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Adaptation to climate change in Uganda: Evidence from micro level data

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ABSTRACT

This study employed data from the 2005/06 Uganda national household survey to identify adaptation strategies and factors governing their choice in Uganda's agricultural production. Factors that mediate or hinder adaptation across different shocks and strategies include age of the household head, access to credit and extension facilities and security of land tenure. There are also differences in choice of adaptation strategies by agro-climatic zone. The appropriate policy level responses should complement the autonomous adaptation strategies by facilitating technology adoption and availing information to farmers not only with regard to climate related forecasts but available weather and pest resistant varieties.

1. Introduction and motivation

The current unfavourable patterns in climatic outcomes in many parts of the world have brought the need to identify and understand possible adaptation strategies to the limelight. Changes in climatic conditions have been manifested through different channels including longer and more frequent drought spells, rising temperatures, as well as heavier and erratic rains with differing amplitudes on the spatial dimension (Below et al., 2010). The literature has identified several channels through which these changes impact on ecosystems and human development. Both heavier rains and persistent droughts increase soil erosion and vegetation damage through run off with effects on agriculture and sustainable livelihoods. Higher temperatures also mediate faster loss of soil moisture, and prolonged droughts and increasing temperatures create favourable conditions for pests and diseases to multiply (Hoffmann, 2009). The 2007/2008 Human Development Report provides a detailed description of the processes through which current climatic changes might affect attainment of major human development goals as envisaged in the Millennium Development Goals (HDR, 2007).

The primary impacts of climate change will invariably be more pronounced in the productivity of activities that depend more than proportionately on favourable climate outcomes—such as the rain fed agriculture that is practiced in most parts of sub Sahara Africa (McCarthy et al., 2001). In Uganda some climate change induced outcomes have been identified as integral components of the overall constraints to agricultural productivity. Hisali and Kasirye (2008) for example estimate that up to 34% of crop damage in the country is caused by climate induced stimuli such as rainfall shortage, crop diseases and insect damage. Their study also reports that 13%, 20%, and 23% of the community leaders interviewed for the 2005/06 Uganda national household survey (UNHS) indicate crop pests and diseases to be the first, second, and third major constraints respectively to agricultural production.

The secondary effects on economies and livelihoods derive from the importance of agriculture in sub Sahara Africa. The sector is the mainstay of economies of most countries in Africa providing primary employment to an average of 70% of the population (Thornton et al., 2006) and playing a major role in ensuring food security. Notwithstanding the significant decline in the share of agriculture in GDP[1] for example the sector remains of great importance in Uganda—at least with regard to employment.

The interaction of limited resources, high incidences of poverty, ecosystem degradation, conflicts, and a weak institutional capacity, however, imply that the effects will be much stronger in the poorer countries of the world (Francisco, 2008). The adverse impacts of climate change combined with a weak adaptive capacity the micro level of households in Africa that brings the need to ascertain viable and sustainable adaptation strategies to the center of policy analysis and debate. In as much as

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[1] The contribution of agriculture to GDP reduced from 52% in 1992/93 to 15% in 2009/10 (Background to the Budget, 1994/95 and 2009/10). Nonetheless, the sector still employs about 77% of the rural adult population and accounts for more than about 60% of the merchandise exports.

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the literature (see for instance Patt and Schroter, 2008; Below et al., 2010; IPCC, 2007) has identified some broad adaptation strategies, the diverse spatial difference with which climate change manifests itself implies that the relevant responses to the adverse impacts (as well as the opportunities) arising from climate change tend to be context specific and localised. Whereas analysis by the IPCC (2007) shows mean temperatures in Africa to have risen by one degree Celsius between 1900 and 2000, and with a projected increase of three degrees Celsius by 2050 the long term projections depict considerable variability. Boko et al. (2007) for example project a decrease in mean annual rainfall by up to 20 percent along the Mediterranean coast and the northern Sahara compared to a 7 percent increase in tropical and eastern Africa projected by Case, 2006. The IPCC on the other hand suggests that northern and southern Africa are likely to experience an increase in the number of people suffering from water stress whereas more parts of eastern and western Africa will likely experience a reduction in water stress (IPCC, 2007).

Such variability with which climate change outcomes manifest themselves calls for appropriate adaptation responses in the different contexts. Presently however, there is very limited research on adaptation strategies and their determinants in Uganda's agricultural production. It is in this context that this study sought to identify the major climatic changes that have taken place in Uganda and examine the various adaptation strategies as well as factors that influence choice of a particular strategy. This, we believe is imperative in efforts aimed at designing incentives to enhance private adaptation.[2] In addition, the findings should provide an informed basis for designing strategies that support existing adaptation measures of local farmers through appropriate public policy, investment and collective actions so as to reduce the negative consequences of predicted changes in future climate.

The study employed the nationally representative Uganda national household survey (UNHS) 2005/06 data set collected by the Uganda Bureau of Statistics. In as much as the main aim of the survey was not to collect climate change information per se it probed households on the major climate change related shocks experienced as well as the response strategies they had adopted in the five years preceding the survey. Of particular interest to climate change are questions related to floods/hailstorm, drought, livestock epidemic and pest attack. The Uganda Bureau of Statistics uses sampling weights to account for over- and under-sampling in various enumeration areas making the sample data nationally representative.

After the introduction, the rest of this paper is organized as follows: an overview of the literature and adaptation benchmarking is presented in Section 2 followed by a description of the data in Section 3. The presentation of the climate change events and adaptation strategies of farmers in Uganda is undertaken in Section 4 followed by the methodology and empirical results in Section 5. Concluding remarks are contained in Section 6.

2. Overview of the literature

This section presents a summary of the literature regarding perceptual processes that mediate response to actual or expected climatic stimuli or their effects. It also presents factors that influence the ability to use a particular strategy.

2.1. Perceptions and adaptation

The ongoing changes in global climatic conditions are exposing communities to ever increasing risk and threatening the very sources of livelihood especially in the poorer parts of the world (Francisco, 2008). Contrary to what one would expect, the relationship between some of the climatic induced stimuli and autonomous responses are not automatic but rather, are cognitive processes. In particular, the decision to adapt to climate change risks is mediated by perceptual processes that underlie both the understanding and assessment of risk (Rogers, 1975, 1983).

In estimating the likelihood of threats agents employ patterns to construct temporary internal models known as heuristics as opposed to using the more formal Bayesian approaches (Arthur, 1984). Among the most prominent of these heuristics are the availability and the representative heuristics. The availability heuristic posits that judgments will be based on what people can remember and that they search their memories for instances of a particular kind of event occurring which is theoretically expected to increase with freshness of memory of a given event or strength of emotional impact attached to particular memories (Tversky and Kahneman, 1973; Covello, 1990). The representativeness heuristic attaches a high likelihood to a particular event occurring if it is deemed to be representative (Tversky and Kahneman, 1974).

It is the cognitive nature of autonomous adaptation decisions that explains the commonly observed conflicts between exposure to climate related risk and inaction, as well as conflict between autonomous and policy adaptations. Theoretically these conflicts can be attributed to the endowment effect and the omission bias. The endowment effect explains the tendency of making decisions that guard against potential losses and detachments as opposed to potential gains.[3] The omission bias attaches high probability values to inaction "... because [decision makers] assign more personal responsibility to the negative consequences of decisions than they do of omission, and want to avoid that personal responsibility for negative outcomes" (Patt and Schroter, 2008, p. 460). Grothmann and Patt (2005) used the sociocognitive Model of Private Proactive Adaptation to provide insights into the cognitive barriers to adaptation in rural Zimbabwe and showed that farmers were not partaking adaptation practices because they perceived both the associated risk and capacity to adapt to be rather low.

In addition to insights inherent in perceptual processes, the required adjustments can also be mediated by economic, informational as well as social and ecological considerations such as threats to livelihood sources, awareness of severity of the problem and contextualization of external climate forecasts.

The cognitive nature of autonomous adaptation decisions calls for partnership between analysts and decision makers in designing strategies that support existing adaptation measures of local farmers through appropriate public policy, investment and collective actions.

2.2. Choice of adaptation strategies

Adaptation strategies are responses to actual or expected climatic stimuli (and their effects) which are intended to moderate harm or exploit associated beneficial opportunities. The adjustments can be broadly categorized either as responses to current occurrences (climate variability) or planned adaptation to long term changes. In terms of characterization a range of practices have been identified at different levels from household to more institutionalized settings. The review by Below et al. (2010)

[2] Private adaptations are micro level responses to actual or expected climatic stimuli (and their effects) which are intended to moderate harm or exploit the associated beneficial opportunities. Owing to limited resources to facilitate adaptation at a broader scale private adaptations are the most widely employed responses by farmers in Uganda to climate change.

[3] This can be used to explain phenomena such as reluctance on the part of some people to cope to climate related risks by migrating for example, due to strong attachments they may have to their communities and ancestral roots.

concludes that the most common ones involve some form of diversification and portfolio shifts (including changes in land use and livelihood strategies, and variations in crops and improved crop varieties), changes in timing of cropping and cropping patterns, migration, water conservation techniques and irrigation. Deressa et al. (2009) identify tree planting, soil conservation, different crop varieties, variation in planting time, and irrigation to be the most common adaptation strategies by agriculturalists.

With regard to the choice of a given adaptation strategy, the literature has identified many considerations that influence decision making ranging from behavioral and socio-economic to gender and ecological. Behavioral factors such as the level of perceived risk determine the likelihood of partaking adaptation practices. Grothmann and Patt (2005) for instance show that the likelihood of partaking adaptation practices reduces when the perceived risk associated with climate change and the capacity to adapt are low. Patt and Schroter (2008) show that implementation of adaptation policies will fail if there is asymmetry of beliefs and risk assessments between beneficiaries and policy makers and suggest a strong role for dialogue across groups in policy formulation. (Below et al., 2010) on the other hand quote studies which suggest that "... cognitive factors, such as experience, influence farmers' processing of the probability of climate events, as well as their ability to apply climate forecasts..." (p. 9).

Studies (see for instance Norris and Batie, 1987; Maddison, 2007; Deressa et al., 2009) also point to the important role of socioeconomic factors such as the individual decision maker's position on the life cycle, experience, education, wealth status and availability of resources (such as land, credit and water storage facilities). Others include distance to markets, availability of extension advice (information), farm and household size, and tenure status. Social networks are a decisive factor in acceptance of forecast information (Valdivia et al., 2001, 2002).

Societal construction of gender roles in much of the developing world has important implications for the medium of delivery of climate change information (Broad and Petty, 2004). In this respect, certain delivery vehicles such as time specific programmes through the electronic media which do not take into account the limited time flexibility of women have are likely to delay adaptation. Gender discrimination may also make it difficult for some women to gain access to complementary inputs as well as relevant information (Tenge et al., 2004), though some studies argue that the dominant role of women in Africa's agriculture gives them the relevant experience and information (Nhemachena and Hassan, 2008).

The study by Deressa et al. (2009) concludes that agro-ecological zones also affect choice of adaptation strategies. Stringer et al. (2009) on their part focus on the interface between policy and autonomous adaptations and point to the role of national level adaptations in ensuring sustainability of autonomous adaptations.

The empirical analysis in this paper is modeled as much as possible (subject to data limitations) along variables identified in this section.

3. Data description

The study employed the 2005/06 Uganda national household survey (UNHS) collected by the Uganda Bureau of Statistics. This was a multipurpose survey designed with three modules, namely, socioeconomic survey, community survey, and agriculture survey. Apart from the standard socio-economic information the socio-economic survey probed households on the various shocks experienced, the timing of the shock as well as response and coping mechanisms over the five-year period preceding the survey. Of particular interest to climate change are questions related to floods/hailstorm, drought, livestock epidemic and pest attack. Information from this section was merged with other sections and modules to identify the socio-economic, community and other determinants of the choice of a particular adaptation strategy. The community survey was designed to collect data on the characteristics of local council one areas (LC 1),[4] consumer markets, farm input markets and produce outlets, demographic information relating to communities residing in the sampled enumeration areas (EA) and various details on economic and social infrastructure in those areas.

The agriculture survey was intended to collect information on the crop area, inputs, outputs and allied characteristics, covering farming households. In addition, the surveys also capture information relating to household access to key agricultural institutions such as financial service providers, input and output markets. The information from the above three surveys were collected at the same time and from the same enumeration area. Adaptation strategies in the survey were captured by asking households to list the most important adaptation strategies they employed. The specific adaptation strategies and how they were reconstructed for purposes of analysis is presented in the next section. The survey information is collected and compiled on the basis of political and geographical units such as LC 1, districts and regions. To capture the spatial aspects of Uganda's climate, agricultural households for purposes of this study are also classified on the basis of agro-ecological zones.

To facilitate meaningful transformation of the data, efforts were made to clean the data by checking for duplicates, inconsistencies and outliers. Sampling weights were used throughout the analysis to account for over- and under-sampling in various enumeration areas, making the sample data nationally representative.

4. Climate change events and adaptation strategies of farmers in Uganda

Uganda's climate is characterized by two rainy seasons. The first rains, which also define the main planting season are more intense and are realized between March and June. The second (lighter) rains take place between the months of October/November–December/January. These patterns are mediated by the La Nina and the El Nino phenomena in the Indian Ocean (LTS International, 2008). The country is demarcated into seven agro-climatic zones on the basis of spatial differences in soils, topography and to a certain extent climate (Table 1).

Extreme weather events are not a new phenomenon in Uganda's history. Reference is made here to the more than usual rainfall recorded in 1961/62, 1997/98 and 2007 and severe drought that hit the country in 1993/94. Unfortunately though, the available scientific projections on Uganda's future climate outcomes are inconclusive. Some reports suggest that temperatures will increase by 4.3 degrees Celsius by 2080, but there are also indications that Uganda may become wetter and may experience changes in rainfall patterns with the second rains becoming more intense (LTS International, 2008; Ministry of Water and Environment, 2007). In any case the changing patterns bring the need to ascertain viable and sustainable adaptation strategies to the center of policy analysis and debate. Indeed, at the strategic level the country finalized a National adaptation plan of action (NAPA) to coordinate activities and to attempt to mainstream local adaptations. As part of the activities leading to production of Uganda's NAPA a long list of adaptation related activities were identified or suggested. These include: exploitation of aquatic resources, food preservation, herbal medicines, alternative livelihood systems, resorting to under-utilized and non-conventional foodstuffs and water harvesting. Others are changes in soil conservation and

[4] The LC 1 is the smallest political administrative unit in Uganda.

Table 1
Uganda's agro-ecological zones.

Farming system	Districts
Banana/coffee system	Bundibugyo, parts of Hoima, Kabarole, Mbarara, Bushenyi, Mubende, Luweero, Mukono, Masaka, Iganga, Jinja, Kalangala, Mpigi and Kampala
Banana/millet/cotton system	Kamuli, Pallisa, Tororo, parts of Masindi and Luweero
Montane system	Kabale, Kisoro, parts of Rukungiri, Bushenyi, Kasese, Kabarole, Bundibugyo, Mbarara, Mbale and Kapchorwa
Teso systems	Soroti, Kumi and Kaberamaido
Northern system	Gulu, Lira, Apac and Kitgum
Pastoral system	Kotido, Moroto, parts of Mbarara, Ntungamo and Masaka, Ntungamo, Masaka and Rakai
West Nile system	Moyo, Arua and Nebbi

husbandry practices, greater involvement in self-help initiatives, traditional vector control approaches and indigenous approaches to rainmaking and thunderstorm prevention. Increased law enforcement, hygiene and sanitation strategies, renting land, shifting cultivation, sale of assets and use of starter stock and change in eating behavior were also identified, among others.

The socioeconomic module of the 2005/06 integrated household survey also asked respondents to describe major distress events that they had experienced, their frequency and severity, and duration in the five years preceding the survey. They were also asked to list the adaptation strategies that they had employed. The distress events that were identified and bear close relationship to climate change are drought, floods, pest attack, and livestock epidemics. Table 2 presents the percentage of respondents who reported that they had experienced some of climate change related event. The distress events do not show marked differences though pest attacks appear to be a more common threat.

The regional totals show some variation in the geographical occurrence of shocks with 29.4 percent of respondents in the north reporting that they had experienced some type of climatic related shock compared to only 18.9 percent in the western part of the country.

The climate related shocks as captured by the 2005/06 UNHS appear to be path dependent with their occurrence being reported by an increasing number of households over time (Fig. 1).

The duration of shocks over the five years preceding the survey shows variability but again pest attacks appear to be more persistent (Fig. 2).[5] Drought is also a persistent problem with about 49 percent of the respondents reporting that it lasted for over five months in each of the years preceding the survey. Whereas floods and livestock epidemics are becoming increasingly common, they last for shorter time periods.

The increased episodes and persistence of climate distress events computed from the 2005/06 UNHS data appear to be indicative of long term climatic changes and are interestingly consistent with anecdotal and other evidence from reports on climate change in Uganda such as LTS International (2008) and Republic of Uganda (2007).

In response to the observed changes in climate related outcomes households have been employing a range of adaptation practices. The 2005/06 survey identified mortgaging household assets, selling assets, using past savings and withdrawing children from school as some of the adaptation mechanisms. Other strategies include sending children to live elsewhere, migration,

Table 2
Occurrence of climate related shocks by region.

	Drought	Floods/hailstorm	Pest attack	Livestock epidemic	Total
Central	6.0	6.2	6.1	6.1	24.4
Eastern	6.8	6.8	6.9	6.9	27.4
Western	4.6	4.8	4.9	4.6	18.9
Northern	7.2	7.3	7.4	7.5	29.4
National	24.6	25.1	25.3	25.1	100

Source: Authors' calculations from the 2005/06 UNHS.

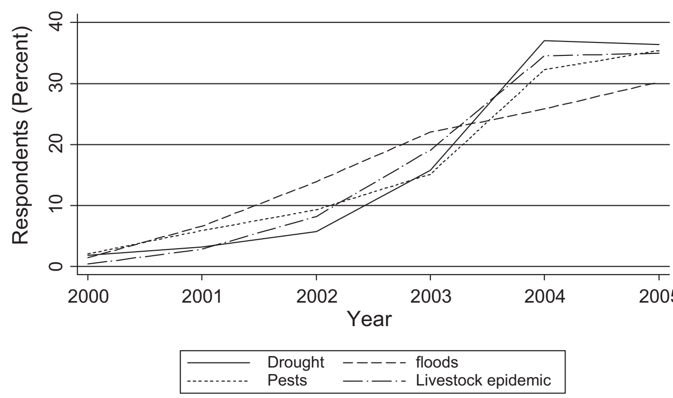

Fig. 1. Percentage of respondents reporting different shocks 2000–2005.

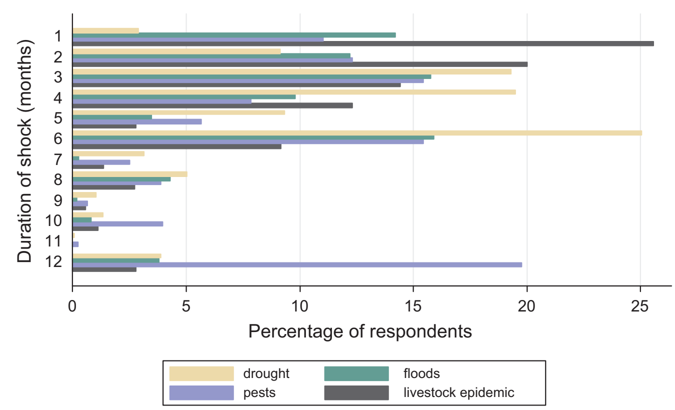

Fig. 2. Duration of climate related shocks.

formal borrowing, informal borrowing, reducing consumption, and reliance on help from relatives, friends and local governments. More wage employment, changing crop choices to avoid bad weather, improving technology, working as self employed, and increasing agriculture labour supply were also commonly used.

In line with the literature the identified coping strategies were in turn collapsed into five categories as follows:

(i) borrowing, both from formal and informal sources;
(ii) labour supply which was constructed to include more wage employment, working as self employed, increasing agriculture labour supply, migration to work elsewhere and withdrawing children from school and sending them to work;
(iii) reducing consumption;
(iv) running down assets and past savings including mortgaging assets, selling assets and utilising savings; and,
(v) technology based adaptation strategies such as changes in crop choices to avoid bad weather and improving technology.

The national and disaggregated description of the use of different strategies is presented in Tables A1–A4. Utilisation of household

[5] This is in line with findings by Hisali and Kasirye (2008) which indicate that 13%, 20%, and 23% of the community leaders interviewed for the 2005/06 UNHS rank crop pests and diseases to be the first, second, and third major constraints, respectively to agricultural production.

Table 3
Credit status of households and adaptation strategy.

Credit/strategy	Drought			Floods			Pests			Livestock epidemic		
	Credit	No credit	National	Credit	No credit	National	Credit	No credit	National	Credit	No credit	National
Borrowing	3.80	0.00	3.80	5.30	0.00	5.30	1.34	0.00	1.34	1.46	0.00	1.46
Labour supply	5.56	17.47	23.03	5.97	17.88	23.85	3.44	14.94	18.38	6.84	23.60	30.44
Technology	2.11	2.75	4.86	2.94	4.66	7.60	13.05	27.41	40.46	8.83	7.57	16.40
Savings	6.74	33.13	39.87	4.62	35.38	40.00	3.87	15.27	19.14	7.29	40.37	47.66
Reduce consumption	7.00	21.45	28.45	5.80	17.44	23.24	6.44	14.24	20.68	3.07	0.98	4.05
Total	25.20	74.80	100.00	24.63	75.37	100.00	28.14	71.86	100.00	27.49	72.52	100.00

Table 4
Extension services and coping strategies.

Extension/strategy	Drought			Floods			Pests			Livestock epidemic		
	Extension	No extension	National	Extension	No extension	National	Extension	No extension	National	Extension	No extension	National
Borrowing	0.35	3.43	3.78	0.31	4.98	5.29	0.17	1.18	1.35	0.48	0.98	1.46
Labour supply	1.15	21.88	23.03	1.43	22.41	23.84	1.47	16.91	18.38	0.66	29.79	30.45
Technology	0.31	4.54	4.85	0.82	6.79	7.61	5.55	34.91	40.46	1.39	15.00	16.39
Savings	3.73	39.89	43.62	2.68	37.24	39.92	1.89	17.25	19.14	4.53	43.12	47.65
Reduce consumption	2.33	28.44	30.77	1.03	22.31	23.34	0.65	20.03	20.68	0.00	4.04	4.04
Total	7.87	94.75	100.00	6.27	93.73	100.00	9.73	90.28	100.00	7.06	92.93	100.00

savings, scaling back on consumption and labour based strategies are the most frequently employed strategies in response to drought events. Technology based strategies and reducing consumption on the other hand are the most frequently employed strategies by households faced with a pest attack whereas utilisation of savings and increased labour supply are the most common response strategies to floods. Households faced with a livestock epidemic usually rely on savings and supply of additional labour.

The bivariate relationship between adaptation strategies and some focal independent variables (such as sex and education of the household head, credit access and extension services as well as geographical location of the household) is generally weak (Tables A1–A4). In terms of sex of the household head both male and female headed households employ similar strategies in response to floods, pest attacks and livestock epidemics. The sex based difference in adaptation strategies is observed only in the event of a drought where female headed households accommodate drought related climate changes by reducing consumption while male headed use their savings (Table A1).

Geographically, a higher percentage of households in the eastern and western parts of the country rely on savings in response to drought episodes whereas increased labour supply and reducing consumption are more commonly used in the north and central parts of the country, respectively. Use of household savings and technology based responses are robust across the different regions as responses to livestock epidemics and pest attacks, respectively. Savings are also the most common response to floods except in the north of the country where households respond by supplying more labour which is plausible given the higher incidence of poverty in the northern part of the country. Increased labour supply and reduced consumption as adaptation strategies are more prominent in the northern part of the country (Table A2). The disaggregated results fail to show differences in adaptation strategies on the basis of education level (Tables A3–A4).

The limited variance of adaptation strategies on the basis of education and to a large extent sex of the household head is conjectured to reflect either the local public good nature of indigenous knowledge or the role of externalities. In any case one important implication is that the policy adaptations that should be implemented are those that complement some of the current practices that are sustainable.

Borrowing does not only under perform all the other adaptation strategies but also contrary to standard thinking does not appear to enhance adoption of more sustainable adaptation strategies (Table 3).

This is possibly mediated by the stringent repayment conditions coupled with the relatively high interest rates on the Ugandan financial market.

In relative terms the bivariate descriptive analysis results show that there is no difference in adaptation strategies on the basis of whether a household received extension advise or not which is conjectured to reflect the possibility that the existing extension services being provided to farmers are yet to incorporate information on climate change (Table 4).

Generally the most common adaptation strategies employed by households in Uganda are unsustainable and call for implementation of policies that seek to enhance the resilience of households to respond in a more sustainable manner to climate related climate shocks.[6]

The Kruskal–Wallis test was also employed to assess the statistical significance of the adaptation strategies within and between regions as well as agro-ecological zones. The test results indicate a statistically significant difference in the drought adaptation strategies between regions (Tables A5–A8) and agro-ecological zones (Tables A9–A12). At the national level the rank sum shows that utilisation of household savings is the most common drought adaptation strategy followed by reduced consumption and increased labour supply (Table A5). Geographically the use of household savings is ranked higher in the western and eastern parts of the country whereas households in the central region accommodate drought related climate changes by reducing consumption while those in the north mostly rely on increased supply of labour.

The pest attack adaptation strategies are also significantly different both within and between regions (Table A6) and agro-ecological zones (Table A10). Technology based strategies have a

[6] Some of the viable policy options are presented in the concluding section of the paper.

higher rank sum followed by reducing consumption and the finding is robust across the different regions (Table A6). In addition there is a statistically significant difference in the floods adaptation strategies both within different regions and agro-ecological zones. At the national level savings rank higher than all other strategies followed by reduced consumption. Use of household savings also ranks higher in three of the four regions.

Whereas the test fails to distinguish among the different floods adaptation strategies in the western region it distinguishes the strategies in all the other regions and nationally as well. Use of savings is ranked higher in the central and eastern regions and nationally whereas increased labour supply is more likely to be used in the north (Table A7).

The livestock epidemic adaptation strategies are significant at the national level but there is no significant difference among the strategies in central and eastern regions. The strategies are statistically different in the western and northern regions with savings dominating in both and nationally (Table A8).

The adaptation strategies employed by households in Uganda compare considerably well with those reported in studies from other developing countries (see for instance Boko et al., 2007; Below et al., 2010; Deressa et al., 2009). Reducing consumption as an adaptation strategy is in line with evidence from other studies which indicate that households accommodate exogenous changes that they may face by making adjustments to suit the new situation (Gregory et al., 2005). The use of technology based adaptation strategies is also in line with practices elsewhere (see for instance Thomas et al., 2007). In terms of policy, it will be helpful if these autonomous efforts by farmers were supported by research to facilitate technological developments that are suitable to changing environments. The prominence of increased labour supply as an adaptation strategy in Uganda probably reflects agriculture extensification which would conform to findings from other studies (Gregory et al., 2005; Paavola, 2008).

The bivariate analysis of the relationship between adaptation strategies and some focal independent variables undertaken in this section provides insights into factors that facilitate or hinder choice of a given adaptation strategy. It should, however, be pointed out that this kind of descriptive work cannot be relied on to provide conclusive analysis of the underlying relationships among the variables. It is for example not possible to explicitly control for other intervening variables in such settings. There is thus need to increase the statistical plausibility of the relationships by undertaking analysis in a multivariate setting. This is undertaken in the next section.

5. Determinants of choice of adaptation strategies

5.1. Empirical strategy and results

This section employed the multinomial logistic method to establish factors that govern choice of a particular adaptation technique. The MNL technique compares any given outcome with a reference outcome. This technique is deemed suitable to study adaptation to climate change since households employ different adaptation strategies which are typically not mutually exclusive. In the MNL each pair of classes (Y_j, Y_1) can be described by the ratio:

$$\log\frac{(Y=j|x)}{(Y=1|x)} = \alpha_j + \beta_j' x,$$

where x is the vector containing the predictor variables, α_j the intercept parameter for the jth level and β the vector of regression coefficients. On the basis of these $J-1$ regression equations, it is possible to compute the probability of a household employing a strategy j on the basis of its features contained in the vector x. This may be calculated using the equation:

$$P(Y=j|x) = \frac{\exp(\alpha_j + \beta_j' x)}{1 + \sum_{h=2}^{J}\exp(\alpha_h + \beta_j' x)}.$$

Notice that for the baseline category (here, $j = 1$), α_1 and $\beta_1 = 0$. Thus, when looking for the probability of an adaptation strategy belonging to the baseline level, it is easy to compute the numerator, since $\exp(0) = 1$. The value of the denominator is the same for each j The parameter estimates provide only the direction of the effect of the independent variables on the dependent variable, but the estimates do not represent either the actual magnitude of change nor probabilities. We subsequently utilise the odds ratios. The odds ratio assesses whether the odds of a certain event or outcome is the same for two groups.

In line with the literature on autonomous adaptation strategies and subject to data availability we included as part of our explanatory variable vector, x, a range of variables that describe the probability of choosing a particular adaptation strategy.

The multinomial logistic models crucially depend on the independence of irrelevant alternatives (IIA) assumption which posits that deleting (or adding) an outcome category should not affect the odds among the remaining categories. Appropriate tests were employed to assess the validity of the IIA assumption. The Wald and Likelihood ratio tests were employed to drop redundant explanatory variables whereas predicted probabilities were used to ascertain the relative importance of the different adaptation strategies. The variables used in the study are defined in Table A13.

Factors that mediate a household's choice of an adaptation strategy in response to drought are presented in Table 5.

The Hausman test validates the IIA assumption (Table A14). The probability value associated with the 'F' test suggests that we can reject the null that all predictor variables in our models are jointly not different than zero. Whereas some predictors appear to be unable (in a statistical sense) to distinguish among outcomes, a number of them have sufficient predictive power. The predictors in the latter category as well as their relationship to the various adaptation strategies are presented in what follows.

Off farm employment. Lack of access to off farm employment opportunities reduces the relative risk of adapting by borrowing relative to using savings by 0.58 which underscores the negative effect that limited access to employment opportunities (formal or otherwise) has on credit worthiness hence diminishing chances of borrowing. Lack of access to off farm employment opportunities also reduces the relative risk of using labour supply and technology as coping strategies by about 42 percent and 30 percent respectively when compared to past savings.

Extension services. Access to extension services reduces the relative risk of using labour supply as opposed to savings by about 40 percent. This result is plausible if extension advice is used to encourage households to diversify their crop portfolio to include some drought resistant crops. Other things being equal, this constrains the ability of household members to work off the farm as more labour may be required on the farm.

Agro-ecological setting. The odds of borrowing relative to utilising savings reduce in the west Nile but increase by about 2.5 times and 1.65 times respectively in the pastoral and Montane zones. Utilisation of labour as opposed to savings is a more common practice in the west Nile and northern systems but less common in the Montane system. The same conclusion holds when use of technology and reduction in consumption are compared with utilisation of savings.

Land tenure. A more secure land tenure arrangement is associated with an increase in the chances of adapting to drought through technology and through reduced consumption.

Table 5
Relative risk ratios (rrr) of the multinomial logistic model for coping with drought.

Variable/coping strategy	Borrowing		Labour supply		Technology		Reduce consumption	
	rrr	s.e.	rrr	s.e.	rrr	s.e.	rrr	s.e.
Age head	1.009	0.008	0.984*	0.004	1.007	0.008	1.006	0.004
Disttown1	1.005	0.003	1.003	0.002	1.007	0.005	1.004***	0.002
Educhead1	2.289	1.226	1.324	0.248	1.925**	0.530	1.560*	0.250
Extension11	0.973	0.42	0.599**	0.147	0.796	0.362	0.918	0.168
Offfarmh2	0.579***	0.186	0.578*	0.098	0.919	0.295	0.704**	0.111
credith2	1.842***	0.602	1.223	0.195	1.898**	0.475	1.052	0.169
femalehhd11	0.828	0.214	0.711**	0.097	0.886	0.234	0.612*	0.090
tenure1	0.468	0.229	0.931	0.213	2.142**	0.702	1.767*	0.252
Banana/millet/cotton	0.408	0.254	1.071	0.238	0.466	0.228	0.717	0.156
Montane	1.660***	0.474	0.540*	0.101	0.319**	0.148	0.696**	0.102
Northern	0.810	0.494	2.499*	0.630	7.755*	2.967	1.975*	0.508
Pastoral	2.493**	1.018	1.515	0.419	0.317	0.332	0.973	0.307
West Nile	0.000*	0.000	5.405*	1.127	5.040*	1.964	4.085*	0.809

Diagnostics	
Base category = Savings	Design *d.f.* = 139
Number of observations = 2143	$F(52, 88) = 802.5$
Number of strata = 4	Prob > F = 0.000
Number of PSUs = 143	Population size = 1,469,268

s.e. denotes the standard error.
* Significance at the 1% test level.
** Significance at the 5% test level.
*** Significance at the 10% test level.

Sex of household head. The relative risk of increasing labour supply relative to using household savings in the face of a drought reduces by 0.71 in female headed households. This reflects the limited flexibility women have with respect to participating in wage employment. Societal construction of gender roles in Africa assigns household responsibilities which limits their time to competing for wage jobs. It might also represent discrimination and lack of requisite skills. Female headed households are also more likely to reduce consumption as opposed to use of past savings, reflecting a strong endowment effect.

Education of household head. Basic education of the father increases the chances of adopting technology and drought resistant varieties relative to use of savings. They would also rather reduce consumption than use their savings, again reflecting a fairly strong endowment effect.

Distance to the nearest town. Distance to the nearest town is used to proxy for availability of input and output markets. It increases the relative risk of reducing consumption as opposed to using savings by 0.42 percent in response to a drought. This might be attributed to the difficulty in accessing markets for disposing off the 'physical savings'. It might, however, also be possible to argue that the endowment effect is stronger in rural areas.

Access to credit. Access to credit increases the chances of borrowing and adoption of technology as opposed to utilisation of savings in the adaptation to climate change. In particular, access to credit facilities increases the relative risk of borrowing relative to use of savings by 1.84 and increases the relative risk of technology adoption by 1.89.

Age of household head. Age of the household head quite understandably reduces the odds of using labour supply as opposed to utilisation of savings which underscores the relatively higher vulnerability of the elderly.

The predicted probabilities confirm findings from the descriptive analysis which indicated that agricultural households were more likely to use past savings in response to a drought episode. The probability that a household will rely on borrowing is the lowest when compared to all the other strategies (Fig. 3).

The econometric results for factors that influence choice of an adaptation strategy in response to a pest attack are presented in Table 6.

Our model is significantly better than the 'know nothing' specification as judged by the 'F' probability value. The Small–Hsiao test supports the null of IIA since the probability values ($P >$ chi2) range from 0.98 to 1.00 (Table A15). The predictor variables that influence choice of strategies to adapt to pests are explained in what follows.

Off farm employment. Availability of off farm employment opportunities increases the relative risk of using labour as an adaptation strategy relative to technology by 1.75.

Extension services. Access to extension services reduces the relative risk of reducing consumption as opposed to using technology by 0.14. This can be the case for instance if extension services are used as conduits for passing on advice and information about new crop varieties which, other things being equal, would encourage utilisation of technology as an adaptation strategy.

Age of household head. Age of the household head increases the relative risk of reducing consumption relative to technology adoption by 1.02 which points to vulnerability of the elderly.

Length of the last pest attack. Length of the last pest attack was included in the specification to capture the availability heuristic.

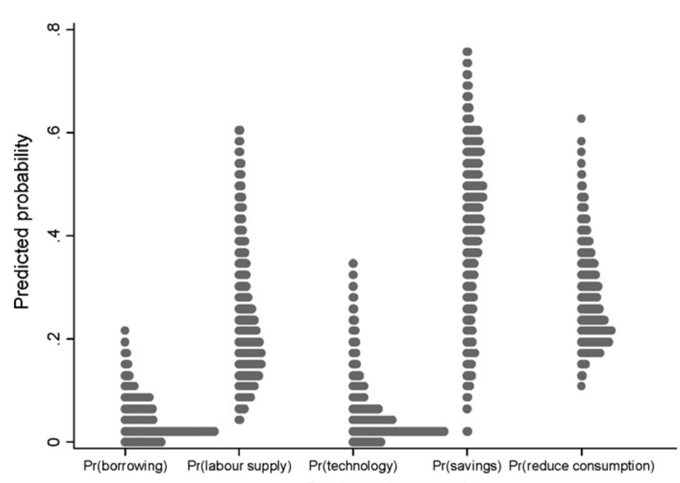

Fig. 3. Predicted probabilities of different drought adaptation strategies.

Table 6
Relative risk ratios (rrr) of the multinomial logistic model for coping with pests.

Variable/coping strategy	Labour supply		Use savings		Reduce consumption	
	rrr	se	rrr	se	rrr	se
Lengthpests	0.959***	0.024	0.932*	0.021	0.960***	0.023
Agehead	0.987	0.011	1.000	0.009	1.020**	0.009
inputmktlc1	0.787	0.234	1.245	0.349	1.449	0.435
extension11	0.613	0.267	0.614	0.266	0.143*	0.092
offfarmh1	1.756**	0.480	1.181	0.362	1.186	0.420
credith1	1.910***	0.664	1.071	0.337	1.054	0.352
Farm size	0.964	0.036	0.988	0.008	0.956	0.042
bananacoffee	0.388**	0.169	3.885*	1.388	1.491	0.595
bananamilletcotton	0.818	0.362	2.865*	1.080	0.871	0.474
montane	0.818	0.352	3.522*	1.392	2.219***	0.993
pastoral	0.450	0.232	0.668	0.780	0.871	0.828

Diagnostics	
Base category = Technology	Design *d.f.* = 122
Number of observations = 496	$F(33, 90) = 3.7$
Number of strata = 4	Prob > F = 0.000
Number of PSUs = 126	Population size = 346,219

s.e. denotes the standard error.
* Significance at the 1% test level.
** Significance at the 5% test level.
*** Significance at the 10% test level.

The results indicate that duration of the last pest attack reduces chances of using savings, labour supply and scaling back on household consumption relative to using technology based options. In particular, chances of utilising past savings, labour supply and scaling back on consumption reduce by 0.93, 0.96 and 0.96 respectively relative to technology adoption. Put another way, longer pest attack episodes other things being equal mediate technology usage as a coping strategy.

Agro-ecological setting. The odds of increasing labour supply relative to utilising technology based adaptations are lower for those households living in the banana-coffee zone with the relative risk of relying on increased labour supply relative to technology reducing by about 60 percent. The odds of utilising savings as opposed to technology as a coping strategy to a pest attack is high in the banana-coffee, banana-millet-cotton and montane systems. The chances of scaling back on household consumption relative to technology usage are higher in the montane zone.

The predicted probabilities indicate that households are more likely to utilise technology based strategies and increased labour supply in response to a pest attack (Fig. 4).

The MNL regression results for factors that influence choice of an adaptation strategy in response to a livestock epidemic are presented in Table 7.

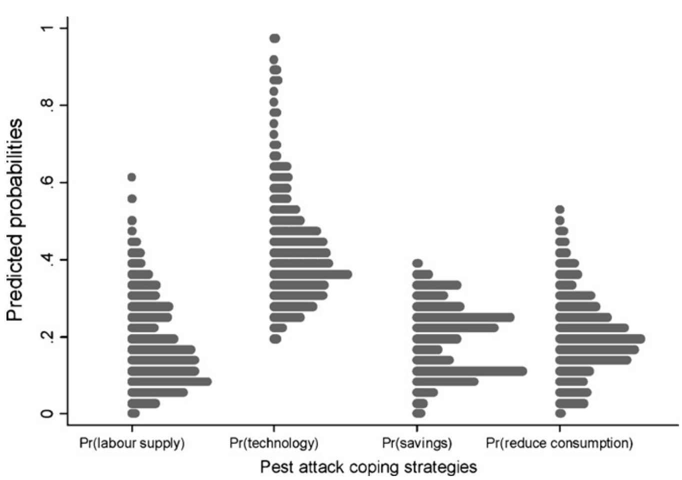

Fig. 4. Predicted probabilities of different pest attack adaptation strategies.

The Hausman test renders support the null of IIA (Table A16). The predictors of the different adaptation strategies to a live stock epidemic include:

Extension services. Access to extension services reduces the relative risk of using labour supply as opposed to utilising savings.

Agro-ecological setting. Households in the Teso and Montane systems are more likely to adapt to livestock epidemics using technology based practices relative to utilising savings.

Land tenure. A more secure land tenure arrangement is associated with an increase in the chances of adapting to a livestock epidemic through technology relative to savings. A more secure land tenure arrangement increases the odds of using technology by about 4 times in relation to relying on savings.

Access to credit. Quite surprisingly, households that did not get credit have higher chances of using technology adoption relative to utilisation of savings in the adaptation to a livestock epidemic. This might be the case where loan repayment reduces available resources for technology adoption or that credit can be used for other purposes other than climate change adaptation.

Table 7
Relative risk ratios (rrr) of the multinomial logistic model for coping with a livestock epidemic.

Variable/coping strategy	Labour supply		Technology	
	rrr	s.e.	rrr	s.e.
extension11	0.114***	0.142	1.370	1.108
Credith2	1.003	0.437	3.860**	2.567
femalehhd11	0.600	0.291	1.833	1.182
tenure1	0.797	0.379	3.748***	2.599
montane	0.345***	0.216	5.725**	4.181
Nothern	0.906	0.410	2.230	1.544
teso	2.448	1.460	4.973***	4.683

Diagnostics	
Base category = Savings	Design *d.f.* = 83
Number of observations = 190	$F(14, 70) = 1.77$
Number of strata = 4	Prob > F = 0.0.06
Number of PSUs = 87	Population size = 124,305

s.e. denotes the standard error.
** Significance at the 5% test level.
*** Significance at the 10% test level.

Table 8
Relative risk ratios (rrr) of the multinomial logistic model for coping with floods.

Variable/coping strategy	Labour supply		Technology		Reduce consumption	
	rrr	se	rrr	se	rrr	se
lengthfloods	0.965	0.036	0.999	0.040	0.863*	0.042
disttown1	1.004	0.004	0.998	0.006	0.997	0.004
offfarmh2	0.250*	0.075	0.406**	0.173	0.537**	0.154
femalehhd12	1.129	0.291	2.158**	0.809	0.831	0.225
tenure1	1.231	0.569	12.860*	8.763	1.759***	0.607
bananacoffee	0.159*	0.083	0.044*	0.034	0.698	0.358
bananamilletcotton	0.376**	0.157	0.521	0.247	0.480	0.270
montane	0.117*	0.043	0.013*	0.013	0.647	0.277
Nothern	0.749	0.333	1.333	0.634	1.239	0.553
pastoral	0.214**	0.149	0.075*	0.076	1.126	0.765
Diagnostics						
Base category = Savings					Design *d.f.* = 124	
Number of observations = 692					*F*(30, 95) = 4.64	
Number of strata = 4					Prob > *F* = 0.000	
Number of PSUs = 128					Population size = 483,606	

s.e. denotes the standard error.
* Significance at the 1% test level.
** Significance at the 5% test level.
*** Significance at the 10% test level.

The predicted probabilities indicate that technology based strategies, labour supply and use of savings are almost equally likely in response to a livestock epidemic (Fig. 5).

The maximum likelihood estimation results for factors that influence choice of an adaptation strategy in response to floods are presented in Table 8.

Whereas some variables included in the model fail to distinguish between the different adaptation outcomes a number of them have considerably good statistical predictive abilities (Table 8). These include:

Off farm employment. Lack of access to off farm employment opportunities reduces the relative risk of adapting to floods by increasing labour supply relative to using savings. It also reduces chances of using technology and reducing consumption as opposed to reducing savings. This is plausible if decision makers at the household level perceive the flood occurrences as temporary phenomena.

Agro-ecological setting. The relative risk of supplying more labour as opposed to using savings as a coping mechanism to floods reduces for households in the pastoral, montane, banana-coffee and banana/millet/cotton systems. Households in the pastoral, montane and banana-coffee systems are less likely to use technology as opposed to using savings as a coping strategy to floods.

Land tenure. A more secure land tenure arrangement is associated with an increase in the chances of adapting to floods through technology and reduced consumption relative to savings.

Length of the last flood. Length of the last flood reduces chances of scaling back on household consumption relative to using savings. Loosely speaking reduced consumption might only be a short term strategy which gives way to using savings as the shock duration increases.

The predicted probabilities indicate that savings and labour supply are the most commonly used strategies in response to floods (Fig. 6). The Small–Hsiao test supports the null of IIA (Table A17).

5.2. Overview of results and comparison with findings from other studies

Whereas it was important to identify factors that explain the choice of adaptation strategies to different climate related outcomes the explanatory power of some factors is invariant across some climate shocks. The main variables in this category include age of the household head, access to credit and extension facilities and security of tenure. There are also notable differences in the choice of the adaptation strategies by agro-climatic zone possibly reflecting the importance of indigenous knowledge and externalities in climate change adaptation.

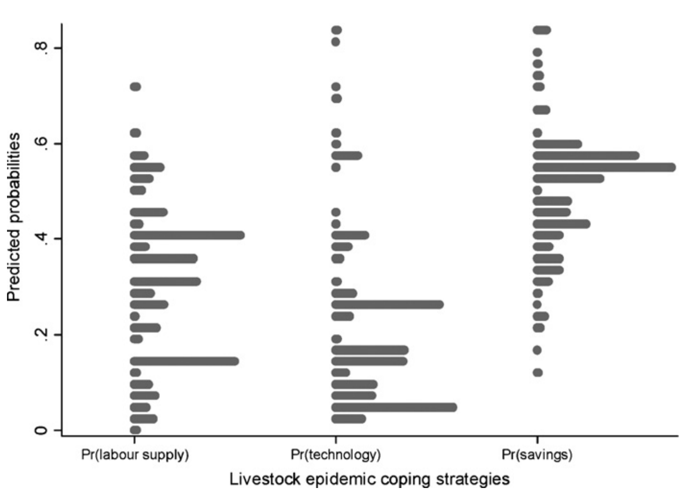

Fig. 5. Predicted probabilities of different livestock epidemic adaptation strategies.

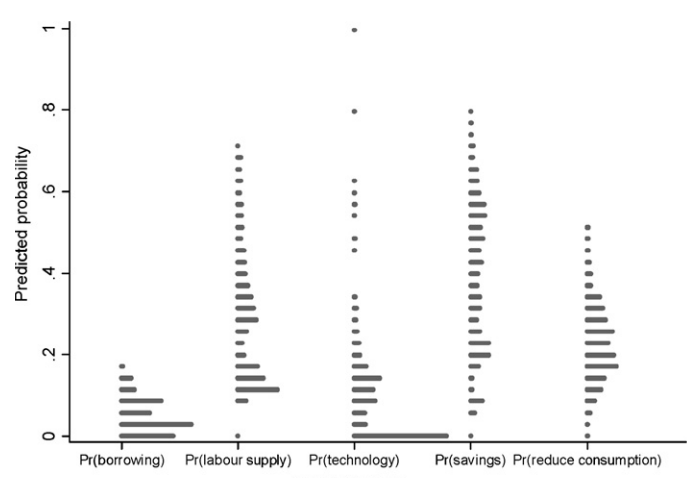

Fig. 6. Predicted probabilities of the different strategies for coping with floods.

These findings compare favourably with those from the existing literature. The results from this study show that older farmers are less likely to increase labour supply as an adaptation strategy and more likely to reduce consumption (see Tables 7 and 8) which points to their relatively higher vulnerability. This finding may be used to explain the conflicting findings in part of the existing literature—Shiferaw and Holden (1998) for example find a negative relationship between age and adoption of improved soil conservation practices whereas (Deressa et al., 2009) show that older farmers are more likely to employ adaptation strategies in the face of changes in climate related variables.

The results also show that availability of extension services reduces the relative risk of using labour supply which can be possible if extension advice is used to encourage households to diversify their crop portfolio to include some drought resistant crops. Other things being equal, this constrains the ability of household members to work off the farm as more labour may be required on the farm. This result is in line with an interesting finding by (Maddison, 2007) who established that access to information and knowledge (through extension services for instance) about appropriate adaptation strategies promoted adaptation. The important role of other variables such as access to credit, security of tenure and agro-climatic zone is also borne out by other studies (see for instance Norris and Batie, 1987; Maddison, 2007; Deressa et al., 2009) who point to the important role of socioeconomic factors such as education, wealth status and availability of resources (such as land, credit and water storage facilities). The study by Deressa et al. (2009) also found that agro-ecological zones also affect choice of adaptation strategies. A summary of the study and possible policy options is presented in the next section.

6. Summary and policy implications

The ongoing changes in global climatic conditions are exposing communities to ever increasing risk and threatening sources of livelihood especially in the poorer parts of the world. This calls for responses both to current occurrences and to more long term climate changes.

This study employed data from the 2005/06 Uganda national household survey (UNHS) to shed light on some of the main climate change related shocks that have a bearing on the agricultural sector, how households were adapting as well as the perceptual, socioeconomic and institutional factors that mediate adaptation in Uganda. The most commonly observed climate related shocks include livestock epidemics, pest attacks, drought and floods.

The study also identified the major categories of autonomous adaptation strategies undertaken by households in response to climate related shocks as well as the behavioural and socioeconomic factors that mediate them. The main adaptation strategies can be broadly categorized to include reducing consumption, running down past savings, technology based options and to a lesser extent, borrowing. The sustainability of many of these strategies is, however, questionable. Whereas reducing consumption and utilising past savings for example are plausible short term strategies, they expose households to even more vulnerability in the face of persistent climatic variability. The exposure is likely to be more pronounced in certain categories of households such as those headed by the elderly. In this regard our findings call for policies that smooth the consumption patterns of households. Access to credit which is conditioned to climate change adaptation would not only enhance the ability of households to smooth short term consumption fluctuations that result from climate related shocks but would also enable them to get access to resources that are required to implement certain adaptation practices. Policies such as reduction of information asymmetries so as to reduce the high cost of credit on the Uganda financial market would go a long way in improving access to credit facilities and in strengthening the ability of households to adapt to climate change. The current prosperity for all programme is a right step in efforts aimed at improving access to credit. Affirmative action targeting the disadvantaged and more vulnerable groups could be considered. Complementing credit access with extension advice would be of immense value.

Increased labour supply (both on and off-farm) constitutes a major—and more sustainable category of responses to climate change stimuli. These adaptation strategies will, however, only be helpful in the long term if they are complemented by policies that enhance the productivity performance in sectors that employ larger sections of the population. Agricultural prosperity in Uganda is key to generating productive employment that strengthens the ability of households to adapt to climate change. Raising labour productivity in agriculture will also augment the low incomes of the work force and release workers to find jobs elsewhere in the economy in order to solve the surplus labour problem in agriculture and hence reduce on the extensification pressures. Increased productivity will require more public investment in research and advisory services, strategic types of infrastructure as well as access to credit and farm implements at favourable terms. These should be supplemented by value addition initiatives and increased access to markets. A number of these initiatives are already being pursued by government but they have not had significant effect on the sector's productivity performance. What needs to be done is to mobilize resources so as to scale up the investments. But most importantly, these initiatives need to be closely coordinated and where possible implemented simultaneously both spatially and temporally.

It will also be necessary to compliment credit availability and job creation with information both on climate change and some examples of sustainable responses to support the autonomous technology related practices. This will require more public investment in research and advisory services to facilitate technological developments that are suitable to changing environments.

Other policies that improve resilience such as investments in public health and education systems would compliment the autonomous responses by farmers. Programmes that control the pace at which the population is expanding will be helpful in curbing pressure to extensify agriculture.

Appendix A

Table A1
Climate change coping strategies and sex of household head.

Strategy/gender of head	Drought			Floods			Pests			Livestock epidemic		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
Borrowing	3.1	1.5	4.7	3.5	1.4	4.9	0.3	0.2	0.5	0.5	0.0	0.5
Labour supply	16.6	6.3	22.9	18.5	5.6	24.0	12.1	4.0	16.1	18.3	5.6	23.9
Technology	3.9	1.3	5.3	6.0	1.9	7.9	34.3	7.7	41.9	15.8	3.8	19.6
Savings	29.1	9.0	38.1	31.9	9.1	41.0	13.1	5.9	19.0	43.1	9.4	52.5
Reduce consumption	18.4	10.7	29.1	18.0	4.3	22.2	15.5	7.1	22.6	1.5	2.0	3.5

Table A2
Climate change coping strategies and region.

Strategy/region	Drought					Floods					Pests					Livestock epidemic				
	Central	Western	Eastern	Northern	National	Central	Western	Eastern	Northern	National	Central	Western	Eastern	Northern	National	Central	Western	Eastern	Northern	National
Borrowing	0.5	2.7	1.0	0.4	4.7	0.0	3.5	0.9	0.5	4.9	0.1	0.2	0.0	0.1	0.5	0.0	0.2	0.2	0.2	0.5
Labour supply	3.7	3.9	5.3	10.0	22.9	1.5	6.3	7.9	8.4	24.0	2.2	2.3	3.6	8.0	16.1	5.1	0.3	9.7	8.8	23.9
Technology	1.6	0.3	0.5	2.9	5.3	2.1	0.5	2.2	3.1	7.9	12.6	11.6	9.0	8.7	41.9	7.6	2.3	3.6	6.1	19.6
Savings	6.6	15.9	10.4	5.1	38.1	4.6	22.3	9.9	4.2	41.0	7.2	4.0	6.0	1.9	19.0	11.1	4.1	21.5	15.8	52.5
Reduce consumption	8.9	6.0	5.0	9.1	29.1	2.9	8.4	5.6	5.4	22.2	9.8	4.5	4.3	4.0	22.6	1.6	0.0	0.4	1.5	3.5

Table A3
Climate change coping strategies and education level of household head.

Strategy/education level of head	Drought								Floods							
	Male				Female				Male				Female			
	Primary	Secondary	Tertiary	Total	Primary	Secondary	Tertiary	Total	Primary	Secondary	Tertiary	Total	Primary	Secondary	Tertiary	Total
Borrowing	4.3	0.3	0.1	4.7	4.58	0.1	0.0	4.7	4.07	0.46	0.38	4.91	4.65	0.27	0	4.9
Labour supply	19.8	3.0	0.2	22.9	22.53	0.4	0.0	22.9	20.05	3.64	0.32	24	23.22	0.8	0	24.0
Technology	4.4	0.8	0.1	5.3	5.24	0.0	0.0	5.3	6.47	0.97	0.43	7.87	6.93	0.93	0	7.9
Savings	31.4	5.8	0.9	38.1	35.53	2.4	0.3	38.1	35.25	5.22	0.51	41	37.86	2.36	0.77	41.0
Reduce consumption	24.3	4.5	0.2	29.1	27.16	1.8	0.0	29.1	20.18	1.93	0.12	22.2	21.75	0.46	0	22.2

Table A4
Climate change coping strategies and education level of household head.

Strategy/education level of head	Pests								Livestock Epidemic							
	Male				Female				Male				Female			
	Primary	Secondary	Tertiary	Total	Primary	Secondary	Tertiary	Total	Primary	Secondary	Tertiary	Total	Primary	Secondary	Tertiary	Total
Borrowing	0.32	0.12	0	0.4	0.45	0	0	0.5	0.34	0.16	0	0.5	0.51	0	0	0.5
Labour supply	11.67	4.35	5.70E−02	16.1	15.56	0.54	0	16.1	20.69	3.2	0	23.9	24.15	5.50E−02	0	24.2
Technology	33.3	7.93	0.7	41.9	38.14	3.24	0.49	41.9	17.59	2.01	0	19.6	19.68	0.17	0	19.9
Savings	15.07	3.18	0.75	19.0	17.44	1.51	6.90E−02	19.0	40.5	11.86	0.16	52.5	50.82	2.4	0	53.2
Reduce consumption	17.5	4.61	0.43	22.5	22.46	0.11	0	22.6	3.36	0.13	0	3.5	2.09	0.13	0	2.2

Table A5
Kruskal–Wallis rank test within and between regions for drought coping strategies.

Strategy/region	Central		Western		Eastern		Northern		National	
	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum
Borrowing	38	21,719.5	177	178,464	76	76,447	41	53,248.5	332	1,660,000
Labour supply	264	20,5954	238	286,615	448	380,376	995	1,250,000	1945	7,000,000
Technology	115	120,450.5	17	19,303	39	37,391.5	262	376,417	433	1,720,000
Savings	504	428,681.5	1123	1,100,000	859	756,446.5	474	651,520	2960	12,900,000
Reduce consumption	733	591,879.5	432	395,520.5	387	386,484	832	1,060,000	2380	9,130,000
chi-squared	40.349 [0.0001]		42.386 [0.0001]		22.703 [0.0001]		17.921 [0.0013]		204.648 [0.0001]	
chi-squared with ties	40.356 [0.0001]		42.392 [0.0001]		22.705 [0.0001]		17.923 [0.0013]		204.649 [0.0001]	

Table A6
Kruskal–Wallis rank test within and between regions for coping with pests.

Strategy/region	Central		Western		Eastern		Northern		National	
	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum
Borrowing	2	643	3	697.5	–	–	3	580	8	8430
Labour supply	45	10,709.5	34	7369	77	16,148.5	169	45,797	325	292,915
Technology	243	78,625.5	175	34,075.5	183	40,801.5	185	46,416	786	814,089
Savings	146	39,890.5	85	9087.5	118	30,283.5	45	10,262.5	394	350,574.5
Reduce Consumption	182	61,402.5	65	14,473.5	85	20,182.5	92	19,209.5	424	410,944.5
chi-squared	19.199 [0.0007]		60.604 [0.0001]		7.113 [0.0684]		12.709 [0.0128]		24.043 [0.0001]	
chi-squared with ties	19.209 [0.0007]		60.681 [0.0001]		7.117 [0.0683]		12.719 [0.0127]		24.044 [0.0001]	

Table A7
Kruskal–Wallis rank test within and between regions for coping with floods.

Strategy/region	Central		Western		Eastern		Northern		National	
	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum
Borrowing	1	35.5	76	39,527.5	25	7491	20	5480	122	178,149.5
Labour supply	39	5819	143	68,055	220	66,143	278	88,228.5	680	747,847.5
Technology	51	8685.5	10	4000	56	21,315	96	29,792	213	242,938.5
Savings	123	15,941.5	515	229,291.5	259	93,761.5	123	44,144	1020	1,410,000
Reduce consumption	77	12,004.5	181	87,401	136	53,845.5	154	57,811.5	548	755,657
chi-squared	11.349 [0.0191]		7.642 [0.1056]		24.102 [0.0001]		14.375 [0.0062]		83.454 [0.0001]	
chi-squared with ties	11.794 [0.0189]		7.645 [0.1045]		24.114 [0.0001]		14.382 [0.0062]		83.458 [0.0001]	

Table A8
Kruskal–Wallis rank test within and between regions for coping with livestock epidemic.

Strategy/region	Central		Western		Eastern		Northern		National	
	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum	Obs	Rank sum
Borrowing			1	4	1	125	1	214	3	1534
Labour supply	35	3522	2	6	70	7668	73	8604	180	57,135.5
Technology	49	4353.5	12	213	23	2504.5	41	6372	125	48,703.5
Savings	86	7476.5	20	407	142	17,721.5	121	13,877.5	369	130,074
Reduce consumption	11	1119			2	422	11	1560.5	24	8604
chi-squared	2.243 [0.5235]		7.211 [0.0655]		6.390 [0.1718]		12.794 [0.0123]		11.432 [0.0221]	
chi-squared with ties	2.248 [0.5226]		7.594 [0.0552]		6.398 [0.1713]		12.818 [0.0122]		11.434 [0.0221]	

Table A9
Kruskal–Wallis rank test within and between agro-ecological zones for drought coping strategies.

Strategy/agroecological Zone	Banana/coffee		Banana/millet/ cotton		Montane		Teso		Northern		Pastoral		West Nile		National	
	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank
Borrowing	54	42,452	12	2059.5	163	157,221.5	30	7830	13	6856	60	20,695	–		332	1,660,000
Labour supply	371	401,048	219	71,465	262	274,321.5	80	13,514	403	238,258	133	28,295	477	257,721	1945	7,000,000
Technology	128	177,424	13	5491.5	17	17,962	13	964	194	113,983	1	499	67	45,767	433	1,720,000
Savings	865	992,861	364	143,348.5	988	917,586	168	25,189	284	178,635	177	55,879	114	63,040	2960	12,900,000
Reduce consumption	837	929,857	151	66,055.5	440	382,294	43	8448.5	372	264,280	153	32,183	388	181,054	2384	9,130,000
chi-squared	38.312 [0.0001]		36.266 [0.0001]		19.363 [0.0007]		49.727 [0.0001]		26.006 [0.0001]		74.585 [0.0001]		35.006 [0.0001]		204.648 [0.0001]	
chi-squared with ties	38.315 [0.0001]		36.287 [0.0001]		19.365 [0.0007]		49.934 [0.0001]		26.076 [0.0001]		74.783 [0.0001]		35.030 [0.0001]		204.649 [0.0001]	

Table A10
Kruskal–Wallis rank test within and between agro-ecological zones for pests coping strategies.

Strategy/agroecological Zone	Banana/coffee		Banana/millet/ cotton		Montane		Teso		Northern		Pastoral		West Nile		National	
	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank
Borrowing	2	808			2	399.5			2	455	2	45			8	8430
Labour supply	53	17,330	25	1560	34	6808	40	2053.5	152	34,970.5	4	163.5	17	550.5	325	292,915
Technology	335	146,443	93	8615	107	17,553	24	803	175	35842.5	43	1857.5	9	335.5	786	814,089
Savings	220	85,317	30	2951.5	78	8575	20	713.5	37	8154	9	79			394	350,575
Reduce consumption	196	75,324	27	2273.5	98	17,706			64	13243	11	270	28	599	424	410,945
chi-squared	15.054 [0.0046]		8.573 [0.0355]		34.954 [0.0001]		10.114 [0.0064]		3.763 [0.4390]		26.661 [0.0001]		9.333 [0.0094]		24.043 [0.0001]	
chi-squared with ties	15.059 [0.0046]		8.603 [0.0351]		35.017 [0.0001]		10.234 [0.0060]		3.769 [0.4384]		27.635 [0.0001]		9.601 [0.0082]		24.044 [0.0001]	

Table A11
Kruskal–Wallis rank test within and between agro-ecological zones for floods coping strategies.

Strategy/agroecological Zone	Banana/coffee		Banana/millet/ cotton		Montane		Teso		Northern		Pastoral		West Nile		National	
	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank
Borrowing	13	1372.5	10	1937	65	31,214.5	3	276.5	10	3185	12	1206.5	9	270	122	178,149.5
Labour supply	75	14,487	93	14,544.5	165	64,950.5	51	2652.5	197	43,428.5	21	1580	78	7879.5	680	747,847.5
Technology	60	18,516.5	30	5150.5	2	804.5	16	778	83	17,783.5	9	391.5	13	996	213	242,938.5
Savings	230	50,760	127	20,536	446	192,802.5	42	3086.5	91	25,502.5	52	4298.5	32	2095	1020	1,410,000
Reduce consumption	83	21,355	69	12,117	185	83,044	12	956.5	108	29,905.5	45	2253.5	46	4690.5	548	755,657
chi-squared	42.542 [0.0001]		2.831 [0.5865]		7.218 [0.1248]		15.451 [0.0039]		23.747 [0.0001]		27.311 [0.0001]		26.364 [0.0001]		83.454 [0.0001]	
chi-squared with ties	42.566 [0.0001]		2.840 [0.5850]		7.221 [0.1247]		15.636 [0.0035]		23.769 [0.0001]		27.945 [0.0001]		26.474 [0.0001]		83.458 [0.0001]	

Table A12
Kruskal–Wallis rank test within and between agro-ecological zones for livestock epidemic coping strategies.

Strategy/agroecological Zone	Banana/coffee		Banana/millet/ cotton		Montane		Teso		Northern		Pastoral		West Nile		National	
	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank	Obs	Rank
Borrowing					1	41	1	11.5	1	148					3	1534
Labour supply	48	5904	30	1679.5	20	344	9	77.5	51	4557.5	16	335	6	72.5	180	57,135.5
Technology	59	7549.5	10	260.5	13	852	2	28	41	4360					125	48703.5
Savings	132	16463.5	40	1300	52	2504	22	479	86	7136	24	485	13	159.5	369	130,074
Reduce consumption	12	1709					1	34	2	269.5			9	174	24	8604
chi-squared	0.779 [0.8544]		21.926 [0.0001]		34.130 [0.0001]		13.683 [0.0084]		8.160 [0.0859]		0.037 [0.8468]		4.581 [0.1012]		11.432 [0.0221]	
chi-squared with ties	0.780 [0.8542]		22.140 [0.0001]		34.431 [0.0001]		14.376 [0.0062]		8.193 [0.0848]		0.039 [0.8438]		4.855 [0.0833]		11.434 [0.0001]	

Table A13
Variable definitions.

Abbreviation	Variable name
tenure2	Customary land tenure
tenure1	More formal tenure types
credith2	No Access to credit by household head
credith1	Access to credit by household head
offfarms2	No access to off farm employment
offfarms1	No access to off farm employment
offfarmh2	No access to off farm employment
offfarmh1	No access to off farm employment
edufather3	University education
edufather2	Secondary and other
edufather1	Primary education
extension12	No access to extension services
extension11	Access to extension services
femalehhd	Female headed household
malehhd	Male headed household
westNile	West Nile agro-climatic zone
pastoral	Pastoral agro-climatic zone
Nothern	Northern agro-climatic zone
teso	Teso agro-climatic zone
montane	Montane agro-climatic zone
bananamill~n	Banana/millet/cotton agro-climatic zone
bananacoffee	Banana/coffee agro-climatic zone
inputmktlc1	Availability of input market in LC1
outputmktlc1	Availability of output market in LC1
disttown1	Distance to nearest town
farmsize	Farm size
extension	Access to extension services
coplepidemic	Coping strategies for livestock epidemic
coppests	Coping strategies for pests
copfloods	Coping strategies for floods
copdrought	Coping strategies for drought
lengthlepi~c	Length of last livestock epidemic
lengthpests	Length of last pest attack
lengthfloods	Length of last floods
lengthdrou~t	Length of last drought
yrlepidemic	Year last livestock epidemic occurred
yrpests	Year when the last pest attack occurred
yrfloods	Year when the last floods occurred
yrdrought	Year when the last drought occurred
tlepidemic	Frequency of livestock epidemics
tpests	Frequency of pests
tfloods	Frequency of floods
tdrought	Frequency of drought
agrecology	Agro-ecological zone

Table A14
Hausman tests of IIA assumption for the drought model.

Omitted	chi2	*d.f.*	*P* > chi2	Evidence
Borrowing	−1.476	40	–	–
Labour supply	0	1	1	for Ho
Technology	0	1	1	for Ho
Reduce consumption	0	1	1	for Ho

Table A15
Small–Hsiao test of IIA assumption for the pest attack model.

Omitted	chi2	*d.f.*	*P* > chi2	Evidence
Labour supply	11.509	24	0.985	for Ho
Savings	7.194	24	1.000	for Ho
Reduce consumption	12.410	24	0.975	for Ho
Technology	7.743	24	0.999	for Ho

Table A16
Small–Hsiao test of IIA assumption for the livestock epidemic model.

Omitted	chi2	*d.f.*	*P* > chi2	Evidence
Labour supply	3.180	8	0.923	for Ho
Technology	14.565	8	0.068	for Ho
Savings	2.246	8	0.973	for Ho

Table A17
Small–Hsiao test of IIA assumption for the floods coping model.

Omitted	chi2	*d.f.*	*P* > chi2	Evidence
Labour supply	33.185	22	0.059	for Ho
Technology	33.691	22	0.053	for Ho
Savings	30.586	22	0.105	for Ho

References

Arthur, W.B., 1984. Inductive reasoning and bounded rationality. American Economic Review, Papers and Proceedings 406–411.

Below, T., Artner, A., Siebert, R., Sieber, S., 2010. Micro-level practices to adapt to climate change for African small scale farmers: a review of selected literature. IFPRI Discussion Paper 00953.

Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R., Yanda, P., 2007. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J., Hanson, C.E. (Eds.), Africa. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, pp. 433–467.

Broad, O.B.K., Petty, A., 2004. Factors that influence the use of climate forecasts: evidence from the 1997/98 El Nino event in Peru. Bulletin of the American Meteorological Society 85, 1735–1743.

Covello, V., 1990. Risk comparisons in communication: issues and problems in comparing health and environmental risks. In: Kasperson, R., Stallen, D. (Eds.), Communicating Risks to the Public: International Perspectives. Kluwer Academic Publishers, Dordrecht, pp. 79–124.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T., Yesuf, M., 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environment Change 19, 248–255.

Francisco, H.A., 2008. Adaptation to climate change: needs and opportunities in southeast Asia. ASEAN Economic Bulletin 25 (1), 7–19.

Gregory, P., Ingram, J.S.I., Brklacich, M., 2005. Climate change and food security. Philosophical Transactions of the Royal Society B: Biological Sciences 360, 2139–2148.

Grothmann, T., Patt, A., 2005. Adaptive capacity and human cognition: the process of individual adaptation to climate change. Global Environmental Change 15, 199–213.

Hisali, E., Kasirye, I., 2008. Review of agricultural sector investments and institutional performance, final report submitted to the Poverty Monitoring and Analysis Unit of the Ministry of Finance Planning and Economic Development (MFPED).

Hoffmann, I., 2009. Livestock and climate change. <http://www.ifad.org/lrkm/factsheet/cc.pdf>.

IPCC (Intergovernmental Panel on Climate Change), 2007. Climate Change 2007: Impacts, adaptation and vulnerability. Summary for policy makers. <http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf> (accessed 01.07.09.).

LTS International, 2008. Climate change in Uganda: understanding the implications and appraising the response. Scoping mission for DFID Uganda. <www.ltsi.co.uk>.

McCarthy, J., Canziani, O.F., Leary, N.A., Dokken, D.J., White, C. (Eds.), 2001. Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.

Maddison, D., 2007. The perception of and adaptation to climate change in Africa. World Bank Policy Research Working Paper 4308.

Nhemachena, C., Hassan, R., 2008. Micro-level analysis of farmers' adaptation to climate change in southern Africa. IFPRI discussion paper 00714.

Norris, E., Batie, S., 1987. Virginia farmers' soil conservation decisions: and application of tobit analysis. Southern Journal of Agricultural Economics 19 (1), 89–97.

Paavola, J., 2008. Livelihoods, vulnerability and adaptation to climate change in Morogoro, Tanzania. Environmental Science & Policy 11, 642–654.

Patt, G.A., Schroter, D., 2008. Perceptions of climate risk in Mozambique: implications for the success of adaptation strategies. Global Environmental Change 18, 458–467.

Republic of Uganda, 2007. Climate Change: Uganda National Programmes of Action. Ministry of Water and Environment.

Rogers, R.W., 1975. A protection motivation theory of fear appeals and attitude change. Journal of Psychology 91, 93–114.

Rogers, R.W., 1983. Cognitive and physiological processes in fear appeals and attitude change: a revised theory of protection motivation. In: Cacioppo, J., Petty, R. (Eds.), Social Psychophysiology. Guilford Press, New York.

Shiferaw, B., Holden, S., 1998. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: a case study in Andit Tid, North Shewa. Agricultural Economics 18, 233–247.

Stringer, L.C., Dyer, J.C., Reed, M.S., Dougill, A.J., Twyman, C., Mkwambisi, D., 2009. Adaptations to climate change, drought and desertification: local insights to enhance policy in southern Africa. Environmental Science and Policy. doi:10.1016/j.envsci.2009.04.002.

Tenge, De Graaff, J., Hella, J.P., 2004. Social and economic factors affecting the adoption of soil and water conservation in West Usambara highlands, Tanzania. Land Degradation and Development 15 (2), 99–114.

Thomas, D.S.G., Twyman, C., Osbahr, H., Hewitson, B., 2007. Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa. Climatic Change 83 (3), 301–322.

Thornton, P.K., Jones, P.G., Owiyo, T., Kruska, R.L., Herrero, M., Kristjanson, P., Notenbaert, A., Bekele, N., Omolo, A, with contributions from Orindi, V., Otiende, B., Ochieng, A., Bhadwal, S., Anantram, K., Nair, S., Kumar, V., Kulkar, U., 2006. Mapping climate vulnerability and poverty in Africa. Report to the Department for International development. ILRI, Nairobi, Kenya.

Tversky, A., Kahneman, D., 1973. Availability: a heuristic for judging frequency and probability. Cognitive Psychology 5, 207–232.

Tversky, A., Kahneman, D., 1974. Judgment under uncertainty: heuristics and biases. Science 211, 1124–1131.

UNDP, 2007. Human Development Report 2007/2008. Fighting climate change: human solidarity in a divided world. <http://hdr.undp.org/en/media/HDR_20072008_EN_Complete.pdf>.

Valdivia, C.J., Gilles, J., Espejo, R., Carrillo, R., 2001. Current users and diffusion nodes of local climate forecasts in the Andes of Bolivia: lessons on potential users, timing, and content of climate forecast communications. In: IRI Communication of Climate Forecast Information Workshop. Palisades, New York.

Valdivia, C., Jetté, C., Quiroz, R., Gilles, J.L., Materer, S., 2002. Peasant households' strategies in the Andes and potential users of climate forecasts: El Niño of 1997–1998. Selected paper for the Annual Meeting of the American Agricultural Economics Association, July 30–August 2, Tampa, FL.