Ensuring Agricultural Productivity over Time: Impact of Sustainable Land Management Program on Rural Farmers in Ethiopia

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Abstract

Agricultural productivity in the highlands of Ethiopia is threatened by severe land degradation, resulting in significant reductions in agricultural GDP. In order to mitigate ongoing erosion and soil nutrient loss in the agricultural productive highlands, the government of Ethiopia initiated a Sustainable Land Management (SLM) Program targeting 135 woredas (districts) in 6 regions of the country. This study measures the impact of the SLM program on value of production in select woredas by using a panel survey from 2010 to 2014. Whereas previous studies have used cross-sectional data and field trials to measure SLM effects on agricultural productivity, this analysis provides insight to the medium term effects of SLM investment and maintenance over a 4 year period.

Results suggest that SLM investments must be maintained in order to achieve significant increases in value of production, however this analysis suggests that exposure (in terms of time in the program) to the SLM program reaps quicker benefits than previously thought. While households that were in the SLM program for only one year prior to the end line survey had no significant increase in value of production, households that received SLM assistance for four years had an 18 percent higher value of crop production compared to control households.

1. Introduction

Agriculture remains the cornerstone of the Ethiopian economy accounting for almost two-fifths of GDP and three-quarters of total employment in 2012/13 (CSA 2014a; 2015). In order to maintain current economic growth rates (GDP grew 10.7 percent per year from 2005/06 to 2012/13), it is important that the agricultural sector remains buoyant. Given agriculture's importance in the Ethiopian economy, the government has warned of a risk of pervasive land degradation causing productivity declines throughout the agricultural highlands of the country. Production in the highlands is dominated by rainfed agriculture, characterized by a mixed crop-livestock farming system which often leaves farmland absent of groundcover and vulnerable to erosion during the rainy season (Haileslassie et al. 2005; Werner 1986). Recent studies in Ethiopia have estimated the loss of agricultural production due to land degradation ranges from 2 to 5 percent of agricultural GDP per year (Yesuf et al. 2005, citing estimates by FAO (1986); Sonneveld 2002; World Bank, 2013).

The most recent 5 year development plans highlighted sustainable land management (SLM) as a key pillar to maintaining economic growth in the country. The Plan for Accelerated and Sustainable Development to End Poverty (PASDEP – 2006-2010) outlined an investment strategy that included a series of land and watershed management activities with the goal of augmenting agricultural production. Similarly, the Growth and Transformation Plan (GTP – 2010 – 2015), prioritizes investments in soil and water conservation infrastructure that take into account the unique conditions of varying agro-ecological zones (MoFED 2010). In addition, the Ethiopia Strategic Investment Framework for Sustainable Land Management (ESIF – 2009-2023) was created to improve rural livelihoods by scaling up sustainable land management practices with the objective to restore, sustain and enhance the productivity of Ethiopia's land resources (MoARD, 2010).

In order to address ongoing concerns of land degradation in the Ethiopian highlands, the Government of Ethiopia (in collaboration with development partners) has implemented a variety of soil and water conservation programs. Most recently, the Sustainable Land Management Program (SLMP) is working in 937 *kebeles* and 135 woredas (districts) to scale up and increase adoption of appropriate SLM technologies tested for specific agro-ecological conditions in the program *kebeles* (administrative sub-districts). The program consists of three components: construct watershed and land management structures to stabilize soils, improve water retention and support efficient tillage practices; and build capacity of key service providers and rural households in planning and implementation of SLM practices.

We use panel household survey data collected in 2010 and 2014 in order to understand the impact that the SLM program had on household level value of total crop production in 9 *kebeles* (7 woredas) in the Blue Nile Basin. Given that the program was rolled out in two separate phases (2009 and 2012), we separate the sample into three 'exposure' groups: households that received 0 years of SLM program (control), households that were in the SLM program for 4 years, and households that were in the SLM program for 1 year. Results suggest that households that were exposed to 1 year of SLM program activities have no significant increases in value of total crop production compared to households that were not in an SLM program. However, households that were exposed to 4 years of SLM program activities have significantly higher value of total crop production after the 4^{th} consecutive year of being in the program. Contrary to previous studies, this evaluation suggests that improvements in agricultural productivity via investments in soil and water conservation structures are achievable within a medium time horizon.

The remainder of the paper is organized as follows. Section 2 provides a review of the literature on the impact of soil and water conservation structures in Ethiopia. Section 3 describes the panel survey data and sampling strategy. Section 4 describes the households included in the survey and specific household and agricultural production characteristics. Section 5 discusses the methods implemented to assess impact. Section 6 discusses results. We conclude in section 7.

2. Literature review

Ethiopia's ongoing land degradation continues to challenge sustainable land management interventions in a country characterized by smallholder farmers in rural areas with high population density.[3] Studies evaluating the economic costs and benefits of soil and water conservation practices suggest that agricultural production is improved by SLM structures (terraces, bunds, enclosures, etc.), however long term maintenance of SLM structures is crucial for benefits to outweigh the initial construction costs. For example, Schmidt and Tadesse (2014) report that agricultural plots in the Ethiopian highlands that received an SLM investment (soil bunds, stone terraces, or check dams) experience a significantly higher value of total crop production after 7 years of maintenance. Schmidt et al. (2014) evaluate the trade-offs of SLM investments taking into account foregone off-farm labor opportunities, and potential decreases in agricultural prices from increased supply within thin market environments. They suggest that SLM interventions must be paired with other input and infrastructure investments in order to incentivize farmer adoption and long term maintenance of SLM practices.

Estimates of the impact of soil and water conservation efforts on land productivity in Ethiopia are mixed. Pender and Gebremedhin (2006) conducted a survey of 500 households that invested in stone terraces in Tigray region, results suggest that plots with SLM experienced higher crop yields. Holden et al. (2009) measured the impact of stone terraces in Tigray region and found a significant and positive effect on land productivity. Kassie et al. (2007) found positive effects on value of total crop production of stone bunds on semi-arid plots in Tigray and Amhara, however in another study Kassie et al. (2008) found that plots with bunds resulted in lower yields (compared to plots with no bunds) in high rainfall areas in western Amhara. Araya et al. (2011) performed an experimental study over six years to look at the impact of specific soil and water conservation practices in sloping fields in the Ethiopian highlands. They report that SLM structures must be maintained for an average of five years in order to experience a significant increase in crop yield. Most importantly, although SLM investments aim to promote agricultural sustainability, studies suggest that maintenance of SLM structures

[3] The 2007 Ethiopia Population and Housing census reported that 86 percent of the Ethiopian population is rural, farming on an average 1.2 hectares per household (CSA, 2014b)

is largely absent over the medium to long term in Ethiopia (Shiferaw and Holden, 1998; Benin, 2006; Tadesse and Belay, 2004; Anley et al., 2007; Moges and Holder, 2007; WFP, 2005).

Previous studies suggest that SLM interventions must be tailored to the appropriate agro-ecological zone and that long term maintenance is critical to achieving increases in agricultural production. However, these studies rely on cross-sectional data and/or are targeted to a specific watershed, limiting more robust analysis of impact over time and geographic space. We address this limitation by using a panel survey in Amhara and Oromiya region in differing agro-ecological zones to evaluate the private benefits (in terms of household level value of total crop production) within an SLM program *kebele* that invested in household and community level soil conservation activities.

3. Survey Data

The Ethiopian Watershed Survey (EWS) was conducted in 2010 and 2014 in order to evaluate the impact of the SLMP in Amhara and Oromiya regions. The surveys were conducted by the International Food Policy Research Institute (IFPRI) in collaboration with the Ethiopian Development Research Institute (EDRI). Round 1 of the EWS was completed in September 2010 and included 1,810 households spatially distributed within the Blue Nile Basin. Round 2 of the EWS survey was completed in January 2015 and surveyed the same households. In order to minimize the effect of seasonality on impact estimates, round 1 and round 2 surveys asked about the previous harvest season (for example, Round 1 asks households to recall production totals from the *meher* harvest in 2009; Round 2 asks households to recall production totals from *meher* harvest in 2013).

The sample for the 2010 EWS was drawn from a list of *kebeles* (sub-districts) that were programmed to receive SLMP assistance. Based on the list of SLMP *kebeles*, a random sample of woredas (districts) were selected whereby a woreda must contain one SLM program *kebele*. The sample consists of approximately 200 households per woreda, and was stratified by *kebele* including households that were in: 1) a *kebele* selected for an SLM program, 2) a *kebele* not selected for an SLM program and had no experience in any past SLM program, and 3) a *kebele* that was not selected for an SLM program and had experience from a past SLMP program. The final round 1 sample included 9 woredas in 27 *kebeles*.

There were 1,810 households interviewed during the baseline (2010) survey, of which 1748 of those households were again interviewed in 2014, yielding an attrition rate of 3.4% over 4 years, or 0.85% per year. The effective sample of households for this analysis comprises households for which complete data exist on baseline and endline household characteristics, which we employ in the double difference estimation (described in section 5). In addition, 2 of the sample woredas did not receive an SLM program (Fogera and Diga woredas), thus we exclude households from these woredas. Finally, 1,352 households comprise the panel sample; the remainder of this paper limits the discussion to the households that are included in the SLM panel analysis.

4. Household characteristics and change over time

The Ethiopia Watersheds Survey (EWS) was designed to understand farmer investment of sustainable land management (SLM) structures and maintenance, as well as changes in other agricultural inputs (fertilizer, improved seeds, etc.) and their impact on agricultural productivity. The survey focused on watershed management activities, agricultural production inputs and outputs, and various factors expected to affect these activities and outcomes (i.e. household endowments of land and labor, gender composition and aspects of land tenure). The survey also collected plot-level data on crop production, soil fertility, reported erosion and other biophysical characteristics of each plot operated by the household.

Overall, households within the sample show an increase in the value of total crop production in the primary harvest (*meher*) season between 2009 and 2014. Average value of total crop production for the survey sites increased by 30 percent between the survey years from 6.4 to 8.5 thousand Birr (2009 prices) between 2009 and 2014 (Table 1). Significant increases were experienced across woredas as well (Table 1). Agricultural inputs also increased over the study period. Only 23 percent of households used improved seed on at least one of their plots in 2009, while 51 percent of households used improved seed in 2014. Similarly, fertilizer application increased over time. Approximately 68 percent of households used fertilizer in 2009 compared to 81 percent of households in 2014.[4]

Table 1: Household agricultural production and SLM activities in 2009 and 2014

	Baseline	Endline	T-test
Value of total crop production (in 2009 prices)	6,469.0	8,524.3	***
Total land ownership (ha/household)	2.0	1.9	
Cultivated land ha/household (*meher* and permanent crops)	1.6	1.5	*
Percent of total land allocated (*meher* and permanent crops):			
Cereal	78.9	76.7	*
Pulses	5.6	5.6	
Oil seeds	4.7	5.5	
Root crops	5.4	5.5	
Fruits	0.3	0.9	***
Vegetables	0.2	0.2	
Coffee	1.8	2.1	
Chat	0.1	0.2	
Other permanent crops	2.3	1.9	
Other crops	0.8	1.5	**
Percent of households with fertilizer use	68.0	80.5	***
Percent of households with improved seed use	22.9	50.9	***
Percent of households with an SLM structure	65.9	74.9	***
Percent of households with specific structures			
Irrigation	1.1	1.5	
Stone terrace	22.9	31.0	***
Soil bund	33.5	47.5	***
Check dam	0.2	1.8	***
Trenches	0.5	9.2	***
Trees planted	0.8	5.2	***
Others	3.5	10.0	***

[1] Includes *meher* and permanent crops only

The share of households (including SLM program and non-program households) that reported at least one SLM investment on at least one plot of land increased significantly from 66 to 75 percent between 2009 and 2014 (Table 1). In particular, stone terraces, soil bunds and trenches (structures that diminish erosion and siphon excess rainfall runoff away from agricultural fields) increased dramatically. In 2009, 23 and 34 percent of households reported

[4] Improved seed and fertilizer application rates in the baseline echo similar studies such as the Agricultural Growth Program (AGP) baseline data (2011) that report 22 and 57 percent of household application rates, respectively.

constructing terraces or bunds (respectively) on at least one of their plots. In 2014, approximately 31 percent of households reported using soil bunds on their land and almost half (48 percent) of the sample were using stone terraces on their land. Trench construction to direct excess runoff increased from less than 1 percent of households in 2009 to almost 10 percent of households in 2014.

Although the survey sites are within the highland regions of the Blue Nile basin in Ethiopia, substantial diversity in agricultural production exists across woredas. The main cultivated crops, as well as the mean value of total crop production vary dramatically by site. Whereas Toko Kutaye and Gozamin woreda focus 40 and 30 percent (respectively) of production area on teff (a high value crop used to make injera in Ethiopia), Jeldu woreda focuses on barley and wheat production which make up 33 and 18 percent of cropped area, respectively (Table 2). Maize production dominates in Alefa, Dega Damot and Mene Sibu comprising 22, 19 and 19 percent of total cropped area respectively.

Differences in cropping patterns are related, in part, to differences in agro-ecological zones among woredas. For example, 40 percent of households in Mene Sibu woreda are located in the lowlands (kolla agro-ecological zone), while in Dega Damot, 95 percent of sample households are located in the highlands (Dega agro-ecological zone) (Table 2). Farmers in Mene Sibu dedicate the largest share of agricultural area to maize and coffee production, while Dega Damot focuses on high elevation cultivation of barley and horse beans (a variety of fava bean). A large share of households in the sample grow crops on mixed and steep slopes. Hillside farming is particularly prevalent in Toko Kutaye where 72 percent of the cultivated area of a household is located on mixed or steep slopes. The survey also asked households about weather shocks. Data from Dega Damot suggests more extreme weather events, with 50 and 54 percent of households reporting that they experienced flooding and drought, respectively, within the last 5 years. In order to take into account these differences among program and control households, we use propensity score matching and double difference estimations to isolate impact of SLM on value of total crop production in SLM program *kebeles*.

Table 2: Biophysical and agricultural characteristics of survey woredas

	Agro-ecological Zone[1]	Steep or mixed slope[2]	Flood or too much rain[3]	Drought[3]	Major crops[2]	Value of total crop production in Birr (2009 prices)
Alefa	Woina Dega (69%) Kolla (30%)	29.4	23.2	23.2	Maize (22%) Teff (19%)	10,496
Misrak Estie	Dega (92%) Wurch (9%)	43.3	50.0	22.3	Teff (29%) Wheat (24%)	5,506
Gozamin	Woina Dega (65%) Dega(35%)	38.0	48.2	23.8	Teff (33%) Wheat (20%)	11,110
Dega Damot	Dega (95%) Woina Dega (5%)	59.0	50.5	53.5	Barley (34%) Horse beans (20%)	5,164
Mene Sibu	Woina Dega (58%) Kolla (40%)	52.5	10.1	11.1	Maize (19%) Coffee (18%)	9,261
Jeldu	Dega (82%) Woina Dega (17%)	59.8	28.1	9.4	Barley (33 %) Wheat (18%)	9,743
Toko Kutaye	Dega (65%) Woina Dega (34%)	72.1	33.7	16.3	Teff (40%) Wheat (15%)	8,112

[1] Kolla refers to lowlands (500-1,500 meters above sea level (masl)); Woina Dega refers to lower-highlands (1500-2300 masl); Dega refers to mid-highlands (2,300-3,200 masl); and Wurch refers to upper-highlands (3,200-3,700 masl)
[2] Measured in percent of cultivated area per household
[3] Households were asked whether they had experienced this weather shock in the last 5 years

5. Methodology

The SLM program was rolled out in different woredas at different times. For our particular case, the program sites (included in the household survey) in Amhara region began initial SLM activities in 2009, while SLM activities of program sites (included in the survey) in Oromiya region started in 2012. In order to take into account differences between program roll-out in Amhara region and the implementation of the baseline survey (implemented in June 2010), the questionnaire asked about production inputs and outcomes from the 2009 harvest. Although the SLM program in Amhara region started in 2009, activities in the sample *kebeles* consisted of program stakeholder meetings and initial SLM preparatory training which occurred between April and June of 2009. The rainy season begins in June for the primary *meher* harvest in this region, thus SLM activities are largely suspended until after the 2009 *meher* harvest which concludes in December and January. Given that the baseline survey collected production data from the June – January, 2009 *meher* harvest, it is unlikely that the baseline survey is contaminated. However in order to account for any minor differences across treatment *kebeles*, we control for the timing of program implementation in the regression framework. Similarly, since the survey sites in Oromiya region didn't receive an SLM program until 2012, double difference estimates that do not take into account the interaction of being in a treatment *kebele* and household exposure (number of years in the program) to an SLM program could possibly overestimate potential program impact for these households since these sites received less (in terms of time) treatment compared to *kebeles* in Amhara region.

Households are categorized as treated and control based on whether they live in *kebeles* that received an SLM program or not. Given the nature of the SLM program, particular interventions are targeted not only at the household level but also at a community level. This could mean that even though a household may not have a specific SLM structure on its land, it may benefit from other interventions, for instance, on upstream private or communal lands or from village training that forms a part of the intervention package.

In order to take into account differences in program roll-out, we create three respective groups: households that had 0 exposure to the program throughout the entire study period (control); households that had the program for 0 years at baseline and 1 year at the endline[5], and households that had the program for 1 year at baseline and 4 years at follow-up. Thus, differences (or changes) in exposure to the SLM program between the 2010 baseline and 2014 follow-up are 0, 1, and 4 years, respectively. We expand on these definitions in the following equations.

Given that the SLM program was targeted to provide assistance to communities struggling with soil and water conservation, SLM program placement was not random. In the absence of prior randomization of the SLM program, beneficiary households are likely to be systematically different from non-beneficiary households. For example, agricultural production varies dramatically across agro-ecological zones and between treated and non-treated *kebeles*,

[5] The endline survey implemented in 2014 collected data on agricultural production from the 2013 meher season.

and biophysical endowments differ depending on the location of household agricultural production and access to inputs. SLM impact estimates would be biased if the evaluation does not control for potential pre-program differences. This is the key challenge for program impact evaluations that are not randomly designed a priori.

In order to account for potential sources of selection bias, we combine propensity score matching (PSM) with double difference methods. PSM identifies comparison households based on their similarity in observable variables correlated with the probability of being in the program given observed household and village level characteristics (see Heckman et al. (1997, 1998) for greater discussion of PSM).[6] The sample is then balanced by calculating and verifying that the means of the observed characteristics are similar for treatment households as compared to non-treatment households. After matching, program impact is measured using double difference (DD) between average outcomes for households within an SLM *kebele* (treatment households) and a weighted average of outcomes for households in non-SLM *kebeles* (non-beneficiary households) where the weights are a function of observed variables.

The main strength of a DD estimate is that it removes the effect of any time-invariant unobserved variables that represent differences between the beneficiary and control group (for example unobserved factors such as market depth or farmer willingness to participate in a program). Given that DD assumes that unobserved heterogeneity is time invariant, this bias is canceled out through differencing.

In order to take into account that the SLM program was rolled out in two distinct periods in the survey sites, we calculate the DD estimate within a regression framework to further distinguish program effects by households that received the program during the first roll-out period and households that received the program during the second implementation. In doing so, rather than having a single treatment variable, we create two separate treatment groups (G_2 and G_3) based on the timing of the treatment. We then estimate equation 1 in order to understand the effects of 1 year and 4 years of exposure to the SLM program, respectively:

[6] Methodology description is adapted from Kumar and Quisumbing (2010)

$$Y_{it} = \alpha + \beta_1(G_2 t_1) + \ \beta_2(G_3 t_1) + \rho_1 G_2 + \rho_2 G_3 + \gamma t_1 + \delta X t_1 + \varepsilon_{it}$$

whereby β_1 and β_2 are the impact estimates for households in G_2 and G_3 compared to the control households, respectively. In addition to the interaction term that defines β_1 and β_2 (household group and time of endline survey), the variables G and t are included separately to account for any separate mean effects of time and of being in a specific SLM program group. Given the possibility of heterogenous secular trends, we also interact a selection of baseline covariates (X) that might have been used by program officers or local government officials to select *kebeles* into the program with the 2014 survey endline identifier. This allows the equation the flexibility of the time trend to have different effects according to its values. Finally, ε represents the error term.

6. Results and Discussion

In order to account for inherent differences in treatment and control households, we use PSM and estimate a Probit model to predict households' probability of participating in the program as a function of household and community level characteristics.[7] Out of the 1,352 households in the sample at the baseline, 1,170 households are in the common support (533 control and 637 treated households).[8] The final propensity score matching results are presented in Appendix 1. The overlap in the propensity scores distribution of the treated and control households indicates a strong common support (see Appendix 2).

We further evaluate the balancing of the distribution of variables in the propensity score matching, and results indicate that the matching has reduced the standardized bias. The statistically significant mean difference of the covariates before matching disappears after matching for almost all of the covariates. The statistically insignificant likelihood ratio test for the matched sample also indicates that the two groups have similar covariate distribution after the matching (see Appendix 3). Hence, we use these matched households to conduct the impact evaluation estimation.

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[7] Once a balanced sample is achieved, we trim 5 percent of the sample from top and bottom of the distribution and redo the balancing on the trimmed sample.

[8] After the final sample is balanced and trimmed, the analysis results in 2108 observations. Matching is performed on round 1 data. Some of the households that were in the common support in round 1 were missing or had incomplete information in round 2. This resulted in 232 households that were present in the common support being dropped from the regression in the final analysis.

Household level value of agricultural production (the outcome variable of interest) is calculated in both rounds from reported crop output in 2009 and 2013, respectively, and average 2009 CSA producer crop price data in order to maintain comparability. Since the program implementation date varies by *kebele*, we construct 3 groups: group 1 which represents the control group, group 2 that received an SLM program for 4 years, and group 3 that received an SLM program for 1 year at the time of the endline survey.

In evaluating the impact of SLM on value of total crop production, we estimate two models to insure robustness of results. In both models, we use a household fixed-effects regression to control for household's unobservable and time-invariant characteristics that could possibly influence the outcome variable of interest. Appendix 4 presents the descriptive statistics of the outcome variable and a complete list of control variables that are used in the impact evaluation regression.

Model 1 takes into account other potential determinants of value of total crop production controlling for household and land characteristics, shocks, and input use. However, controlling for initial differences at baseline, it is possible that treatment and control households may experience divergent trajectories between the two survey periods. For example, agricultural extension service delivery may be similar in the treatment and control *kebeles*, however the effect of extension information may differ over time depending on whether a household is within an SLM *kebele* or not. We can think of a scenario where development agents (DA) are better informed due to increased training, or conversely a household is more inclined to take advice from a DA since being included in the SLM program. To control for such heterogeneous secular trends among the control and treated groups we also interact cropping patterns, land characteristics, input variables and extension services with the 2014 survey end line identifier (year 2014 dummy) and estimate a second model (Model 2).

Table 3 presents the results of the impact evaluation estimation. The regression results from Model 1 suggest that households that were in an SLM *kebele* for four years at the time of the endline survey (received an SLM program in 2009) have 17 percent higher value of total crop production than households that were not involved in an SLM program, after controlling for other possible determinants. Households that have been in an SLM *kebele* for 1 year (received the program in 2012) do not have any statistically significant increases in value of total crop production in 2013 compared to control households. Model 2 estimation of impact of SLM on household value of total crop production are similar to Model 1 results after controlling for the possibility of heterogeneous trends in the covariates between the different groups of households over the two survey periods. Model 2 results suggest that households in an SLM program *kebele* in 2009 have 18 percent greater value of production in 2013 compared to households were not in an SLM *kebele*.

Table 3: Double difference regression results

	Model 1	Model 2
Year 2014 (yes=1)	0.374**	0.439*
	(0.157)	(0.245)
Group2*year 2014	0.179**	0.183*
	(0.080)	(0.097)
Group3*year 2014	0.009	-0.174
	(0.164)	(0.175)
Household size	0.047	0.04
	(0.052)	(0.057)
Number of dependents	0.012	0.025
	(0.032)	(0.032)
Number of male adults in the households	-0.01	-0.028
	(0.068)	(0.072)
Tropical Livestock units	0.041***	0.021
	(0.013)	(0.013)
Participated in nonfarm activity (yes=1)	0.067	0.088
	(0.069)	(0.064)
Participated in wage work (yes=1)	0.012	-0.009
	(0.055)	(0.052)
Land size in hectares	0.297***	0.332***
	(0.053)	(0.054)
Land size squared	-0.019***	-0.020***
	(0.004)	(0.004)
Proportion of fertile land	0.084	0.089
	(0.085)	(0.079)
Proportion of steep land	-0.187	-0.11
	(0.159)	(0.257)
Proportion of land with mixed slope	-0.035	-0.031
	(0.095)	(0.121)
Improved seed use (yes=1)	0.124**	0.022
	(0.055)	(0.075)
Fertilizer use (yes=1)	0.485***	0.495***
	(0.080)	(0.100)
Credit (yes=1)	-0.048	-0.023
	(0.054)	(0.054)
Number of agricultural extension agents	-0.079	0.198
	(0.114)	(0.145)
Experienced drought in the past 5 years (yes=1)	-0.115**	-0.125**
	(0.057)	(0.058)
Experienced flood in the past 5 years (yes=1)	-0.055	-0.068
	(0.052)	(0.047)
Experienced severe erosion (yes=1)	0.076	0.067
	(0.116)	(0.170)
Average rainfall (average of the past 30 years)	-0.686	-0.913
	(0.600)	(0.610)
Average temperature (average of the past 30 years)	-5.853**	-6.239***
	(2.333)	(2.313)
Land in hectares*year 2014		-0.046

			(0.030)
Proportion of steep slope*year 2014			-0.048
			(0.345)
Proportion of mixed slope*year 2014			-0.021
			(0.138)
Improved seed use*year 2014			0.187**
			(0.094)
Fertilizer use*year 2014			-0.01
			(0.146)
Number of agricultural extension agents*year 2014			-0.240**
			(0.101)
TLU*year 2014			0.027**
			(0.013)
Experience severe erosion*year 2014			-0.02
			(0.242)
R-squared			
	Within	0.3509	0.3822
	between	0.0125	0.013
	overall	0.0072	0.0075
Number of observations		2108	2108

Source: Authors’ computation from SLM surveys (2010 and 2014)
Note: Figures in parentheses are robust standard errors; ***Significant at 1% level; **Significant at 5% level; *Significant at 10% level. Other controls included are proportion of land allocated to different crop types and their interaction with year 2014 dummy.

Overall, there were statistically significant cereal yield increases for households in treated and control *kebeles* (Table 4). In part, this is likely due to increases in the number of households using fertilizer and improved seed over time, whereby approximately twice the amount of households are using improved seed in the treatment and control households. Similarly, both treatment and control households increased investments in SLM structures. While the overall increase in an SLM structure in treatment and control households was not significant, specific investments in SLM structures in both groups significantly increased across all SLM structure types with the exception of irrigation infrastructure (Table 4).

Table 4: Agricultural production inputs and outputs in treated and control kebeles

Households in Treated Kebeles				**Households in Control Kebeles**			
	Baseline	**Endline**	**T-test**		**Baseline**	**Endline**	**T-test**
Value of total crop production (2009 prices)	6,254	8,450	***	**Value of total crop production (2009 prices)**	6,679	8,596	***
Cereal	4,728	5,606	***	Cereal	4,932	5,880	
Pulses	647	640		Pulses	1,006	997	
Oil seeds	874	870		Oil seeds	1,811	1,945	
Root crops	651	1,192	***	Root crops	760	1,816	***
Fruits	564	546		Fruits	539	422	*
Vegetables	395	405		Vegetables	179	323	
Coffee	7,327	6,557		Coffee	4,230	3,395	**

Chat	292	16,406		Chat	193	3,379	
Other permanent crops	6	13		Other permanent crops	19	20	
Other crops	906	460		Other crops	2,290	1,844	
Percent of total land allocated				**Percent of total land allocated**			
Cereal	78.9	77.7		Cereal	78.9	75.7	***
Pulses	4.8	5.2		Pulses	6.4	6.0	
Oil seeds	3.8	3.4		Oil seeds	5.6	7.5	**
Root crops	6.1	5.7		Root crops	4.6	5.3	
Fruits	0.5	0.9		Fruits	0.1	0.8	***
Vegetables	0.3	0.1		Vegetables	0.1	0.2	
Coffee	2.3	2.8		Coffee	1.2	1.3	
Chat	0.1	0.4	***	Chat	0.0	0.1	
Other permanent crops	2.8	2.2		Other permanent crops	1.7	1.7	
Other crops	0.2	1.6	***	Other crops	1.3	1.4	
Yield (kg/hectare)				**Yield (kg/hectare)**			
Cereal	1,353	1,404	**	Cereal	1,278	1,548	***
Pulses	1,085	1,160		Pulses	1,236	1,015	*
Oil seeds	607	688		Oil seeds	1,269	721	
Root crops	5,451	7,981	***	Root crops	7,071	7,458	
Fruits	7,204	20,054		Fruits	17,777	25,784	
Vegetables	4,503	14,408		Vegetables	1,772	2,884	
Coffee	730	1,169	***	Coffee	883	1,179	**
Chat	3,344	24,505	*	Chat	1,518	3,286	
Other permanent crops	16,546	33,547	*	Other permanent crops	16,493	28,489	
Other crops	1,516	7,707		Other crops	3,326	2,317	
Fertilizer use	77.5	84.8	***	**Fertilizer use**	58.7	76.3	***
Improved seed	28.7	55.2	***	**Improved seed**	17.3	46.5	***
SLM structure	71.7	79.9		**SLM structure**	60.2	70.0	
Irrigation	1.2	1.9	-	Irrigation	1.0	1.0	-
Stone terrace	23.0	32.6	***	Stone terrace	22.9	29.4	***
Soil bund	45.9	52.0	***	Soil bund	21.3	43.0	***
Check dam	0.1	2.2	***	Check dam	0.3	1.5	***
Trenches	0.9	8.2	***	Trenches	0.1	10.3	***
Trees planted	0.7	6.6	***	Trees planted	0.9	3.8	***
Others	4.9	12.0	***	Others	2.1	8.0	***

Note: Fertilizer use, improved seed, SLM structures and Specific SLM structures report percent of households that use the specific technology; Crop data report *meher* season and permanent crops

Baseline and endline data in treated households suggest that yield increases in specific crops and changes in cropping patterns may have driven a large share of the increase in value of production in treated households. For example, households in the treatment group experienced a 46 percent increase in yield of root crops (which represent 5.7 percent, the second largest share, of the cropped area in treated households) compared to no significant increases in these crops in control kebeles (Table 4). For coffee and pulses, SLM investments appear to have prevented yield and production declines, rather than increased output. There was no significant change in the value of production of either crop in treatment *kebeles*, while coffee production declined significantly and yields of pulses fell (by 22 percent) in control households.

Cereal yields were significantly higher for both treatment and control households, however there was no significant increase in the value of cereal production in control households. A closer examination of individual cereals shows that there was a significant shift in area from wheat to (higher-value) teff in treatment *kebeles*. Although there was significant decline in teff yields, the value of teff production increased due to a 5 percentage point increase in the share of area planted to teff (that was accompanied by a 7 percentage point decrease in the share of area planted to wheat, Table 5).

Table 5: Cereal crop production in control and treated kebeles

Households in treated kebele				**Households in Control kebele**			
	Baseline	**Endline**	**T-test**		**Baseline**	**Endline**	**T-test**
Area (Percent of total land allocated)				**Area (Percent of total land allocated)**			
Cereals	0.79	0.77		**Cereals**	0.79	0.79	
Teff	0.33	0.38	***	Teff	0.35	0.38	**
Barley	0.34	0.36		Barley	0.30	0.38	***
Wheat	0.34	0.27	***	Wheat	0.29	0.30	
Maize	0.25	0.23		Maize	0.24	0.24	
Sorghum	0.19	0.23	*	Sorghum	0.31	0.30	
Value of production (2009 prices)				**Value of production (2009 prices)**			
Cereal	4,728	5,606	***	**Cereal**	4,932	5,880	
Teff	2,767	2,751		Teff	3,308	2,799	
Barley	1,501	2,308	***	Barley	1,524	2,407	***
Wheat	1,811	1,837		Wheat	1,962	2,079	***
Maize	1,366	1,919	***	Maize	1,011	1,672	
Sorghum	1,267	948	***	Sorghum	1,527	1,800	***
Yield (kg/hectare)				**Yield (kg/hectare)**			
Cereal	1,353	1,404	**	**Cereal**	1,278	1,548	***
Teff	1,056	954	***	Teff	970	965	
Barley	1,446	1,478		Barley	1,252	1,467	***
Wheat	1,546	1,508		Wheat	1,317	1,485	***
Maize	1,455	1,884	***	Maize	1,523	2,045	***
Sorghum	1,004	1,336	**	Sorghum	1,261	1,456	**

The significant increase in value of production in this study after 4 years suggests that SLM investments may reap quicker benefits than previously thought. In the baseline evaluation, Schmidt and Tadesse (2014) report that the impact of SLM investments on plot-level value of production is not significantly greater than matched plots with no SLM investments until after 7 years of ongoing maintenance of the SLM structure. However, the baseline evaluation was unable to identify potential community level effects of being within an SLM program *kebele*. In addition, the baseline evaluation was unable to control for specific program implementation because analysis was limited to defining SLM treatment as any plot that had received an SLM investment (regardless of whether the household was in an SLM *kebele* or not). The panel data analysis presented in this paper allows impact to be assigned to a distinct program with explicitly defined exposure periods. Double difference results echo the previous baseline analysis, suggesting that longer term maintenance of SLM structures remains an important component to program planning. Nevertheless, results suggest that households within an SLM program *kebele* achieve significantly greater value of production within 4 years of program exposure.

7. Conclusion

In a country with 86 percent of the population in rural areas and three quarters of the labor force employed in agriculture, ensuring sustainable agricultural production is vital to maintaining economic growth. The government of Ethiopia has prioritized the need to address ongoing land degradation in the agricultural highlands by investing in a wide-spread Sustainable Land Management Program (SLMP). In 2009, the SLMP was launched to provide assistance and funding in three key areas: construction of soil and water conservation structures, capacity building of watershed and landscape planning, and enhanced land tenure security for households within the SLMP program areas.

In order to understand the potential impact of the SLMP on treatment households, we use panel household survey data collected in 2010 and 2014 to compare value of total crop production between treatment and control households within the same woreda. Given that the SLM program was rolled out in two separate phases (2009 and 2012), we form three 'exposure' groups: households that received 0 years of SLM program (control), households that were in the SLM program for 4 years, and households that were in the SLM program for 1 year. Results suggest households with only 1 year of SLM program activities (SLM program started in 2012) have no significant increase in value of total crop production. However, households that were in an SLM program since 2009 (4 years) show significantly higher value of total crop production in 2013 compared to the control group. Contrary to previous studies, this evaluation suggests that improvements in agricultural productivity via investments in soil and water conservation structures are achievable within a medium time horizon.

According to the SLM program implementation documents, a large emphasis was placed on community participation and identification of appropriate SLM investments taking into account differences in household livelihoods in different geographic areas. Moreover, rather than individual investments, the SLM program targeted private and communal land investments in an effort to enhance household level agricultural output via improved and rehabilitated landscape development. Going forward, understanding the magnitude of impact of individual components of the SLM program would provide greater understanding as to how to prioritize or replicate specific interventions in other similar agricultural development programs.

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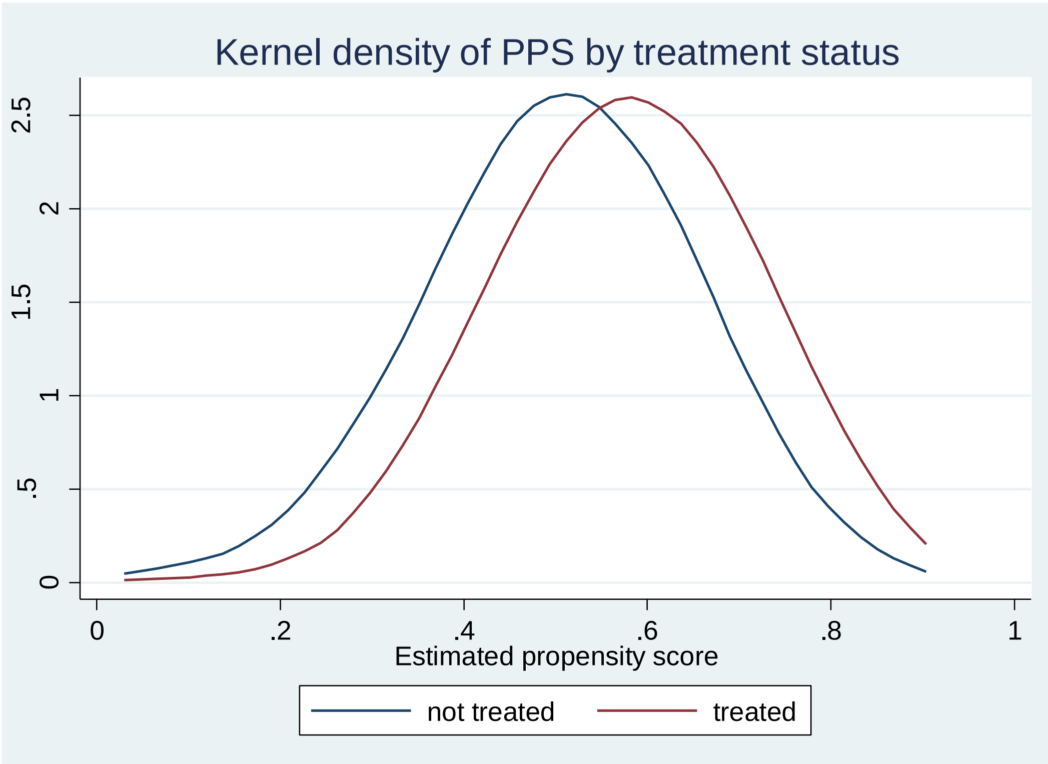
Appendix 1: Result of the propensity score estimate

Variable	Coefficients and standard errors
Head age (in years)	0.005*
	(0.003)
Head education (in years)	-0.016
	(0.015)
Head sex (male=1)	0.302
	(0.231)
Household size	0.053**
	(0.026)
log (land size in ha)	-0.233***
	(0.057)
Head is an official (yes=1)	0.199*
	(0.108)
Number of dependents	-0.167***
	(0.034)
Household has experienced drought in the past 5 years (yes=1)	-0.336***
	(0.082)
Head married (yes=1)	-0.163
	(0.225)
Head was born in the village (yes=1)	0.052
	(0.112)
Proportion of land on cereals	-0.127
	(0.175)
log (Temprature in degree celcius)	1.101**
	(0.500)
log (Rainfall in mm)	0.620*
	(0.368)
Woreda (Omitted=Low lands (500-1500meters)	
Low highland (1500-2300)	6.760***
	(1.726)
Mid highlands (2300-3200)	6.735***
	(1.793)
High highlands (3200-3700)	5.373***
	(1.772)

Source: Authors' calculation from SLM Survey (2010)

Note: *, **, and *** are significance level at 10%, 5% and 1%, respectively; Standard errors in parenthesis.

Appendix 2: Distribution of the propensity scores of treated and non-treated households



Source: Authors' computation from SLM survey (2010)

Appendix 3: Propensity Score and Covariate Balance

Variable	Unmatched Matched	Mean Treated	Mean Control	%bias	%reduct |bias|	t-test t	t-test p>|t|
Propensity score	U	0.575	0.402	92.4		16.59	0
	M	0.575	0.575	-0.1	99.9	-0.02	0.983
Head age (in years)	U	47.538	44.866	18		3.31	0.001
	M	47.796	47.546	1.7	90.7	0.3	0.763
Head education (in years)	U	1.839	1.982	-5.2		-0.96	0.335
	M	1.765	1.844	-2.9	44.5	-0.52	0.6
Head sex (male=1)	U	5.949	6.285	-14.3		-2.62	0.009
	M	5.978	6.173	-8.3	41.8	-1.53	0.127
Head married (yes=1)	U	0.842	0.868	-7.3		-1.35	0.178
	M	0.845	0.849	-1.2	83.6	-0.21	0.834
Head was born in the village (yes=1)	U	0.851	0.758	23.7		4.35	0
	M	0.851	0.806	11.3	52.2	2.11	0.035
Head is an official (yes=1)	U	0.854	0.880	-7.5		-1.39	0.166
	M	0.862	0.860	0.6	92.2	0.1	0.918
Household size	U	0.425	0.537	-14		-2.58	0.01
	M	0.428	0.465	-4.6	67.2	-0.83	0.409
Number of dependents	U	2.683	3.181	-30		-5.51	0
	M	2.686	2.728	-2.5	91.7	-0.47	0.638
Household had experienced drought in the past 5 years (yes=1)	U	0.455	0.545	-18.1		-3.33	0.001
	M	0.477	0.452	5.1	72	0.9	0.367
log (land size in ha)	U	0.167	0.142	6.8		1.24	0.214
	M	0.170	0.187	-4.9	27	-0.83	0.406
Proportion of land on cereals							
	U	0.789	0.789	0.1		0.02	0.987
log (Temperature in degree Celsius)	M	0.792	0.789	1.4	-1373.3	0.23	0.815
	U	0.000	0.201	-70.9		-12.99	0
log (Rainfall in mm)	M	0.000	0.000	0	100	.	.
	U	0.420	0.295	26.3		4.84	0
Agro-ecological zone (Omitted=Low lands (500-1500meters))	M	0.411	0.405	1.4	94.7	0.24	0.812
Low highland (1500-2300)	U	0.003	0.023	-18		-3.3	0.001
	M	0.003	0.002	1.4	92.4	0.57	0.565
Mid highlands (2300-3200)	U	2.955	2.990	-32.1		-5.85	0
	M	2.956	2.952	2.9	91	0.55	0.582
High highlands (3200-3700)	U	1.536	1.505	27.1		4.96	0
	M	1.535	1.536	-0.6	97.7	-0.11	0.91

	Ps R2	LR chi2	p>chi2	MeanBias	MedBias	B	R	%var
Unmatched	0.058	93.55	0	24.2	18	57.0*	0.75	56
Matched	0.007	11.73	0.762	3	1.7	19.2	0.86	56

* if variance ratio outside [0.86; 1.16] for U and [0.86; 1.17] for M

Source: Authors' computation from SLM survey (2010)

Appendix 4: Descriptive statistics of the variables included in the difference-in-difference regression

	Number of observation	Mean	Standard Deviation	Min	Max
Outcome Variable					
Value of total crop production (in Birr)	2108	7386.65	6433.91	0.00	49997.6
Control Variables					
Household characteristics					
Age of head (in years)	2108	48.04	14.85	16	99
Head is married (yes=1)	2108	0.86	0.34	0	1
Education of head (in years)	2108	1.96	2.74	0	15
Sex of head (male=1)	2108	0.87	0.33	0	1
Head was born in the village (yes=1)	2108	0.87	0.34	0	1
Head holds an official position (yes=1)	2108	0.19	0.39	0	1
Household size	2108	6.63	2.35	1	20
Number of dependents	2108	2.97	1.53	0	9
Number of male adults in the households	2108	3.43	1.67	0	10
Tropical Livestock units	2108	4.36	3.45	0	27.4
Participated in nonfarm activity (yes=1)	2108	0.19	0.40	0	1
Participated in wage work (yes=1)	2108	0.45	0.50	0	1
Land characteristics					
Land size in hectares	2108	1.94	1.67	0.0	16.7
Proportion of fertile land	2108	0.37	0.35	0	1
Proportion of steep land	2108	0.12	0.22	0	1
Proportion of land with mixed slope	2108	0.40	0.32	0	1
Experienced severe erosion (yes=1)	2108	0.16	0.24	0	1
Input Use					
Improved seed use (yes=1)	2108	0.41	0.49	0	1
Fertilizer use (yes=1)	2108	0.82	0.38	0	1
Number of extension agents in the Kebele	2018	0.99	0.49	0	3
Crop choice (Proportion of land with)					
Cereals	2108	0.79	0.22	0	1
Pulses	2108	0.06	0.12	0	1
Oil seeds	2108	0.03	0.09	0	1
Root crops	2108	0.06	0.13	0	1
Fruits	2108	0.01	0.04	0	1
Vegetables	2108	0.00	0.02	0	1
Coffee	2108	0.01	0.07	0	1
Permanent crops	2108	0.03	0.11	0	1
Shocks					
Experienced drought in the past 5 years (yes=1)	2108	0.40	0.49	0	1
Experienced flood in the past 5 years (yes=1)	2108	0.36	0.48	0	1
Experienced severe erosion (yes=1)	2108	0.16	0.24	0	1
Average rainfall (past 30 years)	2108	4.71	0.54	4.0	5.6
Average temperature (past 30 years)	2108	19.20	2.00	17.3	24.2

Source: Authors' computation from SLM survey (2010 and 2014)

Note: Data report households that are in the common support only, thus are not comparable with Table 1 in the text.