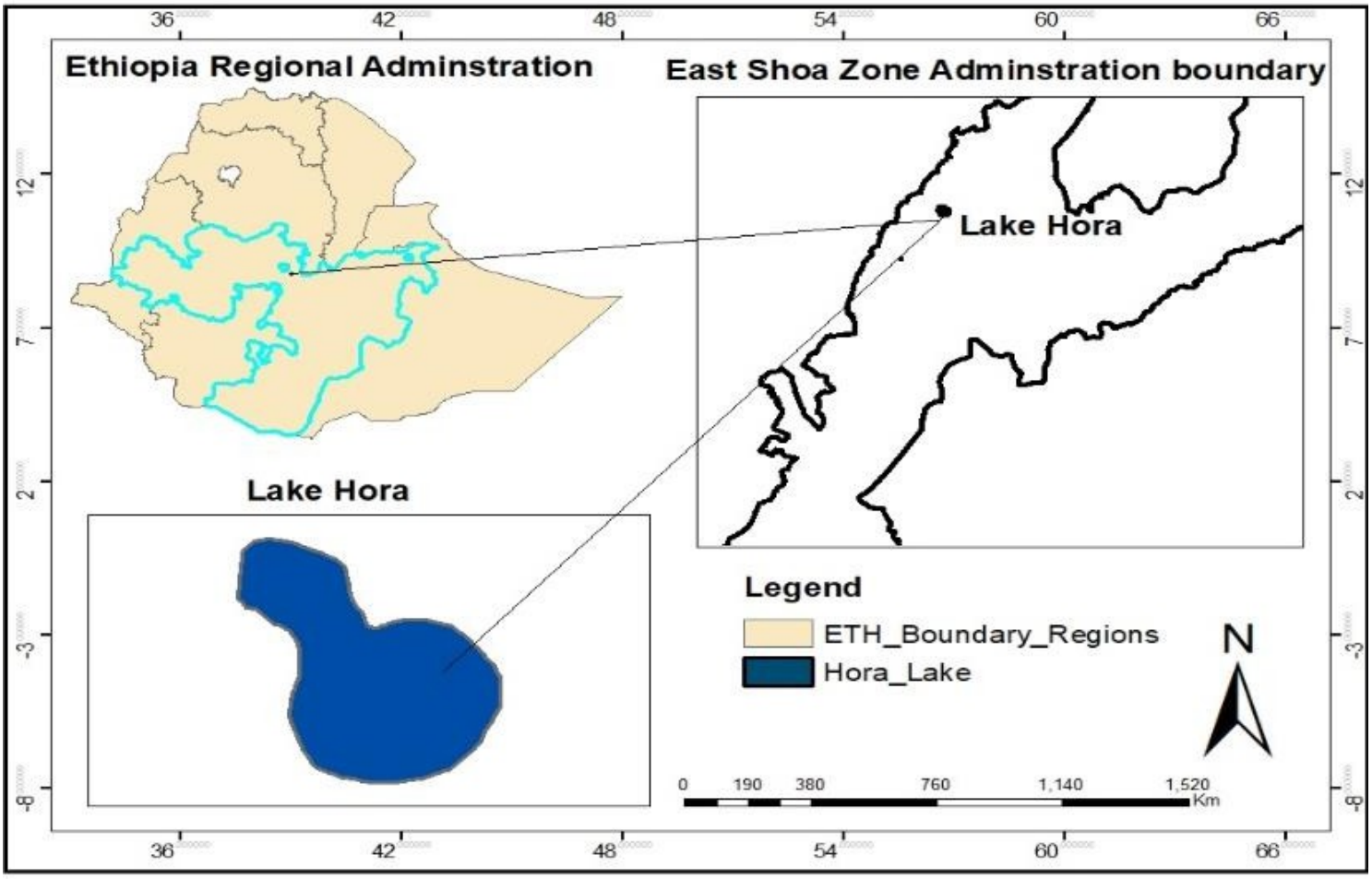

Figure 1: Map of the research area

2.3 Data type, source, and collection techniques

Both primary and secondary data were used for the study. Secondary data was obtained from published and unpublished documents and reports. The primary data were collected from sample respondents through household surveys, key informant interviews (KII), and focus group discussions (FGD) using a structured questionnaire via face-to-face interviews with the heads of the households. The developed questionnaire was pre-tested before conducting the final survey and was translated into the local language (Afaan Oromo), to increase the enumerators' as well as respondents' understanding of the questionnaires. Before conducting the household survey, FGDs and KIIs were done to gather complementary data about the study. The FGD comprises men, women, elders, and youth who are native to the area. Contingent valuation method (CVM) in the form of a double-bounded dichotomous choice elicitation method with an open-ended follow-up question was also employed to elicit households' WTP for the improvements of the lakes' ecosystem. The double-bounded dichotomous choice format (yes-no, no-yes responses) makes clear bounds on unobservable true WTP, and the yes-yes; no-no response sharpens the true WTP (Haab and McConnell 2002). The double-bounded dichotomous choice format also helps to elicit more information about respondent's WTP than single bounded format Arrow et al. 1993; Hanemann et al. 1991)

2.4 Preliminary Survey and Bids

Before implementing the survey, pre-testing was conducted in each of the three kebelesto determine the potential bid level. Random samples of 15 households were participated from each kebele and a total of 45 household heads were interviewed under the pilot survey those did not appear in the final survey. Finally, the starting price was identified for WTP as 10, 20, 40, and 60 Birr. Using these initial bids, sets of bids were determined for follow-up questions based on whether the response is "no" or "yes" for the initial bid. The actual survey was undertaken by dividing the total sampled households randomly into four groups and there would be 51 randomly assigned households per bid level. The survey was completed with a relatively small number of protest zeros (about 5%). The protest zero bidders checked for sample selection bias and they were excluded from the data set.

2.5 Data Analysis

The survey data were analyzed using descriptive statistics and econometric models. The descriptive statistics include mean, standard deviation, percentages, and frequency distribution

2.5.1 Econometric Model Specification

When the dependent variable in the regression model is continuous, the analysis can be conducted using a linear regression model. However, when the dependent variable in a regression model is binary, the analysis could be conducted using linear probability, logit, or probit models (Pindyck,1981). The results of the linear probability model may generate predicted values less than zero or greater than one, which violates the basic principles of probability (Gujarati,2004). On the other hand, logit or probit models generate predicted values between 0 and 1, and they fit well with the non-linear relationship between the probabilities and the explanatory variables (Pindyck,1981; Gujarati,2004). Besides, the probit model works better for bivariate models than the logit model. Therefore, in this study, the probit model was used to determine the factors that affect a household's willingness to pay (WTP) for the conservation of the lake ecosystem services. Following (Cameron,1994), the probit model was specified as:

$$Y^* = \boldsymbol{\beta}'\mathbf{x} + \varepsilon \tag{2}$$

$$Y_i = \begin{cases} 1 & \text{if } Y^* > I_i^*, \\ 0 & \text{if } Y^* < I_i^*, \end{cases} \tag{3}$$

where:

- $\boldsymbol{\beta}'$ = vector of unknown parameters of the model,
- $\mathbf{x}_i$ = vector of explanatory variables,
- Y_i^* = unobservable household's actual WTP for conservation of the lake ecosystem services,
- Y_i = discrete response of the respondents for the WTP,
- I_i^* = the offered initial bids assigned arbitrarily to the i^{th} respondent,
- ε_i = unobservable random component distributed $N(0, \sigma)$.

Bivariate Probit Model

Bivariate normal probability density functions are among the familiar bivariate distributions employed commonly by statisticians. Crucially, they allow for a non-zero correlation, whereas the standard logistic distribution does not Cameron,1994). Hence, the bivariate probit model is used in this study to estimate the mean WTP from the double-bounded dichotomous choice model. The j^{th} contribution to the likelihood function is given as:

$$L_j(\boldsymbol{\mu}/\mathbf{t}) = \Phi_{\varepsilon_1\varepsilon_2}\left(d_{1j}\left(\frac{t_1-\mu_1}{\sigma_1}\right), d_{2j}\left(\frac{t_2-\mu_2}{\sigma_2}\right), d_{1j}d_{2j}\rho\right) \tag{5}$$

where:

- $\Phi_{\varepsilon_1\varepsilon_2}$ = standardized bivariate normal distribution function with zero means,
- $Y_{1j} = 1$ if the response to the first question is yes, and 0 otherwise,
- $Y_{2j} = 1$ if the response to the second question is yes, and 0 otherwise,
- $d_{1j} = 2Y_{1j} - 1$, and $d_{2j} = 2Y_{2j} - 1$,
- ρ = correlation coefficient,
- σ = standard deviation of the errors.

This general model is estimated using the standard bivariate probit algorithms. Finally, the mean willingness to pay (MWTP) from the bivariate probit model was calculated using the formula specified by (Haab,2002):

$$\text{MWTP}(\boldsymbol{\mu}) = -\frac{\alpha}{\beta} \tag{6}$$

where:

- α = coefficient for the constant term,
- β = coefficient of the offered bids to the respondent.

Description of Explanatory Variables

Table 1 summarizes the explanatory variables used in the model to analyze households' WTP for the conservation of the lake ecosystem services.

The data were analyzed using STATA version 11.0 and SPSS version 16.0.

$$L_j(\boldsymbol{\mu}/\mathbf{t}) = \Pr(\mu_1+\varepsilon_{1j} > t_1, \mu_2+\varepsilon_{2j} < t_2)^{YN} \times \Pr(\mu_1+\varepsilon_{1j} > t_1, \mu_2+\varepsilon_{2j} > t_2)^{YY} \times \Pr(\mu_1+\varepsilon_{1j} < t_1, \mu_2+\varepsilon_{2j} < t_2)^{NN} \times \Pr(\mu_1+\varepsilon_{1j} < t_1, \mu_2+$$

Table 1: Variables name, expected signs, definitions, and coding

List of variables	Defining and coding	Expected sign
WTP1/WTP2	Willingness to pay decision for proposed initial bid coded, (0-no, 1-yes)	
Age	Age of the respondents (in years)	-
Sex	Sex of the respondents coded, (1-male, 0-female)	+
Family Size	Number of family members in the household	+
Income	Monthly income of the households (in birr)	+
Educational Level	The educational level of the respondents (in years of schooling)	+
Occupation	Occupation of the households (1 if employed, 0 otherwise)	+/-
Marital Status	The marital status of the respondents coded, 1-married, 0-unmarried	+
Awareness	Awareness, coded, 1-aware household, 0-otherwise	+
Years stay in the area	The number of years in residence in the area	+
Satisfaction	Level of satisfaction with the existing ecological service (0-satisfied, 1-unsatisfied)	-
Initial bid	Initial bid offered to the respondents	

Table 2: Descriptive statistics of some socio-economic characteristics for willing and non-willing to pay respondents.

Variable	Responses	No willing		Willing		Total	
		No.	%	No.	%	No.	%
Sex	Female	21	10.3	45	22.2	66	32.5
	Male	31	15.3	106	52.2	137	67.5
	Total	52	25.6	151	74.4	203	100
e Occupation	Employed	31	15.3	77	38	108	53.3
	Unemployed	21	10.3	74	36.4	95	46.7
	Total	52	25.6	151	74.4	203	100
Marital status	Single	21	10.3	16	7.9	37	18.2
	Married	31	15.3	135	66.5	166	81.8
	Total	52	25.6	151	74.4	203	100
Awareness of Lake	No	12	5.9	62	30.5	74	36.45
Conservation	Yes	40	19.7	89	43.8	129	63.55
	Total	52	25.6	151	74.4	203	100
Respondents	Yes	38	18.7	26	12.8	64	31.5
satisfaction with the	No	14	6.8	125	61.6	139	68.5
existing service	Total	52	25.9	151	74.4	203	100

3 Results and discussion

3.1 Socioeconomic characteristics of the respondents

The socio-economic characteristics of respondents were presented by response category of willing and non-willing to pay respondents and summarized in table 2.

The probability of households responding “yes” to offer bid decreases as the amount of bid increases. This could indicate the presence of the first response effect on the response for the follow-up question, which is consistent with studies done by Cameron and Quiggin (1994) and Bamlaku et al (2015). Using double bounded dichotomous choice format the mean WTP from responses of both the first and the second bids were estimated. The analysis was conducted using a seemingly unrelated bivariate probit model (Table 4). The result revealed that the correlation coefficient of the error term is less than one implies that the random component of WTP for the first question is not perfect correlation with the random component from the follow-up question.

As a result, the mean WTP value of the conservation of Lake Hora ranged from 47 to 56 ETB per year for the initial bid and the follow-up bid, respectively according to the formula of Habb and McConnell (2002) (See Equation 4). Therefore the annual mean WTP was computed at 51.7 Birr per year per

In a contingent valuation (CV) study, the aggregation of WTP for the environmental resource is very important. But before aggregation, protest zero bidders were excluded to minimize the biases. Based on the double bounded dichotomous questionnaires, the aggregate WTP for conservation of Lake Hora was computed at 2,180,706 ETB ($47,811.13) per year as shown in table 5. It was calculated by multiplying the mean willingness to pay from dichotomous choice responses result by the total number of valid responses which is 42,180.

Table 3: Distribution of initial bids and their willingness responses

Bid values	Frequency	Percent	Willingness responses	
			No (%)	Yes (%)
10	51	25.37	0.00	100.00
20	51	25.37	9.00	91.00
40	51	25.37	36.00	64.00
60	50	24.89	57.00	43.00
Total	203	100.00	25.5	74.5

Table 4: Parameter estimates of bivariate probit for conservation of Lake Hora household.

Dependent variables	Explanatory variables	Coefficients	St. Error	Z-value	P-value
Response 1	Bid1	-0.0364	0.0059	-7.03	0.000
	Cons	2.0400	0.2111	8.83	0.000
Response 2	Bid2	-0.0183	0.0065	-2.84	0.005
	Cons	0.8677	0.2249	3.86	0.000
rho = 0					
chi2 (1) = 5.26222					
prob ¿ chi2 = 0.0218					

3.2 Determinants of WTP for Conservation of Lake Hora

The estimated result on factors affecting the households' WTP for the conservation of the lake Hora ecosystem is presented in Table 6 below. The sign of most of the explanatory variables was as expected. Eleven explanatory variables were included in the model to predict the maximum willingness to pay of the respondents in monetary value. A chi-squared test was used to measure the overall significance of the model and the result of the model shows thatthe probability of chi-squared distribution is 0.000, which is significant at less than 1%. Thisimplies that the variables used in explaining the WTP for Lake Hora conservation fit the probit model at less than a 1% probability level. As it has been indicated in Table 6 below, out of eleven (11) variables used in the model, eight (8) variables were affecting the willingness of the local community. Variables like age, occupation, education, marital status, Income and households' awareness of ecosystem conservation positively and significantly influence willingness to pay at p-value less than 1%, whereas, initial bid and satisfaction with the current status of the lake negatively and significantly influence WTP at p-value lessthan 10%.

Age of the household head: had a positive effect on the willingness to pay households for the conservation of Lake Hora. The positive and significant correlation between age and WTP might be perhaps respondents of older ages were expected to pay more for the conservation of natural resources as they have awareness of the environment., This result is consistent with the findings of Calderon et al. (2006) and Gebremariam Gebrelibanos (2012).

The result of the marginal effect shows that keeping the influences of other factors constant, a one-year increase in the age of the respondents increases the probability of WTP by 0.56%. This may be due to the multifunctional purpose of Lake Hora, especially for its cultural ("*Irreecha*") value that they had been experiencing for a long period.

Households' income: has a positive relationship with the households' WTP and is statically significant at 10%. This effect indicated that respondents with higher income pay more for the conservation of the lake than households with lower income. The marginal factor shows that keeping the influence of other variables constant, for a one birr increment of a household's net monthly income, the probability of his/her willingness to pay for the conservation of Lake Hora will increase by 0.0019 %. This result was also consistent with the findings of (Bamlaku Ayenew et al 2015; Calderon et al. 2006; Gebremariam Gebrelibanos 2012).

Educational Level of respondents: The education level of the respondents is positively and significantly at 1 % significant level. The marginal effect result shows that for each additional increment of education, the probability of willingness of a household to pay for the lake conservation practices will increase by 2.04 %, ceteris paribus. One possible reason could be that more educated individuals are concerned about environmental goods including lake conservation in our case. This result is also supported by the findings of (Bamlaku Ayenew et al. 2015; Calderon et al. 2013; Gebremariam Gebrelibanos 2012).

Age of the household head: had a positive effect on the willingness to pay households for the conservation of Lake Hora. The positive and significant correlation between age and WTP might be perhaps respondents of older ages were expected to pay more for the conservation of natural resources as they have awareness of the environment., This result is consistent with the findings of Calderon et al. (2006) and Gebremariam Gebrelibanos (2012). The result of the marginal effect shows that keeping the influences of other factors constant, a one-year increase in the age of the respondents increases the probability of WTP by 0.56%. This may be due to the multifunctional purpose of Lake Hora, especially for its cultural ("*Irreecha*") value that they had been experiencing for a long period.

Households' income: has a positive relationship with the households' WTP and is statically significant at 10%. This effect indicated

Table 5: Average and aggregate willingness to pay of households for conservation of Lake Hora

Total HHs in Bishoftu	Number of sample HHs	samples with protest zero	Expected protest	HHs with valid responses	Mean WTP (birr)	Total WTP (birr)
44,403	203	10	2,220	42,180	51.7	2,180,706

Table 6: The probit model estimation results of households' WTP

Variables	Coef.	Std. Err.	Z	P¿—z—	Marginal Effects
Length of stay in town	-0.0013	0.0019	-0.70	0.486	-0.0013
Sex	-0.0303	0.0213	-1.43	0.153	-0.0303
Age	0.0056***	0.0013	4.44	0.000	0.0057
Occupation	0.2900***	0.0420	6.91	0.000	0.2900
Education	0.0205***	0.0055	3.70	0.000	0.0205
Net monthly income	0.0001*	0.0001	1.76	0.079	0.00002
Family size	-0.0024	0.0059	-0.41	0.683	-0.0024
Marital status	0.3780	0.0508	7.44	0.110	0.3780
Awareness	0.1372***	0.0393	3.49	0.000	0.1372
Satisfaction	-0.0465*	0.0268	-1.74	0.082	-0.0465
bid 1	-0.0020***	0.0006	-3.35	0.001	-0.0020
cons	-0.2247	0.0914	-2.46	0.015	
Number of ob = 203	Prob ¿ chi2 = 0.0000	LR chi2(1) = 52.66	Log likelihood = -88.57	Pseudo R2 = 0.2292	

*, **, & *** significant at less than 10%, 5%, & 1% respectively.

that respondents with higher income pay more for the conservation of the lake than households with lower income. The marginal factor shows that keeping the influence of other variables constant, for a one birr increment of a household's net monthly income, the probability of his/her willingness to pay for the conservation of Lake Hora will increase by 0.0019 %. This result was also consistent with the findings of (Bamlaku Ayenew et al 2015; Calderon et al. 2006; Gebremariam Gebrelibanos 2012).

Educational Level of respondents: The education level of the respondents is positively and significantly at 1 % significant level. The marginal effect result shows that for each additional increment of education, the probability of willingness of a household to pay for the lake conservation practices will increase by 2.04 %, ceteris paribus. One possible reason could be that more educated individuals are

concerned about environmental goods including lake conservation in our case. This result is also supported by the findings of (Bamlaku Ayenew et al. 2015; Calderon et al. 2013; Gebremariam Gebrelibanos 2012).

Occupation of respondent: has a positive relationship with the households' WTP and statically significant at 1 % significant level. The households who are working in the government and non-government organization and paid regular salary has more willingness to pay for the conservation of Lake Hora than those who were not employed.

Awareness of Lake Conservation: is positive and significant at a 10 % level. This conforms with a priori expectation; meaning that, if the respondent is aware of the benefits of lake conservation then his/her WTP will be high. Those respondents who are aware of lake conservation benefits are willing to pay 4.65 % more for improved lake conservation than those who are not aware of lake conservation benefits, ceteris paribus.

Respondents' satisfaction with the current status of Lake Ecosystem: The variable satisfaction level of the respondent with the existing lake ecosystem service was found to have significant at 10 % with a negative parameter estimate on the probability of WTP decision for lake conservation. This means that as respondents feel the existing lake ecosystem service is unreliable and/or poor quality; he/she become more likely to pay for conservation programs which possibly ensures the improvement of the existing lake ecosystem service. The marginal effect of this variable shows, that those respondents having dissatisfaction with the existing lake ecosystem service will have 4.65 % more probability of paying for lake conservation than those who are satisfied.

Initial bid: The result revealed that the initial bid value significantly and negatively affects households' decisions on WTP. The coefficient of starting bid price has a negative sign and is significant at a p-value less than at a 1% level of significance. The negative sign and the significance of this coefficient indicated that, as the initial bid value increases by one unit, the probability of a household's willingness to pay will be reduced by 0.2%. The finding is in line with (Carlson et al. 2004; Mousavi and Akbari 2011; Deginet Berhanu et al. 2022).

4 Conclusion

Hora Lake is essential for the local communities' livelihoods. However, the lake ecosystem resource is shrinking from time to time due to different factors. The main cause of this incidence is the absence of a clear demarcate boundary of the lake, illegal settlements and improper use of indigenous and exotic tree species, lack

of environmental education, and socio-political factors Local community perception towards the use and conservation of natural resources is important for policymakers and sustainable conservation of the ecosystem. This study quantified the potential contributions of the community to the conservation of Lake Hora in terms of monetary value. Our findings revealed that about 74.5% of households were willing to pay for ecosystem conservation, while 25.5% were not willingto take the offered initial bids. The mean willingness topay from the double bounded dichotomous responses and aggregate willingness to pay for the conservation of Lake Hora was 51.7 ETB and 2,180,706 ETB ($47,811.13) per year respectively. The findings indicated that age, occupation, education, marital status, income, level of satisfaction, awareness about conservation activities, and initial bid are key factors influencing the WTP Therefore, actions to be made towards these socio-economic aspects that significantly influenced household's WTP is a first step towards conserving Lake Hora to sustain quality and quantity ecosystem services.

Acknowledgments

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Competing interests

The authors declare that they have no competing interests.

Ethical Consent

The rights and well-being of participants were respected and they were informed about the research before collecting primary data. Not only that, the research was conducted on the area based on the information from the local community during problem identification. Participants were fully informed about the purpose of the research and were willing to participate in the study. Local enumerators were used to collect data and the researchers also engaged in recording their voices during focus group discussions. So the recorded voices were used as supplementary information, while collected data were used as input directly for the analysis. For this participation, they reflect their willingness even though they couldn't provide written consent to the researchers. Thus, we'd like to declare that the participation was voluntary and free from coercion, and participants had the right to withdraw at any time.

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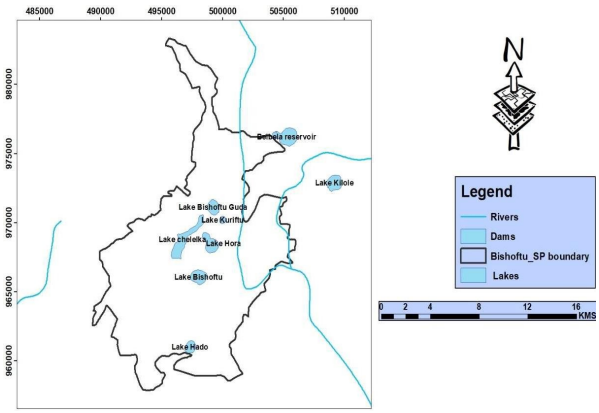
Appendices

Table 7: Annex I Summary of ecosystem services and function of Lake Hora

Ecosystem services	Frequency of respondents (out of 203)	Percentage (%)
Provisioning services		
Fish	105	52
Fodder	133	66
Medicinal plants	109	54
Water supply	122	61
Others (specify if any)	73	36
Regulating services		
Climate regulation	143	71
Erosion control	147	73
Supporting services		
Habitat	178	89
Cultural services		
Recreational and tourism	189	94
Spiritual		



Appendix 2 Lakes in Bishoftu

Source: Bishoftu city Administration (Bishoftu Structural Plan, 2019).

Ecosystem services of Lake Hora (Recreation)

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Research Article

Determinants of the adaptation mechanisms to the impacts of rangeland degradation: A case of Yabello district, southern Ethiopi

Deginet Berhanu[1*], Yoseph Melka[2], Gemedo Furo[1]

Article Info

[1] Ethiopian Environment and Forest Research Institute, P.O.Box: 24536 (Code 1000), Addis Ababa, Ethiopia; Phone: +251-916-64-33-13
[2] Hawassa University, Wondo Genet College of Forestry and Natural Resource, P.O. Box 128, Shashemene, Ethiopia. E-mail: yosef.melka@gmail.com
[1] Ethiopian Environment and Forest Research Institute, P.O.Box: 24536 (Code 1000), Addis Ababa, Ethiopia. E-mail: gemedofuro@gmail.com

*Corresponding author: gurashi78@yahoo.com.

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Abstract

Over the decades, drought has occurred more frequently than previously documented in southern Ethiopia. Many projections of the causes and impacts of rangeland degradation on the pastoralists' livelihood have been reported. However, they were arguably too general to understand the magnitude of the impacts of rangeland degradation to suggest possible adaptation mechanisms in the pastoralists region of the country. A better understanding of the existing adaptation mechanisms and factors affecting pastoralists' choice is crucial for policies and programs that aim at promoting successful rangeland management in Ethiopia. The objective of this study was to assess possible adaptation mechanisms and to identify the factors that affect pastoralists' choice of adaptation mechanisms in Yabello district, southern Ethiopia. A total of 172 randomly selected households from two kebeles were interviewed using structured questionnaires. Multivariate probit regression and descriptive statistics were used for data analysis. The results showed that pastoralists' possessed their own adaptation mechanisms to cope up and prevail through the impacts of rangeland degradation. Herd diversification, buying of supplementary feed, destocking and hay making are among the common adaptation mechanisms of the area. Parameter estimates from the multivariate probit model revealed that the choice of adaptation mechanisms among pastoralists of Borana was significantly influenced by sex, age, family size, education livestock holding, access to weather forecast, access to credit service, and distance from the market center. Therefore, considering all these factors affecting pastoralists' choice of the adaptation mechanisms would help to develop more effective rangeland management. Furthermore, the finding of this research derived entry points for the policies aimed to work with the local communities' future research to cope-up with the impacts of rangeland degradation.
Keywords: Adaptation mechanisms, Borana, degradation, multivariate probit model,

Pastoralists, rangeland

1 Introduction

Rangelands are defined as uncultivated land that are suitable for browsing and grazing animals, which make up about 50 to 70% of the world's landmass with 50% of which is arid and semi- arid (Holechek, 2013). The rangelands of Ethiopia are located around the border line of the country and found below 1500 m a s l (Friedel et al. 2000). They are estimated to cover an area of 78 million hectare and are classified as arid and semiarid (Fenetahun et al. 2018). Rangelands provide several benefits, like forage for the livestock, protection and conservation of soil and water resources, provision of flora and fauna, and contribution to the attractiveness of the landscape (Carlier et al. 2009; Faraz et al. 2021).They provide a living for about six million Ethiopians, an estimated 10-12% of the country's total human population. Pastoralists keep about 40% of the country's total population of the cattle, half of the small ruminants and nearly all the dromedaries.

The rangeland of southern Ethiopia, including Borana rangeland is an important area of cattle production. They cover about 61 to 65% of the total area of the country and are characterized by high temperatures, low and high variables rainfall regimes, low density of vegetation cover and human population (Solomon et al. 2007).

The Borana rangeland is one of the pastoral areas that located in the southern part of the country, consisting of almost homogenous ethnic groups having the same culture and livestock- range management practices. It has been the center of widespread nomadic culture (Solomon et al. 2007). In recent decades, these lifestyles have come under enormous pressure due to rangeland degradation and fail to maintain the standard of living of a large sector of the pastoralists of the area (Tache and Oba, 2010). The major causes of rangeland degradation are overgrazing, recurrent drought, crop cultivation, bush encroachment, shortage of rainfall, inappropriate uses of land resources and soil erosion (Oba and Kotile, 2001; Kassahun Ameha et al. 2008; Mohammed Musa et al. 2016). The rangeland degradation resulting from those natural and man-made causes in the area leads to feed shortage for the cattle, death of livestock, food shortage for human and poverty. As a result, more than 80% of the livestock populations were died in Ethiopia (Kassahun Ameha et al. 2008). Consequently, the Borana communities have become food insecure and dependent on external food aid. Several studies have been conducted in the area; however, lessons learnt related pastoralists' perception on the rangeland degradation and its impacts on their livelihoods were far less documented for the future use (Tadesse Girma, 2001; Gemedo Dalle et al. 2006; Mekuria Wolde et al. 2007). Borana pastoralists have possessed indigenous adaptation mechanisms to cope up the impacts of degradation. The commonly adopted mechanisms in the area are haymaking, herd mobility, destocking, accumulating crop residue, providing supplementary feed and herd diversification. Although they developed indigenous adaptation mechanisms, the efforts are still low when compared with the impending calamity. Failure to incorporate the indigenous knowledge, skills, practices, goals and strategies of the pastoral communities, as well as lack of their involvement in the planning and implementation processes are the most important reasons for poor adaptability to variations in climatically conditions (Oba and Kotile, 2001; Angassa Ayana, 2002). Across Ethiopia, many people are experiencing the changing seasonal patterns of temperature and rainfall, which are expected to lower livestock production.

A better understanding of why pastoralists opt for certain coping mechanisms and identifying determining factors are the crucial for policies and programs that aim at promoting sustainable rangeland management. Several studies have been carried out about the adaptation mechanisms in different parts of Ethiopia. But it's difficult to generalize on the specific area. This is because the adaptation mechanisms are highly diverse and complex as they vary by community, social group, individuals, gender, age, season and time in history (Coulibaly, 2015). Thus, the key point is therefore, how do pastoralists in the area respond to the impact of rangeland degradation? Identifying potential adaptation measures thus helps in defining factors that influence the choice decisions of pastoralists in the study area. The ability to adapt to changing climate and other factors are determined by predictor variables, which are demographic, socioeconomic and institutional (Juana et al. 2013). However, experience has shown that nationally identified adaptations do not certainly translate into practice since adaptations are local and sector-specific. The fact that adaptation

choices vary contextually and spatially, thus, provide room for location and household level inquiry. A number of studies also identified specific variables; those may positively or negatively influence the particular adaptation choice to both natural and man-made changes and most of them focus on the wider East African region (Jones and Thornton, 2008). However, this paper focused on the specific adaptation mechanisms in Yabello District of southern Ethiopia where the changing climate and other factors put pressure on the areas. Results from this study will deliver empirical evidence on adaptation mechanisms there by helping to discern wherewithal to exploit the adaptation mechanisms sustainably. It also helps development practitioners to make an informed decision in their context.

2 Materials and Methods

2.1 Description of the study area

The study was conducted on the Yabello district, of Borana zone which is located about 600 km to the south of the capital city Addis Ababa. The Borana zone shares a boundary with Somali regional state in the East, SNNPR in the North and guji zone in the NE. The rangelands of Borana are located in the southern part of the Ethiopian lowlands and they cover a total land areas of 95,000 km^2 (Coppock, 1994). The area extends from 4.60^0 N to 4.90^0 N latitude 37.90^0 E 38.40^0 E longitudes (Figure1). The region is dominated by a semi-arid climate where the annual mean temperatures vary from19 to 24°C. The rainfall pattern in the area is bimodal with

the long rainy seasons between March and May and the short rainy seasons between September and November with an average annual rainfall ranging from 400 mm in the south to 600 mm in the north. The savannah communities containing mixtures of perennial herbaceous and woody vegetation are the dominant vegetation species in the region. Households on the area are highly dependent on livestock production as they are pastoralists and daily labor in different farming season.

2.2 Sampling design and Sample

Two rural pastoralist *kebeles* (the smallest administrative unit) namely Harewoyu and Utalo were selected randomly to represent pastoralists production system in the district. The sample size was determined using the formula (Yamane, 1967):

$$n = N/1 + N(e)^2 \tag{1}$$

Where n is the sample size, N is the population size, and e is the level of precision (with 7%).

Finally, 172 sample households (from a total of 1080 households of the two *kebeles*) were selected randomly following Probability Proportional to Size sampling procedure. Where n is the sample size; N is the total population and e is the level of precision (with 7%). The sample size taken to represent total population is the appropriate with regard to the sparsely distributed behavior of pastoralists' community in the study area.

2.3 Method of data collection

The primary data were collected from sample respondents, key informant interview (KII) and focus group discussion (FGD) through a structured and semi-structured questionnaire and the secondary data were collected from different journals and published documents to supplement the primary data.

2.4 Data analysis

The primary data collected from were analyzed by using computer STATA software. The analysis for household characteristics and their perception on the rangeland degradation impacts was undertaken by using appropriate tools, like descriptive statistics, frequency distribution or percentage. A five point Likert scale measure were used to measure the extent of perception of sample respondents on the impacts of degradation. The multivariate probit model was used to identify determining factors that affect pastoralists' choice of adaptation mechanisms for the impacts of rangeland degradation.

2.5 Empirical Model Specification

The multivariate probit model (MVP) is appropriate to simultaneously estimate the influence of the set of explanatory variables on each of the different practices, while allowing for the potential correlation between unobserved disturbances as well as the relationship between the adoptions of different practices (Ojo and Baiyegunhi, 2018). The study used MVP model characterized by a set of binary dependent variables Yij such that:

$$Y_{ij} = X_i\beta_i + u_i \tag{2}$$

$$Y_{ij} = \begin{cases} 1, & \text{if } Y_{ij} > 0 \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

Where $j = 1, 2, \ldots, m$ denotes the type of adaptation mechanisms available; X_i is a vector of explanatory variables, β_i denotes the vector of parameters to be estimated, and u_i are random error terms distributed as multivariate normal distribution with zero mean and unitary variance.

It is assumed that a rational i^{th} household has a latent variable Y_{ij} which captures the unobserved preferences or demand associated with the j^{th} choice of adaptation mechanism.

The MVP analyses were aimed to identify key determinants of the choices of adaptation mechanisms based on households' decision. The empirical approach was successfully used by several previous studies. Greene, (2008); Nhemachena et al. (2014) have used the model to assess factors affecting the choices farmers make in the context of climate change adaptation strategies in the agricultural sector. For this study, it was found to be the appropriate model because pastoralists' use several adaptation strategies simultaneously. The estimated dependent variables were pastoralists' choice of adaptation mechanisms on the impacts of rangeland degradation given the explanatory variables. Four dummy dependent variables were selected for this study: herd diversification, buying of supplementary feed, herd destocking and haymaking.

2.6 Dependent and Independent Variables

The choices of these dependent variables in the equation were based on literature review and the suitability of each adaptation mechanisms for pastoralists in the study area. The dependent variables assume a value of 1 if individual apply specific adaptation mechanism and 0 otherwise. After testing for multicollinearity, only eleven explanatory variables were selected. Table 1 lists the summary of the explanatory variables their measurement and hypothesized effect on different dependent variables. Moreover, the model was tested for heteroskedasticity using the robust standard error procedure.

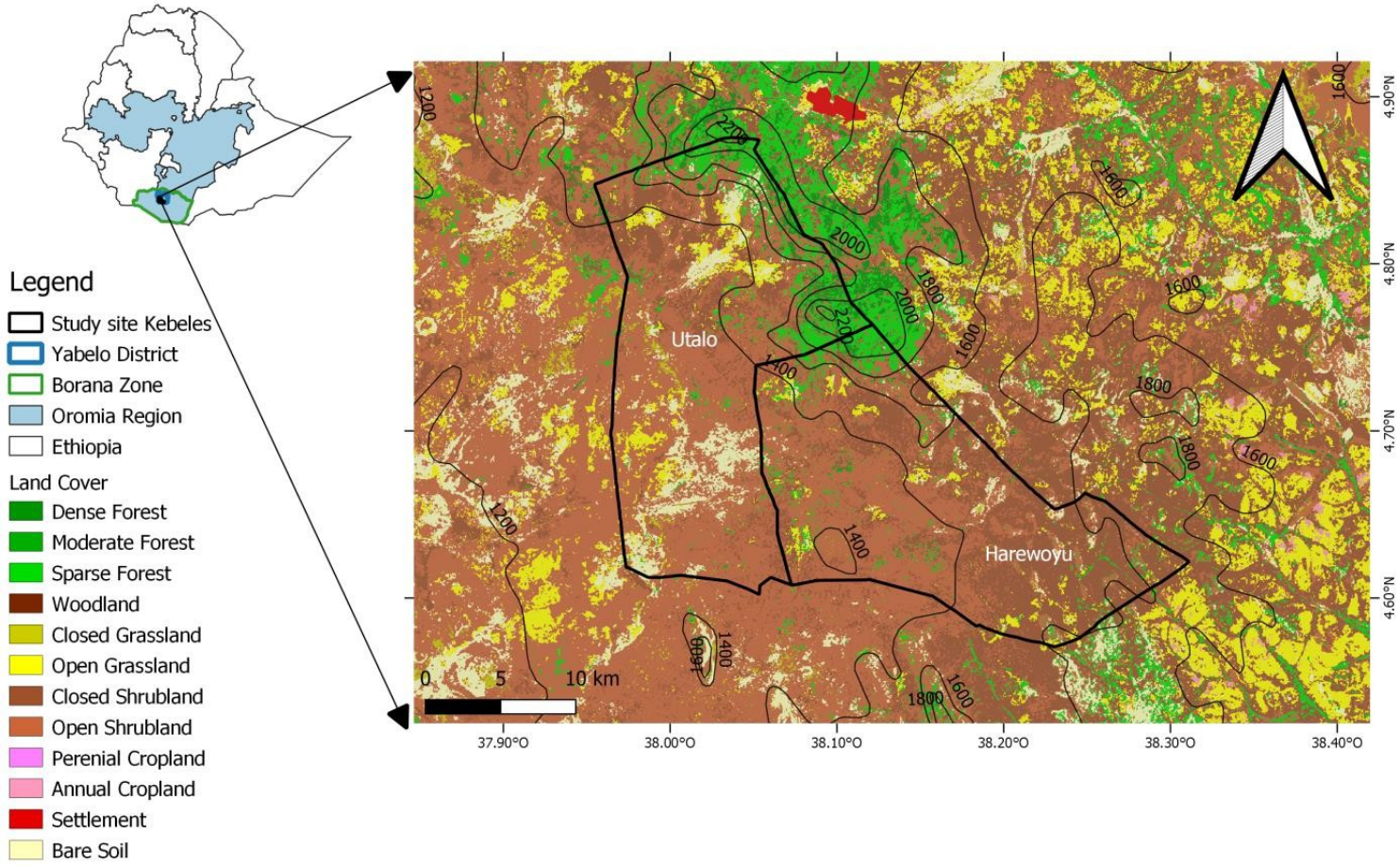

Figure 1: Map of the study area

3 Result and Discussion

3.1 Socio-economic /demographic/ institutional characteristics

Out of the total sample respondents about 90.7% was covered by male while the remaining 9.3% were females. About 80.23% of the respondents were illiterates (those who did not attend formal education), and only 19.77% can read and write (attend formal education). From the study sample respondents, there was no respondent who attained primary education and above. This shows that the households of the study area a little figure with compared to national level. With regard to the age of the respondents, the average age of the respondents was 45; with minimum age 22 and maximum of 88. From the total sample, majority of the respondents, about 88.37%were found within the productive age group and hence it is rational that they are engaged in different economic activities. The average family size of household Respondents was 6; with maximum house-hold of 12 and minimum size 1. The results of the survey revealed that the average livestock size of the respondents in the study area were 9 in TLU. Marital status of the respondents has a significant role in the resource utilization and management. Thus, it was investigated under the survey. Accordingly, results of the study showed that about 93.61% of the respondents were married 5.23% were widowed and the rest 1.16% were single and there was no divorced participant in terms of marital status in the household survey. The livelihood characteristics of a given society may determine the way on which they interact with their environment, thus, it was investigated under the study. Accordingly, livestock production is the most commonly practiced old age economic system. The result showed that, about 86.047% of the sample respondents stated that the major source of livelihood activities in the study area is livestock where crop cultivation and safety net program accounts only about 11.046% and 2.907% respectively.

3.2 Pastoralists perception on the causes and impacts of rangeland degradation

Respondents were asked about their perception towards rangeland degradation. According to the survey, 93.65% of the respondents from both *kebeles* perceived that rangeland resources are under its normal state. The finding of the study reveals that most of the households agreed that rangeland rehabilitation practices are important to minimize the rate of pasture degradation. This indicates that households had good perception towards the participation of rangeland resource conservation. The group discussion conducted with the pastoralists indicated that encroachment of the bush to the former

Table 1: Description of Independent Variables

Independent variables	Description	Types of variable	Expected sign
Sex	Sex of the respondent	Dummy variable	Positive/negative
Age	Age of the respondent	Continuous variable	Positive/negative
Marital	Marital status of the respondent	Categorical variable	Positive/negative
Total fam	Total family size of the respondent	Continuous variable	Positive/negative
Education	Education of the respondent	Dummy variable	Positive/negative
Major crops	Major livelihood activities of the respondent	Categorical variable	Positive/negative
Total land	Total cultivated land size of the respondents	Continuous variable	Negative/positive
TLU	Total livestock in tropical livestock unit	Continuous variable	Positive/negative
Credit	Access to credit service	Dummy variable	Positive/negative
Weather	Access to weather forecast	Dummy variable	Negative/positive
Market	Distance from market center	Continuous variable	Negative/positive

grassland has been the major cause of rangeland degradation and reduced both the quality and quantity of rangeland productivity.

The data collected through household survey revealed that Acacia tree species like *A. senegal*, *A. reficiens*, *A. drepanolobium* change and other species like *Tephrosia pentaphylla* (locally, named as sephansa, sigirso, chake and keessa ka'ii) are the major encroaching trees/ shrub species those are invading the rangelands. 87.8% of the respondents confirmed that the five most prevailing causes of rangeland degradation in the area are bush encroachment, climatic condition, overgrazing, population pressure, and poor policy.

From the total sample respondents, about 99.4% of interviewed pastoralists strongly agreed that feed shortage is the major and the first impacts of rangeland degradation while 57%, 47.9% and 45.3% of the respondents strongly agreed that livestock yield reduction (in terms of meat and milk), decline in crop products and the decline of rangeland productivity both in terms of quantity and quality are also the primary impacts of rangeland degradation respectively. On the other side, the result of weighted mean also showed that; feed shortage, livestock yield reduction, decline in the crop products, decline in the rangeland productivity and long distance travelled to feed animals are the five most common primary impacts of rangeland degradation on the study area (Table 2).

3.3 Descriptive statistics result of Pastoralists' adaptation mechanisms

The four most commonly used adaptation mechanisms listed above were involved in the analysis and summarized in figure 2 below.

3.4 Diversification

According to the result from the survey, 62.8% of sampled households use diversification as their adaptation mechanism choice and they ranked it as the second best option to reduce the impact of rangeland degradation on their livelihood. Diversification of herd composition is a key strategy that has enabled pastoralists to thrive in a harsh environment for centuries (Speranza, 2010). Herd diversification in favor camel and goats is the important strategy of pastoralist adaptive response to climate-induced shifts in rangeland ecosystems. In nature, Borana pastoralists predominantly practice a cattle- specialized pastoral system. A person with a few number of cattle in the Borana custom is considered as qolle (destitute) and "incomplete" because of the comprehensive social functions (Berhanu Wassie, and Fekadu Beyene 2015). The most important product in subsistence pastoralism is milk. The attractiveness of camel in pastoral households' animal species portfolio is that, camel breeds produce more milk than cows (Berhanu Wassie et al. 2007).

3.5 Supplementary feed

According to the results from the survey conducted on the two *kebeles* from Yabello district, 61.6% buy supplementary feed like floury and crop residue. This is because providing supplementary feed during the drought season is the other important means to cope up the impact of rangeland degradation. The average annual expenditure the pastoralists spent on purchasing supplementary feed was 2,160 ETB ($45.60) with a minimum value of 720 ETB ($15.2) and a maximum value of 4,320 ETB ($91.17) per year. More than half of pastoralists buy flour and rapeseed oil to feed animals in a harsh winter. Nowadays, buying supplementary feed has become a large financial burden for pastoralists' community. Many studies revealed that the proportion or the percentage of providing supplementary feed for the livestock depend on the individual pastoralist's financial capacity.

3.6 Destocking

In the study area, there is a changing behavioral pattern; some pastoralists are more commercially oriented, even though they have cultural and social attachments to their livestock. Also, in drought season, they prefer to sell part of their livestock instead of taking the risk of losing their animals. Some of them reported that the income generated from herd destocking is reinvested

Table 2: Pastoralists' perception on the impacts of rangeland degradation

No	Perception	Strongly agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly disagree (1)	Total	Weighted mean	Rank
1	Decline in rangeland productivity	78 (45.3%)	94 (54.6%)	0	0	0	766	4.45	4
2	Feed shortage	171 (99.4%)	1 (0.6%)	0	0	0	859	4.99	1
3	Livestock yield reduction (meat & milk)	98 (57%)	74 (43%)	0	0	0	786	4.57	2
4	Decline in Crop products	81 (47%)	91 (53%)	0	0	0	769	4.47	3
5	Livestock price decline	11 (6.4%)	158 (91.9%)	0	3 (1.7%)	0	693	4.03	7
6	Death of livestock	6 (3.5%)	162 (94.2%)	0	4 (2.3%)	0	686	3.99	8
7	Damage from the bush on women	7 (4%)	165 (96%)	0	0	0	695	4.04	6
8	Long distance travelled	40 (23.3%)	132 (76.7%)	0	0	0	728	4.23	5
9	Migration of household	25 (14.5%)	121 (70.3%)	0	26 (15.1%)	0	661	3.84	9
10	Malnutrition	1 (0.6%)	51 (29.6%)	0	120 (69.8%)	0	449	2.61	10

in supplementing the remaining animals with concentrated feed and floury during the dry season. The result showed that about 51.2% use herd destocking as their best option to cope with the impacts of rangeland degradation on their livelihood. Herd destocking refers to selling some of their animals in order to keep a number of livestock that can be well managed.

3.7 Hay storage

The result showed that 63.95% of the total respondents have adopted hay making and use as their first choice of adaptation mechanism. Hay storage is a traditional means for pastoralists to cope with a harsh winter. Sufficient stocks of hay reduce livestock loss by death. One yak needed 30 kg of surplus fodder to ensure survival through the cold season in the township of Tawu in Sichuan. Even private enclosures for fodder production are not allowed in pastoralists' communities, they calculated stance by fencing the communal land for the double purpose of cereal cultivation and dry season hay-making.

3.8 Marginal success probability for each adaptation mechanisms

The marginal success probability for each adaptation mechanism is reported in Table 3. The likelihood of choosing destocking as an adaptation mechanism is relatively low (51.16%) as compared to the probability of selecting supplementary feed (61.6.0%), diversification (62.8%) and haymaking (63.95%). The joint probabilities of success or failure of adoption of the four adaptation mechanisms suggest that households are less likely to fail to jointly adopt all the adaptation mechanisms together. The likelihood of households' failure to jointly adopt all the adaptation mechanism is only 2% compared to their success to jointly adopt them 11.2%. Joint probability of success and failure to use all adaptation mechanisms together are reported in Table 4.

3.9 Factors affecting choice of adaptation mechanisms

Different factors determine choice of adaptation mechanism based on the pastoralists' interest to use. Demographic, socio-economic, and technical factors affect the choice of the adaptation mechanisms. Result showed that the choice of different adaptation mechanisms is significantly explained by age, gender, education, major livelihood activity, total family size, total herd size in TLU, access to credit services, access to weather forecast and market distance (Table 5).

The Wald test was used to test the model fits. The data is statistically significant at a 1% significance level, which implies that the subsets of coefficients are jointly significant and the independent variables included in the model are acceptable. Moreover, the likelihood ratio test in the model

$$\rho_{21} = \rho_{31} = \rho_{41} = \rho_{32} = \rho_{42} = \rho_{43} = 0$$

is significant at less than 1%. This indicates the goodness-of-fit of the model, implying that the decisions to choose these adaptation mechanism options are interdependent.

Coefficients from MVP regression designate the direction of the influence rather than the magnitude, so the interpretation commenced using marginal effects (Table 5). Some factor variables of the households (sex, age, educational status, total family size, and total number of livestock in TLU) had a significant influence ($P < 0.01$) on the household's choices of adaptation strategies, as discussed below.

Gender of the household head: Being a male household positively and significantly influenced the adaptation of herd diversification, buying of supplementary feed and haymaking practices and negatively and significantly affects adoption of herd destocking. So the marginal effect indicated those male households are 1.86 times more likely to adopt diversification, 2.09 times more likely to adopt buying of supplementary feed and 1.42 times more likely to adopt haymaking than female households to recruit the rangeland degradation effects. In the other side, female households are 1.48 times more likely to adopt herd destocking than male household heads. This can be due to the fact that women culturally have limited access to control critical resources (land, cash, and labor), which often undercuts their decision and ability to carry out large cost incurring activities. This finding is thus, consistent with (Kebede Wolka et al. 2014), affirming that males are more likely to access information on climate change and pleased to take risks than their counterparts.

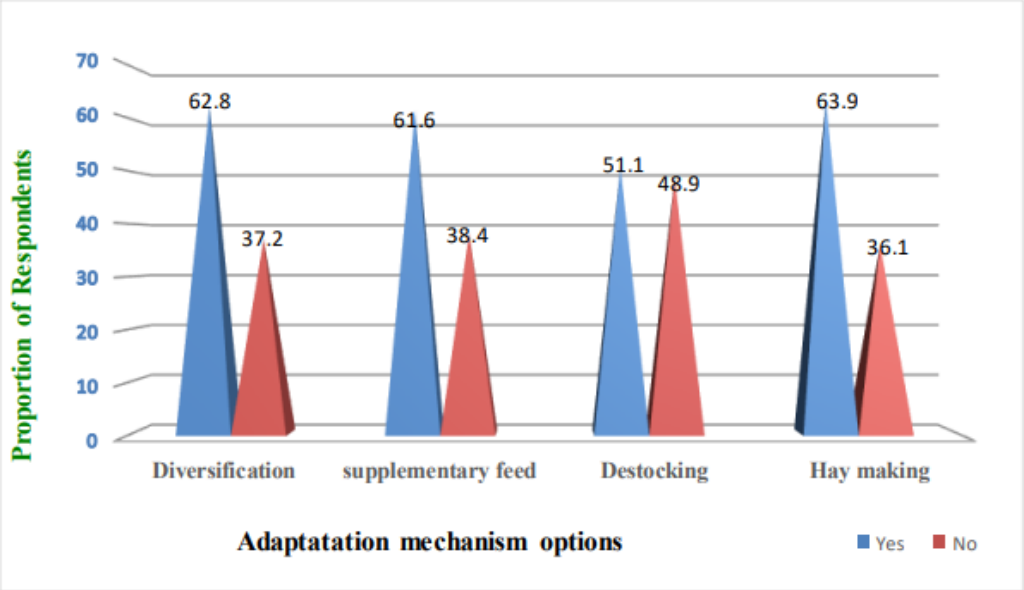

Figure 2: Adaptation mechanism options to cope up the impacts of rangeland degradation

Table 3:

Variable	n	Mean	Std. Dev.
Diversification	172	0.6283	0.4798
Supplementary feed	172	0.6163	0.4877
Herd destocking	172	0.5116	0.5013
Haymaking	172	0.6395	0.4863

Age of household: Age of the household head was significantly and positively influenced the choice of destocking by rural pastoralists, whereas, significantly and negatively influenced the choice of diversification and supplementary feed at (p-value=0.004) and (p=0.000) respectively. It is found that the probability of adjustment in pastoral practices of buying supplementary feed and herd diversification significantly decreases as age of the respondents' increases. This is good evidence that, the younger pastoral households have more capacity to buy supplementary feed as well as to use diversification strategy during the shock and climatic risks and older households may take their decision to choose better option to minimize any cost they incur regarding adaptation mechanism than the younger ones.

Educational status of the household head (educat): The result showed that, educational status of the respondent plays a vital role and has a negative and significant effect on herd destocking at less than 1% whereas, it has a positive and significant effect on buying supplementary feed, diversification and hay

making at less than 1% , 5% and 10% respectively. The result is in line with Addisu Solomon, et al. (2016), Gadédjisso, (2015) and Adeoti et al. (2016) that confirmed as the educational level of the household head increases, the level of understanding about adaptation strategies.

Family size of the household (totfam): Family size had a significant negative effect on pastoralists' adaptation choices. It has a negative and significant effect on buying of supplementary feed and haymaking at (p-value= 0.000) and at (p-value= .055) respectively. Moreover, it has a positive and significant effect on herd destocking at (p-value= 0.027). A unit increase in family size thus would result in a decline in the probability of using buying supplementary feed and haymaking by 44.92% and 12.78% respectively. This could be due to, the more the number of family size; the more the mouths to be fed, to fulfill the need of food for family members, everybody scarifies their money and time searching the food than buying supplementary feed to their livestock and hay making. Tazeze Aemero et al. (2012) proved the same finding for stating households with large families may be forced to divert part of their labor to other activities with an attempt to earn income and ease the consumption pressure imposed by a large family.

Total livestock holding (TLU): the households' livestock holding capacity is positively and significantly affects herd diversification (in favor of camels and goats), providing supplementary feed and haymaking, whereas; negatively and significantly affect herd destocking. Abraham Belay et al. (2017), revealed that owning large number of livestock in tropical livestock unit increases farmers" likelihood of adapting different mechanisms. The conversion factors used to estimate TLU is shown below in Annex Table 1.

Access to weather forecast (weather): Access to weather forecast is positively and significantly influences all adaptation mechanisms. The more access to forecast weather, the more to use different adap-

Table 4: Joint probability of success and failure to use all adaptation mechanisms

Variable	n	Mean	Std. Dev	Min	Max
tecjprls	172	0.1118	0.0754	1.60×10^{-7}	0.3008
tecjpros	172	0.0198	0.0256	5.79×10^{-9}	0.1746

Where tecjprls is joint probability of success
and tecjpros is joint probability of failure

Table 5: Parameter estimation of MVP in adaptation mechanism choices

Variables	Diversifications		Supplementary feed		Destocking		Hay making	
	Coef.	P¿—z—	Coef.	P¿—z—	Coef.	P¿—z—	Coef.	P¿—z—
Sex	1.8556	0.003	2.0875	0.000	-1.4807	0.008	1.4184	0.001
Age	-0.0234	0.017	-0.0411	0.000	0.0257	0.004	-0.0105	0.227
marital	0.4035	0.380	-0.5482	0.269	-0.1371	0.725	0.2505	0.541
education	0.7741	0.030	0.1561	10.00	-0.8709	0.003	0.5541	0.075
Total fam	-0.1134	0.139	-0.4492	0.000	0.1576	0.027	-0.1278	0.055
Major crop	0.4752	0.262	0.9097	0.036	-0.1748	0.637	0.8457	0.023
Total land	-0.3065	0.271	-0.3940	0.177	0.0199	0.938	-0.1415	0.583
TLU	0.2242	0.000	0.2545	0.000	-0.0757	0.024	0.1006	0.006
Credit	0.0234	0.217	0.0411	0.000	-0.1257	0.004	0.0105	0.227
Weather	1.0559	0.004	1.0875	0.006	1.0207	0.008	1.6184	0.000
Market	0.6541	0.100	-1.0121	0.002	-0.8709	0.103	0.5405	0.705
Cons	-3.0036	0.030	1.1173	0.416	0.5893		-1.8826	0.107

Log likelihood = -302.34694, No of obs = 172, Wald chi2 (32) = 112.18, Prob¿ chi2 = 0.000
Where, Coef: coefficient, Major: major livelihood activities, totland: total cultivated land size

tation mechanisms. Access to weather forecasts is important for pastoralists to be able to plan what to do in the future.

Access to Credit (credit): Access to credit service positively and significantly influence buying of supplementary feed, whereas, negatively and significantly influence destocking. Pattanayak et al. (2003); Deressa Temesgen et al. (2009) showed a positive relationship between the level of adaptation and the availability of credit. Availability of credit eases the cash constraints and allows pastoralists to buy different feed for their cattle as well as keep rearing their livestock rather than selling to solve households' food shortage problem.

Distance from the market (market): The result showed that distance to market center negatively and significantly affect pastoralists' decision to buy supplementary feed. Proximity to market is an important determinant of adaptation, presumably because the market serves as a means of exchanging different information with others (Maddison, 2007).

4 Conclusion

The Borana rangelands have been degrading due to the presence of various natural and man- made factors like recurrent drought, bush encroachment, overgrazing, over population, over utilization, inappropriate government intervention and poor rangeland management policy. The results showed that pastoralists' possessed their own adaptation mechanisms to cope up and prevail through the impacts of rangeland degradation. Herd diversification, buying of supplementary feed, destocking and hay making are among the common adaptation mechanisms to sustain their livelihoods on the study area. Choice of these adaptation mechanisms were significantly influenced by sex, age, educational level, family size, major livelihood activity, livestock holding (TLU), access to weather forecast, access to credit and distance from the market of the households. The marginal success probability of adapting herd destocking was lowest compared to other adaptation mechanisms practiced on the area. It also showed that the joint probability of using all adaptation strategies was 11% and the joint probability of failure to adopt all of the adaptation strategies was only 2%. This shows, pastoralists' were less likely to fail than succeed in adopting all choice sets jointly. The results of this study can be relevant for the development and sustainable management of rangelands in arid environments. It's recommended that strengthening the research and development intervention in rangeland improvement schemes in order to reverse and restore rangeland degradations in to sustainable use and full participation from all stakeholders is imperative. Moreover, to minimize the pressure on rangeland resources, various stakeholders should emphasize to expand adult education to enable them to select appropriate adaptation mechanisms.

Competing interests

The authors declare that they have no competing interests.

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Table 6: Conversion factors used to estimate TLU (Storck et al., 1991)

Livestock	Horse	Camel	Ox	Cow	Bull	Calf	Donkey	Sheep	Goat	Chick
Conversion factors	1.1	1.25	1.1	1	0.75	0.25	0.7	0.13	0.13	0.01

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Research Article

Evaluating farmers' perception on soil erosion and management of physical soil and water conservation measures in southwest Ethiopia

Wondimu Bekele Goba[1*], Alemayhu Muluneh[2], Kebede Wolka[3]

Article Info

[1] Gena Bosa woreda Agriculture and Natural Resources Office, Dawuro Zone, Ethiopia.
[2] Faculty of Biosystems and Water Resources Engineering, Hawassa University, P.O.Box 05, Hawassa, Ethiopia
[3] Wondo Genet College of Forestry and Natural Resource, Hawassa University, P.O. Box, 128, Shashemene, Ethiopia.

*Corresponding author: kebedewolka@gmail.com

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Abstract

Land degradation is one of the major challenges affecting soil quality and food security. To control erosion, soil and water conservation (SWC) measures such as bunds are implemented. However, farmers' perception of erosion and management of introduced SWC measures are poorly documented. Therefore, this study is aimed to assess the farmers´ perception, adoption, and management of physical SWC in the Fanta watershed, southwest Ethiopia. Data were collected by interviewing 128 randomly selected households from three kebeles (lowest administration unit), which were beneficiaries of the Productive Safety Net program that incentivizes SWC activities in the region. In addition, focus group discussions were carried out. Results showed that 75% of farmers categorized soil erosion on their farmland as severe, and 40% of farmers experienced gullies. As a result, the majority of the farmers (87%) believe that there is a decline in soil fertility. Farmers (66%) practice traditional techniques such as short fallowing and diversion ditch to control erosion. After the construction of government-supported physical SWC measures such as soil bunds, in the past ten years, 66% of the farmers observed a decrease in soil erosion, and 93% of the farmers perceived improvement in soil fertility. However, 38% of the farmers do not repair the constructed SWC measures expecting external incentives. Age of farmers had a negative association, while education level, the slope of the field, training, and extension service had a positive effect on the adoption and management of physical SWC conservation measures. Without soil bunds, soil fertility decreases, but the adoption and management of conservation measures are under incentive syndrome. In the study watershed, continued awareness creation activities could enhance farmers' participation and commitment to the adoption and repairing of physical SWC measures. **Keywords:** crop yield; Productive safety net program; sustainability; incentive; repairing conservation structure; soil bunds

1 Introduction

Ensuring and sustaining global food security and environmental safety rely on soil quality. The mismanagement of physical land resources could adversely affect soil quality. Soil erosion has been among the major processes challenging soil quality. Soil erosion removes 36–75 billion tons of soil every year across the world (Pimentel & Burgess, 2013; Borrelli et al., 2017). About 80% of the global soil erosion is due to agricultural activities (Pimentel, 2006). The removal of soil organic carbon and nutrient-rich topsoil by erosion affects soil quality and land productivity, implying adverse effects on food security. Deposition of sediment in aquatic ecosystems and flood plains could have negative effects on the functioning of dams, water quality, and ecosystem (Wolancho, 2012). The agri-

cultural activities of Sub- Saharan Africa (SSA) have been affected by severe soil degradation due to erosion, which on average removes 35–75 t of soil ha-1 yr-1 (Tamene and Le 2015). In countries such as Rwanda soil loss of up to 420 t ha-1 yr-1 was reported in cropland (Karamage et al., 2016). Conventional agriculture in the sloping highlands of Ethiopia, where the majority of the population inhabits, caused severe soil erosion that removes about 2 billion tons of soil every year (Bewket, 2007; FAO, 2019). In Ethiopia, about 10 million people are food insecure, e.g., in 2020 (IPC, 2020), for which soil degradation through erosion and nutrient depletion is one of the important contributing factors. About 50% of the total soil loss in Ethiopia originates from cropland, in which more than 30 t ha^{-1} yr^{-1} of soil eroded (Hurni, 1993; Haregeweyn et al., 2015; FAO, 2019).

On cultivated lands, scientists and farmers developed, tested, and practiced soil and water conservation techniques such as fallowing, crop rotation, and soil and stone bunds (Critchely et al., 1994; Giller et al., 2009; Wolka et al., 2018). Many countries in SSA have practiced combinations of soil and water conservation measures in erosion-prone as well as water-scarce areas. In Ethiopia, indigenous soil and water conservation measures such as fallowing, crop rotation, traditional diversion ditches, agroforestry, and stone bunds have been implemented for centuries (Ali & Surur, 2012; Mushir & Kedru, 2012; Dotterweich, 2013; Mulat, 2013). Institutionalized soil and water conservation measures, particularly bunds, were implemented in the past five decades following the severe soil degradation and drought as well as food insecurity concerns (Abera et al., 2019). Recognizing the positive effects of earlier interventions and the need for wider implementation, since 2011, the government of Ethiopia implemented a new approach, national physical soil and water conservation campaign that run for about two months (January and February) every year throughout the country. The campaign is aimed to mobilize the community to construct expert-recommended soil and water conservation measures following the principles of watershed management. This was coordinated by the local development committee. Some studies claimed that this approach contributed considerably to the rehabilitation of the agricultural landscape despite some technical and management weaknesses as work annually focuses on building new structures with little attention to monitoring the previous works (Meshesha & Birhanu, 2015; Wolancho, 2015; Assefa et al, 2018, 2021).

The physical SWC measures are considered as an investment for which significant benefits are expected later and for years to come. The short-term effects of physical soil and water conservation measures such as bunds and Fanya juu are reduction of slope length and surface runoff. The progressive deposition of sediment above the physical measures could reduce inter-bund slope and form bench terraces over a long time. Previous studies indicated that bunds reduce more than 50% of soil loss (Adimassu et al., 2014; Wolka et al., 2018). Bunds have various effects on crop yield, ranging from no effect to a positive role on the yield (Herweg & Ludi, 1999; Adgo et al., 2013; Adimassu et al., 2014).

The adoption and management of improved physical SWC technologies in developing countries have attracted much attention from scientists and policymakers mainly because land degradation is a key problem for agricultural production (De Graaff et al., 2008). Adoption and management are processes expected to pass steps including acceptance, implementation, and continuous management including repairing, which is highly linked to farmers' perception. Farmers may wait for visible evidence such as gullies, the severe form of erosion, to accept soil and water conservations. Teshome et al. (2016) reported that farmers are aware of the negative consequences of soil erosion and the need for conservation, particularly when erosion creates visible features such as rills and gullies. Adoption and management of introduced soil and water conservation measures are affected,

for example, by the socio-economic status of farm households, topography, and institutional arrangements. Farmers' decision to adopt soil conservation measures is influenced by their perception of erosion hazards and types of structures and their attributes (Bewket, 2007). In Zimbabwe, the management of dead level contour for soil and water conservation is influenced by resource ownership of the household (Munamati and Nyagumbo, 2010). Amsalu and De Graaff (2007) reported that farmers' age, land area owned, and the slope of cultivated land are among the factors influencing conservation structures adoption and management in the Beressa watershed of central Ethiopian highlands. Education, extension service, training, and age of farmers affect the adoption of physical soil and water conservation measures in the south Wollo zone of Ethiopia (Asfaw & Neka, 2017). In southwest Ethiopia, land area, age, household labor, and education affect the adoption and management of soil and water conservation measures (Anley et al., 2007). Mekuriaw et al. (2018) reported that government-based incentives had a positive effect on adopting soil and water conservation measures. In general, farmers' adoption and management of soil and water conservation measures vary geographically due to socio- economic, environmental, and institutional circumstances (De Graaff et al., 2008; Teshome et al., 2016), and thus results in farmers' perception, and adoption remain inclusive.

In the Fanta watershed of southwest Ethiopia, physical soil and water conservation measures were introduced to food insecure areas in 2005 through the Productive Safety Net Program (PSNP). Soil degradation and drought affect the food security of the rural households of this watershed. To reduce the effect of erosion and soil degradation, the PSNP has implemented incentivized physical soil and water conservation measures such as soil and stone bunds, Fanya juu, and cutoff drain. The public campaign works also constructed conservation measures in this watershed. However, some farmers do not manage the constructed conservation measures sufficiently, and thus, the measures could not

serve effectively in controlling erosion. Farmers rarely construct conservation measures by investing their family labor, instead, wait for incentive-based government projects or public campaigns. In the region, the farmers' perception of soil erosion and adoption and management of introduced physical soil and water conservation are not well documented. Therefore, this study aimed to assess the farmers´ perception, adoption, and management of physical soil and water conservation technologies that were introduced to the mountainous food insecure Fanta watershed.

2 Materials and methods

2.1 Description of the study area

The study was conducted in the Fanta watershed, Omo-Gibe River basin, southwest Ethiopia. Geographically, the watershed is situated at 7°17'30"–7°20'30"N latitude and 37°17'10"–37°19'40"E longitude (Figure 1). The watershed drains to Gibe III hydro-electric dam on Omo River, Dawuro zone. The Omo-Gibe River basin, on the Omo River, has three hydroelectric dams and the fourth, the Koyisha dam, is under construction implying the economic, environmental, and political importance of the area. Fanta watershed covers about 4230 ha and is characterized by steep slopes, mountains, valleys, and a small plateau with an altitudinal range of 1000–2860 m above sea level. The mean annual minimum and maximum temperatures are 15.1°C and 27.5°C. The mean annual rainfall is about 1400 mm. In the area, soil types such as Nitisols and Leptosol are dominant (SNNPRS-BOFED, 2004). Subsistence crop-livestock farming of the area relies on rainfall, which is commonly in between March and September with a short break in May/June. Crops such as maize (Zea mays), teff (Eragrostis tef), sorghum (Sorghum bicolor), and barley (Hordeum vulgare) are cultivated, while enset (Ensete ventricosum), a staple food in the region, grows together with other perennials, e.g., tree, coffee and fruit tree at home garden. Cattle (Bos taurus) and goats (Capra aegagrus hircus) are common livestock. Livestock production is an essential part of the farming system as nearly all seedbed preparations are done with oxen-driven plows.

2.2 Sampling and data collection

Farmers' perception of soil erosion as well as adoption and management of physical soil and water conservation measures were assessed using household interviews and focus group discussions. The Fanta watershed was chosen due to the reasonable years (15 years) of experience in the introduced physical soil and water conservation measures in the region, which have been supported by the Productive Safety Net Program. For the interview, 128 (95 adopters and 33 non-adopters of the introduced representing ˜8% of the total households, were randomly selected from three kebeles (lower government administration unit), viz. Beza Shota, Bodola Mamado, and Mela Galda (Table 1). Those kebeles of the Fanta watershed were purposively selected considering accessibility, soil erosion features, and implementation of the introduced physical soil and water conservation measures. Heads of the household responded to face-to-face interviews based on a structured questionnaire. The questionnaire included socio- economic characteristics (e.g., age, farm size, family size, livestock owned) of the household, physical SWC measures households, challenges in agricultural land management perceived severity of soil erosion on the farmland, implemented land management practices and technologies to prevent soil erosion, effects and limitation of the soil and water conservation measures, and challenges in adopting and repairing physical soil and water conservation measures. Furthermore, three focus group discussions, one in each kebele, were carried out. In each focus group, 8–12 heads of household, representing different villages and experiences in managing soil and water conservation techniques, were participated. The discussion was focused on soil erosion severity, mitigating erosion, benefits of the introduced soil and water conservation measures, adoption of physical soil and water conservation measures, factors determining adoption of physical soil and water conservation measures, and challenges in repairing the constructed conservation structures.

2.3 Data analysis

Quantitative data were analyzed using a statistical package for social sciences (SPSS) computer software (version 20). Descriptive statistics were used to assess the socio-economic characteristics of respondents as well as erosion impacts on the livelihood of subsistence farming. Implementation of erosion mitigation measures and effects of conservation measures on soil and crop yield were evaluated using mean and percentage values. A binary logistic regression model was applied to evaluate factors affecting farmers' adoption of the physical soil and water conservation measures. In the binary logistic model, two categories, viz. adopter and non- adopter, and selected independent parameters including sex, age, education level, family size, number of farm plots, farmland area, the slope of farmland, livestock, extension service, and training were tested. Odd ratio, Wald statistics, and significance level of $p<0.05$ were used for data interpretation.

3 Results and discussion

3.1 Socio-economic characteristics of the households

Ninety-five percent of the respondents were from male-headed households. About 95% of the household heads were below 65 years old (Table 1), implying many of the farm heads can engage in tasks requiring intensive labor such as soil bund construction. The majority of the respondents, about 60%, have a family size of 3– 7. Among the residents of the Fanta watershed, 41% are illiterate, which indicates the considerable proportion of farmers having limited access to information including literature and radio in different languages. This could have a negative effect to understand technological options including the soil and water conservation measures and their management and performance.

More than 75% of the farmers own farmland of less than ˜1 ha, indicating farmland scarcity that could result in continuous cultivation of the land to sustain subsistence crop-livestock mixed livelihood. The results showed that the livestock, on average about 2 livestock per household, mainly feed on cultivated fields (35.9%) during the off-cropping season, and on community grazing land (31.3%). The grazing of livestock on cultivated land would remove residue and thus, degrade the land. Livestock tramples and damages the constructed bunds of the cultivated lands. The result indicated that 90% of the respondents had access to agriculture and natural resource extension services. In the study area, the extension service is a major means to provide agriculture and natural resource information, with

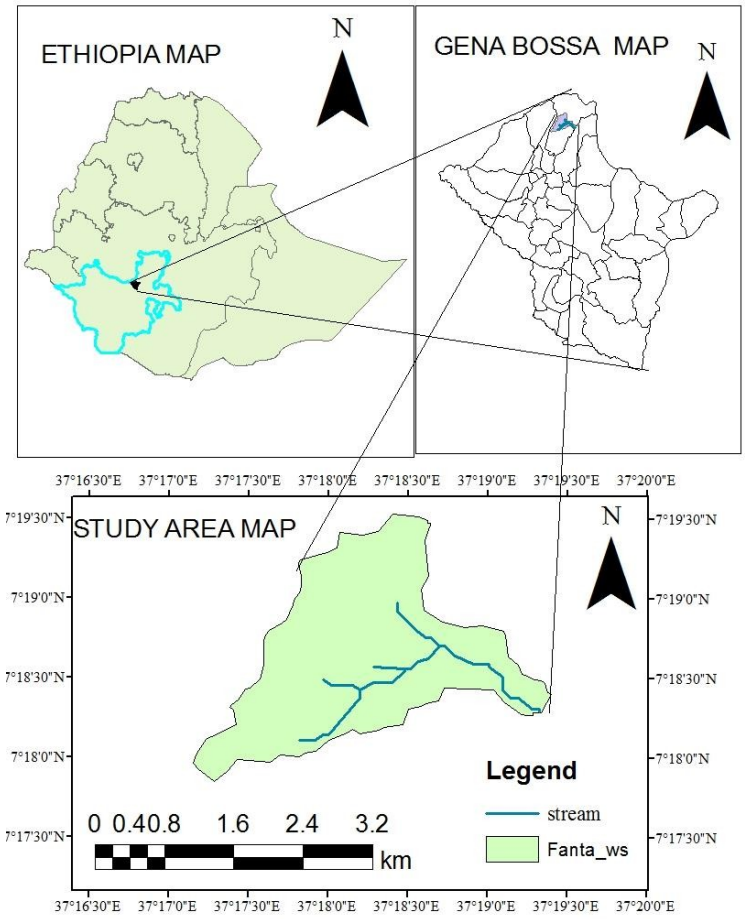

Figure 1: Map of the Fanta watershed in the Omo-Gibe river basin

basic principles and demonstrations of agricultural inputs application, forest development, soil and water conservation, and livestock production. This could be the main information source for illiterate farmers.

3.2 Soil erosion and effect

In Beza Shota, Bodola Mamado, and Mela Galda kebeles 90%, 93%, and 80% of the farmers have cultivated land on moderate to steep slopes, respectively, implying susceptibility to soil erosion by water. In the area, soil erosion happens, at least to a certain extent, on all farmers' cultivated land as perceived by the majority of the respondents (Table 2). About 75% of farmers had severe soil erosion that forms visible features such as rills and gullies, where soil erosion formed gullies on plots of 40% of the farmers. About 87% of the farmers experienced soil fertility decline due to soil erosion, adversely affecting crop yields and food security. Focus group discussants explained that, three decades ago, croplands were more fertile and productive than their present condition, and currently their lands do not give sufficient yield unless inorganic fertilizer is added. This indicated that soil erosion is a problem in the area. Studies in the Omo-Gibe basin, and Lake Awassa watershed reported that farmers recognize soil erosion based on visible erosion features and a significant decline in crop yield (Moges and Holden; Betela and Wolka, 2021). Farmers who replied soil erosion as a major problem in the farming system were asked to explain the main causes of erosion, and about 80% replied overgrazing and cultivation of steep slopes, while 61% perceived deforestation. In the study area, cattle graze freely after crop harvest, which could increase soil erosion due to the removal of residue cover and compacting of the soil. Livestock damages constructed physical soil and water conservation measures. Cultivation of sloping land becomes common practice due to the nature of topography in the area and increasing demand for land and production. Lack of alternative livelihood to agriculture, low awareness, and poor land use policy has contributed to plowing on steep slopes, which without appropriate soil and water conservation measure could result in severe soil erosion. Conventional cultivation on steep slopes is widespread in the region and in the country (Asfaw and Neka, 2017; Wolka et al., 2018), which requires awareness creation and land use policy implementation.

About 95% of farmers reported that soil erosion reduces soil fertility, while 60% perceived yield decline, and 32% of the farmers abandoned their land due to severe erosion such as gully formation and severe removal of topsoil. The yield decline and abandoning of cultivable plots negatively affect production and food security. The effect of soil erosion on soil fertility and yield is expected to be higher than perceived by the farmers as farmers could sense only the visible features of erosion and a considerable decline in crop yield.

Table 1: Socio-economic characteristics of respondent households in the Beza Shota, Bodola Mamado and Mela Galda kebeles of the Fanta watershed, Omo-Gibe river basin of southwest Ethiopia.

Respondents socio-economic characteristics	Kebeles			Total (n=128)
	Beza Shota (n=43)	Bodola Mamado (n=42)	Mela Galda (n=43)	
	%	%	%	%
Age, year				
<25	9.3	7.1	11.6	9.4
25-35	9.3	14.3	18.6	14.1
35-45	18.6	26.2	30.2	25.0
45-65	60.5	45.2	34.9	46.9
>65	2.3	7.1	4.7	4.7
Family size, number				
1-3	16.3	21.4	14.0	17.2
3-7	67.4	50.0	55.8	57.8
8-10	14.0	21.4	25.6	20.3
≥11	2.3	7.1	4.7	4.7
Formal education level, grade				
Illiterate	39.5	47.6	37.2	41.4
Primary (1-4)	27.9	35.7	32.6	32.0
Secondary (5-8)	23.3	14.3	18.6	18.8
Above secondary	4.7	2.4	11.6	7.8
Land size, ha				
<0.25	14.0	7.1	4.7	8.6
0.25-0.5	32.6	19.0	16.3	22.7
0.5-1	39.5	47.6	51.2	46.1
1.0-5.0	11.6	19.0	23.3	18.0
>5	2.3	7.1	4.7	4.7

4 Soil and water conservation in Fanta watershed

In the study area, to limit the effect of soil erosion on croplands, many farmers practice traditional land management practices such as fallowing (42%), crop rotation (76%), cutoff

drain (83%), contour cultivation (55%) and mixed cropping (78%). Similarly, a study in the Chencha area of southern Ethiopia reported that farmers have experiences in characterizing the severity of soil erosion and practice indigenous conservation measures to mitigate the effect of erosion on land degradation (Engdawork and Bork, 2014).

Traditional cut-off drains, a small ditch constructed on cultivated fields using oxen- driven plow, are the widely used erosion controlling practice in the Fanta watershed. Traditional cut-off drains are constructed to allow excess water to drain out of cultivated land and are also practiced in other parts of the country (Ali & Surur, 2012; Mulat, 2013). The majority of adopter farmers implemented soil bunds (92%). Other physical SWC measures such as stone bunds (48%), check dams (35%), cut-off drain (39%), and *Fanya juu* (12%) were implemented in the area by a considerable proportion of farmers. Physical SWC measures, which were built on farms and rangelands for soil and water conservation, could reduce surface runoff and increase infiltration (Desta et al., 2005). As result, 66% of the farmers, in our study area, observed less soil erosion by water on plots with soil bunds, and 93% of the farmers perceived improvement in soil fertility. Thus, due to soil bunds, 71% of the farmers perceived an increase in crop yield. Furthermore, focus group discussants explained the positive effects of physical soil and water conservation measures

in reducing soil erosion and improving soil fertility and crop yield. Related studies by Wolka et al., (2018) also reported that implementation of physical soil and water conservation such as soil and stone bunds and Fanya juu increased soil fertility and consequently improved crop yield in the west and south Ethiopia. Abdallah et al. (2014) reported that SWC measures increase maize yield in Ghana. The positive effect of SWC measures in the present study area could be associated with surface runoff and soil loss protecting the ability of the physical conservation measures.

5 Sustainability of physical SWC measures

Farmers (100%) and focus group discussants reported the damage to constructed SWC measures (Table 3). Soil erosion preventing capacities of soil and water conservation measures, e.g. soil bunds, depend on their potential to retain surface runoff. The soil and water conservation structures can be damaged due to sedimentation, trampling of freely grazing livestock, and planned removal by landowners as reported by 71%, 94%, and 20% of respondents, respectively. In the study area, cultivated land is exposed for intensive

Table 2: Perceived soil erosion severity in the Beza Shota, Bodola Mamado and Mela Galda kebeles of the Fanta watershed of Omo-Gibe river basin, southwest Ethiopia.

Perceived soil erosion problem and conservation effect	Kebeles			Total
	Beza Shota (n=43) %	Bodola Mamado (n=42) %	Mela Galda (n=43) %	(n=128) %
Have you experienced soil erosion on any of your plot?				
Yes	100	100	100	100
No	0.0	0.0	0.0	0.0
What is the extent of soil erosion problem?				
Severe	74.4	83.3	67.4	75
Moderate	23.3	16.7	27.9	22.7
Slight	2.3	0.0	4.7	2.3
What effects do soil erosion have?				
Reduce soil depth	81.4	61.9	90.7	78.1
Difficulty during plowing	30.2	40.5	20.9	30.5
Soil fertility decline	95.3	88.1	76.7	86.7
Gully formation	53.5	45.2	27.9	42.2
Abandon the land	34.9	47.6	14	32
Yield decline	67.4	54.8	62.8	61.7
To what extent soil erosion occur after constructing conservation structures?				
Severe	7.0	11.9	7.0	8.6
Moderate	34.9	45.2	37.2	39.1
Low	58.1	42.9	55.8	52.3

grazing during the off- cropping season, which could damage the constructed structures. In addition, focus group discussants indicated that cultivation activities such as cultivating close to the structures, in inter-bund areas could damage the constructed SWC measures. Few farmers remove some of the structures in order to use the fertile sediment retained above bunds, which challenges the sustainability of the built structure. To sustain the erosion-controlling role of physical soil and water conservation measures, periodic repairing is essential. About 62% of the respondents

expressed their commitment to repairing the destroyed parts of constructed physical soil and water conservation measures through sediment excavation and managing riser of bunds (Table 3), but 38% stated that they did not maintain the bunds. Within group discussions, farmers acknowledged the introduced physical SWC measures and widely accepted their effectiveness and the potential to improve land productivity. Nonetheless, sustainability of the already constructed structures and adoption of new conservation measures at the farm level appeared below expected, which is due to the farmers' expectation of incentives to repair the constructed conservation structures. Focus group discussants also debated on this issue and agreed that farmers wait for incentives, e.g., from PSNP to repair and construct physical soil and water conservation measures. The other weakness is that the government and development partners are more focused on constructing new physical SWC measures than repairing the previously constructed measures,

implying poor monitoring, evaluation, and enforcing or encouraging sustainable management and use. Furthermore, without the government supported-incentive, many farmers did not construct physical soil and water conservation measures including soil bunds, indicating that adoption of physical SWC is incentive-driven. More than 80% of the farmers mentioned reasons for not sufficiently repairing the constructed SWC measures including lack of awareness, measures occupying cultivable land, labor shortage, and inconvenience of the structures for cultivation practices. This suggests the need for revisiting the approach. To sustain the productivity of the land, farmers should invest, e.g., by controlling erosion and other processes of degradation. The incentive-based conservation can be considered as a step to demonstrate technologies, otherwise, expecting incentives for construction and repairing could not help for realizing sustainable land management.

6 Farmers' adoption of physical SWC measures

Most of the local farmers acknowledged the introduced physical SWC technologies as effective measures in controlling soil erosion and improving land productivity. However, many farmers did not show interest to repair the constructed measures. In addition, the non- adopted farmers did not initiate constructing, e.g., bunds by themselves, implying little chance for farmer-to-farmer diffusion. Rather many farmers rejected newly introduced physical SWC mea-

Table 3: Farmers' response on repairing the constructed physical soil and water conservation measures in the Beza Shota, Bodola Mamado and Mela Galda kebeles of the Fanta watershed, Omo-gibe river basin of southwest Ethiopia.

Respondents characteristics	Beza Shota		Bodola Mamado		Mela Galda		Total	
	n	%	n	%	n	%	n	%
Is there any destroyed soil bunds?								
Yes	34	100	29	100	32	100	95	100
No	0	0.0	0	0.0	0	0.0	0	0.0
If "Yes", what destroys it?								
Planned removal by cultivation	7	20.6	9	31.0	3	9.4	19	20.0
High rainfall	29	85.3	21	72.4	18	56.3	68	71.6
Livestock	32	94.1	28	96.6	29	90.6	89	93.7
Do you repair the bunds?								
Yes	25	73.5	17	58.6	17	53.1	59	62.1
No	9	26.5	12	41.4	15	46.9	36	37.9
If yes, how do you repair it?								
Excavating sediment	3	12.0	1	2.9	4	23.5	12	20.3
Planting vegetation on bund	8	24.0	9	52.9	3	17.6	18	30.5
Stabilizing by leaving the riser slope with grass cover	6	32.0	4	23.5	7	41.2	19	32.2
Increasing bund height	19	76.0	16	94.1	14	82.4	49	83.1
Stabilizing the damaged bunds with stone and soil	23	92.0	17	100	17	100	57	96.6
If not repair, why?								
Erosion is minimal	0	0.0	0	0.0	0	0.0	0	0.0
Difficulty for ploughing	8	88.9	9	75.0	12	80.0	29	80.6
Labor shortage	8	88.9	10	83.3	13	86.7	31	86.1
Structures occupy plot area	9	100	8	66.7	15	100	32	88.9
Lack of awareness	9	100	12	100	14	93.3	35	97.2

Note: n= number of respondents

sures even though they were aware that adoption of the conservation technology improves the productivity of their lands. These could be associated with socioeconomic and institutional factors in the implementation of the technology as part of the agricultural production systems.

The binary logistic regression model showed that sex, family size, number of farm plots, and land size showed no significant association with the adoption of introduced physical SWC measures. Whereas, age of the

household head, education level, slope of the land, frequency of contact with extension workers, and access to training opportunities had significant ($p<0.05$) effects on the adoption of physical soil and water conservation measures (Table 4). The age of the household head showed a significant ($p<0.05$) negative influence on the adoption of physical SWC measures. The result of Wald statistics (4.404) and odds ratio also revealed that young farmers more adopted the introduced physical SWC measures than old aged counterparts. This could be because younger farmers are often educated and aware of the new technologies, while older farmers may be inclined to maintain their traditional farm management experiences. The older farmers would lack labor to construct and repair physical soil and water conservation measures as some of their sons/daughters leave. Our result supports earlier findings by Shiferaw & Holden (1999). Contrary to this, Chomba (2004) reported that the age of the household head had a positive relationship with the adoption of physical soil and water conservation measures.

The odds ratio revealed that farmers with educated household heads adopted the introduced physical soil and water conservation measures by a factor of 16 compared to illiterate household heads. The level of formal education showed a positive significant ($p<0.05$) effect on the adoption and management of the introduced physical SWC measures. Educated farmers would be more interested in the newly introduced physical soil and water conservation measures to improve the productivity of croplands. Educated farmers who are eager for positive changes have options to access information and the ability to analyze improved technologies. This agreed with the results reported by Asfaw & Neka (2017) and Sileshi et al. (2019), who reported a positive association between formal education and the adoption of physical SWC measures in northern and eastern Ethiopia. Earlier, a similar finding was also reported by Tenge et al. (2004) in the West Usambara highlands of Tanzania. Sometimes, educated farmers would prefer off-farm activities and employment opportunities that require less labor than traditional farming. However, that was not the case in our study area where educated farmers were motivated to implement soil and water conservation technologies to improve cropland productivity.

The slope of farmland influences the adoption and use of physical soil and water conservation measures significantly ($p<0.05$) and positively. About 44% and 38% of respondents have farmland on steep and medium slopes, respectively, which are susceptible to soil erosion by water. The effect of slope gradient on soil erosion by water has been well documented (Morgan, 2005; Zhao et al., 2015). The increasing erosion and soil degradation on cultivated sloping

Table 4: Binary logistic regression results of factors influencing adoption of soil and water conservation measures in the Fanta watershed, Omo-Gibe river basin of southwest Ethiopia.

Socio-economic characteristics	Coefficient (B)	Error	Wald	p-value	Exp(B)
Sex	3.448	2.807	1.509	0.219	31.430
Age	-3.118	1.486	4.404	0.036*	0.044
Education level	2.779	1.290	4.642	0.031*	16.106
Family size	-0.729	0.538	1.836	0.175	0.482
Plot number	-1.487	0.988	2.263	0.132	0.226
Land size	-0.587	0.518	1.288	0.256	0.556
Slope of the land	0.575	0.630	0.833	0.036*	1.778
Contact with extension	1.807	0.636	8.087	0.004*	6.095
Access to training	2.995	1.202	6.207	0.013*	19.991
Livestock number	-0.927	0.668	1.926	0.165	0.396

* Statistically significant ($p<0.05$)

farmlands could motivate farmers to undertake control measures. Thus, farmers owning land on steep slopes have a greater interest to accept physical SWC measures. Our study supports the findings of Bekele & Drake (2003) and Sileshi et al. (2019), who reported that slope affects farmers' decision to adopt conservation structures positively in eastern Ethiopia.

Farmers' contact with extension service providers and participation in training opportunities showed a significant ($p<0.05$) positive effect on the adoption of physical SWC measures. Agriculture and natural resource extension workers could provide information to farmers and increase willingness to implement new physical SWC measures and maintain the existing practices. Asfaw & Neka (2017) and Sileshi et al. (2019) reported that extension service had a positive association with the adoption of physical soil and water conservation measures in northern Ethiopia. Sometimes, extension service providers participate in multiple tasks and thus, the frequency of their contact with farmers would have limited importance on the adoption and management of physical soil and water conservation measures, which was not the case in our study area. Training of farmers on soil erosion and conservation had a significant ($p<0.05$) and positive effect on the adoption of physical SWC measures. The Wald statistics (1.20) indicated a significant association and the odds ratio of farmers who had access to training was greater by a factor of 19.99 than non-trained farmers to the adoption of introduced physical SWC measures. Less awareness of the functions and technical requirements of the physical SWC measures, as well as a lack of awareness of agricultural knowledge and physical SWC measures, could be major challenges. Previous studies reported better perception and knowledge of farmers about conservation could contribute significantly to the sustainable use of introduced soil and water conservation measures in Tanzania (Tenge et al., 2004) and Uganda Turinawe et al. (2015).

7 Conclusions

Soil erosion by water can adversely affect soil fertility and food security. Farmers believe that PSNP-supported physical SWC measures such as soil bunds improved soil fertility and crop yield. The sustainability of constructed physical SWC measures is a challenge as many farmers did not repair the structures on their farmland despite their observation of better soil fertility on fields with bunds than without bunds. Farmers expect government-based money or grain incentives for repairing the constructed physical soil and water conservation measures, mentioning labor shortage and unsuitability of the measures for oxen-driven plowing practice. Without an incentive, the construction of introduced physical SWC measures including soil bunds was not common. Age of the household head, education level, slope of the land, frequency of contact with extension workers, and access to training opportunities were found to influence the adoption of erosion- mitigating technologies such as bunds. We conclude that, without soil conservation measures, soil erosion was severe enough to reduce soil fertility, but the adoption and management of conservation technologies are under incentive syndrome. Continued awareness creation activities could enhance farmers' participation and commitment to the adoption and repairing of physical SWC measures.

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Competing interests

The authors declare that they have no competing interests.

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Journal of Forestry and Natural Resources (JFNR)

Authors Guideline

Abbreviation J. for. nat. resour.
ISSN 3005-4036

1. Editorial policy and Author's Guidelines

1.1. Background

The Journal of Forestry and Natural Resources (J. for. nat. resour., or JFNR) (JFNR) is a peer- reviewed online open-access published annually by the Wondo Genet College of Forestry and Natural Resources, Hawassa University. JFNR publishes original research findings in all subject-matter areas of forestry and natural resources. It seeks disciplinary and interdisciplinary research articles, review articles, featured articles, and short communication.

- Name of the publisher: Wondo Genet College of Forestry and Natural Resources, Hawassa University
- Publishing Frequency/Schedule: Bi-annual (December, June)
- Publication medium: Printed and online
- Physical Address: Wondo Genet College of Forestry and Natural Resources,
- P.O. Box 128, Shashemene, Ethiopia,
- Journal website: https://journals.hu.edu.et/hu-journals/index.php/jfnr
- Email of the journal: editorinchiefJFNR@hu.edu.et, maneditorJFNR@ehu.edu.et

1.2. Aims and Scope

Aims:

- serve as a communication medium among scientific communities in forestry, natural resources research, and other related fields
- publish original and innovative scientific works relevant to forestry and natural resources situation of Ethiopian as well as global problems
- encourage Ethiopian researchers, graduates, and postgraduate students to align their disciplinary and interdisciplinary researches in the direction of solving major problems in the areas of forestry and natural resources and conservation needs of the country, and
- serve as a platform to foster scientific knowledge sharing among researchers, scientists, policymakers, and practitioners working on sustainable forestry, green economy transition, issues of sustainable development goals, desertification, and dryland agriculture and forestry, combating desertification and drought, natural resource management, and conservation and other related topics.

Scope of the journal

The JFNR publishes scientific articles related to social, economic, policy, and environmental aspects: forestry, agroforestry, wildlife, soil, water and land resources, renewable energy, tourism, urban forestry, and greening, environmental science, GIS, and remote sensing.

2. Submission Guidelines

Submission system: Online

General contents of the journal JFNR uses the following format:

2.1. Research articles

These papers treat both disciplinary and interdisciplinary (thematic) types of researches encompassing basic and applied researches, graduate and postgraduate studies researches related to forestry and natural resources. JFNR will consider for publication articles from the regional and international forest and natural sources covering tropical and subtropical regions.

2.2. Review articles

Encompass critically reviewed scientific papers covering the state of the art knowledge in various aspects of forestry and natural resources. Review articles will be submitted by experts in the fields of forestry and natural resources with their expertise and experiences or invited by the editor-in-chief, associate editors, or editorial board.

2.3. Featured articles

These include topics in forestry and natural resources management, conservation, utilization, education, and non-conventional research articles.

Technical papers in the areas of forestry and natural resources development encompassing different aspects of socio-economics, policy issues, wildlife, environment, rehabilitation efforts and forestry and natural resources inventory and surveys, biodiversity conservation, processing and value addition of forest products, agroforestry, non-timber forest products, medicinal plants and their domestication and commercialization, integrated watershed management, green economy transition, green initiative related studies, climate change and development, land degradation and drought, aquatic ecosystem management, fisheries, etc.

2.4. Short communications

This includes articles of brief scientific notes on preliminary results, scientific observations, experimental techniques, and recent technological advances in forestry and natural resources. It also included information on specific cases and limited applications. Manuscripts for this column should not be more than six typed pages. They should have a brief abstract and not contain more than two figures and/or two tables.

2.5. Book Reviews

A critical evaluation of recently published books in any discipline of forestry and natural resource sciences will be published under this column.

3. Manuscript evaluation process

The manuscript must be written and prepared in English. Grammar and language quality are the responsibilities of the authors to submit the manuscripts in clear and communicable language quality. Once manuscripts are submitted the editor-in-chief or associate editors will check the manuscript for possible plagiarism results, originality of the work and contents of editorial policy and scope, and authors' guidelines of JFNR. Submission of a manuscript to the Journal must be accompanied by a cover letter stating that no similar paper, other than an abstract or an oral presentation, has been or will be submitted for publication elsewhere. The manuscript should be submitted online or by email to the editorial manager, who gives the manuscript number and notifies the author of receipt of the manuscript. The manuscript number will be used in all correspondence regarding the manuscript. The editor-in-chief will consult associate editors to decide whether the manuscript is within the scope of JFNR and whether the contents are worthy of further review. Manuscripts that do not meet the minimum criteria will be returned back to the author within two weeks' time. Those that meet the minimum criteria will be passed to associate editors for quick check-ups and suggestions of potential reviewers. The associate editor is an expert selected in certain disciplinary areas and who has a wide network among professionals in their field of specialization.

3.1. Peer review process

The peer-review process will follow double-blind where the manuscript will first be evaluated by the editor-in-chief or associate editors, followed by at least two reviewers. The names of the authors will be kept anonymous while sending them to the reviewers. At least one of the reviewers will be out of the staff of the publisher institute. If the reviewers recommend publication without any change(s) and the associate editors agree(s), the manuscript and the reviewer's comments are sent to the editor-in-chief who will notify the author accordingly. If the reviewer and the associate editor recommend that the manuscript could be published after revision, the editor-in-chief will return the manuscript to the author for minor or major revision. If the reviewer and the associate editor recommend that the manuscript be rejected, the associate editor sends the manuscript and the reviewers' comments to the editor-in-chief, and the editor-in- chief will check the comments forwarded by reviewers and associate editor to make a decision and return to the authors. If very different comments and decisions are observed between or among reviewers, a third or fourth reviewer will be invited to resolve the issue. The author whose manuscript is released has the option of appealing to the editorial board. The first review process will take 6-8 weeks.

If a manuscript, sent to an author for revision, is not returned within the period specified by the editor-in-chief (normally a maximum of two months), the editor-in-chief will release it. Once released, the author must resubmit a manuscript as a new manuscript for reconsideration.

Authors whose manuscript has been accepted for publication will receive a letter of acceptance. The authors will also receive the proofreading to send their opinion in five days. The pdf version of the published manuscript will be sent to the author and co-authors via their email addresses and also will be available online on the website of the college and university. The hard copy of published articles will be dispatched to various institutions upon request free of charge.

3.2. Reviewers' Report

Reviewers are requested to evaluate the manuscript on originality of the work, state of the art and nobility of the study topic, relevant objectives, soundness, latest and appropriate methodology, results in quality to address the objectives, adequate discussion, and relevant conclusion made.

And also, the way references are presented both in the text and reference lists. Reviewers are expected to give their comments and suggestions clearly (referring to the line numbers in the paper) to the authors to assist the author (s) to address all comments and suggestions given. Language correction is not part of the review process but suggestions can be made by reviewers.

3.3. Submission checklist

You can use this list to carry out a final check of your submission before you send it to the journal for review.

One author has been designated as the corresponding author with contact details:

- E-mail address
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All necessary files have been uploaded:

- Manuscript:
- Include keywords
- All figures (include relevant captions)
- All tables (including titles, description, footnotes)
- Ensure all figure and table citations in the text match the files provided Further considerations
- The manuscript has been 'spell checked' and 'grammar checked'
- All references mentioned in the Reference List are cited in the text, and vice versa

3.4. Authorship requirements

Where the family name may be ambiguous (e.g., a double name), please indicate this clearly. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name, and, if available, the e-mail address of each author.

Corresponding author: Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. Ensure that telephone and fax numbers (with country and area code) are provided in addition to the the e-mail address and the complete postal address.

3.5. Changes in Authorship

Change in authorship requests is only made by the corresponding author to editor-in-chief.

4. Format for mansucripts

The manuscript should be prepared in Times New Roman with 11 font sizes, double space, and 2.5 cm marginal indentions on all sides. The maximum number of words should be 8000. The first page should contain the full title of the manuscript, the name(s) of the author(s) including address (es), and the institution(s) in which the research was carried out. For ease of communication, authors are requested to include their email addresses. For manuscripts with multiple authors, an asterisk should indicate the author to whom all correspondence is to be addressed.

Second and consecutive paragraphs after a heading should be indented while the first paragraph after a heading should start flush left. No space should be left between two consecutive paragraphs. Scientific names should be written in full when mentioned for the first time in the text. They should be italicized. Subsequent citations should abbreviate the genus name.

4.1. Title:

The title of the manuscript should be concise, descriptive, in good order, and carefully chosen. It should clearly reflect the contents of the article.

4.2. Abstract:

This appears on the second page after the title. The abstract should reflect the concise contents of the paper. It should not exceed 250 words and must include a brief background on the study topic, the rationale for the study, objectives, methods used, results, and a conclusion. References and uncommon abbreviations should be avoided. Keywords should be up to five words, separated by a comma and in alphabetical order.

4.3. Introduction:

This section of the manuscript should include state of the art of background on the topic being studied, an in-depth description rationale of the study, objectives of the study, hypothesis, and significance of the study. It should provide a brief review of literature, limited to information essential to orient the reader.

4.4. Material and methods:

sub-headings under this section include specific study site description and selection, sample layout (experimental design) or survey methods, methods of data collection, and data analysis.

4.5. Results:

The major findings in response to objectives set in the study. Be selective and focus on reporting your results.

4.6. Discussion:

It should follow your major findings. Interpret the findings, show relationships

and implications, and compare with other studies in similar topics and relevant to the study. It should explore the significance of the results of the work and don't repeat what has been already described in the results. In some cases, results and discussion can be merged. (Results and discussion part could also be written as a separate chapter optionally)

4.7. Conclusions:

This can be written in a separate section or can be part of the discussion. It should also be concise, clear, and align to stated objectives and major findings.

4.8. Funding

Information that explains whether and by whom the research was supported

4.9. Conflicts of interest/Competing interests

Include appropriate disclosures

4.10. Acknowledgments

Collate acknowledgments in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof-reading the article, providing finance, logistics, etc.).

4.11. Submission system

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- In the case of Ethiopian names, the author's given (first) name precedes that of the
- father's name; e.g., Mesfine Bekele and not Bekele, don't abbreviate Ethiopian names.
- (Kumar and Nair 2012)
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Examples of acceptable formats for listing references in the reference section are shown below.

Journal article

Kuyah S, Dietz J, Muthuri C et al (2012a) Allometric equations for estimating biomass in agricultural landscapes: I. Aboveground biomass. Agric Ecosyst Environ 158:216–224.

Assegid Assefa and Tesfaye Abebe (2014). Ethnobotanical study of wild medicinal trees and shrubs in Benna Tsemay district, Southern Ethiopia. J. Sci. Dev. 2, 17–33.

Book

Chapman DH and Pratt PF (1961) Methods of Analysis for Soils, Plants, and Waters. University of California, Riverside, California.(N.B. initials appear before the last author's family name).

Chapter in book

Cunningham AB, Shanley P, Laird S (2008). Health, habitats, and medicinal plant use. In: Pierce CJ (Ed.), Human Health and Forests: A Global Overview of Issues, Practice, and Policy.Earthscan, London, pp. 35–62.

Paper in proceedings

Tesfaye Awas, Sebsebe Demissew (2009) Ethnobotanical study of medicinal plants in Kafficho people, Southwestern Ethiopia. In: Svein Ege, Harald Aspen, Birhanu Teferra and Shiferaw Bekele, Trondheim (Eds.), Proceedings of the 16th International Conference of Ethiopian Studies. Addis Ababa, Ethiopia.

4.13. Provide full names of periodicals in the reference list. Do not abbreviate.

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Main headings and sub-heading should be numbered consecutively 1, 1.1, 1.1.1…, 2, 2.1, 2.1.1…. Main headings should be bold, capitalize the first letter, followed by lowercase letters. Sub-headings should be lower case letters. Minor sub-headings should be light font italics.

Tables and figures

Tables and figures should be numbered consecutively in the order of their citation in the text. Each table and figure must be typed on a separate sheet and should be placed at the end of the manuscript. Footnotes should contain information relevant to specific entries or parts of the table. The approximate position of each table and figure should be indicated in the text.

Photographs and illustrations

Illustrations may be submitted in the form of black and white photographs or computer drawings or both.

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Follow internationally accepted rules and conventions: use the international system of units (SI). If other quantities are mentioned, give their equivalent in SI.

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