FARMERS’ PERCEPTION ABOUT SOIL EROSION IN ETHIOPIA

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ABSTRACT

Soil erosion is a significant problem in the Ethiopian highlands. The objective of this study was to investigate how farmers perceive the severity of soil erosion in the Upper Blue Nile Basin. The study is based on a detailed survey of 300 households and 1,010 plots owned by these households in three watersheds. Descriptive statistics and a partial proportional odds model were applied to analyze factors that affected farmers’ perceived soil erosion severity at the plot-level. Results showed that variables such as plot distance from the residence, plot shape and position on hill slopes affected farmers’ perceptions of soil erosion severity, as well as the amount of rainfall during the growing season. Farmer interaction with extension service agents also affected farmers’ perception of soil erosion severity. Despite their expected importance, education and number of livestock owned had no effect on the farmers’ perception of soil erosion. The results indicate that farmers’ perceptions generally match empirical and theoretical findings on soil erosion determinants; thus, farmers should be considered as important partners not only to counter soil erosion, but also to obtain local expertise on soil erosion severity and restoration of degraded land. © 2016 The Authors. Land Degradation and Development published by John Wiley & Sons, Ltd.

KEY WORDS: soil erosion perception; drought; partial proportional odds model; Upper Blue Nile Basin; Ethiopia

INTRODUCTION

Soils have played significant roles in the earth’s life-support system through the provision of a multitude of essential ecosystem services (i.e. provisioning, regulating, cultural and supporting services) to humans and the environment (Keesstra et al., 2016b; Schwilch et al., 2016). Nonetheless, most human interferences for pursuing economic benefits contribute to rapid and extensive degradation of soils over the past half a century (Millennium Ecosystem Assessment, 2005; Brevik et al., 2015), and consequently jeopardize their ability to provide services to society (Millennium Ecosystem Assessment, 2005). Soil degradation is a major threat to development in most economies of the world (Erkossa et al., 2015; Taguas et al., 2015; Keesstra et al., 2016a). About 15% of land worldwide is degraded, of which 16% is in Africa (Lal, 2003; Bai et al., 2008). Soil degradation induced by water erosion in sub-Saharan Africa (SSA) is of concern mainly because of its consequences for subsistence agriculture, from which about 75% of the population derives their livelihoods (Erkossa et al., 2015; Tully et al., 2015). Among the SSA countries, Ethiopia has a high level of soil erosion (Mekonnen et al., 2015; Gessesse et al., 2016). Continued soil erosion seriously threatens peoples’ livelihoods, especially in drought-prone highland parts of the country, where arable land is a very scarce resource. Over the past several decades, government and international agencies have been trying to support better land use and promote soil and water conservation (SWC) technologies to halt soil erosion and improve peoples’ livelihoods (Tesfaye et al., 2014a; Tesfaye et al., 2014b; Haregeweyn et al., 2015; Gessesse et al., 2016). Reports (Bewket & Sterk, 2002; Tesfaye et al., 2014b; Tesfaye et al., 2014a), however, have indicated a relatively low level of success in this respect across the wider landscape. Soil erosion rates as high as 42 Mg ha⁻¹ year⁻¹ have been reported on cultivated lands across the country (Bewket & Sterk, 2003; Tesfaye et al., 2014b; Haregeweyn et al., 2015), and recent estimates by Hurni et al. (2015) indicated rates of 20 Mg ha⁻¹ year⁻¹ on currently cultivated lands and 33 Mg ha⁻¹ year⁻¹ on formerly cultivated degraded lands. Similarly, soil erosion has been a serious problem in the Upper Blue Nile Basin. Gelagay & Minale (2016) stated a soil erosion rate of 47 Mg ha⁻¹ year⁻¹ in the Koga watershed, and Bewket & Teferi (2009) reported a rate of 93 Mg ha⁻¹ year⁻¹ in the Chemoha watershed. In one of our study sites,
The Universal Soil Loss Equation, Revised Universal Soil Loss Equation and expert judgement based qualitative re-

dence models are the most widely used models to predict soil loss and identify erosion hotspots (Tamene & Vlek, 2008; Sonneveld et al., 2011). These models make use of qualitative and quantitative data to estimate the magnitude and spatial distribution of soil erosion (Sonneveld et al., 2011). In data-sparse (i.e. agricultural, geological and hydro-

dical data) regions like Ethiopia, where estimations of soil loss are highly driven by empirical models (Bewket &

teri, 2009; Gelagay & Minale, 2016; Haregeweyn et al., 2017), however, their application is worrisome. Moreover,

these models do not incorporate the observations of farmers who experience the phenomenon on a daily basis (Boardman,

et al 2006) either as part of model input parameters complementing expert knowledge (e.g. assignments of weight scores, and crop cover, management practice and soil erodibility factor values) or means for validating results ob-

tained. Furthermore, these approaches do not acknowledge the importance of local knowledge in perceiving the extent of the erosion problem.

A growing body of literature (Tegene, 1992; Shiferaw &

et al. 1998; Bewket & Sterk, 2002; Tefera & Sterk, 2010; Assefa & Hans-Rudolf, 2016) has demonstrated farmers’ considerable knowledge in categorizing their land according to their soil erosion severity. Likewise, it is often highlighted that farmers’ environmental behaviors (i.e. land management decisions) depend on their own perceptions of conditions in their environment (Shiferaw &

et al. 1998; Assefa & Hans-Rudolf, 2016; Keshavarz &

arami, 2016). Conversely, SWC intervention plans in the country to date have not considered but often rather ig-
nored such abilities of local farmers’ (Snyder et al., 2014; Assefa & Hans-Rudolf, 2016), and take them as mere labor contributors as a result (Bewket & Sterk, 2002; Abebe & Sewnet, 2014; Haregeweyn et al., 2015). This results in locally undifferentiated SWC measures and little acceptance of the same by farmers, possibly explaining the little success in the past decades (Tegene, 1992; Snyder et al., 2014; Tesfaye et al., 2014b; Assefa & Hans-Rudolf, 2016). If it can be shown that farmers can perceive soil erosion, for example, there can be a good reason to change the top–down dominated strategic and operational SWC planning process into a relatively interactive and participa-
tory process.

The objectives of the paper are: (i) to determine whether farmers are apt to perceive soil erosion patterns, and (ii) to examine which factors influence farmer’s ability to perceive soil erosion. Hence, we aimed to investigate factors that influ-
ence farmers’ perception of soil erosion severity by exam-
ining the case of farmers in the Upper Blue Nile Basin, Ethiopia. We also compared our findings with theoretical predictions and empirical findings to determine whether farmers correctly perceive soil erosion as well as introduce appropriate measures.

MATERIALS AND METHODS

Study Sites

The study was undertaken in three watersheds (see Figure 1): the Guder and Aba Gerima watersheds from the Fagita Lekoma (10°57’ to 11°11’ N, 36°40’ to 37°05’ E) and Bahir Dar Zuria (11°25’ to 11°55’ N, 37°04’ to 37°39’ E) districts, respectively, of Amhara Region, and the Dibatie watershed from the Dibatie district (10°01’ to 10°53’ N, 36°04’ to 36°26’ E) of the Benishangul Gumuz Region. These watersheds are part of the north-western highlands of the Upper Blue Nile Basin, Ethiopia. The watersheds are selected pur-

posely because of their specific SWC experience, states of soil erosion, their ability to capture bio-physical and socio-

economic heterogeneity, and represent higher, medium and lower elevation watersheds within the highlands of the basin. They thus provide a most suitable environment for the empirical study, as maximum potential factors affecting and determining farmers’ soil erosion perception can be found.

Besides the traditional SWC technologies (e.g. traditional stone bund, drainage ditch, agroforestry, etc.) practiced by farmers, various improved SWC technologies (e.g. soil bund, fanya jiu (a ditch dug along a contour and put the soil uphill to form a ridge), stone-faced soil bund, trench, etc.) are implemented. Each area has participated in the national government’s regular extension programs and other public-

based SWC interventions, but the areas’ experiences with other externally funded programs have varied a great deal. The Aba Gerima watershed is part of the Swiss Agency for Development and Cooperation (SDC) funded Water and Land Resource Centre (WLRC) project since 2011. The Guder watershed has received support from the World Bank under the Sustainable Land Management Programme (SLMP) since 2008. The Dibatie watershed is not under any external support for SWC projects. Although it may need further study, we hypothesize that there is a better per-
ception of soil erosion severity in sites where these projects are active. Agriculture in the watersheds is dominated by subsistence mixed crop–livestock farming systems (Table I).

Figure 1. Location of the study sites. [Colour figure can be viewed at wileyonlinelibrary.com]
Table I. Bio-physical characteristics of the study sites

| Feature (unit)                   | Aba Gerima watershed | Guder watershed | Dibatie watershed |
|----------------------------------|-----------------------|-----------------|-------------------|
| Altitude (m a.s.l.)              | 1922–2250             | 1800–2900       | 1479–1709         |
| Temperature (°C)                 | 13–27                 | 9.4–25          | 25–32             |
| Annual rainfall (mm)             | 895–2037              | 1951–3424       | 850–1200          |
| Rainfall pattern                 | Unimodal              | Unimodal        | Unimodal          |
| Agro-ecological zone             | Humid subtropical     | Moist subtropical | Tropical hot humid |
| Total area (ha)                  | 719                   | 742.5           | 700               |
| Soil type                        | Nitosols, Leptosols   | Acrisols, Nitosols | Vertisols, Nitosols |
| Dominant crop                    | Teff, finger millet, wheat, maize, khat | Barley, teff, wheat, potatoes | Finger millet, teff, maize, ground nut |
| Dominant livestock               | Cattle, sheep, goats and donkeys | Cattle, sheep, donkeys and horses | Cattle, sheep, goats and donkeys |
| Soil erosion severity*           | Moderate              | Very severe     | Slight            |
| SWC-related projects             | WLRC                  | SLMP            | None              |
| SWC activities                   | High                  | Medium          | Low               |

Sources: Achamyeleh, 2015; Kindye, 2016; Nigussie et al., 2016; Own surveys.

Teff (*Eragrostis tef*), finger millet (*Eleusine coracana*), wheat (*Triticum aestivum*), maize (*Zea mays*), ground nut (*Arachis hypogaea*).

* Slight = 5–15 Mg ha⁻¹ year⁻¹; Moderate = 15–30 Mg ha⁻¹ year⁻¹; Very severe ≥ 50 Mg ha⁻¹ year⁻¹ (Hargeweyn et al., 2017).

Data, Sampling and Data Analysis

The data used in this study came from detailed household and plot surveys of 300 farm households and 1,010 plots operated by the respondents in three watersheds of the Upper Blue Nile Basin. 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 based on the characteristics described in the section on the study sites above. In the second stage, 100 households were selected from each watershed, for a total of 300. Respondents were selected using systematic random sampling techniques on lists of households obtained from the respective local agricultural offices.

The household survey was conducted using semi-structured questionnaires and covered detailed information at the household, plot and watershed levels. A pre-survey test was also conducted in each watershed to customize instruments to local conditions. The plot survey covered specific plot-level information (i.e. plot elevation and slope) using a checklist. Plot elevation was measured by using GPS (GPSMAP 62st, Garmin), and slope was measured with a clinometer (PM-5/360 PC Clinometer, Suunto). Rainfall data was obtained from weather stations. To match with the period that farmers were asked to consider in their judgment of soil erosion severity, we took 10-year monthly rainfall data. The data were input into SPSS statistical software (ver. 23.0, IBM, Armonk, NY, USA) and analyzed with a combination of descriptive and econometric methods.

Empirical Model

The determinants of farmers’ perceptions of plot-level soil erosion severity can be analyzed using qualitative response statistical models. In a case where a dependent variable takes graduated discrete-ordinal values, for example, when respondents are asked to rate their plot-level severity of soil erosion on a scale that takes several different values. In this type of case, we can assume that the probability of a farmer perceiving a specified level of soil erosion severity is the probability that the perception function falls in a range around the respective value, given that random disturbances in the perception function follow a logistic probability distribution.

In our case, farmers were asked to respond to two questions: (i) whether they identified soil erosion as a problem on each of their plots since the last 10 years for owned plots, or since the time that they have started farming for rented in ones, and (ii) the extent of the problem (severity level). They evaluated them on a limited scale: “very low”, “low”, “medium”, “high” or “very high”. Often, these types of evaluations are converted into a numeric score, in this case, from 1 (very low) to 5 (very high). For convenience, many researchers treat these scores as continuous variables, calculate the mean score and compare those means using standard statistical tools. Unfortunately, this type of analysis is based on assumptions that are hard to justify. One such assumption is that the numeric distance between scores has a specific meaning, for example, that two scores of 3 (medium) would have the same value as a score of 2 (low) and a score of 4 (high), even though this cannot necessarily be presumed from what the farmers actually said. Farmers’ evaluations fell into different categories, which are clearly ordered but are not measured on an interval scale. Therefore, these scores should be treated and analyzed as ordered categorical responses, leading to the use of ordered-response models. In such models, it is assumed that scores represent ordered segments. In our case, respondents scored a level of soil erosion severity in a given plot in a particular ordered category, driven by a latent, unobserved variable \( y^* \), which represents the farmer’s ordering of the plot-level severity of soil erosion. Instead of this latent variable, we observed \( y \), a variable that falls into one of \( j \) ordered categories, in our case from 1 (very low) to 5 (very high).

Given that the outcome categories of the dependent variable appear to be ordered in terms of perceived soil erosion severity, a typical approach would be to use the standard...
ordered logit model (OLM) (Weisburd & Britt, 2014). The results from this type model are only valid, however, if the proportional odds assumption (i.e. parameter estimates are constant across the severity scores) is met (Williams, 2006; Weisburd & Britt, 2014). Therefore, after we fitted the standard OLM, we also conducted a formal test (the Brant test) on that assumption to reveal whether it had been violated by any subset of variables. If the assumption was found to be violated, a generalized OLM was used to express the probability of perceived soil erosion severity \( j \) by a farmer for a given plot such that:

\[
p(y_i > j) = \frac{\exp \left( a_j - X_i' \beta_j \right)}{1 + \exp \left( a_j - X_i' \beta_j \right)}, \quad j = 1, 2, 3, 4
\]

Where: \( X_i \) is a \((m \times 1)\) vector containing the values of perceived soil erosion severity \( i \) on the full set of \( m \) explanatory variables, \( \beta_j \) is a \((m \times 1)\) vector of regression coefficients and \( a_j \) represents the cut-off point for the \( j^{th} \) cumulative logit.

However, this model relaxes the proportional odds assumption for all independent variables, which is not always correct. Because this assumption may be violated by only a few variables, however, a partial proportional odds model (PPOM) can be employed, in which one or more \( \beta \)’s differ across equations and others can be the same for all equations. A gamma parameterization of the PPOM with logit function can be specified as:

\[
p(y_i > j) = \frac{\exp \left[ a_j - (X_i' \beta_j + T_i' \gamma_j) \right]}{1 + \exp \left[ a_j - (X_i' \beta_j + T_i' \gamma_j) \right]}
\]

Where: \( T \) is a \((n \times 1)\) vector \((n \leq m)\) containing the values of perceived soil erosion severity \( i \) on the subset of the \( m \) predictor variables for which the proportional odds assumption was not fulfilled, \( \gamma_j \) is a \((n \times 1)\) vector of regression coefficients associated with the \( n \) covariate in \( T \), so that \( T_i' \gamma_j \) is the increment associated with the \( j^{th} \) cumulative logit. In the model, each explanatory variable has one \( \beta \) coefficient, and \( k - 2 \gamma \) coefficients, where \( k \) is the number of alternatives (in our case, \( k = 5 \)). There are \( k - 1 \alpha \) coefficients reflecting cut-off points. The overall contribution of these variables on different perceived categories of soil erosion severity can be computed by adding the gamma coefficients of the respective equation and the beta coefficients.

In this study, parameters of the OLM and PPOM were estimated by the maximum likelihood procedure in Stata software (ver. 14.1, StataCorp, College Station, TX, USA). The PPOM was fitted with a user-written Stata routine gologit2 gamma parameterization alternative (Williams, 2006). Interpreting the coefficients of intermediate categories requires caution because the direction of the effect is not always determined by the sign of the estimate (Weisburd & Britt, 2014). Marginal effects (measures of the impacts of the variables on the probability of each soil erosion severity level) were considered in the interpretation of the variables. For continuous variables, the partial derivative was calculated numerically; for dummy variables, the difference was computed.

**Variables Considered**

Based on economic theory and previous empirical research of soil erosion (Gould et al., 1989; Tegene, 1992; Shiferaw & Holden, 1998; Tefera & Sterk, 2010; Tesfaye et al., 2014b; Haregeweyn et al., 2015; Teshome et al., 2016), explanatory variables included socio-economic, demographic and institutional variables (age, gender, level of education, extension contact, number of livestock owned and number of days participating in public SWC works); plot-specific variables (plot size, plot tenure, plot distance to residence, plot shape, plot soil depth, plot position in the watershed, presence of SWC technology in neighboring plots, whether plot received public SWC improvements, and plot elevation and slope); and village-level factors (June rainfall, July rainfall and perception of watershed-level soil erosion). Definitions of the selected variables, hypotheses of the direction of their influence and their descriptive statistical measures are presented in Table II.

**RESULTS**

Plots in our sample were small, with an average size of 0.41 ha (Table II). Household heads had an average of 1.26 years of schooling, and the average age was 47.6 years. About 86% of households were male-headed, with about 3.24 available adult equivalent laborers and 5.11 tropical livestock units. Most of the plots were owner operated, and on many plots and neighboring plots SWC technologies (traditional and improved) had been installed. Household members participated in public SWC works an average of 13 days per year, and more than half of the respondents perceived that the watersheds had been degraded through water erosion.

**Farmers’ Perceptions of Soil Erosion Severity**

Farmers had varied perceptions regarding the extent of soil erosion on their plots (Table III). The differences in the percentages of farmers’ judged plot-level soil erosion severity were significantly different among the three study sites \((p < 0.01)\). In particular, a significant difference \((p < 0.01)\) was observed among those plots perceived with “medium” to “high” soil erosion severity levels.

**Model Results**

Although we present parameter estimates of both the OLM and PPOM in Table IV for comparison, our discussion is limited to the PPOM output. This model had one beta coefficient for each variable, three gamma coefficients for variables violating the proportional odds assumption, and four alpha coefficients reflecting the cut-off points. Because there are five perceived soil erosion severity levels, we have four equations. Altogether, the model estimated 21 coefficients: 21 in the first equation (beta) and five each in the remaining three equations. The coefficients that are omitted in the last
FARMERS’ PERCEIVED SOIL EROSION SEVERITY

Table II. Summary statistics and description of the variables used in the analysis

| Variable (unit of measurement) | $H_0$ sign | Mean | SD |
|--------------------------------|------------|------|----|
| Age of the household head (years) | + | 47.64 | 11.58 |
| Gender of the household head (1 = male, 0 = female) | + | 0.86 | 0.34 |
| Education level of the household head (years) | + | 1.26 | 2.17 |
| Frequency of extension contacts per annum (no. of contacts) | + | 2.94 | 2.72 |
| Household size (adult equivalent) | + | 3.24 | 1.37 |
| No. days household participated in public SWC (days) | + | 13.43 | 9.13 |
| Livestock size owned by the household (tropical livestock unit) | + | 5.11 | 2.73 |
| Plot size (ha) | + | 0.41 | 0.49 |
| Plot ownership/tenure (1 = own, 0 = rent) | – | 0.83 | 0.38 |
| Plot distance to residence (minutes of walking) | + | 24.74 | 13.44 |
| Plot is convex shaped (1 = yes, 0 = no) | + | 0.30 | 0.46 |
| Farmer reports plot has shallow soil depth (1 = yes, 0 = no) | + | 0.36 | 0.48 |
| Position of plot in watershed, upper part (1 = yes, 0 = no) | + | 0.32 | 0.47 |
| Position of the plot in watershed, lower part (1 = yes, 0 = no) | – | 0.30 | 0.46 |
| Neighboring plots have SWC measures (1 = yes, 0 = no) | – | 0.44 | 0.50 |
| Plot received public SWC improvements (1 = yes, 0 = no) | – | 0.34 | 0.47 |
| Plot elevation (m a.s.l.) | + | 2059.72 | 431.36 |
| Plot slope (%) | + | 11.16 | 7.77 |
| June rainfall, average (mm) | + | 210.58 | 30.54 |
| July rainfall, average (mm) | – | 348.29 | 47.64 |
| Watershed perceived as being degraded (1 = yes, 0 = no) | + | 0.51 | 0.50 |

Note: $H_0$ sign shows the $a priori$ hypothesized direction of influence.

Table III. Farmers’ plot-level perceptions of soil erosion severity (N = 1010)

| Perceived soil erosion | Watershed | Total | Sig. ($\chi^2$) |
|------------------------|-----------|-------|----------------|
|                        | Aba Gerima | Guder | Dibatie | |
| Very low               | 60 (12.74) | 44 (11.99) | 21 (12.21) | 155 (15.35) | 0.1 |
| Low                    | 133 (28.24) | 86 (23.43) | 35 (20.35) | 305 (30.2) | 3.8 |
| Medium                 | 155 (32.91) | 92 (25.07) | 79 (45.93) | 336 (33.27) | 15.9*** |
| High                   | 104 (22.08) | 122 (33.24) | 24 (13.95) | 179 (17.72) | 20.1*** |
| Very high              | 19 (4.03) | 23 (6.27) | 13 (7.56) | 35 (3.47) | 3.6 |

Figures are counts. Values in parentheses are percentages of the column total. ***$p < 0.01$.

three equations (i.e. gamma_2, gamma_3 and gamma_4) are identical to those in the first equation.

The first equation is similar to a binary logistic regression model where the dependent variable is recoded as “very low” severity versus the other categories. The second equation is similar to the first one, but the dependent variable is recoded as “very low” severity + “low” severity versus the others. For the third equation, the dependent variable is recoded as “very low” + “low” + “medium” severity versus “high” + “very high” severity. For the fourth equation, the dependent variable is recoded as the lowest four levels versus “very high” severity. The estimations for the PPOM with logit function are presented in Table IV, and the marginal effects are shown in Table V.

The proportional odds assumption for each variable included in the model was tested using a series of Wald tests to see whether the variable’s coefficients differed across equations. Number of days that a household participated in public SWC activities ($p < 0.001$), farmer’s perception of a shallow soil depth ($p < 0.001$), plot slope ($p < 0.01$), June rainfall ($p < 0.001$) and July rainfall ($p < 0.001$) were found to be violating the proportional odds assumption. The gamma_2 and beta coefficients for the shallow soil depth variable were (0.8707) and (−0.7418), respectively. We added these two values to obtain the coefficient of this same variable in the second equation (0.1289). Likewise, we added the gamma_3 and gamma_4 coefficients with their corresponding beta coefficients to obtain the effect of this same variable in the third and fourth equations, respectively. Similarly, the effect of the other variables that did not satisfy the proportional odds assumption in various perceived soil erosion severity categories was different. Their respective parameter estimates in the second, third and fourth equations were computed in a similar manner as was used for the shallow soil depth variable.

Household Characteristics
Household characteristics (demographic, institutional and economic) such as education level of the household head, number of extension contacts, number of livestock units and number of days of participation in public SWC were identified as significant factors that affect the likelihood of
a farmer perceiving a certain level of soil erosion severity (Tables IV and V). Farmers with more education were less likely to perceive severe soil erosion in their plots as compared with less educated farmers (coef. = −0.31292, \( p < 0.01 \)), with other factors held constant. Similarly, farmers with more livestock were less likely to perceive soil erosion as severe as compared to those with fewer livestock units (coef. = −0.0449, \( p < 0.1 \)). The effect of increased frequency of contact with extension agents was as initially expected. Farmers with more frequent contact with extension agents were more likely to perceive severe soil erosion in their plots as compared with those who had fewer extension

| Table IV. Model estimation results for perceived soil erosion severity |
|----------------------------------|----------------|----------------|
| Variables                        | Model 1: OLM Coef. SE | Model 2: PPOM Coef. SE |
| Age of the household head        | 0.0062 0.0058   | 0.0073 0.0059   |
| Gender of the household head     | 0.1975 0.1837   | 0.1868 0.1858   |
| Education level of the household head | −0.2787*** 0.0906 | −0.31292*** 0.0944 |
| Frequency of extension contacts per annum | 0.0872*** 0.0244 | 0.0987*** 0.0254 |
| Household size, adult equivalent | 0.0824* 0.0490 | 0.0695 0.0501 |
| No. days household participated in public SWC | −0.0159 0.0086 | −0.0056 0.0128 |
| Livestock size owned by household | −0.0442* 0.0235 | −0.0449* 0.0239 |
| Plot size                        | 0.1825* 0.0932 | 0.1799* 0.0948 |
| Plot ownership/tenure            | −0.0649 0.1838 | −0.0665 0.1889 |
| Plot distance to residence       | 0.3361*** 0.1181 | 0.3795*** 0.1215 |
| Plot is convex shaped            | 1.8473*** 0.1504 | 1.8368*** 0.1532 |
| Farmer reports plot has shallow soil depth | 0.1594 0.1335 | −0.7418*** 0.1983 |
| Position of plot, upper watershed | 0.8398*** 0.1489 | 0.8799*** 0.1532 |
| Position of plot, lower watershed | −0.4653*** 0.1469 | −0.4915*** 0.1523 |
| Neighboring plots have SWC measures | 0.1279 0.1937 | 0.1127 0.2025 |
| Plot received public SWC improvements | −0.0019 0.2125 | 0.0176 0.2215 |
| Plot elevation                   | 0.0016*** 0.0004 | 0.0015*** 0.0004 |
| Plot slope                       | 0.0039 0.0083 | −0.0218*** 0.0110 |
| June rainfall                    | 0.0801*** 0.0236 | 0.0274 0.0268 |
| July rainfall                    | −0.0570*** 0.0159 | −0.0244 0.0177 |
| Watershed perceived as being degraded | −0.1307 0.1175 | −0.1557 0.1203 |
| Gamma_2                          |                   |                   |
| No. days household participated in public SWC |                     |                   |
| Farmer reports plot has shallow soil depth |                     |                   |
| Plot slope                       |                   |                   |
| June rainfall                    |                   |                   |
| July rainfall                    |                   |                   |
| Gamma_3                          |                   |                   |
| No. days household participated in public SWC |                     |                   |
| Farmer reports plot has shallow soil depth |                     |                   |
| Plot slope                       |                   |                   |
| June rainfall                    |                   |                   |
| July rainfall                    |                   |                   |
| Gamma_4                          |                   |                   |
| No. days household participated in public SWC |                     |                   |
| Farmer reports plot has shallow soil depth |                     |                   |
| Plot slope                       |                   |                   |
| June rainfall                    |                   |                   |
| July rainfall                    |                   |                   |
| Alpha                            |                   |                   |
| Constant 1                       | −0.1796 0.8665 | 0.5200 1.0727 |
| Constant 2                       | 1.6335 0.8663 | −1.0851 0.9308 |
| Constant 3                       | 3.5986 0.8741 | −4.8715 0.9972 |
| Constant 4                       | 5.9870 0.8990 | −3.5115 1.3229 |
| Number of observations           | 1010            | 1010            |
| Log likelihood                   | −1282.00        | −1220.47        |
| AIC                              | 2614.00         | 2520.94         |
| LR(df)                           | 341.9(21)       | 464.9(36)       |

Note: — indicates data not applicable.

*p < 0.1; **p < 0.05; ***p < 0.01.
| Variable                                      | Very low = 1 | Low = 2 | Medium = 3 | High = 4 | Very high = 5 |
|-----------------------------------------------|--------------|---------|------------|----------|---------------|
| Age of the household head                     | 0.0008       | 0.0007  | 0.0006     | -0.0005  | -0.0007       |
| Gender of the household head                  | -0.0211      | 0.0210  | -0.0144    | 0.0235   | 0.0131        |
| Education level of the household head         | 0.0354***    | 0.0107  | 0.0242     | 0.0269   | -0.0219**     |
| Frequency of extension contacts per annum     | -0.0112***   | 0.0029  | -0.0076    | 0.0087   | 0.0069***     |
| Household size, adult equivalent              | -0.0097      | 0.0057  | -0.0054    | 0.0073   | 0.0049        |
| No. days household participated in public SWC | 0.0006       | 0.0115  | -0.0008    | 0.0017   | 0.0056***     |
| Livestock owned by the household              | 0.0051*      | 0.0027  | 0.0035     | 0.0048   | -0.0031*      |
| Plot size                                     | -0.0203*     | 0.0107  | -0.0139    | 0.0192   | 0.0126        |
| Plot ownership/tenure                         | 0.0075       | 0.0214  | 0.0051     | 0.0158   | -0.0046       |
| Plot distance to residence                    | -0.0429***   | 0.0138  | -0.0293    | 0.0349   | 0.0265**      |
| Plot is convex shaped                         | -0.2077***   | 0.0198  | -0.1419    | 0.1619   | 0.1283***     |
| Farmer reports plot has shallow soil depth    | 0.0839***    | 0.0219  | -0.1084    | 0.0776   | -0.0832***    |
| Position of plot in watershed, upper part    | -0.0995***   | 0.0179  | -0.0679    | 0.0786   | 0.0615***     |
| Position of plot in watershed, lower part    | 0.0556***    | 0.0173  | 0.0379     | 0.0451   | -0.0343**     |
| Neighboring plots have SWC measures           | -0.0127      | 0.0229  | -0.0087    | 0.0178   | 0.0079        |
| Plot received public SWC improvements         | 0.0019       | 0.0251  | -0.0014    | 0.0174   | 0.0012        |
| Plot elevation                                | -0.0002***   | 0.0001  | -0.0001    | 0.0001   | 0.0001**      |
| Plot slope                                    | 0.0025**     | 0.0012  | 0.0044     | 0.0027   | 0.0009        |
| June rainfall                                 | -0.0031      | 0.0030  | -0.0094*** | 0.0034   | 0.0008        |
| July rainfall                                 | 0.0028       | 0.0020  | 0.0069***  | 0.0026   | -0.0019       |
| Watershed perceived as being degraded         | 0.0176       | 0.0136  | 0.0120     | 0.0166   | -0.0109       |

*p < 0.1; **p < 0.05; ***p < 0.01.
contacts (coef. = 0.0987, p < 0.01). However, greater participation in public SWC initiatives was not found to enhance the probability of farmers perceiving “high” and “very high” levels of soil erosion.

**Plot Characteristics**

Of the 11 plot-level factors included in the model, eight were found to significantly affect farmers’ perceptions (Tables IV and V). Greater plot size (coef. = 0.1799, p < 0.1) and distance from the residence (coef. = 0.3795, p < 0.01) raised the likelihood of farmers perceiving a higher level of soil erosion severity, as did having a convex shape (coef. = 1.8368, p < 0.01), being in the uplands (coef. = 0.8799, p < 0.01) and higher elevation (coef. = 0.0015, p < 0.01). Conversely, farmers in lowland areas (coef. = –0.4915, p < 0.01) were more likely to perceive a lower level of soil erosion severity. The probabilities of perceiving “high” and “very high” soil erosion severity levels were higher for farmers who possessed plots with shallow soil depth, holding other factors constant. The results obtained on plot slope were mixed. Farmers who owned steeply sloped plots were more likely to perceive the two extreme erosion severity levels (i.e. very low and very high).

**Watershed Characteristics**

June and July rainfall distributions were found to have a significant effect on farmers’ perceived level of soil erosion severity (Tables IV and V). June rainfall amount was more likely to form a “very high” perceived soil erosion level (marginal effect = 0.0083, p < 0.01) on farmers, whereas July rainfall amount was less likely to have that perception (marginal effect = –0.0056, p < 0.01). However, the opposite held true for plots that were perceived to have a “low” level of soil erosion severity.

**DISCUSSION**

This study assessed potential predictors associated with farmers’ plot-level perception of soil erosion severity by using PPOM. Of these factors, level of education of the household head, frequency of contact with an extension agent, number of days that household members participated in public SWC works, number of livestock owned by the household, plot size, distance to residence, plot shape, reported soil depth, position in the watershed (i.e. upstream or downstream), elevation and slope, and June and July rainfall distributions were found to be significant. This section provides a discussion regarding the effect of these factors. However, given our findings, we must be cognizant of a risk that by having many confounding factors, for example, watersheds with high, middle and lowland location as well as diverging previous exposure to SWC projects, causality of observed significant effects may remain speculative. Yet still, significance shows that there are a number of possible factors affecting farmers’ soil erosion perception.

Formal education is generally believed to be important to complement indigenous knowledge and to enhance the ability of farmers to process new information. However, our findings demonstrated that the level of education attained by household heads was less likely to help farmers in perceiving the risk of soil erosion severity in their plots, which is not in agreement with the findings of previous studies (Ervin & Ervin, 1982; Asrat et al., 2004). A possible explanation is that the curriculum in the existing formal primary education system in this area does not adequately emphasize environmental issues and instead focuses on basic literacy and numeracy skills (Dalelo, 2011); educated farmers have implemented better SWC measures (Asrat et al., 2004), as a consequence experience lower erosion risk; or it may be rooted in the generally low level of school enrollment in the study area. This explanation is in accordance with that of Bekalo & Bangay (2002), who argued that the formal education sector is not well suited to deliver a meaningful program that identifies the symptoms of soil erosion and proposes alternatives towards more sustainable land management practices. Similarly, greater household participation in public SWC initiatives was not found to enhance the probability that farmers would perceive higher levels of soil erosion. A possible explanation for this may be that the top-down nature of government-led initiatives often overlook local conditions and community views (Snyder et al., 2014).

Livestock pressure has been blamed as a major contributing factor to severe soil erosion in the highlands of Ethiopia. Several studies (Mwendera & Saleem, 1997; Mwendera et al., 1997; Taddesse et al., 2002; Alemayehu et al., 2013) have reported that vegetation cover decreases and soil compaction increases with increasing grazing pressure, which leads to lower infiltration rates, increased runoff and soil loss. In contrast, our results showed that, with other factors held constant, farmers with a greater number of livestock were associated with lower perceived levels of soil erosion. The farmers’ reported perceptions could stem from their fear of the current government’s approach of banning free grazing to reduce damage on installed SWC technologies by livestock. Alternatively, it may be a result of the farmers’ belief that livestock contribute to land fertility improvement rather than degrade the environment (Bewket & Sterk, 2002; Kassie et al., 2009); or wealthy farmers with more livestock may have applied more SWC measures (Kassie et al., 2009; Abebe & Sewniet, 2014) and face lower erosion risk as a result. Furthermore, Tesfaye et al. (2014b) asserted that farmers with more livestock are less likely to introduce improved SWC technologies on their croplands because the technologies compete for land that could otherwise be used for food or feed production. These factors may suggest the importance of bundling enhanced community awareness activities (Tesfaye et al., 2014b) with the introduction of better performing multipurpose livestock breeds (Benin et al., 2003), which in the medium to long term may help to reduce both herd size and pressure on land resources.

The number of contacts that farmers had with agricultural extension agents was found to positively and significantly (p < 0.01) affect farmers’ perception of soil erosion severity. This is likely true because greater contact with extension...
agents enables farmers access to knowledge-intensive information related to land and sustainable land management options (Kassie et al., 2009; Matouš et al., 2013), which gives them the opportunity to mix indigenous knowledge with modern technology and methods. Furthermore, Tesfaye et al. (2014a) reported that farmers with more contacts with extension agents are also more likely to maintain SWC structures because it allows them to access technical support and information about sustainable land management technologies.

Slope was found to have a positive significant effect \( p < 0.1 \) on the “very high” severity level, implying that farmers with plots in steeply sloped areas are more likely to perceive the impact of plot gradient on severity of soil erosion. This finding is in agreement with that of Teshome et al. (2016), who found a positive relationship between slope and soil erosion severity. The shape of the plot in terms of slope was also significant. We found that convex (hill-shaped) plots were perceived to lose more soil, presumably because the symptoms of erosion are more prevalent in these types of plots.

Plot size and soil depth were also important factors. The larger the field, the higher is the likelihood of witnessing rills, surface runoff, sediment deposition and redeposition by farmers (Bewket & Sterk, 2003). Larger parcel size may create a positive incentive for small-scale farmers to invest in SWC technologies (Tesfaye et al., 2014b; Teshome et al., 2016). This is presumably true in subsistence agriculture because farmers assume that SWC technologies compete for space on small plots, which reduces productivity in the short run, thereby increasing farmers’ reluctance to apply countermeasures (Tesfaye et al., 2014b). Farmers were very likely to perceive severe soil erosion in plots with shallow soil depth. Although farmers may need a relatively long time to witness a significant decline in soil depth because of erosion, they are generally more aware of a decline in rooting depth in eroded farmlands and of exposed subsoil materials (Tegene, 1992).

If farmers observe these conditions, especially in shallow soils as in our study, it may partly influence their decisions to apply SWC technologies. However, Kassie et al. (2009) reported that farmers preferred to treat such plots with fertilizer rather than use SWC technologies.

Distant plots were perceived to be more prone to soil erosion, probably because the farther the plot is from the farmer’s residence, the less attention it receives and the likelihood of severe soil erosion increases. This explanation is consistent with the results of Teshome et al. (2016) and Tefera & Sterk (2010), who found that more distant plots received less care as compared to nearby plots. Moreover, Mwendera & Saleem (1997) reported that plots receiving less care were very likely to become eroded because of soil nutrient depletion, particularly organic matter content, and increased soil loss through water erosion.

Differences in elevation within and between watersheds affected farmers’ perceptions of soil erosion severity. Farmers in the Aba Gerima and Guder watersheds perceived higher levels of soil erosion than farmers in the Dibatie watershed. Plot elevation, which was closely associated with within and between watershed differences, had a significant positive effect \( p < 0.01 \) on farmers’ perceived level of soil erosion severity. Tamene & Vlek (2008) found that, in higher elevations with rugged topographies, higher rates of runoff and greater rainfall energy contribute to detaching and transporting soil particles.

We found that the upstream areas were more likely to be perceived to be affected by soil erosion, whereas the downstream farmlands were less likely to be perceived in that manner. These results conform with those of Bewket & Sterk (2003) and Tefera & Sterk (2010), who reported that the perceived severity of soil erosion was site specific, that is, relatively higher in upstream areas and lower in downstream fields.

Farmers’ perceptions of soil erosion also showed intra-seasonal variation; they perceived high levels of soil erosion in June and relatively lower ones in July. This result is consistent with that of Bewket & Sterk (2003), who found that high levels of soil erosion occur in June. A plausible explanation for this is that seedbed preparation is accompanied with frequent tillage in the highland and midland watersheds, as many as 10 tillings for teff, which loosens the soil and increases its vulnerability to soil erosion in June. The lower level of perceived soil erosion in July corresponds a period of increased crop cover.

**CONCLUSION**

We found that farmers’ perception of soil erosion severity corresponded well with expectations of soil erosion because of site-specific factors, such as plot shape, soil depth, plot position on hills and exposure to rainfall during the cropping season. Given this correspondence with both theoretical predictions and empirical findings from previous scientific studies, we conclude that farmers’ expertise is apt to assess soil erosion situations, which suggests the importance of using participatory approaches when working to reduce soil erosion. Moreover, interaction with extension service agents increased the likelihood that farmers would perceive soil erosion problems. Despite their expected importance, level of education and number of livestock owned were not found to be significant indicators in farmers’ perceptions of severe soil erosion. This situation could be addressed by introducing environmental issues in the earlier years of the school curriculum as well as by sustainable land management oriented adult education. A better understanding of the relationship between soil erosion and livestock may require detailed community-level discussions and a closer assessment of the potential linkages between livestock wealth and land conditions.

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