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Mintewab Bezabih, Abe Damte Beyene, Zenebe Gebreegziabher, Livousew Borga

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# Social Capital, climate change and soil conservation investment: panel data evidence from the Highlands of Ethiopia[1]

Mintewab Bezabih
*The Grantham Research Institute on Climate Change and the Environment,*
*London School of Economics and Political Science*
Tower 3 | Clements Inn Passage | London WC2A 2AZ
m.bezabih@lse.ac.uk
Abebe Damte Beyene
*Environmental Economics Policy Forum for Ethiopia*
*Addis Ababa, Ethiopia*
abebed2002@yahoo.co.uk
Zenebe Gebreegziabher
*Department of Economics,*
*Mekelle University*
*and Environmental Economics Policy Forum for Ethiopia*
*Addis Ababa, Ethiopia.*
zenebeg@yahoo.com
Liyousew Borga
*Centre for Economic Research and Graduate Education*
*The Czech Republic*
liyousew@gmail.com

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## Abstract

The paper analyses the impact of climate change and local social networks on farmers' soil conservation behaviour in the Central Highlands of Ethiopia. Farm household level panel data with multiple plots combined with climate data from the adjacent meteorological stations, interpolated at a household level, are employed in the analysis. The extent to which local social networks contribute to soil conservation investment in the presence of climate change is assessed using multivariate probit and poison estimation methods. In light of similar previous studies, the major contributions of the paper are: 1) the use of wide ranging social capital measures, and 2) the availability of different soil conservation structures in multiple plots within the same household. The results show that climate change is a significant determinant of soil conservation investment. In addition, the relationship between local social networks and soil conservation is context specific.
**JEL classification:** C25, D02, D85

**Key words:** local social networks, shocks, climate change, soil conservation, multivariate probit

# 1. Introduction

Pervasive economic and social risk is a fact of life for rural households in low-income developing countries (Dercon, 2002; Yesuf and Bluffstone, 2009). The enormous scope and diversity of these shocks, both covariate or idiosyncratic, contribute to the lack of viable formal insurance markets. As a result, unlike farm households in developed countries that can trade away the risk of crop failure in the insurance market, in developing country settings, such markets are lacking (e.g. Janvry et al. 1991; Udry, 1994) and farmers employ relatively sophisticated methods to offset such risks (Dercon, 2002). Given that climate change is increasingly becoming among the most important of such risks, understanding how farm households' endowments are used to adapt to climate change is critical to the design of effective adaptation measures. In this study, we focus on soil conservation investment as a central adaptation tool and examine the role of social capital in soil conservation investment in the face of climate change.

The emphasis on soil conservation investment as a climate change adaptation tool, stems from the significant association of in soil erosion rates and climate change measures (O'Neal et al., 2005; Boardman and Favis-Mortolock, 1993). Particular to developing countries, Deressa et al. (2009) identify soil conservation as one of the major strategies farmers employ towards the threats of climate change. In addition, Difalco and Bulte (2012) argue that adoption of certain farm management strategies reduces exposure to such shocks, given that agriculture is most exposed to climate change. Based on their study in the Nile Basin of Ethiopia, Kato et al. (2009) find that more than 30 percent of farmers adopted soil and water conservation measures in response to perceived long-term changes in temperature and rainfall.

While there is a wealth of evidence suggesting an important role of social capital in mitigating against income risks in general,[2] the recently growing literature on the links between social capital and climate change adaptation provides mixed evidence.

[2] For details on the links between social capital and income risk, see section 2.

Proponents of the positive role of social capital in mitigating against the risks of climate change pursue the argument that an individual's adaptation behaviour is triggered by his or her recognition of the need to adapt (Fankhauser et al. 1999), perceived climate risk, costs of adaptation and potential reduction in damage (Kane and Shogren, 2000). Social networks and social skills can possibly affect these determinants of adaptation behaviour (Nam, 2012). Findings from a number of other studies, particularly in developing countries, attest to this view.

In their study of the role of social capital in adaptation to climate change in Ethiopia, Deressa et al. (2009) show that informal institutions such as peer networks aid climate change adaptation through sharing experiences of adaptation options and channeling informal financial sources that help on investments in adaptation. Social networks are also found to play an important role in asset recovery and growth after environmental shocks (Mogues, 2006). In South Africa, Carter and Maluccio (2003) find that trust has a mitigating effect on weather shocks. Similarly, van Rijn et al (2012) show a significant relationship between an aggregate measure of social capital and agricultural innovations by using data collected from seven African Countries[3].

However, a strand of the recently growing climate change literature also holds the view that social capital may act as a hindrance to climate change adaptation activities. In line with this, Di Falco and Bulte (2012) argue that investment in climate change adaptation may be hampered by the disincentive effects of strong social ties in the form of kinship. Difalco and Bulte (2011) examine the impacts of traditional risk sharing norms in kinship networks on consumption and accumulation strategies and find that such networks attenuate accumulation incentives and more extensive kinship networks are associated with lower incomes. In addition, individual adaptation incentives may be weakened through strong institutional norms such as the labor sharing norm in farming

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[3] There is also evidence of support for this view from studies outside of Africa. In extreme weather related events such as Hurricane Mitch, the Honduras Trust, as the norm in a community, also helped households in asset recovery and growth after (Carter and Castillo, 2006). In addition, social capital in the form of voluntary labor contribution has evolved to facilitate collective adaptation practices such as sea dike maintenance in the absence of governmental support in Vietnam (Adger, 2000). In a study from the Philippines, Cramb (2005) shows that social capital, measured in terms of membership in land care, had a significant impact on the adoption of soil conservation.

activities (Agrawal et al., 2008). Similarly, Wolf et al. (2010) suggest that strong bonding networks could potentially raise the vulnerability of elderly people in the UK to the effects of heat waves, by perpetuating the notion that waves posed a significant risk to them personally. Furthermore, Nam (2012) shows that in general, social capital at the individual level does not affect farmers' private adaptation to climate change.

In light of this conflicting evidence on the social capital and its role on climate change adaptation, **t**his paper sets out to extend existing analyses, by focusing on three major issues that remain underexplored. First, we argue that the responsiveness of adaptation measures to climate change may depend on the nature of local social networks. As Nam (2012) notes, focus on single social capital variables by many studies implies that very limited exposition exists on the role the different social capital components play as adaptation tools. Similarly, according to Cater and Castillo (2006), distinguishing between aspects of social capital that enhance or distort incentive compatibility in (non) contract based negotiations are critical in understanding the wider role of social capital in economic outcomes. Hence, simultaneously looking at the impact of different forms of social networks on soil conservation investment behaviour, as a strategy of adapting to climate change, will illuminate our understanding of the possibly wide ranging impacts social capital might have on soil conservation. Accordingly, in this study we look into personal interrelationships such as kinships and number of relatives, labour sharing networks such as *debbo*, as well as different measures of trust as possible social capital measures[4].

Second, the multi-plot characteristics of the individual farms in our study provide us with the opportunity to assess the rationale for employing alternative types of soil conservation. This observation of multiple structures that exist within a single farm household also carries estimation challenges. Given that we investigate several different practices, adoption of which appears to be correlated within a given household, we follow Cappellari and Jenkins (2006) in allowing for the possibility of correlation across each of

[4] Except for Nam (2012), we are not aware of any other study has investigated the different impacts of multiple social capital variables.

the different SWC practices simultaneously, allowing the covariance between the errors to be correlated across practices but not across observations within a given practice.

Third, households' unobserved attributes may be as important in determining adaptive capacity as the observed determinants of adaptation. Consistent estimation of the effect of social capital and climate change on conservation investment requires that the observed covariates are orthogonal to the error term which will be invalid if unobserved factors are correlated with the observed explanatory variables. In our case, the availability of panel data, albeit short, would enable us to control for the effect of such unobserved effects. The use of longitudinal data to study dynamic patterns of adoption of different types of natural resources management practices is still novel in the broader literature (Marenya and Barrett, 2007).

The data source employed in this analysis is the Sustainable Land Management Survey conducted in 2005 and 2007 in two Zones in the Amhara National Regional State of Ethiopia that consists of data on socioeconomic and farm level characteristics of the households, along with social capital and soil conservation variables combined with climate data from the Ethiopian Meteorological Authority. The results of the analysis demonstrated that climate change variables are found to positively contribute to an increased level of soil conservation with social capital variables having a positive but less significant role.

The rest of the paper is organized as follows. Section 2 presents an overview of social capital, climate change and soil conservation investment in the context of Ethiopia. The econometric methodology is presented in section 3 and section 4 describes variables and data employed in the analysis along with the survey design. Section 5 discusses the empirical findings and section 6 concludes the paper.

## 2. Social Capital, Risk Mitigation, Soil Conservation Investment, and Climate Change: A Literature Review

### 2.1. Social Capital and its Non-Uniform Impacts on Risk Mitigation

In the face of incomplete formal insurance mechanisms, local social networks are likely to take on a special role in mitigating the risks that agricultural households face. There is indeed a wealth of evidence suggesting that local social relationships (high level of social capital) have a positive effect in mitigating against shocks faced by households, directly through increased asset holdings, and by mitigating the impact of income shocks on livestock capital (Mogues, 2004), helps speed up disaster responses and reduce exposure to external risks (Carter and Maluccio, 2003), and enables consumption smoothing (Dercon and Krishnan, 2000).

While informal social relationships can arguably form efficient short term safety nets, a number of studies qualify their sustained benefits. As Mogues (2004) argues, the advantage of kinship ties being able to be sustained over space and time in implicit insurance-based transfer schemes hinge on households' ability to ascertain the distribution of risks over time. Furthermore, as commitment is not perfectly enforceable in informal social arrangements, there is the possibility of the inability to consistently contribute towards supporting members affected by shocks at different points in time and on different scales (Clarke and Dercon, 2002).

In addition, the links between shocks and local social networks, particularly in the context of developing countries are believed to be non-uniform, depending on the nature of the shocks, as well as the characteristics of individual networkers. In particular, informal social networks tend to be the most effective when used against idiosyncratic risk (Besley 1995). In line with this, Coate and Ravallion, (1993) show that covariate shocks may lead to the breakdown of reciprocal exchange as both parties are pushed close to the subsistence constraint, and the ability to reciprocate favours could be significantly reduced. Further, informal mechanisms tend to be weak against repeated shocks (Deaton, 1992; Murdoch, 1998); are more effective for slightly richer households (Kletzer and Wright, 1998); and are limited by access to assets and are ill-equipped to deal with asset related shocks (Murdoch, 1998; Dercon, 2000). [5]

[5] For comprehensive reviews on the less than full effects of social capital on risk sharing, across the developing world, see Dercon and Krishnan (2002).

In addition to their limitations in terms of delivering sustainable benefits, local social networks may, in some cases, suffer from crowding out against formal institutions. For instance, Stiglitz (1999) argues that the economic progress entails partial replacement of interpersonal networks with formal institutions. In addition, Durlauf and Fafchamps (2005) suggest that social capital can be a second-best response to the absence of formal institutions, which is the first-best solution.

## 2.2. Climate Change and Soil Conservation Investment in Ethiopia

Adaptation through sustainable land management practices enable farmers and communities to adapt to climate change by increasing food production, conserving soil and water, enhancing food security and restoring productive natural resources. As a result of an increase in potential erosion rates due to climate change, agricultural productivity can be reduced by 10% to 20% (Delgado et al., 2011). Understanding the complementary factors to soil conservation in the face of climate change would therefore aid in the design and implementation of sound conservation practices.

Accordingly, a growing body of literature identifies a strong link between climate change and soil conservation. For instance, Kassie et al. (2007) indicates that the effect of mean annual rainfall on the adoption of stone terracing varies based on agro ecology type. Their findings show the significant productivity benefit of the technology in conserving moisture in drier areas compared to higher rainfall areas. Similarly, based on a study of a sample of farmers in the Nile basin, Deressa et al (2009) indicate that the probability of adopting soil conservation practices in drier regions is higher than that of wetter regions. In the same study, Deressa et al (2009) show a direct link between an increase in temperature and increasing the probability of using soil conservation by about 2.6%. They further argue that, with more warming, farmers will conserve soil to preserve the moisture content and use drought-tolerant varieties to cope with increased temperature.

Apart from the climate related variables, a number of socioeconomic factors are indicated in most empirical literature as the main significant determinants of the adoption of different types of sustainable land management practices. For example, access to credit and extension, and farmers' awareness of climate change are some of the important determinants of farm-level adaptation (Nemachena and Hassan, 2007). Tiwari et al.(2008) also indicate that several factors such as education of the household head, caste of the respondent, land holding size, cash crop vegetable farming, family member occupation in off farm sector, membership of the Conservation and Development Groups, and use of credit, influence the adoption of improved soil conservation technology in central Nepal.

Similarly, Gebremedhin and Swinton (2003) have indicated that secure land tenure, labour availability, proximity to the farmstead and learning opportunities via the existence of local food-for-work projects are important determinants of farmers' long term investments in stone terraces in the Tigray region of Ethiopia. By contrast, insecure land tenure and the absence of local food-for-work projects are associated with short-term investments in soil bunds.

As could be seen from this brief review, different methods have been used to cope with the adverse effects of climate change on small holder agriculture in sub-Saharan Africa. Use of improved seed varieties (e.g. drought resistant varieties), changing planting dates, water management and irrigation, tree planting and soil and water conservation practices, are some of the adaptation options which have been suggested and used to counteract the negative consequences of climate change (Bradshaw et al. 2004). Though there are some empirical evidences on the socioeconomic determinants of adoption of sustainable land management technologies, there is still a need to have additional empirical evidences from Africa that will help policy makers understand the complex factors that affects the adoption behavior of small holder farmers.

## 3. Variables and Data description

Data used in this analysis were taken from Sustainable Land Management Survey in the central highlands of Ethiopia, conducted by the Environmental Economics Policy Forum for Ethiopia. The survey involved approximately 1,760 farm households randomly selected in 14 villages, located in two districts of the Amhara National Regional State of Ethiopia, in two waves in the years 2005 and 2007. The dataset includes detailed information on the socioeconomic characteristics of the households, physical characteristics of their farms, social capital measures, land tenure and land use, including information on soil conservation measures. In addition to this, rainfall and temperature data from eight meteorological stations close to the survey villages were obtained from Ethiopian Meteorology Service Agency[6].

The main dependent variable is the soil conservation measure. The respondents stated that they adopt SWC technologies in order to increase soil fertility, reduce the risk of flood, and conserve moisture and a combination of the three. Soil conservation structures identified in the survey include stone bund terrace (local or modern), soil bund terrace (local or modern), fanjo, grass planting, cut off drain, and check dam construction and river diversion. For this study, we consider categories of households adopting soil bund, stone bund, and cut off drain, and stone-soil-bund.

More than 41% of the sample farmers engage in constructing stone bund terraces. Some 24.5% of the sampled households have participated in constructing soil bund terraces. The use of both soil and stone bund terraces is also common in the study areas. More than 20% have practiced these types of SWC measure. Farmers practice cut off drain as a way of conserving moisture and preventing runoffs[7].As a result, we found that around 19% of the farmers have indicated that they practice cut off drain. Close to 21% of the sampled farmers have not participated in any type of soil and water conservation measures.

Stone bunds are only found in very few areas where stone is abundant. Mostly, stone bunds are practiced in mountainous areas where the bunds are constructed by community participation in a farmer's field. It has disadvantages since it harbors rodents and crop pests and as a long term SC technique which takes up a very large space on a

[6] Given that microclimate is a critical factor in farm household decision making, farm level climate data would be a more precise measure of clmate change at a farm level. Unlike many previous studies that use village level climate variables, (with the exception of DiFalco and Bulte 201s), we employ farm level climate change measures in our analysis that are generated based on an inverse distance weighing interpolation technique.

[7] In the study areas, cutoff drains are dug across a slope to intercept surface runoff and carry it safely to an outlet such as a canal or stream. They are used to protect cultivated land, compounds and roads from uncontrolled runoff, and to divert water from gully heads. Diversion ditches are (also cut-off drains, mainly used in flat areas to drain (not divert) water out of areas with water logging. Both stone and soil bunds are common types of soil and water conservation measures. Stone bunds are constructed where suitable stones are available on or near the field. Pure soil bunds are susceptible to heavy rainfalls and easily eroded by water and wind.

farm. For these reasons, farmers do not like to construct stone bunds on their farms unless the problem of soil erosion is so severe that it cannot be managed by soil bunds. Soil bunds are the most dominant and widely practiced SC technique in the study area. Unlike the stone bunds, soil bunds take up less space and are a short term SC measure. Some farmers destroy the soil bunds and disperse the accumulated soil over the whole field every three to five years and later on they reconstruct the bunds in different locations on the farm. Other farmers also maintain their bunds and cultivate crops on them.

Though they individually account for a small proportion of our sample, SWC activities such as contour farming, check dam construction, river diversion and grass planting are being undertaken by around 4.7 % of our sample and hence we consider it as another category in our empirical analysis, called ‘other’. We did not consider other types of SWC measures in the study area as the number of observations are too small to consider them as a separate category. Due to the presence of multiple plots within the household, we consider households with both stone (local and modern) and soil bund (local and modern) as a separate category. The purpose of combined stone and soil bunds within a field is to increase the proportion of arable land through leveling of steep land; reduction runoff and stop erosion.

The central determinant of soil and water conservation in this paper, social capital, refers to the institutions, relationships and norms that shape the quality and quantity of a society's social interactions. As discussed in the introduction, we employ multiple indicators of social capital, including trust, reciprocal networks, and number of relatives or kinship. The trust variables are formed from trust in people, and trust in institutions. Trust in people is captured as a dummy variable with a value of 1 if respondents think that people in general are trustworthy and 0 otherwise. Trust in institutions is represented by a dummy variable with a value of 1 if respondents have confidence in *kebele*, and 0 otherwise. On average, 58% and 52% of the sample households have trust in people and trust in kebele, respectively. Reciprocal networks involve actual interactions of households with people (other households) within their localities including the number of deals that households made in the local arrangements in the form of *wenfel*, and *mekenajo. Wenfel* refers to the traditional (reciprocal) labor sharing arrangement. *Mekenajo* is the traditional labor sharing arrangement where help is awarded with small in-kind payment (not necessarily reciprocal). In addition to the above indicators of social capital, we have also included the number of relatives the household has (both in and outside of the respondent's village). On average, a household has about 14 kinships (relatives).

Indicators of climate change i.e. rainfall and temperature, were also included in the analysis. In order to station level meteorological measures into individual farm level climate data, the Inverse Distance weighting method is used. Following Deshenes and Greenestone (2007), we use degree days based on daily temperature values[8]. The resulting degree day temperature values and precipitation measures are used to construct the weather measures.For the year 2007, for instance, the rainfall and temperature average weather change measures are calculated as the average of the monthly observations for the year 2007.

In addition to covariate shocks largely represented by the weather and climate variables, we also included a variable measuring the households' perceptions of experiencing shocks including idiosyncratic shocks. The proportion of households facing various shocks also varied between the two survey years in which experience of shocks in the last two years before the survey period declined from 61 percent in 2005 to 49 percent in 2007.

**Another important determinant of technology adoption we control for our analysis is tenure security. Respondents were asked about what they expect to happen in the next five years to the size of land they held at the time of each survey.** The responses were coded as 1 if the respondent expected the size to decrease due to village-level redistribution, and 0 otherwise[9]. This is considered as a measure of tenure insecurity. Other independent variables included in the study are household characteristics

[8] Most other previous studies have calculated degree days based on monthly temperature(e.g., Schlenker et al., 2007).

[9] Expectation of a decrease in size of land due to other reasons such as inheritance or familiy redistribution, etc are not considered.

(education, household size, age, gender); household level endowments (livestock owned and land size); as well as location factors such as distance to town, average distance to parcel, and dummy for regions (zones). Table 1 presents descriptive statistics of variables considered in the analysis.

Table 1: Descriptive statistics of explanatory variables

| Description of Variables | Mean | S. D. | Min | Max |
|---|---|---|---|---|
| **Household level Variables** | | | | |
| Sex of household head (=1 if male) | 0.81 | 0.39 | 0 | 1 |
| Age of household head | 50.75 | 15.24 | 13 | 100 |
| Whether the household head can read and write | 0.36 | 0.48 | 0 | 1 |
| Average number of family size | 5.18 | 2.03 | 0.51 | 15.17 |
| **Household asset endowment** | | | | |
| Average total farm area in hectare | 1.29 | 0.91 | 0 | 10 |
| Average Number of livestock owned | 3.81 | 2.92 | 0 | 23.79 |
| **Location factors** | | | | |
| Average distance to parcel in minutes | 16.03 | 13.16 | 0 | 90 |
| Distance to the nearest town in minutes | 71.27 | 52.53 | 0 | 280 |
| Dummy (=1) if the household is in East Gojjam | 0.472 | 0.50 | 0 | 1 |
| **Social Capital Variables** | | | | |
| Trust in people (=1if respondent believes people are trust worthy) | 0.58 | 0.49 | 0 | 1 |
| Trust in Kebele (=1 if respondent confidence to kebele) | 0.52 | 0.50 | 0 | 1 |
| Number of deals the household participated in (wenfel and Mekenajo) | 4.81 | 5.15 | 0 | 70 |
| Number of relatives in and outside this village | 14.10 | 16.91 | 0 | 179 |
| **Indicators of climate change** | | | | |
| Average annual rainfall in mm | 1142.08 | 312.28 | 0 | 2294.3 |
| Average annual temperature | 523.99 | 35.40 | 408 | 614.17 |
| **Tenure security, shocks and extension** | | | | |
| Dummy for any shock that the HH has been affected with | 0.56 | 0.50 | 0 | 1 |
| Land Tenure insecurity (=1 if insecure) | 0.84 | 0.37 | 0 | 1 |
| If the household has contacted a development agent in past year | 0.33 | 0.47 | 0 | 1 |
| Dummy(=1) if Year=2005 | 0.499 | 0.50 | 0 | 1 |

The average distance to the nearest town is about 71 minutes. The average distance to parcel takes around 16 minutes. The size and composition of the household remained almost the same during the two survey periods. However, on average, the proportion of households with a head that can read and write declines from around 39% to 33%. But there is a slight improvement on the number of households who can read only between 2005 and 2007.

## 4. Conceptual Framework and Econometric Strategy

Here we follow the framework adopted by studies in technology adoption such as Rahmand Huffman (1984) and Adesina and Zinnah (1993). According to the analytical framework used in these studies, farm households' adoption decisions on SWC practices are assumed to be based upon utility maximization. Let us define the different SWC technologies by j, where j = 1, 2, 3, 4 and 5.

We assume that each household attaches a utility value $U_{ij}$ to each technology depending on personal perception of the specific attributes of the technology, household characteristics $\eta_{ij}$ , and other climate related variables, $\theta_{ji}$ .

The non-observable utility function that ranks the $i^{th}$ farmers' preference is given by $U(\eta_{ji}, \theta_{ji}, \lambda_{ji})$, where $\eta_{ji}$ represent a vector of farmer specific and economic characteristics, and indicators of social capital; $\theta_{ji}$ represents a vector of climate related factors (rainfall and temperature), and $\lambda_{ji}$ represents a vector of variables that can capture farmers' location and time effect. The underlying utility function for the farmer can then be represented as

$$U_{ji} = \mu_j F_i(\eta_{ji}, \theta_{ji}, \lambda_{ji}) + e_{ji} \quad (1)$$

where $j = 1,2,\ldots,4$ $and\ i = 1, 2, \ldots, n\ and\ e_{ji} is\ the\ disturbance\ term$

Here the model assumes that the farmer chooses the technology that maximizes his/ her utility. In this model, a farmer decides to adopt the technology if the utility derived from the choice of j is greater than any other technology.

In line with this, we specify a multivariate probit model suited for our analysis. The econometric methodology employed in the analysis also needs to take into account the fact that multiple structures could exist within a single farm household. Given that we investigate several soil conservation structures within a given household, we want to allow for the possibility of correlation across each of the different SWC practices simultaneously. The multivariate probit estimator corrects for the problem by allowing for non-zero covariance in adoption across practices. Ignoring the prospective correlation in the adoption of practices and simply estimating the equations independently, will generate biased and inconsistent estimates of the standard errors of the parameter estimates for each technology (Greene 2003), and induce incorrect inference as to the determinants of different variables such as rain fall and social capital on the adoption of SWC practices.

Following Cappellari and Jenkins (2006), we therefore use a multivariate probit estimator, allowing the covariance between the errors to be correlated across practices but not across observations within a given practice.

The multivariate probit estimates M-equation probit models, by the method of maximum simulated likelihood (MSL). The variance-covariance matrix of the cross-equation error terms has values of 1 on the leading diagonal, and the off-diagonal elements are correlations to be estimated$(\rho_{ji} = \rho_{ij})$, and $\rho_{ii} = 1$, for all *i* = 1,...,m.

The multivariate probit model, for observation *i* and equation *m*, is:

$$y_{im}^{*} = \beta_m x_{im}^{*} + \varepsilon_{im} \quad (1)$$

$$y_{im} = II(y_{im}^{*} > \tau_m)$$

$$\text{where} i = 1,2,..,n \quad and\ m = 1,2,...,m$$

$y_{im} = 1$ if $y_{im}^{*} > \tau_m$ and 0 otherwise, (2)

$x_{im}$is an $K\ by\ 1$are vectors of covariates of independent variables that are considered to determine levels of SWC investments.For *i = 1,.....,n* different forms of SWCinvestments.$\beta_m$is the vector of parameters to be estimated, $\tau_m$is the cut off point or threshold of the $m^{th}$response variable, and $\varepsilon_{im}$are the error terms. It should be noted that and the error term $\varepsilon_{im}$ embodies an unobserved fixed effect, $\alpha_m$, as given by the expression in (3).

$$\varepsilon_{im} = \alpha_m + \eta_{im} \quad (3)$$

$\eta_{im}$ is an error term distributed as multivariate normal each with a mean zero and variance covariance matrix. An additional estimation issue that we attempt to address in this paper is controlling for unobserved effects that our panel data enables doing. The observable covariates in equation (1) do not account for all the systematic variation in $y_{im}$ as an unobserved fixed effect, $\alpha_m$, is not accounted for in the estimations.

Accordingly, the random effects or fixed effects estimators are routinely used to remedy this, albeit with their respective shortcomings. Specifically, the random effects is associated with the strong assumption of no correlation between the fixed effect $\alpha_i$ and the regressors/observed covariates (Baltagi, 2001). The fixed effects estimator, on the other hand, relies on a transformation to remove this individual specific constant term along with time invariant observed covariates (Wooldrige, 2001).

Our estimation procedure involves the pseudo-fixed effects estimation approach (Wooldridge, 2002) which involves explicitly modeling the relationship between time varying regressors and the unobservable effect in an auxiliary regression (Mundlak, 1978). Accordingly, time varying regressors $Z_{it}$ and the unobservable effect $\alpha_i$ in an auxiliary regression. In particular $\alpha_i$ can be approximated by a linear function:

$$\alpha_i = \omega \bar{s}_{im} + \zeta_{im} \tag{3}$$

Where $\bar{s}_{im}$ represents a vector of time invariant explanatory variables, $\omega$ is a vector of parameters to be estimated. Averaging over t for a given i and substituting the resulting expression into (1) gives:

$$y^*_{im} = \beta_m x^*_{im} + \omega \bar{s}_{im} + \xi_{im} \tag{4}$$

## 5. Discussion of Results

In this section we discuss the results of empirical investigation of the role of climate change and social capital on the decision to adopt soil and water conservation in rural Ethiopia, as presented in Table 2. The dependent variable stone_bund refers to whether the household has practiced either local or modern stone bund terracing. The variable soil_bund refers to whether the household has practiced either local or modern soil bund terracing. The last category ‘codr’ refers to the practice of cut off drain. Though there are other types of SWC measures in the study area, we have not considered them as each of them cannot be considered as a separate category due to the very small number of observations.

The multivariate probit estimates of this three equation model are run for the case in which the number of random draws is 50. The option ‘robust’ was used to reduce the effect of any outliers, if there is any. The likelihood ratio test (chi2(10) = 11.7954; Prob > chi2 = 0.0081) for independence between the disturbances is strongly rejected, implying correlated binary responses between different SWC investment decisions and supporting the use of a MVP model. In order to interpret the magnitude of the effect of each explanatory variable, the marginal effect which is the percentage change in the probability of adoption associated with a unit increase of the explanatory variable from the mean value can be calculated, for which we present just the coefficients.

**Table 2: Multivariate probit estimates of determinants of soil and water conservation (stone bund teraccing, soil bund terracing and cut off drain)**

| Description of Variables | stone_bund | | | soil_bund | | | codr | | |
|---|---|---|---|---|---|---|---|---|---|
| **Household Characteristics** | Coef. | Sd. Er. | P>z | Coef. | S. Er. | P>z | Coef. | S. Er. | P>z |
| Sex of hh head | 0.143 | 0.07 | 0.042 | 0.166 | 0.08 | 0.029 | -0.030 | 0.08 | 0.721 |
| Age of hh head | -0.005 | 0.00 | 0.006 | -0.002 | 0.00 | 0.206 | -0.002 | 0.00 | 0.302 |
| Read and write | -0.037 | 0.06 | 0.505 | 0.052 | 0.06 | 0.370 | -0.004 | 0.06 | 0.948 |
| Family size | 0.034 | 0.07 | 0.645 | -0.112 | 0.08 | 0.144 | -0.147 | 0.09 | 0.095 |
| **Household asset endowment** | | | | | | | | | |
| Livestock | 0.110 | 0.11 | 0.327 | 0.121 | 0.12 | 0.309 | 0.264 | 0.13 | 0.044 |
| land area | 0.050 | 0.14 | 0.712 | 0.105 | 0.14 | 0.463 | 0.488 | 0.18 | 0.008 |
| **Mean variables** | | | | | | | | | |
| Family size_m | -0.013 | 0.07 | 0.863 | 0.124 | 0.08 | 0.111 | 0.119 | 0.09 | 0.185 |
| Livestock_m | -0.291 | 0.12 | 0.016 | -0.033 | 0.13 | 0.793 | -0.193 | 0.14 | 0.172 |
| Land_m | 0.055 | 0.15 | 0.718 | -0.149 | 0.16 | 0.352 | -0.752 | 0.21 | 0.000 |
| **Social Capital Variables** | | | | | | | | | |
| Trust _kebele | 0.121 | 0.05 | 0.026 | 0.019 | 0.06 | 0.738 | -0.141 | 0.06 | 0.022 |
| Number of informal deals(unpaid_labor) | 0.000 | 0.00 | 0.931 | 0.000 | 0.00 | 0.929 | 0.019 | 0.01 | 0.001 |
| Number of relatives | 0.007 | 0.00 | 0.000 | 0.001 | 0.00 | 0.317 | 0.003 | 0.00 | 0.063 |
| **Climate variables** | | | | | | | | | |
| Mean rainfall | 0.000 | 0.00 | 0.033 | 0.000 | 0.00 | 0.715 | 0.000 | 0.00 | 0.431 |
| Mean temperature | -0.001 | 0.00 | 0.474 | -0.001 | 0.00 | 0.374 | 0.004 | 0.00 | 0.012 |
| **Tenure security, shocks and extension** | | | | | | | | | |
| Shocks | -0.007 | 0.05 | 0.888 | 0.135 | 0.05 | 0.009 | 0.184 | 0.06 | 0.002 |
| Extension visit | 0.041 | 0.05 | 0.441 | 0.147 | 0.06 | 0.008 | 0.107 | 0.06 | 0.087 |
| Land insecurity | -0.076 | 0.07 | 0.265 | -0.068 | 0.07 | 0.333 | 0.103 | 0.08 | 0.179 |
| **Location factors** | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Distance to town | 0.106 | 0.03 | 0.000 | -0.130 | 0.03 | 0.000 | 0.139 | 0.04 | 0.000 |
| Distance to Parcel | 0.058 | 0.03 | 0.037 | -0.074 | 0.03 | 0.010 | 0.050 | 0.03 | 0.122 |
| Dummy for East Gojjam | -1.020 | 0.09 | 0.000 | -0.085 | 0.09 | 0.344 | 1.201 | 0.11 | 0.000 |
| Year 2005 | 0.302 | 0.07 | 0.000 | -0.278 | 0.07 | 0.000 | -0.255 | 0.08 | 0.001 |
| _cons | -0.142 | 0.67 | 0.832 | 0.482 | 0.68 | 0.478 | -3.971 | 0.80 | 0.000 |

Note: The numbers in parenthesis are robust standard errors. Superscripts ***, **, * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Variables such as distance to parcel, distance to town, livestock owned and land size are in log form

The findings show that a number of variables do have a significant and different effects based on the type of SWC practices. Regarding the effects of weather, we find that the average annual rainfall has a positive impact on farmers decision to adopt stone bund terracing has no significant effect on the adoption of the other two types of SWC practices. The significant effect of rainfall on the probability of adopting stone bund terracing might be due to the nature of stone bund to reduce run off and heavy erosion due to very high rainfall. Hence, the result is not surprising given that farmers practice stone bund as a long term solution to soil erosion problems. This is in line with other studies which show that in high land areas where rainfall is higher, farmers have strong incentive to adopt stone terracing as the expected benefits from erosion abatement will also be higher. Kassie et al. (2007) found that mean annual rainfall has opposite effect on the adoption of stone terracing in Amhara and Tigray regions. The adoption decision of soil bund terracing does not seem to be affected by climate related variables. The mean annual temperature has a positive and significant effect only on the adoption of cut off drain.

We also found mixed evidence in that the effect depends on the type of social capital indicator used and type of SWC activities. For example, social capital in the form of trust in people was found to have no effect on adoption of stone bund, soil bund and cut off drain. On the other hand, households trust in one of the important government institutions, kebele, has a positive and significant effect on the adoption of stone bund terracing but has a negative and significant effect on cut off drain. Our findings of the effect of social capital on SWC are in line with other similar studies. As described in section 2, the literature on the link between social capital and technology adoption on the one hand and soil and water conservation on the other provide mixed evidence. For example, based on analysis from different African countries, van Rijn et al. (2012) argue that an aggregate measure of social capital and the adoption of agricultural innovations by farmers are highly correlated. But they further argue that different dimensions of social capital are associated with agricultural innovation in a variety of ways: some are positively related while others are negatively related. In addition, Bouma et al. (2008) found that social capital is not a significant determinant for household investment in soil and water conservation when such investments are subsidized. Similarly, Gebremedhin and Swinton (2003) examined the effect of community influence (social capital) in inducing adoption of soil conservation in the northern part of Ethiopia. They found that it had no significant effect on adoption of both soil and stone bund terraces.

We have also used other social capital measure indicating the informal (non-paid) labour sharing arrangements known as ‘wenfel’ and ‘mekenajo’, variables not used in other similar studies. While it has a positive and significant effect on the probability of adopting SWC practices such as cut off drain, it has no significant influence on the probability of adopting both stone bund and soil bund terracing. This result may not be surprising because these kinds’ arrangements are primarily organized production activities such as harvesting and hence may not have long term impacts on soil conservation.

Another dimension of social capital considered in this paper is the total number of relatives of the household living both in and outside of the respondent’s village. This is positively and significantly correlated with the probability of adopting SWC technologies such as stone bund and cut off drain. The results discussed above show that the nature of relationship between social capital and adoption of SWC technologies depends on the type of SWC as well as the type of indicator used for social capital.

The dummy variable for any shocks that affected the living condition of the household also turned out significant and positive in the case of soil bund terracing and cut off drain but not significant in the case of stone bund terracing. It appears that shocks enhance involvement in SWC activities which might be because households who have already experienced some kind of shocks may consider this as a coping mechanisms and sustainable solution in the future. As expected, farm households’ contact with extension or development agents has a positive effect on the adoption of SWC technologies particularly on soil bund and cut off drain practices.

As a measure of access to infrastructure, distance to town is also included in the analysis. As households are far from towns then the probability of adoption of SWC activities such as stone bund and cut off drain will likely be higher. Among the household characteristic variables, household size has no significant effect on SWC activities included in this study. This is unexpected given that the adoptions of most of these technologies require labor. Households with male headed are positively and significantly correlated with the adoption decision of both stone and soil bund terracing. Literacy, however, does not appear to have any significant effect on the adoption of soil and water conservation activities. Among the household endowment variables, livestock ownership has a no effect on SWC. On the other hand, land size is negatively associated with SWC practices such as cut off drain in the study area but has no effect on both stone bund terracing and soil bund terracing. This hints the need to separately analyze the role of land size for different types of SWC technologies. But our result is contrary to some of the findings of other studies. For example, Marenya and Barrett (2007) found a positive effect of land size on the adoption of integrated natural resources management and integrated soil fertility management techniques such as manure application, agro forestry and in organic fertilizer in western Kenya. Another study by Gebremedhin and Swinton (2003) found that land size is not a significant factor in the adoption of both soil and stone bund terracing in northern Ethiopia. Our results also show that land tenure insecurity has no significant effect on the decision to adopt any of the SWC activities considered in this study. The dummy variables representing regions is included to control for unobserved regional variations. We found that adoption of stone bund is less likely in East Gojjam zone compared to south Wollo.

**Table 3 Covariance matrix for the regression equations**

| | Stone bund | Soil bund |
|---|---|---|
| Soil bund | -0.032 | |
| Cut off | **-0.094**** | **-0.074*** |

**, * indicate statistical significance at the 5% and 10% levels, respectively.

To assess the validity of the multivariate probit method, as a preferred estimator for our purpose, Table 3 presents the result of the correlation between the error terms of the three types of SWC practices considered in the study. The high level of correlation between most of the SWC technologies (and the significance of the coefficients) supports the use of the multivariate probit. A positive coefficient suggests complementarity between the two practices, meaning that adoption of one practice is associated with the adoption of the other. A negative correlation coefficient suggests that the two practices concerned are substitutes and hence compete for the same scarce resources such as labor. This analysis, therefore, suggests that practices such as cut off drain is a substitute to both stone bund and soil bund terracing suggesting that it is competing for resources such as labor and other necessary materials for the conservation work.

## 6. Conclusions

This study intends to assess the roles of different forms of social capital and rainfall patterns and temperature (both short term and long term measures in the adoption of different kinds of soil and water conservation measures).This study uses data collected in the years 2005 and 2007 from the North Western part of the Amahra region of Ethiopia, namely the East Gojjam and South Wollo regions, to analyse the determinants of different kinds of SWC technologies, specifically social capital and climate change.

While the impact of social capital and climate change on soil conservation have been assessed in previous studies, our analysis focuses on two major gaps in the literature: alternative social capital measures (considered simultaneously) and multiple soil conservation activities in a single farm (by virtue of a multi-plot farming system), which enables controlling for unobserved farm level heterogeneity. The analytical method employs a multivariate profit model that accommodates the correlations in soil conservation structures across households. In most African countries in general and Ethiopia in particular, SWC technologies have been actively promoted without accounting for agro-ecological conditions (Kassie et al., 2007). Hence, our empirical findings suggest an important policy implication for the country: the need to consider variations among regions in the design of appropriate SWC structures.

Our findings show that both annual rainfall and temperature have different effects on the adoption decision of SWC technologies by farmers. The positive and significant effect of the average annual rainfall on farmers decision to adopt stone bund terracing indicate that farmers practice stone bund as a long term solution to soil erosion problems.

This is in line with other studies which show that in high land areas where rainfall is higher, farmers have strong incentive to adopt stone terracing as the expected benefits from erosion abatement will also be higher.

The role of different kinds of social capital indicators included in the analysis provides interesting results. The results show that different forms of social capital have different relationships with the different kinds of SWC measures. This is in line with some of the previous findings that social capital and inclusive decision-making institutions promote the sustainability and legitimacy of any adaptation strategy. We have also found that informal (non-paid) labour sharing arrangements known as ‘wenfel’ and ‘mekenajo’ affect the decision to adopt different SWC practices differently.

Overall, the empirical observations made in this study support the argument that the impact of social capital in soil conservation efforts as adaptation mechanisms to climate change are specific to the type of SWC as well as the indicator of social capital. Policy actions could harness the positive impacts of such informal systems especially in settings where formal mechanisms are weak or not well set up. However, while the findings in general highlight the role of social networks, they also resonate with the identification of a broader gap in the working of informal mechanisms.

There remain challenges that limit the explanatory power of social capital as a tool in climate change adaptation. Perhaps most important is the lack of sufficient studies from both developing and developed countries that highlight the context specific nature of social capital and clarity over whether social capital has desirable impacts in aiding adaptation measures. Identifying the most effective social networks in enhancing conservation might enhance the flexibility of climate change policy action and its relevance to specific local social contexts.

Further studies may extend the current study by including other kinds of sustainable land management practices such as agroforestry, maintenance of soil fertility such as manure application and the use of chemicals etc., to understand and provide a complete picture on the role of social capital, climate change and other household specific variables.

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**AppendixA**

**Multivariate probit estimates of determinants of soil and water conservation (with the social capital variables 'trust people knew' included)**

| | stone_bund | | | soil_bund | | | codr | | |
|---|---|---|---|---|---|---|---|---|---|
| **Household Characteristics** | Coef. | S. E. | P>z | Coef. | S. E. | P>z | Coef. | S. E. | P>z |
| Sex of hh head | 0.141 | 0.07 | 0.043 | 0.165 | 0.08 | 0.030 | -0.028 | 0.08 | 0.737 |
| Age of hh head | -0.005 | 0.00 | 0.006 | -0.002 | 0.00 | 0.208 | -0.002 | 0.00 | 0.316 |
| Read and write | -0.039 | 0.06 | 0.486 | 0.051 | 0.06 | 0.379 | -0.004 | 0.07 | 0.951 |
| Family size | 0.035 | 0.07 | 0.636 | -0.118 | 0.08 | 0.126 | -0.151 | 0.09 | 0.088 |
| **Household asset endowment** | | | | | | | | | |
| Livestock_m | 0.107 | 0.11 | 0.324 | 0.108 | 0.11 | 0.341 | 0.273 | 0.13 | 0.030 |
| land area | 0.048 | 0.14 | 0.721 | 0.105 | 0.14 | 0.464 | 0.489 | 0.18 | 0.008 |
| **Mean variables** | | | | | | | | | |
| Family size_m | -0.014 | 0.08 | 0.855 | 0.130 | 0.08 | 0.096 | 0.123 | 0.09 | 0.173 |
| Livestock_m | -0.286 | 0.12 | 0.014 | -0.019 | 0.12 | 0.874 | -0.201 | 0.13 | 0.136 |
| Land_m | 0.055 | 0.15 | 0.716 | -0.151 | 0.16 | 0.345 | -0.755 | 0.21 | 0.000 |
| **Social Capital Variables** | | | | | | | | | |
| Trust people knew | 0.037 | 0.05 | 0.469 | 0.025 | 0.05 | 0.639 | -0.022 | 0.06 | 0.717 |
| Trust _kebele | 0.116 | 0.05 | 0.035 | 0.016 | 0.06 | 0.786 | -0.139 | 0.06 | 0.026 |
| Number of informal deals | 0.000 | 0.00 | 0.921 | 0.000 | 0.00 | 0.934 | 0.019 | 0.01 | 0.001 |
| Number of relatives | 0.007 | 0.00 | 0.000 | 0.001 | 0.00 | 0.320 | 0.003 | 0.00 | 0.061 |
| **Climate variables** | | | | | | | | | |
| Mean rainfall | 0.000 | 0.00 | 0.034 | 0.000 | 0.00 | 0.716 | 0.000 | 0.00 | 0.420 |
| Mean temperature | -0.001 | 0.00 | 0.458 | -0.001 | 0.00 | 0.355 | 0.004 | 0.00 | 0.012 |
| **Tenure security, shocks and extension** | | | | | | | | | |
| shocks | -0.008 | 0.05 | 0.871 | 0.134 | 0.05 | 0.010 | 0.184 | 0.06 | 0.002 |
| Extension visit | 0.039 | 0.05 | 0.463 | 0.146 | 0.06 | 0.008 | 0.108 | 0.06 | 0.082 |
| Land insecurity | -0.078 | 0.07 | 0.254 | -0.071 | 0.07 | 0.317 | 0.105 | 0.08 | 0.169 |
| **Location factors** | | | | | | | | | |
| Distance to town | 0.106 | 0.03 | 0.000 | -0.130 | 0.03 | 0.000 | 0.140 | 0.04 | 0.000 |
| Distance to Parcel | 0.058 | 0.03 | 0.038 | -0.074 | 0.03 | 0.010 | 0.050 | 0.03 | 0.125 |
| Dummy for East Gojjam | -1.018 | 0.09 | 0.000 | -0.085 | 0.09 | 0.347 | 1.201 | 0.11 | 0.000 |
| Year 2005 | 0.296 | 0.07 | 0.000 | -0.284 | 0.07 | 0.000 | -0.254 | 0.08 | 0.001 |
| _cons | -0.140 | 0.67 | 0.835 | 0.496 | 0.68 | 0.465 | -3.986 | 0.80 | 0.000 |