Landholders’ Choice to Adopt Improved Watershed Management in the Lower Blue Nile Basin, Ethiopia

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Abstract

Watersheds are tremendously degraded worldwide, largely in developing countries especially in the Blue Nile Basin in Ethiopia. The degradation is due to several factors including pressure from land use and economic development. The degradation might be characterized by poor water quality, irregularity in water quantity, heavy floods that destroy life and property, sediment deposition in streams and irrigation canals; and sediment deposition on dams etc. Several researchers have suggested different watershed management interventions to end these problems, especially in developing countries. They include reforestation; construction of stone terrace; soil bunds; water harvesting technologies; and crop residue management. However, most landholders are not adopting these recommended technologies mainly due to socio-economic, institutional and policy-related issues. This paper empirically examines existing factors that are perceived to affect landholders’ decisions for adopting improved watershed management intervention technologies in the Blue Nile Basin in Ethiopia. A multi-stage probability sampling techniques was used to sample 300 respondents and a binary Logit model was applied to the data. Results indicate that education, farm size, fertilizer, tropical livestock unit, traditional local institutions, land security and distance to nearest market are found to be significant factors that influence downstream landholders’ decision to adopt improved watershed management technologies.

Keywords: Adoption behavior, improved watershed management, Blue Nile basin, downstream landholders, binary logit model.
1. Introduction

Watershed encompasses environmental and natural resources, which sustain diversified ecosystem services (Randhir et al., 2001) as well as economic and recreational benefits (Alemayehu et al., 2008; Legesse, 2014). Studies show that watersheds have been extremely degraded in developing countries (Kosoy et al., 2006; Engel et al., 2008; Legesse, 2014) due to erosion, changes in farming systems, overgrazing, deforestation, pollution etc. (Alemayehu et al., 2008; Darghouth et al., 2008; Wunder et al., 2008). The degradation has caused adverse impact on water quality, irregularity of water quantity, heavy floods, sediment deposition etc. especially in developing countries like Ethiopia (Pagiola et al., 2007; Wunder and Albán, 2007; Setegn, 2008; Darghouth et al., 2008; Asquith et al., 2008; Ashagre, 2009; Legesse, 2009; Mengstie, 2009). The Blue Nile Basin is one of the endangered Basins in Ethiopia due to the degradation. Studies suggest various watershed management interventions to end these problems. These include soil conservation practices, preservation of hydrologic services, rehabilitation of degraded lands through physical and biological measures etc. (World Bank, 2006; Alemayehu et al., 2009; MOA-SLM, 2013). Also exist, are various improved watershed management technologies recommended for the downstream stratum that differ from the upper stratum of the Basin (BOA, 2012; MOA-SLM, 2013). These practices include construction of soil bunds, grass strips plantation, crop rotation, intercropping, strip cropping, manure/compost, inorganic fertilizer application, multi-storage gardening and farm ponds construction (Alemayehu et al., 2009; BOA, 2012; MOA-SLM, 2013). Among these measures, soil bund has been practiced for a couple of decades in the lower stratum of the Basin. However, this measure is not adopted by downstream landholders due to various reasons (Legesse, 2014; BOA, 2012). This paper examines determinants of landholders’ adoption behavior towards soil bunds as a management practice that contributes to a pollution-free watershed. This study was done in the lower stratum of Koga watershed of the Blue Nile Basin through interviewing 300 respondents. The sampled respondents were selected using multi-stage probability sampling techniques. We employed a binary logit model to the data.

2. The study area

Kog watershed is located in eastern part of the Blue Nile Basin, Ethiopia, between 11°8’ North to 11°25’ North latitude and 37°2’ East to 37°20’ East longitude with a total drainage area of 299 km² (Bitew and Gebremichael, 2011; Legesse, 2014) (see Figure 1). The watershed’s elevation ranges from 1,800 to 3,200 m. a. s. l. with an average annual rainfall of 1,560 mm and average daily temperature between 16°C to 20°C (Alemie, 2009; Kasahun, 2009; Legesse, 2014). According to the district agro-ecological zones classification, the downstream part is characterized by wide flat to gently sloping topographies (Legesse, 2014). The watershed has high rainfall during July to September with highest mean monthly rainfall in July and highest evapotranspiration in May (Alemayehu et al., 2008).

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1 Watershed management refers to integrated measures that have been put in to practice to secure sustainable provisions of watershed services (Kaledhonkar et al., 2007).

2 Agro-ecological zones classified based on rainfall patterns, temperature, soil types, altitude and other physical landscapes (Alemu et al., 2009).
3. Methodology

3.1 Data collection and sampling techniques

Data was collected from sampled farmers by employing structured questionnaires. The questionnaires were used to collect socio-economic, demographic, behavioral and institutional information. Experienced enumerators administered the data collection with close supervision. The survey data was augmented with secondary data from Central Statistical Agency, Ministry of Agriculture and District Bureau of Agriculture to obtain general information about the study area.

The study employed multi-stage sampling techniques to select respondents: in the first stage, Koga watershed was selected purposively. In the second stage, five Kebeles (the lower local administrative region next to district) were selected based on simple random sampling procedure. In the third stage, Gottes (the lower local administrative region next to Kebele) were selected based on proportional random sampling procedure. In this stage, the Gottes in each sampled Kebele were stratified into three groups depending on their distance (nearby, moderate, far away) from the center of local administration office. Following, six Gottes from each Kebele (at the rate of two Gottes from each stratified groups) were selected based on random sampling procedures. Finally, the sampled farmers were selected from sampled Gottes based on systematic random sampling procedures. The lists of farmers and Gottes were obtained from development centers and local administrative offices of the respective Kebeles. A total of 300 downstream farmers were selected for this study.

3.2 Theoretical Framework

Binary logit and Probit models are quite comparable and have the same S-shaped curves that bound in an interval from 0 to 1 (Pindyck and Rubinfeld, 1981; Gujarati, 1995; Alemayehu, 2007). The logit model has slightly flatter tails and assumes cumulative logistic probability function. Whereas, Probit model is associated with cumulative normal distribution (Pindyck and Rubinfeld, 1981; Gujarati, 1995; Alemayehu et al. 2010; Legesse, 2014). This study employs binary logistic
regression over Probit due to the following advantages: binary logit model transforms problem of predicting probabilities within (0, 1) interval to problem of predicting the odds of an event occurring within actual condition (Pindyck and Rubinfeld, 1981), simple to work, flexible and straightforward (Hosmer and Lemeshew, 1989; Alemayehu 2007).

The dependent variable in the binary logit is a dummy variable (binary), which takes a value zero or one depending on whether downstream farmers adopt soil bunds. However, explanatory variables are either continuous or dummy variables. According to Pindyck and Rubinfeld (1981) and Alemayehu et al. (2010), the cumulative binary logistic probability function is specified below:

$$P_i = F(Z_i) = F\left[\alpha + \sum_{i=1}^{m} \beta_i X_i\right] = \frac{1}{1 + e^{-\left[\alpha + \sum_{i=1}^{m} \beta_i X_i\right]}}$$  \hspace{1cm} (1)

$$Z_i = \alpha + \sum_{i=1}^{m} \beta_i X_i$$  \hspace{1cm} (2)

Where: $e$ represents the base of natural logarithms, $X_i$ represents the $i$th explanatory variable, $P_i$ represents the probability that downstream landholders’ choice to implement soil bunds, and $\alpha$ and $\beta_i$ are parameters to be estimated

Interpretation of coefficients could be easier if the binary logistic model reformulates in terms of the odds and log of odds (Hosmer and Lemeshow, 1989; Gujarati, 1995). The odds ratio implies a ratio of the probability that an individual would choose an alternative ($P_i$) to the probability that she/he would not choose it ($1 - P_i$), which is defined below:

$$[1 - P_i] = \frac{1}{1 + e^{Z_i}}$$  \hspace{1cm} (3)

Using equations (1) and (3), the odds ratio presented by equation 4.

$$\left[\frac{P_i}{1 - P_i}\right] = \frac{1 + e^{Z_i}}{1 + e^{-Z_i}} = e^{Z_i}$$  \hspace{1cm} (4)

Alternatively,

$$\left[\frac{P_i}{1 - P_i}\right] = \frac{1 + e^{Z_i}}{1 + e^{-Z_i}} = e^{\left[\alpha + \sum_{i=1}^{m} \beta_i X_i\right]}$$  \hspace{1cm} (5)

Taking the natural logarithms of equation 4 and 5 give the binary logit model that can be presented as below:
The binary logit model can be presented as follows if the disturbance term, \( u_i \), is considered.

\[
Z_i = \ln \left[ \frac{P_i}{1-P_i} \right] = \alpha + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_m x_{mi} + u_i
\]  

Equation (7) was estimated using iterative maximum likelihood estimation procedure, which is consistent with utility maximization theory. This estimation procedure yields unbiased, efficient and consistent parameter estimates, particularly for large sample size (Legesse, 2014). We employed SPSS for Windows (version 19) to estimate the logit model.

Prior to the model estimation, Variance Inflation Factor (VIF) and Contingency Coefficients (C) techniques were employed to detect multi-collinearity among continuous and dummy explanatory variables respectively. The mathematical form of VIF and C are given by equation 8 and 9, respectively (Gujarati, 2004; Andren, 2007; Alemayehu et al., 2010; Legesse, 2014).

\[
VIF(X_i) = \left(1 - R_i^2\right)^{-1}
\]  

Where: \( R_i^2 \) is the squared multiple correlation coefficient and \( X_i \) is the \( i^{th} \) explanatory variable.

\[
C = \sqrt{\frac{\chi^2}{n + \chi^2}}
\]  

Where: \( \chi^2 \) is Chi-square and \( n \) is total sample size.

4. **Results and discussions**

Results show that about 34 percent of downstream landholders are likely to be adopters of soil bund practice. The explanatory variables used in the model are **Age, Education, Farm Size, Field Visit, Fertilizer Application, Distance to Nearest Market, Tropical Livestock Unit**, **Informal Local Institution (Debo)**, **Cooperative and Land security**.

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3 Researchers recommend to omit variables with a VIF value of 10 and more from the analysis in order to avoid serious multicollinearity problem (Healy, 1984; Adugna, 2005; Alemayehu et al., 2010; Beshir et al., 2012; Beshir, 2014; Legesse, 2014).

4 C values, which ranges between 0 to 1, measures the degree of correlation between discrete variables based on chi-square measure of association. C value with 0.75 or more shows a strong degree of association between discrete variables, C value close to zero indicts absence of series association between discrete variables (Healy, 1984; Adugna, 2005; Alemayehu et al., 2010; Beshir et al., 2012; Beshir, 2014; Legesse, 2014).

5 TLU is commonly taken to be an animal of 250 kg live weights (Storck et al. 1991), TLU conversion factors that used in this study which is presented in Appendix Table 1.

6 Informal local institutions employ traditional rules and customs that govern human behavior but not codified by state law (Joireman 2001 cited in Degefa, 2010). “Debo” is one of traditional local institutions in the study area that established by the community as labor sharing pulling system, where the person requiring labor typically provides food and drink in exchange for labor.
The $VIF$ values for continuous explanatory variables were found to be small, which were less than 10. The $C$ values for dummy explanatory variables were found to be small, which were less than 0.75. The chi-square value of the result shows the overall goodness of fit of the model at less than 1% probability level (Table 1). The $R^2$ goodness of fit employed is based on the theory that an event may not occur if estimated probability of an event is less than 0.5 and otherwise it may occur (Maddala, 1989; Alemayahu et al., 2010; Legesse, 2014). Hence, the $i^{th}$ respondent was considered to be adopter if and only if the computed probability value greater or equal to 0.5 otherwise non-adopter of soil bund intervention. The binary logit model correctly predicts 83 percent of the total observed values. The sensitivity of the model shows the proportion of correctly predicted downstream landholders as adopters of improved soil bund practice is 93.90 percent. The specificity of 91.20 percent indicates the proportion of correctly predicted downstream landholders as non-adopter of improved soil bund measures. Therefore, the model predicts both groups adequately.

As presented in Table 1, seven explanatory variables included in the analysis are found to have statistically significant impact on farmers’ adoption behavior with less than 10% probability level. These variable include education, farm size, fertilizer application, distance to nearest market, informal local institution, tropical livestock unit, and land security. A brief discussion on the statistically significant explanatory variables is provided below:

**Education**: Studies show that farmers’ educational level influences their adoption behavior (Dasgupta, 1989; Chomba, 2004; Yehzbalem, 2005). This variable is significant at (P<0.01) and has a positive association with landholders’ choice to adopt improved soil bund practice. Educated farmers incline to spend more time and money in soil conservation measures (Shiferaw, 2002, Abdulai and Huffman, 2014). This result coincides with Okoye (1998), Gould et al. (1989) Bekele and Drake (2003), Anley et al. (2006), Bienen and Hearne (2006), Ojeda et al. (2007), Chukwuone and Okorji (2008), Yoo et al. (2008), Deressa et al. (2009) and Stithou and Scarpa (2012) who reported the positive influence of education on farmers’ adoption behavior. The odds ratio of this variable indicates that farmers’ decision to adopt the measure will increase by the factor of 5.70 for a unit increase in this variable, ceteris paribus.

**Farm size**: Farm size is a wealth indicator and a proxy for social status (Zegeye et al., 2001; Asfaw et al., 2011; Beshir et al., 2012). Farmers who have large farm size are more likely to adopt the technology (Norris and Batie, 1987). This variable affects farmers’ adoption behavior positively and found to be significant at (P<0.01). The odds ratio of the variable implies that farmers’ choice to adopt the measure will increase by a factor of 1.40 for an additional unit increase in farm size, ceteris paribus. Sureshwaran et al. (1996), Sangkapitux et al. (2009), Adugna (2005), Ndetewio et al. (2013), Oladele (2008), Abu et al. (2011) and Kwau et al. (2013) also reported that farm size highly and positively correlated with farmers’ choice to adopt watershed management interventions.

**Fertilizer application**: Fertilizer application is one of the biological management technologies used to minimize runoff through infiltration of rainfall and also improves crop yields (Nkonya et al., 2005; Alemayehu et al., 2008; Zelleke, et al., 2010; Spielman et al., 2011; MOA, 2012; Getnet and MacAlister, 2012; Minot and Sawyer, 2013). Studies revealed that farmers who apply
fertilizers are adopters of the technologies as compared to those who do not apply (Schmidt and Tadesse, *et al.*, 2012; Legesse, 2014). This variable correlates positively with farmers’ adoption behavior and found to be significant at (P<0.01). The probability of downstream landholders’ choice to adopt the measure will increase by 0.99 as compared to those who do not use fertilizer, ceteris paribus. Alemayehu *et al.* (2009) and Schmidt and Tadesse *et al.* (2012) also reported the positive association between fertilizer application and adoption of watershed management interventions.

**Distance to the nearest market:** Studies revealed that the nearest market distance saves time, reduces transportation costs and increases access to information (Beshir *et al.*, 2012; Legesse, 2014). This variable is a proxy indicator for market accessibility and it is found to be significant at (P<0.01) but associate negatively with farmers’ adoption behavior. This suggests that farmers’ decision to adopt the measure most likely declines with distant from the central market. The reason is that farmers’ chance of accessing information about improved watershed management measures reduces the further away from the central market. This result agrees with what is stated in Chirwa (2005), Langyintuo and Mekuria (2005), Maddison (2006), Mariara (2007), Bittinger (2010), Cavatassi *et al.* (2011) and Tedla (2011). The odd ratio of the variable implies that farmers’ decision to adopt the measure will decline by a factor of 0.75 for an increase in distance.

<table>
<thead>
<tr>
<th>Table 1: Parameter estimates for binary logit model</th>
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<tbody>
<tr>
<td><strong>Explanatory Variables</strong></td>
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<tr>
<td>Education</td>
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<tr>
<td>Farm size</td>
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<tr>
<td>Field visit</td>
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<tr>
<td>Fertilizer</td>
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<tr>
<td>Distance to nearest market</td>
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<tr>
<td>Tropical livestock unit</td>
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<tr>
<td>Informal institution</td>
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<tr>
<td>cooperatives</td>
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<tr>
<td>Land security</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>Constant</td>
</tr>
</tbody>
</table>

| **-2 Log likelihood** | 110.6 |
| **Nagelkerke R Square** | 0.83 |
| **Overall prediction** | 93.0 |
| **Sensitivity** | 93.9% |
| **Specificity** | 91.2% |
| **Sample size** | 300 |

***,**,* and * Shows significance at 1%, 5% and 10% probability levels

*Based on a 50-50 probability classification scheme

*Correctly predicted adopters

*Correctly predicted non-adopters

Source: Model analysis, 2016
Membership in informal local institution: Informal local institutions are participatory local social institutions, which are established by the local community (Degefa, 2010; Legesse 2014). This variable is significant at (P<0.05) and correlates positively with farmers’ adoption behavior. This implies that downstream landholders incline to adopt soil bund measure as compared to those who are not the member of informal institutions. The reason is that farmers considered traditional institutions as means to address their need (Nyangena, 2008). This result coincides with findings of Sangkapitux et al. (2009), Ayuya, et al. (2011), and Sebhatu (2012) and Legesse (2014). The odds ratio suggests that farmers’ choice to adopt the measure will increase by a factor of 4.60 as they acquire additional service from informal institutions, ceteris paribus.

Tropical livestock unit: This variable is significant at (P<0.10) and has a positive association with farmers’ adoption behavior. Livestock serves for income or wealth, wealthy landholders are less risk averse and are more likely to adopt first than less wealthy ones. Sambrook and Akhter, (2001), Tesfaye et al. (2001), Alemayehu et al. (2008) and Banks and Dagher (2012) also reported the positive influence of TLU on farmers’ adoption behavior. Downstream landholders’ choice to adopt the measure will increase by a factor of 1.20 as this variable increases by one additional unit, ceteris paribus.

Land security: Farmers’ sense of tenure security correlates positively with their adoption behavior and found to be significant at (P<0.10). This implies that security in land rights encourages farmers to invest in improved watershed management (Southgate, 1988; Yehzalem, 2005; Legesse, 2014). This might be due to the fact that downstream farmers opt to adopt the measure when they have the confidence to use their parcel at least during their lifetime. This result is in accordance with findings of Illukpitiya and Gopalakrishnan (2004), ORGUT (2010), Juana et al. (2013), Banks and Dagher (2012) and Legesse (2014) who reported positive effects of land tenure on farmers’ choice to participate in watershed management interventions. The odds ratio suggests that farmers’ adoption behavior most likely will increase by a factor of 5.50, ceteris paribus, as their sense of tenure security improve by an additional unit.

5. Conclusions and policy implications
The results of the study show that education, farm size, fertilizer application, distance to nearest market, informal local institution, tropical livestock unit, and land security are found to be influence a landholder’s decision to adopt the technologies. Farmers’ level of education has a positive and significant impact on their decision to opt the measures. This implies that educated farmers understand the problems and are more likely first to adopt the measures. This result suggests providing education and training services to farmers to improve adoption of the technologies. Farm size is one of the important factors that has a positive influence on farmers’ adoption behavior. Farmers with large farms are more likely to adopt the technology than small farms. This implies that policy makers should give attention to large farmers so that the technologies can reach other farmers through a farmer-to-farmer way of information dissemination. It is also found a positive significant impact of fertilizer application on farmers’ adoption behavior. This indicates that farmers who use fertilizers are adopters of the technologies. This result suggests enhancing the provision and accessibility of fertilizers to improve adoption of the technologies. The study shows that membership in informal local institution directly correlates

Traditional institutions refer to traditional rules and customs that govern human behavior but not codified by state law (Joireman 2001 cited in Degefa, 2010).
with farmers’ adoption behavior. The reason is that local institutions have high level of trust, acceptance and recognition by farmers. Tropical livestock unit has significant positive association with farmers’ adoption behavior. The reason is that livestock serves for income and wealthy farmers are more likely to adopt the technologies.

Farmers’ sense of tenure security has a significant positive correlation with their adoption behavior. This might be due to the fact that farmers adopt the measure when they have the confidence to use their parcel at least during their lifetime. Distance to the nearest market has a significant negative impact on farmers’ adoption behavior. The reason is that farmers’ chance of accessing information reduces the further away from the central market.

Based on the findings of the study, the following points need to be considered by policy makers in order to improve adoption of improved watershed management interventions: (i) there is a need to incorporate educational and training components in watershed management policies to promote the conservation, management and sustainable use of watersheds; (ii) improving farmers’ income is an essential element to boost their capacity to invest in improved watershed management measures. To achieve this responsibility, all concerned stakeholders such as the Ministry of Agriculture, Agricultural Research Centers, NGOs, informal local institutions and others need to collaborate through designing appropriate systems to raise farmers’ income; (iii) there is also a need to increase the number of local markets, improve existing rural marketing system and integrate farmers with the existing marketing system; and (iv) there is a need to consider farmers’ land ownership rights in watershed management policies and strategies.

6. References


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Yehzbalem, M.T., 2005. Farmers’ Response and Willingness to Participate in Water Harvesting Practices: A Case Study In Dejen District / East Gojam Zone


Appendix Table 1: Conversion factors used to estimate tropical livestock unit

<table>
<thead>
<tr>
<th>Animal Category</th>
<th>Total TLU</th>
<th>Animal Category</th>
<th>Total TLU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calf</td>
<td>0.25</td>
<td>Donkey (adult)</td>
<td>0.70</td>
</tr>
<tr>
<td>Weaned calf</td>
<td>0.34</td>
<td>Donkey (young)</td>
<td>0.35</td>
</tr>
<tr>
<td>Heifer</td>
<td>0.75</td>
<td>Camel</td>
<td>1.25</td>
</tr>
<tr>
<td>Cow and ox</td>
<td>1.00</td>
<td>Sheep and goats (adult)</td>
<td>0.13</td>
</tr>
<tr>
<td>Pigs</td>
<td>0.20</td>
<td>Sheep and goats (young)</td>
<td>0.06</td>
</tr>
<tr>
<td>Horse</td>
<td>1.10</td>
<td>Chicken</td>
<td>0.013</td>
</tr>
</tbody>
</table>