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Article

Exploring the nexus between livelihood diversification and agricultural land management practices in the Southern Ethiopian Highlands

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Abstract: Farm households in developing countries are often involved in a variety of livelihood income-generating activities to achieve basic needs and enhance food security. While some studies have examined this relationship, gaps still remain—such as conflicting findings, limited context-specific analyses, or a lack of focus on the study region.. This study explored the nexus between livelihood diversification and Agricultural Land Management (ALM) practices in the Southern Ethiopian Highlands. Data for this study were gathered through a structured questionnaire, interviews, and focus group discussions. A total of 423 sample respondents were selected by using multistage random sampling techniques. The data were analyzed using the Inverse Herfindahl Hirschman Diversity Index (IHHDI), the multinomial logit model (MNL), and the probit regression model. The findings of the study revealed that on-farm income activities are the most dominant livelihood income strategies (69.1%), followed by non-farm (21%) and off-farm (9.64%). The multinomial logit model analysis demonstrated that variables such as sex, education, family size, distance to market, land size, extension contact, membership in cooperatives, and household income were the major drivers of farmers income diversification activities (p<0.05). The results of the probit analysis indicated that income from crop production, daily labor work, rents from farmland, and farm assets have a positive and significant effect on households' decisions to implement ALM practices. In contrast, incomes from remittance and migrant sources have a negative but statistically significant impact on the adoption of ALM measures. The farm household sources of income-generating strategies substantially affected the adoption intensity of ALM measures. Income generated from the on-farm sector alone cannot be considered a core income-generating activity for households or a means of achieving food security. Therefore, land management policies and program implementations should consider farmers' livelihood diversification and income-generating strategies. In addition, such interventions need to promote sustainable farming practices, enhance innovation, and related measures for the adoption of ALM measures to ensure land sustainability.

Keywords: livelihood diversification; On-farm; off-farm; non-farm; agricultural land management practices

1. Introduction

Agriculture is the predominant source of livelihood for over 80% of the rural population in Ethiopia (Yussuf et al., 2022). It accounts for 33% of the gross domestic product (GDP), 82% of exports, and 66% of the workforce (Habte et al., 2020; EEA, 2021; Weldemichel, 2022). Despite agriculture's wide range of contributions, ranging

from rural livelihoods to the export earnings of the nation, the sector faces multiple challenges (Anshiso et al., 2016). Some of the challenges include land degradation in the form of soil erosion and nutrient depletion, farm land fragmentation, and compounding effects from recent climate variability and change (Mekuria et al., 2019). Hence, the majority of rural households have not been able to support their livelihoods and earn meager incomes from agricultural production. Consequently, rural households face food insecurity, malnutrition, and persistent poverty (Yenesew-Sewnet et al. 2015; Tamerat, 2016; Yussuf et al., 2022). Rural farm households' responses are largely towards adopting diversified livelihood strategies (Gebreyesus, 2016; Bekele & Rajan, 2017).

Ellis (2003:10) defines livelihood diversification as 'the combination of activities, choices, and processes of a household involving the continuous adoption of an incredibly different range of activities'. Livelihood diversification may also include the notion of either a sectorial shift from farming to non- or off-farming (Samuel & Sylvia, 2019) or an increase in their number of income-generating activities (Liu *et al.,* 2016; Abera et al., 2021). It plays a vital role in enhancing sustainable livelihoods, reducing vulnerability, ensuring food security, and improving the income and well-being of rural farm households (Anshiso et al., 2016; Dong et al., 2019).

Livelihood diversification strategies also play a strong role in environmental management systems (Dong et al., 2019; Kidane et al., 2019; and Adem & Tesafa, 2020). Hence, the relationship between livelihood diversification and household adoption intensity of land management practices has a positive relationship (Gebreyesus, 2016; Kassie, 2017), mutually reinforces each other (Bajpai et al., 2016), and safeguards the environment while ensuring household food security (Habte et al., 2020). In view of these, the government of Ethiopia designed and implemented various agricultural land management strategies (Mamush et al., 2021) for the highlands of Ethiopia, including the current study sub-watershed. The most widely implemented measures were soil bund, fanyajuu, terracing, mulching, crop rotation, intercropping, fallow, agroforestry, compost, farm manure, minimum tillage, and contour plowing (Abonesh et al., 2021).

Following such implementations, a growing number of farm households adopted a variety of land management measures to enhance agricultural productivity and ensure food security (Adimassu, 2012; Nigussie et al., 2107). Despite the growing recognition of the role of livelihood diversification in shaping agricultural land management (ALM) practices, the relationship between these two aspects remains underexplored, particularly in the Ethiopian context. While existing studies for instances Gebreyesus, 2016; Bekele et al., 2017; Kassie, 2017 have primarily focused on income generation and livelihood diversification as independent strategies, few have systematically examined how different income sources influence farmers' decisions to adopt ALM measures. Moreover, prior research presents conflicting findings—some studies suggest that diversified livelihoods enhance ALM adoption by increasing financial capacity and reducing risk (Pender et al., 2008; Onyeneke & Mmagu, 2017), while others argue that non-farm income sources may divert resources away from agricultural investments, thereby reducing ALM adoption (Mirzabaev et al., 2015; Rahman et al., 2017).

Additionally, the Ethiopian highlands present unique environmental and socioeconomic conditions—such as high population pressure, fragmented landholdings, and reliance on subsistence farming—which may alter the dynamics of livelihood diversification and ALM adoption. Existing studies have yet to provide a site-specific analysis that accounts for these contextual variations. This study aims to bridge this gap by offering empirical evidence on how different livelihood diversification strategies (on-farm, off-farm, and non-farm) influence ALM adoption intensity among farm households in the Ojoje sub-watershed, Southern Ethiopian Highlands.

By employing a combination of quantitative modeling (Inverse Herfindahl Hirschman Diversity Index, multinomial logit, and probit models) and qualitative insights from focus group discussions, this research contributes to a deeper understanding of how livelihood choices shape land sustainability efforts in rural Ethiopia. Hence, this study focused on exploring the nexus between livelihood diversification and Agricultural Land Management Practices in the Southern Ethiopian Highlands.

Conceptual framework

The conceptual framework illustrates the relationship between the adoption of Agricultural Land Management (ALM) measures, mediating factors, livelihood strategies, and sustainable land use and livelihood resilience. The adoption of ALM measures—such as structural erosion control, agronomic practices, soil fertility management, and cultivation practices—plays a key role in improving land productivity. However, this adoption is influenced by mediating factors, including institutional support, household and socioeconomic factors, and environmental conditions. These mediating factors shape how farmers implement ALM measures and engage in different livelihood strategies, categorized into on-farm, off-farm, and non-farm activities. Ultimately, the successful integration of ALM measures, influenced by mediating factors and livelihood diversification, leads to sustainable land use and livelihood resilience, ensuring long-term agricultural productivity and economic stability for farm households (**Figure 1**).

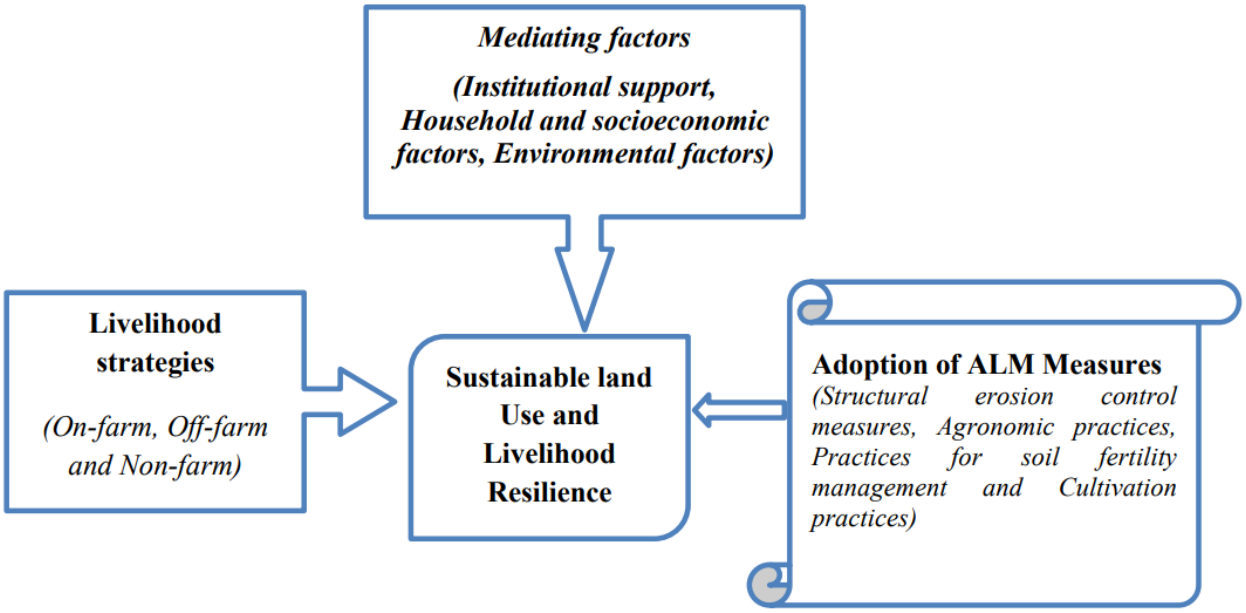

Figure 1. Conceptual framework.

2. Materials and methods

2.1. Description of the study area

The study was conducted in Ojoje sub-watershed that is located in the Doyogena district, Kambata zone, the Central regional state of Ethiopia (Lelago et al., 2022) (**Figure 2**). It is located 258 km southwest of the Addis Ababa. The elevation of the study area ranges from 1816 to 2,752 meters above mean sea level (Taddese, 2021). The principal topographic features of the study sub-watershed include gorges, steep and gentle slopes, plains, and ridge terrain (Mariye et al., 2022).

According to data from the Hosanna Branch meteorological station for the years 2000–2019, the areas lowest and highest annual temperatures were, respectively, were 15°C and 24.6°C. In addition, the research area has a mean annual rainfall of 1158.49 mm and characterized by a mono-modal rainfall distribution (**Figure 3**). The climatic conditions of the study area is dominated by the Weyna-Dega agro-ecological type (Alemayehu, 2017). This agroecology makes up roughly 68.48% of the region's overall agro-ecological type (DWRAD office, 2021).

The soils of the study area are dominated by clay to loamy clay soils. A typical soil profile indicates that the typical soil profile in the area comprises 44.79% clay, 21.91% sand, and 33.3% silt (Abera and Wana, 2023). Regarding the vegetation, there are several dominant species, including *Eucalptus globules, Grevillea robusta, Juniperus procera, Cordia africana, Afrocarpus falcatus, Croton macrostachyus, Syzygium calophyllifolium, Vernonia amygdalina, Euphorbia ampliphyla,* and many others that belong to the tree and shrub categories.

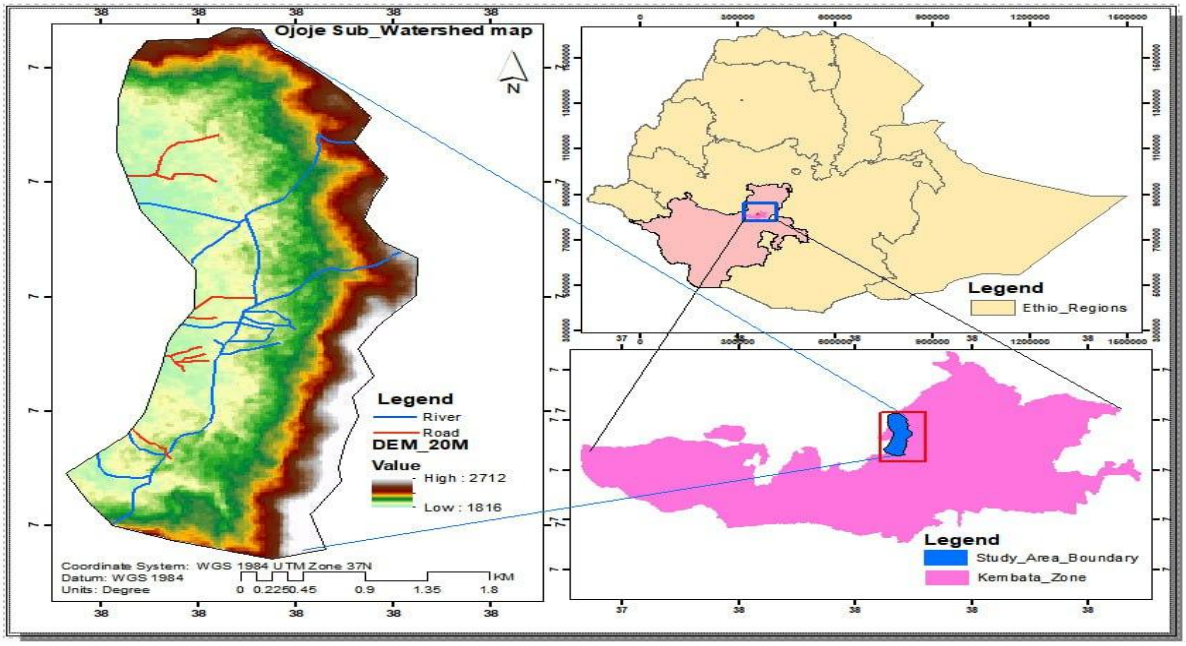

Figure 2. Map of the study area.

According to the CSA's 2007 national census, 105,265 people lived in the study area, with slightly higher proportion of women (50.9%) than men (49.1%). The study area is among one densely populated area in Ethiopia having over 500 persons per square kilometre (Taddese, 2021). The majority of rural population depends on subsistence mixed farming for household incomes and livelihoods (Abonesh et al., 2021).

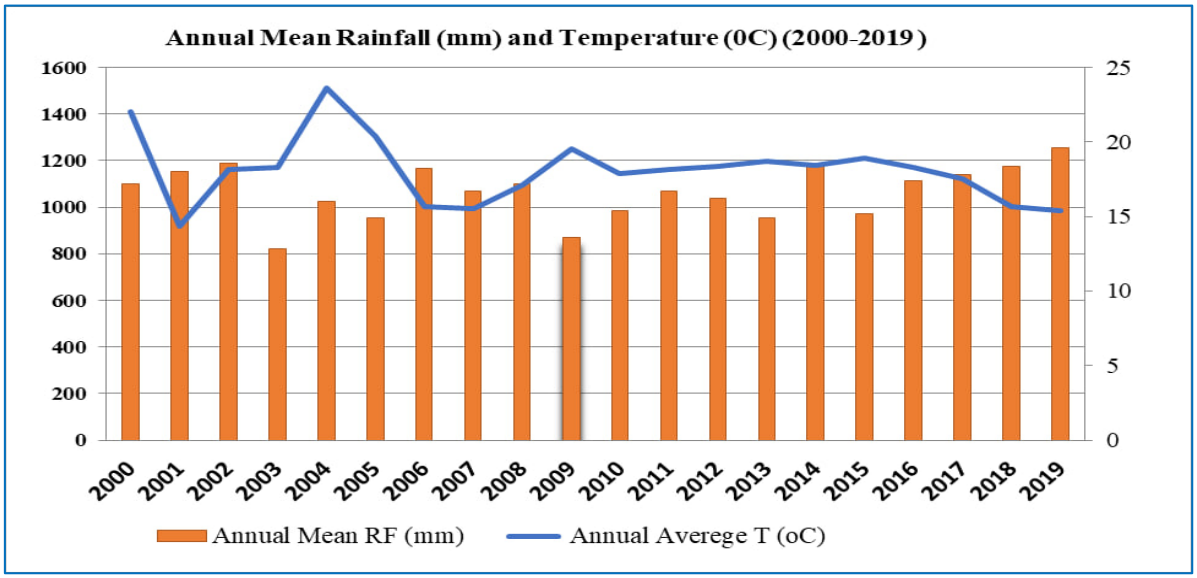

Figure 3. Mean annual rainfall (RF, mm) and maximum and minimum temperatures T °C.

Due to high population pressure, intercropping is a widely practiced phenomenon. It is quite common to find intercropping of cereals (maize, sorghum, barley, wheat, and teff), pulses (beans and soybeans), and root crops (potatoes) in many individual farms. There are also a few farmers who produce vegetables and fruits mainly for

markets. Perennial crops such as enset *(Enseteventricosum*) and stimulants (chat) are also grown in considerable amounts as cash crops. In addition, livestock rearing is a complimentary source of livelihood and often serves as an integral part of crop farming (Abonesh et al., 2021).

However, households' landholding size is declining due to generational sub-division of plots (Maryo, 2020). This made it more difficult for farm households in the study sub-watershed to feed the entire family and meet the basic nutritional requirements (Maryo 2020; Lelago et al., 2022). Hence, farmers respond to these dire conditions by engaging in livelihood diversification activities to generate income, including on-farm (crop and livestock production), off-farm (petty trade, pottery work, and daily labor work), and non-farm (renting of assets, wage employment, salary, remittance and migrant sources).

2.2. Source of data

A questionnaire survey, focus group discussions, key informant interviews, and field observations were used to collect primary data. Through the above methods socioeconomic situation of the households, major income sources, main livelihood activities, variables influencing livelihood income choices, and ALM practices were collected.

2.3. Sampling techniques and sample size

Multistage sampling techniques were used to select sample respondents. First, Doyogena woreda (district) was randomly selected from the various districts of the Kembata Tambaro Zone, southern Ethiopian highlands. Second, the Ojoje sub-watershed was purposefully selected due to i) the extensive application of agricultural land management practices over a long period of time (Mariye et al., 2022). ii) It is assumed to represent most parts of the southern Ethiopian highland in terms of agro-ecology, landscape, climatic conditions, and the socioeconomic settings of the farming communities (Abonesh et al., 2021). Finally, it to the best of our knowledge there has been no study was done on the linkagae of livelihood strategies and adoption intensity of ALM. Third, six villages (Sege, Kin-Oba, Kachera, Ollawa, Dogame, and Odogola) were purposefully selected based on their level of adoption of agricultural land management practices with the help of district agriculture and rural development office employees and development agents (DAs).

Here, we followed a proportionate sample to draw 30% of the sample respondent’s from the total number of households that inhabit in each village. Thus, 423 sample household heads were selected from a 1,410 households (**Table 1**).

After deciding the 30 % quota we used a random sampling technique to select individual households form each sampled villages. This sampling techniques ensures afforded each household in the study sub-watershed equal chances to engage in part in the study thereby gave sufficient justification for the research's conclusions to be generalised to a enter population of the study sub-watershed Furthermore, it enhances the validity and reliability of the research's findings.

Furthermore, sample respondents for key interviews and focus group discussions (FGDs) were chosen using purposive sampling methods. Here, we selected

respondents for key informant interviews and focus group discussions from district agriculture and rural development office leaders, agricultural experts, and knowledgeable farmers (age and long peiod of residence, and familiarity with issues related to the study objectives) were used as the principal criteria.

Table 1. Distribution of sample households.

Village	Total number households			Selected households		
	Male	Female	Total	Male	Female	Total
Sege	217	23	240	65	7	72
Kin-Oba	214	19	233	64	6	70
Kachera	234	31	265	70	9	80
Ollawa	211	26	237	63	8	71
Dogame	194	22	216	58	7	65
Odogola	183	36	219	55	11	66
Total	1253	157	1410	376	47	423

NB. 1 village includes 3 locally named as *'Limat Budun' and every 'limat Budun' has 65–100 households.*

2.4. Data analysis

We employed the Inverse Herfindahl Hirschman Diversity Index (IHHD), the multivariate logit model (MNL) and Probit models for data analysis. A brief description of each of them is provided below:

1. The Inverse Herfindahl Hirschman Diversity Index (IHHD): was used to determine the level of income diversification. This method was frequently used in ecological and related research areas (Anderson et al., 2005; Teklewoldm et al., 2013 & Eririogu et al., 2019). It was calculated by a formula that was adopted by Idowu et al. (2011):

$$\mathbf{HHDI} = \frac{\mathbf{1}}{\frac{(\Sigma\,\boldsymbol{\alpha_{ij}})^{\mathbf{2}}}{\mathbf{Y_j}}} \tag{1}$$

Where, **HHDI**=Herfindahl-Hirschman Diversity Index of the ith farmer

$\boldsymbol{\alpha_{ij}}$=Income from the (ith) activity of the (j th) farmer and

Yi= Total income of the j th farmer.

Here (j) indicates the three major groups income sources of farm household (i.e., on-farm, off-farm and non-farm) activities (Ellis et al. 2003). In this approach, all sample households are considered to be involved in at least one form of on-farm activity (i.e., crop production and animal husbandry). The lowest and highest value of the HHD index lies between one (1) and three (3). Hence, household is considered to be highly diversified in its livelihood sources, if HHD index is greater than or equal to two (HHDI ≥ 2), moderately diversified (1 < HHDI <2), and no diversification (HHDI = 1).

Likewise, livelihood diversified strategies have an impact on household adoption intensity of agricultural land management practices (Alemayehu, 2017; Meron, 2018).

2. **Multinomial logit model (MNL):** Multinomial logit model is used when the dependent variable has more than two alternatives. Hence, it was used to analyze the

major determinants that influence farm households' livelihood income choice strategies. This method has frequently been employed by several authors in Ethiopia and elsewhere (Adimassu, 2012; Kassie *et al.,* 2015; Weltin *et al.,* 2017; Mamo *et al.* ,2021 & Abera *et al.,* 2021),

3. Probit model: the Probit model was used to analyse the effect of farmers' participation in diverse livelihood activities on their adoption of agricultural land management (ALM) practices (Kassie, 2017). Finally, all data were processed and analysed by using SPSS version 26.0.

2.5. Model specification

Multinomial logit model (MNL) specifications: A multinomial logit model (MNL) for three livelihood income sources including on-farm activities only (ONF), on-farm plus off-farm activities (ONF+OFF) and on-farm plus non-farm activities (ONF +NFF) are specified as:

$$Y^*_{hj} = \mathbf{X}_h \boldsymbol{\beta}_j + \boldsymbol{\varepsilon}_i = \textbf{(j=}\ \text{ONF, ONF+OFF, ONF +NFF)} \quad (2)$$

Where Y^*_{hj}= observed dependent variables, (Xh) = are explanatory variables, j= is parameters to be estimated, and$(\boldsymbol{\mu_i})$ =is a random distributionof an error term

For the three (J = 3) alternative livelihood income activities that we identified and its equation can be described as:

$$Y^*_{hj} = \mathbf{X}_h \boldsymbol{\beta}_j + \boldsymbol{\varepsilon}_i = \textbf{for j=}\ \text{ONF} \quad (3)$$

$$Y^*_{hj} = \mathbf{X}_h \boldsymbol{\beta}_j + \boldsymbol{\varepsilon}_i = \text{for } \textbf{j=}\ \text{ONF+OFF}$$

$$Y^*_{hj} = \mathbf{X}_h \boldsymbol{\beta}_j + \boldsymbol{\varepsilon}_i = \text{for } \textbf{j=}\ \text{ONF +NFF}$$

Basically, if an outcome variable has J categories, the jth livelihood diversification strategies that the ith household decide to maximise its utility should have the value =1, if it does and 0 if it does not. The likelihood that a respondent with specific characteristics "x" chooses livelihood diversification strategy (*J)*, (Y_{ij}) is defined as:

$$\mathrm{Y}_{ij} = \frac{exp(\mathrm{X}_i\beta_j)}{\sum_{j=0}^{J} exp(\mathrm{X}_i\beta_j)} \ (J = 0) \quad (4)$$

Given the conditions that $\sum_{j=0}^{J} \mathrm{Y}_{ij}$=1 regarding to any (i),

Where, Y_{ij} = an expectation showing the ith probability that respondent fall into category (j); (Xi) = models for predicting response probabilities and (β_j)=Covariate influences specific to jth response category with the first group as a reference.

As mentioned by Chan (2005); Abera *et al.* (2021), a useful normalization that minimizes uncertainty in the model is to suppose that (β_j=0). Since probabilities sum to 1, simply (J) parameter vectors are required to calculate the probability for (J+1).Given that exp (Xiβj) = 1, the generalised Equation (5) can be equivalent to:-

$$\left(\mathrm{P}_i = \frac{\boldsymbol{j}}{\mathrm{X}_i}\right) = \boldsymbol{Y_{ij}} = \frac{exp\left(\mathrm{X}_i\boldsymbol{\beta_j}\right)}{1 + \sum_{j=1}^{j} exp\left(\mathrm{X}_i\beta_j\right)} \; forj = 1,2,3) \quad and$$

$$\left(\mathrm{P}_{\mathbf{1}} = \frac{\mathbf{1}}{\mathrm{X}_i}\right) = \boldsymbol{Y_{i1}} = \frac{1}{1+\sum_{j=1}^{3} exp\left(\mathrm{X}_i\beta_j\right)} \tag{5}$$

Where (P) = an outcome variable that is polytomous and has codes ranging from 0 to J. Here, the approximate probability of Yi1 arises from the fact that the sum of the J probabilities equals 1. That is $Y_{i1} = 1 - \sum Y_{ij}$. In light of this, as pointed out by Wulf (2014), Yizengaw *et al.* (2015); Abera *et al.* (2021), it suggests that, like the binary logit model, we can calculate J log-odds ratios, which are given as:

$$\ln\left(\frac{\mathrm{Yij}}{\mathrm{YiJ}}\right) = \mathrm{X}'(\beta j - \beta J) = \mathrm{X}'\beta j, \text{ if } J=0 \tag{6}$$

The probit model is specified as:

Given the land management index, households are observed to adopt agricultural land management practices if Yi* exceeds the minimum value of 0. It is:

Y_i =1, if $Y_i^* \geq 0$, if the ith households adopt the ALM practices

Y_i=1, if $Y_i^* < 0$, if the ith households do not adopts.

This is defined as:

$$\boldsymbol{Y_{ij}} = \begin{cases} 1 \; if \mathrm{yi} * \geq \; 0 \\ 0 \; \; if \mathrm{yi} * < \; 0 \end{cases} \tag{7}$$

Hence, a general probit model specified as:

$$Y_i^* = \boldsymbol{\beta}\mathbf{X_i} + \boldsymbol{U_i} \tag{8}$$

The partial derivatives of the likelihood that (yi = 1) relates to a non-dichotomous variable describes its marginal probability. The marginal odds for the jth variable of explanatory were presented as follows:

$$\frac{\partial p}{\partial \mathbf{X}_{ij}} = \varphi(\mathbf{X_i}\boldsymbol{\beta})\, \boldsymbol{\beta_j} \tag{9}$$

Where, Yi*=Observed dependent variable (1, when (ith) farmer adopts ALM and 0, otherwise); Yi^*=Underlying latent variable; (β_j) = Vector parameter evaluation of (jth) variable; (X_i) =Vector exogenous variables (sources of livelihood income choices),(φ) =Distribution function for the standard normal random variable

(Ui) = Standard normally distributed error term.

2.6. Definition of Variables and Working Hypothesis

Dependent variable: the dependent variable of the study was the source of income choice of livelihood strategies, which included on-farm, on-farm plus off-farm, and on-farm plus non-farm activity. The hypothesised dependent variable was to have the following values: α = 1, if the choice is on-farm activities only (ONF); α = 2, if the choice is a combination of on-farm plus off-farm activities (ONF+OFF); and Y=3, if

the choice is a combination of on-farm plus non-farm activities (ONF +NFF) (Table 2).

Independent variables: These are predictor variables that are expected to determine a dependent variable (the source of income choice of livelihood activities of the farm households). In this study, important explanatory variables that were hypothesised to determine households' decisions to engage in various livelihood income diversification activities are selected on the basis of the existing literature. Accordingly, household sex, education level, family size, land size, urban linkage, market distance, credit access, membership in cooperatives, livestock owned, land holding, and annual income are assumed to affect the income diversification of livelihood activities. The specification of independent variables and their respective hypotheses are presented in **Table 2**.

Table 2. The specification of independent variables and their respective hypotheses are presented in.

Variables	**Description of variables**			
	Dependent variable			
α =1,	On-farm alone			
α =2	On-farm plus off-farm			
α =3	On-farm plus non-farm			
	Independent variable	**Nature**	**Sign**	**Reference**
Sex	Sex of household (1 if male; 0 otherwise)	Dummy	−	Mekuria & Mekonnen., 2018
Education	Education level of HH (in years of schooling)	Continuous	+	Yenesew-Sewnet et al. 2015 &Yussuf, et al., 2022
Family size	Family Size of Household	Continuous	+	
Livestock	Livestock owned by the HH (number)	Continuous	+/-	»
Distance to market	Distance of household's home from the market in km	Continuous	+	»
Land size	Land size of the Household in hectares	Continuous	-	»
Credit access	Access to credit services(1 if yes; 0 otherwise)	Dummy	+/-	(Okere & Shittu, 2012) &Yussuf, et al., 2022
Extension contact	Total frequency of contact with household within a year	Continuous	+	»
Membership in cooperative	Household membership in cooperative (1 if yes; 0 otherwise)	Dummy	+	Liu et al., 2016 and Mekuria & Mekonnen, 2018
HH Income	Annual income of the household head in Birr	Continuous	+	»

3. Results and Discussion

3.1. Major agricultural land management practices in the study area

The percentage distribution of respondents and their multiple responses by the most frequently adopted agricultural land management measures in the study area are presented in **Table 3**. Our findings revealed that among the structural soil erosion

control measures 88.19%, 74.46% and 71.33% of the respondent's adopted soil bunds, fanyajuu, and terracing, respectively (**Table 3**). With regard to agronomic practices 58.07%, 52.29% and 41.93% adopted crop rotation, intercropping and mulching, respectively (**Table 3**). In addition, farmer's adoption of soil fertility management measures showed that 96.87% of them applied inorganic fertilizers, 31.57% used compost, and 57.11% used inorganic fertilizer, while 20.2% and 67.23% practised minimum tillage and contour plough, respectively (**Table 3**).

Table 3 Distribution of respondents by adopted agricultural land management practices.

Major practices	Frequency	Percentage (%)
Structural erosion control measures		
Soil bund	366	88.19
Fanyajuu	309	74.46
Terracing	296	71.33
Agronomic practices		
Mulching	174	41.93
Crop rotation	241	58.07
Intercropping	217	52.29
Fallow	119	28.67
Agroforestry	134	32.29
Practices for soil fertility management		
Inorganic fertilizer	402	96.87
Compost	131	31.57
Farm manure	178	57.11
Cultivation practices		
Minimum Tillage	83	20.2%
Contour plough	136	67.23

Source: Field survey result, 2022.

3.2. Level of diversification of livelihoods in the study area

The Inverse Herfindahl-Hirschman Diversity (IHHD) index value indicated that 63.5% of the respondents have a moderate level of livelihoods income diversification while 22.9% had highly diversified sources of income (**Table 4**). On the other hand only 13.3 % of the respondents reported that they depend on a single source of income for their livelihoods (HHDI=1) (**Table 4**). Previous studies (Getnet et al., 2021; Gebreyesus, 2016; Kassu et al., 2019) have found closely similar results regarding households in the Ethiopian highlands. These studies reported that about 64.4% of households were moderately diversified, 23.23% were highly diversified, and 12.37% were not diversified. This suggests that, like most of the highland areas of Ethiopia, households in the study sub-watershed area tend to opt for multiple sources of livelihood to sustain their livening.

Table 4. Percentage share of respondents by level of income diversification.

Diversification level	Frequency	Percentage
Not diversified (HHDI = 1)	55	13.3
Moderate (1<HHDI≤2)	263	63.5
Highly Diversified (HHDI>2)	97	22.9
Total	**415**	**100**

Source: Field survey result, 2022.

3.3. Income composition of livelihood diversification strategies

Farm households in the study area combine a variety of farm, non-farm (petty trade, remittances, pension, and salary-based employment) and off-farm (agriculture-based daily wage, firewood, and charcoal-making) activities to support their families (Anshiso et al., 2016). The analysis of the sample respondents' income sources showed that agriculture alone (i.e., crop and livestock production) contributes roughly 69.1% of income for the sample households, while the contributions of non-farm and off-farm income-generating activities were 21% and 9.64%, respectively (**Figure 3**). A 20–25% share of off-farm and non-farm income-generating activities to farm households' income was previously reported in the Ethiopian highlands (Fikru, 2008; Mengistie & Kidane, 2016; and Abera et al., 2021).

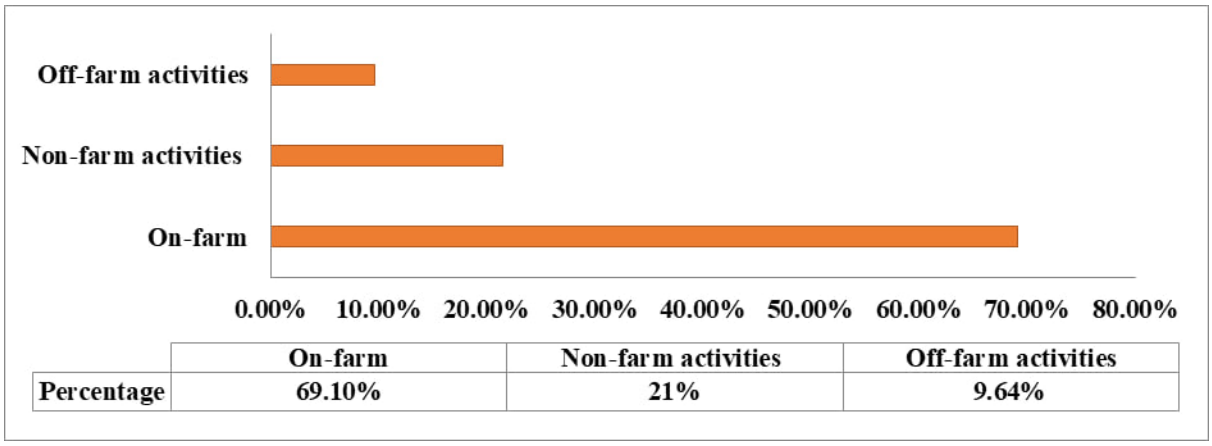

Figure 3. Sources of livelihood income share.

Specifically, in the study area, farm households rely on a combination of activities to support their families, including farm-related work and non-farm activities such as petty trade, remittances, pensions, and salary-based employment. Off-farm activities such as daily wage work related to agriculture, as well as firewood and charcoal-making, also contribute to household income. The survey conducted in the study area showed that the majority (more than 67.9%) of income for farm households came from crop production and livelihood rearing activities (Table 5). This finding is consistent with a previous study conducted by Adgo et al. (2019), which found that crop production and livelihood rearing are the main sources of income for approximately 79.5% of rural farmers in Ethiopia.

Furthermore, income generated from remittances is a significant contributor to the livelihood income sources of farming households in the Ojoje sub-watershed. According to a survey, almost 37% of adopter farm households and 33% of non-

adopter farm household livelihood income were supported by income through remittances. Moreover, 12.5% and 9.2% of adopter and non-adopter farm households also receive income from migrant sources, respectively (**Table 5**.).

This suggests that remittances and migrant income were an important source of support for farm households, regardless of whether they have adopted agricultural land management practices or not. In addition, there were several other sources of livelihood income for farm households in the study sub-watershed area. These included handcrafts, pensions, firewood sales, daily laborer work, rent from land, and other means. Hence, his clearly shows that farm households in this area rely on a diverse set of income sources to sustain their livelihoods.

Table 5. Specific income composition of the livelihood diversification of activity adopters and non-adopter farm households (multiple responses).

Livelihood income composition	**Sample household**	
	Adopters (%)	**Non-Adopters (%)**
Crop production and livestock	68.2	67.9
Petty trade	4.2	8.3
Remittanc**e ****	36.7	32.8
Migrant income*******	8.9	12.8
Handcrafts	2.4	0.7
Pension	4.5	0.2
Fire wood/grass other sale	7.2	5.9
Daily laborer work on other farm	16.8	24.3
Rent (land, farm assets)	14.7	21.9
Others	5.4	62.9

** refers type of income that money sent by relatives' permanently living elsewhere, *** refers temporary job outside community by household member.

3.4. Drivers of farmers' decision for livelihood income diversification activities

The multinomial logit model reveals that among the predicted variables, sex, educational level, family size, livestock rearing, market distance, land size, credit access, extension contact, membership in cooperatives, and annual income were the major determinants of livelihood diversification strategies (**Table 6**). We briefly discuss each of them below:

Sex of HH: The multinomial logistic regression model analysis result reveals that the sex group of farm households has significant negative effects on sources of livelihood diversification for on-farm activities, while it showed positively significant effects for on-farm plus off-farm livelihood diversification activities ($p<0.05$) (**Table 6**). If we assume other factors are kept unchanging, male-headed households are more likely to diversify than those of female-headed households. This is often the case that male-headed households have better chances for resource management (Oluwatayo, 2009), social interaction with others, participation in agricultural technological advancements (Okere et al., 2013; Ayantoye et al., 2017), and activities that are related to a wide range of livelihood options such as crops and livestock production, daily

laborer work, charcoal making, petty trade, construction, migrant income, remittances, and others. (Khan et al., 2020) A number of studies (Bekele et al., 2014; Ayantoye et al., 2017; and Abera et al., 2021) have reported that male-headed households were more likely to engage in on-farm livelihood activities and less likely to engage in on-farm and off-farm livelihood diversification activities than women-headed ones.

Educational Level of HH: The farm households' educational level was statistically significant and had a positive impact on their choices of engaging in on-farm, on-farm plus non-farm, and on-farm plus off-farm income diversification activities ($p<0.05$). In this case, the coefficient is positive, indicating that educational level of have a significant impact on farmers' participation in various income diversification activities. All other variables being held constant, a one-unit increase in education increased the likelihood of farmers choosing on-farm, on-farm plus non-farm, and on-farm plus off-farm income diversification activities by 17.5%, 47.5%, and 37.9%, respectively (**Table 6**).

Thus, educated farmers are more likely to diversify their income-generating activities as compared to those of non-educated households. The main explanation is that non-educated households lack information, knowledge, and familiarity with having diverse livelihood income choices (Bekele et al., 2017; Kassa, 2019), and to meet their basic requirements, they primarily concentrate on farm activities to maximize their basic needs (Ayantoye et al., 2017).

Family Size Households: The coefficient of family size has a positively significant relationship to on-farm and on-farm plus off-farm livelihood income diversification activates ($p<0.05$). Hence, households with large number of family sizes were more likely to diversify their income-generating activities compared to those with small number of family size. Similarly, Bekele et al. (2017) reported that household's involvement in income diversification activities was determined by sustaining the needs of large families and meeting the corresponding demand for food. Farmers' decisions to participate in on-farm ($p<0.01$) and off-farm ($p< 0.05$) income-diversification activities have a statistically significant but negative relationship (**Table 6**).

Land Size of Households: There was a positive and statistically significant relationship between land size and farmers' income diversification measures ($p<0.05$). Households with larger land sizes diversify their income more into on-farm plus non-farm activities and less into on-farm plus off-farm activities. As the farm size increases by one hectare the likelihood of households to engage in income-diversifying activities of on-farm, on-farm plus off-farm, and on-farm plus non-farm activities increase by 42.1%, 21.5%, and 27.4%, respectively (**Table 6**).

This is because farm households having smaller plots, had to look for diverse income sources other than on-farm production activities. The findings are consistent with those of Adugna (2008), Kebede et al. (2014) & Gebreyesus (2016), who confirmed that land size has a positive and significant influence on farmers' participation in income diversification activities. This can be explained by the fact that, according to Tamerat (2016); Bekele et al. (2017) & Mekuria et al. (2018), as household size increased, it became less likely that people would participate in livelihood diversification activities.

Urban linkage: Linkage to urban centres have a positive and statistically significant effect on on-farm plus off-farm and on-farm plus non-farm income diversification activities ($p<0.05$) (**Table 6**). Here, the positive coefficient suggests that the likelihood that a farm household interacts with urban residents and that they engage in income-diversified activities, including on-farm plus off-farm and on-farm plus non-farm activities rises by 45.7 and 19.6%, respectively. It's possible that having relatives in urban areas increases households' experiences of income diversification activities from various sources. Thus, strengthening rural-urban interaction could make it easier for households to diversify their sources of income.

Annual income: Annual farm household income has a positive and statistically significant effect on participation in on-farm, on-farm plus non-farm, and on-farm plus off-farm strategies ($p<0.05$) (**Table 6**). This implies that households with higher annual incomes are more likely to diversify their sources of livelihood activities compared to those with lower annual incomes. Higher annual incomes were reported to help households invest in a variety of livelihood diversification activities (Reta &Ali, 2012; Mekuria et al., 2018 & Kidane et al., 2019). In light of their explanation, households with sufficient income can overcome financial constraints to participate in alternative livelihood income-generating activities.

Market Distance: Distance to the nearest market centre has a negatively significant relationship to farmers' decision to participate in on-farm, on-farm plus off-farm, and on-farm plus non-farm income diversification activities ($p<0.05$). The likelihood of a farmer choosing to engage in on-farm, on-farm plus off-farm, or on-farm plus non-farm activities is reduced by 21.4%, 39.4%, and 51.6%, respectively, for a unit increase in travel time from the nearest market centre (**Table 6**). In this case, the implications for the negative relationship between households' participation choice of livelihood diversification activity and market distances show that households were less likely to adopt their option of livelihood diversification as the labour market distance increased.

In short, households located closer to the market's centre engage in various income diversification activities than rural households that are located further apart (Yenesew-Sewnet et al., 2015; Tamerat et al., 2016). This could be related to the fact that being closer to the market centre would reduce transport costs and make it easier to assess the transport facility and related services. Conversely, market distance had a significant positive impact on households' decisions about livelihood diversification activities (Kung et al., 2001).

Membership in a Cooperative Union: The choice of on-farm, on-farm plus off-farm, and on-farm plus non-farm activities is positively and significantly influenced by a household's membership in various cooperatives ($p< 0.05$). Membership in a cooperative organization raised by 1 unit meant that households engaged in on-farm, on-farm plus off-farm, or on-farm plus non-farm activities increased by 20.7%, 27.1%, and 19.4%, respectively (**Table 6**). According to Gebru et al. (2018), this could be related to the fact that farm households who become members of cooperative unions can receive a number of advantages. For instance, they can share their labor force, access loans, minimize the cost of individual transactions, and stay informed with the latest market data. This can ultimately encourage their livelihood diversification strategies.

The findings of the study are in line with previous research results conducted by Khatun & Roy (2012) and Gebru et al. (2018), who found that rural household engagement on-farm; on-farm plus off-farm; and on-farm plus non-farm livelihood diversification activities were positively and significantly affected by their participation in the cooperative union.

Extension Contact: Contact with an extension agent had a positive and statistically significant effects on participation in income diversification activities in both on-farm plus off-farm and on-farm plus non-farm activities ($p<0.01$). Hence a unit increase in the households' contact with an extension agent increases the likelihood of on-farm plus off-farm and on-farm plus non-farm activities by 23.6% and 35.4%, respectively (**Table 6**).

The results of this investigation are consistent with those of Selvaraju et al. (2006) and Teshome & Edriss (2013), who reported that an increase in the frequency of extension contact, especially with extension agents (DAs), could play a significant role in improving the availability of valuable information related to land degradation, land management measures, agricultural production systems, rural livelihood diversification, and related income sources. Additionally, Demissie & Legesse (2013) similarly found that information provided by extension systems related to land degradation and land management measures can positively and significantly assist in the adoption of farm-level measures and enable possible livelihood diversification.

Access to Credit: access to credit services has a positive and statistically significant relationship to farmers' involvement in on-farm plus off-farm and on-farm plus non-farm sources of income diversification activities. However, a negative and insignificant relationship was reported with household engagement in only on-farm activities (Table 6).

The study shows a similarity to the findings of previous research conducted by Anshiso et al. (2016), Amare et al. (2013), and Yenesew-Sewnet et al. (2015). These studies reported that households with higher access to credit facilities were more engaged in various livelihood diversification activities compared to their counterparts. This is attributed to the fact that having access to credit services enables them to diversify the livelihood means in general and invest in non-farm and off-farm activities in particular.

Table 6. Multinomial logit model results on determinants of households' choice of livelihood diversification strategies.

Variable	On-farm			On-farm and off-farm			On-farm and non-farm		
	Coef (β)	P-value	ME	Coef (β)	P-value	ME	Coef (β)	P-value	ME
SEX	-0.062	0.001	0.451	-0.264	0.201	0.654	0.274	0.000	0.112
EDLH	0.315	0.010	0.175	0.047	0.004	0.475	0.191	0.021	0.379
FAS	0.217	0.000	0.543	0.461	0.032	0.445	-0.211	0.472	0.351
LANDSIZE	0.139	0.024	0.421	0.091	0.006	0.215	-2.274	0.013	0.274
URBANLINKAGE	-0.154	0.005	0.350	1.072	0.036	0.457	0.425	0.029	0.196
MARKTDIST	-0.105	0.021	0.214	-2.271	0.001	0.394	-1.091	0.001	0.516
ACCESSCREDIT	-0.062	0.565	0.642	0.025	0.421	0.143	0.396	0.001	0.420
MEMBERSHP TO COOP	0.727	0.007	0.207	0.017	0.006	0.271	0.147	0.024	0.194

EXTENSION CONTECT	0.756	0.143	0.750	1.519	0.000	0.236	1.260	0.000	0.354
LIVSTOCK REARING	0.934	0.002	0.259	0.476	0.000	0.530	0.418	0.007	0.073
INCOME	0.335	0.003	0.326	1.605	0.017	0.324	1.742	0.031	0.361
Constant	-2.286E-027			-5.3116			4.859E-016		

Coef (β) = Regression coefficient (ME)=Marginal Effect (Sig).= Significance level

Number of observation = 415
Log likelihood ratio of Ch^2 = 61.576
Sig = 0.000
Pseudo R^2 =0.6873

3.5. The nexus between livelihood diversification and ALM practices

The probit model's investigation of the effect of households having a variety of sources of livelihood income on the adoption of agricultural land management practises is presented in **Table 7**. The study examines whether income from three types of livelihood income activities (on-farm, non-farm, and off-farm) affects the decision of farm households to adopt ALM practices. Here, the income sources considered are crop production from on-farm sources, remittances and migrated income from non-farm sources, daily laborer work, and rent from farm land from off-farm sources. These sources of income were chosen based on their highest share (**Table 7**) in each case, and they were purposefully selected for this study.

Accordingly the predicted Likelihood Ratio Chi Square (chi^2) results, values for every probit regression model, are statistically significant ($p< 0.05$) (i.e., $chi^2 = 0.000$). The estimated value coefficient of the probit model gives only the strength or direction of the relationship between independent and dependent variables. However, it is not convenient to estimate the actual size of variation or the predicted probabilities (Greene, 2003; Yenesew-Sewnet et al. 2015 & Eririogu et al., 2019). To predict the expected unit change in the dependent variable as a result of the explanatory variables, we used the marginal effect instead of the coefficient since it is the most fitting method in this context (Greene, 2003; Eririogu et al. 2019).

Crop production income (On-farm): The on-farm income source activity was found to be statistically significant ($p = 0.000$) and had a positive effect on the farmer's adoption intensity of ALM practices (**Table 7**). In addition, the findings show that there is a 63.1% rise in the farmers' willingness to implement ALM practices for every 1% increase in on-farm income. This indicates that higher income enables farmers to adopt ALM practices. Enhancing farm productivity and profitability can drive conservation efforts, making it essential for policymakers to improve farmers' access to financial resources, credit, and markets for sustainable agricultural development. This means that farmers' adoption of various agricultural land management practices, such as soil bund, fanya juu, terracing, mulching, crop rotation, agroforestry, inorganic fertilizer, compost, and minimum tillage in the area, can increase when they actively engaged and have high income from crop production activities.

The statistically significant and positive relationship between high crop production income and increased farm household adoption intensity of ALM practices may be due to a variety of reasons. Farmers with higher incomes may have more financial resources to invest in implementing land management practices (Abebe & Bekele, 2014; Mutyasira et al., 2018). Similarly, farm households could be highly

eager to adopt various land management practices as they seek to optimize production, enhance the fertility of the soil, adhere to regulations regarding the environment, and gain access to highly desirable markets that favor sustainably grown agricultural production (Shah and Wu, 2019).

Similar results were reported from previous studies conducted by Awoyinka *et al.* (2009) and Kebede *et al.* (2014), which revealed that farmers were more likely to adopt land management measures if they earned higher incomes from on-farm sources, particularly from crop production. These studies suggest that increased income from crop production can motivate farmers to invest more of their time and resources into adopting land management practices.

Table 7. the model estimate result on effects of having income from diverse activities on farmer's adoption intensity of ALM practices.

Livelihood income source activities	Regression coefficient	Standard error	Sig.	Marginal Effect (dy /dx)
Crop production	1.396	0.066	0.000	0.331
Daily laborer work on other farm	0.754	0.042	0.067	0.256
Rent (land, farm assets)	0.649	0.333	0.114	0.117
Remittances income	-2.105	0.051	0.000	-0.416
Migrated income	-1.950	0.042	0.008	-0.271
Log likelihood ratio of Ch^2 =54.576***	Pseudo R^2 =0.6273	Prob> chi^2 = 0.0000		

Source: Computed from field survey data (2022).

Remittances and migrant income (non-farm):

Based on a survey assessment and a recent study conducted by Kefale and Gebresenbet (2021), many young males and females from farm households in the southern highlands of Ethiopia in general and the Ojoje sub-watershed area have been migrating irregularly to countries like the Republic of South Africa and various locations in the United Arab Emirates, including Dubai, Beirut, Lebanon, Jordan, and others. Here, their primary motive is seeking better career opportunities to improve their lives and escape poverty, economic struggles, and high unemployment rates in their home area. Additionally, other farm households have internally migrated to areas like *Wonji, Matahara, Finacha, and other* sugar factory locations to increase their livelihood income and support their families' basic needs.

In this case, remittance income is refers to the money that migrants send home from abroad, such as the Republic of South Africa, the United Arab Emirates, or other areas, to their family. On the other hand, migrant income is the income earned by farm household members from temporary jobs outside their community within the country. On the other hand, migrant income is the income earned by farm household members from temporary jobs outside their community within the country.

Based on the model analysis, there is a negative but statistically significant ($p<0.05$) relation was reported between the farm household livelihood income obtained from remittances and migrant sources and the adoption of agricultural land management practices. This implies that income from remittance and migrant sources minimizes the possibility of farm household agricultural land management measures adoption. Similarly, the analysis results of the study indicate that there is a negative marginal effect of -0.416 for remittance income and -0.271 for migrant income.

In this case, the relationship between income generated from remittances or migrants and the farm household adoption intensity of agricultural land management measures was inverse. This suggested that while keeping other variables constant, farm households that receive remittances or migrant income increase by one unit, reducing their adoption of agricultural land management practices by 41.6% and 27.1%, respectively.

This could be due to livelihood income earned through both means making farm households economically reliant on those external means (Eshete et al., 2019) which leads to a lack of interest in the adoption of ALM strategies; instead of investing in agricultural land management (ALM) strategies, the farm households invested in non-agricultural activities (Piras et al., 2018); since adoption of ALM practices was labor intensive, the migration of those young age groups resulted in a shortage of the required labor force for adoption of ALM practices, resulting in a reduction in the adoption rate (Adimassu et al., 2016). Additionally, the farm household participation in extension services and training related to ALM practices could stem from a lack of understanding of the significance of these practices and how to invest livelihood incomes from remittance and migrant sources in land management measures (Davis & Lopez-Carr, 2014; FAO, 2018). This lack of understanding may also be contributing to a decrease in the adoption rate of ALM practices.

Hence, the results of the study show that even though in the study area livelihood income generated from remittance and migrant sources farm household invest their livelihood means such as covering food and nutrition expenditures, expenses of ceremonies, child educational costs, healthcare expenses, saving, housing building, and other socioeconomic conditions of rural households, they are less likely to invest in ALM practices, regardless of the above socioeconomic benefits. The findings are supported by the empirical study results of Asmelash (2022). Barney (2012) and Tuladhar et al. (2014), who reported a negative but significant relationship between livelihood incomes generated from remittance or migrant means and adoption of ALM technology.

Similar to this, the results of the results of the focused group discussion and key informant interviews show that livelihood income from non-farm sources (i.e., remittances and migrants) has a negative impact on not only adoption measures but also the overall agricultural production system. For instances, a focus group discussion participant from 'Dogame village' said, *"Before ten years, every farm household actively participated in the adoption of various agricultural land management measures such as soil bund, terracing, fanaya juu, agroforestary, and others, but most of them now lack consideration, even if the impact of land degradation in the form of soil erosion was increasing at an alarming rate and affected overall environmental conditions in the study highland area."* They elaborated that the reason for this is that many farm households consider remittances as their means of livelihood income, and they think it is more crucial to creating financial stability than the agricultural system.

Further, the participants added that "*many farmers are shifting away from protecting already-adopted technology and adopting new agricultural land management measures on their farmland. This may be because migration and related income (remittances income) consequences are contributing to this shift. With young people leaving the area, only older age groups remain, who may not have the energy*

to adopt these ALM measures." Other group discussion results indicated that the availability of livelihood income from remittance and low agricultural productivity could possibly all lead farm households to refrain from adopting different agricultural land management practices.

In contrast to this study result, the research conducted by Zegeye (2021); Quinn (2009); Pandit et al. (2014) Tshikala et al. (2019) who reported that livelihood income generated from remittances sources were positive and statically significant effect on the adoption of land management technology. This could be the remittance income increase the farm household investment on ALM practices potential through reduction of finical constraints (Zegeye, 2021); balance the farm household economic equilibrium and increase funding opportunity (Bahadir et al., 2018), facilitate knowledge transfer as well as improve access to technological advancement (Pandit et al., 2014), and increase productivity (Zegeye, 2021; Kapri& Ghimire, 2020), are some crucial effect of remittances in encouraging farm households to adopt various land management measures.

Daily labor work and rent (land, farm assets) (Off-farm): The probit model result also indicated that farm household participation in off-farm activities specifically daily laborer work on other farms and rent (land, farm assets), addition to on-farm means had a positive impact on their engagement in various ALM practices, but in both cases, the effect was non-significant ($p<0.01$). This implies that, despite the fact that there was a relationship between off-farm activities (daily labor work and rent (land, farm assets)) and the adoption of ALM practices, according to the results of the statistical evaluation, the finding was not sufficiently compelling to be declared significant. However, the marginal effect value indicates that a 1% rise in income from daily laborer work on other farms and rent (land, farm assets) is linked with a 25.6% and 11.7% increase in the probability of farmers adopting agricultural land management practices, respectively (**Table 7**). This the value of marginal effect result suggests that off-farm and rental income provide financial stability, enabling farmers to invest in sustainable land management. Supporting alternative income sources can enhance ALM adoption, improving land sustainability and productivity.

The findings of this study are consistent with those of Holden et al. (2004) and Tamerat et al. (2016), who reported that households' participation in a variety of off-farm income-generating activities (daily labor work and rent (land, farm assets)) in addition to on-farm (crop production and livestock rearing) has reduced their motivation to invest resources and time in conservation of land management measures. However, other studies (Amare et al., 2013; Eririogu et al., 2019) reported that it has a positive and significant impact on the adoption of land management practices.

4. Conclusion and implications

The interaction between the livelihood diversification of farmers and the use of agricultural land management (ALM) practices has emerged as a key area of study in a changing environment. The objective of this research was to investigate the relationship between livelihood diversification and agricultural land management (ALM) practices in the southern highlands of Ethiopia. The findings of the study showed that in the study area, agriculture is their main source of income. However,

shortages of land holdings, high population growth, land degradation, and reductions in crop production forced people to seek alternative livelihood income-generating strategies to meet their survival needs.

Moreover, the results of the multinomial logitt model analysis demonstrated that variables such as sex, education, family size, distance to market, land size, extension contact, membership in cooperatives, and household income were found to be the major drivers that determine farmers livelihood income diversification activities ($p<0.05$). Furthermore, the probit analysis revealed that farm households that generate livelihood income only from on-farm activities, especially crop production, and those who generate income from both off-farm activities (such as daily labor work and rent from farm land and farm assets), plus on-farm means, have a positive and statistically significant impact on their adoption intensity of various ALM practices. This suggests that farm households with diversified income sources (on-farm activities, especially crop production, and on-farm plus off-farm activities) are more likely to invest those sources of livelihood income in adopting various ALM practices.

However, the relation between livelihood earnings generated from remittances and migrant sources, in addition to on-farm means, and the impact on the adoption of ALM measures is negative and significant. This implies that remittance and migrant means of livelihood income negatively influence the probability of farm household adoption of ALM measures, even if they have a positive influence on expenses for food and nutrition, costs of ceremonies, child education, healthcare, savings, housing construction, and other socioeconomic conditions of rural households.

Therefore, diversification of livelihood strategies is an essential survival mechanism for farm households in the study area. This has a significant impact on reducing environmental degradation, increasing production, boosting sustainable livelihoods, fostering food security, and improving the well-being of rural communities. Thus, the design of land management policies and programmes, should consider farmers' livelihood diversification and income-generating strategies in the Ethiopian highlands.

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