Combined-Use of Soil Conservation Practices for Maximizing Crop Yields and Household Income in Goncha District, Northwest Highlands of Ethiopia

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Abstract

Soil and water losses and nutrient depletion are major limiting factors for crop growth and yield. Smallholder farmers need to invest in combined-use of structural, vegetative, and agronomic practices in an attempt to close the yield gap. This study aimed to evaluate the impacts of combined-use of soil conservation practices in maximizing crop yield and household income in the sub-humid highland of Ethiopia using farmer estimation techniques at the field level. Grain yield and household income data were generated through conducting face-to-face interviews with 150 farm household heads selected using a systematic random sampling technique. The data were analyzed using independent t-test, and analysis of variance. The mean grain yields from fields treated with combined-use soil conservation practices increased by 40.18% for tef and 50.37% for the wheat crop, and significantly higher at $f=69.8$ and $p<0.01$ for tef, and $f=35.3$ and $p<0.01$ for wheat, compared to fields treated with common traditional practices. The size of irrigated croplands (in ha), beehive numbers and livestock sizes were positively and significantly (at $p<0.01$) associated with the increase of households' income. The total size of farmlands and trees planted field (in ha) were also positively and significantly (at $p<0.05$) related to the improvement of individual household income. Therefore, efforts should be made to boost crop productivity through scaling-up of combined-use of vegetative stabilized structure practices and compost under the legume-cereal crop farming system. There need to be enhanced forage, livestock and tree production, and plantation of legume and flowering plants on uncultivated privately owned plots for apiculture production.

Keywords: Combined-use, Conservation practice, Crop yields, Ethiopia highlands, household income

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1. Introduction

The ability of sustainable agricultural production has been and continues to be a daunting challenge for billions of small-scale farmers in the developing world (Pimentel, 2006; Hurni et al., 2008). The livelihood of small-scale farmers directly depends on soil and water resources where accelerated soil erosion continues (Pimentel, 2006). Accelerated soil erosion causes the loss of soil, water, and nutrient, organic matter, biota and reduces soil depth. The loss of soil in turn directly influences crop yields on the small-scale farmers' fields. By the year 2020, soil erosion could be a severe threat to crop yield in Africa, in particular where crop yield gaps are among the largest in the world (Pretty, Toulmin & Williams, 2011; Tittonell & Giller, 2013).

In Ethiopia, accelerated soil erosion by water accompanied by nutrient depletion has posed a series threat to the reduction of potential crop yield, where crop/livestock production is the major source of smallholder household income. Before reaching beyond a certain threshold level of soil degradation, effective conservation practice has thus become quite indispensable (Pretty, Toulmin & Williams, 2011). The Ministry of Agriculture of Ethiopia and the World Food Program (WFP) have been investing considerable resources in encouraging and scaling up of the soil conservation practices to enhance crop production and household income.

Findings of various studies indicated the ineffectiveness of introduced terracing practices on cropland productivity. In the high rainfall areas of the Ethiopian highlands, different studies found that the value of crop production for fields with structural practices was lower than for fields without. For example, Menale et al. (2008) found that older *Fanya-juu* correlated with a decline in average crop value of $19.00 (ETB 160), and new soil bunds resulted in a $21.00 (ETB171) decline. Bekele and Holden (2001) reported that gains from soil conservation efforts did not improve as long as the cropping plot occupied by structures remains underused. Zenebe et al. (2017) also discovered that the impacts of physical soil and water conservation practices on crop yield were negative due to the reduction of croplands by soil/stone bunds. The relative performance of introduced terracing in addressing the short-term economic benefits of ecosystem services was more limited in potential and sub-humid areas (Asnake, 2017).

Alternatively, numerous studies reported the positive effect of terracing practices on crop yield enhancement in diverse agro-ecologies of Ethiopia highlands. For instance, some experimental studies found that plots with structural practices were more productive than those without structural practices in the semi-arid environment of Ethiopian highlands where the availability of soil moisture is a principal limiting factor for crop yield (Hengsdijka et al., 2005; Vancampenhou et al., 2006). The long-term maintenance of structural practices (e.g. stone/soil and *Fanya-juu* bunds) is crucial to positive gains in the value of crop yield in the sub-humid highlands of the country (Kato et al., 2009). In the highlands, crop production can increase from 2% to 13% if a household continues to maintain structural practices from seven to fifteen years (Schmidt & Fanaye, 2012). Getachew et al. (2011) reported that plots with *Fanya-juu* and elephant grass (315.9gm^{-2}) and *Fanya-juu* with *vetiver* grass (309.6g m^{-2}) produced a significantly higher yield than non-conserved plots (207.9g/m^{2}). These inconsistent findings on the effectiveness of introduced terracing on the improvement of crop yields in the sub-humid environment of the Ethiopian highlands thus call for an investigation.

Moreover, practicing of terraces is economically more viable and effective in agriculture when combined with agronomic and vegetative practices (Zenebe et al., 2017). The combined use of nutrient saving (controlling of erosion and recycling of crop residues) and nutrient adding through the application of compost or manure should promote sustainable cropland productivity (Erkossa et al., 2018). Smallholder farmers need to invest in a combination of structural, vegetative and agronomic measures in an attempt to close the yield gaps caused by soil and water losses and nutrient depletion (Getachew et al., 2012). The combination of terraces stabilized with vegetation and compost in the legume-cereal crop rotation system was the most accepted system potentially leading to economic, social and ecological benefits (Ermias, 2016). Despite these facts, studies are limited to the impacts of the combined-uses of conservation practices in maximizing agricultural productivity in the sub-humid highlands of Ethiopia. Therefore, the study aimed at assessing the impact of combined-use of soil and water conservation practices on crop yields and household income using farmer estimation techniques at the field level.

1.1 Description of the Study Area

The study was conducted on long wait terraced cultivated fields in three catchments (Beriberi, Woyibila, and Wochitwuha) in Goncha district in the North-western highlands of Ethiopia (Figure 1). In absolute location, the Beriberi catchment is located between $10^{0}55^{'}19.1^{''}$ – 10^{0} $56^{'}46.2^{''}$ N latitudes and 3803'4.3$^{''}$– $38^{0}4^{'}49.8^{''}$ E longitudes. The Woyibila catchment is located between $10^{0}52^{'}48^{''}$ – $10^{0}54^{'}51.23^{''}$ N latitudes and $38^{0}9^{'}21.6^{''}$ – $38^{0}11^{'}31.1^{''}$ E longitudes. The Wochitwuha catchment is found between $10^{0}51^{'}8.52^{''}$ – $10^{0}54^{'}38.71^{''}$ N latitudes and $38^{0}12^{'}57.2^{''}$ – 38^{0} $14^{'}19.7^{''}$ E longitudes. The mean elevations in catchments are 2595.5 in Beriberi, 2677 in Woyibila, and 2471 m.a.s.l., in Wochitwuha. The climatic condition is generally sub-humid. For instance, the mean annual rainfall distributions in the catchments were estimated at 1313.4 mm in Beriberi, 1186.4 mm in Woyibila, and 1084.7 mm in Wochitwuha. Such estimations were done by interpolating a raster surface from the average value of point data of monthly rainfall records from 1994 to 2013. More than three-fourths of the total rainfall occurs during the summer season (from June to September). In all catchments, crop-livestock mixed farming is the prominent livelihood activity. The soil color that covers a large area of the selected study sites is reddish. Greyish brown color soils also cover substantial areas of the Wochitwuha catchment (Hurni et al., 2016).

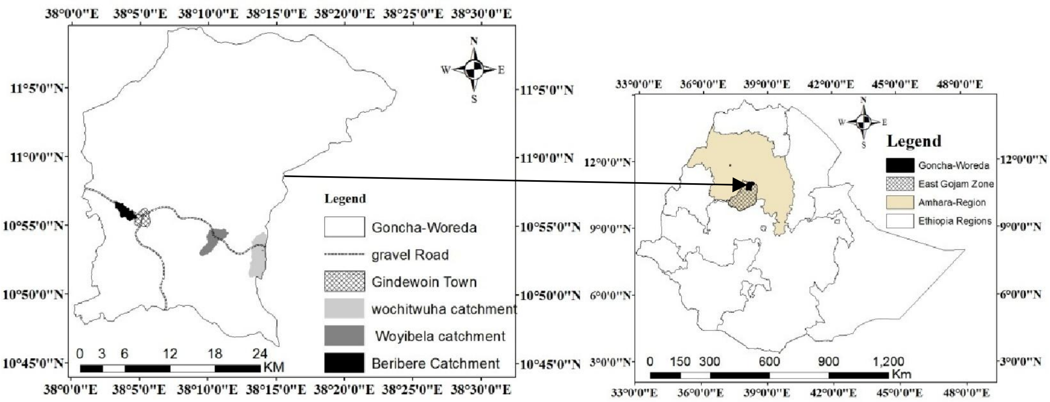

Figure-1: Location of catchments in the Woreda and Woreda location in the administration map of Ethiopia

Under the mixed farming systems, the smallholder farmers predominantly grow *tef* (Eragrostis tef) and wheat (Triticum vulgare). In addition, Niger seed (*Guizotia abyssinica*) in Beriberi*;* maize (*Zea mays*), barley (*Hordeum vulgare*) and Niger seed (*Guizotia abyssinica*) in Woyibila*;* and legume crops (horse beans (*Vicia faba*)), pea (*Pisum sativum*)), barley (*Hordeum vulgare*), maize (*Zea mays*) and Niger seed (*Guizotia abyssinica*) in Wochitwuha are produced. Conventional tilling through a hand press with an ox-pulling traditional technique is the most common one to all farmers of *tef*, wheat and other crop productions. Many times, contour ploughing (ranges from three to nine) is commonly undertaken from mid-September to the end of July for seedbed preparation and sowing. Farmers in these areas rear cattle, sheep, goats, donkeys, and horses using cut-and-carry and open-grazing systems. Crop residues and grasses are harvested from croplands and grazing areas, respectively. Open grazing is typically practiced on free-access grazing lands. In addition to crop and livestock productions, other income-generating farm activities like beekeeping, horticulture and tree production are usually practiced in the highlands of Ethiopia in general and in the study areas in particular.

In the cultivated fields, the commonly implemented conservation practices include stone bunds, soil bunds, soil bunds stabilized with *Sesbania sesban* shrubs, *Fanya-juu* stabilized with *Sesbania sesban* shrubs, *Fanya-juu* and composting. The common indigenous soil conservation practices comprise legume-cereal crop rotation, contour ploughing, the inclusion of some crop residues in the field and traditional drainage ditches. In the study watershed, all cultivated fields are treated with one or a combination of more than two practices (Ermias, 2016).

2. Methodology

2.1 Research Design

Yields obtained from experimental plots, perhaps misleading as they are often, overestimate or underestimate attainable yields under the farmers' conditions. Instead, farmers' estimates of harvested yields from their fields in a harvesting time recognize heterogeneous farming systems and landscape of smallholder agriculture (Tittonell & Giller, 2013). Several techniques of estimating harvested yields of farmers' plots are available. These include farmer estimation, crop cutting, complete harvesting and others. The complete harvesting method represents the entire farmer's plot that would be harvested under project staff supervision. Crop cutting represents direct physical measurement by the enumerator through taking a crop from randomly selected sub-plots that may not represent the total area of the farm plot. For this study, the surveying farmer estimation method is more appropriate as it is simpler, less costly and permits greater sampling efficiency than complete harvesting and crop cutting. Hence, a cross-sectional survey design was employed to generate grain yield data at a fixed point of post-harvesting time, using farmer estimation method at the field level.

2.2. Sampling Design

The purposive identification of the study sites is mainly based on cropping patterns and the status of soil conservation practices.

Table 1: Sample allocation mechanism

Catchments	Numbers of fields treated with ≤3 years age terraces		Numbers of fields treated with ≥7 years age terraces		Total
	Tef cropped	Wheat cropped	*Tef* cropped	Wheat cropped	
Beriberi	38(3)	33(3)	117(11)	105(9)	293(26)
Woyibila	55(5)	47(4)	145(13)	132(12)	379(34)
Wochitwuha	140(13)	125(11)	381(34)	353(32)	999(90)
Total	233(21)	205(18)	643(58)	590(53)	1671(150)

Source: *Kebeles*' land use and administration, and development agent offices

Note: *Values out of and in parentheses represent population and sample sizes of fields' owners, respectively.*

From the selected catchments, farmers who grew *tef* and wheat crops in the cultivated fields treated with terrace age below four years and above six years were the targets of the study. However, farmers who cultivated fields treated with terrace age from four to six years were not included in the sampling. This was because cultivated fields treated with terrace age between four and six years were considered as an intermediate stage for land productivity for this study. From the target study groups, out of 1671 farm household heads, 150 *tef* and wheat growers at the time were selected (Table 1) using systematic random sampling. The sampling was undertaken using a list obtained from the *kebeles'* land use and administration offices. Every eleventh household head on the list was included in the sample.

2. 3 Method and Procedures of Data Collection

Face-to-face interviews were conducted with all the sampled farmers using pre-arranged and structured questions. Farmers' perception of incentives or personal costs can cause a biased response of under or over report grain yield. To reduce the response bias, respondents were informed to recognize that their responses were mainly required for academic purposes only. Generating accurate information about the change of income in the form of money is difficult for the majority of farmers. Thus, memorable dichotomous terms like 'improved' and 'not improved' (including 'no change' and 'decreased') were used for this study. Farmers were asked to try to observe the changing status of their household income after the implementation of the combined-use of conservation practices.

2. 4 Methods of data analysis

Variance of analysis was employed to analyze spatial variability in changes of harvested grain yield of *tef* and wheat crops between cultivated fields treated with different soil conservation practices. Moreover, independent samples T-test was employed to analyze the association between perceived changes of income and other socioeconomic variables and yield changes from specific *tef* and wheat fields in a particular catchment. Statistical Package for Social Sciences Version 24 was used to analyze the quantitative data.

3. Results and Discussion

3.1 Impacts of Combined-Use of Conservation Practices on *Tef* and Wheat Yields

Table 2 reveals the significant impacts of different soil conservation practices in improving wheat (*Triticum durum*) and *tef* (*Eragrostis tef*) yields. For instance, the mean grain yields in fields with 7 and above years old terraces were 1326.2 kg ha^{-1} *tef* and 1903.4 kg ha^{-1} wheat. The average yields in fields with three and below three years old terraces were 1034.9 kg ha^{-1} *tef* and 1496.3k.g ha^{-1} wheat. The results indicate that average grain yields were increased by 28.15 % for *tef* and by 27.21% for wheat in fields treated with more than 6 years old terraces. In these fields, crop yields were significantly higher at $f=22.54$, $p<0.01$ when compared to fields treated with three and below years old terraces. This suggests that terraces with stabilized vegetation have significant effects on *tef* and wheat yields improvement. This agrees with the findings of other studies conducted in the highlands of Ethiopia. For instance, Eniyew, Teshome and Mat (2013) indicate that there was an average yield increment of *tef* by 94% in the 25 years old terraced fields when compared to the adjacent non-terraced fields. Likewise, Schmidt and Fanaye (2012) indicated that crop yield improved from 2% to 13% in fields conserved from 7 to 15 years old terraces. Moreover, Getachew et al. (2011) reported that grain yield increased by 48.9% in croplands conserved with elephant and vetiver grasses' stabilized *Fanya-juu* practice. According to Nigatu, Kalkidan, and Tewodros (2017), vegetation-stabilized terraces improved crop yield by retaining soil moisture and controlling soil loss.

Table 2: Crops yield difference due to terracing, composting, and legume-cereal crop rotation and their combination on a specific cultivated field

Soil management practices	Tef yield Mean(kg h^{-1})	F	Wheat yield Mean(kg h^{-1})	F
Age of terracing on cultivated fields				
Three and below years	1034.9	22.5 [a]	1496.3	10.5 [a]
Seven and above years	1326.2		1903.4	
Type of fertilizers applied to the cultivated field in the past year				
Inorganic alone	1065.2		1647.2	
Combined-use of compost and inorganic	1232.7	15.7 [a]	1686.5	21.5 [a]
Compost alone	1428.5		2411.9	
Type of crop grown on the cultivated field in the past year				
Cereals	1140.7	34.2 [a]	1752.3	2.83 [b]
Legumes	1456.8		1995.2	
Combined-use of seven and above years old terraces, compost and LCCR on a specific cultivated field				
Yes	1618.8	69.8 [a]	2544.4	35.3 [a]
No	1154.8		1692.1	
Total	1248.8		1800.2	

Note: [a] and [b] represent $p<0.01$and $p<0.1$ significant levels

Note: For this study, cultivated fields treated with terrace age between four and six years were considered intermediate stage for land productivity and thus not included in the sampling.

The type of fertilizers applied in the cultivated field in the past year influences wheat and *tef* yields improvement in the next crop season (Table 2). For example, the mean yields from fields treated with inorganic fertilizers in the past year were 1065.2 kg ha^{-1} for *tef* and 1647.2 kg ha^{-1} for wheat. The average grain yields from the fields treated with a combination of inorganic fertilizers and compost in the previous year were 1232.7 kg ha^{-1} for *tef* and 1686.5 kg ha^{-1} for wheat. The mean grain yields from field-amended by compost in the former year were 1428.5 kg ha^{-1} for *tef* and 2411.9 kg ha^{-1} for wheat. Thus, the results showed that the mean grain yields increased by 34.11% for *tef* and 46.42% for wheat in the fields treated with compost in the past year as compared to fields treated with inorganic fertilizers alone in the previous year. Moreover, the average grain yields from fields treated with combined-use of compost and chemical fertilizers in the past year were higher by 15.72% for *tef* and 2.4% for wheat when compared to fields treated with inorganic fertilizers only. The mean grain yields significantly differed at $f = 15.7$ and $p<0.01$ for *tef*, and at $f = 21.5$ and $p<0.01$ for wheat between fields formerly treated with organic fertilizers and fields treated with inorganic fertilizers. This implies that the uses of compost followed by combined-use of inorganic fertilizer and compost in the past year have significant contributions to *tef* and wheat grain yields in the next year. The combined-use of compost and inorganic fertilizer can be an alternative soil conservation practice for sustainable grain production rather than the sole application of inorganic fertilizers (Getachew et al., 2012). The use of composted manure increased crop yield and reduced the cost of inputs (Krauss et al., 2020).

The type of crop grown on the cultivated field in the past year could influence the productivity of *tef* and wheat in the next crop season (Table 2). For instance, the mean grain outputs were 1456.8 kg ha^{-1} for *tef* and 1995.2 kg ha^{-1} for wheat from field residual effect after the legume crop grew, while 1140.7 kg ha^{-1} for *tef* and 1752.3 kg ha^{-1} for wheat from field residue effect after the cereal crop grew. Hence, the results indicated that the mean tef grain yield from fields with the residual effect of legume crop increased by 27.7% (at $f=34.2$, $P<0.01$) when compared to fields cultivated with cereals in the past year. A large number of farmers informally reported that compost use alone for growing legume crops is their preference. Legume crop grown in the past year may contribute more to increasing *tef* crop yield in the coming year than wheat yield. The stronger residual effects of legume crops contributed to improved grain yield of cereal crops (Franke et al., 2018; Uzoh et al., 2019). The interaction effects of the cereal-pulse-cereal rotation system significantly improved biomass, grain, straw of wheat and *tef* (Teklu & Hailemariam, 2009).

In the fields conserved by combined-use conservation practices in the past year, the mean grain yields were 1618.8 kg ha^{-1} for *tef* and 2544.4 kg ha^{-1} for wheat. However, from fields treated with single conservation practice in the past year, the mean grain yields were 1154.8 kg ha^{-1} for *tef* and 1692.1 kg ha^{-1} for wheat (Table 2). The results imply that the mean grain yields from fields treated with combined-use of conservation practices increased by 40.18% for *tef* and 50.37% for wheat. Furthermore, mean grain yields from fields conserved with combined-use of conservation practices were significantly higher (at $f=69.8$, $P<0.01$) for *tef* and ($f=35.3$, $P<0.01$) for wheat. This suggests that combined-use of vegetation-stabilized terraces and compost in the legume-cereal crop rotation system greatly contributed to crop yield improvement when compared to croplands that were conserved with a single soil conservation practice. In agreement with this study, the highest mean effect on crop productivity was obtained from the combination of bunds and biological intervention with a 170% increase (Wuletawu et al., 2019).

3.2 Farmers' Perceptions of the Improvement of Household Income

Table 3 indicates that 14% of farmers participating in the study reported that their household income had increased, while the majority (86%) responded that there was no change in their income or their income decreased. The data in Table 3 further shows the association between different socioeconomic factors and perceived improvement of household income. 0.28 ha perceived that their income improved, while households with a mean area of irrigated cropland of 0.025 ha perceived that their income did not improve. Farmers' perceptions of the improvement of household income differed significantly at $t=13.2$, $p<0.001$ in terms of size of irrigated cropland. In agreement with this, access to traditional irrigation for vegetables and fruit productions contributed to increased household income (see Reddy et al., 2004; Assan & Fikirte, 2013; Mehretie & Woldeamlak, 2013). Variability in rainfall patterns presents a significant challenge to crop yield stability of rain-fed agriculture system; highlighting the importance of irrigated croplands management for optimizing production (Girvetz et al., 2019).

Similarly, households with an average number of four beehives perceived that their income improved, but households with an average number of approximately one beehive perceived that their income did not improve. The perceptions of these households were statistically significantly different at $t=11.8$, $p<0.001$ (Table 3). Diversifying farming income through bee-keeping activity more contributed to improving household income (Assan & Fikirte, 2013).

The average size of pasture and land covered with trees owned by households with improved income was 0.07 ha, and it was 0.038 ha for households without improvement of income. The perceived improvement of household income was statistically significantly varied at $t = 2.14$, $p< 0.05$ in terms of sizes of pasture and area covered with trees in hectares per household (Table 3). Farming income through tree plantation is more likely to contribute to improving household income (Reddy et al., 2004; Assan & Fikirte, 2013). Planting trees on farmland enables to provide fuel, wood, fodder, and fruits for self-consumption and increases income (Mkomwa et al., 2017). *Eucalyptus globules* and *Acacia mearnsii* trees are usually planted on croplands to cover the costs of fuel consumption, to obtain construction materials and to supplement income. The trees are usually plated on the peripheries of a farmland and alongside gullies and waterways. Croplands are sometimes converted into eucalyptus tree production farms if the fields are near to a market and easily accessible to transportation. When the cultivated field is unproductive for crop production, farmers often prefer to convert it into a eucalyptus farm taking into account the high price of timber for construction material. Many farmers plant a shrub locally named *Gesho (Rhamnus prinoides)* in homestead farms for making traditional alcoholic drinks (*Tella and Areki*) to supplement their income. Trees and shrubs (such as grass and herbaceous plants, *Sesbania sesban* shrubs) planted in free space are used as fodder for cattle through cut-and-carry grazing system.

Table 3: The association between perceived changes of household income (improved [n=21] and not improved [n=129]) and socioeconomic factors

Socioeconomic factors	Perceived changes of household income over time (14% improved and 86 % not improved)		t-value
	Improved (**X**)	Not improved (**X**)	
Irrigated croplands(ha)	0.28	0.025	13.2[a]
Pasture & tree-planted fields(ha)	0.07	0.038	2.1[b]
Total farmland size (ha)	2.24	1.76	2.5[b]
Number of beehives	4	1	11.8[a]
Total number of livestock	12	9	3.1[a]
Number of productive labour force	4	4	0.03
Tef & wheat mean grain yields from conserved fields (in kg ha^{-1})	1461.8	1517.6	-.49

Note: [a] and [b] represent significance values at p<0.01 and p<0.05, respectively.

'X' represents the mean values of socioeconomic factors in terms of improved and not improved responses.

Table 3 indicates that the average size of farmland was higher by 0.48 ha for households with improved income when compared to households that did not perceive improved income. Landholding size differed statistically significantly at t = 2.48, p<0.05 between households with improved income and households without improved income. This implies that more landholding size more likely contributes to the improvement of household income.

The mean number of livestock for household with improved income was 12, while it was 9 for households without improved income. The mean size of livestock differed statistically significantly at t = 3.1, p<0.001 between households with improved income and households without improved income. This depicts that more livestock size per household can improve income through selling cattle. Livestock fattening for meat also improved household income by selling fattened cattle (Assan & Fikirte, 2013; Tittonell, Gerard & Erenstein, 2015). Farmers can also improve their income by selling milk and egg products from livestock. Moreover, livestock can reduce labor costs by providing power for farming and land preparation and transport (Tittonell, Gerard & Erenstein, 2015). Thus, there is a need to promote improved feeding strategies and adaptation of more efficient breeds of livestock for improving household income (Shikuku et al., 2017).

However, the size of productive labour force and crop yields improvement from conserved fields of particular catchment did not correlate with perceived improvement of household income. Similarly, the estimated *tef* and wheat yield improvement from conserved fields in a particular catchment did not correlate to perceived household income improvement (Table 3). This is due to the size of conserved fields with income diversification and intensification of farming activities. Contrary to this, terraces can greatly contribute to increased household income despite the types of crops grown (Eniyew, Teshome & Mat, 2013).

4. Conclusions

Smallholder farmers need to invest combined-use of structural, vegetative, and agronomic practices in an attempt to close the yield gap caused by soils and water losses, and nutrient depletion. This study aimed to assess the impact of the combined use of soil conservation practices for maximizing crop yield and household income. The results of the study indicated that long-term maintained terraces stabilized with vegetative measures had contributed significantly to the improvement of *tef* and wheat yields when compared to fields conserved with below four years of age terraces. Legume-cereals crop rotations (LCCR) and composting also contributed to short-term (after one year) improvements of *tef* and wheat grain yield. Moreover, the combined-use of long-term vegetative-stabilized terraces, composting, and LCCR on a specific cultivated field had contributed largely to increase *tef* and wheat yields compared to croplands treated with single practices. The estimated improvement of *tef* and wheat grain yields from conserved fields is insignificantly associated with perceived improving household income. However, the size of irrigated croplands, beehives number, and livestock size were associated significantly with the perceived increased households' income. Total sizes of farmlands and fields covered with trees were also associated significantly with the improvement of household income. Therefore, efforts should be made to boost crop productivity through scaling-up of combined-use of vegetative-stabilized terraces and compost in the legume-cereals crop rotations systems. There is a need to enhance forage, livestock, plantation of trees, plantation of legume and flowering plants on uncultivated fields for apiculture production.

Acknowledgments

The authors wish to thank the cooperation of respondents and enumerators. The financial support from the School of Graduate Studies of Addis Ababa University is acknowledged.

References

Asnake Mekuriaw. (2017). Assessing the effectiveness of land resources management practices on erosion and vegetative cover using GIS and remote sensing techniques in Melaka Watershed, Ethiopia. *Environmental Systems Research, 6, 16 (2017)*

Ashley, C., & Hussein, K. (2000). Developing methodologies for livelihood impact assessment: Experience of the African wildlife foundation in East Africa: Results of research presented in preliminary form for discussion and critical comment, Working Paper*,* 129.

Assan, J. K., & Fikirte Regassa. (2013). Livelihood impacts of environmental conservation programs in the Amhara region of Ethiopia. *Journal of Sustainable Development*, 6(10), 87 - 105.

Bekele Shiferaw, & Holden, S. T. (2001). Farm-level benefits to investments for mitigating land degradation: Empirical evidence from Ethiopia. *Environment and Development Economics,* 6(3), 335–358.

Eniyew Adgo, Teshome Akalu, & Mat, B. (2013). Impacts of long-term soil and water conservation on agricultural productivity: The case of Anjeni watershed, Ethiopia. *Agricultural Water Management*, 117, 55– 61.

Ermias Debie. (2016*). Integrated soil management approach and it's socio-ecological implications in Goncha district, north-western highlands of Ethiopia (Doctoral dissertation)*, Addis Ababa University.

Franke, A.C., Brand, G.J.V., Vanlauwec, B., & Giller, K.E. (2018). Sustainable intensification through rotations with grain legumes in Sub-Saharan Africa: A review. *Agriculture*, *Ecosystems*, *and Environment*, 261, 172-185.

Erkossa, T., Williams, T. O., & Laekemariam, F. (2018). Integrated soil, water, and agronomic management effects on crop productivity and selected soil properties in western Ethiopia. *International soil and water conservation research,* 6,305-316.

Getachew Agegnehu, Angaw Tsigie, & Agajie Tesfaye. (2012). Evaluation of crop residue retention, compost, and inorganic fertilizer application on barley productivity and soil chemical properties in the Central Ethiopian Highlands. *Ethiopian Journal of Agricultural Science,* 22, 45-61.

Getachew Fisseha, Heluf Gebrekidan, Kibebew Kibret, Bobe Bedadi, & Birru Yitaferu. (2011). Participatory development of soil conservation measures at the Debre-Mewi watershed in the upper catchment of the Blue Nile Basin, Northwest Ethiopia. *Biodiversity and Environmental Sciences,* 1(6), 199-213.

Girvetz, E., Ramirez-villeges, J., Claessens, L., Lamanna, C., Navarro-Racines, C., Nowak, A., Thornton, P., & Rosenstock, T.S. (2019). Future climate projections in Africa: where are we headed? Rosenstock, T.S., Nowak, A., and Girvetz, E. (eds.), *The Climate-smart Agriculture Papers Investigating the Business of a Productive, Resilient, and Low Emission Future*, Gewerbestrasse 11, 6330 Cham, Switzerland, Pp 15-27.

Hengsdijk, H., Meijerink, G.W., & Mosugu, M.E. (2005). Modeling the effect of three soil and water conservation practices in Tigray, Ethiopia. *Agriculture, Ecosystems and Environment*, 105, 29–40.

Hurni, H., Berhe Wolde-Arega, Chadhokar, P., Daniel. D., Gete Zeleke, Grunder, M., & Kassaye Gosh. (2016). Soil and water conservation in Ethiopia: Guidelines for development agents. Second revised edition. Bern, Switzerland: Centre for Development and Environment (CDE), University of Bern Open Publishing (BOP). 134 Pp.

Hurni, H., Herweg, K., Portner, B., & Liniger, H. (2008). Soil Erosion and Conservation in Global Agriculture. Braimoh, A. K., &Vlek, P.L.G. (Eds.), *Land Use and Soil Resources*. Springer Science Business Media B.V. Pp, 41-69.

Kato, E., Ringler, C., Mahmud Yesuf, & Elizabeth Bryan. (2009). Soil and water conservation technologies: A buffer against production risks in the efface of climate Change/insight from the Nile basin in Ethiopia. International Food Policy Research Institute (IFPRI) discussion paper, 00871.

Krauss, M., Berner, A., Perrochet, F., Frei, R., Niggli, U., & Mader, P. (2020). Enhanced soil quality with reduced-tillage and solid manures in organic farming – a synthesis of 15 years. *Scientific reports*, 10, 4403(2020).

Mkomwa, S., Lugandu, S., Kuria, P., & Mutai, W. (2017). Empowering smallholder farmers with profitable and sustainable farming using conservation agriculture: The case of East Africa. In Kassam, A.H., Mkomwa, S., & Friedrich, T. (Ed.), *Conservation Agriculture for Africa Building Resilient Farming Systems in a Changing Climate*. CAB international 2017. CABI Nosworthy Way, Wallingford, Oxfordshire OX10 8DE, UK, Pp, 41-70

Mehretie Belay, & Woldeamlak Bewket. (2013). Traditional irrigation and water management practices in highland Ethiopia: Case Study in Dangila Woreda. *Irrigation and Drainage*, 62, 435-448.

Menale Kassie, Holden, S., Köhlin, G., & Bluffstone, R. (2008). Economics of soil conservation adoption in high-rainfall areas of the Ethiopian Highlands. *Environment for Development Discussion Paper Series,* March 2008, EfD DP 08-09

Nigatu Dabi, Kalkidan Fikirie, & Tewodros Mulualem. (2017). Soil and water conservation practices on productivity and its economic implications in Ethiopia: A review. *Asian Journal of Agricultural research*, 11, 128-136.

Pimentel, D. (2006). Soil erosion: A food and environmental threat. *Environment Development and Sustainability*, 8,119-137.

Pretty, J., Toulmin, C., & Williams, S. (2011). Sustainable intensification in African agriculture. International *Journal of Agricultural Sustainability*, 9 (1), 5-24.

Reddy, R.V., Reddy, G.M., Soussan, J., & Springate-Baginski, O. (2004). Participatory watershed development in India: can it sustain rural livelihoods? *Journal of Development and Change*, 35(2), 297-326.

Schmidt, E., & Fanaye Tadesse. (2012). Household and plot-level impact of sustainable land and watershed management practices in the Blue Nile. ESSP Research Note 18

Shikuku, K.M., Valdivia, R.O., Paul, B. K., Mwngera, C., Winowiecki, L., Laderach, P., Herrero, M., & Silvestri, S. (2017). Prioritizing climate-smart livestock technologies in rural Tanzania: A Minimum data approach. *Agricultural Systems*, 151, 204-216.

Teklu Erkossa, & Hailemariam Teklewold. (2009). Agronomic and economic efficiency of manure and urea fertilizers use on Vertisols in Ethiopian Highlands. *Agricultural Sciences in China,* 8(3), 352-360.

Tittonell, P., Gerard, B., & Erenstein, O. (2015). Trade-offs around crop residue biomass in smallholder crop-livestock systems what's next? *Agricultural Systems*, 134,119-128.

Tittonell, P., & Giller K. E. (2013). When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture, *Field Crops Research,* 143, 76–90.

Uzoh, I.M., Igwe, C.A., Okebalama, C.B., & Babalola, O.O. (2019). Legume-maize rotation effect on maize productivity and soil fertility parameters under selected agronomic practices in sandy loam soil. *Scientific Reports*, 9, 8539.

Vancampenhou, K., Nyssen, J., Desta, G., Deckers, J., Poesen, J., Mitiku Haile, & Moeyersons J. (2006). Stone bunds for soil conservation in the Northern Ethiopian Highlands: Impacts on soil fertility and crop yield. *Soil and Tillage Research*, 90, 1-15.

Wuletawu Abera, Lulseged Tamene, Degefie Tibebe, Zenebe Adimassu, Habtemariam Kassa, habtamu Hailu, Kindu Mekonnen, Gizaw Desta, Sommer, R., & Verchot, L. (2019). Characterizing and evaluating the impacts of national land restoration initiatives on ecosystem services in Ethiopia. *Land Degradation and Development*, 31(1), 37-52.

Zenebe Adimassu, Langan, S., Johnston, R., Wolde Mekuria, & Tilahun Amede. (2017). Impacts of soil and water conservation practices on crop yield, run-off, soil loss, and nutrient loss in Ethiopia: Review and synthesis. *Environnemental Management*, 59, 87-101.

Zenebe Adimassu, Mekonnen Kassa, Yirga Chekol, & Kessler, A. (2014). Effect of soil bunds on runoff, soil and nutrient losses, and crop yield in the central highlands of Ethiopia. *Land Degradation and Development, 25, 554-564.*