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Estimating the joint effect of multiple soil conservation practices: A case study of smallholder farmers in the Lake Naivasha basin, Kenya

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ABSTRACT

The current study seeks to assess the private benefits associated with multiple soil conservation practices (MSCPs) by estimating the marginal value of crop production that can be attributed to such practices. In areas where land degradation associated with soil erosion causes serious agri-environmental challenges such as loss of soil fertility, siltation and eutrophication, a multiple approach to soil conservation is necessary. However, notwithstanding efforts to encourage adoption of such practices, their uptake remains generally low. Analysing the effect of MSCPs on crop productivity is one of the ways through which the incentives for soil conservation can be explored. To achieve the stated objective, the current study applied propensity score matching and exogenous switching regression techniques to cross-sectional data collected from a random sample of farm households located in Lake Naivasha basin, Kenya. Results indicate that there is a significant positive effect of implementing multiple soil conservation practices on crop productivity. However, we note that whether the additional benefits will cover the opportunity costs associated with the implementation of these practices will depend on farm specific attributes such as slope and the soil conservation effort. In cases where marginal benefits are not substantial to cover opportunity costs for implementation of soil conservation practices, intrinsic or external incentives could be necessary. Policy interventions could focus on offering technical assistance to farmers in selecting soil conservation practices that are best suited to their local condition.

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Introduction

Land degradation is a major threat to agricultural productivity and food security in many developing countries (Bewket, 2007; Kassie et al., 2008; Mazvimavi and Twomlow, 2009). Land degradation is mainly attributed to inappropriate agricultural practices and other activities and processes that reduce the economic and ecological productivity of land (OECD, 2012). Soil erosion is one of such processes. Besides the on-site effect of reducing the productivity of land, soil erosion also causes off-site effects such as eutrophication and siltation (Mbaga-Semgalawe and Folmer, 2000). Soil erosion also threatens species in both terrestrial and aquatic ecosystems through the degradation and pollution of their habitats. Due to the myriad negative effects caused by soil erosion, soil conservation can undoubtedly generate both private and social benefits. Private gains emerge from increased crop productivity, while social benefits emerge from better ecology and reduced water treatment costs, longer life of reservoirs, and many other benefits (Miller et al., 2008). For this reason, significant efforts have been made by governments and development agencies to promote soil and water conservation technologies among farmers in developing countries (Bekele, 2005; Kassie et al., 2008). Through these efforts, it has been reported previously that environmental recovery through soil and water conservation has been achieved in some parts of the world (Tiffen et al., 1994; Pagiola and Dixon, 1998). However, despite these efforts, the adoption of soil conservation practices has been below expectations in many parts (Khisa et al., 2007; Van Rijn et al., 2012). This raises the question of whether and to what extent soil conservation practices can generate economic benefits substantial enough to motivate farmers into adopting and maintaining them.

Whether soil conservation practices are win-win has been an important research focus in the past, generating mixed findings. While some studies (for example Bekele, 2005; Kassie et al., 2008; Otsuki, 2010; Pender and Gebremedhin, 2007; Shively, 1998; Vancampenhout et al., 2006) conclude that soil conservation practices help to enhance cropland productivity on degraded lands, other studies (for example Kassie et al., 2011; Shiferaw and Holden,

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2001) found that under certain circumstances, some soil conservation may not necessarily be 'win–win'. What we observe from these studies is that evaluation of conservation practices should be context specific. On the one hand, if appropriately selected and given sufficient time, soil conservation practices (SCPs) are expected to reduce soil erosion rates, improve agricultural land quality and enhance crop yields (Lutz et al., 1994; Shively, 1998). On the other hand, due to their land requirements soil conservation practices may lead to a decline in crop yields. Pagiola (1994) finds that this was an important issue for the Kitui and Machakos regions of Kenya where he finds that the effective production area falls faster than the increase in yields therefore leading to an overall production decline. From a private optimization point of view, adoption rates are likely to be low if costs exceed the benefits (Lutz et al., 1994; Pagiola, 1994). Farmers are particularly concerned with high labor and land requirements for implementation and maintenance of some soil conservation technologies since these resources are usually the most limiting among low-income farmers (Shiferaw and Holden, 2001).

Due to the varied potential effects of soil conservation practices, it is necessary sometimes to combine multiple soil conservation technologies within the same farm so as to generate substantial benefits. However, literature on the assessment of complementary effect of multiple soil conservation practices (MSCPs) is currently scanty.

In the current study we hypothesize that implementing multiple soil conservation practices as a conservation package can generate substantial private benefits in-terms of higher crop productivity. Therefore, the research question we seek to explore is whether the net value of crop production for farmers who have implemented multiple soil conservation practices are higher than those of the farmers who have not. This is motivated by the tenet that farmers are likely to sustain conservation practices on their farms partly if benefits exceed costs (Shiferaw and Holden, 2001). The main goal of this study is to estimate the effect of implementing MSCPs on the value of crop production among smallholder farmers in the Lake Naivasha basin, Kenya. This helps us to generate information that can be used in evaluating the returns to a soil conservation package as opposed to assessing returns to individual soil conservation practices. Six practices were considered in this study namely: Tree Planting, *Fanya Juu* Terraces, Grass Strips, Napier Grass, Contour farming and Cover crops. The study uses propensity score matching (PSM) to analyze matched observations of farmers who have implemented multiple soil conservation practices and those who have not.

The rest of the paper is structured as follows: the next section summarizes previous research on returns to soil conservation practices. Section 'Methods, data types and description of variables' then describes the methodology employed in this study, including data collection and sampling methods and analytical techniques. Results and discussions are presented in Section 'Results and discussion', while Section 'Conclusions and policy implications' concludes and draws policy implications.

Literature on returns to soil conservation practices

As has already been mentioned, despite the unanimous agreement in literature that most soil conservation technologies control erosion and generate off-site positive effects, such technologies remain poorly adopted[1] in many developing countries (Khisa et al., 2007; Pretty et al., 1995; Van Rijn et al., 2012). This state of affairs has been the driving force behind many government efforts to promote soil conservation and has also received substantial focus in research. Studies in this area have focused on assessing the effect of soil conservation practices on crop productivity using either econometric approaches (for example Bekele, 2005; Kassie et al., 2008; Nyangena and Köhlin, 2009; Otsuki, 2010; Pender and Gebremedhin, 2007; Shively, 1998) or Cost Benefit Analysis (CBA) (for example Araya and Asafu-Adjaye, 1999; Ellis-Jones and Tengberg, 2000; Lutz et al., 1994; Posthumus and De Graaff, 2005; Shiferaw and Holden, 2001; Tenge, 2005). Regardless of the method used, most findings converge to one agreement that the effect of soil conservation on crop productivity is context specific and depends on various factors. The current study seeks to advance the debate by looking at how the combination of multiple soil conservation practices may influence the value of crop production.

A study by Kassie et al. (2008) analyzed the impact of stone bunds on the value of crop production in Ethiopia and revealed that their effects on crop productivity differed with agro-ecological settings. Implementing stone bunds increased crop productivity in low rainfall areas, whereas in the high rainfall areas this was not the case. Beside the agro-ecological conditions, studies conducted in Kenya by Nyangena and Köhlin (2009) and Otsuki (2010) found that the erosion status of the farm was a major determinant of the effect of agro forestry, bunds and terracing on crop productivity.

A study by Araya and Asafu-Adjaye (1999) in Eritrea found that plots where stone and soil bunds, *Fanya Juu* terraces and double ditches were implemented yielded negative net present values (NPVs). However, when the authors accounted for social benefits, the NPVs were positive, emphasizing on the fact that even when SCPs are not economically viable for individual farmers, the net gain to the society can be positive. This finding is confirmed by Shiferaw and Holden (2001) who applied a different approach to Ethiopian smallholder farms and concluded that SCPs only yielded positive benefits at very low discount rates. A similar study conducted by Tenge (2005) among smallholder farmers in the West Usambara Highlands in Tanzania estimated the financial efficiency of bench terraces, *Fanya Juu* terraces and Grass Strips and revealed that profitability of these SCPs depended on soil type, slope and opportunity costs of labor and farmers' subjective discount rates. For instance, *Fanya Juu* terraces constructed on both moderate and steep slopes were economically viable only for farmers with low opportunity costs of labor, whereas farmers with high opportunity costs could only benefit from the practice if it was constructed on gentle slopes. Similarly, implementation of grass strips on steep slopes with both stable and unstable soils for farmers with high opportunity costs would yield negative NPVs and Internal Rate of Return (IRR) below the market discount rate (Tenge, 2005). However, soil erosion is often present on steep slopes with unstable soils that accelerate soil surface movement and run-off. Consequently, smallholder farmers with farms located on extremely sloped areas would need additional incentives to make soil conservation technologies economically attractive for them. A study by Posthumus and De Graaff (2005) among Peruvian farmers arrives at similar findings, and also finds the type of crop enterprise an important determinant of the profitability of soil conservation practices.

Most of the studies highlighted here analyze soil conservation practices in isolation not taking into account the possible effect that may result from integrating more than one soil conservation practices in one farm/plot. Further, as Kassie et al. (2008, 2011) and Shively (1998) indicate, any analysis on the effect of soil conservation practices on the value of crop production that ignores the presence of self selection may yield biased estimates. Self-selection problem arises because farmers are not randomly assigned to the groups of adopters and non-adopters, but they choose themselves to adopt a soil conservation practice based on their individual

[1] There is however some exceptions found in literature. For example Pagiola and Dixon (1998) find high adoption rates in El Salvador than it is commonly assumed.

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