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The Sustainable Land Management Program in the Ethiopian highlands

An evaluation of its impact on crop production

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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 productive agricultural highlands of the country, the government of Ethiopia initiated a Sustainable Land Management Program (SLMP) targeting 209 woredas (districts) in six regions of the country. This study evaluates the impact of SLMP on the value of agricultural production in select woredas by using a panel survey from 2010 to 2014. Whereas previous studies have used cross-sectional data and short timeframe field trials to measure sustainable land management (SLM) effects on agricultural productivity, this analysis exploits data collected over four years to assess impact.

The results of this analysis show that participation by farmers in SLMP, regardless of the number of years of participation in the program, is not associated with significant increases in value of production. This may be due to several reasons. First, similar to previous studies, it is possible that longer term maintenance is necessary in order to experience significant benefits. For example, Schmidt and Tadesse (2014) report that farmers must maintain SLM for a minimum of seven years to reap benefits in value of production. Second, this analysis finds that value of production, as well as SLM investments, increased significantly in both treatment and non-treatment areas over the study period. Previous research has found that non-treatment neighbors learn from nearby program areas, and adopt technologies similar to programed areas, which would dilute the impact measurement of program effects (Bernard et al. 2007; Angelucci and DiMaro 2010). Finally, it is important to note that kebeles that were not selected in the SLMP, but are downstream relative to a targeted kebele may receive indirect benefits through reduced flooding, increased water tables, etc. Thus, the impact of the SLMP may be underestimated in this analysis if non-program kebeles are benefiting indirectly from the program.

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 rain-fed agriculture within 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 five-year development plans for Ethiopia 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) implemented the Sustainable Land Management Program (SLMP) starting in 2009. The program is currently working in 937 *kebeles* (177 critical watersheds) and 209 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 four components: construct watershed and land management structures to stabilize soils; improve water retention and support efficient tillage practices; build capacity of key service providers and rural households in planning and implementation of SLM practices; and enhance land tenure security of smallholder farmers.

We use panel household survey data collected in 2010 and 2014 in order to evaluate the impact of SLMP at household and plot level 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 for the household level analysis:

- households that did not participate in SLMP (control),
- households that were in SLMP for one year, and
- households that were in SLMP for four years.

Results suggest that regardless of household level exposure to the program, SLMP activities have no impact on the value of total crop production compared to households that were not in SLMP. To test the robustness of these results, we compare plot level data of treatment and non-treatment groups with regards to SLMP using single-difference estimates. This allows us to account for possible smoothing effects in the household level analysis given that agricultural plots differ in terms of slope, fertility, and access to infrastructure. Similar to the household-level results, we find no impact on value of production at the plot level for either exposure group. These results provide a quantifiable justification to previous findings suggesting that improvements in agricultural productivity via investments in soil and water conservation structures are achievable only within a medium- to long-term 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.

1. LITERATURE REVIEW

Ethiopia's ongoing land degradation continues to challenge SLM interventions in a country characterized by smallholder farmers in rural areas with high population density.[1] 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 in order 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) only experienced a significantly higher value of total crop production after seven 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. The 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 realize a significant increase in crop yield. Most importantly, although SLM investments aim to promote agricultural sustainability, studies suggest that maintenance of SLM structures 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 rely on cross-sectional data or are targeted to a specific watershed, thus limiting more robust analysis of the impact over time and geographic space. We address this limitation by using panel survey data collected over four years in Amhara and Oromiya region in differing agro-ecological zones to evaluate the potential impact of SLM interventions on household-level value of agricultural production and to conduct robustness checks at plot level.

[1] 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)

2. SURVEY DATA

The Ethiopian Watershed Survey (EWS) was conducted in 2010 and 2014 in Amhara and Oromiya regions. The surveys were implemented 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 of the EWS surveys focused on production in the previous harvest season. That is, in Round 1 survey sample households were asked to recall production totals from the *meher* harvest in 2009, while in Round 2 households were asked to recall production totals from the *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 SLMP *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 SLMP intervention[2], 2) a *kebele* not selected for an SLMP intervention and had no experience with SLMP, and 3) a *kebele* that was not selected for an SLMP intervention, but had experience with SLMP in the past. The final Round 1 sample included 9 woredas in 27 *kebeles*.

Of the 1,810 households interviewed during the baseline survey of 2010, 1,748 of those households were again interviewed in 2014, yielding an attrition rate of 3.4 percent over four years, or 0.85 percent 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, two of the sample woredas did not receive an SLMP intervention (Fogera and Diga woredas), thus we exclude households from these woredas. In sum, 1,355 households comprise the panel sample. The discussion in the remainder of this paper is limited to the households in this SLM panel sample.

3. HOUSEHOLD CHARACTERISTICS AND CHANGE OVER TIME

The Ethiopia Watersheds Survey (EWS) was designed to understand farmer investment in the construction and maintenance of SLM structures, as well as changes in their use of 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, including gender composition of labor and aspects of land tenure. The survey also collected plot-level data on crop production, soil type, erosion, and other biophysical characteristics of each plot operated by survey households.

Overall, survey sample households show an increase in the average 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 approximately 17 percent from 5,700 to 6,700 Birr (2009 prices) between 2009 and 2014 (Table 4.1). Agricultural inputs also increased over the study period. Only 24 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.[3]

The share of households (including SLMP 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 4.1). 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 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 constructed stone terraces on their land.

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[2] Within these kebeles, the SLMP program identified specific micro-watersheds to target for program assistance. In order to obtain a representative sample of program households, the survey team randomly selected households from within the critical micro-watershed of the program kebele.

[3] 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.

Table 4.1: Household agricultural production and sustainable land management activities in 2009 and 2014

	Baseline	Endline	t-test
Value of total crop production, 2009 prices	5,710	6,660	***
Total land ownership, ha/household	2.0	1.9	
Cultivated land (*meher* and permanent crops), ha/household	1.6	1.5	*
Percent of total cultivated land, by crop:			
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	
Other permanent crops	2.3	1.9	
Other crops	0.8	1.5	**
Fertilizer use, percent of households	68.0	80.5	***
Improved seed use, percent of households	24.1	50.9	***
Have an SLM structure, percent of households	66.0	74.9	***
Percent of households with specific structures:			
Irrigation	1.1	1.5	
Stone terrace	22.9	30.9	***
Soil bund	33.4	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.
Source: Authors' calculations from Ethiopia Watersheds Survey (2010, 2014)

Although the survey sites are all located within the highland regions of the Blue Nile basin, substantial diversity in agricultural production exists across woredas. Differences in cropping patterns and farming practices 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 4.2). Similarly, 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, whereas in Alefa woreda 30 percent of agricultural land is located on sloped terrain.

Table 4.2: Biophysical and agricultural characteristics of survey woredas

Survey woreda	Agro-ecological zone[1]	Steep or mixed slope, %[2]	Flood or too much rain, %[3]	Drought, %[3]	Major crops[2]	Average value of total crop production, in 2009 prices
Alefa	Woina Dega (69%) Kolla (30%)	29.4	24.1	28.4	Maize (22%) Teff (19%)	8,761
Misrak Estie	Dega (92%) Wurch (9%)	43.3	52.9	27.0	Teff (29%) Wheat (24%)	5,434
Gozamin	Woina Dega (65%) Dega (35%)	38.0	49.7	31.6	Teff (33%) Wheat (20%)	8,984
Dega Damot	Dega (95%) Woina Dega (5%)	59.0	52.5	55.6	Barley (34%) Horse beans (20%)	4,337
Mene Sibu	Woina Dega (58%) Kolla (40%)	52.5	10.1	12.1	Maize (19%) Coffee (18%)	5,994
Jeldu	Dega (82%) Woina Dega (17%)	59.8	29.2	11.5	Barley (33 %) Wheat (18%)	7,713
Toko Kutaye	Dega (65%) Woina Dega (34%)	72.1	37.4	19.0	Teff (40%) Wheat (15%)	5,792

[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 five years.
Source: Authors' calculations from Ethiopia Watersheds Survey (2010).

Crop cultivation has a direct effect on the mean value of total crop production regardless of SLM investments. Whereas households in Alefa and Gozamin obtain a comparatively high value of production (greater than 8,700 birr per year) by focusing on teff, maize, and wheat production, Dega Damot focuses on high elevation cultivation of barley and horse beans (a variety of fava bean) with farmers averaging a value of crop production of approximately 4,300 Birr per year. Differences in weather-related agricultural shocks across woredas may also affect overall value of crop production. 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 five 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 the impact of SLM on the value of total crop production in SLMP *kebeles*.

4. METHODOLOGY

SLMP was rolled out in different woredas at different times. The program sites in Amhara region began initial SLM activities in 2009, while SLM activities at program sites in Oromiya region started in 2012. In order to take into account differences between program roll-out, the baseline questionnaire asked about production inputs and outcomes from the 2009 harvest. Although the SLMP 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 were largely suspended until after the 2009 *meher* harvest which ended in December and January. Given that the baseline survey asked farmers to recall production from the 2009 *meher* harvest (June 2009 - January 2010), it is unlikely that the baseline survey data 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 SLMP was not implemented at the survey sites in Oromiya region until 2012, double-difference estimates must take into account the interaction of being in a treatment *kebele* and household exposure (number of years in the program) in order to ensure that potential program impact is not underestimated in Amhara and overestimated in Oromiya.

Households are categorized as treated and control based on whether they live in *kebeles* that received an SLMP intervention or not. Given the nature of SLMP, particular interventions are targeted not only at the household level but also at the 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 example, on upstream private or communal lands or from village training that forms a part of the intervention package.[4]

In order to take into account differences in program roll-out, we create three respective groups: households that had no exposure to the program throughout the entire study period (control, in both Amhara and Oromiya); households that had the program for one year at baseline and four years at follow-up (in Amhara); and households that had the program for zero years at baseline and for one year at the endline (in Oromiya).[5] Thus, differences (or changes) in exposure to the SLMP between the 2010 baseline and 2014 follow-up are zero, four, and one years, respectively. We expand on these definitions in the following equations.

Given that SLMP 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 SLMP, 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*, 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 comparable households based on their similarity in observable variables correlated with

[4] Not all households in the programmed kebeles may have received direct support from SLMP if they were not located in the specific micro-watershed that received assistance. Given that kebeles are geographically small, we assume that information spillovers to other households in the kebele, as well as indirect benefits of SLMP program implementation would have some influence over households that may have not received direct support. Thus, we include these households in the treatment group.

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

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 SLMP *kebele* (treatment households) and a weighted average of outcomes for households in non-SLMP *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 depth of market participation 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 accommodate for the SLMP rollout 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 four years and one year of exposure to SLMP, respectively:

$$Y_{it} = \alpha + \beta_1(G_2t_1) + \beta_2(G_3t_1) + \rho_1G_2 + \rho_2G_3 + \gamma t_1 + \delta Xt_1 + \varepsilon_{it} \qquad [1]$$

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 SLMP 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.

5. RESULTS AND DISCUSSION

5.1 Propensity score matching

In order to account for inherent differences in treatment and control households, we use propensity score matching (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 1,355 households in the sample present in both the baseline and the endline rounds, 1,168 households are in the common support (531 control and 637 treated households). 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 PSM. The 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.

5.2 Difference in difference evaluation

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 three groups: group 1 which represents the control group, group 2 that received SLMP for four years by the time of the endline survey round, and group 3 that received SLMP for one year by the time of the endline survey round.

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

[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.

Evaluating the impact of SLM on value of total crop production, we estimate two models to insure robustness of the 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 value of production. 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 potential determinants of the value of total crop production outside of SLM investments, 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 SLMP *kebele* or not. Consider a scenario where development agents (DA) are better informed due to increased training or a household is more inclined to take advice from a DA since being included in SLMP. 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 6.1: Double-difference regression results to investigate the contributions of Sustainable Land Management investments on the value of total crop production

	Model 1		Model 2	
	Coefficient	Stnd error	Coefficient	Stnd error
Year 2014 (yes=1)	0.282*	(0.155)	0.392	(0.242)
Group2*year 2014	0.118	(0.079)	0.105	(0.095)
Group3*year 2014	-0.024	(0.168)	-0.162	(0.178)
Household size	0.034	(0.052)	0.029	(0.056)
Number of dependents in household	0.029	(0.032)	0.035	(0.032)
Number of male adults in household	0.003	(0.068)	-0.001	(0.073)
Tropical Livestock Units (TLU) owned, number	0.045***	(0.014)	0.023	(0.015)
Participated in nonfarm activity (yes=1)	0.068	(0.069)	0.094	(0.061)
Participated in wage work (yes=1)	-0.023	(0.055)	-0.038	(0.051)
Land size in hectares	0.298***	(0.052)	0.332***	(0.055)
Land size squared	-0.018***	(0.004)	-0.020***	(0.004)
Proportion of fertile land	0.130	(0.083)	0.147*	(0.078)
Proportion of steep land	-0.232	(0.157)	-0.123	(0.261)
Proportion of land with mixed slope	-0.061	(0.094)	-0.086	(0.121)
Improved seed use (yes=1)	0.127**	(0.055)	0.016	(0.073)
Fertilizer use (yes=1)	0.490***	(0.079)	0.492***	(0.099)
Credit (yes=1)	-0.048	(0.053)	-0.026	(0.054)
Number of agricultural extension agents in *kebele*	-0.038	(0.114)	0.241*	(0.142)
Experienced drought in the past 5 years (yes=1)	-0.121**	(0.056)	-0.129**	(0.059)
Experienced flood in the past 5 years (yes=1)	-0.036	(0.051)	-0.040	(0.047)
Experienced severe erosion (yes=1)	0.073	(0.116)	0.053	(0.172)
Average rainfall (average of past 30 years)	-0.827	(0.595)	-1.334**	(0.639)
Average temperature (average of past 30 years)	-4.408*	(2.300)	-4.925**	(2.301)
Land in hectares*year 2014	-	-	-0.050	(0.033)
Proportion of steep slope*year 2014	-	-	-0.134	(0.353)
Proportion of mixed slope*year 2014	-	-	0.021	(0.135)
Improved seed use*year 2014	-	-	0.191**	(0.094)
Fertilizer use*year 2014	-	-	-0.052	(0.145)
Number of agricultural extension agents*year 2014	-	-	-0.251**	(0.104)
TLU*year 2014	-	-	0.032**	(0.014)
Experience severe erosion*year 2014	-	-	0.027	(0.244)
R-squared				
Within	0.375		0.404	
between	0.006		0.007	
overall	0.004		0.004	
Number of observations	*2,118*		*2,118*	

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.

Source: Authors' computation from EWS surveys (2010 and 2014)

Table 6.1 presents the results of the impact evaluation estimation. The regression results from Model 1 suggest that regardless of the amount of time in an SLMP (one or four years), households that were in the treatment group (Group 2 or Group 3) do not have any statistically significant increases in value of total crop production in 2013 compared to control households. Model 2 estimations echo Model 1 results after controlling for the possibility of heterogeneous secular trends in the covariates between the different groups of households over the two survey periods.[8]

A possible explanation for these lackluster results could be that analysis at the household level does not sufficiently capture the variety of plot-level characteristics and investments that are being employed at the sub-household level. Households in the Ethiopian highlands typically have more than a single plot, and often plots are not contiguous. In the study sites, households have an average of nine plots, with some households having more than 15 plots. This diversity across the landscape may allow farmers to benefit from unobservable differences in soil characteristics, soil fertility, and soil moisture. Differences in plot characteristics would also affect farmer's decisions on land management strategies. As a robustness test, we used the plot level data from the 2014 survey in order to perform single-difference estimates in outcomes analysis by matching household-owned plots (we do not include rented in or rented out plots) that are within an SLMP kebele with household-owned plots that are located in a control kebele.

Similar to the household level analysis, we estimated a propensity score that is based on a probit regression (at the plot level) of the probability of investing in SLM given observed plot, household, and village level characteristics (Appendices 5, 6 and 7). Once a balanced sample was achieved, we proceeded to estimate the average treatment effect of adopting SLM on a private plot using nearest neighbor matching (NNM). NNM matches each treatment plot to a control plot with its closest propensity score allowing for five nearest neighbors in terms of absolute difference in propensity scores (see Quisumbing et al. 2011 for a comprehensive overview of NNM). We then calculated the average impact of the treatment on the treated (ATT), measuring how total agricultural value of production differs between treatment and control plots. Impact is measured in two manners: including all plots that were within an SLMP area (plots that had an investment for one and four years), and limiting the sample to estimate treatment effects of only those plots that had four years of investment during the round 2 survey.

The results of these analyses presented in Table 6.2 suggest that the activities introduced with SLMP have not had a significant effect on the value of production when taking into account plot-level specific characteristics, such as slope and soil type—see Appendix 5 and 6 for plot level matching. We test these results using several matching techniques including stratification and kernel matching, as well as the nearest neighbor matching described above. We find similar insignificant results of SLMP on the plot-level value of production.

Table 6.2: Average plot-level impact of Sustainable Land Management adoption (single difference estimates)

Outcome variable: log of value of agricultural production	Observations	ATT: Nearest neighbor matching	ATT: Stratification matching	ATT: Kernel matching
All plots (whole sample)	7,064	0.006	0.012	0.035
		(0.039)	(0.025)	(0.028)
Plots with SLM program for four years	6,273	-0.029	0.028	0.039
		(0.044)	(0.027)	(0.029)

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

Source: Authors' calculation from SLM Survey (2010)

Note: Plots with SLM program for four years include control plots used to calculate the average treatment effect on the treated. It comprises 1,813 treated plots and 4,460 control plots.

Although we are unable to detect a significant increase in the value of agricultural production in SLMP areas compared with control areas, the overall change in agricultural productivity across survey sites suggests a promising trend between survey years. Total value of production increased by 25 and 21 percent in households located in treatment and control kebeles, respectively. Households in both treatment and control areas experienced significant cereal yield increases between 2009 and 2013 (Table 6.3). Similarly, root crop yields and value of production significantly increased in both treatment and control kebeles. Households in the treatment group experienced a 73 percent increase in yield of root crops which represent 5.9 percent, the second largest share, of the cropped area in treated kebeles (Table 6.3).

[8] We also tested impact of the SLMP on value of total yield outcomes in order to assess changes in agricultural productivity taking into account changes in farming intensity. However, we find insignificant impacts using this indicator as well.

Table 6.3: Agricultural production inputs and outputs in treated and control kebeles at baseline in 2009 and at endline in 2014

	Households in Treated Kebeles			Households in Control Kebeles		
	Baseline	Endline	t-test	Baseline	Endline	t-test
Value of total crop production, 2009 prices	5,727	7,150	***	6,319	7,649	***
Cereals	4,658	5,707	***	5,178	5,804	*
Pulses	640	582		1,038	1,026	
Oil seeds	890	764		1,188	1,017	
Root crops	595	1,133	***	778	1,946	***
Fruits	271	438		561	340	
Vegetables	244	481		333	333	
Coffee	7,194	6,018		4,355	3,960	
Other permanent crops	134	14	*	19	14	
Other crops	836	508		2,383	1,736	
Percent of total land allocated				79.4	79.3	***
Cereals	79.1	78.5		79.4	79.3	***
Pulses	5.0	5.2		8.0	7.5	
Oil seeds	3.9	3.4		2.7	2.6	**
Root crops	6.3	5.9		5.6	5.7	
Fruits	0.5	0.9		0.1	0.7	***
Vegetables	0.3	0.1		0.1	0.3	
Coffee	1.7	2.5		1.0	0.8	
Other permanent crops	2.9	2.2		2.2	2.0	
Other crops	0.2	1.3	***	0.8	1.0	
Yield (kg/hectare)				1,251	1,443	***
Cereals	1,383	1,437		1,251	1,443	***
Pulses	1,091	1,131		1,201	1,053	
Oil seeds	502	724		565	520	
Root crops	4,601	7,956	***	5,503	7,514	**
Fruits	3,440	5,786		6,497	4,334	
Vegetables	3,788	6,826		1,153	4,889	**
Coffee	639	1,031	**	581	1,403	
Other permanent crops	13,047	28,649	*	4,246	27,906	**
Other crops	1,213	8,584		2,389	1,544	
Input use and SLM investments, percent of households						
Fertilizer use	80.2	86.4	***	72.0	85.8	***
Improved seed	29.7	58.1	***	20.6	52.1	***
SLM structure	72.9	80.4		64.4	71.8	
Irrigation	1.2	1.9		1.0	1.0	
Stone terrace	23.0	32.6	***	22.9	29.4	***
Soil bund	45.9	52.0	***	21.3	43.0	***
Check dam	0.1	2.2	***	0.3	1.5	***
Trenches	0.9	8.2	***	0.1	10.3	***
Trees planted	0.7	6.6	***	0.9	3.8	***
Others	4.9	12.0	***	2.1	8.0	***

Note: Crop data report on those grown in *meher* season and on permanent crops.
Source: Authors' calculations from Ethiopia Watersheds Survey (2010, 2014)

In part, these increases may be due to an increase in the number of households using fertilizer and improved seed over time—approximately twice the number of households used improved seed in the treatment and control households in 2013 compared to 2009. 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 6.3). This suggests that possible spillover effects from the SLM program may be present. For example, given that kebeles are relatively small, farmers in a control kebele may be aware of SLM program activities, through talking with farmers in a program kebele or own observation, and choose to implement a similar activity on their own land.

Focusing on cereals, which represents more than three-quarters of area planted, both treatment and control kebeles experienced significant increases in the value of cereal production (Table 6.4). Treatment kebeles, in particular, increased value of cereal production by approximately 23 percent due to an increase in maize yields. In control kebeles, although the area dedicated to maize increased significantly, yields and the value of production did not experience significant increases. However, in treatment kebeles, data suggest that maize production has intensified, utilizing a similar area planted as 2009, but significantly increasing yields in 2013.

Table 6.4: Cereal crop production in control and treated kebeles at baseline in 2009 and at endline in 2014

	Households in Treated Kebeles			Households in Control Kebeles		
	Baseline	Endline	t-test	Baseline	Endline	t-test
Area, percent of total land allocated						
All cereals	79.1	78.5		79.4	79.3	***
Teff	23.3	24.4		26.0	27.1	
Barley	28.7	32.5	**	13.3	12.6	
Wheat	26.2	20.1	***	12.3	9.9	**
Maize	18.7	19.5		32.9	37.6	***
Sorghum	3.1	3.5		15.5	12.8	**
Value of production, 2009 prices						
All cereals	4,658	5,707	***	5,178	5,804	*
Teff	2,873	2,879		3,499	3,296	
Barley	1,501	2,258	***	1,525	2,246	***
Wheat	1,819	1,945		1,986	2,189	***
Maize	1,302	1,933	***	921	1,746	
Sorghum	899	954	***	1,003	1,264	***
Yield, kg/hectare						
All cereals	1,383	1,437		1,251	1,443	***
Teff	1,046	905	***	957	959	
Barley	1,487	1,459		1,280	1,374	
Wheat	1,587	1,599		1,374	1,488	
Maize	1,544	1,802	***	1,465	1,985	
Sorghum	938	1,298	**	1,182	1,298	***

Source: Authors' calculations from Ethiopia Watersheds Survey (2010, 2014)

Although this study finds that SLMP had no significant impact on value of production after four years of implementation compared to control areas, descriptive data suggest that improvements in agricultural productivity are occurring throughout the survey sample. This analysis supports previous work that finds that longer term maintenance of SLM structures is critical to achieving their intended goals. 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 seven years of ongoing maintenance of the SLM structures. However, this 2014 study was unable to identify potential community level effects of being within an SLMP *kebele*. In addition, using cross-sectional data from the baseline survey limited the analysis to defining SLM treatment as any plot that had received an SLM investment in the past, not taking into account whether a household was in the current SLMP designed for specific agro-ecologies and incorporating community-level investments in SLM.

The panel data analysis presented in this paper allows quantitative impact to be assigned to a distinct program with explicitly defined exposure periods, taking into account community infrastructure as well. Household level double-difference results (as well as plot level single-difference analysis) echo the previous baseline analysis, suggesting that regardless of program type, longer-term infrastructure maintenance may be needed in order to achieve program objectives. Mechanisms to encourage long-term maintenance could include a labor subsidy for farmers maintaining SLM structures (private or communal) over the medium-term, coupling of other productivity enhancing inputs, such as fertilizer and improved seed, or investments in infrastructure to decrease transportation costs and improve distribution channels (see Schmidt et al. 2016 for simulations of such instruments).

6. 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. To address ongoing land degradation in the agricultural highlands, the government of Ethiopia has prioritized investing in a widespread Sustainable Land Management Program (SLMP). In 2009, 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 SLMP areas. According to SLMP 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. In addition, SLMP targeted private and communal land investments in an effort to enhance household level agricultural output via improved and rehabilitated landscape development.

In order to understand the potential impact of SLMP on treatment households, we use panel household survey data collected in 2010 and 2014 to compare the value of total crop production between treatment and control households within the same woreda. Given that SLMP was rolled out in two separate phases (2009 and 2012), we form three 'exposure' groups: households that received no exposure to SLMP (control), households that were in the SLMP for four years, and households that were in SLMP for one year. Results suggest that regardless of exposure period (four or one years), the SLMP program has no significant effect on value of total crop production. Similar to previous studies, this evaluation underlines that improvements in agricultural productivity via investments in SLM structures may only be achievable through longer term maintenance and program participation. Thus, in order to achieve sustainability of program impacts, a medium to long term investment approach is needed. Further analysis of SLMP as it continues to reshape the landscape and livelihoods of rural households will provide insight as to the necessary time horizon and key investments that are needed to expect significant impact of SLM investments on agricultural outcomes at the household and plot level.

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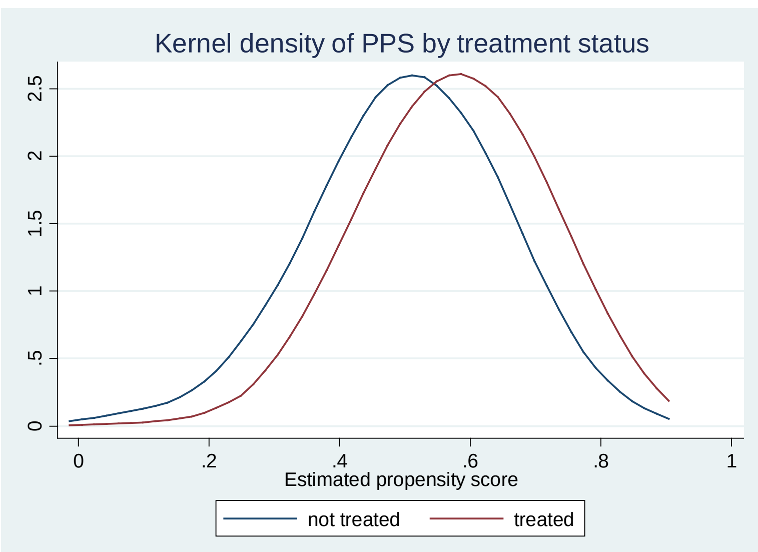
APPENDICES

Appendix 1: Result of the propensity score estimate

Variable	Coefficient	Standard error
Head age (in years)	0.003	(0.003)
Head education (in years)	-0.024	(0.015)
Head sex (male=1)	0.273	(0.231)
Household size	0.313 **	(0.129)
log (land size in ha)	-0.015 *	(0.009)
Head is a government or local official (yes=1)	0.200 *	(0.108)
Number of dependents	-0.183 ***	(0.033)
Household experienced drought in the past 5 years (yes=1)	-0.297 ***	(0.081)
Head married (yes=1)	-0.202	(0.227)
Head born in the village (yes=1)	0.061	(0.112)
Proportion of land on cereals	-0.104	(0.174)
Log Temperature (°C)	0.912 *	(0.496)
Log Rainfall (mm)	0.799 **	
Agro-ecological zone (Omitted=Lowlands (500-1,500 meters elevation)		
Low highland (1,500-2,300 m elevation)	6.693 ***	(1.723)
Mid highlands (2,300-3,200 m elevation)	6.628 ***	(1.789)
High highlands (3,200-3700 m elevation)	5.407 ***	(1.768)

Source: Authors' calculation from Ethiopia Watersheds 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 analysis of data Ethiopia Watersheds Survey (2010)

Appendix 3: Propensity Score and Covariate Balance

Variable	Unmatched or Matched	Mean: Treated	Mean: Control	% bias	% reduction in bias	t-test
Propensity score	U	0.577	0.399	93.8		16.85
	M	0.577	0.575	1.5	98.4	0.40
Head age (in years)	U	47.538	44.866	18.0		3.31 ***
	M	47.796	47.017	5.2	70.9	0.94
Head education (in years)	U	1.839	1.982	-5.2		-0.96
	M	1.765	1.833	-2.5	52.2	-0.46
Head sex (male=1)	U	0.854	0.880	-7.5		-1.39
	M	0.862	0.863	-0.3	95.6	-0.06
Head married (yes=1)	U	0.842	0.868	-7.3		-1.35
	M	0.845	0.868	-6.6	10.4	-1.18
Head was born in the village (yes=1)	U	0.851	0.758	23.7		4.35 ***
	M	0.851	0.808	10.9	53.9	2.04 **
Head is a government or local official (yes=1)	U	0.167	0.142	6.8		1.24
	M	0.170	0.203	-9.3	-37.3	-1.54
Household size	U	5.949	6.285	-14.3		-2.62 ***
	M	5.978	6.343	-15.5	-8.9	-2.77 ***
Number of dependents	U	2.683	3.181	-30.0		-5.51 ***
	M	2.686	2.770	-5.1	83.1	-0.93
Household experienced drought in past 5 years	U	0.455	0.545	-18.1		-3.33 ***
	M	0.477	0.460	3.5	80.7	0.62
log land area (ha)	U	0.425	0.537	-14.0		-2.58 ***
	M	0.428	0.442	-1.8	87.2	-0.32
Proportion of land on cereals	U	0.790	0.789	0.5		0.09
	M	0.793	0.794	-0.7	-28.0	-0.12
Log Temperature (C)	U	2.955	2.990	-32.1		-5.85 ***
	M	2.956	2.949	5.8	82.0	1.14
Log Rainfall (mm)	U	1.536	1.505	27.1		4.96 ***
	M	1.535	1.536	-0.1	99.6	-0.02
Low highland (1,500-2,300 m elevation) [b]	U	0.577	0.480	19.4		3.57 ***
	M	0.586	0.644	-11.8	39.4	-2.15 **
Mid highlands (2,300-3,200 m elevation) [b]	U	0.420	0.295	26.3		4.84 ***
	M	0.411	0.354	12.0	54.5	2.09 **
High highlands (3,200-3,700 m elevation) [b]	U	0.003	0.023	-18.0		-3.30 ***
	M	0.003	0.002	1.4	92.4	0.57

	Pseudo R^2	LR Chi^2	$p>Chi^2$	Mean Bias	Median Bias	B	R	% var
Unmatched	0.161	292.38	0.000	21.3	18.0	81.1 [a]	0.02 [a]	56
Matched	0.027	46.95	0.000	5.5	5.1	38.7 [a]	0.85 [a]	56

[a] If variance ratio outside [0.86; 1.16] for U and [0.86; 1.17] for M

[b] For the agro-ecological zones, the omitted zone is the lowlands (500-1,500 meters elevation).

Note: *, **, and *** are significance level at 10%, 5% and 1%, respectively

Source: Authors' computation from Ethiopia Watersheds Survey (2010)

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

	Mean	Standard Deviation	Min	Max
Outcome Variable				
Value of total crop production (in Birr)	6,653	4,887	0	23,755
Control Variables				
Household characteristics				
Household size	6.54	2.31	1	17
Number of dependents	2.93	1.53	0	9
Number of male adults in the households	3.37	1.66	0	10
Tropical Livestock Units owned	4.19	3.26	0	27.36
Participated in nonfarm activity (yes=1)	0.20	0.40	0	1
Participated in wage work (yes=1)	0.46	0.50	0	1
Land characteristics				
Land size in hectares	1.88	1.60	0.03	16.75
Proportion of fertile land	0.37	0.35	0	1
Proportion of steep land	0.12	0.22	0	1
Proportion of land with mixed slope	0.40	0.32	0	1
Input Use				
Improved seed use (yes=1)	0.39	0.49	0	1
Fertilizer use (yes=1)	0.81	0.39	0	1
Credit access in the Kebele (yes=1)	0.53	0.50	0	1
Number of extension agents in the Kebele	0.99	0.48	0	3
Crop choice (Proportion of land with)				
Cereals	0.80	0.22	0	1
Pulses	0.06	0.12	0	1
Oil seeds	0.03	0.09	0	1
Root crops	0.06	0.13	0	1
Fruits	0.01	0.04	0	1
Vegetables	0.00	0.03	0	1
Coffee	0.01	0.07	0	1
Permanent crops	0.02	0.10	0	1
Spices and others	0.01	0.05	0	1
Shocks				
Experienced drought in past 5 years (yes=1)	0.42	0.49	0	1
Experienced flood in the past 5 years (yes=1)	0.36	0.48	0	1
Experienced severe erosion (yes=1)	0.16	0.24	0	1
Log average rainfall (past 30 years), mm	4.71	0.53	3.96	5.57
Average temperature (past 30 years), °C	19.19	1.98	17.27	24.18

Note: Observations: 2,118. Data report households that are in the common support only, thus are not comparable with Table 4.1 in the text.
Source: Authors' computation from Ethiopia Watersheds Survey (2010 and 2014).

Appendix 5: Result of the plot level propensity score estimate (all plots)

Variable	Coefficient	Standard error
Age of household head, years	0.009 ***	(0.001)
Education of household head, years	0.013 **	(0.006)
Head is a government or local official (yes=1)	0.002	(0.037)
Number of adult males in household	-0.044 ***	(0.013)
Log household size	0.390 ***	(0.062)
Log land area, ha	-0.185 ***	(0.017)
Plot is flat sloped (yes=1)	0.289 ***	(0.030)
Plot is mixed sloped (yes=1)	0.066	(0.103)
Plot is not fertile (yes=1)	0.250 ***	(0.042)
Pseudo R^2	0.032	
Number of observations	7,976	

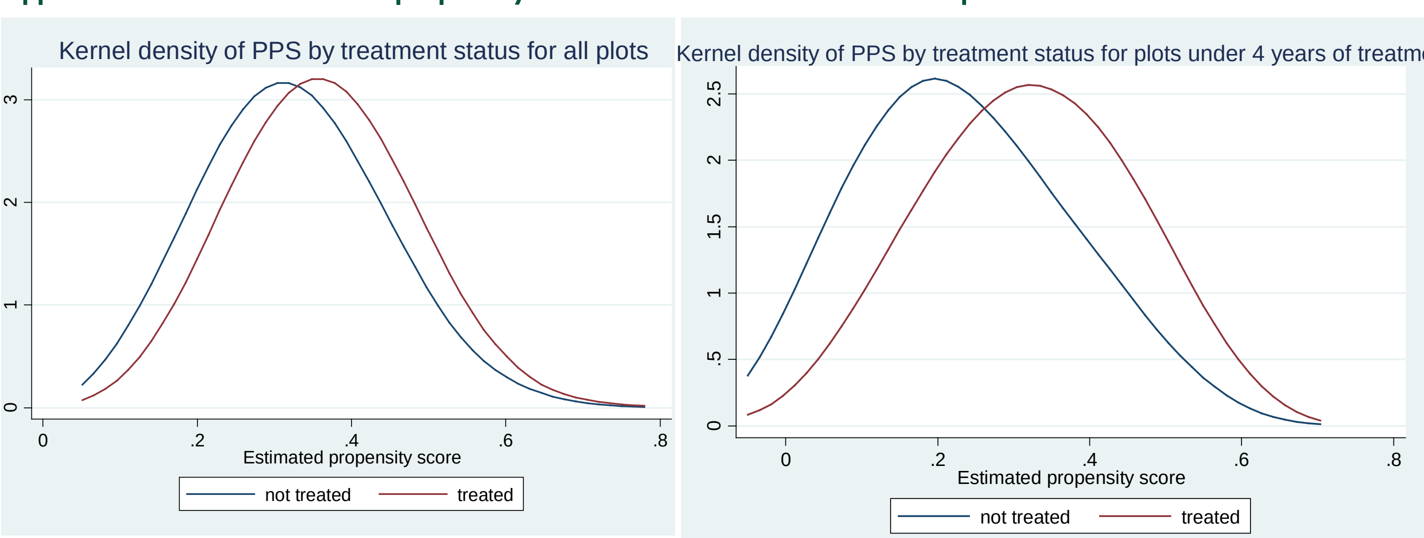
Source: Authors' calculation from Ethiopia Watersheds Survey (2010).
Note: *, **, and *** are significance level at 10%, 5% and 1%, respectively; Standard errors in parenthesis.

Appendix 6: Result of the plot level propensity score estimate, plots with four years of Sustainable Land Management Project exposure

Variable	Coefficient	Standard error
Age of household head, years	0.008	(0.009)
Age squared, years	0.001	(0.000)
Education of household head, years	-0.046***	(0.008)
Number of adult males in the household	-0.075***	(0.016)
Household head is an official (yes=1)	-0.086*	(0.047)
Log household size	0.274***	(0.075)
Log land area, ha	-0.074***	(0.025)
Household has modern roof (yes=1)	0.685***	(0.053)
Household has experienced flood (yes=1)	0.188***	(0.036)
Plot is flat sloped (yes=1)	0.419***	(0.037)
Plot is moderately fertile (yes=1)	-0.299***	(0.037)
Pseudo R^2	0.781	
Number of observations	6,321	

Source: Authors' calculation from Ethiopia Watersheds Survey (2010).
Note: *, **, and *** are significance level at 10%, 5% and 1%, respectively; Standard errors in parenthesis.

Appendix 7: Distribution of the propensity scores of treated and non-treated plots



Source: Authors' calculation from Ethiopia Watersheds Survey (2010).

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The Ethiopia Strategy Support Program is an initiative to strengthen evidence-based policymaking in Ethiopia in the areas of rural and agricultural development. Facilitated by the International Food Policy Research Institute (IFPRI), ESSP works closely with the government of Ethiopia, the Ethiopian Development Research Institute (EDRI), and other development partners to provide information relevant for the design and implementation of Ethiopia's agricultural and rural development strategies. For more information, see http://www.ifpri.org/book-757/ourwork/program/ethiopia-strategy-support-program or http://essp.ifpri.info/ or http://www.edri-eth.org/.

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