AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

Adaptation to climate change under poverty, food security and gender perspective of rural maize-legume farmers in Kenya

Songporne Tongruksawattana

Invited paper presented at the 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013, Hammamet, Tunisia

Copyright 2013 by [authors]. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.

84- Adaptation to climate change under poverty, food security and gender perspective of rural maize-legume farmers in Kenya

Songporne Tongruksawattana
International Maize and Wheat Improvement Center (CIMMYT), Nairobi – Kenya
s.tongruksawattana@cgiar.org

Abstract

In order to help poor, food insecure and female-headed farmers to build adaptation capacity to changing climatic conditions, it is essential to understand the current conditions of climate-related production shocks faced by small-scale farmers as well as to identify available adaptation strategies. This study of rural maize-legume farmers in Western and Eastern Kenya identified drought, flooding/excessive rain as well as crop pests and diseases as most frequent and important over the last 10 years and all farmers expect the frequency of these shocks to increase during the next 10 years. Although the majority of farmers applied adaptation strategies, a significant proportion of farmers did nothing. In addition, each type of shock calls for specific pattern of adaptation strategies. Replanting is found to be the most common and preferred adaptation strategy to cope with all three shock types and it is the single dominant strategy to cope with flooding/excessive rainfall. Additional common adaption strategies for drought includes sell assets, reduce consumption and borrow while additional crop pests/diseases adaptation strategies are sell assets, borrow and seek treatment. Standard and multivariate probit models identify and analyze determinants of adaptation action as well as choice of particular strategies for each type of climate-related production shocks for different groups of farmers.

This research was conducted under the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and Sustainable Intensification of maize-legume Farming Systems for Food Security in Eastern and Southern Africa (SIMLESA)

1) Introduction

Climate change is a serious threat for agriculture, food security and fight against poverty especially in Sub-Saharan Africa where every second person is struggling to live with less than 1 USD per day. Crop failure due to unexpected shock incidents of drought, flooding, excessive rainfall, pests and diseases increases a risk of longer period of hunger and more severe livelihood hardship of the many rural poor who rely on small-scale farming for food and income. Rural farming system in this part of the world remains primarily traditional subsistence with low utilization of external inputs and technologies such that yield of food crops depend on favourable climatic and biophysical conditions. To cope with increasing unprecedented incidents of shifting in precipitation patterns and rising temperatures some farm households undertake different adaptation strategies whereas some others do not take any action. As a result some households suffer more frequency and more severe impact of climate change than some others both at the present and in the future. The inadequate ability of household to adapt to progressive climate change is seen as an important driving force that makes households vulnerable to poverty especially for those living in rural area with fewer social, technical and financial resources (World Bank 2010, UNFCCC 2007). Hence understanding factors influencing their coping and adaptation behaviour based on empirical evidence is urgent and essential to design guidelines for policy in order to better target promising interventions to increase resilience of rural farm households in vulnerable environments.

Despite being the largest and fastest growing economy in East Africa, Kenya is battling the fight of poverty for more than 67% of the 42 million populations (World Development Indicators 2012). Agriculture employs 75% of the workforce and contributes the largest share of GDP growth (24%) but grows only at 1.5% in 2011 (KNBS). In Kenya, maize is a foundation staple food accounting for about 40% of daily calories. Maize is planted in one out of every two acres of cultivating land and about 70 – 80% of maize is produced by smallholder farmers. Maize production is mainly for subsistence consumption with only 36% of all maize-growing farm households sell it and 20% accounting for the majority of sales (FAO, 2009). Not only they are abundant and cheap but also rich in nutrients and calories, maize remain traditional favourite meal components with average annual consumption of 98 kilograms per capita. However, Kenya has been relying on import and food aid for maize since 2000 (USAID KMDP 2011).

Drought, flooding, erratic rainfall pattern, crop pests and diseases as well as declining soil fertility, deteriorating soil structure and low production-enhancing technology have been attributed to successive crop failures which make the major cause of low self-sufficiency in maize (Nyoro et al., 2007). Because almost all of agriculture in Kenya is rain-fed with low fertilizer application, the impact of drought on maize production is substantial where over 80% of land area is arid or semi-arid and most of these areas receive low and uncertain rainfall distribution patterns averaging 500 – 800 mm per annum (WEMA 2012). With the IPCC climate outlook for the 21st century, the future of maize production in Kenya remains under threat of more intense and frequent droughts as well as increasing in temperatures. Effective adaptation to these progressive changes in climatic condition is the key to secure food production and livelihoods of the poor millions.

To address low soil fertility and soil moisture retention problems, maize and legume intercropping under conservation agricultural practices (i.e. minimum soil disturbance, crop rotation and crop residue retention) has been proposed as a sustainable intensification of food crop production which aims to increase resilience of maize-based farming systems to progressive climate change. The "Sustainable Intensification of maize-legume Farming Systems for Food Security in Eastern and Southern Africa (SIMLESA)" is an example of the pioneer effort led by The International Maize and Wheat Improvement Center (CIMMYT) and its partners in Eastern and Southern Africa with support from the Australian Centre for International Agricultural Research (ACIAR). The project is currently on-going in Kenya, Tanzania, Ethiopia, Malawi and Mozambique and targeting maize and five main legumes grown in the region (beans, pigeon pea, groundnut, cowpea and soybean).

Several studies emphasized on livelihood-based adaptation to climate change disturbances in a number of farming systems and communities in Sub-Saharan Africa (e.g. Cooper et al. 2008, Osbahr et al. 2008, Roncoli et al. 2001). Because the decision whether or not to adapt and the choice of particular adaptation strategy have different implications and consequences for livelihood, adaptive capacity and resilience of farm households, this paper aims to understand how poor rural maize-legume farmers cope with climate-related production shocks in Eastern and Western Kenya. Data collected from a sample of 613 farm households in SIMLESA sites provide comprehensive information for an in-depth analysis of their coping behaviour regarding decision to adapt and the specific choice of livelihood-based adaptation strategies. In particular, this paper will assess the following research questions:

1. What are major climate-related production shocks that maize-legume farm households face?
2. For each type shock, how do farm households decide whether or not to adapt?
3. What are common livelihood-based adaptation options and how do farm households decide for specific choice of adaptation strategies?
4. Specifically, what are determinant of adaptation strategies for poor, food-insecure and female-headed farm households for each type of shock?

The remainder of this paper is organized as follows: Section 2 presents conceptual framework and literature review of climate change, production shocks and livelihood-based adaptation strategies. Section 3 elaborates the study area and data source. Section 4 shows empirical evidences of major climate-related production shocks and available adaptation strategies. Section 5 introduces methodology and includes empirical results from econometric models. Finally, Section 6 concludes and discusses policy implications for the study area.

2) Climate change, production shock and livelihood-based adaptation strategies

The Intergovernmental Panel on Climate Change (IPCC) refers climate change to "a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period. Climate change may be due to natural internal processes or external forces or to persistent anthropogenic changes in the composition of the atmosphere or in land use". Climate variability here refers to "variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate at all spatial and temporal scales beyond that of individual weather events." (IPCC 2007). On the other hand, United Nations Framework Convention on Climate Change (UNFCC) differentiates between anthropogenic climate change caused by human activities altering the global atmospheric composition and climate variability caused by natural influences (UNFCC 2007). This paper focuses on climate change attributed to human drivers especially the one that arises from farm households through agricultural activities.

The main process driver of climate change is a result of increasing anthropogenic emissions and concentrations of primary greenhouse gases (GHG)—carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4) — more than natural level in the atmosphere. Agriculture directly and indirectly contributes to global greenhouse gas emissions since all three GHG are critical by-products of agriculture (Bellarby et al. 2008). IPCC held agricultural sector to be accountable for 13.5% of total anthropogenic greenhouse gas emission in 2004 (IPCC 2007). The linkages between climate change, farm household, agricultural production shock (*ex-post*) including adaptation and mitigation to such risk (*ex-ante*) can be summarized in Figure 1. Farm household in the human systems interacts with climate in the earth systems through crop and livestock farming for food production and consumption. To increase yield, forest lands are converted to crop lands (extensification) and chemical inputs are intensively used (intensification). As soil is an effective carbon sink, when forest lands are converted to farming fewer carbon is sequestered in the soil and more carbon is released in to the atmosphere to form carbon dioxide estimated at 5,900 million Tonnes CO_2-eq in 2005 (Bellarby et al. 2008). According to the same study, high concentration of nitrous oxide from soils is released from residues of chemical inputs especially nitrogen-based fertilizers and manure (2,128 million Tonnes CO_2-eq in 2005) whereas livestock farming is responsible for methane emission from enteric fermentation of cattle (1,792 million Tonnes CO_2-eq in 2005). Other agricultural activities such as biomass burning, fertilizer and pesticide production, irrigation, and farm machinery are accountable for further GHG emission.

The thermal infrared radiation emitted by the Earth's surface is absorbed by greenhouse gases within the Earth's system leading to an increased infrared opacity of the atmosphere and radiative forcing. The heat and evaporation trapped in this process causes temperature to rise and precipitation pattern to change. Since farming depends essentially on temperature and rainfall, higher temperature and erratic rainfall pattern pose shocks and risks to agriculture. In the short-run, prolonged period of drought, erratic rainfall pattern (e.g. late rain onset, early rain termination, sporadic rainfall distribution) and flooding are direct consequence of temperature and precipitation fluctuation while greater incidents of pests and diseases of crop and livestock can be accounted for indirectly. In the long-run, continuous variability and severity of weather distresses eventually leads to environmental degradation such as land degradation, biodiversity loss and unsustainable forestry which damage natural resources essential for agriculture and livelihoods. Although climate fluctuation may increase rainfalls and reduce temperature in some dry areas but the shifting of mean values and widening variation of climatic pattern requires fundamental adjustments of farm planning and cultivation pattern for farm households (Jitsuchon 2010).

Having suffered from unexpected agricultural production shocks, farm households may adapt to changing climatic conditions by using available skills, resource, and opportunities to address, manage, and overcome adverse conditions brought about by such shocks to maintain livelihoods. The exposure of agricultural production shocks creates initial impact on household's food production and consumption. Farm households have a number of options to adjust to actual or expected production shock effects in order to moderate harm and minimize residual impact. These livelihood-based adaptation strategies may include following options:

1) Adjustment of farming practice and technology including replanting; application of external inputs and machinery; treatment of pests and diseases; use improved varieties with tolerance to drought, disease and pest early or relay planting, conservation agricultural practices, crop diversification, crop intensification (e.g. Claessens et al. 2012, Kristjanson et al. 2012, Mercer et al. 2012, Cavatassi et al. 2011, Thompson et al. 2010)
2) Sell assets such as livestock, lands and other assets and use savings (e.g. Kochar 1999, Newhouse 2005)
3) Borrow (e.g. Tadesse and Brans 2012, Newhouse 2005, Kochar 1999)
4) Reduce consumption (e.g. Dercon 2007, Jalan and Ravallion 1999)

At the same time, farm households may undertake mitigation strategies to reduce the sources or enhancing the sinks of greenhouse gases. Possible climate change mitigation strategies which aim to increase the uptake and storage of carbon in plants, trees and soils (carbon sequestration) in the earth systems are

1) Conservation agriculture (e.g. minimal soil disturbance, surface residues retention, crop rotation)
2) Sustainable intensification (e.g. intercropping, relay cropping)
3) Agroforestry

In addition to agricultural production shocks and risks, farm households simultaneously face shocks and risks from other sources. Fluctuations in input, output and food prices, reduction in household business and employment income represent economic shocks/risks. Health shocks/risks include family sickness and death of household member. Lastly, social shocks/risks encompass theft, discrimination, conflict and violence. Hence household income and food security is a result of overall intra-household adaptation to shocks and management of risks.

Central and cross-cutting to climate change adaptation, farm households and mitigation are dimensions of poverty, food insecurity and gender. To critically address climate change and offer targeting policy recommendation, it is important to understand how the poor, the food-insecure and the female-headed farm households are affected from climate-related production shocks, how are they adapting and mitigating, if at all, differently than farm households who reside above the poverty and food-security line and led by male household head.

In this paper, the focus of attention is placed on the adaptation to climate-related agricultural production shocks while treating other components of the framework as exogenous parts of the analysis.

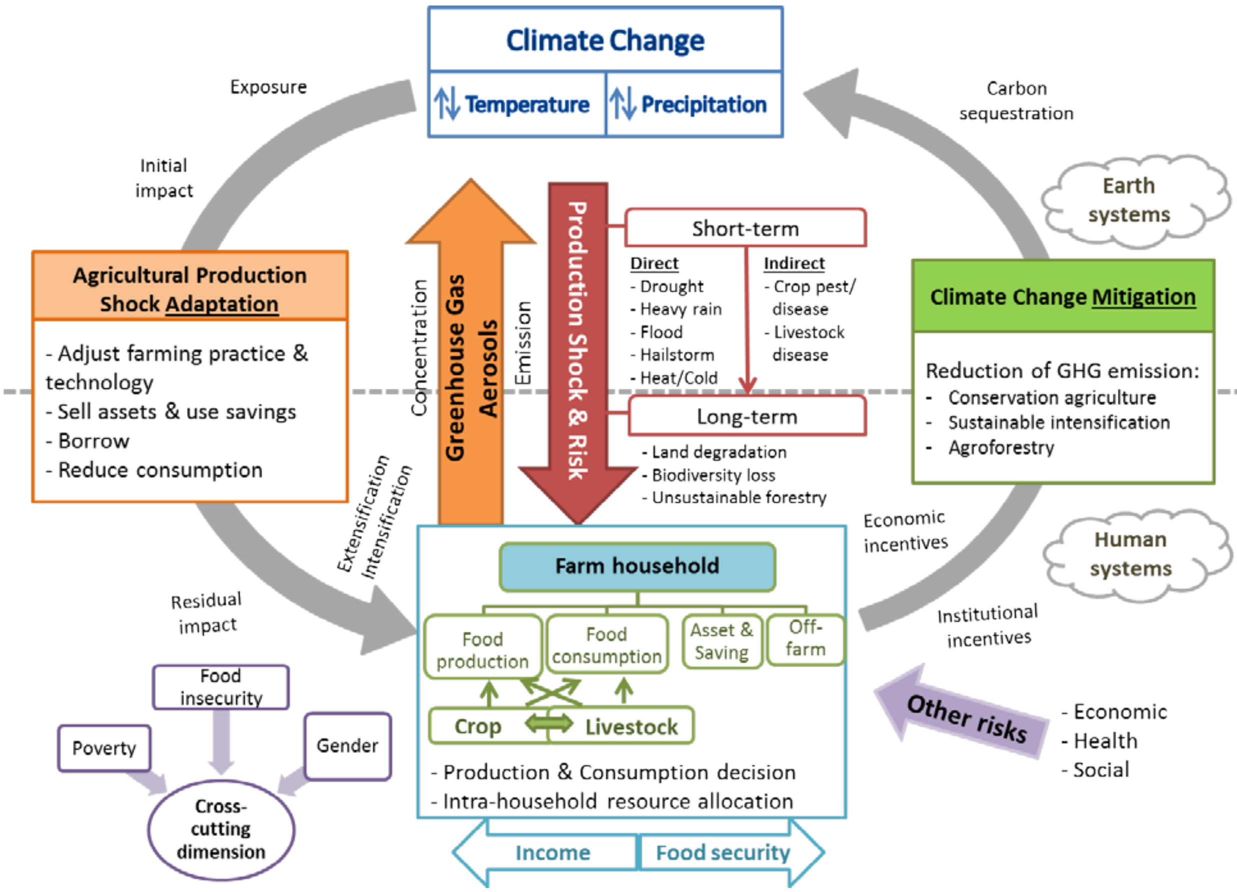

Figure 1: Conceptual framework on climate change, farm households and adaptation to agricultural production shocks
Source: Own illustration

Considering adaptation strategies, farm household level of adaptation capacity is largely determined by the level of asset endowment. For example, larger cultivating land allows for flexibility in changing farming practices, larger stock of assets such as livestock, land and other tangibles allows households to liquidate for cash and the same stock of assets can be converted into collateral for borrowing. However, the dynamic relationship between asset-based adaptation capacity and shock frequency/severity is non-linear as depicted in Figure 2. Facing incidents of multiple and sequential shock, the accumulative impact of shocks increases and eventually hampers the adaptation capacity. In this case, the adaptation capacity increases initially with low frequency and severity of shock before reaching the turning point and beginning to fall when the accumulative shock severity is high such that asset becomes insufficient to implement adaptation strategy. At the onset, asset-poor farm households therefore have lower adaptation capacity and are more vulnerable to climate-related risks than better-off households with larger asset accumulation (Cutter et al. 2003, Glewwe and Gillette 1998).

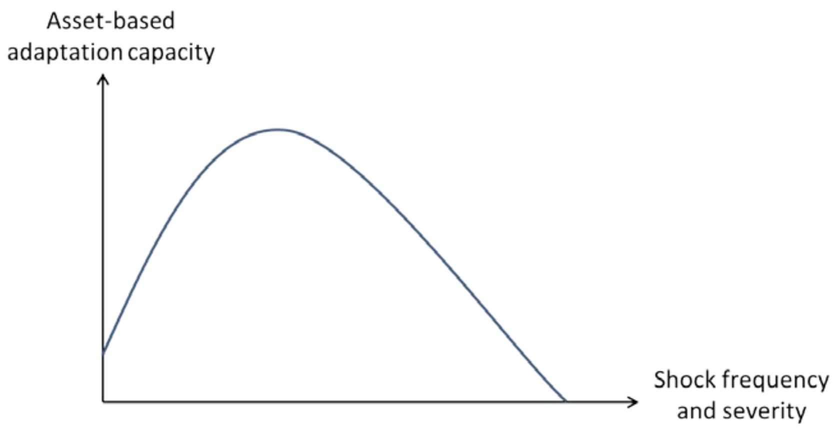

Figure 2: Asset-based adaptation capacity to cumulative shock
Source: Own illustration

In the early stage when initial asset level is high, household is more likely to draw on these assets to adapt to sequential shocks. Depending on household's choice of adaptation strategy, four possible outcomes of the adaption strategy are shown in Figure 3: 1) *effective adaptation* – asset is recreated greater than the initial level and enhances household's adaptation capacity for the next period; 2) *neutral adaptation* – asset is restored to the initial level; 3) *ineffective adaptation* – asset is depleted below the initial level and reduces household's adaptation capacity to subsequent risk in the following period; and 4) *no adaptation* – asset is continuously and more progressively depleted than ineffective adaptation. In this simple framework, households are assumed to follow one single path although they may be able to shift between paths through learning effects. The choice of coping actions of households depends on the type and severity of shocks as well as household characteristics, asset, the diversity and stability of household income sources and local environment (Tongruksawattana et al. 2012, Rashid et al. 2006, Takasaki et al. 2002).

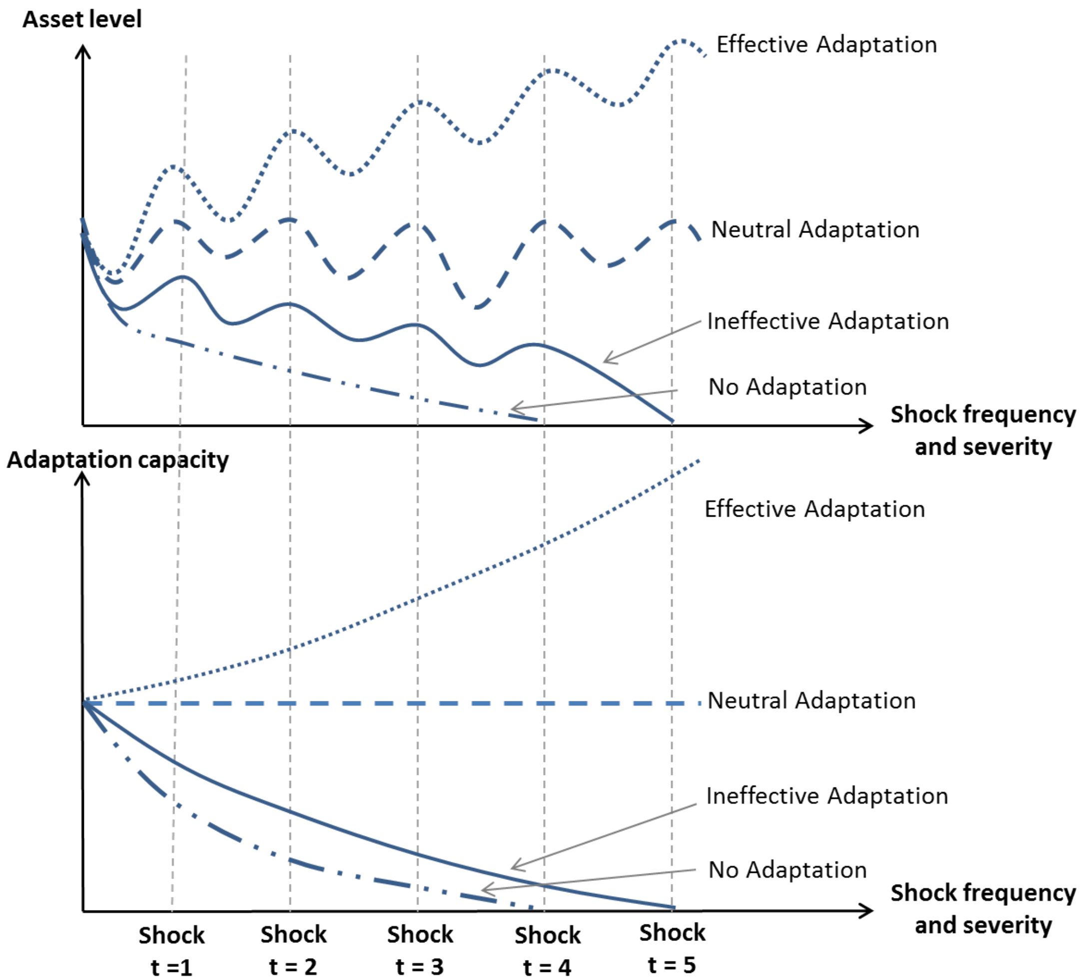

Figure 3: Asset-based adaptation capacity pathways
Source: Own illustration

3) Data and Study area

Data for this study is drawn from SIMLESA baseline survey conducted in 2010. The survey targeted two major farming systems in Kenya, i.e. western highlands in the Western region (Kakamega) and central highlands in the Eastern region (Embu). Both regions have a bimodal rainfall pattern and two cropping seasons. The target sites are considered to have good potential for agriculture with well drained soils and relatively high rainfall (1,100 – 1,600 mm per year). The target sites are also densely populated and majority of the farmers are smallholders. As shown in Figure 4, a total of five districts were selected, of which two districts were from the Western region (Bungoma and Siaya) and three districts from the Eastern region (Embu, Meru South and Imenti South).

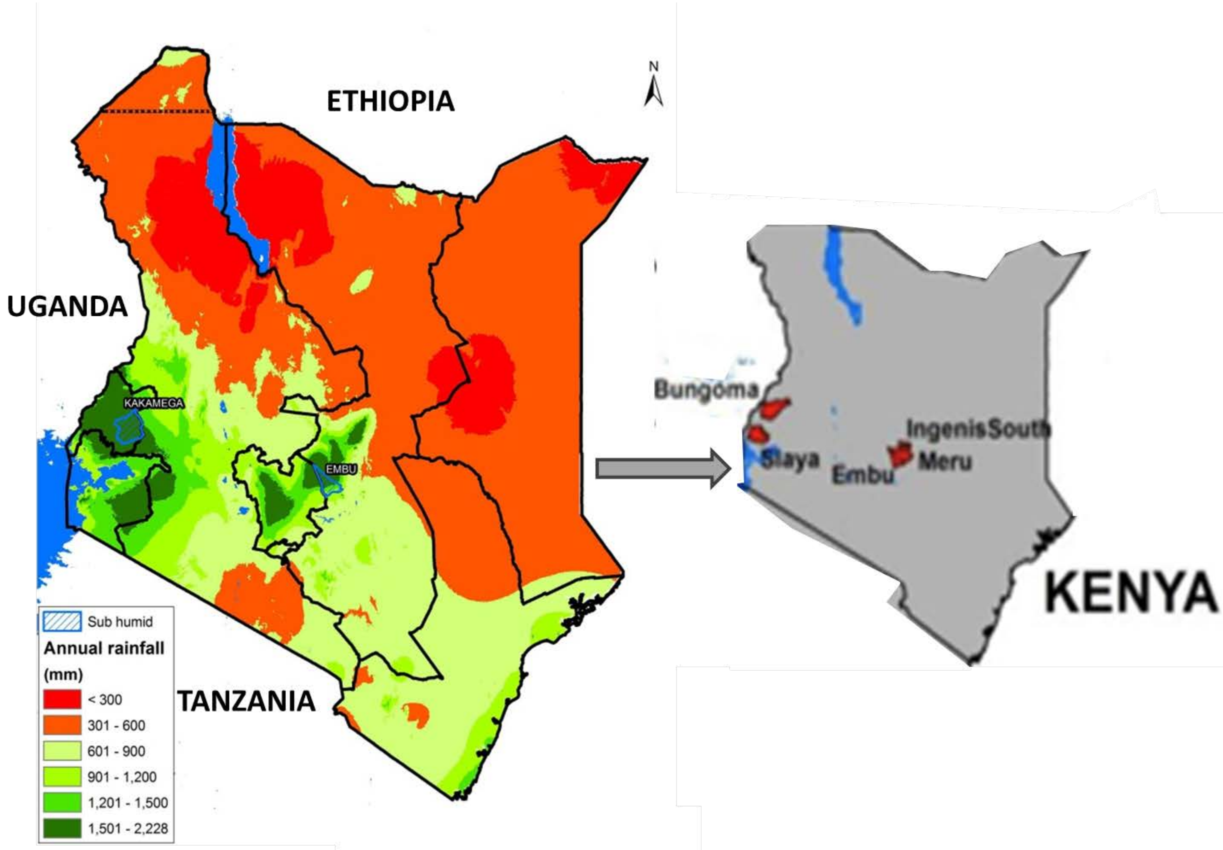

Figure 4: SIMLESA study sites in Kenya
Source: Adapted from SIMLESA

All five districts are characterized by small-scale cash crop and subsistence farming system. Common food crops grown include maize, beans, potatoes and vegetables while main cash crops are tea, coffee, sugarcane and cotton. Cattle and small livestock keeping are also widely practiced. Average land size under small-scale agriculture in the area ranges approximately between 1.7 to 2.6 acres. Despite high potential for agricultural productivity, the number of people living with less than 1 USD per day in the districts remains substantial with highest poverty rate in Bungoma (50.7%), followed by Siaya (40.1%), Embu (36.6%) and Meru (31.2%).

Compared to other districts, Bungoma is blessed with highest average rainfall while the opposite is found for Embu and Meru. Over the past 50 years (1961 – 2012) the amount of rainfall has been substantially fluctuating for all districts and the annual trend has decreased for all districts except Bungoma (Figure 5). On the other hand, the incidents of drought have been increasing at smaller intervals especially during the last 10 years. While Siaya, Meru and Embu usually suffered from rainfall shortage, Bungoma has been more exposed to excessive rainfall. This observed change in climatic pattern evidently put small-scale farm households in all five districts under production risk due to unpredicted lack or excess of rainfall.

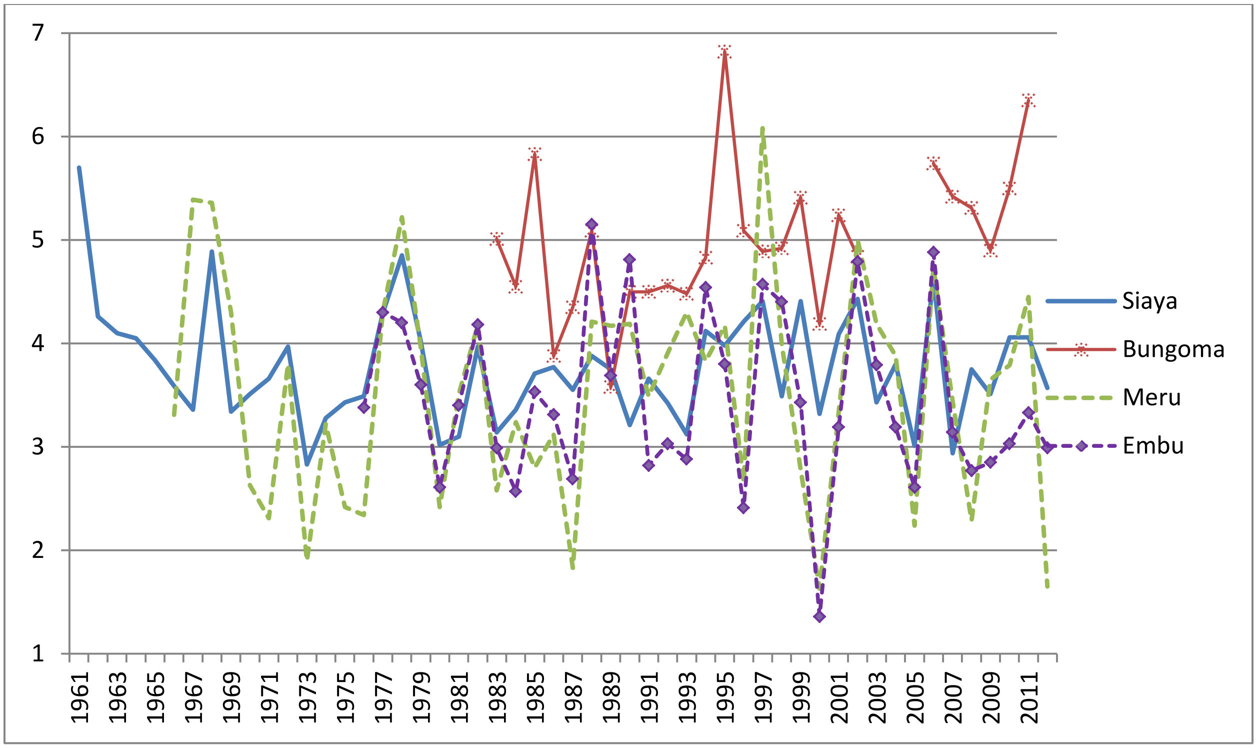

Figure 5: Average daily precipitation in study sites 1961 – 2012 (millimetre)
Note: Imenti South is omitted due to lack of data.
Source: Kenya Meteorological Department

A total of 613 households were sampled for this survey with an equal distribution of 300 in each region. This translates in to approximately 150 and 100 households allocated to each district in the Western and Eastern region, respectively. Next, the number of villages to be surveyed was identified proportional to the total number of households in each of the division and the sampled villages were randomly selected from each division. Similarly, the number of households to be surveyed was identified proportional to the total number of households in each village and the sampled households were randomly selected from each village.

Table 1 summarizes key dimensions of 613 surveyed farm households from 30 divisions and 117 villages. Of all surveyed households, almost 20% are female-headed in both regions where the highest share of female-headed households was found in Siaya (26%) and the lowest in Bungoma (13%). In both regions, approximately 54% of surveyed households are living in poverty with below 1 USD per day. The highest poverty rate of 59% belongs to Siaya, followed by 57% in Meru, 54% in Embu, 53% in Imenti South and 49% in Bungoma. On the other hand, 70% of surveyed households in Western region compared to 30% in Eastern region identified themselves as food-insecure, i.e. experienced occasional and complete food shortage throughout the year taking into consideration of all available food sources[1]. The proportion of food-insecure households was found as high as 70% in Siaya.

[1] These include own food production, food purchase, help from different sources, food collected from forest and lakes, etc.

Table 1: Overview of sampled households

District	Total no. of divisions	Total no. of villages	No. of households sampled						
			Total	Poor[1]		Food insecured		Gender of HH head	
				yes	no	yes	no	male	female
Western region	**17**	**63**	**299**	**162**	**137**	**205**	**93**	**241**	**58**
Bungoma	10	20	150	74	76	100	50	131	19
Siaya	7	43	149	88	61	105	43	110	39
Eastern region	**13**	**114**	**314**	**171**	**143**	**91**	**222**	**253**	**61**
Embu	5	31	111	60	51	39	72	83	28
Meru South	3	39	102	58	43	21	79	87	15
Imenti	3	44	101	53	49	31	71	83	18
Total	**30**	**117**	**613**	**333**	**280**	**296**	**315**	**494**	**119**

[1] Annual per capita expenditure less than 1 USD/day

4) Evidence of climate-related production shocks and available livelihood-based adaptation strategies

Almost every maize-legume farm households in the study area experienced climate-related production shocks over the 10-year period between 2000 and 2010 (Table 2). Out of 613 surveyed households, drought was found most common shock type suffered by the highest share of households followed by crop pests/diseases, livestock diseases/death, hailstorm and flooding/excessive rain. At the same time households appear pessimistic about the future outlook as they expect all types of shock to occur by 1.5 times more frequently in the next 10 years than experienced in the past decade. Drought, although occurred on average only almost three times during the 10-year period, has most severe effect on food crop production and income reduction at 43.5% and 29%, respectively and was anticipated by almost 70% of households to be more important in the future due to climate change. Crop pests/diseases, which ranks second highest frequency of occurrence in the last 10 years after hailstorm, affected household's food crop production and income at second most severe and was perceived by the more than 90% of surveyed households as becoming more important in the future due to climate change. Common pests of maize in the area are cutworms, armyworm, maize leaf aphid, stem and stalk borers while maize streak virus, head smut, crazy top and common rust are common maize diseases (ACDI/VOCA 2007). Flooding/excessive rain, although being least experienced, frequent in the past, affected food crop production and income substantially and is perceived to be more important in the future due to climate change by almost 60% of the surveyed households. Hail storm was experienced among the least share of households and affected food crop production more than income. Livestock diseases/death, on the other hand, had the mildest effect on household food crop production and income and are least expected to be important in the future. The empirical findings highlight the relevance and importance of drought, crop pests/diseases and flooding/excessive rain and hence the focus of analysis in this paper will focus on these three shock types.

Table 2: Climate-related production shocks faced by all households during 2000 – 2010

Shock type	No. of affected households[1]	Frequency in last 10 years		Shock effect (% reduction in...) Food crop production		HH income		Shock will be more important in future due to climate change[1]	Expected frequency in next 10 years	
	(%)	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	(%)	Mean	Std. Dev.
Drought	91.7	2.8	2.4	43.5	28.9	29.0	24.1	66.6	4.5	3.6
Flooding/Excessive rain	36.2	2.3	2.3	23.5	23.7	15.0	15.7	57.5	3.4	2.7
Crop pests/diseases	59.1	4.2	3.6	30.1	22.9	18.5	16.7	91.2	5.3	3.4
Hail storm	37.7	4.5	3.6	29.2	28.8	15.8	17.0	56.4	6.7	4.4
Livestock diseases/death	42.7	3.6	3.3	15.1	20.1	16.8	20.6	43.1	5.4	4.0
Total	**96.2**	**9.5**	**9.9**	**34.4**	**24.0**	**23.5**	**18.3**	**84.6**	**10.7**	**10.4**

[1] N = 613

Table 3 shows the incidents, effects and anticipations of drought, flooding/excessive rain and crop pests/diseases by different household categories. More of poor households experienced drought, flooding/excessive rain and crop pests/diseases than non-poor households although the frequency reported by the latter is greater by one occurrence for all three shocks. The same pattern is found for food insecure households in comparison to food secure households except for flooding/excessive rain. The effect of all shocks on food crop production and income including the anticipation of future occurrence, however, are comparable between the poor and non-poor groups. The food secure group seems to suffer more from drought and less from two other shocks than the food insecure group and they anticipate all three shock types to occur more in the future. Larger proportion of all shock-affected households is male-headed who experienced higher shock frequency than female-headed households. The effects of flooding/excessive rain are higher for female than male-headed households while the opposite is found for drought and crop pests/diseases. Female-headed households also have negative outlook for future occurrence for all three types of shock than male counterparts.

Table 3: Climate-related production shock by poverty, food insecurity and gender

Shock type	No. of households		Frequency in last 10 years		Shock effect (% reduction in...) Food crop production		HH income		Shock will be more important in future due to climate change[1]	Expected frequency in next 10 years	
	N	%	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	(%)	Mean	Std. Dev.
Drought (N = 562)											
Poor[1]	302	49.3	2.7	2.2	41.5	28.9	29.4	24.5	65.9	4.5	4.0
Non-poor	260	42.4	3.0	2.5	45.9	28.7	28.5	23.5	66.5	4.4	3.1
Food insecure	266	43.4	2.8	2.3	40.9	29.4	26.1	22.0	60.5	4.8	3.4
Food secure	294	48.0	2.9	2.4	45.9	28.2	31.6	25.6	71.4	4.3	3.8
Female-headed	109	17.8	2.5	1.7	43.5	28.4	27.2	21.8	70.6	4.4	2.6
Male-headed	453	73.9	2.9	2.5	43.5	29.0	29.4	24.6	65.1	4.5	3.9
Flooding/excessive rain (N = 222)											
Poor[1]	125	20.4	2.0	2.0	23.8	22.9	16.3	16.9	56.0	3.3	2.8
Non-poor	97	15.8	2.7	2.6	23.2	24.8	13.4	13.8	57.7	3.6	2.4
Food insecure	129	21.0	2.4	2.3	26.6	24.8	16.7	16.4	51.9	3.4	2.7
Food secure	93	15.2	2.2	2.3	19.3	21.5	12.6	14.4	63.4	3.5	2.7
Female-headed	40	6.5	2.1	1.6	32.6	29.3	20.1	22.3	55.0	4.0	2.4
Male-headed	182	29.7	2.4	2.4	21.5	21.9	13.9	13.7	57.1	3.3	2.7
Crop pests/diseases (N = 362)											
Poor[1]	189	30.8	3.7	3.4	29.7	22.3	19.7	18.1	93.1	5.3	3.5
Non-poor	173	28.2	4.7	3.8	30.5	23.7	17.2	14.9	89.0	5.3	3.4
Food insecure	150	24.5	4.0	3.4	29.3	22.6	20.1	17.7	89.3	5.1	3.1
Food secure	212	34.6	4.3	3.7	30.6	23.2	17.4	15.9	92.5	5.5	3.6
Female-headed	67	10.9	4.0	3.4	28.1	22.5	17.3	15.7	94.0	5.3	3.1
Male-headed	295	48.1	4.2	3.6	30.5	23.1	18.8	16.9	90.5	5.3	3.5

[1] Households with less than 1 USD/day per capita expenditure

Almost 90% of 573 households who were affected by drought, flooding/excessive rain or crop pests/diseases have applied any adaptation strategy to cope with the reduction in food crop production and income (Table 4). For all types of shock, 94% of adapted households are female-headed as compared to 86% who are male-headed and 91% of food secure households applied adaptation strategy as compared to 84% of food insecure households, both with a t-test of 10% significant level. Highest share of households reported to have adapted to drought, followed by crop pests/diseases and flooding/excessive rain.

Table 4 Number of households who applied any adaptation strategy

Shock type	No. of affected households [a)]	Applied any adaptation strategy	
		N	%
Drought	559	463	82.8
Too much rain or floods	219	163	74.4
Crop pests/diseases	360	283	78.6
Total	**573**	**503**	**87.8**

[a)] Some households were removed due to incomplete data

Figure 6 elaborates adaptation behaviour for each household category. For all types of shock, poor households applied less adaptation strategy than the non-poor group. The same is found for the food insecure households especially to cope with crop pests/diseases (t-test at 10% significant level). Female-headed households are more active in adapting to all types of shock than male-headed households especially to cope with flooding/excessive rain (t-test at 10% significant level).

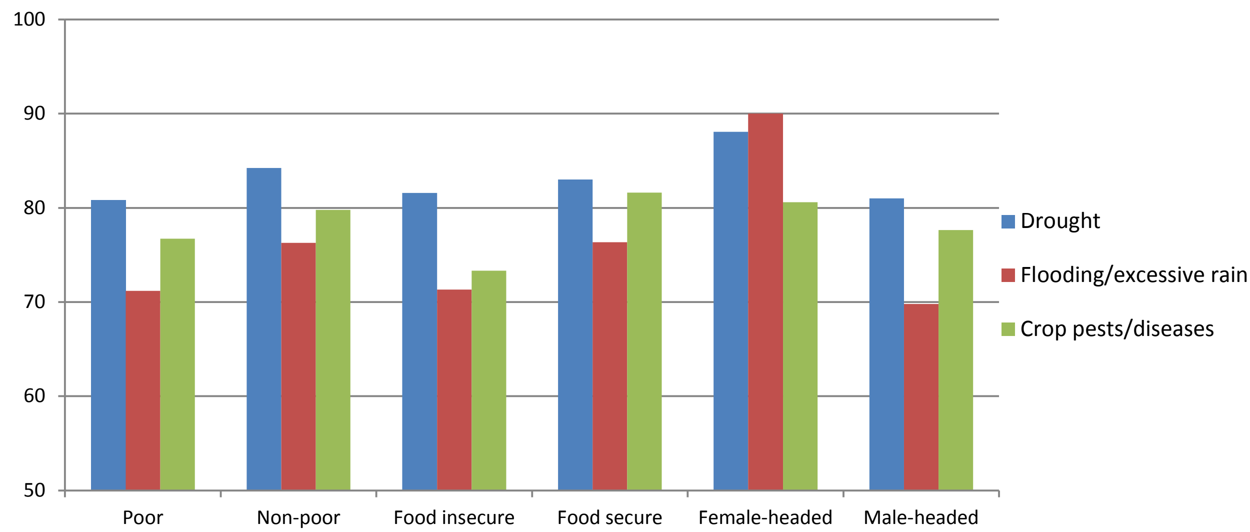

Figure 6: Adaptation to climate-related production shocks (% of shock-affected households for each household category)

Once households decide to adapt to shocks, they make a successive decision which particular livelihood-based adaptation strategy to apply. To adapt to one type of shock, they may use only one strategy, or they may use a combination of strategies simultaneously or subsequently. Our empirical results identified a set of available adaptation strategies commonly applied for all households regardless of poverty, food security and gender status to cope with each of the three types of shock (Table 5). To adapt to drought, four dominant strategies are found ranked by the frequency of application, namely, replanting, sell assets, reduce consumption, and borrow, respectively. A slightly different set of four ranking dominant strategies are identified for crop pests/diseases which are replanting, seek treatment, sell assets and borrow. On the other hand, replanting appears to be the single most outstanding strategy to adapt to flooding/excessive rain. Each type of strategy has different composition, implication and consequence on household resources as following.

Replanting

When crop is destroyed by drought, flooding/excessive rain or pests/diseases, farmers will try to plant again to recover the loss in food crop production and income. This strategy includes not only the repeating business-as-usual process of planting from the beginning but may involve application of additional non-traditional inputs such as fertilizer, manure, pesticide and herbicide to stimulate and safeguard yield. In order to apply this strategy, farmers need to deplete their assets to invest upfront in seeds, inputs and implements. To carry out farm work, farmers need to invest in time and own labour resources if not depleting more assets to hire casual labour. This strategy is considered long-term as it requires a complete period of planting cycle until yield can be harvested. In addition, this strategy is considered risky as the new planting is once again subject to similar potential risk of climatic fluctuation.

Sell asset

To compensate for reduction in food crop production and income, households may sell assets for cash or other consumables. These assets include, for example, livestock, land, saved agricultural products and other tangible assets such as tools and luxury items. To sell assets, access to market and favourable market conditions are required. In reality, however, many rural households locate in remote area far away from markets and selling prices are often bargained at their disadvantage due to desperation. This strategy is considered short-term but unsustainable as it directly depletes household's asset accumulation in exchange for money and/or food while reduces household's adaptation capacity in the future.

Borrow

To bridge food and income shortage, households may take loans from formal and informal sources. Common institutions for formal lending are commercial banks, cooperatives, farmer's groups and associations, deposit taking micro-finance institutions such as Faulu Kenya and Kenya Women Finance Trust (KWFT). Informal borrowing sources include relatives, friends, neighbours and private money lenders, for example. Terms and conditions of borrowing vary substantially between sources. However, households are usually required to present some assets as collateral as a signal of credibility in order to be eligible for loans. As a general rule, the higher valued assets, the better lending terms and conditions. In some cases, social network can be used as collateral. This strategy is considered favourable only to households who have large assets, credible social status and access to credit channels.

Reduce consumption

For households with fewer or no assets to invest in replanting, borrow or sell, eating fewer meals per day or less nutritious meals becomes the only viable option to deal with decreased food crop production and lower income. Alternatively households may change their usual diet plan and search for consumption substitution which are cheaper and easier to find but may not satisfy their preferences and nutritional requirements. This strategy is considered most acute action which has substantial chronic effect on functionality and growth of all household members especially women and children.

Seek treatment

To cure crop pests and diseases and to prevent repeating outbreaks, households may seek advisory and treatment from experts such as agrovets, extension officers and national research institutions. As some pests and diseases are becoming more widespread and resistant due to changing in climatic conditions, it is important that households receive correct diagnostics and recommendations on their particular farms while taking into account the potential spillovers to neighbouring areas as well as ecological and environmental system. Acquiring such advisory and treatment, however, is not free of charge as some amount of advisory fee and cost of treatment are borne by farmers.

To cope with drought, poor, food insecure and female-headed households chose to replant more than non-poor, food secure and male-headed counterparts, respectively. The food secure households opted for selling assets more than food insecure households who reduced consumption more often. While male-headed households prefer selling assets, female-headed households prefer borrowing. To cope with flooding/excessive rain, replanting is undertaken more by the poor, the food secure and the male-headed households as compared to the non-poor, the food insecure and the female-headed group, respectively. Replanting and selling assets are more undertaken by the poor to cope with crop pests/diseases than the non-poor who prefer to seek treatment. The food insecure households tend borrow more than the food secure group who tend to replant, sell assets and seek treatment. Lastly, female-headed households replant and sell assets more than male-headed households who prefer seeking treatment.

Table 5: Adaptation strategies undertaken to cope with drought, flooding/excessive rain and crop pests/diseases

Shock type	No. of adaptation undertaken	Adaptation strategy[1] (%)				
		Replanting	Sell assets	Reduce consumption	Borrow	Seek treatment
Drought						
All households	731	51	23	13	11	-
Poor	377	53	23	12	11	-
Non-poor	357	50	22	14	12	-
Food insecure	335	55	15	15	12	-
Food secure	395	48	29	11	11	-
Female-headed	148	53	18	11	15	-
Male-headed	586	51	24	13	11	-
Flooding/excessive rain						
All households	206	69	10	6	10	-
Poor	117	71	11	3	9	-
Non-poor	89	66	8	9	10	-
Food insecure	117	67	6	6	15	-
Food secure	89	72	15	6	3	-
Female-headed	50	64	8	8	14	-
Male-headed	156	71	10	5	8	-
Crop pests/diseases						
All households	366	43	19	1	9	24
Poor	195	47	22	2	9	16
Non-poor	171	39	15	1	9	33
Food insecure	139	40	14	1	17	22
Food secure	227	44	22	1	4	25
Female-headed	75	45	21	1	9	15
Male-headed	291	42	18	1	9	26

[1] The remaining percentage refers to other adaptation strategies

5) Two-step decision-making model and empirical results

Facing climate-induced agricultural production shock that affects food production and income, household can either undertake any adaptation strategy to minimize the loss from shock and to prepare itself for a possible recurrence; or household can continue business-as-usual and bear the shock consequences. Each of the alternatives brings a different stream of utilities — U_1 from adaptation and U_0 from non-adaptation – which are index functions of a set of deterministic (S, X, L) and stochastic variables ($\varepsilon_1$and ε_0). S is a vector of climate-related shock incidents that a household i experienced during the last 10 years, X is a vector of socio-demographic characteristics of the household and L is a vector of location-specific of the village. Vector X can be further disaggregated in three indices to highlight poverty status (index P - below poverty line: $P_i = 1$; above poverty line: $P_i = 0$), food security status (index F - food secure: $F_i = 1$; food insecure: $F_i = 0$) and gender of household head (index G - male: $G_i = 1$; female: $G_i = 0$) of i^{th} household. $\alpha, \rho, \varphi, \sigma, \beta$ and δ are parameter vectors to be estimated measuring the signs and magnitudes of the deterministic variables. The utility from taking a coping action can be interpreted as the benefit from undertaking measures that compensate for food production and income losses caused by shocks. Since utility derived from adaptation and non-adaptation varies for different type of shock, the utility function for drought, flooding/excessive rain and crop pests/diseases can be separately defined as following:

Utility from adaptation: $U_1 = \alpha_1 S + \rho_1 P + \varphi_1 F + \sigma_1 G + \beta_1 X + \delta_1 L + \varepsilon_1$

Utility from non-adaptation: $U_0 = \alpha_0 S + \rho_0 P + \varphi_0 F + \sigma_0 G + \beta_0 X + \delta_0 L + \varepsilon_0$

Since utility derived from adaptation and non-adaptation varies for different type of shock, the utility function for drought, flooding/excess rain and crop pests/diseases can be separately defined. For each type of shock a household will decide to adapt only if the stream of utility derived from adaptation is greater than non-adaptation. Although utility is unobservable, the observed choice of adaptation action ($Y = 1$) or non-adaptation ($Y = 0$) provides a proxy for such utility comparison and the same set of shock, household and location-specific explanatory variables (S, P, F, G, X, L) disposes the household to adapt or not to adapt to each type of shock with a certain probability.

Probability to adapt: $Pr(Y = 1|S, P, F, G, X, L) = Pr(U_1 > U_0)$

Probability not to adapt: $Pr(Y = 0|S, P, F, G, X, L) = Pr(U_1 < U_0)$

Based on utility maximization and probability to adapt, the key questions in this paper essentially address two steps of decision-making. In the first step, a household decides whether or not to take any action to adapt to each type of climate-related production shock, i.e. drought, flooding/excess rain and crop pests/diseases. To solve the decision at this initial step the univariate binary-response probit regression can be applied for each type of shock (Model 1). In the second step, an adapting household will choose one or more specific adaptation strategies among available options (Model 2). For this purpose, Model 1 can be expanded to multivariate probit regression (MVP) with a standard normal distribution to allow for coexistence of multiple adaptation strategies which need not be non-exclusive, non-exhaustive and independent of the irrelevant options (Model 2). Standard probit model is widely used in similar research literature which explores the correlation between shocks and coping activities and MVP is appropriate for making different choices for binary dependent choice (e.g. Tongruksawattana et al. 2012, Di Falco et al. 2011, Rashid et al. 2006, Takasaki et al. 2002,).

1) Step one – Explaining adaptation decision

This section focuses on analysing factors influencing farm household's decision whether or not to adapt to each type shock. The analysis aims to understand key characteristics of adapters and non-adapters which may explain their difference in adaptation decision to drought, flooding/excessive rain and crop pests/diseases (Table 6). Although each type of shock calls for different adaptation behaviour, compound effects between different types of shocks cannot be underestimated as households may as well experience other shocks during the same period. For example, drought and flooding/excessive rain adapters suffered twice more from crop pests/diseases than non-adapters in the last 10 years. 60% of drought-adapters have multiplicative experience of drought and crop pests in the last 10 years compared to 40% of non-adapters. Effects of drought and crop pests/diseases on food production and income (are higher for drought- as well as crop pests/diseases-adapters than the non-adapters of both shocks separately. Gender of household head seems to have significant difference on adaptation to drought and flooding/excessive rain with 80% male-headed adapters compared to 90% non-adapters for both shock types. For drought and crop pests/diseases, the adapters are more food secured than the non-adapters. However, poverty status does not show any significant differences for all shocks. In terms of socio-demographic characteristics, drought-adapters have lower education than the non-adapters by 1 school year. Drought- and crop pests/diseases adapters also have smaller (5 persons) household size than the non-adapters (6 persons). Adapters of drought and flooding/excessive rain received on average more contacts with extension services than the non-adapters. On average, adapters of all three shock types have smaller (1 ha) farm size compared to 1.5-2.5 ha owned by the non-adapters. 80% of households who did not adapt to drought practiced intercropping of maize and legume compared to 70% of adapters. Drought- and crop pests/diseases adapters receive 0.4 mm/annum lower average district rainfall and 1.1 degree Celcius lower temperature than the non-adapters. Distance to market seems to play an expected role as crop pests/diseases adapters locate almost 2 kilometres further away from the market than the non-adapters.

Table 6: Household characteristics of adapter and non-adapter

Household characteristics	Unit	Drought					Flooding/excessive rain					Crop pests/diseases				
		Adapter (N = 502)		Non-Adapter (N = 70)			Adapter (N = 163)		Non-Adapter (N = 56)			Adapter (N = 283)		Non-Adapter (N = 77)		
		Mean	Std. Dev.	Mean	Std. Dev.	t-test	Mean	Std. Dev.	Mean	Std. Dev.	t-test	Mean	Std. Dev.	Mean	Std. Dev.	t-test
Shock experience and effect																
Drought frequency in last 10 years	Times	2.7	2.3	3.0	3.0	ns	2.9	2.6	3.7	3.6	*	2.9	2.1	3.1	2.9	ns
Flood/rain frequency in last 10 years	Times	0.9	1.8	1.0	2.3	ns	2.4	2.2	2.3	2.7	ns	0.9	1.8	1.5	2.4	**
Crop pests/diseases frequency in last 10 years	Times	2.9	3.6	0.8	1.2	***	4.2	4.2	2.3	3.7	***	4.2	3.6	3.8	3.5	ns
Experienced drought & flood/rain in last 10 years	1 = Yes	0.4	0.5	0.4	0.5	ns	1.0	0.2	0.9	0.2	ns	0.4	0.5	0.5	0.5	***
Experienced drought & crop pests in last 10 years	1 = Yes	0.6	0.5	0.4	0.5	***	0.7	0.5	0.6	0.5	ns	1.0	0.2	0.9	0.2	ns
Experienced flood/rain & crop pests in last 10 years	1 = Yes	0.3	0.4	0.2	0.4	ns	0.7	0.5	0.6	0.5	ns	0.4	0.5	0.6	0.5	***
Food production reduction from drought	%	44.5	29.0	29.0	27.7	***	34.4	26.0	28.0	24.1	ns	45.1	29.6	37.9	29.0	*
Food production reduction from flood/rain	%	9.2	18.8	8.1	17.7	ns	25.7	24.3	17.6	20.9	**	8.6	17.5	13.1	22.4	*
Food production reduction from crop pests	%	19.8	23.7	12.7	19.4	**	13.6	16.5	18.8	21.0	*	31.7	23.4	24.0	20.4	***
Income reduction from drought	%	29.7	24.4	18.3	19.8	***	22.2	19.2	21.9	20.7	ns	29.8	25.8	22.8	24.3	**
Income reduction from flood/rain	%	5.8	12.3	5.3	11.2	ns	16.4	16.4	11.2	12.7	**	5.2	10.0	9.2	16.7	***
Income reduction from crop pests	%	12.2	15.8	7.9	16.8	**	9.8	9.4	14.4	18.3	**	18.9	16.3	17.1	18.2	ns
Poverty	***1 = Below 1 USD***	***0.5***	***0.5***	***0.4***	***0.5***	***ns***	***0.4***	***0.5***	***0.3***	***0.5***	***ns***	***0.5***	***0.5***	***0.4***	***0.5***	***ns***
Food security	***1 = Food secured***	***0.5***	***0.5***	***0.4***	***0.5***	********	***0.4***	***0.5***	***0.4***	***0.5***	***ns***	***0.6***	***0.5***	***0.5***	***0.5***	*******
Gender of household head	***1 = Male***	***0.8***	***0.4***	***0.9***	***0.3***	********	***0.8***	***0.4***	***0.9***	***0.3***	********	***0.8***	***0.4***	***0.8***	***0.4***	***ns***
Socio-demographic characteristics																
Education of household head	Year	7.2	3.9	8.1	4.0	*	7.4	3.8	7.8	3.6	ns	7.4	3.9	7.6	4.0	ns
Age of household head	Year	49.7	14.6	50.8	15.6	ns	50.2	15.1	51.6	15.8	ns	49.4	14.9	49.6	15.0	ns
Household size	Persons	4.8	2.2	5.6	2.8	***	5.2	2.4	5.7	2.8	ns	4.6	2.1	5.8	3.2	***
Asset	1,000 KSH	52.0	72.9	70.5	170.2	ns	56.1	101.6	76.2	224.3	ns	60.7	148.5	70.3	118.4	ns
Off-farm income	1,000 KSH	90.4	116.0	108.8	234.1	ns	135.7	306.7	86.2	106.6	ns	87.1	169.9	148.6	355.0	**
Expenditure	1,000 KSH	191.8	228.0	243.4	1,671.6	ns	391.5	2,840.8	170.1	148.4	ns	281.6	2,159.5	161.9	130.0	ns
Had contact with extension in 2009/2010	1 = Yes	0.5	0.5	0.4	0.5	**	0.6	0.5	0.4	0.5	***	0.5	0.5	0.5	0.5	ns
Number of associations household belong to	Unit	1.1	0.9	1.0	0.9	ns	1.0	0.8	1.0	0.9	ns	1.0	0.9	1.0	0.9	ns
Tropical Livestock Unit	TLU	2.1	2.6	2.6	2.3	ns	2.3	2.1	2.7	2.6	ns	2.0	1.8	2.7	3.1	**
Farm size	Hectare	1.0	0.9	2.5	9.3	***	1.0	1.0	1.5	2.2	**	1.0	0.9	2.4	8.9	***
Area under improved maize variety	Hectare	0.7	0.6	0.7	1.1	ns	0.6	0.6	0.7	1.1	ns	0.7	0.6	0.7	1.0	ns
Practiced maize-legume intercrop	1 = Yes	0.7	0.5	0.8	0.4	*	0.8	0.4	0.8	0.4	ns	0.7	0.5	0.7	0.4	ns
Practiced maize-legume rotation	1 = Yes	0.8	0.4	0.9	0.3	ns	0.9	0.3	0.8	0.4	ns	0.8	0.4	0.7	0.4	ns
Practiced crop residue retention	1 = Yes	0.7	0.5	0.7	0.4	ns	0.8	0.4	0.8	0.4	ns	0.7	0.5	0.7	0.4	ns
Location																
Average district rainfall 2010	mm	4.1	0.8	4.5	0.9	***	4.6	0.9	4.7	0.9	ns	4.1	0.9	4.5	1.0	***
Average district temperature 2010	Celcius	20.8	2.2	21.9	2.0	***	22.0	1.9	22.2	1.6	ns	20.5	2.1	21.6	1.8	***
Distant to the main market from residence	km	6.3	6.7	5.9	6.0	ns	5.8	4.2	6.3	6.4	ns	6.5	8.0	4.8	3.6	*

* significant at 10% level, ** significant at 5% level, *** significant at 1% level, ns - not significant

Next, a standard probit regression is applied to estimate the relationship between a latent discrete bivariate decision variable Y_i^* as dependant variable (adapt: $Y_i = 1$; non-adapt: $Y_i = 0$) and a set of explanatory variables ($S_i, P_i, F_i, G_i, X_i, L_i$) and an error term ($\varepsilon_i$) for all households i up to n.

$$Y_i^* = \alpha_i S_i + \rho_i P_i + \varphi_i F_i + \sigma_i G_i + \beta_i X_i + \delta_i L_i + \varepsilon_i$$

$$Y_i = 1 \quad \text{if} \quad Y_i^* > 0$$

$$Y_i = 0 \quad \text{otherwise}$$

The probability that a household chooses to adapt to each type of shock depends on the values of $S_i, P_i, F_i, G_i, X_i, L_i$ and the parameters $\alpha_i, \rho_i, \varphi_i, \sigma_i, \beta_i, \delta_i$ which describe the influence of respective changes in $S_i, X_i, P_i, F_i, G_i, L_i$ and the covariance of error terms ε_i. The functional form of a probit model assumes a cumulative normal distribution of the error term and the estimation is based on the maximum likelihood method. The generic step-one model (Model 1) for drought (1A), flooding/excessive rain (1B) and crop pests/diseases (1C) can be specified as following:

Model 1: Adaptation decision

$$Y_i = \begin{cases} 1 \text{ (adapt)} & \text{if } Y_i = \alpha_i S_i + \rho_i P_i + \varphi_i F_i + \sigma_i G_i + \beta_i X_i + \delta_i L_i + \varepsilon_i > 0 \\ 0 \text{ (not-adapt)} & \text{if } Y_i = \alpha_i S_i + \rho_i P_i + \varphi_i F_i + \sigma_i G_i + \beta_i X_i + \delta_i L_i + \varepsilon_i < 0 \end{cases} \quad ; i = 1, \ldots, n$$

$$Pr(Y_i = 1 | S_i, P_i, F_i, G_i, X_i, L_i) = \Phi(\alpha_i S_i, \rho_i P_i, \varphi_i F_i, \sigma_i G_i, \beta_i X_i, \delta_i L_i)$$

$$\log L = \sum_{Y_i = 0}^{n} \log[1 - \Phi(\alpha_i S_i, \rho_i P_i, \varphi_i F_i, \sigma_i G_i, \beta_i X_i, \delta_i L_i)] + \sum_{Y_i = 1}^{n} \log \Phi(\alpha_i S_i, \rho_i P_i, \varphi_i F_i, \sigma_i G_i, \beta_i X_i, \delta_i L_i)$$

Results from standard probit regression for drought, flooding/excessive rain and crop pests/diseases are summarized in Table 7. For all types of shock, experiences and effects of shocks and socio-economic factors have significant influence on the likelihood to apply any adaptation strategy while the influence of poverty, food security and gender is found insignificant. To cope with drought, the adaptation probability firstly decreases with the frequency of drought in the last 10 years but increases with the drought frequency square term. On the other hand, the compound effect of multiple shock types is significantly evident. Households who experience additional crop pests/diseases and suffer from additional reduction in income due to this shock are more likely to adapt to drought. However, the household’s adaptation probability reduces by 9% and 6% respectively when a household experienced drought together with flooding/excessive rain and crop pests/diseases. Furthermore, the probability to adapt to drought significantly increases with household asset, contact with extension services, number of associations and distance to main market. On the contrary, the probability to adapt to drought decreases with years of schooling. Households with smaller farm size who practice crop residue retention are more likely to adapt to drought. At the district level, lower average temperature is found to positively contribute to the likelihood to adapt to drought, i.e. households who reside in the colder area are more likely to adapt to drought.

The probability to adapt to flooding/excessive rain is positively correlated with income reduction as a result of its own shock type. Similar to adaptation to drought, frequency of crop pests/diseases in the last 10 years increases the probability that adaptation to flooding/excessive rain is undertaken although the opposite direction is found for food crop production reduction. Furthermore, reduction in food crop production among drought-affected households is likely to encourage adaptation to flooding/excessive rain. Contact with extension services and conservation agricultural practice of crop residue retention are again found to have significant positive correlation to flooding/excessive rain adaptation decision.

Adaptation decision to cope with crop pests/diseases is more likely for more severe food crop production reduction. Large asset-holding households who experienced more frequent drought and flooding/excessive rain are more likely to adapt to crop pests/diseases. In terms of socio-economic, elder household heads with smaller household and farm size who adopted improved maize variety and maize-legume rotation are found more likely to adapt to crop pests/diseases. Similar to drought, lower annual average temperature in a district increases the probability to adapt to crop pests/diseases. In addition, further distance to main market increases the probability to adapt to crop pests/diseases.

Table 7: Probit regression results for adaptation to drought, flooding/excessive rain and crop pests/diseases

Probit regression Model 1: Applied any adaptation strategy	1A - Drought[1] Coef.	Std.Err.	Marginal Effect		1B - Flooding/excessive rain[2] Coef.	Std.Err.	Marginal Effect		1C - Crop pests/diseases[3] Coef.	Std.Err.	Marginal Effect	
Shock experience and effect												
Drought frequency in last 10 years	-0.192	0.076	-0.0392	**	0.078	0.218	0.0133		-0.019	0.130	-0.0040	
Flood/rain frequency in last 10 years	0.309	0.192	0.0631		0.052	0.199	0.0088		0.377	0.224	0.0815	
Crop pest frequency in last 10 years	0.634	0.172	0.1297	***	0.533	0.191	0.0900	***	0.077	0.139	0.0166	
Drought frequency in last 10 years (squared)	0.008	0.005	0.0016	*	-0.025	0.020	-0.0043		-0.008	0.012	-0.0018	
Flood/rain frequency in last 10 years (squared)	-0.022	0.018	-0.0045		-0.008	0.016	-0.0014		-0.031	0.021	-0.0067	
Crop pest frequency in last 10 years (squared)	-0.049	0.015	-0.0101	***	-0.022	0.016	-0.0037		0.001	0.012	0.0002	
Experienced drought & flood/rain in last 10 years	-1.212	0.389	-0.2904	***	-1.376	1.279	-0.0995		1.096	1.041	0.2161	
Experienced drought & crop pest in last 10 years	-1.091	0.376	-0.1945	***	1.855	1.487	0.4491		-0.028	0.837	-0.0059	
Experienced flood/rain & crop pest in last 10 years	0.227	0.322	0.0436		-1.870	1.538	-0.2230		-1.526	1.109	-0.370	
Food production reduction from drought	0.002	0.004	0.0005		0.030	0.012	0.0051	**	-0.009	0.006	-0.0019	
Food production reduction from flood/rain	0.011	0.008	0.0023		-0.006	0.012	-0.0010		-0.001	0.007	-0.0003	
Food production reduction from crop pest	-0.008	0.006	-0.0016		-0.032	0.011	-0.0054	***	0.018	0.006	0.0040	***
Income reduction from drought	-0.006	0.005	-0.0012		-0.033	0.015	-0.0055	**	0.005	0.006	0.0010	
Income reduction from flood/rain	0.009	0.011	0.0017		0.062	0.018	0.0105	***	0.000	0.011	0.0000	
Income reduction from crop pest	0.020	0.009	0.0041	**	-0.020	0.017	-0.0033		-0.003	0.008	-0.0006	
Asset x Drought frequency in last 10 years	0.000	0.000	0.0000		0.000	0.000	0.0000		0.000	0.000	0.0000	**
Asset x Flood/rain frequency in last 10 years	0.000	0.000	0.0000		0.000	0.000	0.0000		0.000	0.000	0.0000	*
Asset x Crop pest frequency in last 10 years	0.000	0.000	0.0000		0.000	0.000	0.0000		0.000	0.000	0.0000	
Poverty	***0.187***	***0.171***	***0.0380***		***0.087***	***0.349***	***0.0145***		***-0.216***	***0.240***	***-0.0470***	
Food security	***-0.091***	***0.173***	***-0.0186***		***0.501***	***0.377***	***0.0810***		***-0.162***	***0.225***	***-0.0345***	
Gender of household head	***0.004***	***0.208***	***0.0008***		***-0.184***	***0.457***	***-0.0288***		***-0.095***	***0.261***	***-0.0198***	

Probit regression Model 1: Applied any adaptation strategy	1A - Drought[1] Coef.	Std.Err.	Marginal Effect		1B - Flooding/excessive rain[2] Coef.	Std.Err.	Marginal Effect		1C - Crop pests/diseases[3] Coef.	Std.Err.	Marginal Effect	
Socio-demographic characteristics												
Education of household head	-0.054	0.024	-0.0111	**	-0.071	0.050	-0.0120		0.007	0.029	0.0015	
Age of household head	-0.001	0.006	-0.0002		-0.009	0.011	-0.0015		0.013	0.008	0.0029	*
Household size	-0.024	0.039	-0.0048		0.033	0.074	0.0056		-0.096	0.050	-0.0208	*
Asset	0.000	0.000	0.0000	**	0.000	0.000	0.0000		0.000	0.000	0.0000	
Off-farm income	0.000	0.000	0.0000		0.000	0.000	0.0000		0.000	0.000	0.0000	
Expenditure	0.000	0.000	0.0000		0.000	0.000	0.0000		0.000	0.000	0.0000	
Had contact with extension in 2009/2010	0.354	0.160	0.0724	**	0.863	0.296	0.1617	***	0.210	0.194	0.0456	
Number of associations household belong to	0.190	0.095	0.0389	**	0.066	0.189	0.0111		0.083	0.114	0.0179	
Tropical Livestock Unit	-0.005	0.034	-0.0010		-0.089	0.074	-0.0151		-0.028	0.044	-0.5981	
Farm size	-0.140	0.079	-0.0285	*	-0.018	0.145	-0.0031		-0.277	0.109	-0.0599	**
Area under improved maize variety	-0.157	0.120	-0.0322		-0.287	0.271	-0.0485		0.375	0.200	0.0812	*
Practiced maize-legume intercrop	0.126	0.204	0.0265		0.467	0.441	0.0945		-0.153	0.242	-0.0322	
Practiced maize-legume rotation	-0.121	0.220	-0.0236		-0.422	0.457	-0.0584		0.415	0.241	0.1015	*
Practiced crop residue retention	0.473	0.184	0.1084	**	1.062	0.450	0.2639	**	0.294	0.222	0.0674	
Location												
Average district rainfall 2010	-0.021	0.116	-0.0043		-0.570	0.219	-0.9634	**	-0.241	0.145	-0.0521	
Average district temperature 2010	-0.161	0.049	-0.0330	***	-0.116	0.109	-0.0197		-0.142	0.066	-0.0308	**
Distant to the main market from residence	0.002	0.015	0.0003		-0.013	0.030	-0.0022		0.056	0.024	0.0121	**
Constant	4.948	1.189		***	5.742	3.033		*	3.549	1.710		*
obs. P	0.8280				0.7443				0.7861			
pred. P	0.8761				0.9051				0.8658			
N =	558				219				360			
LR chi2(37) =	106.7				114.42				87.52			
Prob > chi2 =	0.0000				0.0000				0.0000			
Pseudo R2 =	0.2082				0.4595				0.2342			
Log likelihood =	-202.83				-68.136				-143.1			

[1] 2 failures and 0 successes completely determined. [2] 1 failure and 4 successes completely determined. [3] 1 failure and 3 successes completely determined.
* significant at 10% level, ** significant at 5% level, *** significant at 1% level

2) Step two – Choice of adaptation strategy

After having decided to take an adaptation action in step one, the analysis in step two focuses on the adapting households to find out how they make a decision to choose a particular livelihood-based adaptation strategies for each type of shock. In step two, the models in step one can be expanded to multivariate probit regression to allow for multiple options of a given number of adaptation strategies $j = 1, \dots, J$. The MVP regression also extends the error term ε_i which now has multivariate normal distribution, each with a zero mean and variance-covariance matrix V, where variance $\rho_{jk} = 1$ for $j = k$ and covariances $\rho_{jk} = \rho_{kj}$ to allow for correlation with each other (Cappellari and Jenkins 2003).

As shown in the previous section, four common adaptation strategies are identified for drought (replanting, sell assets, reduce consumption and borrow) and crop pests/diseases (replanting, sell assets, borrow and seek treatment. Hence MVP regression with four options is suitable for modeling drought and crop pests/diseases adaptation strategy choice decision-making. Both models can be specified as following:

Model 2A and 2C: Choice of adaptation strategy for drought and crop pests/diseases

$$Y_{i1} = \begin{cases} 1 \text{ (Adaptation strategy 1)} & \text{if } Y_{i1}^* = \alpha_1 S_{i1} + \rho_1 P_{i1} + \varphi_1 F_{i1} + \sigma_1 G_{i1} + \beta_1 X_{i1} + \delta_1 L_{i1} + \varepsilon_{i1} > 0 \\ 0 \text{ (Otherwise)} & \text{if } Y_{i1}^* \leq 0 \end{cases}$$

$$Y_{i2} = \begin{cases} 1 \text{ (Adaptation strategy 2)} & \text{if } Y_{i2}^* = \alpha_2 S_{i2} + \rho_2 P_{i2} + \varphi_2 F_{i2} + \sigma_2 G_{i2} + \beta_2 X_{i2} + \delta_2 L_{i2} + \varepsilon_2 > 0 \\ 0 \text{ (Otherwise)} & \text{if } Y_{i2}^* \leq 0 \end{cases}$$

$$Y_{i3} = \begin{cases} 1 \text{ (Adaptation strategy 3)} & \text{if } Y_{i3}^* = \alpha_3 S_{i3} + \rho_3 P_{i3} + \varphi_3 F_{i3} + \sigma_3 G_{i3} + \beta_3 X_{i3} + \delta_3 L_{i3} + \varepsilon_{i3} > 0 \\ 0 \text{ (Otherwise)} & \text{if } Y_{i3}^* \leq 0 \end{cases}$$

$$Y_{i4} = \begin{cases} 1 \text{ (Adaptation strategy 4)} & \text{if } Y_{i4}^* = \alpha_4 S_{i4} + \rho_4 P_{i4} + \varphi_4 F_{i4} + \sigma_4 G_{i4} + \beta_4 X_{i4} + \delta_4 L_{i4} + \varepsilon_{i4} > 0 \\ 0 \text{ (Otherwise)} & \text{if } Y_{i4}^* \leq 0 \end{cases}$$

Based on the simulated maximum likelihood (SML) method, estimation of the MVP models applies the Geweke-Hajivassilion-Keane smooth recursive conditioning simulator which draws upon the product of sequentially conditioned univariate normal distribution functions with joint probability.

On the other hand, replanting is the only dominant adaptation strategy for flooding/excessive rain. Therefore a standard probit regression with one dichotomous decision variable is appropriate and specified as following:

Model 2B: Replanting as a choice of adaptation strategy for flooding/excessive rain

$$Y_i = \begin{cases} 1 \text{ (Replanting)} & \text{if } Y_i^* = \alpha_i S_i + \rho_i P_i + \varphi_i F_i + \sigma_i G_i + \beta_i X_i + \delta_i L_i + \varepsilon_i > 0 \\ 0 \text{ (Otherwise)} & \text{if } Y_i^* \leq 0 \end{cases}$$

Estimation of Model 2B is similar to that of Model 1B.

Each of the three models uses the same set of explanatory variables as the preceding univariate model of the first step.

Table 8 summarizes results of multivariate probit regression for specific adaptation strategies to cope with drought. Replanting is found to be a competing strategy for selling assets and borrowing. On the other hand selling assets is a substitution for consumption reduction but complementary for borrowing while the latter is in turn complementary for consumption reduction. Replanting as the first and most preferred adaptation strategy is encouraged by lower severity of income reduction from drought and food crop production decrease from flooding/excessive rain and crop pests/diseases. The probability to choose replanting is higher for households who belong to larger networking of associations, having lower herd size of livestock, smaller farm size and adopted improved maize variety. Furthermore, households reside in dry and high-temperature areas are more likely to choose replanting as adaptation measure to drought. Frequency of drought and its income reduction together with compound experience of drought and crop pests/diseases increase the likelihood that assets will be sold. More interestingly, poor and food insecure households tend to resort to consumption reduction. The likelihood to reduce consumption increases with less drought and crop pests/diseases experience especially when food crop production reduction from crop pests/diseases is severe. Larger household size puts more constraint on consumption for each of the member especially when they do not earn additional off-farm income. Consumption reduction is found to be more likely for households in rain-abundant and low-temperature areas. Borrowing is more likely for poor households with less severe income loss from flooding/excessive rain and do not practice maize-legume intercropping.

Determinants for replanting as the single dominant adaptation strategy for flooding/excessive rain are summarized in Table 9. Standard probit regression shows that the likelihood of replanting increases for households who did not experience frequent crop pests/diseases alone but as a compound experience of drought and crop pests/diseases with low severity in income reduction from crop pests. Moreover, the negative significant multiplication term between asset and flooding/excessive rain shows that small asset base and frequent incidents of flooding/excessive rain encourages decision to replant. Replanting is also significantly supported by lower education level and older age of household head with large association network and coverage of extension services.

Factors influencing decision to choose specific adaptation strategy for crop pests/diseases are summarized in Table 10. Replanting is less likely if households have experienced both crop pests/diseases in combination with drought and the income reduction from drought is high. Less severe income reduction from crop pests/diseases, on the other hand, supports replanting. Households with large asset who experience flooding/excessive rain and crop pests/diseases are more likely to replant. The probability to replant is higher for households above poverty line who earn additional off-farm income. Maize-legume intercropping reduces the probability that replanting is chosen. Households living in dry and warm area are more likely to replant to cope with crop pests/diseases. Drought frequency encourages selling of assets only if income reduction from drought is not severe while households are more likely to sell assets if crop pests/diseases reduces large income. Moreover, selling assets are more likely for food secure and female-headed households with high education, large household size, large livestock herd, practice maize-legume rotation but no additional off-farm income. Borrowing, on the other hand, is favoured among food insecure households with no additional off-farm income living in high-rainfall areas. Lastly, households who suffered frequent flooding/excessive rain and drought together with crop pests/diseases are more likely to seek treatment but only if drought and crop pests/diseases did not severely reduce food crop production and income. Socio-economically, poor and small-size households with elder heads who adopted improved maize variety are more likely to seek treatment to cure crop pests/diseases. In contrast to replanting, households living in high rainfall and cold temperature area are more likely to seek treatment which is further encouraged by short distance to main market.

Table 8: Multivariate probit regression results for specific adaptation strategies to cope with drought

Multivariate Probit regression (SML, # draws = 30)	**Replanting**			**Sell assets**			**Reduce consumption**			**Borrow**		
Model 2A: Applied specific adaptation strategy for <u>drought</u>	Coef.	Std.Err.	Marginal Effect	Coef.	Std.Err.	Marginal Effect	Coef.	Std.Err.	Marginal Effect	Coef.	Std.Err.	Marginal Effect
Shock experience and effect												
Drought frequency in last 10 years	-0.200	0.172	-0.0374	0.273	0.136	0.0798 **	-0.202	0.106	-0.0400 *	0.050	0.087	0.0115
Flood/rain frequency in last 10 years	-0.053	0.309	-0.0098	-0.232	0.235	-0.0680	0.368	0.564	0.0728	0.641	0.667	0.1490
Crop pest frequency in last 10 years	-0.112	0.165	-0.0209	-0.233	0.151	-0.0682	-0.014	0.174	-0.0027	0.079	0.164	0.0184
Drought frequency in last 10 years (squared)	0.026	0.020	0.0048	-0.025	0.014	-0.0073 *	0.012	0.009	0.0023	0.002	0.007	0.0005
Flood/rain frequency in last 10 years (squared)	0.023	0.038	0.0042	0.018	0.023	0.0052	-0.100	0.108	-0.0199	-0.161	0.141	-0.0375
Crop pest frequency in last 10 years (squared)	0.009	0.015	0.0017	0.016	0.014	0.0045	0.011	0.016	0.0021	-0.014	0.015	-0.0033
Experienced drought & flood/rain in last 10 years	0.406	0.474	0.0759	-0.203	0.365	-0.0595	-0.609	0.695	-0.1207	-0.290	0.702	-0.0673
Experienced drought & crop pest in last 10 years	-0.167	0.371	-0.0312	0.788	0.308	0.2306 **	-0.710	0.393	-0.1406 *	-0.115	0.337	-0.0267
Experienced flood/rain & crop pest in last 10 years	2.065	0.428	0.3863 ***	-1.504	0.325	-0.2814 ***	-0.159	0.400	-0.0298	-0.466	0.353	-0.0872
Food production reduction from drought	-0.002	0.005	-0.0003	-0.007	0.004	-0.0020 *	0.005	0.005	0.0010	0.000	0.004	0.0000
Food production reduction from flood/rain	-0.013	0.007	-0.0023 *	0.004	0.007	0.0013	0.000	0.007	0.0001	0.011	0.007	0.0025
Food production reduction from crop pest	-0.016	0.006	-0.0030 ***	0.004	0.005	0.0011	0.027	0.006	0.0054 ***	0.003	0.006	0.0008
Income reduction from drought	-0.012	0.006	-0.0023 **	0.008	0.005	0.0025 *	-0.002	0.005	-0.0004	-0.001	0.005	-0.0003
Income reduction from flood/rain	0.008	0.011	0.0015	0.008	0.009	0.0024	0.017	0.010	0.0033	-0.025	0.011	-0.0058 **
Income reduction from crop pest	-0.001	0.008	-0.0002	-0.005	0.008	-0.0016	-0.025	0.009	-0.0050 ***	-0.002	0.008	-0.0006
Asset x Drought frequency in last 10 years	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000
Asset x Flood/rain frequency in last 10 years	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000
Asset x Crop pest frequency in last 10 years	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000
Poverty	***0.293***	***0.189***	***0.0549***	***-0.011***	***0.162***	***-0.0032***	***0.516***	***0.199***	***0.1021 *****	***0.409***	***0.174***	***0.0951 *****
Food security	***-0.046***	***0.197***	***-0.0086***	***0.234***	***0.161***	***0.0684***	***-0.370***	***0.188***	***-0.0734 *****	***-0.033***	***0.177***	***-0.0077***
Gender of household head	***0.053***	***0.226***	***0.0100***	***0.304***	***0.194***	***0.0890***	***-0.011***	***0.234***	***-0.0022***	***-0.072***	***0.207***	***-0.0167***

Multivariate Probit regression (SML, # draws = 30) **Model 2A: Applied specific adaptation strategy for <u>drought</u>**	**Replanting**			**Sell assets**			**Reduce consumption**			**Borrow**		
	Coef.	Std.Err.	Marginal Effect	Coef.	Std.Err.	Marginal Effect	Coef.	Std.Err.	Marginal Effect	Coef.	Std.Err.	Marginal Effect
Socio-demographic characteristics												
Education of household head	-0.016	0.026	-0.0031	-0.001	0.021	-0.0003	0.008	0.026	0.0016	-0.034	0.024	-0.0079
Age of household head	0.008	0.006	0.0016	-0.002	0.005	-0.0005	0.007	0.006	0.0014	0.000	0.006	-0.0001
Household size	0.052	0.052	0.0098	-0.045	0.040	-0.0131	0.119	0.051	0.0235 **	0.034	0.046	0.0078
Asset	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000
Off-farm income	0.000	0.000	0.0000	0.000	0.000	0.0000	-0.0000	0.000	-0.0000 **	0.000	0.000	0.0000
Expenditure	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000
Had contact with extension in 2009/2010	0.150	0.176	0.0280	-0.142	0.145	-0.0414	0.054	0.174	0.0107	0.025	0.162	0.0057
Number of associations household belong to	0.380	0.102	0.0712 ***	-0.064	0.084	-0.0186	-0.112	0.098	-0.0221	0.000	0.090	0.0000
Tropical Livestock Unit	-0.099	0.038	-0.0186 ***	0.044	0.031	0.0129	-0.044	0.042	-0.0088	-0.013	0.035	-0.0029
Farm size	-0.313	0.108	-0.0585 ***	-0.012	0.101	-0.0036	0.001	0.107	0.0003	-0.061	0.104	-0.0143
Area under improved maize variety	0.516	0.207	0.0964 **	0.125	0.125	0.0366	-0.111	0.189	-0.0220	0.149	0.142	0.0347
Practiced maize-legume intercrop	0.244	0.197	0.0456	-0.042	0.174	-0.0124	-0.045	0.215	-0.0089	-0.513	0.196	-0.1192 ***
Practiced maize-legume rotation	0.028	0.216	0.0053	-0.160	0.190	-0.0468	0.179	0.239	0.0355	0.021	0.216	0.0050
Practiced crop residue retention	0.027	0.200	0.0051	-0.134	0.167	-0.0393	-0.298	0.202	-0.0590	-0.235	0.183	-0.0546
Location												
Average district rainfall 2010	-0.408	0.142	-0.0764 ***	-0.072	0.115	-0.0210	0.613	0.138	0.1215 ***	0.064	0.123	0.0149
Average district temperature 2010	0.174	0.061	0.0326 ***	-0.075	0.047	-0.0219	-0.156	0.056	-0.0308 ***	0.077	0.052	0.0180
Distant to the main market from residence	-0.014	0.013	-0.0027	0.023	0.015	0.0068	-0.001	0.018	-0.0002	0.015	0.009	0.0035
Constant	-0.786	1.400		0.844	1.122		-0.390	1.296		-2.374	1.226	*

/atrho21	-1.053	0.159 ***	rho21	-0.783	0.062 ***		Log likelihood =	-668.527
/atrho31	-0.163	0.138	rho31	-0.162	0.135		Number of obs =	462
/atrho41	-0.508	0.124 ***	rho41	-0.468	0.097 ***		Wald chi2(148) =	299.15
/atrho32	-0.272	0.108 ***	rho32	-0.266	0.101 ***		Prob > chi2 =	0.0000
/atrho42	0.196	0.103 *	rho42	0.193	0.099 *			
/atrho43	0.763	0.140 ***	rho43	0.643	0.082 ***			

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: chi2(6) = 139.458 Prob > chi2 = 0.0000

* significant at 10% level, ** significant at 5% level, *** significant at 1% level

Table 9: Standard probit regression results for replanting as adaptation strategy to flooding/excessive rain

Probit regression Model 2B: Replanting as adaptation strategy for flooding/excessive rain	Replanting[1] Coef.	Std.Err.	Marginal Effect
Shock experience and effect			
Drought frequency in last 10 years	-1.63	0.10	0.0000
Flood/rain frequency in last 10 years	0.83	0.41	0.0000
Crop pest frequency in last 10 years	-2.31	0.02	0.0000 **
Drought frequency in last 10 years (squared)	1.95	0.05	0.0000 *
Flood/rain frequency in last 10 years (squared)	0.23	0.82	0.0000
Crop pest frequency in last 10 years (squared)	2.43	0.02	0.0000
Experienced drought & flood/rain in last 10 years	(omitted)[2]		
Experienced drought & crop pest in last 10 years	1.88	1.12	0.0008 *
Experienced flood/rain & crop pest in last 10 years	(omitted)[3]		
Food production reduction from drought	1.01	0.31	0.0000
Food production reduction from flood/rain	-0.30	0.76	0.0000
Food production reduction from crop pest	1.19	0.23	0.0000
Income reduction from drought	-1.49	0.14	0.0000
Income reduction from flood/rain	1.06	0.29	0.0000
Income reduction from crop pest	-1.66	0.10	0.0000 *
Asset x Drought frequency in last 10 years	-1.30	0.19	0.0000
Asset x Flood/rain frequency in last 10 years	-1.80	0.07	0.0000 *
Asset x Crop pest frequency in last 10 years	1.53	0.13	0.0000
Poverty	-1.62	0.11	0.0000
Food security	0.39	0.70	0.0000
Gender of household head	1.41	0.16	0.0001
Socio-demographic characteristics			
Education of household head	-1.74	0.08	0.0000 *
Age of household head	2.82	0.01	0.0000 ***
Household size	-0.57	0.57	0.0000
Asset	1.14	0.25	0.0000
Off-farm income	-0.24	0.81	0.0000
Expenditure	-0.21	0.84	0.0000
Had contact with extension in 2009/2010	-2.12	0.03	0.0000 **
Number of associations household belong to	1.65	0.10	0.0000 *
Tropical Livestock Unit	-0.56	0.57	0.0000
Farm size	-0.77	0.44	0.0000
Area under improved maize variety	0.70	0.48	0.0000
Practiced maize-legume intercrop	-1.30	0.19	0.0000
Practiced maize-legume rotation	1.08	0.28	0.0001
Practiced crop residue retention	-1.35	0.18	0.0000
Location			
Average district rainfall 2010	-0.11	0.91	0.0000
Average district temperature 2010	1.04	0.30	0.0000
Distant to the main market from residence	0.40	0.69	0.0000
Constant	-0.65	0.52	0.0051
obs. P	0.8671		
pred. P	1.0000		
N =	158		
LR chi2(37) =	62.52		
Prob > chi2 =	0.0040		
Pseudo R2 =	0.5049		
Log likelihood =	-30.658		

[1] 0 failures and 21 successes completely determined. [2] Variable predicts success perfectly. [3] Collinearity.

* significant at 10% level, ** significant at 5% level, *** significant at 1% level

Table 10: Multivariate probit regression results for specific adaptation strategies to crop pests/diseases

Multivariate Probit regression (SML, # draws = 5) **Model 2C: Applied specific adaptation strategy for crop pests/diseases**	**Replanting** Coef.	Std.Err.	Marginal Effect	**Sell assets** Coef.	Std.Err.	Marginal Effect	**Borrow** Coef.	Std.Err.	Marginal Effect	**Seek treatment** Coef.	Std.Err.	Marginal Effect
Shock experience and effect												
Drought frequency in last 10 years	0.420	0.271	0.0752	1.602	0.543	0.2849 ***	-0.316	0.395	-0.0354	-0.078	0.185	-0.0185
Flood/rain frequency in last 10 years	0.333	0.455	0.0597	-1.379	1.831	-0.2454	-1.015	0.644	-0.1137	0.847	0.311	0.1995 ***
Crop pest frequency in last 10 years	-0.328	0.241	-0.0587	0.053	0.258	0.0094	-0.066	0.315	-0.0074	-0.276	0.181	-0.0651
Drought frequency in last 10 years (squared)	-0.028	0.029	-0.0051	-0.263	0.088	-0.0467 ***	0.005	0.057	0.0006	0.027	0.021	0.0063
Flood/rain frequency in last 10 years (squared)	-0.044	0.050	-0.0078	0.065	0.415	0.0115	0.067	0.095	0.0075	-0.062	0.032	-0.0146 *
Crop pest frequency in last 10 years (squared)	0.023	0.021	0.0041	-0.035	0.026	-0.0062	0.015	0.026	0.0017	0.013	0.016	0.0032
Experienced drought & flood/rain in last 10 years	-0.424	0.670	-0.0759	0.632	1.581	0.1125	0.090	0.952	0.0101	-0.658	0.479	-0.1549
Experienced drought & crop pest in last 10 years	-2.590	0.943	-0.4640 ***	-0.816	1.020	-0.1451	5.210	#####	0.5835	1.337	0.720	0.3149 *
Experienced flood/rain & crop pest in last 10 years		(omitted)[1]			(omitted)[1]			(omitted)[1]			(omitted)[1]	
Food production reduction from drought	0.008	0.009	0.0015	0.004	0.008	0.0008	-0.004	0.014	-0.0005	-0.021	0.007	-0.0050 ***
Food production reduction from flood/rain	-0.006	0.011	-0.0011	-0.007	0.017	-0.0013	0.009	0.014	0.0010	0.001	0.009	0.0003
Food production reduction from crop pest	-0.007	0.008	-0.0013	-0.007	0.009	-0.0012	0.005	0.013	0.0005	0.003	0.007	0.0007
Income reduction from drought	0.025	0.009	0.0046 ***	-0.025	0.010	-0.0045 ***	-0.002	0.013	-0.0002	0.011	0.007	0.0025
Income reduction from flood/rain	0.020	0.023	0.0036	-0.013	0.029	-0.0023	0.032	0.020	0.0036	-0.026	0.020	-0.0061
Income reduction from crop pest	-0.027	0.012	-0.0048 **	0.031	0.013	0.0055 **	-0.027	0.020	-0.0030	-0.019	0.010	-0.0044 *
Asset x Drought frequency in last 10 years	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000
Asset x Flood/rain frequency in last 10 years	0.000	0.000	0.0000 *	0.000	0.000	0.0000 *	0.000	0.000	0.0000	0.000	0.000	0.0000
Asset x Crop pest frequency in last 10 years	0.000	0.000	0.0000 **	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000
Poverty	***-0.514***	***0.270***	***-0.0921 ****	***0.175***	***0.276***	***0.0312***	***0.389***	***0.370***	***0.0436***	***0.598***	***0.227***	***0.1408 ******
Food security	***-0.012***	***0.297***	***-0.0022***	***0.584***	***0.296***	***0.1038 *****	***-0.875***	***0.364***	***-0.0980 *****	***0.080***	***0.252***	***0.0188***
Gender of household head	***0.240***	***0.335***	***0.0430***	***-0.850***	***0.349***	***-0.1513 *****	***0.736***	***0.460***	***0.0824***	***0.424***	***0.301***	***0.0998***

Multivariate Probit regression (SML, # draws = 5) **Model 2C: Applied specific adaptation strategy for crop pests/diseases**	**Replanting**			**Sell assets**			**Borrow**			**Seek treatment**		
	Coef.	Std.Err.	Marginal Effect	Coef.	Std.Err.	Marginal Effect	Coef.	Std.Err.	Marginal Effect	Coef.	Std.Err.	Marginal Effect
Socio-demographic characteristics												
Education of household head	0.023	0.039	0.0041	0.067	0.037	0.0120 *	-0.066	0.050	-0.0074	0.026	0.031	0.0061
Age of household head	0.013	0.009	0.0024	-0.007	0.009	-0.0013	0.005	0.011	0.0005	0.014	0.008	0.0032 *
Household size	-0.034	0.078	-0.0060	0.256	0.086	0.0456 ***	-0.053	0.086	-0.0059	-0.116	0.066	-0.0273 *
Asset	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000
Off-farm income	0.000	0.000	0.0000 *	-0.0000	0.000	-0.0000 **	-0.0000	0.000	-0.0000 *	0.000	0.000	0.0000
Expenditure	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000	0.000	0.000	0.0000
Had contact with extension in 2009/2010	0.271	0.281	0.0486	0.140	0.278	0.0249	-0.024	0.348	-0.0027	-0.069	0.219	-0.0162
Number of associations household belong to	0.003	0.150	0.0005	-0.063	0.167	-0.0112	0.051	0.232	0.0057	0.117	0.132	0.0275
Tropical Livestock Unit	0.056	0.075	0.0101	0.116	0.070	0.0206 *	0.000	0.070	0.0000	0.024	0.076	0.0058
Farm size	-0.154	0.210	-0.0275	0.232	0.183	0.0413	-0.218	0.192	-0.0244	-0.198	0.133	-0.0467
Area under improved maize variety	0.489	0.307	0.0876	-0.349	0.243	-0.0621	0.295	0.272	0.0330	0.328	0.184	0.0773 *
Practiced maize-legume intercrop	-0.613	0.261	-0.1099 **	0.208	0.288	0.0371	0.202	0.436	0.0226	-0.146	0.233	-0.0343
Practiced maize-legume rotation	-0.297	0.305	-0.0532	0.639	0.337	0.1137 *	0.216	0.541	0.0242	-0.237	0.264	-0.0559
Practiced crop residue retention	0.079	0.273	0.0141	0.224	0.263	0.0399	0.458	0.467	0.0513	-0.051	0.242	-0.0121
Location												
Average district rainfall 2010	-1.491	0.248	-0.2671 ***	-0.109	0.256	-0.0193	0.536	0.309	0.0600 *	0.589	0.186	0.1387 ***
Average district temperature 2010	0.505	0.106	0.0905 ***	-0.134	0.093	-0.0238	0.086	0.097	0.0097	-0.255	0.088	-0.0600 ***
Distant to the main market from residence	0.003	0.013	0.0005	0.006	0.017	0.0011	-0.031	0.041	-0.0035	-0.059	0.028	-0.0140 **
Constant	-2.642	2.335		-0.050	2.093		-8.980	#####		1.743	1.992	

/atrho21	-0.558	0.183 ***	rho21	-0.507	0.136 ***		Log likelihood =	-321.186
/atrho31	-0.626	0.313 **	rho31	-0.555	0.217 **		Number of obs =	280
/atrho41	-0.206	0.170	rho41	-0.203	0.163		Wald chi2(148) =	243.2
/atrho32	0.528	0.247 **	rho32	0.483	0.189 **		Prob > chi2 =	0.0000
/atrho42	-0.517	0.163 ***	rho42	-0.475	0.127 ***			
/atrho43	-0.361	0.222 *	rho43	-0.346	0.195 *			

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: chi2(6) = 52.5656 Prob > chi2 = 0.0000

[1] Collinearity * significant at 10% level, ** significant at 5% level, *** significant at 1% level

6) Conclusion and discussion

Adaptation to climate-related agricultural production shocks is essential to building resilience for small-scale farm households towards progressive climate change and to support sustainable intensification for food security of the poor. Drought, flooding/excessive rain and crop pests/diseases are identified as major climate-related production shocks for maize-legume farm households in Western and Eastern Kenya where the effects of these shocks are translated into reduction in food crop production and income. Moreover, all farmers expect the frequency of these shocks to increase during the next 10 years. Although the majority of farmers applied adaptation strategies, a significant proportion of farmers did nothing. Decision to adapt to each of the shock and to choose a particular adaptation strategy depends on not only one shock incident and its severity in isolation but also on compound experience and severity of different shock types over a given period as well as different in rainfall and temperature in the location. Food insecure households are found to be less capable to adapt to drought and crop pests/diseases than food secure households while female-headed households are more active in adapting to drought and flooding/excessive rain than male-headed households. Replanting is found to be the most common and preferred adaptation strategy to cope with all three shock types and it is the single dominant strategy to cope with flooding/excessive rainfall. Additional common adaption strategies for drought includes sell assets, reduce consumption and borrow while additional crop pests/diseases adaptation strategies are sell assets, borrow and seek treatment. Some of the adaptation strategies are complementary to each other while some others are substituting. To bridge hunger from drought, poor and food insecure households are more likely to eat less. To cope with crop pests/diseases, poor households are less likely to replant but more likely to seek treatment while food secure households and female-headed households are more likely to sell assets. Similar to drought adaptation, food insecure households are more likely to borrow to cope with crop pests/diseases.

Understanding how the poor, the food insecure and the female-headed households are usually faced with climate-related production shocks and how they make decision to adapt is the first step for policy to target effective assistance. For example, public programs can be set up to enhance adaptation capacity by giving support for replanting, access to market and credit to the poor, the food insecure and the female-headed households in drought-, flooding/excessive rain- and crop pests/diseases-prone areas. To cushion consumption reduction, additional food aid can be arranged targeting especially at the poor and the food insecure households. However, more research is required to understand the implication and effectiveness of each adaptation strategy on household's food security and income for each of the household category.

References

ACDI/VOCA (2007) Kenya Maize Handbook. ACDI/VOCA – Kenya Training Manual No. 27

Bellarby , J. , Foereid , B. , Hastings , A. and Smith , P. (2008) Cool Farming : Climate impacts of agriculture and mitigation potential , Greenpeace International , Amsterdam, Netherlands.

Cavatassi, R., Lipper, L. and Narloch, U. (2011) Modern variety adoption and risk management in drought prone areas: insights from the sorghum farmers of eastern Ethiopia. *Agricultural Economics*, 42: 279–292.

Claessens, L., Antle, J.M., Stoorvogel, J.J., Valdivia, R.O., Thornton, P.K. and Herrero, M. (2012) A method for evaluating climate change adaptation strategies for small-scale farmers using survey, experimental and modeled data. *Agricultural Systems*, 111: 85-95.

Cooper, P.J.M., Dimes, J., Rao, K., Shapiro, B. and Twomlow, S. (2008) Coping better with current climatic variability in the rain-fed farming systems of Sub-Saharan Africa: An essential first step in adapting to future climate change? *Agric. Ecosyst. Environ*, 126: 24-35.

Cutter, S.L., B.J. Boruff and Shirley W.L. (2003) Social vulnerability to environmental hazards. *Social Science Quarterly*, 84: 242–261.

Dercon S. (2007). Fate and fear: Risk and its consequences in Africa. Oxford: Oxford University. Paper prepared for the African Economic Research Consortium.

Di Falco, S., Yesuf, M.., Kohlin, G. and Ringler, C. (2011) Estimating the impact of climate change on agriculture in low-income countries: household level evidence from the Nile Basin, Ethiopia. *Environmental and Resource Economics*, 52 (4): 457-478.

FAO, 2009. FAO's role in the Syria Drought Response Plan 2009. Food And Agriculture Organization, Rome, Italy.

Glewwe, P. and Gillette, H. (1998) Are some groups more vulnerable to macroeconomic shocks than others? Hypothesis tests based on panel data from Peru. *Journal of Development Economics*, 56(1): 181-206.

IPCC (2007) Climate Change 2007: Synthesis report.

Jalan, J. and Ravallion, M. (1999) Are the poor less well insured? Evidence on vulnerability to income risk in rural China. *Journal of Development Economics*, 58(1): 61-81.

Jitsuchon, S. (2010) Adaptations to climate change of poor Thai farmers. Background paper for Conference on the "The Environments of the Poor", Asian Development Bank, 24-26 Nov 2010, New Delhi.

Kochar, A. (1999) Smoothing consumption by smoothing income: Hours-of-work responses to idiosyncratic agricultural shocks in rural India. *The Review of Economics and Statistics*, 81(1): 50-61.

KNBS (2013) Kenya National Bureau of Statistics

Kristjanson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F.B., Desta, S., Sayula, G., Thiede, B., Förch, W., Thornton, P.K. and Coe, R. (2012) Are food insecure smallholder households making changes in their farming practices? Evidence from East Africa. *Food Security*, 4(3): 318 - 397

Mercer, K.L., Perales, H.R., Wainwright, J.D. (2012) Climate change and the transgenic adaptation strategy: Smallholder livelihoods, climate justice, and maize landraces in Mexico *Global Environmental Change,* 22: 495-504

Newhouse, D.L. (2005) The persistence of income shocks: Evidence from rural Indonesia. *Review of Development Economics,* 9(3): 415-433.

Nyoro J, Ayieko M and Muyanga M. (2007) The Compatibility of Trade Policy with Domestic Policy Interventions Affecting the Grains Sector in Kenya. Tegemeo Institute, Egerton University.

Osbahr, H., Twyman, C., Adger, N. and Thomas, D.S.G. (2008) Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique. *Geoforum*, 39: 1951-1964.

Rashid, D.A., Langworthy, M. and Aradhyula, S. (2006) Livelihood shocks and coping strategies: An empirical study of Bangladesh households. Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Long Beach, California, 23-26 July, 2006

Roncoli, C., Ingram, K. and Kirshen, P. (2001) The costs and risks of coping with drought: Livelihood impacts and farmer's responses in Burkina Faso. *Clim. Res.*, 19: 119-132.

Tadesse, M., & Brans, M. (2012) Risk Coping Mechanisms and Factors Affecting demand for Micro-insurance in Ethiopia. *Journal of Economics & International Finance,* 4(4): 79-91.

Takasaki, Y., Barham B.L. and Coomes O.T. (2002) Risk coping strategies in tropical forests: Flood, health, asset poverty, and natural resource extraction. Paper prepared for the 2nd World Congress of Environmental and Resource Economists, 23-27 June 2002, Monterey, California.

Tongruksawattana, S., Junge, V., Waibel, H., Revilla Diez, J. and Schmidt, E. (2012) "Ex-post Coping Strategies of Rural Households in Thailand and Vietnam." *Vulnerability to Poverty: Theory, Measurement, and Determinants.* Ed. Stephan Klasen and Hermann Waibel. Palgrave.

UNFCCC (2007) Uniting on Climate. A Guide to the Climate Change Convention and the Kyoto Protocol.

USAID KMDP (2011) USAID Kenya Maize Development Program.

WEMA (2012). Water Efficient Maize for Africa. Reducing Maize Insecurity in Kenya: the WEMA project Policy Brief.

World Bank (2010) World Development Report 2010: Development and Climate Change. Oxford University Press: Washington D.C. 2010.

World Development Indicators (2012) The World Bank.