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Valuation of Forest Ecosystem services and Farmers' Willingness to Pay for Improved Options: The Case of Choke Mountains

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Abstract

This study was held in the Choke mountain area having a fragmented natural forest patches, in Amhara region, north-western part of Ethiopia. It aims to identify the main attributes that the local people attached to the existing forest ecosystem services and estimate their willingness to pay for that forest ecosystem services. A cross-sectional survey was used to collect data using choice experiment method and focus group discussions. Then 384 respondents were contacted from four randomly selected villages. In order to identify the main attributes of the forest, fractional factorial design was used and eight attributes were identified. As a result, 16 choice sets were generated with three strategic options (option A, option B, and option C). We have used SPSS version 25 for ease of choice set determination by orthogonal design (then fractional factorial was used) and Stata 16 for analyzing the data using an econometric model, i.e., to reveal the regression result of the multinomial logit model. Finally, the variables of 'increasing or decreasing of grass availability' and 'the payment amount' set in the choice options were significant at 1%, 'increase in forest products', 'high amount of available water' and 'provide shade service to animal' and 'the alternative specific constant become significant at 5% and the variable that is 'reduce flood & soil erosion risk' were significant at 10% level of significance. While other attributes like 'creating job opportunities for youths' and 'keeping the available biodiversity' were insignificant parameters, when other things kept constant. Finally, the result of estimated willingness to pay value revealed Br.496 was the maximum amount of a respondent's willingness to pay per year for the significant variables. Hence, the finding helps to *make decisions on which attribute that the government and the population should give more efforts in promoting conservation actions on forest ecosystem services in Choke watershed.*

Key Words: Choke, Choice experiment, forest ecosystem

INTRODUCTION

1.1 Background

The concept of "ecosystem services" emerged during the 1970s and has roots in older observations. It gained increasing recognition in the following decades (Johnston, 2014). Ecosystem services are the benefits that humans receive from nature, either directly or indirectly, which include outputs, conditions, or processes of natural systems that enhance human well-being. Different types of ecosystems, such as terrestrial, marine, freshwater, forest, and grasslands provide different services. As of Millennium Ecosystem Assessment (MEA) classifications, ecosystem services can be classified into four major service categories: regulating supporting, provisioning and cultural services. The Millennium-Ecosystem Assessment, launched in 2001, is a major assessment of human impact on the environment. It focuses on regulating services such as climate regulation, disease regulation, and mitigating droughts and floods. Supporting services include waste decomposition, air and water purification, flood protection, soil formation, and erosion protection. Cultural services include diversity, spirituality, and ecotourism (MEA, 2005).

Around 2 billion people worldwide rely on forests for livelihoods (Chao, 2012), with planted forests covering 7% of the world's forest area (FAO, 2015). As Christopher (2007) revealed that South and Southeast Asia and Africa, with their natural resources and ecological diversity rely on forests. In addition, wetlands share ecosystem services with forests, including provisioning services such as food and water; regulating services like water flow and erosion prevention; supporting services like nursery services and habitat provision; and cultural services like aesthetic information, recreation, tourism, and education-based and scientific evidences (Ibrahim and Minwyelet, 2018). In this regard, the Choke area forest ecosystem offers various services to users, including provision services like timber, non-timber products, food, and grazing areas, as well as regulating services like water, soil, and air quality. Forests provide livelihood, ecological benefits, and incomes for Sub-Saharan African countries (Dissanayake *et al*., 2015). Economists determine the optimal use of forest resources by maximizing the value of ecosystem services (Boadu, 2016).

Africa's forests are rapidly diminishing, affecting climate, biodiversity, and millions of people (Karimeh, 2011). Between 2000 and 2010, 34 million hectares were lost, with agriculture and livestock pasture being the most significant threats (Eric, 2018). Deforestation accounts for over one-sixth of global greenhouse gas emissions (Hyunshik and Tamirat, 2018). Ethiopia has lost over 60% of its forests since 1900 (Gobena, 2018). Ethiopia's forest resources, including high forests, riverine forests, ericaceous vegetation, woodlands, and trees on farms provide goods and services that have economic, ecological, and social value (AFF, 2011). Ethiopia's government aims to enhance the forest sector's contribution to economic growth and environmental sustainability. With 17.35 million hectares of forests covering 15.7% of the country, degraded lands are suitable for forest restoration (MEFCC, 2017). However, unsustainable use of these resources can lead to environmental degradation, economic decline, and decreased livelihood opportunities (Teme *et al.*, 2018).

1.2 Statement of the Problem

Choke Mountain's population has grown due to agricultural conversion; leaving fragmented Ericaceous forest patches (Aramde and Demelash, 2013). Community management is challenging, but understanding the relationship between forests and agriculture is crucial for assessing benefits and implementing conservation and sustainable management strategies. Considering the relationship between forests and agriculture is crucial for assessing forest benefits in goods and services. Limited studies have focused on the economic value of forest ecosystem services, especially using choice experiment methods, especially in the study area is nil. Identifying forest attributes helps implement conservation and sustainable management strategies.

1.3 Research Questions

We want to investigate optimal packages of strategies or policy options to be implemented in the field of environmental and economic valuation professions. That is why this study wants to answer the following questions, such as:

- What types of attributes and levels can be identified and preferred vis-a-vis the existing forest ecosystem services?
- What type of alternative options to be made to preserve Choke mountain forest ecosystem?

- What characteristics of Choke natural forest or the forest ecosystems are most important for the rural dweller or policy makers to take up sustainable conservation strategy?
- What proportion of respondents has accepted the defined characteristics of the choices of the identified alternatives?
- How much value respondents' could contribute for Choke mountain forest ecosystem services?

1.4 Objectives of the Study

The main objective of the study is to identify the main attributes of Choke Mountain forest and make valuation of the forest ecosystem services with estimating the farmers' willingness to pay for its improved options.

2. METHODOLOGY

2.1. Description of the Study Area

The study focused on the Choke Mountains in Sinan and Debaytilatgen, two districts in East Gojjam Zone, Ethiopia. This mountainous area has a mean monthly temperature of 17°C and an average annual rainfall of 1378 mm (WAO, 2019). It has a sloppy topography with a high peak that rises to 4100 m.a.s.l. (Belay et al., 2013) .

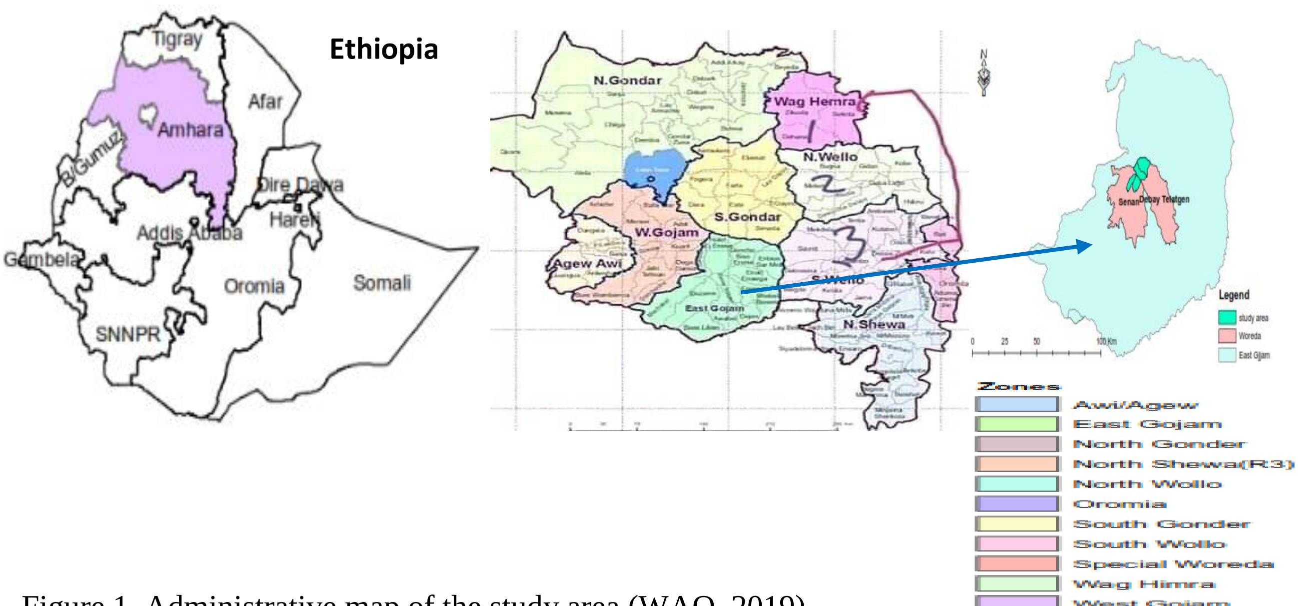

Figure 1. Administrative map of the study area (WAO, 2019)

2.2. Sampling Technique and Sample Size Determination

This study used two-stage sampling, purposively selecting districts with the largest forest patches in Senan and Debaytilatgen. Then, 384 respondents were selected from four kebeles and contacted using structured interview schedules based on their forest area coverage

$$.n = \frac{\mathbf{z^2(1-p)p}}{\mathbf{e^2}} = \frac{\mathbf{(1.96)^2(1-0.5)0.5}}{\mathbf{(0.05)^2}} = 384.16 \qquad \mathbf{(1)}$$

The sample size n, was determined using estimated population proportion p, and the z-value yielding the desired degree of confidence by estimating the population proportion and the absolute size of the error, e (Cochran, 1977). Choice experiments (CE) have been used for estimating consumer preferences and predicting behavior in market and non-market valuation studies. The standard model for analyzing discrete choice experiments is McFadden's (1974) random utility model (RUM). The utility of a good is not derived from the good itself but from its attributes. The utility gained from a certain alternative is described based on the attributes. Discrete choice experiments (DCEs) have been widely used in policy research and policy questions for over 25 years (de Bekker-Grob et al., 2012; Boxall, 2000; Hanley, 2001; and Adamowicz *et al.* 1998). CE reduces biases and provides extensive data, making it preferable to contingent valuation (CV). It has been increasingly used in the valuation of public goods and services over the past two decades, demonstrating the importance of considering attributes and levels in decision-making processes. With regard to the functional forms, the deterministic component of the utility function (V_{ijt}) is specified as linear. It can be written as a product of *β's* and X_{ijt}, which expressed by using a vector of attributes or explanatory variables (X_{ijt}) linked to the individual *i* and their coefficients or vector of the betas (*β's*) as follows:

$$V_{ijt} = \beta' X_{ijt} \qquad (2)$$

In other words, for simplicity equation 1 can describe the relationship of each component in an individual's utility

$$U_{ijt} = V_{ijt} + \varepsilon_{ijt} = \beta' X_{ijt} \quad \varepsilon_{ijt} \qquad (3)$$

where U_{ijt} is the utility of an individual *i* obtained from choosing alternative *j* within the choice situation t, V_{ijt} represents the deterministic/observable component of the utility function; and ε_{ijt} represents the stochastic or random error component of the function.

As expressed in equation 3, an individual *i* derives utility U_{ijt} from the *j* alternatives in a given situation *t* with the complete set of choices C. Hence, the utility is represented as a function of the attributes of the preferred or relevant forest ecosystem goods or services Z_{jt} of each alternative and the individual's socio-economic characteristics S_{it}. These can be given as

$$: U_{ijt} = V_{ijt}(Z_{jt}, S_{it}) + \mathcal{E}_{ijt} \tag{4}$$

The respondent in a CE choice set will maximize his/her utility by choosing the alternative *j* among the other *k* within the choice set if the scenario *j* has higher utility than the others. Hence, equation 3 again can be written as the probability of a consumer *i* choosing the option or alternative *j* over the other *k* as McFadden (1974) and Louviere *et al.* (2000) described in terms of systematic and error components as

$$P(j/C) = Prob(U_{ijt} > U_{ikt}) = Prob[(V_{ijt} - V_{ikt}) > (\mathcal{E}_{ikt} - \mathcal{E}_{ijt})]; \quad j,k \in C; j \neq k \tag{5}$$

where C represents the complete set of choices. To estimate equation (4) the error distribution must be assumed usually, Gumbel distributed and independently and identically distributed (IID), hence the probability of choosing *j* is given by:

$$P_{ijt} = \frac{exp^{(\mu V_{ijt})}}{\sum exp^{(\mu V_{ikt})}} = \frac{e^{(\mu \beta' X_{ijt})}}{\sum e^{(\mu \beta' X_{ikt})}} \text{ for all } k \in C \tag{6}$$

where μ represents a scale parameter (usually set at 1 to keep constant error variance), and inversely proportional to the variance of the error term.

This leads to the expression for the probability P, of choosing alternative j from given options. Assuming the error terms of the resulting utility function are independently and identically distributed, a multinomial logit (MNL) model can be developed.

3. RESULT AND DISCUSSION

3.1. Socio-economic and Demographic Characteristics of the Respondents

The results of the descriptive statistics revealed the socio-economic and demographic characteristics of the respondents. The results for continuous variables were depicted in Table 1

Table 1. Mean values of continuous variables (N=384)

Variable	Mean	Std. Dev.	Min.	Max.
Age of household head (HH) in No. of years	41.9349	9.46139	21	80
Family size of HH in No.	5.0182	1.5421	2	11

Land size of HH in ha.	0.7139	0.3792	0.25	3
Distance of HH's home in min. from forest edge	37.5135	18.8992	4.8	120
Distance of market from HH's home in min.	71.3802	27.7493	10	120
Annual income of HH in Birr (ETB)	14990.91	13326.12	1800	56000
No. of DA contact days in a month	2.7161	1.8635	0	6

Survey result, 2023

The variables like age of the respondents revealed that majority of them (69%) were adults who ranged in 35-54 years having an average 42 years old. The average family size of the respondents shown 5 members but the values varied between a minimum of 2 and a maximum of 11 family members. Among the respondents 94% were male and 6% female. More than 94% of the respondents were married. Since all the respondents were farmers most of them were illiterate of which 55% are unable to read and write. The survey revealed that all respondents generate income from mixed farming, with farmers earning between 1800 and 56000 Birr per annum. The average annual farm income is 14991 Birr, which is underestimated due to wide variations

Table 2. Statistical values of categorical variables (N=384)

No.	Variables	Value	Freq.	Percent	No.	Variables	Value	Freq.	Percent
1	Age	21-34	79	20.6	5	Land size in ha	< 0.25 and no land	3	0.8
		35-44	156	40.6			0.25-0.5	158	41.1
		45-54	110	28.6			0.51-1.0	176	45.8
		55-64	28	7.3			1.01-1.5	38	9.9
		>65	11	2.9			1.51-2.0	7	1.8
		Total	384	100			2.01-2.5	1	0.3
2	Sex	Female	23	6			2.51-3.0	1	0.3
		Male	361	94			Total	384	100
		Total	384	100	6	Income	<2000	259	67.4
3	Marital	Single	0	0			2000-5000	19	4.9
		Married	364	94.8			5001-10000	11	2.9
		Widowed	11	2.9			10001-20000	20	5.2

	status					in Br.		
		Divorced	9	2.3		20001-30000	11	2.9
		Total	384	100		30001-40000	30	7.8
4	Educ. status	Illiterate	211	55		40001-50000	17	4.4
		Literate	173	45		>50000	17	4.4
		Total	384	100		Total	384	100

Survey result, 2023

As depicted in Table 2, 46% of respondents own small land sizes. Literature review and focus group discussions were used to identify Choke mountain forest attributes and set their levels.

3.2 Attributes and levels of CMFES

The list of attributes of the forest ecosystem services presented during the discussion time were:

- source of fuel-wood and other forest products;
- provide shade service to livestock and human;
- balance the micro-climate or keep the local weather condition;
- for recreation or to attract tourists for personal satisfaction;
- forming soil, improve/retain soil fertility
- used for hiking, jogging, and observing views;
- used for research and education activities
-
- prevent flood risk and landslide;
- stop or reduce soil erosion;
- source of gene-pool for diverse plant and animal species;
- Improve biodiversity of flora and fauna;
- food source to people;
- hunting wild animals;
- equestrian show;
- source of grass for livestock;
- supply sustainable water;
- create job opportunity for youths; and
- source of construction material.
- The Choke mountain forest ecosystem services were prioritized by respondents, with grass availability being the most preferred attribute. Improvement in the ecosystem directly implies improved access to grass or forage for livestock. Levels of grass availability were defined as an increase in conservation or a decrease

Table 3. Identified and selected attributes and levels of CMFES

Attributes	Levels	Number of levels
Grass availability	Decrease, Increase	2
Fuel-wood and other forest products	Decrease, Increase	2
Water availability	Low, High	2
Create job opportunity for youths	No, Yes	2
Shade for livestock	No, Yes	2
Biodiversity	Low, High	2
Reduce soil erosion and flood risks	No, Yes	2
Respondent's contribution (payment)	100 Birr, 200 Birr, 300 Birr	3

Own computation, 2023

The Choke Mountain Forest Ecosystem (CMFES) offers various attributes, including fuelwood, water availability, job creation opportunities for youths, shade services for livestock, biodiversity, soil erosion and flood risk reduction, and a payment-related attribute. The forests provide shade to protect from high rainfall, wind and frost, and biodiversity. The ecosystem also helps to reduce soil erosion and flood risks. FGD participants set different payment levels for contributions, ranging from Birr 100 to Birr 300, to improve the management and conservation of Choke Mountain forest ecosystem services.

3.2.1. Experimental design and choice sets

The experimental design used an orthogonal fractional factorial design using by SPSS software to combine attributes and levels, generating 16 combinations for the first option (option A). The second option (option B) was created using a shifted design (Diafas, 2014). The design was uncorrelated and the choice sets were assigned into four blocks to minimize cognitive burden. Respondents were randomly assigned to one of the blocks, with option C having no payment requirement as shown as an example in Table

Table 4. Example of the designed choice set to a given respondent

Block 2			
Choice set 1			
Attributes	Option A	Option B	Option C (Status-quo)
Grass availability	Increase	Decrease	As of today,

Fuel-wood and other forest products	Increase	Decrease	”
Water availability	Low	High	”
Create job opportunity to youths	Yes	No	”
Shade for livestock	No	Yes	”
Biodiversity	High	Low	”
Reduce flood and soil erosion risks	Yes	No	”
Your payment contribution	100 Br	200 Br	”
Which option do you prefer?	Option A ☐	Option B ☐	Option C ☐

Own computation, 2023

The analysis used descriptive methods and econometric tools, with SPSS version 25 software and STATA16 software used for choice sets and regression analysis. Results showed a negative sign of monetary attribute at 1% level, suggesting respondents' preference for higher payment levels. The negative sign of alternative specific constant suggests a reaction to welfare improvement as the status quo changes.

3.2.2. Econometric Results

The econometric results indicate a more meaningful explanation towards the cause-effect relationship of explanatory variables towards the dependent one (individual choice from options)

Table 5. Regression results of the MNL model

Attributes (Choice variables)	B's	Coefficients	SE.	P>|Z|	95% CI	
Alternative specific constant	B_0	-.1666789**	0.0761024	0.029	-.3158368	-.017521
Respondent's payment amount	B_1	-.0062231***	0.0005008	0.000	-.0072047	-.0052414
Increase in grass availability	B_2	3.089441***	0.1627733	0.000	2.770411	3.408471
Decrease in grass availability	B_3	-3.188806***	0.162633	0.000	-2.870051	-3.50756
Increase in forest products	B_4	.1619038**	0.0752376	0.031	0.0144408	0.3093668
Decrease in forest products	B_5	-		-	-	-
High amount of available water	B_6	-.2262943**	0.0751771	0.003	-.3736386	-.07895
Low amount of available water	B_7	-		-	-	-
Create job opp. to youths	B_8	0.0170082	0.0752169	0.821	-.1304142	0.1644306
Don't create job opp. to youth	B_9	-		-	-	-
Provide shade service to	B_{10}	-.1622009**	0.0751665	0.031	-.3095246	-.0148771

animal						
No shade service to livestock	B_{11}	-		-	-	-
Presence of high biodiversity	B_{12}	-0.0882787	0.0751652	0.240	-.2355997	0.0590423
Presence of low biodiversity	B_{13}	-		-	-	-
Reduce flood & soil erosion risk	B_{14}	0.1301652*	0.0752328	0.084	-.0172885	0.2776188
Not reduce flood & soil eros. risk	B_{15}	-		-	-	-
	_const	-2.051189***	0.0803059	0.000	-2.208586	1.893792
Number of respondents		384				
Number of observations		4608				
Log likelihood		-2553.801				
Pseudo R^2		0.1293				

Own computation, 2023 '***', '**', and '*' shows at 1%, 5%, 10% level of significance

The coefficient of the payment attribute represented by $ß_1$, which holds levels of continuous values indicated how much the utility is increased or decreased by having one extra unit of the amount of money attached to it (in this case per one Birr), while the other coefficients measure the change in the utility from the reference category. Thus, the respondents preferred an alternative from the given options that decreases the utility of paying fewer amounts (0.006) to conserve the forest ecosystem. They also preferred choice set that helps to reduce the occurrence of flood and soil erosion risks, as denoted by $ß_{14}$, measure the change in the utility from the reference category or the status-quo option to either of the two options by 0.13 utility level. However, the coefficients for the creation of job opportunities for youths ($ß_8$) and the attribute of high biodiversity conservation level ($ß_{12}$) were insignificant (Table 5).

3.3. Estimation of Willingness to Pay

In order to estimate the monetary value of payment for attributes, the respondent would be willing to pay until an improvement in the status of the forest is observed. The cost/price coefficient can be interpreted as an estimate of the negative marginal utility of income (Hanley *et al.,* 2001). This can be estimated as the ratio of the value of the coefficient of each attribute to the negative of the payment attribute. In this study it is an estimate of marginal willingness to pay (MWTP). Hence, the mean or the average

WTP for a given attribute is calculated with the ratio between the beta parameters of , as follows: interest and the beta parameters of payment item (Train, 2009)

$$WTP = -\frac{\beta a}{\beta c} \quad (7)$$

Where βa is the coefficient of any of the non-monetary is attributes and is the coefficient of any of the non-monetary attributes and βc is the coefficient for cost/price. The simplified formula of the ratio of coefficients is an 'implicit price that represents the MWTP for a unit change in the quantity of an attribute (Ginsburgh and Throsby, 2013). Although the MWTP can be assumed to have positive or negative values, it is possible that individuals would maintain the status quo situation. Thus WTP can be estimated, for example, how much annual payment that a respondent are willing to sacrifice to receive improved grass availability (i.e., one of the forest ecosystem services of Choke mountain) after three years is calculated as

$$WTP\ (incga) = -\frac{\partial U/\partial incga}{\partial U/\partial payt} \quad (8)$$

The maximum value of respondents for the given improvement options were showed the marginal WTP for the attributes of forest ecosystem services to pay Br. 496 per HH as a maximum annual contribution for increasing in grass availability and a minimum of Br. 2 for creating job opportunity for youths of the nearby community using basic MNL and conditional logit model results, respectively

Table 6. Results of respondents' willingness to pay for CFES

Variables	Reg. codes	Values of respondents WTP in			
		basic MNL	extended MNL	clogit	RPL
Alternative specific constant	ASC	-329.6089	-326.9580	-11.0422	75.6673
Increase in grass availability	incga	496.4473	474.7353	478.3752	411.9129
Increase in forest products	incfp	26.0166	25.1063	19.3927	25.5107
High amount of available water	hiwa	-36.3636	-35.4082	-27.9601	-35.0232
Create job opp. to youths	yesjoy	2.7331	2.4736	2.1443	3.0267
Provide shade service to animal	yeshl	-26.0643	-25.5516	-20.2676	-25.5107
Presence of high biodiversity	hibd	-14.1856	-14.0498	-11.2704	-14.2687
Reduce flood & soil erosion risk	yesfer	20.9165	20.4769	16.1874	19.4573

The conditional logit model and MNL were used to analyze forest resource managers' knowledge about biophysical links and incentive structures. They also explored compensation schemes. Ecosystem services have intrinsic and economic value, but often under-estimated due to lack of detailed market values. This highlights the importance of understanding these factors. The conditional logit model and MNL were used to analyze forest resource managers' knowledge about biophysical links and incentive structures. They also explored compensation schemes. Ecosystem services have intrinsic and economic value, but often under-estimated due to lack of detailed market values (Swinton *et al.*, 2015). This highlights the importance of understanding these factors.

4. Conclusions and Recommendations

The study on Choke mountains forest ecosystems highlights the importance of evaluating ecosystem services for sustainable decision-making. The ecosystem provides various services such as provisioning, regulating, cultural, and supporting services, providing timber, non-timber products, fresh water, climate regulation, recreation, tourism, educational, research, and carbon storage. Forest patches offer wider livelihood and ecological benefits, such as increased grass availability, forest products, water availability, and shade services for animals. However, many inhabitants find paying for these services unthinkable. The findings can help forest managers prepare resource management plans to maximize the economic value of forest ecosystem services. However, identifying preferred attributes and setting payment strategies for improved options is crucial for sustaining a healthy environment and maintaining natural forest ecosystem services.

This study aims to reconsider the vulnerability of natural forests to losses and inform the government and policy makers about local community perspectives. Recommendations include providing alternative energy sources, expanding non-farm economic activities, and implementing agricultural intensification. Forest tenure security mechanisms can encourage people to have wood lots for fuel wood and construction, while community campaigns and rehabilitation of degraded areas should be continued annually. Both the government and land users should enhance agricultural productivity and develop eco-friendly economic activities on remaining forest resources.

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Ethical statement

No need tohave an ethical statement for the research because it is a survey based research work and we have got personal concents during data collection time.

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Contribution of authors

Haimanot Aregahegn: Conceptualization; data collection, coding and editing, analysis; investigation; methodology; validation; visualization; writing original draft manuscript; incorporating review comments and editing. Mengistu Ketema: Conceptualization; data tool approval; methodology; supervision; validation; original draft review and editing. Bezabih Emana: Methodology; data tool conceptualization, supervision; validation; original draft review and editing. Belay Simane: Conceptualization; funding acquisition and support; methodology; supervision; validation; original draft review and editing.

Conflict of Interest

The authors do not have any conflict of interest regarding the publication of this article.

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