International Journal of Business and Development (IJBD)

IJBD. Volume 2-Number 1:2025

The Impact of Area Closures on the Adoption of Livestock Manure as Energy Source: Evidence from Tigrai Region, Northern Ethiopia

Guesh Endrias[1]*, Melaku Berhe[2], Nigussie Abadi[3], Teklay Negash[4] and Azeb Gebregziabher[5]

Article History:
Received: Dec 19, 2024
Accepted: May 15, 2025
Published: Aug 01, 2025

Abstract

Natural forests have played vital roles in the provision of a wide range of benefits for the people living around them. The establishment of area closures could help to protect the communal natural resources on one hand, and it might impact the adoption of the traditional rural energy sources. While area closures have been studied globally in different themes, there is a lack of focused research on how area closures affect the adoption of dung cakes as an energy source, and the existing literature has not sufficiently addressed their impact on the rural households in the Tigrai Region. Exploring how area closures impact the adoption of livestock manure as an energy source can offer solutions for enhancing energy access, thereby improving efficient energy consumption, which was lacking due to area closures for local communities. So, this study is intended to examine the impact of area closure on the adoption of livestock manure as an energy source. A cross-sectional household survey of randomly selected respondents was conducted to generate data for the study. The data were analyzed using descriptive statistics, inferential statistics, and Propensity Score Matching methods. The result of this study revealed that households residing near area closures had utilized a smaller (671.6 kg to 746.2 kg) amount of livestock manure than those located farther away from the closures as their energy source. This implies that the presence of area closures had a negative impact on households' livestock manure adoption. This study therefore recommended that the concerned parties like environmental protection agencies, rural development and agricultural extension office, renewable energy companies should provide better extensions to rural households, especially in rural areas which had been unable to achieve a balance between area closures and use of dung cakes as organic fertilizers in lieu of using for energy purposes.

Keywords*:* Area closure, Manure Adoption, Natural Forest, Propensity score matching, Rural households, Traditional energy.

1 Department of Agricultural and Resource Economics, College of Dryland Agriculture and Natural Resources, Mekelle University, P.O. Box. 231, Mekelle, Tigrai, Ethiopia. guesh.endrias@mu.edu.et

2 Department of Agricultural and Resource Economics, College of Dryland Agriculture and Natural Resources, Mekelle University, P.O. Box. 231, Mekelle, Tigrai, Ethiopia, melakuberhe@gmail.com

3 Department of Agricultural and Resource Economics, College of Dryland Agriculture and Natural Resources, Mekelle University, P.O. Box. 231, Mekelle, Tigrai, Ethiopia. nigussieabadi@yahoo.com

4 Department of Agricultural and Resource Economics, College of Dryland Agriculture and Natural Resources, Mekelle University, P.O. Box. 231, Mekelle, Tigrai, Ethiopia. tekelaynegash@gmail.com

5 Department of Agricultural and Resource Economics, College of Dryland Agriculture and Natural Resources, Mekelle University, P.O. Box. 231, Mekelle, Tigrai, Ethiopia. asterwubet21@gmail.com

Introduction

In sub-Saharan Africa, where natural forests play pivotal roles in providing multiple benefits to local people (Ogieriakhi and Woodward, 2022).The issue of how the locals care for the forests is of interest to various policymakers presently (Carlson et al., 2022). But now, the deterioration of natural resources is a significant global issue (Ibrahim et al., 2021), and Ethiopia is heavily dependent on agriculture (Wassie, 2020), which results in deforestation, biodiversity loss, and soil fertility decline (Welemariam et al., 2018). Overgrazing and the conversion of forest land to other land uses are the main drivers of soil nutrient depletion, pollution, soil erosion, and vegetation degradation (Xie et al., 2020). In response to the dire impacts of such human actions, the establishment of area closure has been considered as a mechanism, mainly for restoring degraded land areas (Amin et al., 2015; Desta et al., 2021). As a result of the introduction of area closures across many countries of sub-Saharan Africa, noticeable improvements have been recorded in restoring natural ecosystems, whereby the improved ecosystems further contribute to carbon sequestration and environmental viability (Desta et al., 2021; Feyisa et al., 2017). Area closures can also improve species variety composition, soil quality, ecosystem productivity (Cairns, 2002; Seid et al., 2023), and biomass output (Lishan, 2023).

Area closures are usually established to rehabilitate and restore degraded communal areas by limiting intrusion from humans and domestic animals (Mekuria and Aynekulu, 2013). Given that the majority of the rural population in sub-Saharan Africa lives in off-grid remote areas, area closures positively impacted the availability of traditional energy sources (Van der Kroon et al., 2011; Htay et al., 2022). This is because area closures not only enrich the natural vegetation but also serve as a source of biomass energy for rural households in the form of firewood, charcoal, and dung cake for cooking and heating purposes (Xin et al., 2023). However, people’s excessive reliance on traditional energy options, mainly from natural resources and the environment, has contributed to deforestation and land degradation (Arnold et al., 2003). For instance, studies conducted in Bangladesh showed that households residing close to area closures were unable to collect traditional energy sources, and they were forced to rely on leaves, twigs, animal dried dung, and crop residues to meet their energy demand (Miah et al., 2010).

Similarly, in the Tigrai Region of Ethiopia, traditional energy resources, which are extracted from natural resources, are the main sources of energy for rural households (Danyo et al., 2017; Guta, 2012). However, due to the establishment of area closures and less use of biogas as a source of energy, the rural households rely heavily on animal dung cake as the primary energy source in the Tigrai Region (Kelebe et al., 2017).

This use of animal dung cake for energy purposes might pose an adverse impact on livestock manure adoption and crop production practices (Anteneh and Yadav, 2017). Households’ dependence on animal dried dung consumption as their main energy source further leads to reduced soil fertility and soil quality, which results in the reduction of agricultural productivity (Welemariam et al., 2018; Anteneh and Yadav, 2017).

So far, different studies have been conducted on the area closure measures, focusing on different themes. For instance, Birhane et al., (2006) and Teketay et al., (2018) studied the actual and potential contribution of area closures in terms of enhancing the biodiversity of woody species, stand structure, and regeneration status of woody species through area closure. Mekuria and Veldkamp(2012)investigated the effects of area closure on woody species diversity and population structure in comparison with adjacent open grazing land. Moreover, the effectiveness of governance and management of the area closure has been dealt (Lemenih & Kassa, 2014; Mengistu et al., 2005). The overall results of those empirical results revealed that the establishment of area closures is essential for ensuring sustainable restoration and rehabilitation of severely deforested, eroded, and degraded lands. In addition, information on vegetation diversity and the social capital of area closure is relevant for the sustainable establishment of ex-closure to restore degraded natural resources (Teketay et al., 2018). On top of that, Erdedo et al. (2024) investigate the status of woody species diversity in the area closure in comparison to adjacent open grazing land. In addition to this, Eshetie et al. (2021) also compared the effect of ex-closure and non-ex-closure on woody species restoration, diversity, population structure, and regeneration status. However, there is no well-documented research in the study area on the effect of area closure on the adoption of livestock manure in rural areas of Tigrai. Therefore, this research work was designed to examine the impacts of area closure on households’ livestock manure adoption. This paper mainly contributed to the existing literature on the adoption of livestock manure options by exploring the influence of area closures on farmers' decisions to adopt livestock manure practices in the Tigrai Region, northern Ethiopia.

Materials and Methods

Conceptual framework

There is not enough fuel energy, such as firewood and charcoal, available in rural families because of area closures. Households can switch to alternative energy sources, such as solar, electricity, biogas energy, LPG, crop residue, animal dung, and the like, in order to find additional energy sources. However, using animal manure as fuel has an impact on manure acceptance, lowers soil fertility, and agricultural productivity.

About 7% of Ethiopia's agricultural GDP is lost due to decreased agricultural production brought on using animal manure for domestic fuel (Berry et al. 2023). Particularly in the country's northern regions, there is a significant loss of soil fertility and a widespread usage of animal dung for fuel. The majority of the dung produced in these locations is mostly used for cooking due to the increasing lack of fuelwood for home usage (Legesse, 2021).

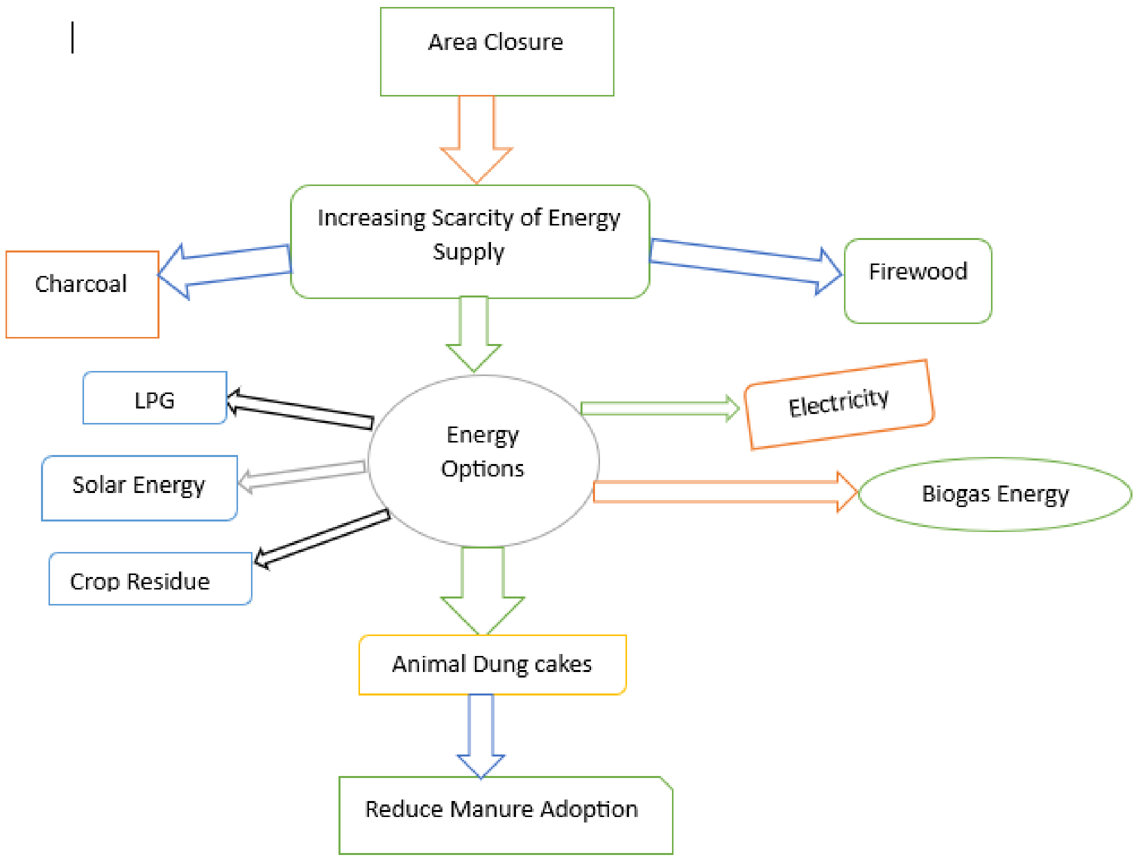

Figure 1: Conceptual framework of the study

Description of the Study Area

The study is conducted in the Atsbi-Wenberta districts of the Tigrai Region, Northern Ethiopia. We selected the Atsbi-Wenberta districts purposively due to the fact that the area closure system has been practiced. From a total of 22 administrative villages (tabias) of this district, only two tabias (villages) were purposively chosen. Accordingly, Barka Adisebha (potential in area closure) and Habes (with no area closure) were purposively selected for this study.

Geographically, Atsbi-Wemberta is delimited by Enderta district on the south, Kilte-Awlaello district on the west, Saese-Tsaeda Emba district on the north, and the Afar Region on the east. The study district practiced a mixed crop and livestock farming system as the major economic activity. Wheat, barley, teff, and pulses are the most staple and dominant cereal crops grown in the district. Cattle, sheep, and donkeys are the major livestock population reared in the study district.

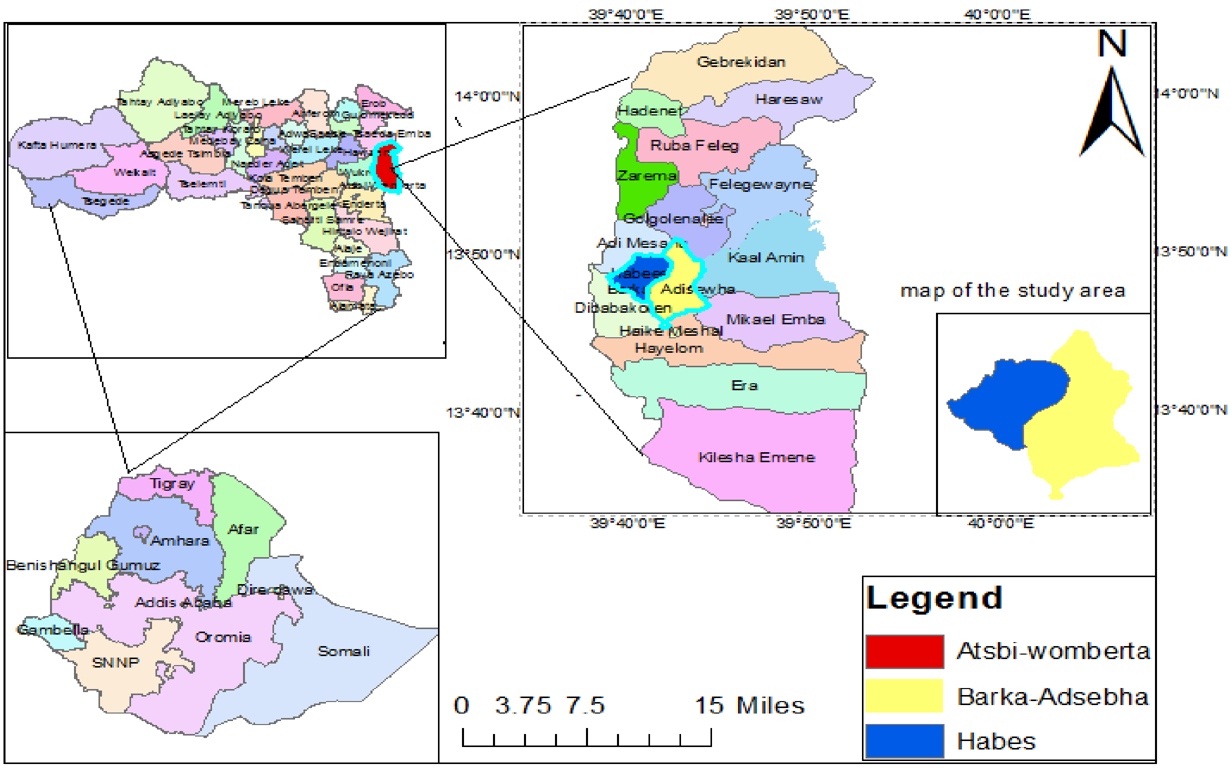

Figure 2: Map of the study area

Data Sources and Collection Methods

In order to analyze the effects of area closures on the adoption of livestock manure by rural households, the study used both quantitative and qualitative data sources. Quantitative data were collected from smallholder farmers using a structured questionnaire. The qualitative data were also gathered through Focus Group Discussion (FGD) to triangulate and explore concepts, generate ideas, and determine differences in opinion among farm households on the adoption of livestock manure in the district. We prepared a checklist to guide focus group discussions, and it was prepared in a manner that enabled us to generate relevant information regarding the perception of discussants on the adoption of livestock manure by rural households in their respective tabias. On top of these, secondary data were obtained from reports and documents of the regional and local administrations.

Sampling Technique and Sample Size

The study employed multi-stage sampling techniques. In the first stage, one district was purposively selected from the Tigrai Region of northern Ethiopia based on the potential of area closures. In the second stage, two tabias from the district were purposively selected because one tabia is fully potential with area closure, but the other one is not, so those two tabias were selected for comparison. Following Muyembe et al. (2023), the required sample size of 335 respondents was determined, of which 56% of the surveyed households were from living adjacent to the area closures and 44% were from the living further from the area closures. In the third stage, the representative sample size was distributed among the study tabias in proportion to their representation of the target population. Finally, the respondent households were randomly selected from the list of rural households obtained from the local government administrations.

Methods of Data Analysis

Data were analyzed using descriptive statistics, inferential statistics, and Propensity Score Matching. In the descriptive statistics, the mean, standard deviation, and percentage were used.

Propensity Score Matching

Noting that this study was conducted across the two administrative villages (Tabias), representing households that adopted area closure (adopters) and those who did not adopt it (non-adopters). Propensity Score Matching (PSM) was used to measure the impacts of area closure on households' adoption of organic manure. This technique is used to assess the portion of the variation in organic manure levels between adopters and non-adopters that can be directly attributed to area closure. Permutational Multivariate Analyses of Variance (PERMANOVA) is a powerful statistical method used to compare group differences based on distance or dissimilarity measures, particularly in ecological and biodiversity studies (Anderson, 2001). In addition to this, Wolka et al.(2024) also uses analysis of variance (ANOVA) to compare groups, but both of these face problems of sensitivity, outliers, and biases. In order to reduce or eliminate biases that may arise from observational findings and estimate the cause of events, the study used propensity score matching (PSM) to take into account parametric units that did not participate in area closure but otherwise shared the same characteristics as those who participated in area closure.

The propensity score matching method is designed to run a logit or probit regression for measuring the probability of a household's exposure because of their adoption of area closure, depending on a bundle of the household's observable behavior that can influence their engagement in area closure. Because propensity score matching (PSM) is supposed to accurately measure the probability of households' adoption, the characteristics included in the propensity score were carefully considered and as comprehensive as possible. However, it was very important that the behaviors that could affect the treatment were not included. For this reason, reference data were used to estimate the probability of occurrence. Once all relevant covariates were selected for inclusion, a probit regression function was performed, and the predicted probabilities were obtained.

The effectiveness of propensity score matching (PSM) depends on two assumptions. These are assumptions of conditional independence and the assumption of common support. The conditional independence assumption (CIA) implies that selection into the treated group is solely based on the observable characteristics. Given the values of some observable covariates, and also implies that the value of the outcome variable is independent of the treatment state. This means the treatment should be independent of the outcome assignment. Therefore, the livestock manure adopters' outcome and the non-adopters' outcome are independent of the treatment status.

$$Y_0, Y_1 \perp A \mid Z \tag{1}$$

$$E(Y_1 \mid P, A_i = 1) = E(Y_0 \mid P, A_i = 0) \tag{2}$$

Where, P is i^{th} households' propensity of treatment group, Y_1 is outcome of i^{th} households when livestock manure is adopted, Y_0 is outcome of i^{th} households when livestock manure is not adopted, E is expectation operator, and A is the state where i^{th} households treated or not treated; 1 for households who was treated and 0 otherwise.

Common support assumption (CSA): states that the average treatment effect for the treated (ATT) is only defined within the region of common support. It also assumes that no explanatory variable predicts the treatment perfectly.

$0 < p\ (A = 1 \mid Z) < 1$ (3)

If the above two assumptions are satisfied, then, conditional on estimates of propensity scores (p), the observed treatment group can be substituted for the missing average outcome observation of the non-treated groups. Given that the propensity scores are balanced and the above assumptions are satisfied, according to (Rosenbaum and Rubin, 1983) the parameter of interest, which is average treatment effect on treated (ATT), can be estimated as:

$ATT = E\ (y_1 - y_0 / A = 1) = E\ (y_1\ / A = 1) - E\ (y_0\ / A = 1)$ (4)

Where, ATT is average treatment effect on the treated, y_1 is outcome of i^{th} households when livestock manure is adopted, y_0 is outcome of i^{th} households when livestock manure is not adopted, E is expectation operator, and A is the state where i^{th} households on treated or not on treated; 1 for a household who was a treated group and 0 otherwise. In impact evaluation, the interest is not on E (y_0 / A = 0), but on E (y_0 / A= 1). Therefore, propensity score matching (PSM) uses estimated propensity scores to match the observed mean outcome of the non-treated group who are most similar in observed characteristics with a treated group. This means it uses E (y_0 / A = 0) to estimate the counterfactual E (y_0 / A= 1). Then:

$ATT = E\ (y_1 - y_0 / A = 1)$

$= E\ [E\ (y_1 - y_0 / A = 1,\ p\ (z))]$

$= E\ [E\ (y_1 / A = 1,\ p\ (z) - E\ (y_0 / A = 1,\ p\ (z) / A = 1)]$

$= E\ [E\ (y_1\ / A = 1,\ p\ (z) - E\ (y_0\ / A = 0,\ p\ (z) / A = 0)]$ (5)

Where ATT, E, y_1, y_0, p, and A are defined as earlier, and the outer expectations are defined over the distribution of p(A=1/Χ).

A number of proposed methods are available to deal with matching similar treatment groups and non-treatment groups. Nearest neighbour matching method (NNM), radius matching method (RM), stratification matching method (SM), and kernel-based matching method (KM) are the most commonly used methods based on the similarity of propensity scores among the observations. The choice of a specific matching algorithm depends on the data in question and, in particular, on the degree of overlap between the treatment and comparison groups in terms of the propensity scores (Yonas, 2006). Becker and Ichino (2002) also stated that consideration of several matching algorithms in tandem is advantageous as it allows measuring the robustness of the impact estimates.

Sensitivity Analysis as Robustness Check

One of the central assumptions of the sensitivity analysis is that treatment assignment is not unconfounded given the set of covariates (z). This implies that the Common Support Assumption (CSA) no longer holds. It is also assumed that the assumption of conditional independence (CIA) holds given z and an unobserved binary variable (U). Where;

U: Y_0 D |(z, U)

As long as U is existing and unobserved, the outcome of the controls, E (Y_0|D= 0), cannot becredibly used to estimate the counterfactual outcome of the treated; E (Y_1|D= 1). This means:

$E\ (Y_0 \mid D = 1,\ z) \neq E\ (Y_0 \mid D = 0,$ (6)

Conversely, if U is known together with the observable covariates (z), then it would have beenpossible to estimate ATT using the outcome of controls. This is because:

$$E (Y_0 | D = 1, z, U) = E (Y_0 | D = 0, z, U). \quad (7)$$

Considering the following equation with binary potential outcomes, $Y = D * Y_1 + (1 - D) * Y_0$

The distribution of the binary confounding factor U is fully characterized by the choice of fourparameters:

$$P_{ij} = p (u=1 | D=i, Y=j) = p (u=1 D=i, Y=j, z) \quad (8)$$

In order to make the simulation of the potential confounder feasible, two simplifying assumptions are made. These are the assumptions of binary U and the conditional independence of U with respect to z. It was also indicated that the simulation assumptions pointed out here have no impact on the results of the sensitivity analysis (Ichino *et al.,* 2008). Using a given set of values of the sensitivity parameters, the matching estimation is repeated many times, and a simulated estimate of the ATT is retrieved as an average of the ATTs over the distribution of U. Then, the simulated U is treated as any other observed covariate and included in the set of matching variables to estimate the propensity score and compute ATT according to the chosen matching algorithms.

Table 1. Summary of explanatory variables and their expected signs used in the model.

Covariates	Nature	Descriptions	Expected sign
Dependent variable			
Adoption of livestock manure			
Explanatory Covariates			
Distance to the forest	Continuous	Distance to the forest in kilometers	+
Age of Hh	**Continuous**	**Age of household head (years)**	-/+
Family size	Continuous	The family size of the household in number	+
Land size	Continuous	The land holding size of the household in hectares	+
TLU	Continuous	Tropical Livestock Unit	+
Distance to nearest market	Continuous	Distance to the nearest market center in minutes	-
Year of schooling	Continuous	Educational level of the household head in the year	+
Sex Hh	Dummy	Sex of the household head (1= male, 0 = female)	+
Credit access	Dummy	Households access to credit, (1= yes, 0 = no)	+
Solar Energy for lighting purposes only	Dummy	Households' access to improved energy source (1= yes, 0 = no)	+
Use of animal dung as fuel energy	Dummy	Households use animal dung as an energy source (1= yes, 0 = no)	_

Results and discussion

General characteristics of the surveyed households

The results showed that the logarithmic mean distance to the forest (community forest (t-value -14.78)), family size (t-value -2.27), TLU (t-value 3.04), distance to the nearest market (t value -4.7), and age of the surveyed rural households (t-value 1.82) differed significantly between those who live adjacent to the area closures and those living further away. Furthermore, the logarithmic mean distance to the forest (community forest (t-value -14.78)), family size (t-value -2.27), and year of schooling were lower in rural households whose live next to area closures than in rural households further away from area closures but distance to the nearest market(t value -4.7) is higher for those households live next to area closures. More specifically, households living close to the area closures have a short distance to the community forest and to the nearest market, and they are unable to obtain firewood from the community forest since they depend on the dried dung and agricultural wastes and also have opportunity to purchase cleaner energy sources from the market as compared to households who's living further away. This result is consistent with the result studied by (Sharma, 2019) and states that the higher the distance, the lower the chances of shifting to cleaner fuel due to transportation difficulty, and the distance to community forests (CF) is also assumed to have a positive relation with firewood demand. Further, the results show that some variables did not exhibit a significant mean difference between the groups of households living adjacent to area closures and those living further from area closures. However, there is a difference in the averages of these variables between the two groups (Table 2).

Table 2. Results on Continuous Variables

Variables	Area closure		Non-area closure		Overall mean	Test statistics
	Mean	**SD**	**Mean**	**SD**		***t*- value**
Distance to forest (Log) (km)	0.25	0.96	1.31	0 .82	7.09	-14.78***
Age Hh	46.9	12.01	49.3	12.4	47.96	1.82*
Family size	4.42	1.91	5.97	1.69	5.20	-2.27**
Land size (hectare)	0.52	0.29	0.56	0.27	0.54	1.299
TLU	2.87	1.71	3.44	1.66	3.12	3.04***
Distance to nearest market (minutes)	73.81	36.15	53.35	43.47	64.71	-4.7***
Year of schooling	2.09	3.02	2.28	2.79	2.197	-0.65

***, ** and * level of significance at 1%, 5% and 10% respectively

Among the 335 respondents, 70.75% of the surveyed households were male-headed, and 29.25% were female-headed. From the key informant interview and FGD, the study also finds that female-headed households were responsible for gathering traditional fuel energies, especially firewood and charcoal, in both groups. This finding is consistent with the findings of (Buba *et al.*, 2017; Berhe et al., 2017), which state that female-headed households, as compared to male-headed households, have higher probabilities of consuming and gathering firewood and charcoal, but male households participate in other agricultural activities more than them. In relation to credit access, 22.6% of the household heads received credit among the households living adjacent to the area closures in order to purchase modern energy sources, since they lacked sufficient energy sources. This finding is consistent with the finding of Walekhwa et al. (2019), which revealed that access to credit services is an important variable in rural energy choices. The availability of credit positively and significantly influenced the adoption of biogas as a modern energy source, while the remaining 77.4% did not receive credit for purchasing modern energy sources. On the other hand, 12.1% received credit among the group of households living further from the area closures, but the remaining 87.9% did not receive credit to purchase modern energy sources because those households have sufficient traditional energy sources to meet their needs for energy sources. Furthermore, 92.5% of the households living adjacent to the area closures used solar energy sources for lighting purposes only during sunset. Likewise, among the households living further away from the area closures, 91.3% of the households used solar energy sources. Furthermore, access to credit and household sex were significantly correlated with area closures (Table 3).

Table 3. Results on Categorical Variables

		Area closure		Non-area closure		Test statistics
Characteristics		Freq.	%	Freq.	%	x^2- value
Sex of Hh	Female	61	32.80	37	24.83	2.54**
	Male	125	67.20	112	75.17	
Credit access	Yes	42	22.58	18	12.08	6.204***
	No	144	77.42	131	87.92	
Solar Energy for lighting purposes only	Yes	172	92.47	136	91.28	0.16
	No	14	7.53	13	8.72	

***, and ** denote values statistically significant at 1%, and 5% respectively

Energy Consumption of Rural Households

Table 4 indicates that firewood (96%, t-value 2.74), dung cake (88%, t- value, -25.49), and charcoal (59%, t-value 2.1) are the most commonly used cooking fuels in the study district. Moreover, crop waste, electricity, and solar energy were also among the sources of energy in the district. The result of this study agrees with the empirical findings of (Lusambo, 2016; Denis *et al.*, 2017; Bhatta *et al.,* 2018), which reported that the most common energy sources in rural areas are firewood, charcoal, kerosene, electricity, solar, crop wastes, and natural gas.

The result of this study also shows that rural households rely on firewood as their primary energy source. However, rural households living further away from area closures are more likely to use firewood than rural households living near the area closure, since rural households residing near the area closure depend more on modern energy sources (Table 4). This finding is consistence with the finding of (Ghimire, 2013), which reports that most rural households residing near exlosure use biogas as modern energy instead of using traditional energy sources. The mean comparison test of the difference in firewood use between the two groups indicates that there is a statistically significant difference at a 1% level. This is because there is no permit to harvest firewood from the nearby area closure, as confirmed from the focus group discussion. The t-test also reveals that the mean difference of the charcoal energy option is significant at the 5% significance level between households near the area closure and those away from the area closure. This indicates that a significant number of households rely on charcoal as their primary energy source for rural households living in areas with no area closure. These results were also confirmed by the results of (Gebregziabher and Soltani, 2019), which empirically states that rural households residing near exclosures do not have permission to collect traditional energy sources since it affects the ecology and the composition of animal varieties.

Table 4 also shows that there is a statistically significant difference between the mean values of a household's reliance on dung cakes energy options as a key source at the 1% significance level. That is, dung cake energy source is primarily used by rural households living adjacent to area closures in comparison to households that live further away from the area closure. This finding is inconsistent with the finding of Ghimire (2013), which reports that animal dung cannot be used as an energy source directly; instead, it is used as a substrate for the production of biogas. The participants of the focus group discussion highlighted that households living adjacent to the area closure are strictly prohibited by the village bylaws not to illegally harvesting forest products. This persuaded the rural households to rely on animal dung and agricultural residues as primary energy sources to compensate for the scarcity of fuelwood energy sources. The result of our study is consistent with the empirical study of (Awan *et al.,* 2023) reported that the rural households depend on dirty fuel like dung cake as their main energy source. Moreover, the result of our study is also consistent with the empirical finding of (Berhe et al., 2017) who reported that in most rural places, dung is a valuable traditional fuel energy source.

Furthermore, the t-test of the mean difference of solar as an energy alternative (89%, t-value -3.21) is found to be significant at the 1% significance level. This means that rural households employed contemporary energy sources to supplement traditional energy sources for lighting purposes during sunset only (Table 4). The result of this study is also in line with the empirical findings of (Awan *et al.,* 2023), which reported that rural households in developing countries have
limited access to renewable energy sources such as electricity and gas. This finding is also inconsistent with the empirical finding of (Eshetie et al., 2021), which finds that nowadays, most rural households use solar energy not only for lighting but also for baking and other housing services.

Table 4. Mean Comparisons of the Most Consumed Energy Options in the Study District

	Area closure		**Non-area closure**		**Overall Mean**	**Test statistics**
	Mean	SD	Mean	SD		*t*- value
Firewood option	0.94	0.25	0.99	0.82	0.96	2.74***
Charcoal option	0.84	0.36	0.92	0.27	0.88	2.1**
Dung cake Option	0.95	0.23	0.14	0.35	0.59	-25.49***
Electricity Option	0.23	0.42	0.20	0.40	0.21	-0.54
Solar Option (for lighting)	0.92	0.2	0.89	0.35	0.91	-3.21***
Biogas Option	0.02	0.13	0.00	0.00	0.01	-1.56

***, ** denote values statistically significant at 1%, and 5% respectively

Table 5 summarizes the results of a survey of the rural households that were asked to list the principal uses of animal feces in their localities. Likewise, the participants of the focus group discussion were asked to list the most common uses of animal feces in rural households in their environs. The study firms that about 93% of households living near area closures used animal excrement as the primary energy source. While only 14% of the rural households living further away from area closures used cow dung cake as an energy source. This indicates that most of the rural households residing near to area closure used less organic manure in comparison to households living further away from the area closure. This outcome was also corroborated by participants in the focus group discussion. The focus group participants from the Tabia next to the area closure brought up the fact that their village's bylaw on the conservation and management of natural resources prohibited both human and animal interference with the closure of the area. As a result, they are compelled to cook using animal excrement or firewood from their own property. On the other hand, Tabia focus group participants who did not live in areas that had been closed emphasized that the majority of farmers employed organic animal waste to increase crop yields. This indicates that rural households resorted to animal dung as an energy source, even if it is an important organic manure, as reported in the empirical finding of Anteneh and Yadav (2017), which documented that animal manure is an important ingredient for agricultural product practices and improves crop productivity.

Table 5. Animal dung use is compared as a fuel energy source between area closure and non-area closure.

		Freq.	%	**Freq.**	%	**x^2- value**
		Area closure		**Non-area closure**		**Test statistics**
Use of animal dung as fuel energy	Yes	174	93.55	21	14.1	214.7***
	No	12	6.45	128	85.9	

*** denote values statistically significant at 1%

Area closures impact on the adoption of livestock manure in rural households

Propensity Score Matching Estimation

This study is intended to examine the impact of the presence of area closures on households' adoption of animal manure as an organic fertilizer. We used a binary probit regression model to compute propensity scores by assigning the value of 1 for households next to area closures or the value of 0 for households residing away from the area closure. To estimate the likelihood of each household being next to the area closures, all factors anticipated to influence area closures were included. Following (Gelgo *et al.,* 2016). We also included the study's influential covariates, such as distance to forest, access to finance, use of better energy, distance to nearest market, age of household head, sex of household head, year of schooling, family size, and TLU. The Chi^2 result given by 148.73 and the corresponding test statistic ($p < 0.000$) suggest that the included explanatory covariates had the capacity to explain the model effectively. Distance to the forested area, access to credit, use of improved energy appliances, distance to the nearest market, sex of the household head, year of schooling, family size of the household head, and TLU significantly affected the probability of the treatment groups (Table 6).

Table 6. The Result of the Binary Probit Estimate for the Propensity Score

Covariates	Coef.	dy/dx	Std. Err.	Z	P>z
Distance to forest(km)	0.604	0.235	0.044	5.32	0.000***
Access to credit	0.783	0.288	0.071	4.06	0.000***
Energy improves	1.215	0.456	0.062	7.37	0.000***
Distance to nearest market (hours)	0.013	0.005	0.001	5.49	0.000***
Age of household	0.011	0.004	0.003	1.32	0.188
Sex HH	-0.412	-0.156	0.074	-2.10	0.036**
Year of schooling	0.090	0.035	0.012	2.72	0.007***
Family size	0.140	0.056	0.018	2.98	0.003***
Land size	0.463	-0.180	0.121	-1.50	0.135
TLU	0.115	0.045	0.021	2.10	0.036**
_cons	-2.439				
Number of obs	335				
LR chi2(10)	148.73				
Prob > chi2	0.0000				
Log likelihood	-155.790				
Pseudo R2	0.6231				

***, and ** level of significance at 1% and 5%, respectively

The overall predicted propensity scores range between 0.003 and 0.99. The estimated propensity scores for households residing adjacent to the area closures range from 0.004 to 0.99. Whereas the estimated propensity scores for households living further away from the area closures range from 0.003 to 0.95 (Table 7). This demonstrates that the zone of common support would be between 0.004 and 0.95, with outliers falling below and above this range. Some of the surveyed households living next to the area closures were excluded from the analysis because their propensity ratings fell beyond the region of common support. Thus, it appears that the observations presented are sufficient to forecast the influence of area restrictions on livestock manure adoption for this study (Figure 2). Furthermore, the propensity score results revealed that the overall average propensity score among the sampled households was approximately 0.56, meaning that the average chance of households living next to area closures was approximately 56% (Table 7).

Table 7. Distribution of the Estimated Propensity Scores

Category	**Observation**	**Mean**	**SD**	**Minimum**	**Maximum**
Area closure	186	0.73	0.23	0.004	0.99
Non-Area closure	149	0.34	0.25	0.003	0.95
Total	335	0.56	0.30	0.003	0.99

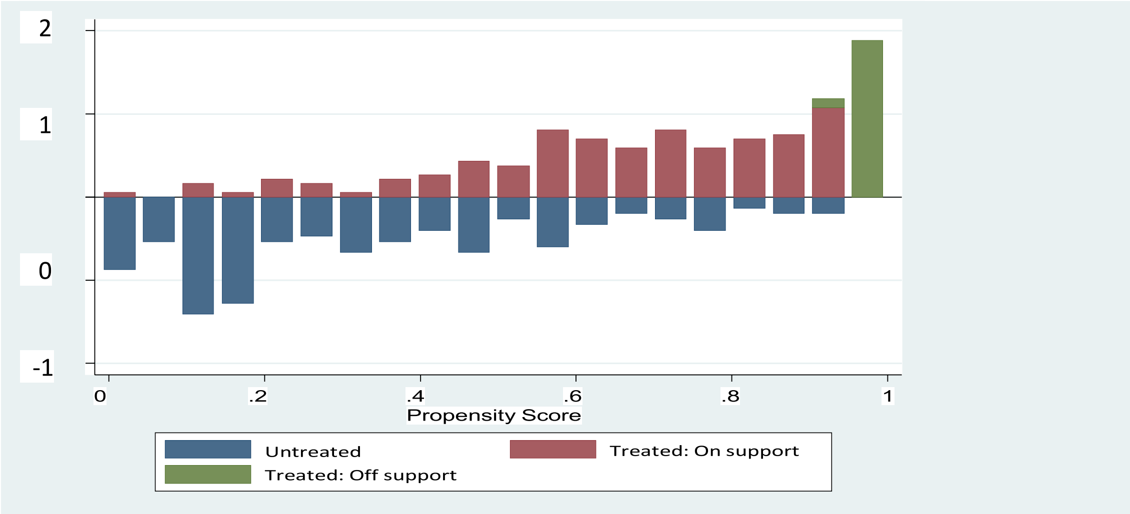

Figure 3: Distribution of the Estimated Propensity Scores (Quality of Common Support)

Considering different matching methods concurrently is advantageous because it allows for the measurement of the robustness of the impact estimates (Becker and Ichino 2002). This study employed kernel matching, nearest neighbor matching, radius matching, and stratification matching approaches to assess the difference in average livestock manure adoption between the treated and control groups. As a result, Table 8 showed that households living adjacent to area closures used from 671.6 kg to 746.2 kg less average animal manure than households living further away from the area closures. This means that area closures have a significant negative impact on households' adoption of livestock manure. The radius matching and stratification matching were found to be significant at a 1% significance level. Similarly, the nearest neighbor matching was significant at the 5% significance level. Likewise, the kernel-based matching was also significant at the 10% significance level. Furthermore, this study demonstrates that area closures contribute to a reduction in the use of animal manure for crop production; instead, the rural households living next to area closures relied heavily on animal dung as an energy source. The participants of the focus group underlined that even if the area closure contributed to the restoration of the degraded lands and enhanced vegetation cover, the rural households could not get firewood, which they otherwise used to collect. The result of this study is consistent with the empirical findings of Teketay et al.(2018) and Seid et al.(2023) which reported that area closure restores the degraded environment and increases the biodiversity of woody species.

Table 8. Propensity Score Matching Results

Matching method	Number of treated	Number of Controlled	ATT	BSE	T-test
NNM (5)	186	56	-688.6	308.5	-2.233**
RM (0.05)	185	145	-746.2	197.3	-3.782***
KM (bw 0.2)	186	148	-672.5	366.5	-1.83*
SM	186	148	-671.624	172.177	-3.901***

***, **and * stand for significance level at 1%, 5% and 10 % respectively.

Results of Sensitivity Analysis for Robustness Check

The primary goal of this analysis is to determine or estimate the extent to which the estimated treatment effects were free of unobserved variables. This might be accomplished by comparing baseline treatment effects to simulated treatment effects or by comparing *Sensatt*-generated outcome and selection effect values to predetermined outcome and selection effect values. Table 9 shows that the simulated outcome effect for nearest neighbor matching was 4.45, 2.25 for kernel matching, and 1.54 for radius matching. For the nearest neighbor matching, radius matching, and kernel matching approaches, the selection impacts were 1.25, 3.64, and 4.04, respectively. The outcome effect, according to Gelgo *et al., (*2016), captures the observable effect of unobserved variables on the controlled outcome, whereas selection effects evaluate the effect of unobserved covariates on treatment selection. This means that in this study, unobserved confounders could have decreased the relative probability of area closure by a factor of 4.04 to 1.25 and also decreased negative treatment outcomes by a factor of 4.45 to 1.54, which is not plausible. When comparing the simulated and baseline ATTs, the overall simulated ATTs are too close to the baseline ATTs, even though U is linked with substantial outcome effects (>1) and selection effects (>1) for the NNM, Kernel, and Radius matching algorithms. As a result, both the outcome impact and the selection effect are more than unity, and the percentage difference between the baseline and simulated ATTs is less than 10%, increasing the credibility of our estimated ATTs. This demonstrates that the matching results were almost immune to the potential unobservable bias, implying that the estimated ATT was the consequence of area closures alone.

Table 9. Simulation-based Sensitivity Analysis Results.

Matching algorism	Simulated ATT (2)	Baseline ATT (1)	Std.Err.	Outcome Effect	Selection Effect	Difference in % (1-2/1)
NNM	-665.38	-688.62	558.986	4.45	1.25	3.37
RM	-752.45	-746.86	240.304	1.54	3.64	0.75
KM	-704.19	-672.46	479.404	2.25	4.04	4.72

Where NNM is nearest neighbour matching, RM is radius matching, and KM is kernel matching.

Conclusions and policy implications

Even though there were different studies conducted concerning area closures but there is no well-documented research in the study area on the effect of area closure on the adoption of livestock manure in rural areas of Tigrai. This study is intended to assess the influence of area closures on household adoption of livestock manure in the Atsbi-Wemberta district of the Tigrai Region, northern Ethiopia. Accordingly, the study concludes that there is a substantial variation in the average kilogram of animal manure adoption between households living adjacent to and away from the area closures. That is, households that live adjacent to the area closures adopted fewer kilograms of livestock manure on average than households further away from the area closures (from -671.6 kg to -746.2 kg). This confirms that the presence of area closures has a detrimental impact on households' adoption of animal manure in the study area. Based on the obtained result, the study recommends the government (Rural development and Agricultural Extension office, Environmental protection office) and concerned stakeholders (renewable energy companies) should supplement the area closure establishment with the provision of alternative energy sources so that the rural households could not compromise the dung cake as organic manure to use it as an energy source in the face of firewood scarcity.

Statement and Declarations

Funding statement

This research did not receive any specific grant from funding agencies.

Conflicting interests

The authors reported no potential conflicts of interest.

Additional information

No additional information is available for this paper.

Data Availability

Data will be made available on reasonable request.

References

1. Amin, A. M., Choumert, J., Combes, J.-L., Motel, P. C., Kere, E. N., Olinga, J.-G. O., & Schwartz, S. (2015). *A spatial econometric approach to spillover effects between protected areas and deforestation in the Brazilian Amazon. ffhalshs-00960476v2f*.
2. Anteneh, W., & Yadav, K. R. (2017). A review sheep production system, yield, quality and preservation methods in Ethiopia. *Greener Journal of Agricultural Sciences*, *7*(9), 243–254.
3. Arnold, M., Köhlin, G., Persson, R., & Shepherd, G. (2003). *Fuelwood revisited: what has changed in the last decade?* (Vol. 37). Center for International Forestry Research.
4. Awan, A., Bilgili, F., & Rahut, D. B. (2023). Household fuel choices and consumption intensity in Pakistan: evidence from HIES data 2001–2019. *Environmental Science and Pollution Research*, 1–16.
5. Becker, S. O., & Ichino, A. (2002). Estimation of average treatment effects based on propensity scores. *The Stata Journal*, *2*(4), 358–377.
6. Berhe, M., Hoag, D., Tesfay, G., & Keske, C. (2017). Factors influencing the adoption of biogas digesters in rural Ethiopia. *Energy, Sustainability and Society*, *7*, 1–11.
7. Bhatta, B. R., Banskota, K., & Giri, D. (2018). Household fuel choice in urban Nepal: a multinomial logistic regression analysis. *Journal of Business and Social Sciences Research*, *3*(1), 65–90.
8. Birhane, E., Teketay, D., & Barklund, P. (2006). Actual and potential contribution of exclosures to enhance biodiversity of woody species in the drylands of Eastern Tigray. *Journal of the Drylands*, *1*(2), 134–147.
9. Buba, A., Abdu, M., Adamu, I., Jibir, A., & Usman, Y. I. (2017). Socio-economic determinants of households fuel consumption in Nigeria. *International Journal of Research-Granthaalayah*, *5*(10), 348–360.
10. Carlson, C. J., Albery, G. F., Merow, C., Trisos, C. H., Zipfel, C. M., Eskew, E. A., Olival, K. J., Ross, N., & Bansal, S. (2022). Climate change increases cross-species viral transmission risk. *Nature*, *607*(7919), 555–562.
11. Danyo, S., Abate, A., Bekhechi, M., Köhlin, G., Medhin, H., Mekonnen, A., Fentie, A., Ginbo, T., Negede, B., & Tesfaye, H. (2017). *Realizing Ethiopia's green transformation: Country environmental analysis, environment and natural resources global practice*. World Bank.
12. Denis, Y., Nwokoye, E., Urom, C., & Ozoh, J. (2017). Socio-economic determinants of energy consumption in Nigeria: evidence from household data. *FUDMA-Economic and Development Review*, *1*(2), 1–23.
13. Desta, G., Tamene, L., Abera, W., Amede, T., & Whitbread, A. (2021). Effects of land management practices and land cover types on soil loss and crop productivity in Ethiopia: A review. *International Soil and Water Conservation Research*, *9*(4), 544–554.
14. Feyisa, K., Beyene, S., Angassa, A., Said, M. Y., de Leeuw, J., Abebe, A., & Megersa, B. (2017). Effects of enclosure management on carbon sequestration, soil properties and vegetation attributes in East African rangelands. *Catena*, *159*, 9–19.
15. Gelgo, B., Mshenga, P., & Zemedu, L. (2016). Analysing the determinants of adoption of organic fertilizer by smallholder farmers in Shashemene District, Ethiopia. *J Nat Sci Res*, *6*, 35–44.
16. Guta, D. D. (2012). Assessment of biomass fuel resource potential and utilization in Ethiopia: sourcing strategies for renewable energies. *International Journal of Renewable Energy Research*, *2*(1), 131–139.
17. Htay, T., Htoo, K. K., Mbise, F. P., & Røskaft, E. (2022). Factors influencing communities' attitudes and participation in protected area conservation: a case study from Northern Myanmar. *Society & Natural Resources*, *35*(3), 301–319.
18. Ichino, A., Mealli, F., & Nannicini, T. (2008). From temporary help jobs to permanent employment: What can we learn from matching estimators and their sensitivity? *Journal of Applied Econometrics*, *23*(3), 305–327.
19. Kelebe, H. E., Ayimut, K. M., Berhe, G. H., & Hintsa, K. (2017). Determinants for adoption decision of small scale biogas technology by rural households in Tigray, Ethiopia. *Energy Economics*, *66*, 272–278.
20. Lemenih, M., & Kassa, H. (2014). Re-greening Ethiopia: history, challenges and lessons. *Forests*, *5*(7), 1717–1730.
21. Lusambo, L. P. (2016). Household energy consumption patterns in Tanzania. *Journal of Ecosystem and Ecography*, *5*(2).
22. Mekuria, W., & Aynekulu, E. (2013). Exclosure land management for restoration of the soils in degraded communal grazing lands in northern Ethiopia. *Land Degradation & Development*, *24*(6), 528–538.

23. Mekuria, W., & Veldkamp, E. (2012). Restoration of native vegetation following exclosure establishment on communal grazing lands in Tigray, Ethiopia. *Applied Vegetation Science*, *15*(1), 71–83.
24. Mengistu, T., Teketay, D., Hulten, H., & Yemshaw, Y. (2005). The role of enclosures in the recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia. *Journal of Arid Environments*, *60*(2), 259–281.
25. Miah, G., Bari, N., & Rahman, A. (2010). Resource degradation and livelihood in the coastal region of Bangladesh. *Frontiers of Earth Science in China*, *4*, 427–437.
26. Muyembe Asenahabi, B., & Anselemo Ikoha, P. (2023). *Scientific Research Sample Size Determination*.
27. Ogieriakhi, M. O., & Woodward, R. T. (2022). Understanding why farmers adopt soil conservation tillage: A systematic review. *Soil Security*, *9*, 100077.
28. Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, *70*(1), 41–55.
29. Seid, M., Shibru, S., Takele, S., Unbushe, D., & Gatew, S. (2023). People's attitudes and perceptions towards area enclosure in Ethiopian central rift valley: Implications for land restoration and livelihood improvement. *Trees, Forests and People*, *11*, 100376.
30. Sharma, B. P. (2019). Household fuel transition and determinants of firewood demand in Nepal. *Econ J Dev Issues*, *25*(1), 83–95.
31. Teketay, D., Kashe, K., Madome, J., Kabelo, M., Neelo, J., Mmusi, M., & Masamba, W. (2018). Enhancement of diversity, stand structure and regeneration of woody species through area exclosure: the case of a mopane woodland in northern Botswana. *Ecological Processes*, *7*(1), 1–15.
32. Van der Kroon, B., Brouwer, R., & Van Beukering, P. (2011). The energy ladder: Theoretical myth or emperical truth. *Results from a Meta-Analysis. Renew Sustain Energy Re*, *2013*, 20.
33. Xin, Y., Li, H., Sunday Adebayo, T., & Ayobamiji Awosusi, A. (2023). Asymmetric linkage between biomass energy consumption and ecological footprints in top ten biomass-consuming nations. *Economic Research-Ekonomska Istraživanja*, *36*(3).
34. Yonas, B. (2006). *The impact of row planting of teff crop on rural Household income: A case of Tahtay Maychew wereda, Tigrai, Ethiopia*. Mekelle University.

Online: ISSN 3078-2333