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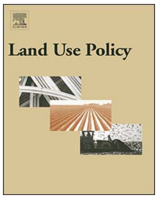

Factors influencing small-scale farmers' adoption of sustainable land management technologies in north-western Ethiopia

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ABSTRACT

Land degradation is a serious global problem because it leads to losses in food production and thus jeopardizes food security worldwide, particularly in developing countries. Despite numerous efforts to introduce sustainable land management (SLM) strategies and practices, their adoption by the primary target group, small-scale farmers in developing countries, has been [s]low. This study assesses the problem for the case of Ethiopia. The aim was to analyze the underlying factors that affect the adoption of SLM technologies in the Upper Blue Nile Basin. A detailed survey of 300 households and 1010 farm plots was conducted. Data were analyzed by using both descriptive and econometric analyses. Results show that farmers' adoption of interrelated SLM measures depended on a number of socio-economic and farm-related factors in combination with the characteristics of the technologies themselves. For example, plot size and the availability of labor, as well as the gender of the household head, affected which SLM technologies were adopted by certain types of households. The adoption of SLM measures depended on the adaptive economic capacity of the farmers, which can be quite diverse even within a small region and can differ from the adoption potential in other regions. Our results suggest that SLM policies and programs have to be individually designed for specific target groups within specific regions, which in turn means that "one size fits all" and "across the board" strategies – which are quite common in the field of SLM – should be abandoned by development agencies and policymakers.

1. Introduction

Land degradation in the form of soil erosion and nutrient depletion is increasingly prevalent across the globe; in particular, it poses a real threat to livelihoods in sub–Saharan Africa (SSA) (Tully et al., 2015). More than half of the SSA population depends on subsistence agriculture, which is jeopardized by extreme weather events such as heavy rainfall and drought (Cordingley et al., 2015). In addition, rapid population growth has also resulted in shrinking and increasingly fragmented cultivated lands as well as expansion of cultivated lands to vulnerable hillsides, which has further contributed to a high level of land degradation, low productivity, and greater poverty (Teklewold et al., 2013). Despite the government's and non-governmental organizations' efforts to increase agricultural productivity and tackle these problems through the promotion of various measures, adoption remains [s]low by small-scale farmers (Cordingley et al., 2015).

Ethiopia is no exception to these realities. Its agricultural sector has failed to make significant soil erosion control and nutrient replenishment investments (Adimassu et al., 2012; Teklewold et al., 2013; Teshome et al., 2016). As a result, soil loss and nutrient depletion continue to be a severe issue in this country, particularly in the highlands, with soil loss averaging 20 t ha^{-1} year^{-1} on currently cultivated lands and 33 t ha^{-1} year^{-1} on formerly cultivated degraded lands (Hurni et al., 2015), and nutrient depletion averaging 122 kg N ha^{-1} year^{-1}, 13 kg P ha^{-1} year^{-1} and 82 kg K ha^{-1} year^{-1} in cultivated lands (Haileslassie et al., 2005). Likewise, soil erosion has

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been a serious problem in the Upper Blue Nile Basin. Bewket and Teferi (2009) reported a soil erosion rate of 93 t ha^{-1} $year^{-1}$ in the Chemoga watershed and Gelagay and Minale (2016) reported a rate of 47 t ha^{-1} $year^{-1}$ in the Koga watershed. The estimated annual cost of land degradation amounts to 2.0–6.8% of the country's agricultural GDP (Yesuf et al., 2005), which contributes to food insecurity and further aggravates the effects of the recurrent droughts (Adgo et al., 2013; SLMP, 2013). Sustainable land management (SLM) investments are considered to be mandatory to address these problems and have been promoted and implemented across different parts of the country (Adgo et al., 2013; MoARD, 2010; SLMP, 2013; Teshome et al., 2016).

Evidence suggests that adoption of SLM practices by small-scale farmers varies with respect to a range of social, economic, institutional, and biophysical factors (Adimassu et al., 2012; Asrat et al., 2004; Haregeweyn et al., 2015; Mamo and Ayele, 2003; Teklewold et al., 2013; Teshome et al., 2016). More specifically, Teshome et al. (2016) and Mbaga-Semgalawe and Folmer (2000) found that a high perceived erosion risk promotes farmers' adoption of SLM technologies; and Cary and Wilkinson (1997) and Amsalu and De Graaff (2007) reported that perceptions of reduced profitability from using SLM technologies deter their adoption. Moreover, different demand- and supply-side restraints have been identified that affect the adoption of SLM technologies, including endowments of physical and human capital (Gebremedhin and Swinton, 2003; Marenya and Barrett, 2007; Teklewold et al., 2013; Teshome et al., 2016); tenure insecurity (Gebremedhin and Swinton, 2003); and access to off-farm opportunities (Holden et al., 2004), agricultural extension services (Paudel and Thapa, 2004), and credit (Tiwari et al., 2008). Most of the studies (e.g., Amsalu and De Graaff, 2007; Mamo and Ayele, 2003; Pender and Gebremedhin, 2008), however, did not adequately consider the possibility of farmers applying a mix of SLM technologies to solve the problem of soil degradation. That is, they did not account for the interdependent and simultaneous characteristics of the SLM practices. As a result, they treated the use of various practices as separate decisions, whereas, Teklewold et al. (2013) affirmed that farmers often simultaneously pursue a number of SLM technologies in their plots, suggesting the importance of considering such issues in any analysis of farmer decision-making. Consequently, our study aimed to contribute to the existing literature through addressing this gap by objectively analyzing the underlying factors that affect the adoption of SLM measures by using a multivariate adoption framework. The results should help improve policymakers' understanding of small-scale farmers' technology adoption behaviors and thereby enable them to introduce appropriate policy measures and interventions to further enhance adoption of SLM technologies.

2. Materials and methods

2.1. Study sites

The study was undertaken in three watersheds (see Fig. 1): the Aba Gerima and Guder watersheds in the Bahir Dar Zuria (11°25′–11°55′ N, 37°04′–37°39′ E) and Fagita Lekoma (10°57′–11°11′ N, 36°40′–37°05′ E) Districts, respectively, of the Amhara Region and the Dibatie watershed from the Dibatie District (10°01′–10°53′ N, 36°04′–36°26′ E) of the Benishangul Gumuz Region, Ethiopia.

These watersheds are part of the north-western highlands of the Upper Blue Nile Basin, Ethiopia. They vary a great deal in their SLM experiences. Each area has participated in the national government's regular extension programs and other campaign-based soil and water conservation (SWC) programs, but the areas' experiences with other externally funded programs has varied a great deal. The Aba Gerima watershed is part of a larger program funded by the Swiss Development Cooperation Water and Land Resource Centre (WLRC). It has been serving as an experimental watershed for integrated water and land resources management since 2011. Physical and biological SWC measures were extensively implemented in the watershed with the support of the WLRC project. The Guder watershed has received support from the World Bank under the Sustainable Land Management Programme (SLMP) since 2008 (SLMP, 2013). Physical and biological SWC technologies were introduced in the watershed during this period, but not to the extent they were in the Aba Gerima area. During the same period, the Dibatie watershed received no external support for SWC projects. As compared to the other two watersheds, few physical SWC structures were introduced in Dibatie, primarily through the regular government extension program and campaign-based SWC interventions. Agriculture in the watersheds is dominated by subsistence mixed crop–livestock farming systems (Table 1).

2.2. Sampling procedure, data, and data analysis

The data used in this study came from detailed household and plot surveys of 300 farm households and 1010 farm plots operated by the respondents in three watersheds of the Upper Blue Nile Basin, Ethiopia. The survey was conducted in February and March 2015. A two-stage cluster sampling procedure, involving a combination of purposeful and random sampling, was used to select sample respondents. In the first stage, we purposely selected three watersheds to represent the upper, middle, and lower parts of the basin: the Guder watershed, from the highlands; the Aba Gerima watershed, from the middle-elevation land; and the Dibatie watershed, from the lowlands. In the second stage, 100 households were selected from each watershed, for a total of 300. Respondents were selected using systematic random sampling techniques based on lists of households obtained from the respective local agricultural offices.

The household survey was conducted using semi-structured questionnaires and covered detailed household and plot-level information. A pre-test survey was also conducted in each watershed to customize instruments to local conditions. The household survey included a series of close-ended questions focusing on respondents' socio-economic, demographic, institutional and plot characteristics, and perceptions about soil erosion severity, fertility and profitability of SLM technologies. Along with the quantitative information, qualitative data were collated to elucidate farmers' reasons for investing and/or not investing in the respective SLM technologies on their plots. Specifically, we sought farmers' general explanation on their plot-level SLM investment behavior to help interpret quantitative results, including: (i) which segment of the community (e.g., young vs. old, literate vs. illiterate, male vs. female, wealthy vs. poor, labor endowed vs. less labor endowed) is applying the respective SLM measures and why, (ii) who is the main player (i.e., intra-household responsibility) in undertaking the various activities (e.g., digging, excavating, compacting, transporting) involved in implementing the respective SLM measures, and (iii) which type of plots (e.g., fertility condition, distance from residence, position in the landscape) are receiving the respective SLM measures and for what reason.

The plot survey covered specific plot-level information (e.g., plot slope, land use, position in the watershed, and existing SLM technologies on the plot and neighboring plots) using a checklist. Plot slope was measured with a clinometer (PM–5/360 PC Clinometer, Suunto). The data were input into the SPSS software (ver. 23, IBM, Armonk, NY, USA) and analyzed with a combination of descriptive and econometric analyses. Parameters of the multivariate probit (MVP) model were estimated with a user-written Stata routine (*mvprobit*) that employed the Geweke–Hajivassiliou–Keane smooth recursive conditioning simulator procedure (Cappellari and Jenkins, 2003). Parameters of the Poisson regression (PR) model were estimated by the maximum-likelihood procedure. The Stata software (ver. 14.1, StataCorp LP, College Station, TX, USA) was used in the model estimates.

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