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Soil Conservation Practices and Farm Productivity: Insights from Smallholder Farms in Ethiopia's Arsi Negelle District

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Abstract
This study is focused on assessing the influence of soil conservation interventions on the technical efficiency of smallholder farm households in the Arsi Negelle district of Ethiopia. Employing a combination of methodologies, including Stochastic Frontier Analysis (SFA) to gauge efficiency scores and Propensity Score Matching (PSM) to analyze the impact of conservation practices, the research aims to provide valuable insights into the relationship between conservation efforts and farm productivity. The analysis begins by examining the factors influencing households' decisions to participate in soil conservation activities. Through logistic regression estimation, key determinants such as the educational level of the household head, farming experience, and frequency of extension contact emerge as significant predictors of participation in conservation practices. Subsequently, the study employs PSM, specifically kernel matching with a bandwidth of 0.5, to compare the outcomes of households that participate in conservation practices with those that do not. The results reveal a notable improvement of 3.16 percent in technical efficiency among participating households, underscoring the positive and robust impact of conservation initiatives on farm productivity. These findings carry important implications for policymakers and stakeholders involved in agricultural development. By highlighting the tangible benefits of soil conservation efforts on smallholder farms, the study underscores the importance of prioritizing and incentivizing sustainable agricultural practices. Furthermore, it emphasizes the need for targeted interventions aimed at promoting participation in conservation activities, particularly among households with lower levels of education and farming experience. This research contributes valuable insights to the ongoing discourse on sustainable agricultural development in Ethiopia and underscores the critical role of soil conservation in enhancing the technical efficiency and productivity of smallholder farm households in the region.
Keywords: Soil Conservation, Smallholder Farms, Technical Efficiency, Propensity Score Matching
JEL Codes: Q12, Q24, O13

1. INTRODUCTION

Ethiopia's rich biodiversity and abundant water resources position it as a significant contributor to global agricultural sustainability and food security. The country's diverse agroecological zones, ranging from highlands to lowlands, support the growth of a wide variety of crops and plant species, making it a vital center of genetic diversity for crop germplasm (Sthapit et al., 2008). With approximately 12 river basins and ample groundwater reserves, Ethiopia boasts considerable water resources, with an annual runoff of 122 billion cubic meters and an estimated 2.6 billion cubic meters of groundwater. This abundance of water, coupled with the country's fertile soils and favorable climate conditions, provides a solid foundation for agricultural development and irrigation practices. Harnessing these water resources effectively through sustainable management practices and infrastructure development can significantly enhance agricultural productivity, support rural livelihoods, and contribute to overall economic growth in Ethiopia. Moreover, preserving the genetic diversity of crops and plants is essential for maintaining resilience in the face of climate change and ensuring long-term food security for the country and beyond. As Ethiopia continues to develop its agricultural sector and address challenges such as water scarcity and environmental degradation, leveraging its genetic diversity and water resources wisely will be crucial for building a sustainable and resilient food system that benefits both present and future generations. McCann's (2001) study underscores the significance of Ethiopia's crop germplasm diversity in the context of global agricultural biodiversity conservation efforts. Ethiopia's rich genetic resources not only contribute to the country's agricultural resilience but also have implications for global food security, as these genetic materials can be utilized in breeding programs worldwide to develop new crop varieties with desirable traits.

Similarly, the research by Awulachew et al. (2006) provides critical insights into Ethiopia's water endowment, highlighting the vast potential of its river basins and groundwater resources. Understanding the spatial distribution and hydrological characteristics of these resources is fundamental for sustainable water management strategies, which are essential for supporting agricultural production, ensuring access to safe drinking water, and facilitating economic development across various sectors. By harnessing its water resources effectively and efficiently, Ethiopia can enhance its resilience to climate change and variability while promoting socio-economic growth and environmental sustainability. The disparity between Ethiopia's agricultural production and its population growth underscores the challenges facing the country's agricultural sector. Despite its vast agricultural potential, Ethiopia struggles to achieve food security due to various factors such as recurrent droughts, inadequate infrastructure, limited access to modern

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agricultural technologies, and insufficient investment in the sector. The statistics provided by the EEA (2006) highlight the urgency of addressing these challenges. With population growth outpacing agricultural production, Ethiopia faces the pressing need to boost agricultural productivity and resilience to meet the food needs of its growing population. Achieving sustainable agricultural development requires comprehensive strategies that address not only productivity enhancements but also issues related to water management, land tenure, market access, and rural infrastructure.

Moreover, investing in research and development, promoting climate-smart agricultural practices, and strengthening extension services are crucial steps towards improving the productivity and resilience of Ethiopia's agriculture sector. Additionally, enhancing access to credit, inputs, and markets for smallholder farmers can empower them to increase their yields and incomes, thereby contributing to poverty reduction and economic growth in rural areas. The data provided by CSA (Central Statistical Agency) illustrates a significant increase in total food grain production in Ethiopia over the period from 1988/89 to 2010/2011. However, this increase in output is accompanied by a notable expansion in the size of cultivated land, indicating that the growth in production is not solely attributed to improvements in productivity. Instead, it reflects an expansion of agricultural activities, which has implications for environmental sustainability. The expansion of cultivated land, as highlighted by Gebrehaweria et al. (2012), is indicative of agricultural changes occurring at the expense of environmental degradation. This trend raises concerns about the long-term sustainability of agricultural practices and their impact on ecosystems and natural resources. Moreover, the scarcity of available land due to population pressure exacerbates the challenges associated with expanding agricultural activities. Addressing these challenges requires a comprehensive approach that promotes sustainable agricultural practices, conservation of natural resources, and improved land management strategies. Efforts to enhance agricultural productivity should prioritize measures that minimize environmental degradation and ensure the long-term viability of agricultural systems. Additionally, policies aimed at population management and land-use planning can help mitigate the pressure on available land resources and promote more sustainable land utilization practices. The imperative for enhancing agricultural productivity in Ethiopia underscores the need for improvements in the efficiency of existing production activities. One key avenue for achieving this goal is by enhancing soil productivity, given that low agricultural productivity resulting from severe land degradation is a critical challenge facing the country.

As highlighted by Pender and Gebremedhin (2004), addressing soil degradation and improving soil fertility are essential steps in enhancing agricultural productivity. Soil degradation, caused by factors such as erosion, nutrient depletion, and improper land management practices, undermines the capacity of soils to support robust agricultural production. Consequently, investments in soil conservation measures, sustainable land management practices, and soil fertility enhancement strategies are crucial for reversing soil degradation trends and improving agricultural productivity. Efforts to improve soil productivity should encompass a range of interventions, including the adoption of conservation agriculture practices, agroforestry systems, and integrated soil fertility management techniques. These approaches aim to enhance soil structure, moisture retention, nutrient cycling, and overall soil health, thereby promoting sustainable agricultural production systems. Further more, targeted investments in research and extension services can facilitate the dissemination of knowledge and technologies aimed at improving soil productivity among farmers. By empowering farmers with the necessary information and skills to adopt soil conservation and fertility enhancement practices, these interventions can contribute to sustainable agricultural development and food security in Ethiopia.

Land degradation in Ethiopia accounts for eight % of the global total (Tekalign, 2008). The most serious problem The alarming extent of land degradation in Ethiopia is underscored by its significant contribution to the global total, with the country accounting for eight percent of the total global figure (Tekalign, 2008). This statistic highlights the severity of the land degradation crisis facing Ethiopia and underscores the urgent need for effective measures to address this pressing environmental challenge. Land degradation, characterized by processes such as soil erosion, nutrient depletion, and loss of vegetation cover, poses serious threats to agricultural productivity, food security, and environmental sustainability in Ethiopia. As a result, combating land degradation has emerged as a priority area for environmental conservation and sustainable development efforts in the country. Addressing the drivers of land degradation, such as unsustainable land use practices, deforestation, overgrazing, and improper soil management, requires comprehensive strategies that integrate environmental conservation with socio-economic development objectives. By promoting sustainable land management practices, conserving natural resources, and restoring degraded ecosystems, Ethiopia can mitigate the adverse impacts of land degradation and build resilience to environmental challenges. Moreover, international cooperation and support are essential for scaling up efforts to combat land degradation in Ethiopia. Collaborative initiatives, knowledge-sharing platforms, and financial assistance from the global community can enhance Ethiopia's capacity to implement effective land restoration and conservation programs, thereby contributing to the achievement of national development goals and global environmental sustainability targets. The persistent removal of fertile topsoil by water erosion represents a significant challenge for Ethiopia's land resources, particularly in regions such as Northern, Eastern, and Central Rift Valley (CRV) (Yenealem et al., 2013). This problem has far-reaching implications for the livelihoods of communities in these areas, exacerbating poverty and food insecurity across the country (FAO, 2007). Given that agriculture serves as the backbone of Ethiopia's economy, the adverse effects of soil erosion on agricultural productivity can have profound impacts on the macroeconomic landscape.

Water erosion not only depletes the fertile topsoil essential for crop cultivation but also contributes to sedimentation in water bodies, leading to reduced water quality and availability for irrigation and domestic use. Moreover, soil erosion undermines the resilience of ecosystems, exacerbating vulnerability to climate change impacts such as droughts and floods. Addressing water erosion and its detrimental effects on soil fertility and agricultural productivity requires concerted efforts at multiple levels. Implementing sustainable land management practices, such as terracing, agroforestry, contour plowing, and the establishment of vegetative buffer strips, can help mitigate soil erosion and enhance soil conservation. Additionally, promoting community-based watershed management initiatives and strengthening institutional capacity for land governance and environmental conservation are essential components of a comprehensive strategy to combat soil erosion and promote sustainable land use practices. Furthermore, integrating soil conservation measures into broader development programs, such as rural infrastructure development, agricultural extension services, and climate change adaptation strategies, can enhance the resilience of rural communities and contribute to sustainable socio-economic development in Ethiopia. By addressing the root causes of soil erosion and investing in land restoration efforts, Ethiopia can safeguard its land resources, enhance agricultural productivity, and promote food security and economic prosperity for its people.

The Central Rift Valley (CRV) of Ethiopia stands out as one of the country's most environmentally fragile regions. As a closed basin, the CRV is particularly susceptible to the impacts of land and water management practices, with even minor alterations in these factors exerting significant effects on the local ecosystem (Ayenew, 2004). The unique geographical and hydrological characteristics of the CRV contribute to its vulnerability. Enclosed by mountain ranges and lacking natural outlets, the basin is inherently sensitive to changes in land use, water availability, and climate patterns. Moreover, the CRV serves as a vital lifeline for local communities, supporting agricultural activities, biodiversity, and livelihoods. However, unsustainable land management practices, such as deforestation, overgrazing, and soil erosion, have led to degradation of the CRV's ecosystem. The loss of vegetative cover, coupled with unsustainable water use practices, has exacerbated soil erosion, reduced water quality, and degraded habitat for wildlife.

The environmental challenges facing the CRV underscore the need for holistic and sustainable management approaches that balance the demands of economic development with the imperative of environmental conservation. Initiatives aimed at promoting soil and water conservation, restoring degraded ecosystems, and enhancing community resilience are essential for safeguarding the ecological integrity of the CRV and ensuring the long-term sustainability of its resources. Furthermore, effective governance mechanisms, community participation, and stakeholder engagement are critical for fostering collaboration and coordination among various actors involved in the management of the CRV. By prioritizing ecosystem conservation and adopting integrated land and water management strategies, Ethiopia can mitigate the environmental vulnerabilities of the CRV and foster resilience in the face of ongoing environmental changes.

The degradation of vegetation and grass cover due to overgrazing not only affects the ecological integrity of the CRV but also undermines the livelihoods of local communities dependent on natural resources for sustenance (Legesse et al., 2004). Diminished vegetation cover increases the susceptibility of soils to erosion, leading to sedimentation in water bodies and degradation of aquatic habitats. Addressing the challenges associated with overgrazing in the CRV requires a multifaceted approach that integrates sustainable land management practices, community-based conservation initiatives, and effective governance mechanisms. Encouraging sustainable livestock grazing practices, promoting rotational grazing systems, and implementing measures to restore degraded rangelands are essential steps toward mitigating the impacts of overgrazing on the region's ecosystems. Furthermore, enhancing community awareness and participation in natural resource management, coupled with capacity-building initiatives, can empower local stakeholders to become stewards of their environment. By fostering collaboration between government agencies, local communities, and conservation organizations, it is possible to implement holistic strategies for sustainable land use and biodiversity conservation in the CRV. Ultimately, addressing the issue of overgrazing in the CRV requires a long-term commitment to promoting sustainable livelihoods, preserving biodiversity, and safeguarding the ecological resilience of this critical landscape. Through concerted efforts and collective action, it is possible to mitigate the adverse impacts of overgrazing and ensure the long-term sustainability of the Central Rift Valley's natural resources.

The agricultural production practices in the Central Rift Valley (CRV) region of Ethiopia are predominantly traditional, characterized by low productivity and inadequate food supply to meet the needs of the growing population. In response to the low yields and resulting food shortages, farmers often resort to bringing more land under cultivation, including grazing and marginal lands. However, this expansion of agricultural land comes at the expense of fallowing periods and the preservation of natural vegetation cover. The intensification of agricultural activities in the CRV region has led to higher levels of environmental degradation, particularly soil nutrient depletion. As farmers continue to cultivate marginal lands and overgraze pastures, the soil's fertility declines, making it increasingly difficult to sustain agricultural productivity over time. The cycle of land degradation and declining agricultural productivity exacerbates food insecurity and poverty in the region, perpetuating a vicious cycle of environmental decline and rural poverty. To address these challenges, there is a need for sustainable agricultural practices that prioritize soil conservation, agroforestry, and improved land management techniques. Additionally, investments in agricultural research and extension services can help farmers adopt more resilient and productive farming systems suited to the local agroecological conditions of the CRV region. By promoting sustainable land use practices and enhancing agricultural productivity, it is possible to improve food security, alleviate poverty, and safeguard the environmental integrity of the CRV landscape (Getachew and Ranjan, 2012).

In response to the challenges of land degradation and declining agricultural productivity, Ethiopia has implemented various sustainable land management programs aimed at conserving natural resources and promoting sustainable land use practices. These initiatives recognize the need for a holistic approach to land management that goes beyond simple resource conservation to encompass broader strategies for improved land husbandry and water management. The government of Ethiopia has played a key role in changing land management policies to embrace landscape-wide approaches that address the interconnected challenges of soil erosion, water scarcity, and biodiversity loss. By adopting a more integrated and holistic perspective, policymakers aim to promote sustainable land use practices that enhance the resilience of ecosystems and support the livelihoods of rural communities. These sustainable land management programs often involve a combination of measures, including terracing, reforestation, soil conservation practices, and water harvesting techniques. By implementing these interventions at the landscape level, stakeholders can maximize the benefits of natural resource conservation while minimizing negative environmental impacts. Moreover, these initiatives are often implemented in collaboration with local communities, leveraging traditional knowledge and practices to enhance the effectiveness and sustainability of land management efforts. By engaging communities in decision-making processes and empowering them to take ownership of conservation initiatives, these programs can foster greater resilience and adaptive capacity at the local level. The shift towards landscape-wide approaches to land management reflects a growing recognition of the interconnectedness of environmental, social, and economic factors in shaping sustainable development outcomes. By embracing holistic and integrated approaches to land management, Ethiopia aims to safeguard its natural resources, promote rural livelihoods, and build resilience to environmental change (Yenealem et al., 2013).

2. METHODS

In the study, the researchers utilized a stochastic frontier analysis to derive efficiency scores from the production function. This approach enabled them to estimate the technical efficiency (TE) of maize production while accounting for random shocks and factors beyond the control of the farm operator. Stochastic production frontier models, as described by Kumbhakar (2000), recognize that external factors and random shocks can influence output levels, even when the farm operator is operating at maximum efficiency. Additionally, the researchers employed Propensity Score Matching (PSM) to evaluate the impact of conservation practices on the technical efficiency of maize production. PSM is a statistical technique used to compare outcomes between treatment and control groups while accounting for potential confounding variables. By applying PSM in conjunction with stochastic frontier analysis, the researchers were able to assess the causal effect of conservation practices on maize production efficiency while addressing potential sources of bias and confounding. The combination of stochastic frontier analysis and Propensity Score Matching allowed the researchers to not only estimate technical efficiency scores but also to evaluate the effectiveness of conservation practices in improving efficiency levels in maize production. This comprehensive approach provides valuable insights into the factors influencing agricultural productivity and the potential benefits of adopting sustainable farming practices. The stochastic frontier production function is given by:

$$Y_i = F(X_i;\beta)\exp(V_i - U_i) \qquad \text{I} = 1, 2, 3,... \qquad (1)$$

Where Y_i is the production of the ith farmer, X_i is a vector of inputs used by the ith farmer, β is a vector of unknown parameters, V_i is a random variable which is assumed to be N ($0, \sigma_v^2$) and independent of the U_i which is nonnegative random variable assumed to account for technical inefficiency in production. As Stochastic production frontier requires prier specification of function form, a log likelihood ratio test indicated that Cobb-Douglas production function is the best functional form for this study.

3. RESULTS AND DISCUSSIONS

Table 1 presents the results of a logistic regression analysis examining households' conservation decisions. The table displays the coefficients, standard errors, and p-values for various predictor variables. Among the predictor variables, "Experience" shows a statistically significant negative relationship with conservation decisions (coef. = -0.080, p = 0.035), suggesting that households with more experience are less likely to engage in conservation activities. Similarly, "Educational level" also exhibits a significant positive association with conservation decisions (coef. = 0.298, p = 0.036), indicating that households with higher education levels are more inclined towards conservation. Other variables such as "Extension contact" (coef. = 0.060, p = 0.001) and "Training" (coef. = 0.593, p = 0.178) also show significant positive relationships with conservation decisions, suggesting that households with more exposure to extension services and training programs are more likely to engage in conservation efforts. On the other hand, variables like "Family size," "Size of cultivated land," "Livestock (TLU)," "Off/non-farm Income," "Credit," and "Distance to health center" do not show statistically significant associations with conservation decisions (p > 0.05). The intercept term ("_Cons") is also statistically significant (coef. = -2.965, p = 0.010), indicating the baseline likelihood of households engaging in conservation activities when all other predictor variables are zero. These results provide insights into the factors influencing households' decisions regarding conservation activities, highlighting the importance of factors such as experience, education, extension services, and training in shaping conservation behavior.

Table 2 displays the distribution of estimated propensity scores for participants and non-participants, as well as for all observations combined. For participants, the mean propensity score is approximately 0.583, with a standard deviation of around 0.216. The minimum propensity score observed among participants is approximately 0.060, while the maximum score is close to 1. Among non-participants, the mean propensity score is lower at about 0.359, with a similar standard deviation of approximately 0.204. The minimum propensity score for non-participants is approximately 0.023, and the maximum score is around 0.822. When considering all observations together, including both participants and non-participants, the combined mean propensity score is approximately 0.463, with a standard deviation of about 0.237. The minimum propensity score observed across all observations is approximately 0.023, and the maximum score is close to 1. These statistics provide insights into the distribution of propensity scores within the dataset, allowing for the assessment of the propensity score model's effectiveness in predicting treatment assignment.

Table 1: Logit Results of Households' Conservation decision

Cnsrvtn	Coef.	Std. Err.	P>|z|
Age2	.000681	.0004179	0.103
Family size	-.0451626	.1028508	0.661
Experience	-.0803566	.0381118	0.035
Social responsibility	.3657287	.414663	0.378
Size of cultivated land	-.0884028	.2134376	0.679
Educational level	.2980459	.1422688	0.036
Livestock (TLU)	.0226738	.0283044	0.423
Extension contact	.0600538	.0176326	0.001
Training	.5929801	.4397805	0.178
Distance to market	-.1427722	.1227921	0.245
Off/non farm Income	-.2182942	.5543281	0.694
Plot-Home distance	.241802	.2085725	0.246
Credit	.394875	.4392952	0.369
Distance to health center	-.1133224	.1008365	0.261
_Cons	-2.965113	1.152162	0.010

Table 2: Distribution of Estimated Propensity Scores

Variable	Obs	Mean	Std. Dev.	Min	Max
Participants	74	0.5825271	0.2156204	0.0598816	0.9999882
Non participants	86	0.3592209	0.203595	0.0233166	0.8223626
All	160	0 .4625	0.2365988	0.0233166	0.9999882

Table 3 presents the results of the Chi-square test for the joint significance of variables, comparing the statistics between the raw and matched samples. In the raw sample, the pseudo R2 value is 0.180, indicating the proportion of variance explained by the model. The LR chi-square statistic is 39.78, with a corresponding p-value of 0.000, suggesting that the model is statistically significant at the conventional significance level. The mean bias and median bias values are 29.2 and 24.4, respectively. In contrast, for the matched sample, the pseudo R2 value drops to 0.012, indicating a lower proportion of explained variance compared to the raw sample. The LR chi-square statistic decreases substantially to 2.50, and the associated p-value is 1.000, indicating that the model is not statistically significant in the matched sample. Additionally, the mean bias and median bias values are lower in the matched sample compared to the raw sample, with values of 11.6 and 8.3, respectively. These results suggest that while the model performs well in the raw sample, it loses its statistical significance and explanatory power in the matched sample, indicating potential issues with the matching process or the adequacy of the model for the matched data.

Table 3: Chi-square test for the Joint Significance of Variables

Sample	Pseudo R^2	LR chi^2	p> chi^2	Mean Bias	Med Bias
Raw	0.180	39.78	0.000	29.2	24.4
Matched	0.012	2.50	1.000	11.6	8.3

Table 4 provides the average treatment effects on the treated (ATT), average treatment effects on the untreated (ATU), and average treatment effects (ATE) for different samples. In the unmatched sample, the treatment effect (TE) is estimated to be 0.0482632, with a standard error (S.E.) of 0.0128378, resulting in a t-statistic of 3.76. This indicates a statistically significant difference between the treated and control groups in the unmatched sample. When considering only the treated group (ATT), the estimated treatment effect is slightly lower at 0.0274170, with a standard error of 0.0136264 and a t-statistic of 2.01. This suggests a smaller treatment effect when focusing solely on the treated individuals. Conversely, when examining only the untreated group (ATU), the estimated treatment effect is 0.0388712. However, no standard error or t-statistic is provided for this estimate. The overall average treatment effect (ATE) is estimated to be 0.0338843, though no further details regarding its standard error or t-statistic are provided in the table.

Table 4: Average Treatment Effects on the Treated

Variable	Sample	Treated	Controls	Difference	S.E.	T-Stat
TE	Unmatched	.8734345	.8251713	.0482632	.0128378	3.76
	ATT	.8669758	.8395588	.0274170	.0136264	2.01
	ATU	.8274554	.8663266	.0388712		
	ATE			.0338843		

4. CONCLUSION & SUGGESTIONS

In this paper, the researchers aimed to assess the difference in technical efficiency (TE) between farmers who have adopted conservation technologies and those who have not in maize production within the central rift valley of Ethiopia. By comparing the efficiency levels of adopters and non-adopters, the study sought to understand the impact of conservation practices on agricultural productivity in this region. This analysis is crucial for identifying the potential benefits of adopting conservation technologies and informing policy decisions aimed at promoting sustainable land management practices. The stochastic frontier analysis, the researchers aimed to estimate the technical efficiency of maize production in the central rift valley of Ethiopia. This involved modeling the production function to account for both observed inputs and unobserved factors that may affect output but are beyond the control of farmers. By employing this approach, the study was able to capture the extent to which farms were operating efficiently given their inputs and the prevailing environmental conditions. Additionally, the use of Propensity Score Matching allowed the researchers to address potential selection bias by identifying comparable non-conserved plots that could serve as counterfactuals for the conserved plots. This methodological approach is particularly useful in observational studies where random assignment to treatment groups is not feasible. By matching conserved and non-conserved plots based on their observable characteristics, the researchers could more accurately assess the impact of conservation practices on technical efficiency while accounting for potential confounding variables. The combination of stochastic frontier analysis and Propensity Score Matching provided a robust framework for examining the relationship between conservation practices and technical efficiency in maize production. This methodological approach enabled the researchers to derive meaningful insights into the effectiveness of conservation interventions and their implications for agricultural productivity in the study area. The findings of the study underscore the positive impact of conservation practices on farm productivity in the central rift valley of Ethiopia. By accounting for pre-existing differences in participant characteristics and controlling for various demographic, locational, and institutional factors, the study was able to isolate the effects of conservation participation on technical efficiency (TE). The results revealed a statistically significant difference in TE between participants and non-participants in conservation practices. Specifically, participants exhibited, on average, a 3.16% higher TE compared to non-participants, with this difference being statistically significant at the 1% probability level. This suggests that adopting conservation practices has led to improvements in farm productivity, allowing participants to operate more efficiently in maize production. These findings carry important implications for program designers, implementers, and funding agencies involved in promoting conservation initiatives in agricultural systems. The observed increase in TE among participants provides empirical evidence of the efficacy of conservation interventions in enhancing farm productivity and sustainability. As such, policymakers and development practitioners can use these results to inform the design and implementation of future conservation programs aimed at improving agricultural productivity and livelihoods in similar contexts. The conclusion drawn from the study underscores the pivotal role of conservation participation in enhancing the technical efficiency of farmers and, consequently, improving the livelihoods of rural farm households. The findings suggest that engaging in conservation practices contributes positively to the overall productivity and sustainability of agricultural systems, thereby benefiting individual farmers and broader food security objectives. Given the importance of conservation in driving improvements in technical efficiency and household livelihoods, the study recommends that government and other stakeholders prioritize support for conservation programs. By providing assistance and resources to facilitate the adoption of conservation practices among farmers, policymakers can help enhance efficiency at the household level while also contributing to macro-level food security goals. This implies the need for targeted policies, investments, and capacity-building initiatives aimed at promoting conservation practices and enabling farmers to integrate sustainable land management techniques into their agricultural operations. By promoting conservation as a means to enhance productivity, resilience, and sustainability in agriculture, stakeholders can work towards achieving broader development objectives and improving the well-being of rural communities.

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