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Understanding Farmers' Ex-Ante Risk Management and Ex-Post Risk Coping Strategies for Climate Risk: A Case Study of Smallholder Farmers in North West Ethiopia

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Abstract

This study analyses the factors affecting Ethiopian farmers' choice of ex-ante adaptation and ex-post coping strategies for climate risk. We use multivariate probit models to explain the choice various adaptation and coping strategies. We find that plot characteristics such as slope, depth, soil type and soil fertility, and farm size are important factors affecting the choice of adaptation strategy. These plot characteristics also significantly affect the choice of particular coping strategies such as selling livestock, reducing meals and borrowing. Furthermore, plot management practices such as soil and water conservation are strongly associated with an increased likelihood of choosing a given adaptation measure. The results also show that plot management practices such as leaving crop residues, intercropping and use of non-recycled hybrid maize are associated with the reduced likelihood of choosing coping measures such as selling livestock. We advocate improved farmer education on improved farm management practices to reduce household vulnerability to climate change and variability.

Keywords: Adaptation, coping, climate risk, multivariate probit model, Ethiopia

JEL Codes: Q18, Q54, C25

1. Introduction

The African continent is projected to be adversely affected by further global warming. Africa is particularly vulnerable because it is amongst the hottest places on the Earth and therefore any further warming is likely to have adverse socioeconomic consequences. Africa's vulnerability is heightened by the fact that most of the economies in this region rely mainly on natural resources and rain-fed agriculture, which are very sensitive to climate change and variability. For example, biomass provides about 80% of the primary domestic energy supply in Africa, while rain-fed agriculture contributes some 30% of GDP and employs about 70% of the population, and is the main safety net of the rural poor (World Bank, 2012). In addition, and perhaps more importantly, Africa's vulnerability is exacerbated by the fact that Africa is home to the largest numbers of the world's poor, with extreme poverty as high as 48% (AfDB, 2013) – which weakens Africa's adaptive capacity.

The current climate modelling results indicate that the African continent will warm by more than 3°C on average by the 2080s, with average temperatures in the Sahara region rising by 3.6°C (IPCC, 2007). Most regions, except East Africa and parts of West Africa, will experience a reduction in rainfall, and there is an increased probability of extremely warm, extremely wet and extremely dry seasons. Fischer et al., (2005) estimate that by the 2080s, there will be a significant decrease in suitable rain-fed land extent and production potential for cereals due to climate change. For the same time horizon, they also project that the area of arid and semi-arid land in Africa could increase by 5–8%, which is equivalent to 60–90 million hectares. Stige et al., (2006) have projected significant reductions in maize production in southern Africa under possible increased ENSO conditions, assuming no adaption. Thornton (2012) estimates that by 2050 climate change could cause maize yields in Africa to drop by 10–20%.

Using a computable general equilibrium model, Asafu-Adjaye (2014) projects that climate change will have the least economic impacts on the EU and North America, and the largest impacts on African economies. Southern Africa and the Rest of Sub-Saharan Africa will be the hardest hit with a decline in GDP growth of nearly 2 percentage points per annum each by the 2050s, followed by North Africa (−1.4 percentage points per annum). In line with the climatic evidence, the East African region will experience the least loss with output decline of about 0.6

percentage points per annum. Cumulatively, the impacts of reduced agricultural output on African economic growth from 2010−2080 are −6 percentage points (Southern Africa and rest of SSA), −4 percentage points (North Africa), and −2 percentage points (East Africa).

Like most African countries, Ethiopia is vulnerable to the effects of climate change and variability because it is heavily dependent on agriculture. Agriculture accounts for about 45% of GDP and the overwhelming majority of the 94 million inhabitants depend on it for their income and livelihood. In contrast, manufacturing accounts for only 12% of GDP (World Bank, 2014). Kebede et al. (2013) have used two downscaled global GCMs (REMO and CGCM3.1) to project trends for temperature and rainfall for Ethiopia. Using the REMO model, they project a trend of +1.3°C changes for maximum temperature for the 2011 to 2050 period; and using the CGCM3.1 model, they project +2.55°C changes in maximum temperature during the same period. Rainfall changes show considerable uncertainty over the basin during the rainy season with a range of −20% to +50%.

The major adverse impacts of climate variability in Ethiopia include the following: food insecurity arising from occurrences of droughts and floods; outbreak of diseases such as malaria, dengue fever, water borne diseases (such as cholera, dysentery) associated with floods and respiratory diseases associated with droughts; and land degradation due to heavy rainfall. Climate change is projected to reduce yields of the wheat staple crop by 33% (Tadege, 2007). Desertification, brought on by human land-use pressures and recurrent drought, has consumed significant land area and continues to threaten arable land.

Given the adverse climatic predictions, a better understanding of how farmers have coped with past and current climate change and variability would enable us to propose more effective strategies to reduce farmers' vulnerability in the future. In this regard our study aims to contribute to the growing literature on climate change adaptation by examining the coping and adaptation strategies of Ethiopian smallholder farmers. The study makes two important contributions to the literature. First, unlike many of the previous Ethiopian adaptation studies, we use plot level data in addition to household data, which allows us to explore the effects of a wider range of variables that relate to plot characteristics and the types of farm management practices employed. Secondly, we also analyse the factors affecting the choice of coping. Whilst most of the past studies have chosen to analyse factors affecting adaptation, it is also important to understand the issue of how farmers cope with adverse climatic events. This would be important in devising appropriate policy responses to the problem of climate change.

The remainder of the paper is organised as follows. Section 2 briefly reviews the literature on adaptation and coping strategies to climate change and variability. This is followed by a brief description of the study area and the data collection method in Section 3. Section 4 puts the study into context with a discussion of the adaptation and coping strategies in the study area. Section 5 discusses the empirical model, the study results are presented and discussed in Section 6. Section 7 concludes with the summary and policy implications.

2. Coping and Adaptation Strategies to Climate Risk and Variability

A distinction needs to be made between farm household risk[1] management and coping behaviour. Risk management can be interpreted as a deliberate strategy by the farm household to anticipate adverse effects on its income stream by taking actions to mitigate the risk, for example, by diversifying its portfolio (see, for example, Walker and Jodha, 1986). On the other hand, coping can be described as an involuntary response to a disaster or unanticipated adverse event. In this regard risk may be viewed as an *ex-ante* income management strategy, whereas coping is an *ex-post* consumption management response following an adverse climatic event (Carter, 1977). An example of ex-ante risk management is income smoothing, which can be accomplished by diversification of the household portfolio. Examples of coping or consumption smoothing strategies include actions such as borrowing, sales of livestock and assets, drawing on savings, family and community transfers, and so on.

Related to coping is the idea of vulnerability to adverse events such as climate change and variability. Vulnerability may be defined as a high degree of exposure to climate risk, shocks and stress, as well as proneness to food insecurity (Davies, 1996). Other concepts related to vulnerability are resilience and sensitivity of a given livelihood

[1] Risk is the subjective probability attached by the individual or household to income generating outcomes they are engaged in (Anderson *et al*., 1977; Ellis, 1998).

system. Resilience may be defined as the ability of the system to absorb change or even exploit the change to advantage, whereas sensitivity refers to the degree to which the natural resource base is susceptible to change. Thus, based on these concepts, a robust livelihood system could be described as one that is highly resilient and has low sensitivity. A further concept related to coping is adaptation. In general livelihood adaptation may be defined as the continuous process of changes to livelihoods, which results in enhancing wealth and security, thereby reducing vulnerability and poverty (Ellis, 1998). In relation to climate change, the IPCC (2001) defines adaptation as the ability of a system to adjust in response to actual or expected climatic stimuli to moderate harm or to cope with the consequences.

There have been a number of empirical studies on coping and adaptive resource management strategies in sub-Sahara Africa (SSA). Bharwani *et al.* (2005) found in a study of South African vegetable farmers that subsistence farmers were the most vulnerable to short-lived droughts even in cases where average rainfall was good. Another South African study by Thomas *et al.* (2007) found that farmers copped during dry spells by reducing cropping effort and focusing on livestock. In Mali, it was found that, in response to reduced rainy seasons, farmers resorted to early maturing varieties of sorghum (Lacy *et al.*, 2007). In Burkina Faso, drought coping strategies were found to include food saving, borrowing and mortgaging of the following year's crop (Roncoli *et al.*, 2001).

Etwire *et al.* (2013) analysed the factors affecting the adoption of climate-change related technologies introduced by research institutions in Northern Ghana. The results indicated that gender, age, farm size access to extension services, agroecology and noticing of unpredictable temperatures were the key determinants of adoption of recommended climate-related strategies. Yila and Resurreccion (2013) also investigated the determinants of climate adaptation in Northeastern Nigeria. The significant variables were found to be agricultural labor force, level of education of the household head, land tenure arrangements, gender of the household head, extension service availability, out-migration of labour, years of farming experience, household size and availability of extension services.

Several efforts have been made to study how farmers adapt to climate change in

Ethiopia. Deressa and Hassan (2009) employed the Ricardian approach to estimate the monetary impact of climate change on Ethiopian agriculture. However, the study did not consider what adaptation methods farmers employ. Deressa et al. (2011) used the Heckman sample selection method to analyse farmers' perception of climate change. This was found to be significantly related to the age of the head of the household, wealth, knowledge of climate change, social capital and agro-ecological settings. Factors significantly affecting adaptation to climate change were: education of the head of the household, household size, whether the head of the household was male, whether livestock were owned, the use of extension services on crop and livestock production, the availability of credit and the environmental temperature. Di Falco et al. (2011) examined the driving forces behind farm households' decisions to adapt to climate change, and the impact of adaptation on farm households' food productivity. They found that access to credit, extension and information were the main drivers behind adaptation, and that adaptation increases food productivity.

While there have been a number of published research on the factors affecting the decision by the African smallholder farmer to undertake adaptation, there is a dearth of empirical studies that have analysed the twin issues of *ex-ante* risk management (i.e. adaptation) and *ex-post* risk coping strategies. This study therefore attempts to enhance our understanding of factors affecting both issues, and by so doing, improve the formulation of policy responses to build farmers' resilience and reduce their vulnerability to climate change.

3. Study Area and Data Collection

The data for this study come from a survey conducted by the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with the Amhara Agricultural Research Institute (ARRI) in South Achefer district, North Western Ethiopia in 2013. The district was chosen for its potential for maize production, an important food security crop in the country. The district is predominantly characterized by a mixed crop production system. Crop production in the study area is rain-fed and erratic rainfall is the major source of production risk. Kebeles with good maize production potential were identified and fourteen Kebeles were randomly selected in the district. A total sample size of 298 was proportionally allocated to the Kebeles based on their population size and farm households were then randomly chosen in the selected Kebeles. Face-to-face interviews were undertaken by experienced enumerators supervised by scientists from CIMMYT and ARRI. It generated plot level data about plot quality, plot size, chemical fertilizer, human labour, draft labour, herbicide and crop yield. Data were also collected on the socio-economic characteristics of the households.

4. Adaptation and Risk Coping Strategies of Farmers in the Study Area

The four major risk factors investigated in the study were drought, floods, crop pests and diseases and hail storm. The respondents were asked how many times the specific risk factor occurred in the past 10 years. About one-third of the respondents reported that drought had occurred at least once in the past 10 years (Figure 1). Roughly a quarter reported that there had been too much rain or floods at least once in the last 10 years, while a similar proportion reported there had been crop pests and diseases in the same period. Twenty percent reported hailstorms had occurred at least once.

[Fig. 1]

The respondents were also asked to rank the importance of the risk factor in affecting the household's livelihood. Drought is by far the most significant risk factor affecting the household's livelihood and was ranked number one by 24.3% the respondents (Figure 2). In contrast, too much rain or floods is ranked number one by 9.1% of the respondents, followed by crop pests and diseases (7.1%) and hail storms (4.6%). Thirty percent of the respondents who reported that drought is an important risk factor indicated that it reduced the household's main food crop by 20% or more.

[Fig. 2]

The ex-ante adaptation strategies employed in the study area include the following: changing crop varieties, early planting, crop diversification (intercropping and rotation), tree planting, construction of stone and soil bunds, undertaking more off-farm work, saving in cash and kind (e.g., jewelry), increasing the seed rate, food preservation and undertaking more non-farm work. The most common ex-ante strategies to deal with drought were changing crop varieties, tree planting, early planting, and saving in cash or kind (Figure 3). On the other, the most common strategy to deal with too much rain or drought was the construction of soil and stone bunds. Among those for which the risk factor was relevant, approximately 30%

adopted some form of ex-ante adaptation action while the remainder took no action whatsoever.

[Fig. 3]

The ex-post coping strategies in the study area include the following: changing crop varieties, replanting, selling livestock, renting out land, selling land and other assets, reducing meals, out-migration, changing from crops to livestock and borrowing. These strategies vary depending on the particular risk factor. The most common coping strategy after a drought is selling livestock (reported by 127 respondents), followed (in decreasing order of importance) by reducing meals, replanting, changing crop varieties and borrowing (Figure 4). Selling or renting out land and the other strategies were used to a lesser extent. Replanting and reducing meals were used as a common coping strategy to the other risk factors.

[Fig. 4]

Drought is by far the risk factor having the greatest effect on farm incomes. The majority of the respondents for whom this was relevant reported that drought reduced their farm incomes by between 40−60% (Figure 5). This is followed to a lesser extent by too much rain or floods, crop pests and diseases, and hail storms.

[Fig. 5]

5. Conceptual Framework, Model Specification and Estimation Approach

The theoretical framework adopted for modelling the household's coping and adaptation strategies is based on random utility theory. Consider the situation of the i^{th} farm household facing a decision on whether or not to implement a given coping strategy j compared to another strategy including the *status quo* or doing nothing. The expected net benefits, y^*_i, that the household derives from choosing the strategy is a latent variable that can be specified as:

$$y^*_{ij} = \bar{V}_{ij} + \varepsilon_{ij} = Z_i \alpha_j + \varepsilon_{ij} \qquad (1)$$

where

$$y_i = \begin{cases} 1 & if \quad y^*_{i1} > 0 \\ 0 & if \quad otherwise \end{cases}$$

That is, farm household i will choose strategy j if it provides net benefits greater than any other strategy. Equation (1) includes a deterministic component $(\bar{V}_{ij} = Z_i \alpha_j)$ and unobserved stochastic (i.e. random) component ε_{ij}. The latter captures all the variables affecting the farm household's decision maker but which are unknown to the researcher (e.g., skills or motivation). On the other hand, the deterministic component depends on factors Z_i that affect the likelihood of choosing strategy j. Examples include age, gender, marital status, education, household size, etc. It is hypothesized that the vector Z_i also includes plot characteristics such as soil fertility, soil depth, soil and water conservation, type of agricultural practice, etc.

It is normally assumed that Z_i is uncorrelated with the random component. That is, ε_{ij} has a mean of zero and a variance of unity. Depending on the assumed form of the distribution of the random disturbance term qualitative choice models such as logit or probit models could be estimated. As indicated earlier, some farm households in the study area choose from a set of risk management and risk copping strategies. However, these strategies could be correlated since the same unobserved farm household characteristics could influence their choice. In this type of situation, the error terms could be correlated and therefore the application of standard univariate logit or probit models would produce inefficient estimates (Greene, 2008). To address this potential problem, we employ a multivariate probit (MVP) model. The MVP model uses the method of maximum simulated likelihood to estimate a set of binary probit models simultaneously. The MVP model (e.g., see Greene, 2008) recognizes the correlation in the error terms and as such 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 $i = 1,...,M$).

5.1 Dependent variables

The most common copping strategies in the study area includeselling livestock, renting out land selling land and other assets reducing meals, and borrowing. On the other hand, the common adaptation strategies include changing crop varieties, early planting, crop diversification (intercropping and rotation), tree planting and construction of soil and stone bunds. Given the large number of climate risks and strategies available, the analysis proceeded in two phases for both adaptation and coping. In the first set of regressions, the dependent variable is whether a farmer adopted a specified strategy in response to any climate risk. The dependent variables for adaptation are changing crop varieties, early planting, crop diversification, tree planting and building stone and soil bunds. For coping, the dependent variables are replanting and selling livestock. To further enhance our understanding of the factors affecting farmers' responses to specific climate risks, the second stage estimated MVP models for the top climate related risk identified in the survey, which is drought. For drought, the dependent variables are changing crop varieties, tree planting, and early planting.

5.2 Independent variables

Three sets of independent variables are considered in this study. These are household characteristics, plot characteristics, and plot management practices.

Household characteristics

The household characteristics (based on head of the household) hypothesized to influence farmers' adaptation and coping strategies are age, education, gender, and occupation. Age is used as a proxy for experience and represents familiarity with the farming system over the years and which may promote a reaction to climate risk. Some studies in Ethiopia (e.g., Kebede et al., 1990) show a positive relationship between experience in agriculture and adoption of agricultural technology, while a study by Shiferaw and Holden (1998) indicates a negative relationship between age and adoption of improved soil conservation practices. On the other hand, more recent studies by Maddison (2006) and Nhemachena and Hassan (2007) suggest that experience in farming increases the probability adopting adaptation measures to climate change. Education is believed to be associated with a higher ability to access and apply relevant information. Previous studies show a positive relationship between education level of the household head and adoption of improved technologies (e.g., see Lin, 1991). The occupation types in the survey include the following: agricultural self-employed, agricultural wage labour, non-agricultural self-employed, non-agricultural wage labour, salaried worker and so on. It is therefore hypothesized that farmers who do not work in the agricultural sector are less likely to perceive climate change and therefore will be less likely to adopt appropriate measures in response to it.

It is also hypothesized that male-headed households are more likely to adopt adaptation measures because they are better able likely to acquire information on new technology (Asfaw and Admassie, 2004). On the other hand, women may have limited access to information and other resources due to traditional social barriers and are therefore unlikely to adopt soil improvement measures (Tenge and Hella, 2004). Furthermore, given that male-headed households have better access to resources, they are more likely to take actions to mitigate the effects of adverse climatic events.

Plot characteristics

We hypothesize that factors likely to influence the choice of adaptation strategy include soil fertility, soil type, soil slope and depth, tenure status, and plot size. For example, plots with gentle slopes, deep and fertile soils might be less affected by adverse weather events and therefore the farmer would be less likely to implement adaptation strategies. Also the more distant plots are from homesteads, the less likely they are to receive attention in terms of adaptation strategies due to the ihigher cost implications. We also include a variable on plot tenure and we hypothesize that plots that are owned are more likely to have adaptation strategies implemented on them given the security. Furthermore, due to greater resource requirements, farmers who own larger plots are less likely to implement adaptation strategies. For ex-post risk coping, plot characteristics likely to influence choice of strategy are area, cultivated, especially the area of key crops such as maize and the use of improved varieties. It is hypothesized that farmers who have larger areas under maize and who use improved varieties will have higher output and can therefore better withstand adverse climatic events such as drought and floods. They are therefore less likely to undertake a given coping strategy.

Plot management practices

The adoption of certain farm practices such as soil and water conservation, leaving crop residues on the plot, composting are known to improve the moisture retention properties of the soil, thereby enhancing the soil's organic content, which in turn results in increased crop yield. Farmers who have undertaken any of these measures are knowledgeable about agriculture and its attendant climate risks. They are therefore more likely to undertake an adaptation strategy. It has also been established that fertilizer use and intercropping with legumes, for example, improve soil fertility and therefore crop yield. Farmers who adopt such measures are more likely to also undertake an adaptation strategy and are less likely to undertake a given coping strategy.

6. Results and Discussion

6.1 Descriptive statistics

The means and standard deviations of the dependent and independent variables are shown in Table 1. The average household head age was about 44 years old with 4.5 years of education. Less than 10% of the households were headed by females. On average, farmers in the sample perceived their plots to have fairly gentle slopes with flat to medium slopes and medium levels of fertility. The average plot tended to be owned by the operator. Improved maize varieties were planted on 80% of the plots, while hybrid maize was planted on 30% of the plots. Ninety eight percent of plots were intercropped, but less than 10% had crop residues from the previous season or had composting applied. Slightly more than half of the plots had fertilizer applied on them. Less than 10% of plots had any form of adaptation measures, with the exception of soil and stone bunds which were applied on 13% of the plots. In terms of coping strategies by plot, 14% involved changing crop varieties, about a quarter involved replanting, and slightly over a third involved selling of livestock. Sixteen percent of plots involved borrowing as a coping strategy.

[Table 1]

6.2 Factors affecting choice of ex-ante climate risk adaptation strategies

Table 2 presents the MVP model estimates for the choice of adaptation strategies in response to climate related risk. Recall that the dependent variable in this case is whether the household took any form of adaptation strategy as against doing nothing. This model involved the simultaneous estimation of five probit models. The Wald χ^2 has a value of 4838.4 and is statistically significant at the 1% level, implying that the independent variables significantly explain the variations in the respective dependent variables. The Likelihood ratio test of the null hypothesis that the error terms of the five equations are significantly zero (i.e. are uncorrelated) is rejected at the 1% level.[2] This therefore provides justification for the use of the MVP model.

[2] These test results are similar to those of the other MVP model estimations in this paper.

The regression results indicate that age and education are not significant variables affecting the choice of an adaptation strategy, with the exception of early planting where younger household heads are more likely to adopt this strategy. The lack of significance of age as a factor affecting adaptation choice in the case of changing crop varieties is consistent with findings for Ethiopia by Di Falco and Veronesi (2013), Di Falco et al. (2012) and Deressa et al. (2009). However, the non significance of education is in contrast to these studies. Gender of the household head is also not significant for all strategies except changing crop varieties where it positive. As hypothesised, farmers who are primarily engaged in agriculture are more likely to adopt strategies such as changing crop varieties, early planting and crop diversification. This supports our view that such farmers are more likely to have accurate perceptions of climate change (perhaps from interactions with extension officers or fellow farmers) and therefore more likely to take ex-ante action.

In regard to plot characteristics, the results indicate that distance of a plot from the home is not a significant factor determining the choice of an adaptation strategy, with the exception of tree planting. In this case, we find that trees are likely to be planted on plots that are nearer to the home. This result could be due to the fact that the transactions costs are higher for more distant plots. The coefficients on slope, depth and fertility are all negative and significant, supporting our *à priori* hypotheses. The results for soil type are mixed. On the one hand, farmers are more likely to change crop varieties on poor soils. But on the other hand, they are less likely to choose crop diversification on good soils. It was hypothesized that plots that are owned are more likely to have adaptation strategies implemented on them. This relationship is only significant for early planting. The coefficients for own land area have negative signs and are significant for all the adaptation strategies, as hypothesized.

The coefficients for soil and water conservation have the expected positive sign and is significant for all the five adaptation strategies, confirming our *à priori* hypothesis. Whether or not a farmer leaves crop residues on the plot does not appear to affect the choice of adaptation strategy. Furthermore, measures such as composting and the use of fertilizer do not significantly influence the choice of adaptation strategy except in the case of tree planting and construction of soil and stone bunds. Farmers who compost and apply fertilizer on their plots are also likely to adopt soil and stone bunds as an adaptation strategy. The coefficient for percentage of land intercropped is negative and significant for all the strategies except crop diversification. This implies that the higher the level of intercropping on a plot, the lower the likelihood of adopting a given strategy.

The results for factors affecting the choice of adaptation strategy to drought as a specific climate risk are shown in Table 3. In this case, the model was estimated for the three key strategies used to address drought, which are changing crop varieties, early planting and tree planting. Younger household heads are more likely to undertake early planting, although age is not significant in the choice of the other two strategies. Unlike the earlier case where education was not significant for all the strategies, in the case we observe that more educated household heads are more likely to undertake tree planting as an adaptation strategy to address drought. The gender of the household head does not significantly affect the choice of a strategy. However, as was the case in Table 2, occupation type significantly influences the choice of adaptation strategy.

With regard to plot characteristics, soil slope and fertility are significant factors affecting strategy choice for drought, with the coefficients having the expected signs. Soil depth is positive and significant for only early planting. Tenure status is found not be significant in all cases, while own land area is significant and has the expected signs for early planting and tree planting. The use of soil and water conservation measures has the expected positive signs in all three cases and is significant for early planting and tree planting. While the use of crop residues was found not be a significant factor as an adaptation strategy to any climate risk, in the case of drought, we observe that it significantly affects the choice of early planting. Also fertilizer use is found to affect tree planting. Finally, as was the case in Table 2, we find a higher level of intercropping reduces the likelihood of choosing and of the three strategies.

6.3 Factors affecting choice of ex-post climate risk coping strategies

The MVP model results for choice of ex-post climate risk coping strategies are reported in Table 4. It is instructive to note that in this case the measures are taken after the given risk factor has occurred. We find that age significantly affects the decision to borrow and to change crop varieties but not for the other strategies. Older farmers are more likely to change crop varieties and to borrow. Education is also a significant factor affecting choice of two coping strategies. More educated farmers are more likely to change crop varieties and to implement early planting. However, they are less likely to reduce meals or to borrow, although the effect in the secondcase is weak as the coefficient is not significant. This result could be explained by the fact that more educated farmers have relatively better access to more resources and do not therefore need to cut back on meals or borrow to smooth their consumption following a natural disaster. When it comes to gender effects, we observe that male-headed household are more likely to sell livestock as a coping strategy, while female-headed households are more likely to borrow. These findings are consistent with what we see on the ground. Males generally tend to control major livestock assets such as cattle, sheep and goats. With regard to occupation type, household heads whose primary occupation is agriculture are less likely to sell livestock, reduce meals or borrow as a coping strategy. However, they are more likely to adopt early planting.

We now consider results for the effects of plot characteristics on coping strategy choice (Table 4). The coefficient on distance has a positive sign for all five strategies but is statistically significant in three cases. Farmers who cultivate more distant plots, *inter alia*, are more likely to resort to early planting, sell livestock and reduce meals. In the case of soil slope, the coefficient has the expected sign in all cases, as hypothesised. But it is only significant for selling livestock, reducing meals and borrowing. Farmers cultivating gentler slopes are less likely to undertake these measures, all things being equal. The results for plot characteristics such as soil depth soil type and soil fertility are however mixed. As expected, farmers with good soil types are less likely to reduce meals or borrow. However, contrary to expectation, farmers with more fertile soils are more likely to undertake these measures. But on the other hand, farmers with less fertile soils are more likely to change crop varieties and implement early planting. Tenure status and size of own land area have negative coefficients in nearly all cases. However, those for tenure are only significant for reducing meals, and those for own land area are significant for selling livestock, reducing meals and borrowing. This implies that farmers who own smaller plots are more likely to sell their livestock, reduce meals and borrow as coping measures, all other things being equal. This finding is consistent with what could be expected as such farmers would have less output to sell and would therefore be more vulnerable to climate risks.

The final set of independent variables in Table 4 relates to plot management characteristics. Many of the farm management practices affect the choice of coping strategy to varying degrees. However, the most consistent set of results are for intercropping, hybrid maize and improved maize varieties. The coefficient of Intercropping has the expected negative sign and is significant for all the five strategies. This implies that farmers who use lower levels of intercropping are more likely to borrow, reduce meals, sell livestock, adopt early planting and change crop varieties. A similar pattern can be observed for hybrid maize and improved maize varieties, to some extent. The MVP model results for coping specifically with drought (Table 5) are fairly similar to those in Table with respect to the signs and significance of the coefficients.

Some general observations can be drawn for factors influencing ex-post coping strategies of the farmers. In general, plot characteristics and farm management practices affect farm productivity and hence income. What the data show is that owners of plots with unfavourable characteristics or with poor management practices are less able to weather adverse climatic events such as drought or floods. However, owners of such plots are more likely to take actions (e.g., borrowing or selling livestock) that can immediately supplement their income compared to other strategies such as changing crop varieties or early planting. Such strategies can also be income enhancing but the effects may not be immediate.

7. Conclusions and Policy Implications

This study analysed the factors affecting Ethiopian farmers' choice of ex-ante adaptation and ex-post coping strategies to climate risk. The analysis was based on cross-sectional survey data collected during the 2012−13 agricultural production year. Multivariate probit (MVP) models were estimated to explain the choice of various adaptation and coping strategies of farmers in the study area. The adaptation strategies analysed were changing crop varieties, early planting, crop diversification, tree planting and construction of soil and stone bunds. The coping strategies investigated were selling livestock, renting out land selling land and other assets reducing meals, and borrowing. The MVP model, which involves simultaneous estimation of the various strategies, was shown to be an appropriate approach because the error terms of the choice equations were found to be correlated with each other. In this situation use of univariate probit (or logit) models would have resulted in inefficient estimates.

The study results show for the first time that farmers' adaptation and coping strategies are significantly affected not only by some household socioeconomic characteristics, but also by plot characteristics and plot management practices. Age and education were found not to be significant determinants of the choice of most adaptation strategies. However, for coping strategies, educated farmers are more likely to change crop varieties and less likely to sell livestock, reduce meals or borrow. Female-headed households are less likely to adopt changing crop varieties as an adaptation strategy. We found that agriculture as a primary occupation is a significant factor affecting the choice of adaptation and coping strategies. Such farmers are more likely to adopt strategies such as changing crop varieties, early planting and crop diversification. However, they are also more likely to choose coping strategies such as selling livestock, reducing meals and borrowing.

Plot characteristics such as slope, depth, soil type and soil fertility, and farm size are important factors affecting the choice of adaptation strategy. These plot characteristics also significantly affect the choice of particular coping strategies such as selling livestock, reducing meals and borrowing. It was also found that some plot management practices significantly affect the choice of adaptation strategy. In particular, the practice of soil and water conservation on a plot is strongly associated with an increased likelihood of choosing a given adaptation measure. Similarly, the use of improved maize varieties on a plot is also strongly related to an increased likelihood of choosing early planting, tree planting and construction of soil and stone bunds. These results lead us to surmise that farmers who engage in these practices might also knowledgeable about other practices that could also assist them to weather adverse climatic events. The study results also indicate that plot management practices also significantly influence the choice of coping strategies. Specifically, higher levels of intercropping and use of hybrid maize (and improved maize to some extent), reduces the likelihood of choosing to sell livestock, reducing meals or borrow as a coping strategy.

A number of policy implications can be drawn from the study's results. Firstly, the low level of adaptation measures (less than 10% on average) observed at the plot level underlines the need for improved farmer extension education on climate change and strategies to adapt to the phenomenon. Secondly, the finding that plot management practices such as leaving crop residues, intercropping and use of non-recycled hybrid maize are associated with the reduced likelihood of coping measures such as selling livestock and borrowing is important. Although these practices may seem to be costly in the short run, in the long run they reduce the household's vulnerability by increasing farm productivity. There is therefore the need for increased farmer education on the benefits of these practices. Thirdly, we observed some gender effects in the choice of some adaptation and coping strategies. Female-headed households are less likely to change crop varieties as an adaptation strategy and are more likely to borrow a coping strategy. This calls for special programs targeted at improving the skills and knowledge of women.

To conclude, it is important to note some caveats and highlights for improvement in future research. This study employed cross-sectional plot level data to analyse the determinants of adaptation and coping strategies in the study area. However, adaptation and coping are complex processes that could be dynamic in nature. Therefore, future studies could use panel data which are better able to capture the dynamics involved in order to provide more robust insights. This study has improved on previous ones by considering different adaptation and coping strategies. However, future studies could improve our understanding by going a step further to analyse which of these strategies are more effective at the plot level.

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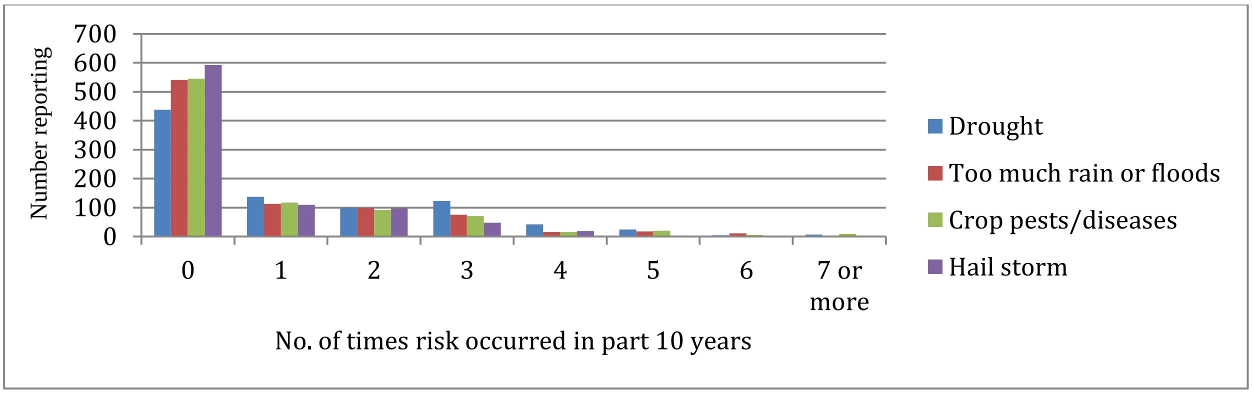

Fig. 1: Frequency of occurrence of risk factors

Source: AP database

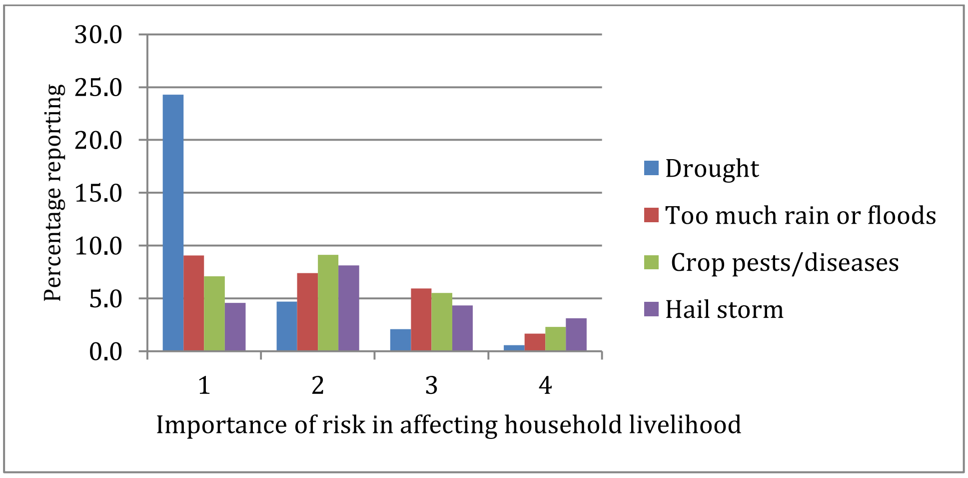

Fig. 2: Importance of risk factor in affecting household's livelihood

Source: AP database

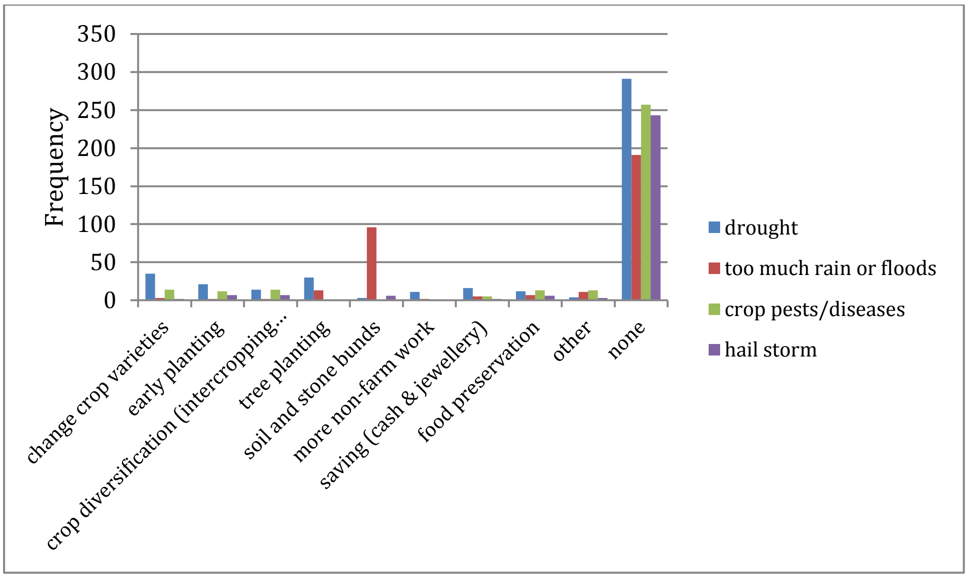

Fig. 3: Ex-ante risk management strategies

Source: AP database

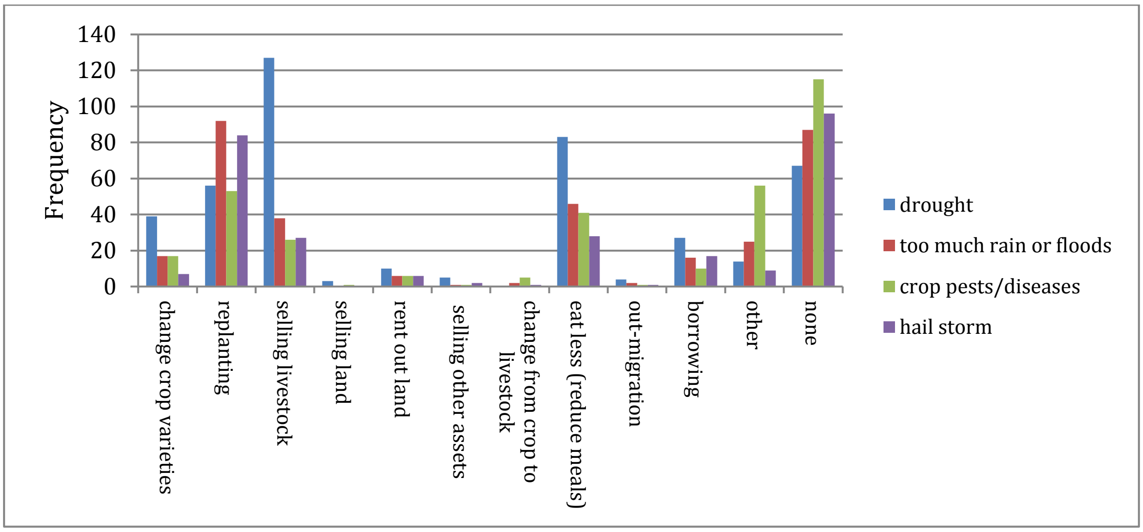

Fig. 4: Ex-post risk coping strategies

Source: AP database

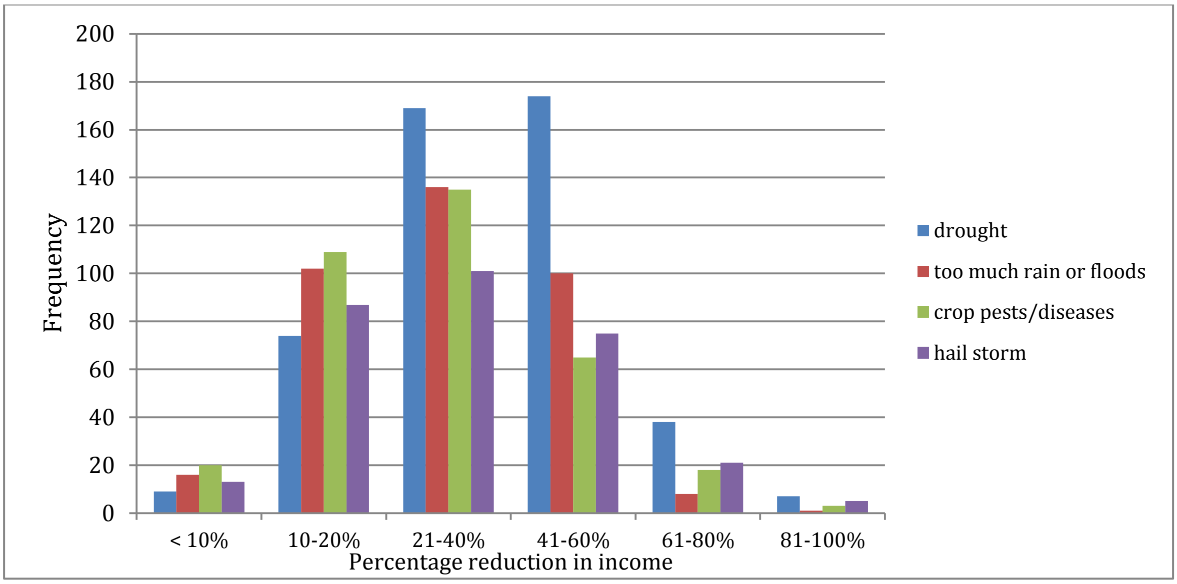

Fig. 5: Reduction in income as a result of risk

Source: AP database

Table 1: Definitions and summary statistics of the dependent variables

Variable	Mean	Std. Dev.
Dependent variables (plot level, dummy, 1=yes)		
Adaptation to any climate related risk		
Changing crop varieties	0.08	0.275
Early planting	0.07	0.262
Crop diversification	0.05	0.225
Tree planting	0.06	0.239
Soil and stone bunds	0.13	0.336
Adaptation to drought		
Changing crop varieties	0.05	0.222
Early planting	0.05	0.224
Tree planting	0.04	0.192
Coping with any climate related risk		
Changing crop varieties	0.14	0.344
Replanting	0.24	0.428
Selling livestock	0.32	0.467
Borrowing	0.16	0.368
Coping with drought		
Replanting	0.09	0.292
Selling livestock	0.26	0.439
Independent variables		
Household characteristics		
Age of household head in years (AgeH)	43.89	12.725
Education of household head in years (EducH)	4.49	11.669
Gender (SexH, 1=male 0=female)	0.92	0.271
Occupation (OccupH, 1=agric. self emp., 2 agric. wage labour, 3=non-agric. self emp., 4=non-agric. wage labour)	1.28	1.138
Plot characteristics		
Distance from home (Dist, minutes)	15.50	27.940
Soil slope (Slope, 1=gentle, 2=medium, 3=steep)	1.32	0.527
Soil depth (Depth, 1=shallow, 2=medium, 3=deep)	2.45	0.725
Soil type (Soiltype, 1=black, 2=brown, 3=red, 4=grey, 5=other)	2.45	1.050
Soil fertility (Fertility, 1=good, 2=medium, 3=poor)	1.58	0.630
Plot tenure (Tenure, 1=owned, 2=rented/shared in, 3= rented/shared out, 4=borrowed in, 5=borrowed out, 6=other)	1.17	0.471
Own land area (Ownlarea, ha)	1.76	1.443
Maize area (Mzarea, ha)	0.87	0.758
Plot management practice		
Soil and water conservation (Swcons_a, 0=none, 1=terraces, 2=mulching, 3=grass strips, 4=trees on borders)	1.02	2.105
Crop residues left on plot (Residues, 1=yes, 0=no)	0.07	0.262
Composting (Compst, 1=yes, 0=no)	0.07	0.246
Percentage of plot intercropped (Percintcr_a, %)	98.13	0.774
Use of fertilizer (fertuse, 1=yes, 0=no)	0.53	0.499
Use of improved maize variety (Impmza, 1=yes, 0=no)	0.80	0.778
Use of non-recycles hybrid maize (Hib2, 1=yes, 0=no)	0.30	0.457

Note: *N*=3694

Table 2: Multivariate probit estimates for ex-ante adaptation to any climate related risk

	Changing crop varieties		Early planting		Crop diversification		Tree planting		Soil and stone bunds	
Variable	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z
Household characteristics										
AgeH	0.003	1.38	-0.010**	-3.76	0.002	0.69	0.000	-0.15	-0.003	-1.33
EducH	-0.005	-1.38	-0.003	-0.88	0.004	1.35	0.002	0.61	0.002	0.77
SexH	0.524**	4.67	0.204	1.45	0.001	0.01	0.099	0.73	0.053	0.49
OccupH	-0.134**	-3.63	-0.086*	-2.31	-0.063*	-1.75	-0.019	-0.57	-0.011	-0.42
Plot characteristics										
Dist	-0.001	-1.20	0.001	0.55	0.000	0.19	-0.004**	-2.93	0.001	1.03
Slope	-0.209**	-2.98	-0.312**	-4.02	-0.358**	-3.88	-0.224**	-2.79	-0.173**	-3.05
Depth	-0.034	-0.75	0.124**	2.56	-0.064	-1.31	0.056	1.13	0.034	0.88
Soiltype	0.137**	4.20	-0.028	-0.89	-0.291**	-7.75	-0.028	-0.83	0.028	1.03
Fertility	-0.379**	-6.32	-0.288**	-4.76	-0.296**	-4.34	-0.502**	-7.28	-0.250**	-5.26
Tenure	0.023	0.32	-0.203*	-2.31	0.008	0.09	0.112	1.86	-0.086	-1.38
Ownlarea	-0.060**	-2.09	-0.114**	-3.56	-0.142**	-3.58	-0.234**	-5.91	-0.262**	-8.53
Plot management practices										
Swcons_a	0.150**	11.73	0.095**	7.20	0.095**	6.25	0.049**	3.35	0.156**	14.05
Residues	0.166	1.48	0.172	1.61	-0.219	-1.55	0.045	0.38	0.139	1.46
Compst	-0.176	-1.36	-0.031	-0.26	-0.001	-0.01	0.234*	2.02	0.180*	1.79
Fertuse	-0.048	-0.68	0.084	1.17	0.118	1.46	0.111	1.46	0.278**	4.52
Percintcr_a	-0.004	-1.87	-0.005*	-2.21	0.002	0.68	-0.008**	-3.38	-0.007**	-3.73

Regression diagnostics
Wald statistics: χ^2 (90) = 4838.4, *p*-value = 0.000
LR test of ρ_{ij}'s=0: χ^2 (10) = 1424.9, *p*-value = 0.000
No. of plots: 3694

** Significant at the 1% level.
* Significant at the 5% level.

Table 3: Multivariate probit estimates for ex-ante adaptation to drought

	Changing crop varieties		Early planting		Tree planting	
Variable	Coef.	z	Coef.	z	Coef.	z
AgeH	0.000	0.05	-0.003**	-2.39	0.002	0.62
EducH	-0.002	-0.43	-0.005	-0.99	0.006*	2.05
SexH	-0.542	-4.17	-0.020	-0.13	0.125	0.69
OccupH	-0.113**	-2.66	-0.088*	-2.04	-0.091*	-1.73
Dist	-0.003	-1.57	0.002	1.71	-0.005**	-2.37
Slope	-0.305**	-3.58	-0.355**	-3.99	-0.304**	-2.84
Depth	0.043	0.78	0.092	1.71	0.066	1.08
Soiltype	0.138**	3.67	0.004	0.11	-0.021	-0.49
Fertility	-0.291**	-4.17	-0.378**	-5.39	-0.713**	-7.24
Tenure	0.010	0.12	-0.117	-1.27	0.108	1.46
Ownlarea	0.033	1.09	-0.092**	-2.64	-0.276**	-5.08
Swcons_a	0.150**	10.23	0.089**	5.95	0.042*	2.28
Residues	0.162	1.24	-0.301*	-2.04	-0.022	-0.15
Compst	-0.161	-1.09	0.026	0.20	0.153	1.04
Fertuse	-0.013	-0.16	0.085	1.06	0.212*	2.19
Percintcr_a	-0.009**	-3.53	-0.006*	-2.06	-0.008**	-2.66

Regression diagnostics	
Wald statistics:	χ^2 (54) = 3694.0, p-value = 0.000
LR test of ρ_{ij}'s = 0:	χ^2 (3) = 1204.8, p-value = 0.000
No. of plots:	3694

** Significant at the 1% level.
* Significant at the 5% level.

Table 4: Multivariate probit estimates for ex-post coping with any climate related risk

	Changing crop varieties		Early planting		Selling livestock		Reducing meals		Borrowing	
Variable	Coef.	z	Coef.	z	Coef.	z	Coef.	z	Coef.	z
Household characteristics										
AgeH	0.004	1.72	-0.001	-0.55	0.000	0.17	0.002	1.06	0.008**	3.96
EducH	0.007**	3.49	0.003	1.80	0.001	0.67	-0.006**	-2.84	-0.002	-0.91
SexH	0.052	0.50	0.104	1.16	0.189*	2.10	-0.089	-1.00	-0.282**	-3.06
OccupH	0.006	0.24	0.052**	2.47	-0.062**	-2.80	-0.112**	-4.73	-0.095**	-3.72
Plot characteristics										
Dist	0.001	1.59	0.002**	2.90	0.001	1.88	0.002**	3.06	0.001	1.50
Slope	-0.046	-0.84	-0.006	-0.13	-0.348**	-7.82	-0.140**	-3.12	-0.110*	-2.21
Depth	-0.012	-0.32	0.073*	2.25	0.092**	3.01	0.344**	10.17	0.123**	3.51
Soiltype	0.002	0.06	-0.100**	-4.43	0.019	0.92	-0.054**	-2.47	-0.119**	-4.89
Fertility	-0.199**	-4.36	-0.230**	-5.89	0.064	1.57	0.153**	4.12	0.149**	3.66
Tenure	-0.057	-0.96	-0.042	-0.83	0.038	0.82	-0.102**	-2.09	0.027	0.55
Ownlarea	-0.033	-1.55	0.004	0.22	-0.045**	-2.47	-0.223**	-9.91	-0.144**	-5.98
Plot management practices										
Swcons_a	-0.001	-0.08	0.045**	4.24	0.088**	8.66	0.047**	4.42	0.011	0.90
Residues	0.347**	3.84	0.002	0.02	-0.213**	-2.45	0.043	0.48	0.173	1.88
Compst	0.187	1.88	0.229**	2.61	0.053	0.59	-0.122	-1.30	0.092	0.92
Fertuse	0.025	0.44	0.228**	4.48	0.172**	3.54	0.043	0.85	0.119*	2.15
Percintcr_a	-0.009**	-4.68	-0.005**	-3.09	-0.007**	-4.37	-0.009**	-5.24	-0.009**	-5.14
Impmza	-0.002	-0.06	-0.089**	-2.55	0.066*	2.04	-0.000	-0.01	-0.120**	-2.96
Hib2	-0.176**	-2.64	-0.094	-1.65	-0.129**	-2.36	-0.139**	-2.45	-0.120	-1.92

Regression diagnostics

Wald statistics:	χ^2 (90) = 4089.5, p-value = 0.000
LR test of ρ_{ij}'s = 0:	χ^2 (10) = 1204.8, p-value = 0.000
No. of plots:	3694

** Significant at the 1% level; * Significant at the 5% level.

Table 5: Multivariate probit estimates for ex-post coping with drought

	Changing crop varieties		Early planting		Selling livestock	
Variable	Coef.	z	Coef.	z	Coef.	z
AgeH	0.004	1.70	-0.001	-0.61	0.000	0.23
EducH	0.007**	3.49	0.003	1.72	0.001	0.53
SexH	0.049	0.48	0.097	1.08	0.183**	2.05
OccupH	0.006	0.24	0.049*	2.32	-0.061**	-2.81
Dist	0.001	1.71	0.002**	2.87	0.001*	1.78
Slope	-0.045	-0.84	-0.015	-0.33	-0.361**	-8.03
Depth	-0.014	-0.39	0.074*	2.30	0.100**	3.25
Soiltype	0.002	0.07	-0.104**	-4.59	0.021	0.99
Fertility	-0.201**	-4.39	-0.225**	-5.76	0.069	1.91
Tenure	-0.054	-0.90	-0.040	-0.78	0.040	0.87
Ownlarea	-0.031	-1.45	0.003	0.18	-0.045**	-2.46
Swcons_a	-0.001	-0.08	0.044**	4.19	0.090**	8.72
Residues	0.343**	3.79	0.005	0.05	-0.217**	-2.48
Compst	0.194	1.95*	0.218 **	2.46	0.043	0.48
Fertuse	0.029	0.50	0.236**	4.63	0.168**	3.45
Percintcr_a	-0.009**	-4.66	-0.005**	-2.95	-0.007**	-4.39
Impmza	-0.007	-0.18	-0.085**	-2.45	0.062*	1.90
Hib2	-0.172*	-2.59	-0.094**	-1.66	-0.127*	-2.34

Regression diagnostics

Wald statistics:	χ^2 (54) = 2713.43, *p*-value = 0.000
LR test of ρ_{ij}'s = 0	χ^2 (3) = 359.15, *p*-value = 0.000
No. of plots	3694

** Significant at the 1% level.
* Significant at the 5% level.