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Research Article

Effects of agricultural land management practices on crop production and household income in Ojoje, southern Ethiopia

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Abstract

Farmers in Ethiopia and other sub-Saharan African countries often implement various agricultural land management (ALM) practices to mitigate the negative impact of land degradation, increase crop yield, improve income, and safeguard the security of food. Despite the widespread use of these measures, their effect on crop productivity and related income has received relatively little attention in research, particularly in the context of mixed farming systems. The objective of this study was to assess the effects of ALM practices on crop production and household income in southern Ethiopia. Data was gathered from 423 sampled respondents, which included adopters and non-adopters of ALM practices. This study adopted multistage sampling to gather the data through a survey questionnaire. This study's findings reveal that ALM strategies have a considerable impact on crop productivity and the incomes of farm households ($p<0.05$). Moreover, the adoption of integrated physical and biological intervention practices for longer durations resulted in a steady increase in both crop productivity and household incomes. Furthermore, analysis of the effect of long-term treatment indicates that farms show a significant and increasing marginal benefit to production after six years of intervention. These findings imply that integrating ALM practices and maintaining them for an extended period (i.e., 10 years) will help to increase crop productivity and household incomes. Hence, adopting a wider range of physical and biological ALM measures and ensuring their continual adoption are key strategies for improving crop production and increasing household income. This strategy will have significant policy implications and provide a solid foundation for sustainable agricultural development.

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Introduction

In Sub-Saharan African (SSA) countries, agriculture is a key driver and the main core of economic growth (FAO, 2019; Alemu et al., 2023). Land degradation, particularly in the form of soil erosion, is a serious problem that has negative effects on the ecosystem and agricultural productivity (Biard and Baret, 1997; Hurni et al., 2018). Consequently, it has resulted in a severe decline in agricultural productivity not only in the SSA region but also globally (Lobell et al., 2011; Ogunniyi et al., 2023). In Ethiopia, the influence of land degradation has been considered one of the main issues that jeopardize the agricultural sector's sustainability, productivity, and food security (Kassa et al., 2013; Miheretu and Yimer, 2018). The degradation of land is driven by various factors such as population growth and weak institutional structures (Masha et al., 2021), improper management of environmental resources, soil erosion, and cultivation of marginal lands (Le et al., 2016; Miheretu et al., 2018). In relation to this, Tun et al. (2015) and Masha et al. (2021) recognize that the stability of the natural ecosystem and the productive potential of the land have been greatly affected by land degradation. For example, land degradation triggered by soil erosion causes a reduction in soil fertility and access to water, which subsequently causes decreased crop production and income and results in food insecurity (Erkossa et al., 2018; Tadesse et al., 2021). Hathie and Sakho-Jimbira (2020) and Mamush et al. (2021) reported that the degradation of land costs about five percent of household crop yields in sub-Saharan African nations.

Over the last three or four decades, the government of Ethiopia, together with various development partners, has adopted several land management measures (Nigussie et al., 2020; Gairhe et al., 2021). The strategies have involved adopting different physical and agronomic land management practices, such as terracing, soil bunds, fanya juu, crop rotation, mulching, intercropping, composting, minimum tillage, farm manure, and others, in the major targeted highland areas (Arega et al., 2018; Abonesh et al., 2021). These measures have been adopted with the aim of improving crop production, decreasing the depletion of soil (Adimassu et al., 2017; Jiru and Wegari, 2022), enhancing nutrient availability, rehabilitating degraded land, increasing incomes, and enhancing food security (Adego et al., 2018). However, the effect of those agricultural land management practices, particularly on improving crop yields and related incomes, was below expectations (Asrat et al., 2017), its economic viability was inconsistent (Hishe et al., 2017), and most of the study results were site-specific (Adgo et al., 2013).

Findings of empirical studies on the effect of agricultural land management practices revealed that they could enhance the fertility of the soil (Hishe et al., 2017; Sinore et al., 2018), improve crop yield (Masha et al., 2021), and farm household income (Belayneh et al., 2019; Tadesse et al., 2021). However, Tesfaye et al. (2016) and Arega et al. (2018) examined the impact of ALM practices on crop productivity but did not consider the associated household income. In general, the outcomes of these earlier studies are heavily aggregated, making it difficult to address adoption-related local conditions in agricultural land management practices.

In most cases, inconsistency was observed in the evaluations conducted. In some cases, however, conflicting findings were reported. In this case, Moreira and Bravo-Ureta (2010) and Gebremedhin et al. (2006) reported that adopters of ALM practices had higher crop yields than non-adopters. In the same vein, Zeleke and Hurni (2001) reported a production value that was 24% more than that of non-adopters. On the other hand, the research findings of Kassie et al. (2008) and Adimassu et al. (2017) showed that land management practices, such as soil bunds and fanya juu, were successful in minimizing the rates of soil erosion and runoff, as well as loss of nutrients. However, these practices did not have a significant impact on crop productivity. Additionally, most of the evaluations are concentrated on the effect of ALM practices on crop productivity, disregarding the effect they have on related household income.

Over the past three decades, ALM practices have been implemented in the study area, which was aimed at increasing crop yields and improving the living standards of farm households. These practices include mulching, agroforestry, fanya juu, soil bunds, crop diversification, intercropping, terracing, and others (Abonesh et al., 2021; Mariye et al., 2022). However, there is no confirmed evidence regarding variation in treatment types and ALM practice age effects on the crop productivity and income of farm households in the southern Ethiopian highlands, specifically, the case of the Ojoje sub-watershed. Hence, keeping this in mind, the effect of ALM practices on crop production and related site-specific income information is pertinent for ensuring the adoption of ALM measures at the watershed level.

Hence, the target of this research was to i) investigate the effect of ALM strategies on crop productivity (like wheat, barley, beans, and potatoes) and the income of farm households, and ii) assess the timing of benefits for every additional year that ALM practices are maintained.

Materials and methods

Study area

The research was conducted in Doyogena District, in the case of Ojoje sub-watershed (Figure 1). Its latitudinal and longitudinal locations lie between 7°18′25″ to 7°21′49″N and 37°45′33″E to 37°48′51″E, respectively (Figure 1). The research area is located 258 km southwest of Addis Ababa. The sub-watershed encompasses 17.9 km^2 and is found between 2,354 m and 2,674 m above sea level.

The study location typically experiences a humid climate, with the highest and lowest temperatures recorded at 24.6°C and 15°C, respectively (Abera and Wana, 2023). The region experiences 1,158 mm of yearly rainfall and is classified under the Dega and Woina Dega Ethiopian agro-ecology zones (Tsegaye, 2014) (Figure 2). Furthermore, the soils in the research sub-watershed vary from clay to loamy clay. A typical soil profile in the area consists of 44.8% clay, 21.8% sand, and 33.4% silt (Lelago et al., 2016; Abera and Wana, 2023). Moreover, in the research sub-watershed, several types of natural vegetation were observed. Among these, the most dominant species include Afrocarpus *falcatus*, *Juniperus procera*, *Cordia africanca*, *Croton machrostachys*, *Ficus vasta*

(Warka), *Eucalyptus globules*, *Dodonaea anguistifola*, *Gravilea robusta*, and various shrub species (Mariye et al*.,* 2022). According to the 2007 population census, the entire population of the study sub-watershed was 105,265. Subsequently, the population density was 458 people per square kilometer (Central Statistics Agency, 2020). Like most rural areas, the major source of income for households in the research area is mixed farming, which includes both crop production and animal husbandry. The primary agricultural products that grow in the study sub-watershed include barley, wheat, beans, soybeans, potatoes, vegetables, fruits, and enset *(Ensete ventricosum)*. Cattle, goats, sheep, horses, donkeys, chickens, and bees are commonly reared as domestic animals on a traditional basis (Mariye et al*.,* 2022; Abera and Wana*,* 2023).

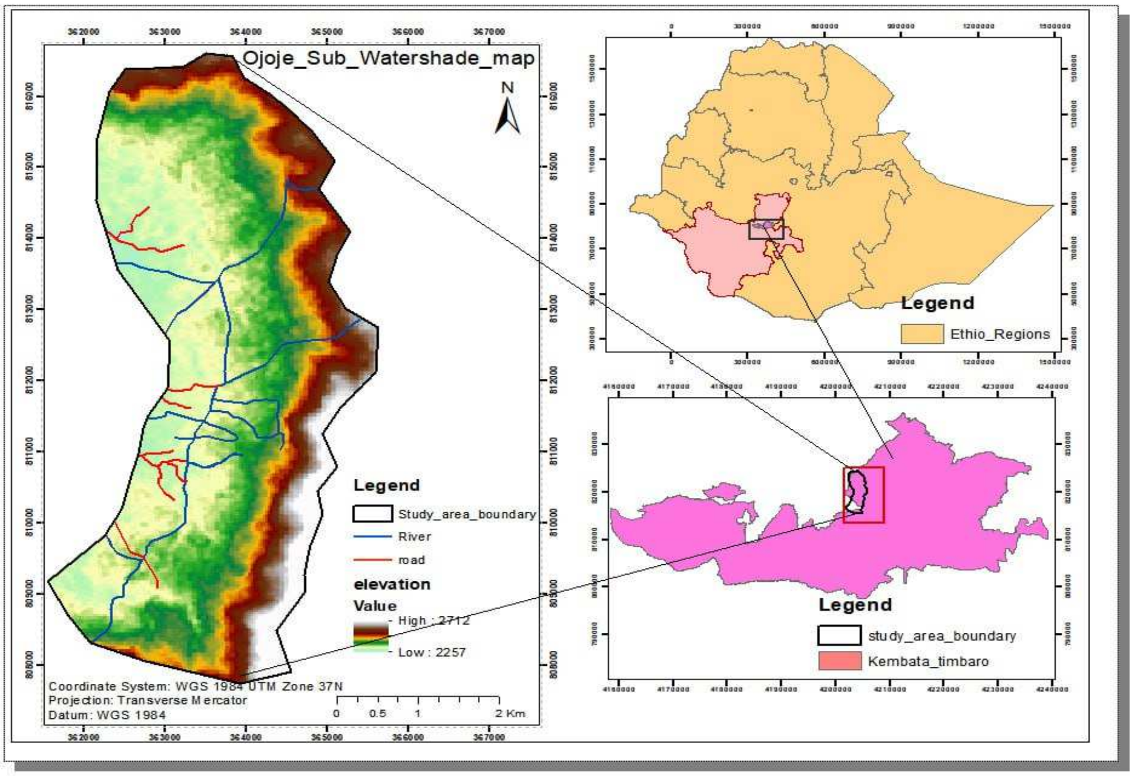

Figure 1. Map of the research area.

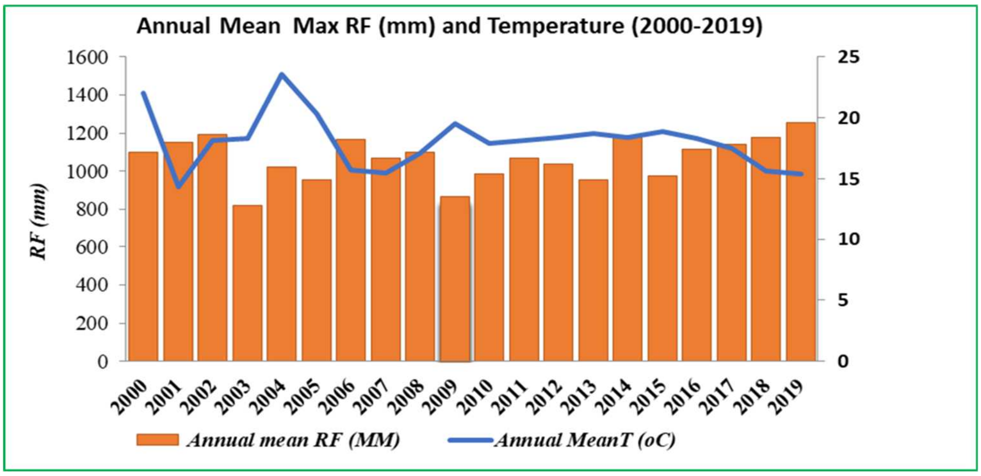

Figure 2. Average annual rainfall and highest and lowest temperatures (2000-2019).

Treatment selection

The preliminary assessment was carried out to determine the boundary and to select a good representation of the sample households within the study sub-watershed. Additionally, a transect walk was used for field observation. Subsequently, sites for sampling were determined to share some socio-ecological attributes, with the exception of the type and duration of ALM practices.

To assess the impact of ALM measures on crop yield and income, this study selected a representative sample household from agricultural land plots that were conserved with ALM measures. The selection was according to differences in their type and duration of intervention with ALM practices and included households that adopted only physical ALM practices, as well as physical and biological measures on their farmland. They practiced the ALM measure for more than five years and served as the treatment group. Besides this, as a control, this study identified and selected a representative sample household from adjacent farmlands that did not adopt ALM practices on their farmlands.

Data source and methods of collection

The data sources for the study were obtained from various sources, including targeted households, kebele or district leaders, development agents (DAs), and experts from district agriculture and rural development offices. The data collected were both qualitative and quantitative in nature. To gather relevant information, various data collection methods were used, including household survey questionnaires, focus groups, interviews, and field observation. The data were collected from December 2022 to June 2023 with the help of trained enumerators who could speak the local language.

Household surveys were conducted to collect quantitative information on various aspects, including household demographic characteristics, socioeconomic conditions, land degradation-related issues, agricultural inputs, and agricultural land management activities. In addition, other data collection methods (i.e., focus group discussions, interviews, and field observations) were conducted to triangulate the information gathered from the household survey data. The data on crop prices were obtained from the agricultural and rural development offices of the study districts and the Hossana branch of the Ethiopian Central Statistical Agency (CSA).

Sampling techniques and sample size

The selection of the study district, the study sub-watershed, the village, and the sample respondents was carried out using a multistage sampling approach. First, define the district of the study area, with Doyogena woreda being selected through purposive sampling techniques. In the second stage, the study sub-watershed (Ojoje sub-watershed) was purposely selected because, in the area, various agricultural land management practices were adopted for a prolonged period of time (Mariye et al., 2022). This area also has the potential to represent the majority of the southern Ethiopian highlands in terms of both agroecological and socioeconomic settings (Abonesh et al., 2021).

In the third stage, study villages were purposefully chosen based on differences in the type and the time since ALM practices were adopted. Here, villages from both treated (with integrated and only physical ALM measures) and untreated land sites were selected. Development agents (DAs), kebele (small administrative unit in Ethiopia) leaders, and staff from the district agriculture and rural development offices were consulted to help with this process.

Here, to collect data, this study opted to select 30% of the sample respondents from all the households living in each village within the study sub-watershed. After that, we selected sample households from the lists of each sample village that were available using a systematic random sampling technique. Thus, 423 sample households were selected from the total of 1,410 households by using a systematic, random sampling technique.

Method of data analysis

To analyze the collected data, descriptive and inferential statistical techniques were used to measure how independent variables (i.e., duration and the type of ALM intervention) affect dependent variables (crop productivity and household income). An analysis of variance (ANOVA) was used to check whether there is a statistically significant variance reported in crop production and households' income between treated and non-treated plots. In relation to this, Moore (2023) indicated that analysis of variance (ANOVA) enables a comparison of variances between treatment and control units. Similarly, ANOVA was applied to ascertain the variation between the control and one or more treatment groups (Tadikamalla et al., 2003; Degfe et al., 2023). Furthermore, the effect of the type and duration of ALM practices on crop productivity and household income was analyzed using simple regression. The Statistical Package for Social Science (SPSS) version 26 was used to analyze the data.

Results and Discussion

The socioeconomic background of the sample households

This section presents the overall relationship between adopter (only physical and integrated measures) and non-adopter farm household's agricultural land management practices. Thus, model estimation reveals that the possibility of farm households choosing action in ALM work was considerably defined by five variables out of seven independent variables (Table 1). Age of household, level of education of household, family size of sample respondents, contact with extension agents, and the livestock number held by households were found to be significant and positive indicators of agricultural land management practices ($p<0.05$) (Table 1). This means that farmer households having a higher likelihood of engaging in ALM practices are those who are comparatively older, more highly educated, have larger families, own more land and have more access to extension agent services. In contrast, household farm distances and sex differences had a statistically non-significant and negative interaction with the implementation of ALM practices (Table 1). Specifically, females and household heads with long distances from their homes to farmland had lower involvement rates.

Table 1. Socioeconomic characteristics of the households.

Variables	Coefficient	St. err	Sig
Constant	-5.780	1.142	0.001
Sex of households	-0.560	0.334	0.135
Age of households	0.080	0.011	0.007
Educational level of households	0.125	0.038	0.003
Family size of households	0.186	0.028	0.001
Livestock	0.342	0.040	0.011
Extension agent	1.635	0.253	0.021
Farm distances	-0.426	0.164	0.065

Effect of ALM practices on socio-ecological environment

The implementation of ALM practices has a substantial role in preventing land degradation and restoring degraded land (Hishe et al*.*, 2017), increasing soil fertility, soil moisture, and agricultural productivity, improving groundwater, and promoting food security in farm households (Mengistu et al*.*, 2016; Arega et al*.*, 2018; Masha et al*.*, 2021). The observed impact of ALM practices on the socio-ecological environment in the study sub-watershed area is described in Table 2. Accordingly, 78.80% and 85.54% of household responses reveal that the implementation of ALM practices had the intended effect of improving soil fertility rates and restoration of land degradation, respectively. Moreover, the survey results indicate that a significant portion of respondents (70.84%) consider the adoption of ALM practices to be a major factor in improving crop productivity and boosting household income. Moreover, about 70% and 68% of the respondents reported that the adoption of ALM practices leads to a decrease in the rate of soil erosion as well as a rise in moisture levels in the soil, respectively. Furthermore, the findings from forum group discussions (FGDs) and interviews indicate that the adoption of ALM practices is crucial in increasing soil fertility, reducing soil erosion, restoring degraded land, increasing agricultural income, and improving soil moisture and water availability.

Table 2. Effect of ALM practices on socio-ecological environment.

Items	Frequency			Percentage		
	Yes	No	No change	Yes	No	No change
Increase soil fertility	327	79	9	78.80	19.04	2.17
Restore degraded land	355	56	4	85.54	13.49	0.96
Increase household income	294	114	6	70.84	27.47	1.45
Reduce soil erosion	291	109	15	70.12	26.27	3.61
Increase soil moisture	283	121	11	68.19	29.16	2.65

Effect of ALM practices on crop production and related income

Effect of ALM on crop productivity

The adoption of ALM practices and crop productivity were found to be highly complementary (Wolka et al*.*, 2018; Tadesse et al*.*, 2021). As indicated by Miheretu and Yimer (2018) and Ejegue and Gessesse (2021), protecting environmental assets, including vegetation, water, and soil, is essential for preserving soil fertility, increasing water availability, and reducing erosion rates. This, in turn, leads to increasing crop productivity, raising household income, and ensuring food security. Crop production serves as the principal means of subsistence for most farm households in the study watershed (Abonesh et al*.*, 2021; Mariye et al*.*, 2022). The dominant crops cultivated in the study area include barley, wheat, potatoes, peas, beans, and others. As indicated in Table 3, the mean values of these crops varied across the type and duration of ALM practice categories. In general, here, it is considered that the treatment and control groups have similar utilization of agricultural inputs. However, the only difference is the type and duration of implemented ALM measures.

The findings reveal that a significant difference was observed in wheat and bean production ($p<0.05$). The average wheat yield ranged from 713.74 kg/ha to 976.58 kg/ha in the plot that was non-treated compared to the plots that adopted ALM practices for 10 years (ToP10Y). The bean average value ranges from 463.5 kg/ha for NT land to 726.2 kg/ha for land ToP10Y sites (Table 3). In addition, as indicated in the analysis of the coefficient of determination (R^2), 45.7% and 52.4% of the variation in wheat and bean production is defined through changes in the types of length and kind of ALM practices (Table 4). In addition, as indicated in Table 3, the mean production values of wheat in the NT land site are lower than those of ToP5Y, ToP10Y, TIN5Y, and TIN10Y by 262.84 kg/ha, 241.1 kg/ha, 149.58 kg/ha, and 112.78 kg/ha, respectively. On the other hand, for bean production, land sites that received ALM treatment, namely, ToP5Y, ToP10Y, TIN5Y, and TIN10Y, were more productive by 113.05 kg/ha, 149.85 kg/ha, 241.09 kg/ha, and 262.77 kg/ha, respectively, compared to those that did not receive the treatment. This study's findings were aligned with those of Amare et al. (2013) and Tilahun et al. (2021), who recognized that plots treated with elephant grass, soil bunds, and fanya juu for the longer term (i.e., 5 years) improved wheat productivity by 64%. Moreover, the findings of the study reveal that the mean output of barley was lower in the non-adopted land site than in its adopted counterparts (Table 3), but the variation was statistically non-significant. Higher barley production (648.7 kg/ha) was reported in farmlands conserved with integrated ALM practices for 10 years, while lower barley production (568.4 kg/ha) was reported in non-adopted land (Table 3). As indicated in the analysis of the coefficient variations in the types and ages of ALM practices, they explain 33.8% of the variation in barley production (Table 4). The outcomes were consistent with those of Guadie et al. (2021) and Tilahun et al. (2021), who found that, in comparison to nearby untreated plots, land treated with stone bund, fanya juu, soil bund, sesbania, terracing, and elephant grass increased barely yields by 56%. Furthermore, the productivity of potatoes varied from 3,893 kg/ha under integrated ALM practices for 10 years to 2,287 kg/ha on non-treated land. This indicates that integrated ALM practices for 10 years resulted in a 1,605.46 kg/ha higher potato production advantage than non-treated lands (Table 3).

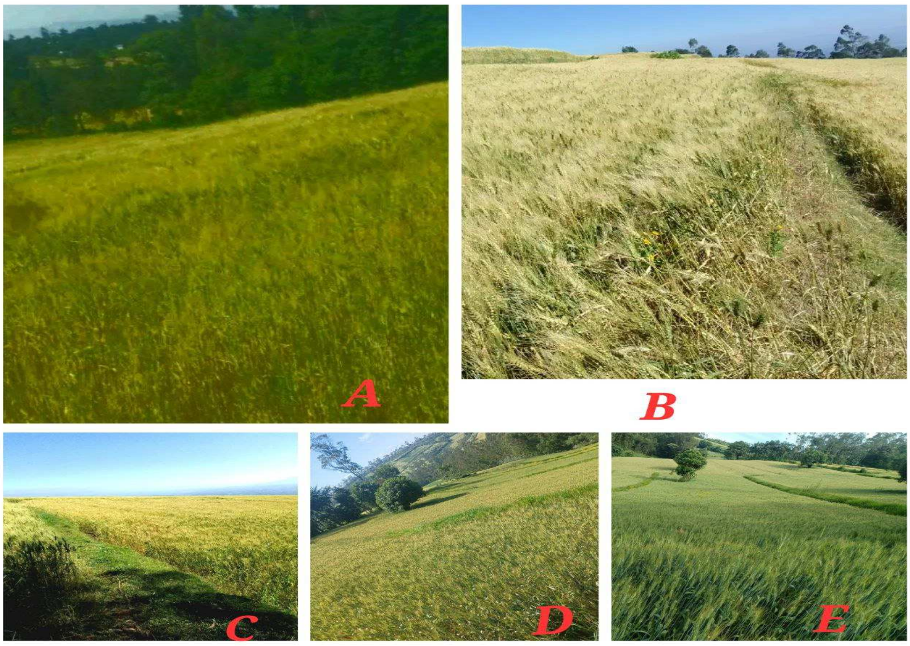

Figure 3. Wheat production under different farm treatments: (A) NT, (B) ToP5Y, (C) ToP10Y (D) TIN5Y, and (E) TIN10Y.

Table 3. Mean amount of crop productivity and household income.

Crop type (kg/ha)							
	NT **Mean**	**ToP5Y** **Mean**	**ToP10Y** **Mean**	**TIN5Y** **Mean**	**TIN10Y** **Mean**	**F**	**Sig**
Wheat	713.7	826.5	863.3	954.8	976.6	31.31	0.002**
Barley	568.4	572.4	563.8	629.4	648.7	9.39	0.055
Beans	463.5	577.5	613.3	704.5	726.2	28.39	0.003**
Potato	2,287.3	2,473.5	3,672.8	3,928.6	3,892.7	16.11	0.028*
Farm household income (Birr)							
Wheat	1,336,146.3	1,547,323.7	1,616,218.5	1,787,519.3	1,828,331.9	131.3	0.000**
Barley	1,177,804.4	1,186,092.9	1,168,272.5	1,304,204.9	1,344,197.3	299.4	0.057
Beans	1,730,454.5	2,003,952.4	2,093,178.3	2,315,031.4	2,367,888.3	127.3	0.001**
Potato	1,652,620.1	1,787,153.2	2,153,671.5	2,338,492.1	2,512,553.6	218.4	0.012*

**significant at p<0.01, *significant at p<0.05, R^2 = coefficient of determination.

Table 4. Estimation of regression coefficients changes for crop production and farm income.

Crop type	**Coefficient**	**p**	**(R)**	**(R^2)**
Wheat	0.243	0.003*	0.676	0.457
Barley	1.125	0.023	0.581	0.338
Beans	0.563	0.002**	0.724	0.524
Potato	1.532	0.021	0.618	0.382
Farm income				
Wheat	0.903	0.004*	0.642	0.412
Barley	0.626	0.016	0.552	0.305
Beans	1.051	0.001**	0.688	0.473
Potato	0.652	0.002**	0.587	0.345

**significant at $p<0.01$, *significant at $p<0.05$, R^2 =coefficient of determination.

The one-way ANOVA indicates that potato production varies significantly with respect to adoption type and duration of ALM measures ($p<0.05$) (Tables 5 and 6). Additionally, based on the coefficient of determination (R^2) report, 38.2% of the variation in potato production could be deified by differences in the types and duration of ALM measures (Tables 4 and 5). Thus, it can be concluded that in the study area, differences in duration and type of ALM measures have a significant effect on crop productivity on farmland (Figures 3 and 4).

The average value of crop productivity steadily rose with an increase in age and the integration of land management measures, particularly the at least 10-year treatment, where the maximum crop production was observed. Substantially higher crop (i.e., wheat, barley, bean, and potato) production reported from plots that were treated with physical and biological ALM measures for 10 years (TIN10Y) could be due to the adoption of ALM practices; this causes the level of organic matter (OM) in the soil to improve (Abinet, 2011), an increased number of tillers per plot area (Tanto et al*.,* 2019), and a reduction in soil compaction, runoff, and soil loss (Tamrat et al*.,* 2018). Thus, subsequently, this results in impacts on the water holding capability of the soil to retain water, an improvement in the soil fertility rate, a better advance in crop status, and increased yield (Erkossa et al*.,* 2018; Ferede et al*.,* 2018). Thus, the implication of the survey result indicated that plots treated with multiple ALM measures and preserving those measures for a prolonged period resulted in crop output improvement, an increase in sample household head earnings, and improved security of food (Tadesse et al*.,* 2021). This confirms what Tanto et al. (2021) and Tadesse et al. (2021) found that adopting integrated physical and biological practices on land for a prolonged time significantly improved crop yield potential.

Effect of agricultural land management practices on household's income

It goes without saying that farmers require economic analyses of suggested conservation measures in order to determine whether programs and conservation measures would pay off economically for them. In addition to understanding the nature of the program to be applied, they also need to be aware of the most profitable strength to adopt (Wagayehu, 2003). The survey results revealed statistically significant variation in farm income from wheat production among different ALM measures ($p<0.05$). The household income generated from wheat production ranged from 1,336,146.3 birr per year for non-treated (NT) plots to 1,828,331.9 birr per year for integrated ALM for 10 years (TIN10Y) sites. This is also supported from an agronomic perspective by the 41.2% higher income advantage that results from adopting integrated ALM practices over a 10-year period over non-treated land (Table 4). The outcomes of the one-way analysis demonstrate a statistically significant difference in wheat production income across at least 5 as well as 10 years between plots treated with integrated and physical ALM measures ($p<0.05$). Hence, the results clearly demonstrated that the duration and integration of physical ALM measures with agronomic practices significantly affected farm income related to wheat production.

This study's findings indicated that the duration and types of ALM measures strongly affect the income level of farm households generated from barley production. The maximum (1,344,197.3 birr/year) and minimum (1,177,804.4 birr/year) average income values of barley were reported from land TIN10Y and NT sites, respectively. However, the variation was not statistically significant ($p<0.05$). Likewise, the outcomes of the study indicated that 30.5% of the variations in income from barley production are explained by the adoption types and duration of ALM practices (Table 4).

The analysis result of ANOVA demonstrates that there is an important difference in the income of barley reported between land conserved for five and a ten-year period using integrated ALM measures ($p<0.01$) (Tables 5 and 6). Here, the influence is more considerable in plot sites where conservation was alongside integrated (i.e., physical and biological) ALM measures for 10 years. Significant variations were found in income from bean production among adopted and non-adopted land sites ($p<0.05$). Accordingly, the maximum household income was reported in plots that were TIN10Y compared to the remaining survey sites in the sample (Table 3).

Additionally, differences in the duration and intervention type of adopted ALM measures accounted for 47.3% of the differences in income from bean production.

The analysis of variance ANOVA results indicated significant differences reported between ToP5Y and NT, ToP10Y and NT, and TIN10Y and NT (Table 5). The study's findings indicate that the adoption of integrated agricultural land management techniques over a longer period led to a significant increase in the income generated from bean production. This study's findings indicate that the type of option and duration of ALM measures significantly affect the value of money generated through potato production ($p<0.05$). While adopting integrated ALM practices, the mean income increased from 1,652,620.1 birr for non-treated land to 2,512,553.6 birr for treated land. It has been found that the duration and type of ALM practices account for 34.5% of the variation in potato income (Table 4). The one-way ANOVA result additionally reveals a statistically significant variation reported between TIN5Y and TIN10Y (F = 16.42) and ToP5Y and ToP10Y (F = 15.92) ($p<0.05$) (Table 6). The research findings clearly showed that the longer the adoption of ALM practices and their integration with biological measures, the more significantly influenced the level of income. The result is also supported by field observation (Figures 3 and 4). This could be because ALM practices have contributed to a reduction in soil erosion rates, runoff (Sinore et al., 2018; Tadesse et al., 2021), and rehabilitated land degradation (Tanto et al., 2019). This leads to improvements in soil nutrients and extended time for increased photosynthesis and related quality indicators, which in turn have a significant effect on crop productivity and income (Masha et al., 2021). Similarly, the adoption of integrated ALM practices is one of the major causes of the increase in agricultural production through improved crop production (Tanto et al., 2019), which reduces household financial constraints (Wainaina et al., 2016) by increasing yields for the major crops (Asfaw et al., 2013) and increasing household income (Masha et al., 2021).

Table 5. One-way ANOVA test.

	Plot sites treated with physical ALM measures for				**Plot sites treated with integrated ALM measures for**			
	5 years		**10 years**		**5 years**		**10 years**	
Crop type	**F**	**P**	**F**	**P**	**F**	**P**	**F**	**p**
Wheat	114.31	0.006	111.6	0.000	105.21	0.001	117.9	0.000
Barley	6.39	0.142	31.53	0.025	61.02	0.002	40.25	0.021
Beans	108.3	0.001	67.79	0.000	43.21	0.009	126.2	0.000
Potato	27.82	0.017	52.16	0.022	50.13	0.012	60.86	0.001
Farm income								
Wheat	88.51	0.006	76.01	0.008	83.9	0.005	104.1	0.002
Barley	17.48	0.247	6.63	0.072	21.8	0.049	23.4	0.034
Beans	73.7	0.021	62.13	0.032	102.1	0.001	97.1	0.003
Potato	221.6	0.008	207.2	0.005	209.4	0.003	224.2	0.003

Table 6. The effect of ALM practices on crop production and farm income between intervention types and treatment age.

	Treated only with physical practices for 5 and 10 years		**Treated with integrated practices for 5 and 10 years**	
Crop type	**F**	**P**	**F**	**P**
Wheat	19.12	0.003	22.6	0.000
Barley	14.63	0.541	22.5	0.003
Beans	14.63	0.001	17.8	0.012
Potato	12.79	0.005	22.16	0.042
Farm income				
Wheat	11.03	0.012	21.4	0.001
Barley	4.36	0.241	19.63	0.003
Beans	17.26	0.024	18.13	0.021
Potato	16.42	0.007	15.92	0.038

This study's results bear out the findings of Adimassu et al. (2014), Erkossa et al. (2018), and Tanto et al. (2019), who revealed that integrated ALM measures for a period of five years had a significant impact on farm income (i.e., wheat and beans) compared to untreated land. Likewise, Eshetu and Mekonnen (2016) noted that higher income from barley was observed on land treated with integrated ALM practices compared to plots treated with only physical measures and untreated land. In this regard, adopters who maintain only physical agricultural land management (ALM) practices (mostly soil bunds and fanya juu terrace) for a minimum of seven years experienced a significant rise in the production output at the completion of the year (Table 7). However, adopters of ALM measures do not see a substantial influence on the output of agricultural production if they have only continued with physical and integrated ALM practices for fewer than seven and five years, respectively.

In other words, over the first seven (for solely physical) and five (integrated) years of ALM practices, non-significant estimated marginal effects were reported (Table 7).

Figure 4. Bean production under different farm management (A) NT, (B) ToP5Y, (C) ToP10Y, (D) TIN5Y, and (E) TIN10Y.

Advantages of every extra year of maintenance for ALM measures

Regarding the estimated odd ratio (marginal effect) of one more year's worth of preservation benefit from both physical and ALM measures, it is important to note that continuous maintenance of those practices is critical to accessing substantial gain from resources assigned to ALM measures. The negative marginal effect value suggests that to increase income, rehabilitate degraded land, lower rates of soil erosion, raise soil moisture levels, and achieve other biophysical nutrient improvements, the long-term adoption of ALM practices on a sustainable basis is needed. Moreover, the results of the study reveal that there is a substantial average advantage that rises at an increasing rate beyond the 7th year for those treated with only physical ALM practices and the 5th year for those treated with integrated ALM measures. Therefore, the more years one continues to practice agricultural land management (ALM), the greater the increase in production value (Table 7).

Table 7. Estimated marginal effect for each extra year of preservation for integrated and physical ALM practices.

Years	**Plot sites treated with physical ALM measures**		**Plot sites treated with integrated ALM measures**	
	Sig	**Marginal effects**	**Sig**	**Marginal effects**
1	0.201	-0.101	0.152	-0.019
2	0.104	-0.071	0.147	-0.016
3	0.062	-0.041	0.109	-0.013
4	0.056	-0.007	0.024	-0.001
5	0.036	-0.004	0.015	0.041
6	0.018	0.051	0.009	0.071
7	0.016	0.071	0.027	0.093
8	0.013	0.091	0.014	0.124
9	0.011	0.111	0.016	0.155
10	0.008	0.139	0.006	0.186

Additionally, the results indicate that when households followed only physical ALM practices and integrated ALM practices for between 7 and 8 years, the value of agricultural production would improve by approximately 9% and 12.4%, respectively. On the other hand, if a farm household protects ALM measures for 9-10 years, the intended value of agricultural output increases by 13.9% from land sites adopted with physical ALM measures and 18.6% from land adopted with physical and biological ALM measures (Table 7). Hence, further studies conducted over a longer time frame may be able to assess the advantages and marginal profits of the ALM practices in the sub-watershed under consideration. Schmidt and Tadesse (2014) and Tadesse et al. (2019) revealed similar results; farmers need to safeguard their physical land management practices for at least 7 years to observe a substantial increase in crop output and related income. However, Asrat and Simane (2017) and Schmidt (2017) have suggested that integrated land conservation measures should be well-maintained as low as possible as six years to derive substantial value from crop production for farm households.

Conclusion

The degradation of land in the highlands of Ethiopia, including the study sub-watershed, leads to a reduction in agricultural productivity and household income, and thereby causing chronic food insecurity. This study examined the effects of ALM measures on crop production and household income in southern Ethiopia's Ojoje sub-watershed. The adopted ALM practices have resulted in significant positive effects on crop and related income for the majority of adopter farmers in comparison to their non-adopter counterparts.

The findings of the study demonstrated that farm households on farms that implemented integrated ALM practices for a 10-year period reported significantly higher crop productivity as well as related income. Owing to the implementation of integrated ALM practices, soil erosion declined, moisture availability increased, and nutrient loss declined in both types of treatments. All of these factors may have contributed to an increase in crop production and farm household income. Moreover, the analysis of marginal effects indicates a significant effect on crop production and household income, implying the need for the maintenance of physical ALM structures for at least seven years and integrated ALM measures for five years. These findings imply that integrating ALM practices and maintaining them for an extended period (i.e., 10 years) will help to increase crop productivity and household incomes. Hence, adopting a wider range of physical and biological ALM measures and consistently sustaining them in the long term is a major strategy for enhancing crop production and increasing household income. This strategy will have significant policy implications and provide a solid foundation for sustainable agricultural development.

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