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**Seed Systems and Climate Change: Exploring Perceptions and Options for Building  
Resilience of Farmer Seed Systems in Uganda**

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## **Abstract**

Given the challenges facing agriculture resulting from climate change, building resilience is a priority. Seed systems are an important area for enhancing such resilience as seed security has direct links to food security, and resilient livelihoods in general. This study used data from a nationally representative sample to assess farmer perceptions of climate change, its effects on livelihoods and seed systems, and options for enhancing resilience of their seed systems. Drought or irregular rains were considered the most important climate factor affecting crop production and farmer seed systems. Effect of climate change on seed system was perceived in relation to the diminishing levels in quantity and quality of yield. The type of seed grown by farmers were mainly local or recycled varieties which they perceived to combine attributes of adaptability to climate, high yield and marketability, and these were generally supplied by the informal sector. Farmers' access to different sources of seed also played an important role in the type of variety they used. Identification and promotion of crop varieties suited for different rainfall zones, and broadening seed production and supply of resilient varieties through farmer seed entrepreneurs are proposed as key actions for enhancing resilience of farmer seed systems.

**Key words:** Drought, Resilience, Seed systems, Varieties.

## **1 Study background and rationale**

Agriculture is the backbone of most African economies and the livelihood of many people. However, agriculture is often characterized by high variability of production outcomes, that is, by production risk. Unlike most other entrepreneurs, agricultural producers cannot predict with certainty the amount of output their production process will yield, due to external factors such as weather, pests, and diseases (van de Steeg et al., 2009). The effects of climate change add to the challenges facing agricultural producers in Africa in producing enough food for the growing population. Rapid and uncertain changes in temperature and rainfall pattern markedly affect food production, lead to food price shocks, increase the vulnerability of smallholder farmers and accentuate rural poverty (AGRA, 2014). The length of the growing period, which is an indicator of the adequacy of moisture availability, temperature and soil conditions for crop growth has been projected to decrease by up to 20% in most parts of Sub-Saharan Africa (SSA) by 2050 (Thornton et al., 2011).

An extensive literature has been developed on the impacts of climate change and variability on agriculture, with the earliest focusing primarily on the vulnerability of the sector (for example Kurukulasuriya and Mendelsohn, 2006). The general message is that the degree of vulnerability of the agricultural sector to climate variability and change is contingent on a wide range of local environmental and management factors: biological conditions, type of crop, extent of knowledge and awareness of expected changes in climate, the extent of support from government and other agencies, and the ability of key stakeholders to undertake the necessary remedial steps to address climate concerns. Livelihoods of households dependent on agriculture are particularly vulnerable to changes in the mean and variability of climate and the need for adaptation is highlighted in studies from Sub-Saharan Africa (for example Lobell et al., 2008).

A number of options for managing climate-induced risk in agriculture have been cited in literature. Diversifying agriculture with crops and varieties that can perform better under various climatic stresses is among the most cited strategies for adapting agriculture to climate variability and change (Di Falco et al., 2006; Kurukulasuriya and Mendelsohn, 2006; Nzuma et al., 2010). Crop adaptation requires farmers to make decisions on which crops to grow that are suited to their environments. Seed systems play a crucial role as a basis for crop selection and hybridization, and farmer selection may lead to incremental on-farm crop adaptation to climate change (Westengen and Brysting, 2014). Developing climate resilient seed systems will serve the key basis to minimize the associated production risks and provide opportunities for development of sustainable seed systems, as well as supporting access to quality seed by farmers.

However how climate change is impacting to seed sector is not well understood. Some previous studies have focused on seed systems during crises such as political and civil conflict, earthquakes or droughts (McGuire and Sperling, 2013). These crises are characterized by rapid onset and major agricultural-linked response following such crises have typically taken the form of supplying seed directly to beneficiaries. On the other hand, stresses caused by climate change are gradual thus seed systems analysis and tailoring of interventions to actual stresses in the system is paramount.

The seed system is the economic and social mechanism by which farmers' demands for seeds and the various traits they provide are met by various possible sources of supply (Lipper, 2003). Two different types of seed systems (i.e. formal and informal) are widely known (Almekinders and Louwaars, 1999). The formal seed system is characterized by a clear chain of activities, usually starting with plant breeding and promotion of materials for formal variety release and maintenance. Regulations exist in this system to maintain variety identity and purity as well as guarantee physical, physiological and sanitary quality. Seed marketing takes place through officially recognized seed outlets, and by way of national agricultural research systems (Louwaars 1994, ISSD Africa, 2013). The formal seed system is market-oriented and characterized by continuous varietal replacement as a mechanism of technology transfer and as a market strategy. Seeds of most cash and horticultural crops, particularly hybrids, are supplied by the formal seed system.

The informal seed system on the other hand embraces most of the other ways in which farmers themselves produce, disseminate and procure seed. The system usually plants local varieties of seed kept from the previous year's harvest or obtained from neighbors and/or the local market. The same general steps take place in the informal system as in the formal but as integral parts of farmers' grain production rather than as discrete activities. Local technical knowledge and standards guide informal seed system performance, including the prevailing market forces. Farm saving and recycling of improved varieties is also common (Lunduka et al., 2012), thus the distinction between the formal and informal seed systems is not clear-cut with regards to varieties in each system. Some studies have demonstrated that recycling and hybridization between landraces and improved varieties is a deliberate strategy used by smallholder farmers to combine desirable traits from improved and local varieties (Bellon et al., 2006; Westengen and Brysting, 2014).

Small-scale or resource-limited farmers, who make up nearly 80% of farming populations in developing countries, rely on the informal sector for their seed needs, particularly of subsistence crops. Like in most of SSA's agriculture, farmers in Uganda obtain up to 89% of their seed from own sources, by saving part of their harvest as seed for the next planting season, or exchange seed among neighbours and relatives, or buying grain at local markets for use as seed (Ferris and Laker-Ojok, 2006; ISSD Uganda, 2014). Taken together, formal organizations produce seed for an estimated 13% of planted area, ranging as high as 29% for maize, while the informal seed sector accounts for the remaining 87% of planted seed

(Gareba-Gaso and Gisselquist, 2012). The informal seed sector also plays a key role in multiplying planting material for vegetative propagated crops (such as *solanum* potatoes, cassava, sweet potatoes, bananas and various tropical fruit trees) as well as seed of self-pollinated crops, for which it is easy to maintain genetic purity through successive generations (such as millet, beans, barley, pigeon peas, cowpeas, green gram, sesame, wheat and rice).

Farmer seed will likely continue to be the main source of seed for subsistence crops in Uganda. Being an integral part of crop production, farmer seed systems face the same shocks facing crop production, including climate-induced stresses. There is therefore the need to introduce effective interventions aimed at ensuring that the informal sector is able to provide resource-limited farmers with the seed security that they require to achieve food security, despite the existing ecological and environmental challenges affecting agricultural production. Resilient seed systems have the capacity to absorb such shocks and stress, and reorganize so as to maintain and strengthen seed security over time (McGuire and Sperling, 2013). Seed security means having the right seed (demanded quantity and quality) available and accessible not just for the imminent planting season, but also for several seasons thereafter.

This study therefore aimed to understand the perceived common drivers of climate change at local level, and how these factors are impacting to livelihoods and seed system functions. Furthermore, the study analyzed the association between different categories of varieties and a range of individual, social and ecological factors to better understand the key factors conditioning farmers' decision about the type of seed they use. Key result of the analysis provide strategic inputs for recommendations for farmer seed system to be more resilient to climate stresses which can serve right varieties and seed to their communities in times of change.

## **2 Methodology**

### **2.1 Data and study area**

The study used data from Living Standards Measurement Survey (LSMS) by Uganda Bureau of Statistics and the World Bank, for the year 2011/2012. The survey reached 2,716 households on a nationally representative sample of households, conducted in two visits in order to better capture agricultural outcomes associated with the two cropping seasons of the country.

In order to capture variability in farming systems across the country, this study constructed a sampling frame based on agriculture production zones. The government of Uganda developed a plan for Zonal Agricultural Production, Agro-processing and Marketing, aimed



at increasing household incomes through sustainable and profitable zonal agricultural products for export. The zoning exercise divided the country into 10 production zones. An “*agricultural production zone*” is an area with similar socio-economic characteristics and where ecological conditions, farming systems and practices are fairly homogeneous (GOU, 2004). The major factors that were considered important for the zoning included: agro-ecological characteristics, cropping and livestock systems, socio-economic factors, geopolitics, infrastructure, land (tenure, availability, land holdings), and on-going agriculture-based initiatives. It is assumed that a unique agricultural production zone has common crops and livestock types, and zones may cut across districts.

Ten districts were randomly selected from each of the 10 production zones. Three of the zones – highland ranges, L. Victoria Crescent and pastoral rangelands showed variability even within the zone. For example, highland ranges cut across districts in western and eastern Uganda, defined largely by altitude, but differences exist in rainfall patterns and farming systems. In the western districts (Kabale, Kisoro and Kasese), the rainfall pattern is defined by two distinct rainy seasons, with the main season stretching from September – December, while in the eastern districts (Mbale, Sironko and Kapchorwa), the rainfall pattern is defined by one long rainy season from March to October (first peak in April and second peak in August). Similarly, districts clustered for L. Victoria Crescent production zone exhibit some differences in farming systems, with districts in central region growing mainly banana/coffee/cocoa, while districts in the east grow mainly annual crops, with millet dominating. Pastoral Rangelands, also exhibit variations in major farming systems, with areas in Masaka being banana/coffee/cattle farming systems while areas in Nakasongola are largely agro-pastoral. In this case, an additional district was purposively selected from each of these three zones to capture the variability within the zone.

In total, 13 agricultural districts were included in the analysis, comprising 331 households. The analysis combined and used data from three different surveys - agriculture survey, household survey and geographical variables. Data were combined using household identity (HHID) as the unique identifier for the three data sets. LSMS survey data was supported by case study analysis in West Nile zone (Arua, Zombo and Nebbi districts) that reached 90 household through a survey and focus group discussions. In addition, literature review, rapid appraisal, expert elicitation and observations were used based on the author’s work and experience with seed sector development in Uganda.

Table 1 shows the main biophysical and production characteristics of the 13 study districts. Data showed variations in average rainfall amounts across the study districts, with western districts having relatively lower rainfall amounts compared to central and northern districts. Coefficient of variation in annual rainfall was generally small (<10%) for all districts except for Kabale which was at 15%. There are two well-defined rainy seasons in the south of the country (e.g., Kabale, Isingiro), progressively merging into one season towards the northern locations (e.g., Lira, Kitgum). In the western part of the country however,

conditions are generally drier and the bimodal cycle more pronounced (USAID, 2013). This is also evidenced by the lowest annual rainfall amounts for Isingiro district, of the study districts. Where the season is unimodal, the rainfall amounts tend to be higher due to prolonged rainy season, usually stretching from April to November with peaks around May and September.

**Table 1: Biophysical and production characteristics of the 13 study districts**

#	Production zone*	Sample district	Farming system	Pop. density (pers. km <sup>-2</sup> )	Annual mean temp. (°C)	Total annual rainfall (mm)	R/fall CV (%)
1	North Eastern Dry lands	Kitgum <sup>a</sup>	Pastoral, some annual crops	29	241	1,105	5.2
2	North Eastern Savannah Grassland	Lira <sup>a</sup>	Annual cropping and cattle northern system	121	227	1,253	2.2
3	North Western Savannah Grasslands	Arua <sup>a</sup>	Annual cropping and cattle, West Nile system	156	235	1150	9.0
4	Para Savannahs	Nebbi <sup>a</sup>	Simsim, sorghum, cattle	155	236	1104	6.7
5	Kioga Plains	Pallisa <sup>b</sup>	Millet, cotton system	328	235	1199	0.2
6	Lake Victoria Crescent	Bugiri <sup>b</sup>	Banana, millet, cotton, lakeshore	284	226	1449	2.1
		Mukono <sup>c</sup>	Intensive banana, coffee lakeshore	256	219	1221	2.3
7	Western Savannah Grasslands	Kibaale <sup>d</sup>	Western banana, coffee cattle	98	224	1186	8.0
8	Pastoral Rangelands	Nakasongola <sup>c</sup>	Agro-pastoral, annual crops	41	230	983	3.1
		Masaka <sup>c</sup>	Banana, coffee, cattle	245	212	1,114	2.6
9	South Western Farmlands	Isingiro <sup>d</sup>	Western banana, coffee cattle	112	192	803	4.2
10	Highland Ranges -	Kabale <sup>d</sup>	Montane farming	281	197	1129	15.2
		Mbale <sup>b</sup>	Medium altitude, coffee banana	534	192	1237	8.2

Superscripts a, b, c and d denote the geographical location where the district falls. A = northern, b = eastern, c = central and d = western

Source: Adapted from GOU (2004). Descriptive data based on LSMS survey data 2012.

## 2.2 *Theoretical framework*

A seed system can be analyzed from different perspectives and with different objectives. Weltzien and vom Brocke (2001) suggest using farmers' perspectives to analyze seed systems for identification of specific strengths and weaknesses. Weltzien and vom Brocke (2001) provide a framework for analyzing seed systems by focusing on their functions. These are; seed quality, appropriateness of variety, timeliness of seed availability, conditions under which seed is available, and capacity to innovate. These five functions can be analyzed based on four process-oriented components of seed system that overlap. These are; germplasm base, seed production and quality, seed availability and distribution, and information flow. Hirpa et al. (2010) modified the framework by Weltzien and vom Brocke by considering seed production and storage; seed quality; seed availability and distribution; and information flow as seed system components. In their case, the component of germplasm was considered to be addressed in the component of seed quality.

On the other hand, Jones (2013) suggests a framework that presents three seed system components; type of exchange, type of seed accessed, and value of the output. The framework by Jones (2013) builds on sociological and political economy critiques of the primacy of market integration (Gibson-Graham, 2006). Seed exchanges might occur across a spectrum that includes formal market structures, informal markets and non-formal exchange arrangements or self-provisioning (Hart, 2006). The second component is the type of seed being accessed, and who defines it, which has important implications for how and why it is accessed. Seeds can vary from those of pure improved varieties, to "creolized" varieties that evolve as improved varieties are saved and reused, to traditional landrace varieties managed by farmers and communities (Bellon et al., 2010). The last component, the value of the seed to the individual, which is conditioned by the social and natural context, informs decisions being made by farmers to access it. Farmers choose which varieties to access and how, based on multiple varietal characteristics, which can be conceptualized as representing varying degrees of use, exchange and commodity value of the output.

However, farmers in many developing countries are often unable to obtain healthy viable seed of preferred varieties at the time and under conditions that are best for them. McGuire (2001) describe this in terms of the health of the seed system and whether particular systems are under stress. This approach uses an ecological approach, drawing parallels with ecosystems that are healthy and those under stress. In this case, many seed systems are functioning imperfectly. In parallel with ecosystem health, Hodgkin and Jarvis (2003) identified properties of a healthy seed system as stability, resilience, diversity, efficiency and equity.

This study employed a modified analytical framework combining sociological and ecological approaches. The approach assumes that decisions about the type of exchange,

the type of seed and the value of seed being accessed by farmers are all conditioned by individual, social context and ecological characteristics. This is in line with McGuire and Sperling (2013) who indicate that resilience is not solely determined by individual household characteristics but rather emerges as a property of socio-ecological systems, influenced by the interplay of bio-physical features and institutions.

The study used farmers' perceptions to analyze climate related stress factors and how they condition the functioning of their seed system components (exchange, type of seed and value of the seed). This helped to understanding the factors that contribute to seed systems performance, how they relate to ecosystem characteristics, and how farmer seed systems can be enhanced to provide the right seed to smallholder farmers at all time. Furthermore, the association between different categories of genetic resources and a range of climate, production and income variables was analyzed.

### 2.3 *Statistical methods*

Analysis of quantitative data involved both descriptive and econometric analyses, with the econometric analysis involving bivariate regression analysis. Inferential statistics such as Chi square and correlation analysis were used to compare proportions of variables by district and along the rainfall gradient to understand level of significance.

In order to analyze the association between various factors (individual, social and ecological) and the type of seed farmers use, a multinomial logistic regression was used. The dependent variable was the type of seed farmers use. This study considered farmers' use of three different types of seed – local, improved and recycled. Following Westengen and Brysting (2014), local varieties were defined as those that had a long history in the community, or land races or those that were introduced from other communities and their genetic descriptors are not known. Improved varieties were those released by research either directly to the communities or through the formal sector. Farm-saved improved varieties re-used on a farm in two seasons or more were classified as farmer-recycled.

When the dependent variable has more than two alternatives among which the decision maker has to choose, the appropriate econometric model would either be multinomial logit or multinomial probit regression model. This study employed the multinomial logit model because of its documented superiority and ease of computation (Greene, 2003). Multinomial logit models comprise multi-equations which allow considerations of several discrete alternatives at the same time. The probability of a farmer  $i$ 's choice of seed type  $j$ , was estimated using multinomial logit model as in equation 1 (Greene, 2003).

$$P_{ij} = \frac{e^{X_i\beta_j}}{\sum_{j=1}^3 e^{X_i\beta_j}}, \text{ for } j = 1 \dots 3 \quad (1)$$

Where  $P_{ij}$  is the probability representing the  $i^{\text{th}}$  farmer's chance of using seed type  $j$ ,  $X_i$  represents a set of explanatory variables,  $e$  is the natural base of logarithms, and  $\beta_j$  are the parameters to be estimated by maximum likelihood estimator (MLE). The estimated equations provide a set of probabilities for the  $j + 1$  choice for a decision maker with  $X_i$  characteristics. For identification of the model, there is need to normalize by assuming  $\beta_0 = 0$ . Thus the probabilities are given by equations 2 and 3:

$$\text{Prob. } (Y_i = j / X_i) = P_{ij} = \frac{e^{X_i \beta_j}}{\sum_{j=2}^j e^{X_i \beta_j}}, \text{ for } j > 1 \quad (2)$$

$$\text{Prob. } (Y_i = 1 / X_i) = P_{1j} = \frac{1}{1 + \sum_{j=2}^j e^{X_i \beta_j}}, \text{ for } j > 1 \quad (3)$$

The marginal effects of explanatory variables on the probabilities are specified as:

$$\Delta_{ij} = \frac{\delta P_{ij}}{X_i} = P_{ij} [\beta_j - \sum_{j=0}^j P_{ij} \beta_j] = P_{ij} [\beta_j - \beta^-] \quad (4)$$

The dependent variables included a set of household/individual socio-economic characteristics, farm characteristics, and ecological factors. Individual characteristics included gender, farming experience, education level, and age of the head of household, and land ownership. Social characteristics included farmers' access to credit, extension services, market information, and the seed system where the particular seed type is found. Ecological aspects included the farmers' perceptions of the marketability, yield potential and climate adaptability of the different crop/seed varieties, as well as perception of climate-related shocks. Average annual rainfall and coefficient of variation were used as a proxy measures for climate change, and climate differences across production zones.

### 3 Results and discussion

#### 3.1 Farming systems in the sample districts

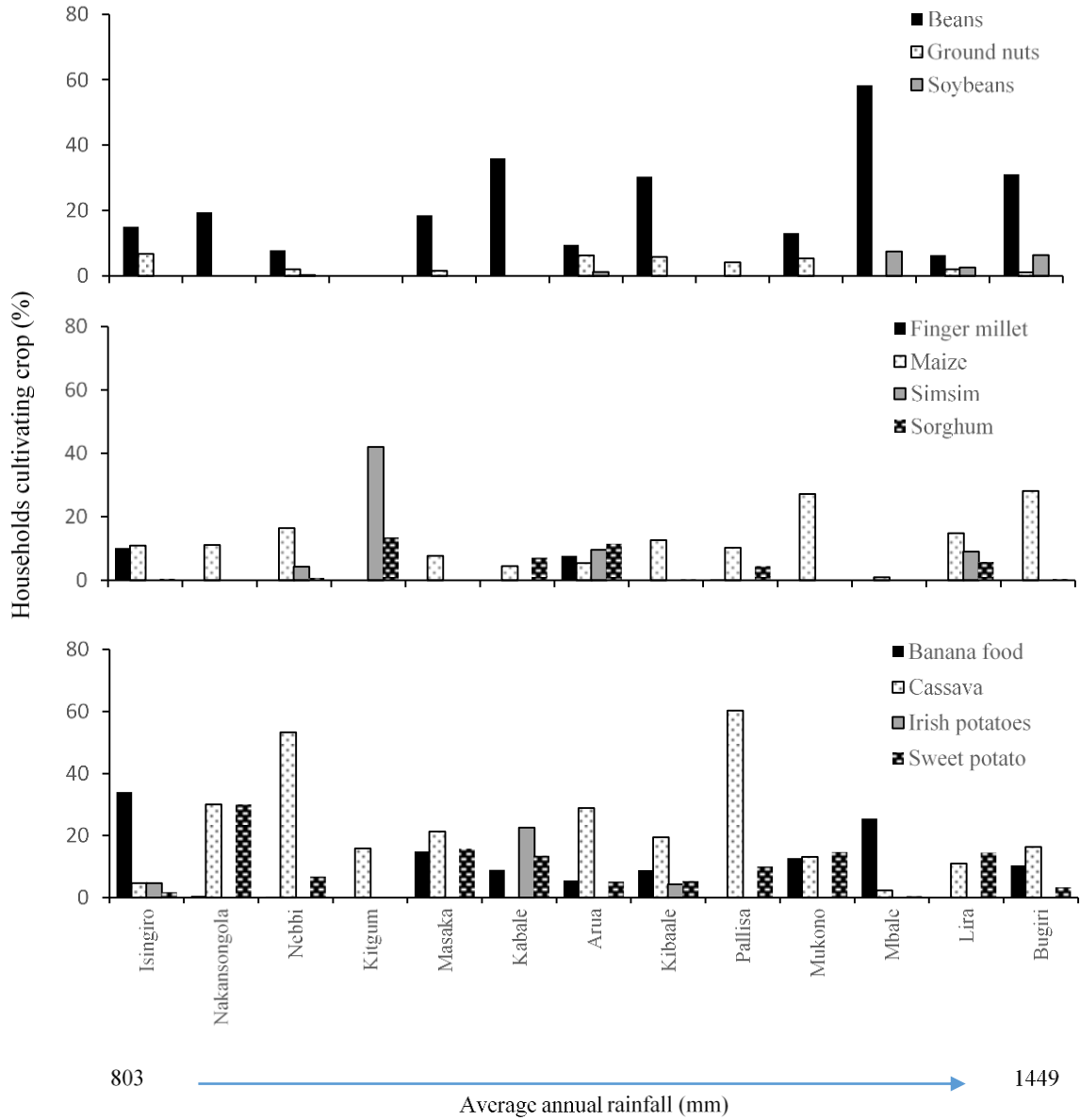
Analysis of farming systems in the 13 districts showed that households are engaged in diversified cropping activities with farmers growing up to 23 different crops in one season. Crop farming combined both annual and perennial crops usually in intercrops, though pure stands were observed particularly for simsim, rice, sweet potatoes and sun flower. Farm sizes were generally small, less than 2 acres on average. Average plot area planted for the various crops was 0.6 acres, but varied between crops. The main food crops were cassava, maize, beans, groundnuts, Irish potatoes and rice. Cassava was the most frequently grown crop followed by beans, maize, banana and sweet potatoes. The frequency of various crops varied by location, also an indicator of crop importance in the different zones of Uganda (Figure 1). The importance of dry land cereals such as sorghum and millet varied across

sites and none dominated at any site. Millet was grown in two sites – Isingiro and Arua, while sorghum was grown in six out of the 13 sites. Banana food was grown at eight of the 13 sites.

Results are shown along a gradient of annual rainfall, from the lowest in Isingiro to the highest in Bugiri (cf Table 1). Across the different districts, farmers seemed to grow almost similar crops, irrespective of differences in annual rainfall amounts. However, crop diversity (number of different crops grown) increased as rainfall increased. In low rainfall zones, farmers may be limited to a few crops/varieties with characteristics suited to the conditions, for example early maturing or tolerance to dry conditions, while the reverse may be true in high rainfall areas.

Crop importance explains the distribution of crops across the study districts. For example, maize is considered number one strategic priority crop at national level and is medium and high in food security and livelihoods, respectively. In this case, most households in Uganda tend to grow maize for cash, with limited amounts for food. Beans and cassava also hold high strategic ranking and rank high for food security but low for livelihoods (USAID, 2013). Banana food on the other hand ranks high for both livelihoods and food security while moderately strategic in terms of national importance. Sweet potato, rice, and sorghum are less strategic from a national perspective, while they rank high for food security. The comparative importance of these crops may also be a factor explaining their distribution across the country.

Crop diversity on the other hand, is typical for rural livelihoods facing climate stresses. By growing a number of different crops, farmers have traditionally spread their risk and guaranteed a harvest – even if they faced late or early rains, droughts, floods, pests and diseases. Additionally, by ensuring diversity, farmers also increase the likelihood that a portion of seeds will germinate under difficult conditions. High crop diversity has higher productivity as it serves as insurance under environment stress (Mulder et al., 2001). Di Falco et al. (2006) indicate that farmers with higher diversity of wheat varieties in Ethiopia highlands significantly lower levels of downside production risk. Growing a number of crops also takes into account the different returns from value-added crops with complementary marketing opportunities. Diversification is also important for food and nutritional security of households.



**Figure 1:** Diversity of crops cultivated at each of the sample districts

Source: Based on LSMS data

### 3.2 Perception of climate variability and effects on rural livelihoods

Droughts and/or irregular rains were considered the most important climate factors affecting smallholder farming systems in the 13 districts. Droughts were noted to occur yearly mostly during the months of January, February, June and December. Flash floods were also noted mainly as a result of heavy and erratic rainfall especially in the districts of

Bugiri, Mbale and Pallisa. Recurrent episodes of pests and diseases were noted for most of the crops especially cassava, millet and bananas.

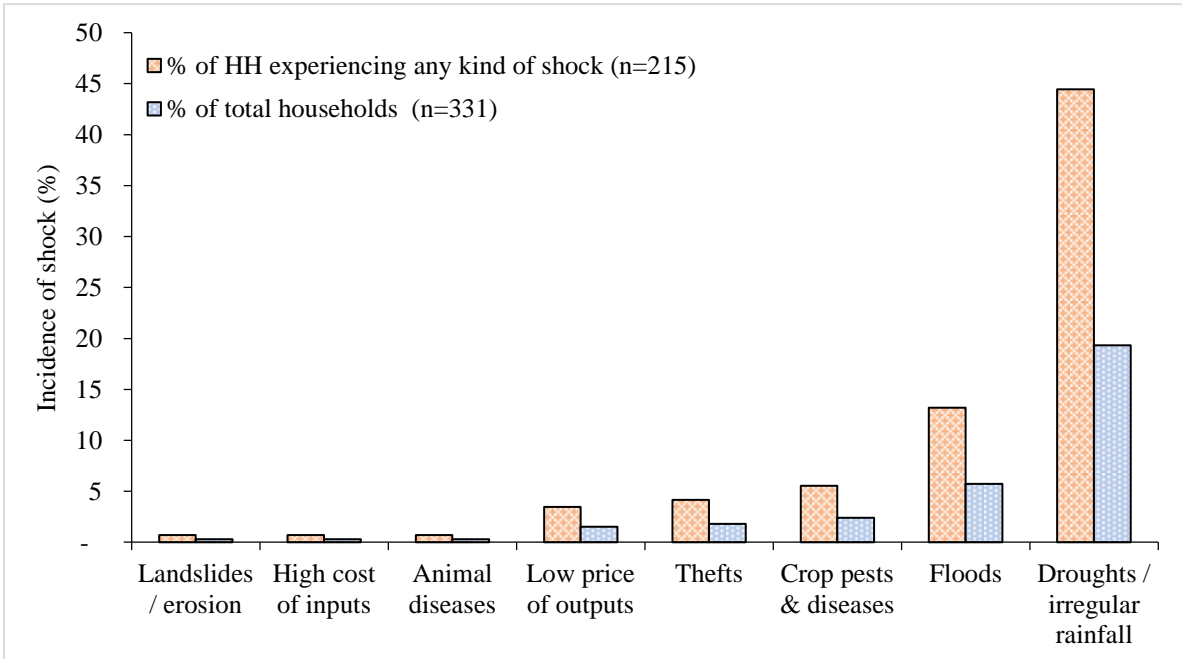
On the seasonal scale, it was noted that rainfall in March had reduced drastically, thus reducing the first growing season to just two months – April and May (especially in Northern and West Nile regions), moreover rainfall in these months has also reduced compared to 15 or so years ago. The first season had shifted from a start in early March to mid or late March, with a variation of more than two weeks for the start of the season. In-season droughts have also been observed especially for season one occurring around May and June. The second season (July-December) though considered to have increased amounts of rainfall, it was also considered highly variable in terms of rainfall distribution and intensity.

Farmers related a number of production shocks to changes in climatic conditions. These included direct climate factors such as droughts, irregular rainfall, floods, and crop pests and disease outbreaks. Other shocks such as high input prices, low output prices and thefts (of assets and agricultural produce) were also related to climate change. Droughts / irregular rains were the most frequently mentioned production shocks across the 13 districts (Figure 2). Evidence is emerging that climate change is increasing rainfall variability and the frequency of extreme events such as drought, floods, and hurricanes (IPCC, 2007). In addition, alterations in climate or weather also indirectly affect biotic factors such as diseases, pests, vectors and weeds.

Incidence of shock was assessed by district, and across districts (Figure 3). Nakasongola and Masaka showed the highest proportion of households who indicated to have experienced climate related shocks in a 12 month period (2012). Both Masaka and Nakasongola fall in the pastoral rangelands zone generally characterized by low rainfall amounts and prolonged dry spells punctuated by intermittent outbreaks of showers and thunderstorms. Kitgum on the other hand, had the smallest proportion of households who indicated to have received any kind of shock in the 12 month period. Kitgum is located in the North Eastern Dry lands, generally characterized by low annual rainfall amounts (average 745 mm per year), and has one rainy season (April – September) (GOU, 2004). However, for the year 2012 (survey year for this study), annual average rainfall for Kitgum was 1,105mm. This indicates that rainfall in this zone could be increasing, facilitating increased farming activities. This is in line with Goulden (2008) who indicates high percentage increases in rainfall for historically dry seasons for many parts of Uganda.

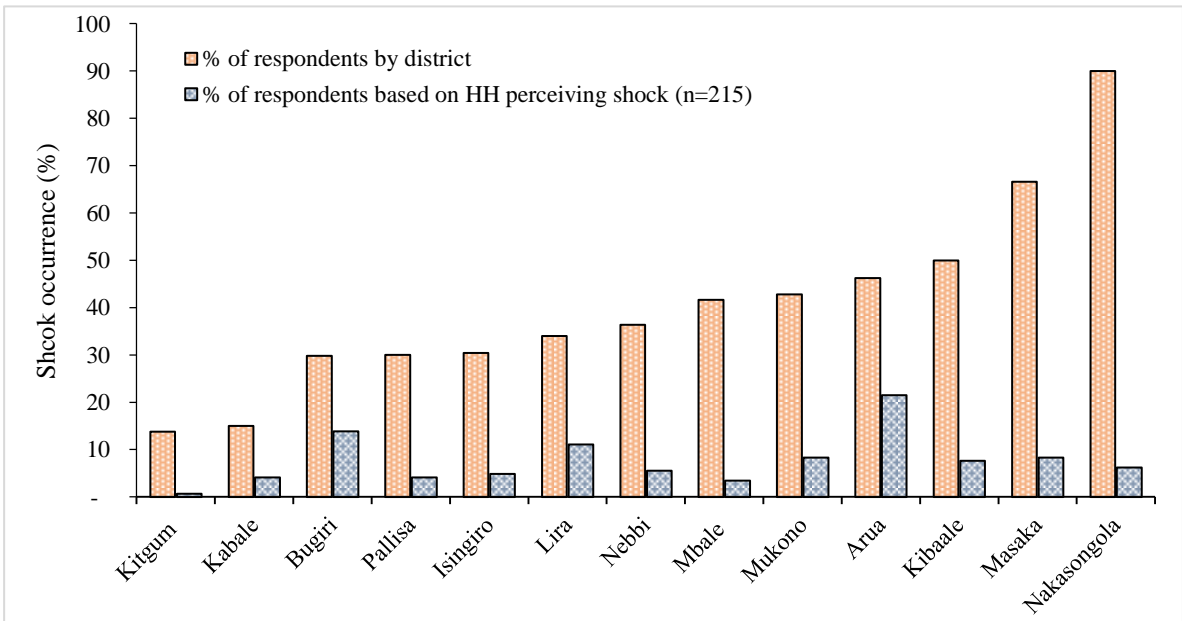
Across districts, Arua, Bugiri, and Lira showed higher proportion of farmers reporting having received some kind of shock. This is largely explained by large sample size from these districts and may not necessarily show that Arua was worse off than say Kitgum. For example, in Arua, the survey reached 67 households, out of the 331 for the entire 13 districts.





**Figure 2:** Frequency of climate related shocks affecting farming and rural livelihoods, as observed by households in the 13 sample districts

Source: Based on LSMS survey data for 2011/2012



**Figure 3:** Frequency of climate related shocks by district

Source: Based on LSMS survey data for 2011/2012

Farmers indicated that, as a result of climate related shocks, food production and household incomes were more likely to decline (Table 2 above). Delayed, erratic or inadequate rains and/or severe droughts affect crop yields as such affecting household food production. Floods, landslides, and crop pests and diseases were also perceived to have a major effect on crop production, since they have a direct effect on yield expectation. Rainfall variability, both within and between seasons creates risk and uncertainty of farm production as well as for the potential impact of innovations for crop, soil and livestock management practices (Cooper and Coe, 2010). Several studies in Africa have confirmed the direct effect of climate change on food production, where losses and yield decreases of up to 50% have been predicted as a result of changes in climatic conditions (for example Agrawala et al., 2003; Boko et al., 2007; Brown and Crawford, 2007). Similarly, studies conducted in Uganda indicate that increasingly unpredictable weather has led to poor yields, a reduction in pastures, poor animal health, rangeland related conflicts, greater expense and labour, food insecurity and reduced incomes leading to poverty (Osbaahr et al., 2011; Oxfam, 2008).

**Table 2: Effect of climate related shocks on farming and rural livelihoods**

Type of shock	Effect of shock on livelihoods (% of households <sup>‡</sup> )									
	HH income		HH assets		Food production		Food purchase		Type of seed	
	Yes	No	Yes	No	Yes	No	Yes	No	Local	Improved
Droughts / irregular r/fall	71	29	10	90	89	11	44	55	91	9
Floods	56	44	11	89	90	10	37	63	90	10
Land slide / erosion	47	53	6	94	88	12	18	82	90	10
High input costs	48	52	22	78	67	33	44	56	89	11
Crop pests and diseases	75	25	11	89	93	7	21	79	91	9
Livestock diseases	45	55	35	65	10	90	19	81	90	10
Low output prices	89	11	8	92	13	87	24	76	89	11
Pearson $\chi^2$ (17)	107.245		159.47		441.52		85.165		4.3226	
Asymp. Sig (2- sided)	0.000		0.000		0.000		0.000		0.999	

<sup>‡</sup> measured from only those households who indicated to have experienced shock (n=144). The question explored if there was a decline in any of the mentioned livelihood indicators.

$\chi^2$  = Chi square value; Asymp. Sig = asymptotic significance

Source: Author's computation based on LSMS survey data for 2011/2012

When farm households have low production, they earn less, but also need to purchase food to bridge consumption gaps. This may further reduce household incomes. Low output prices were also more likely to have a reducing effect on household incomes. Usually, with low output prices, household incomes would be affected negatively. But at times of climate change, we may expect high output prices due to supply shortages, thus households would earn more from sales of output. Increase in prices would help to mitigate the farmers' losses due to lower production. However, according to Deschênes and Greenstone (2007), when the change in weather affects output, change in prices of output is likely to differ in the short and long run. Change in output prices may be positive in the short run, but in the long run, be substantially smaller, or even zero.

High input costs were less likely to affect household incomes, assets and food purchase, while they were more likely to affect crop production. Inputs play an important role in achieving increased crop yields, and in cases where inputs costs increase, households will certainly reduce or abandon input use, unless the added cost from input use can be offset by added value from production. This further reduces food production. While high input cost is believed to incur a household more money than in normal season, thus causing a reduction on household incomes, farmers indicated the reverse. This could possibly be related to the inherent low input use by households in Uganda, and thus as prices increase, farmers purchase less and less of inputs, thus limited effect on incomes. According to GOU (2010), fertilizer use in Uganda is estimated at an average of 1 kg of nutrients per hectare, and is among the lowest in SSA, compared to 4 kg/ ha for farmers in Mozambique, 6 kg/ha in Tanzania, 16 kg/ha in Malawi, 32 kg/ha in Kenya and 51 kg/ha in South Africa. The use of improved seeds stands at 6.3 percent of farmers, while agrochemicals is at a meagre 3.4 percent.

Livestock diseases can lead to deaths and also affect marketability of livestock. This may lead to income crisis, asset depletion, low production (if plowing is made by animals) and resulting high food purchases. But the findings from this study seem to illustrate the other way, indicating that livestock diseases are less likely to affect incomes and assets. However, considering that most of the households derived their livelihood from crop farming, the effect of livestock diseases may not have such direct effects on household livelihoods. A majority of households also indicated that their food purchase had not declined, even amidst climate shocks. In fact farmers could have purchased more to bridge the consumption gaps as a result of low food production. Household assets also seemed largely unaffected by the perceived climate shocks.

Farmers were more likely to use local / traditional seeds on their fields (as measured by the high proportion of farmers using traditional seed compared to improved seed). However, the relationship between perceived climate related shocks and the type of seed farmers use was not statistically significant ( $\chi^2 = 4.32, p=0.999$ ). Though it would be expected that as farmers face production shocks, they select seed types that are suited to their production

environment. But it's also possible that, farmers' decision of which seed to use are generally based on variety characteristic and not the type of seed per se. So if the local seed provides the desired attributes, farmers will more likely grow that seed.

### **3.3 *The role of seed systems in the study districts***

Seed system functions were assessed by crop type and variety to understand if there were specific factors that relate to the type of crops grown by farmers that dictate the functionality of the system. Over 75% of seed used by farmers was local (or traditional) seed for most crops (Table 3). Cassava, soy bean and maize had higher proportions of farmers using improved seed constituting 22%, 12% and 10% respectively. Those who indicated to use improved seed, the type of improved seed was sought, and relative proportions indicated to have used certified seed for maize, beans and sesame. A majority of those who indicated that they used improved seed, did not know the type of improved seed it was. To further understand seed types used by farmers, varieties were categorized into three - local, improved and farmer-recycled. The analysis was done for three most commonly grown crops - maize, beans and cassava, based on case study data from West Nile. Local varieties dominated, followed by recycled varieties (Figure 4a). Use of improved varieties was relatively higher for beans followed by maize and cassava.

In terms of seed exchange, on average, 30% of farmers' seed was sourced from the market, while 70% was from non-market sources. Seed purchase was relatively higher for non-traditional food crops, sesame (62%) and soybeans (52%), compared to traditional food crops (such as cassava, sweet potato, finger millet, and sorghum) (ref. Table 3). Farmer-preferred crop varieties were mainly found in the farmer-saved seed system comprising up to 67% for cassava (Figure 4b). Other sources included, local market, community-based seed multiplication, government or research and the formal sector (Seed Company or agro-dealer). Farmer-saved seed comprised positive selection and seed saving from previous harvest, but also included seed exchange and gifts with in the community. Local market comprised grain bought as seed for the growing season.

Assessment of farmers' reason for cultivating different crop varieties and their perceptions of variety uniqueness showed that farmer-preferred crop varieties combined attributes of high marketability, climate adaptability and high yield (Figure 5). A higher proportion of farmers (>30%) reported cultivating local varieties of cassava because they were considered unique in terms of the three mentioned attributes. On the other hand, there was a relatively higher proportion of farmers growing recycled maize varieties compared to local and improved varieties. Recycled varieties were considered to combine both climate resilience and high yield attributes. Marketability was considered relatively low for local maize and beans varieties. Other attributes included short maturity, quality of grain/flour, taste and tolerance to pests and diseases.

**Table 3: Type of seed used by farmers for different crops, and how it is obtained (n=331)**

Type of crop	Percent of households						
	Type of seed		Type of improved seed <sup>‡</sup>			Seed exchange	
	Local	Improved	Certified	QDS	Don't know	Purchased	Not purchased
Cassava	78	22	2	1	99	9	91
Beans	97	3	24	35	41	30	70
Maize	88	12	31	1	68	24	76
Banana food	99	1	0	0	100	26	74
Sweet potato	96	3	0	82	18	13	87
Ground nuts	95	5	13	56	31	37	63
Finger millet	99	1	0	50	50	15	85
Sorghum	94	6	0	25	75	27	73
Sesame	96	4	22	33	45	62	38
Irish potato	99	1	0	100	0	39	61
Soy bean	94	6	0	0	100	52	48
Pearson $\chi^2$ (26)	906.8		293.29			737.8959	
Asymp. Sig (2- sided)	0.000		0.000			0.000	

<sup>‡</sup> proportion from only those who indicated to be using improved seed

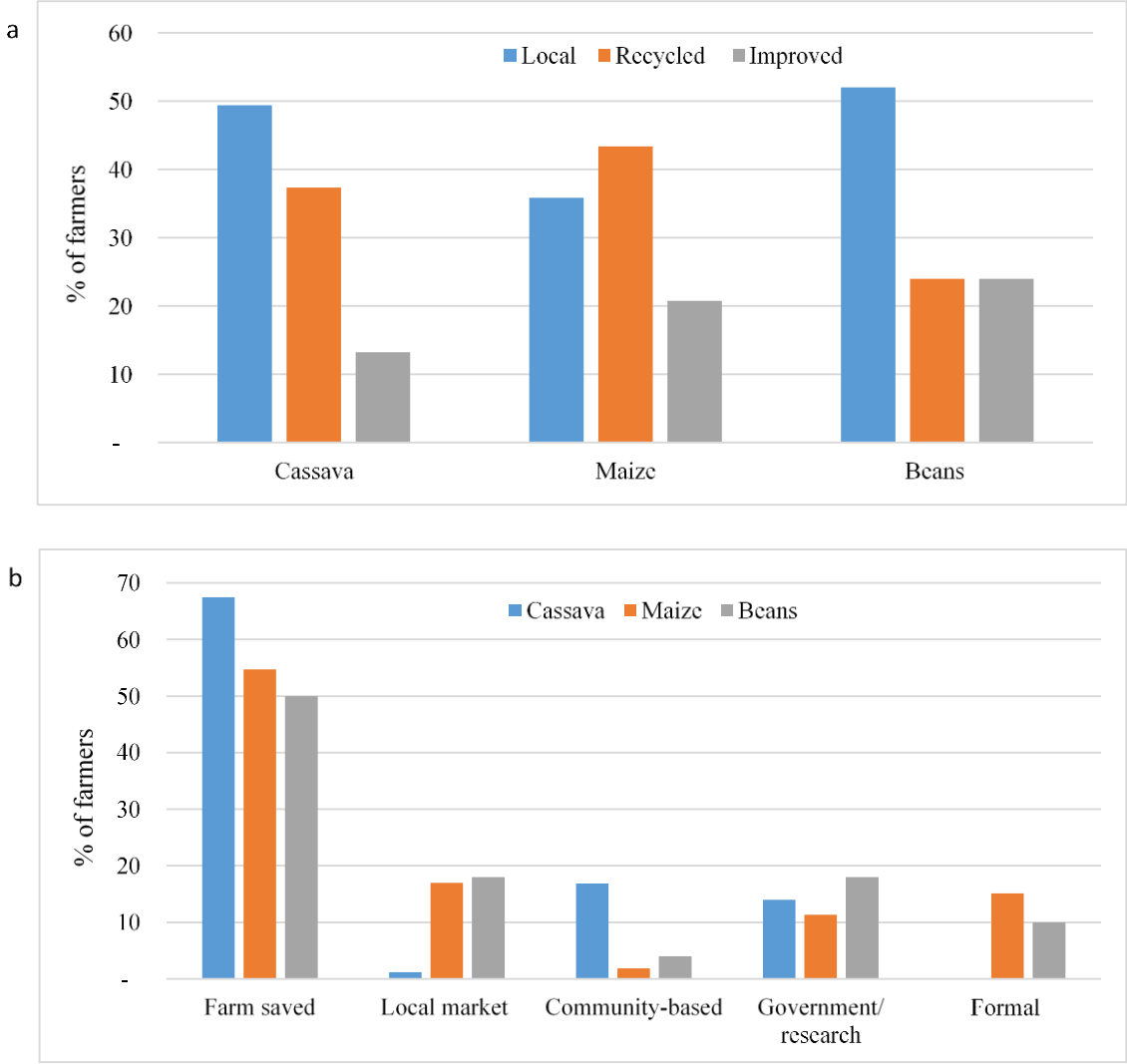
$\chi^2$  = Chi square value; Asymp. Sig = asymptotic significance, QDS =Quality Declared Seed

Source: Author's computation based on LSMS survey data for 2011/2012

Farmer based seed systems were appreciated because they provided the flexibility to obtain the seed required by farmers. Farmer seed systems can offer flexibility and speed through providing a wider selection of crops and varieties and the ability to source from distant locations (Longley, 2000). Farmer seed systems are also characterized by positive selection and knowledge of crop varieties over time and their response under climate variability. In contrast, formal enterprises on the other hand are constrained by narrow crop choice and affordability (Sperling and McGuire, 2010).

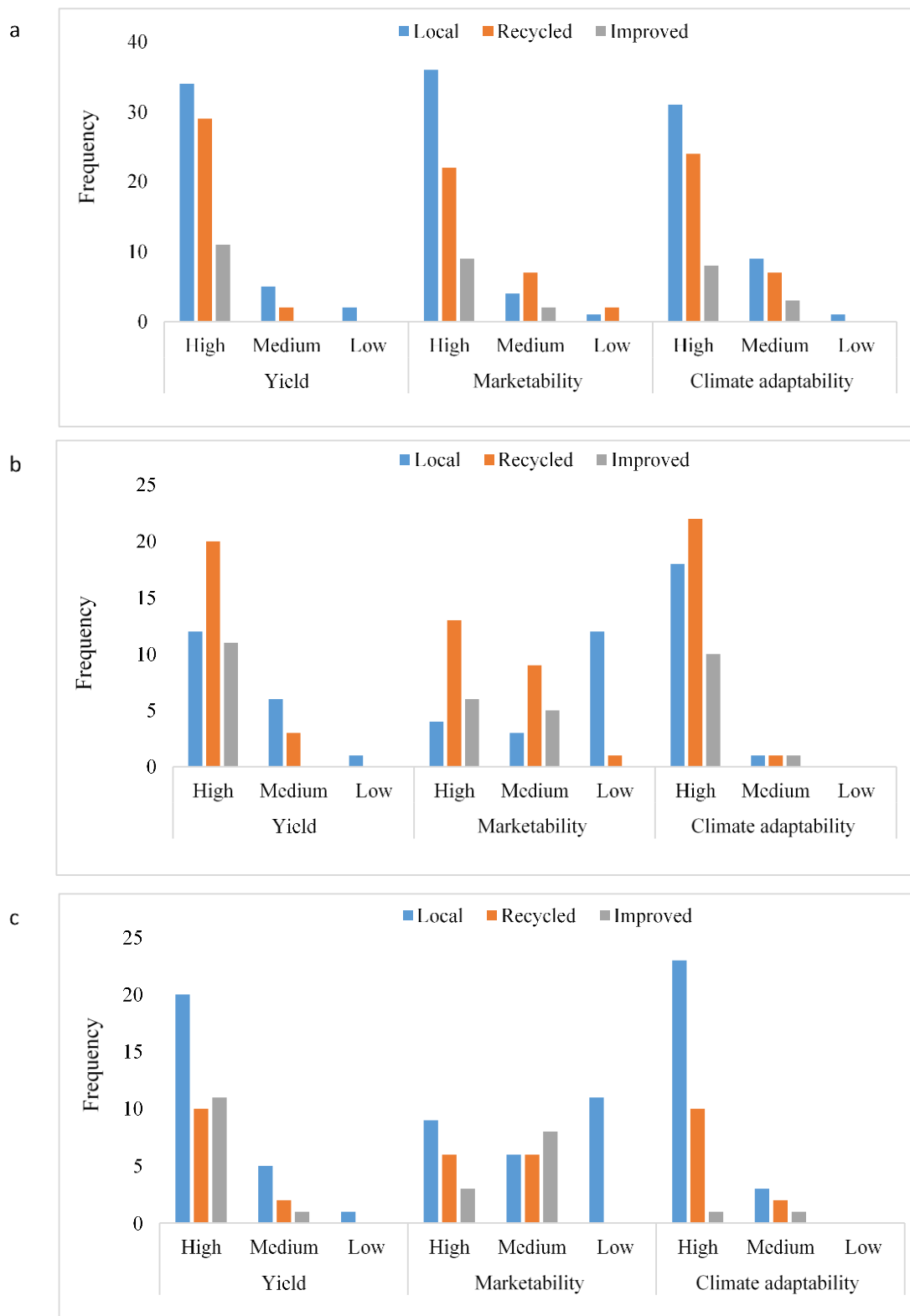
Farmers' seed saving was considered a sure way of maintaining preferred varieties. Farmers will therefore select varieties that address their immediate and perceived needs for production and resilience to stress factors, as well as social and economic aspects. Farmers' emphasis on availability and convenience were the main advantages of keeping their own

seed. Other than production risks, farmers also select their seed based on a combination of factors, that include social, economic and cultural aspects. Other studies have also revealed varied reasons for farmers' use of own saved seed, including the lack of money to buy seed, and a scarcity of seed at planting time (Scott et al., 2003).



**Figure 4: (a) Type of seed used by farmers and (b) seed source for cassava, maize and beans**

Source: Based on household survey in West Nile (n=90)



**Figure 5: Variety uniqueness by type of seed variety a) cassava, b) maize, and c) beans**  
 Source: Based on household survey in West Nile (n=90)

### **3.4 Factors affecting farmer's choice of type of seed**

Multinomial regression of reported variables by farmers showed that individual, social and ecological factors to a great extent explained the type of cassava, maize and bean varieties used by farmers (Table 4). A unit change in farmer's education, age and farm size were associated with a 1.1, 1.3 and 0.07 increase in the relative odds of using local cassava varieties compared to improved varieties. These same factors were significant in explaining farmers' use of recycled cassava varieties as compared to local varieties. Marketability, yield and adaptability to local conditions were also significant factors for farmers' use of recycled varieties of cassava and maize compared to local varieties.

Farmers' access to different sources of seed played an important role in the type of variety they used. Seed system (or seed source), was negatively related to farmers' use of improved varieties of cassava, beans and maize, relative to local varieties. For example, if a farmer used own sources of seed, then the probability of using seed varieties which are improved, decreased. Other studies have also related adoption of new seed varieties to access to seed from different sources (Ghimire et al. 2012). This is also influenced by the poor availability of new varieties of seed due to weak seed distribution systems.

Farmers' exposure to various sources of agriculture related information is always crucial in influencing their decisions and plays a dominant role in adoption and retention of new technologies. In this case, access to extension services and market information were more likely to result in positive impact on use of improved cassava seed varieties, but less likely to influence adoption of improved maize or beans varieties in relation to local varieties. It's therefore difficult to generalize the influence of information on adoption of seed varieties, given the mixed results from this study. This could be related to the kind information that the farmers receive. McGuire and Sperling (2011, 2013) argue that applied to seed systems, technology provision should be linked to relevant information to assist strategic decision-making. Such information may include seasonal dynamics, variety performance and effective market links.

Farmers' perception of climate factors also played a role in defining their choice of crop varieties to grow. In particular, perception of drought decreased the likelihood of farmers growing improved or recycled varieties for cassava, maize and beans, compared to local varieties. Drought was more significant in defining the varieties grown for maize. This implies that farmers' varieties still play an important role in providing planting material even when climate conditions are considered unfavorable. However, in the presence of increased pest and disease incidences, floods and too much rainfall, farmers were more likely to grow improved varieties of maize. This was in recognition that the maize varieties farmers have are less susceptible to pests and diseases, compared to say cassava.



**Table 4: Factors affecting farmers' choice of seed type**

Variety type ♦	Cassava		Beans		Maize	
	Improved	Recycled	Improved	Recycled	Improved	Recycled
<b>Individual</b>						
Gender (Male=1, Female=0)	-0.853	-1.941**	-1.206	-1.573	-44.232	-11.897
Farming experience (# of years)	-1.123	-0.451	2.879**	1.648*	13.958	4.989
Education (Categorical) †	1.118*	0.805*	0.211	1.733*	37.670	5.471
Age (Chronological age)	1.391*	1.155*	-2.552**	0.123	-33.880	-7.093
Farm size (Acres)	-0.072*	-0.032	0.238	0.035	2.003	0.381
<b>Social</b>						
Credit (Yes=1, No=0)	1.181	0.132	0.075	-0.189	-37.912	-3.115**
Extension (Yes=1, No=0)	17.152	1.873**	-0.240	2.286	-4.766	2.723**
Market information (Yes=1, No=0)	16.567	0.359	-0.339	-2.003	7.353	0.042
Seed system (Farmer-saved=1, other=0)	-1.121*	0.836*	-2.930*	1.577	-74.535	-4.268*
<b>Variety characteristics</b>						
Marketability (High=1, Otherwise=0)	-2.669	-2.203*	22.365	0.834	-36.617	2.925*
Yield (High=1, Otherwise=0)	16.803	3.522**	19.373	-0.023	95.732	2.820**
Adaptability (High=1, Otherwise=0)	1.182	-0.866	-0.599	0.764	12.043	7.607*
<b>Perception of climate variability</b>						
Drought (Yes=1, No=0)	-3.215**	-2.008**	-0.261	-1.109	-45.644	3.065
Too much rainfall (Yes=1, No=0)	-2.639	0.223	-0.900	-1.485*	7.771	-0.517
Crop pests & diseases (Yes=1, No=0)	-1.370	-1.033	-1.727**	-1.662**	16.913	-2.522
Floods (Yes=1, No=0)	-17.466	1.841*	-14.117	-13.941	33.209	-19.117
Short season (Yes=1, No=0)	-2.927	-0.884	-0.566	-1.207	-3.755	-11.974
Constant	-62.326	-3.391*	-44.154	-11.594**	-45.786	-4.648
Observations	90		90		90	
LR Chi <sup>2</sup>	78.21		158.59		215.60	
Prob > Chi <sup>2</sup>	0.000		0.000		0.000	
Log likelihood	-44.635		-28.417		-6.402	
Pseudo R2	0.467		0.736		0.944	

Reported figures are coefficients from the MNL model. ♦ Varieties were categories into Local=1, Improved=2 and Recycled=3, and local variety was the base outcome.

† None=1, Primary=2, Secondary=3, Tertiary=4, Adult learning=5

Significance: \*\*\*<0.001, \*\*p<0.05, \*p<0.1

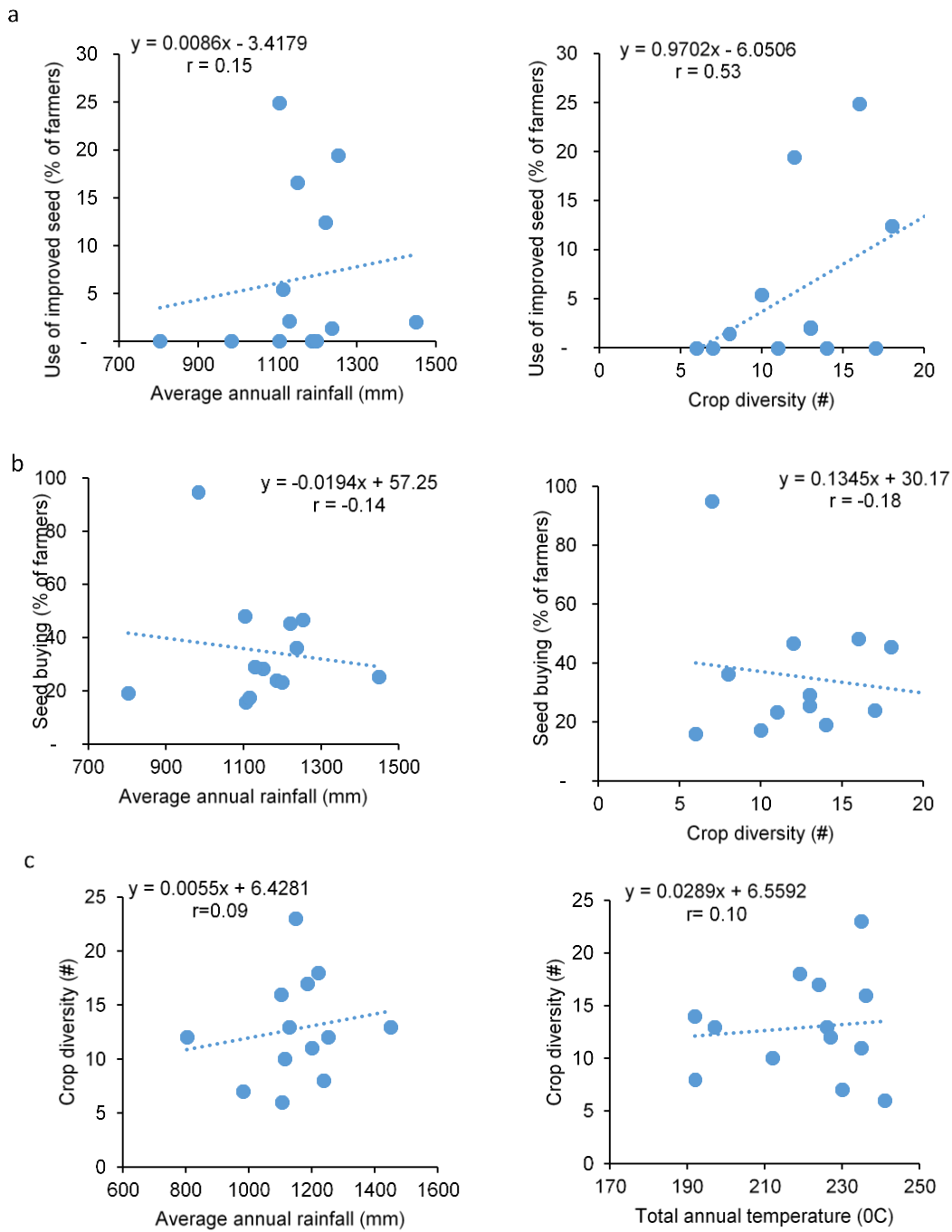
Source: Based on household survey in West Nile

### 3.5 *Seed system functions and climate variability*

Seed system functions were assessed along the rainfall and temperature gradients to understand if there were correlations that could be explained by differences in climatic conditions. Use of improved seed varieties had a positive correlation with average annual rainfall ( $r=0.15$ ), implying that in higher rainfall areas, farmers tended to use more improved seed as compared to areas with low rainfall (Figure 6a). This may be due to the fact that with higher rainfall, farmers generally have higher expectations in terms of production as opposed to low rainfall areas, thus are willing to try improved seed. On the other hand, there was a negative correlation between annual rainfall and seed buying ( $r=-0.14$ ). Farmers indicated that as a result of recurrent climate stresses, they have received new and improved planting materials from the National Agricultural Advisory Services (NAADS). Such materials were mainly elite varieties of cassava (NASE 14) and beans (K132, NABE 14). Provision of improved planting materials by government and non-government agencies could be the reason why farmers indicated to be using improved materials to some extent, yet seed buying was minimal.

In terms of seed exchange, there was a negative relationship between seed buying, and annual rainfall amount and crop diversity (Figure 6b). It can be assumed that with low crop diversity, farmers tend to buy seed, explained by unavailability of seed stocks. For example, in Nakasongola seed buying was up to 95% in a season though use of improved varieties was 0%. Nakasongola is located in the cattle corridor with short growing periods and limited cropping activities. Similarly, there have been noted challenges in retaining and accessing seed in unimodal rain fed growing season in most areas in Northern and West Nile. The correlation between crop diversity, and rainfall and temperature was positive, but weak (Figure 6c). This may imply that the number of crops farmers grow is not necessarily dictated by their experience with rainfall or temperatures, though farmer seed behavior may change given their perception of these climate factors. Also, it could imply that effect of climate factors is not directly related to the crop type per se, but the specific varietal attributes that may be differ across rainfall zones. Therefore, seed systems should be able to address this specific demand for varieties that are suited to various conditions.

At household level, the effects of climate change on seed system were perceived in terms of effect on quantity and quality of yield. In addition, changing seasons were perceived to compromise the levels of viability of the seeds thus affecting farmers' seed security. Seed saving was also affected by poor yields. Low crop production affects grain prices thus farmers may not be able to acquire the right quantities of seed at the right time. Farmers mentioned a number of crops they considered to be resilient to the observed recurrent droughts. Bananas, cassava, finger millet, sorghum and local vegetables were perceived to be resilient to droughts. These crop varieties with resilient traits were generally found in the informal sector (farmer seed system). Most of these comprised either local varieties or recycled varieties.



**Figure 6: Correlation between seed system functions with farm and climate variables, a) type of seed b) source of seed and c) crop diversity**

Source: Based on LSMS data

Bananas play an important role in ensuring food security since they have ability to withstand dry spells. The permanent canopy, root systems, and mulch from the banana plants prevent soil erosion and degradation, thus making the crop more adaptable to current climate variations (Jassogne et al. 2013). Similarly, sorghum and millets have proved important crops especially in the semi-arid areas of East Africa (Mitaru et al. 2012; Mwadalu and Mwangi 2013) and thus hold great potential to provide food and income security in the region as well, responding to increased droughts. Local vegetables such as cow peas, amaranth, and pigeon peas are generally early maturing, thus providing a quick alternative for food and income to farmers, especially in areas where growing seasons are reducing.

#### **4 Building resilience of farmers seed systems to climate change**

It is generally acknowledged that whatever the type of stress situation, continued agricultural production depends on the farmers' ability to maintain and acquire seed (Longley, 2000). Even in stress situations, farmers still retain significant quantities of seed for replanting, relying on their own seed sources. However, in many cases, and following a poor season, this seed is insufficient, particularly for sowing the main rainy season crop, and farmers seek seed from off-farm sources, usually local markets.

Unlike the other seed systems, in which seed production is separate from crop production, seed production under a farmer system is an integral part of crop production, thus constrained by the same factors that affect crop production. These may be social, bio-physical or ecological production constraints. Delayed rains and severe droughts affect crop yields as a result farmer seed saving is affected. Low crop production affects grain prices thus farmers may not be able to acquire the right quantities of seed at the right time. In this study, the effect of climate change on seed systems was perceived in relation to the diminishing levels in quantity and quality of the affected crop resources yield. The need to make local seed systems resilient to climate stresses is thus a priority so as to continue to provide required seed for farmers, majority of whom are smallholder.

McGuire and Sperling (2013) define seed system resilience as the capacity of the system to absorb shocks and stress, and reorganize so as to maintain and strengthen seed security over time. Resilience emerges as a property of germplasm, institutions, and interactive information systems, which allow for strategic response to change. McGuire and Sperling (2013), highlight eight principles to a resilient seed system and among them is the need to nurture a systems perspective that focuses on strengthening knowledge, institutional linkages and response to processes and social dynamics rather than the physical properties of the system like seed. Similarly, Louwaars and de Boef (2012), state that the resilience potential of a seed system is a complexity of social-ecological assets, bio-physical features,

and institutional linkages that aim at improving the production and access to good quality seeds of a desired crop cultivar at an opportune time. Resilience therefore focuses on factors that enable functioning despite adverse conditions and considers society's capacity to manage change (Cabell and Oelofse, 2012).

Such a scenario calls for a proactive, informed and empowered team of stakeholders across the overall seed production and exchange chain. This approach builds on understanding the stakeholders' capacity and identification of knowledge and technology gaps to efficient crop production process and production practices amidst climate hazards. Understanding and managing local resilience in their own fields is the best option that farmers have to face changes and minimize vulnerabilities in their agricultural systems (Allara et al., 2012). At the same time it's important that local and national institutions have a good understanding of resilience in production and food systems to support appropriate decisions on policies and research priorities.

In this study, farmers indicated awareness of climate stresses and various crop choices they make that are perceived to be resilient to current climate variability, droughts/irregular rains being the major climate factors. Crop resources with promising levels of resilience to droughts (the major climate factor) were bananas, cassava, sorghum, finger millet and local vegetables. Bananas play an important role in ensuring food security since they have ability to withstand dry spells. According to Jassogne et al. (2013) the permanent canopy, root systems, and mulch from the banana plants prevent soil erosion and degradation in Uganda's hilly landscape, thus making the crop more adaptable to current climate variations in these areas.

Similarly, sorghum and finger millet were perceived as important adaptation crops against droughts. Sorghum and millets have proved important crops especially in the semi-arid areas of East Africa (Mgonja et al., 2012; Mwalu and Mwangi, 2013) and thus hold great potential to provide food and income security in the region as well, responding to increased droughts. Local vegetables such as cow peas, amaranth, and pigeon peas were also considered to be important adaptation crops mainly due to their short maturity period and ability to withstand droughts. However, these crops are not as widely grown in the study areas.

Most of the crops and varieties considered by farmers to have resilient traits were generally found in the informal sector. Most of these comprise either local varieties or released varieties that have been recycled in the community for a long time and now belong to the informal system. Given the importance of farmer seed systems, ultimately, the bulk of activities that will make seed available have to reside with the informal sector which serves more farmers and which has more agility. This study highlights below two broad areas for consideration to enhance farmer seed systems resilience to climate change. These include short and medium term actions related to the key seed system functions – type of exchange

(including information flow), type of seed (including maintaining the germplasm base), and value of seed in the face of climate uncertainty.

#### ***4.1 Identification and promotion of climate resilient crop varieties***

Farmers already have a stock of crop varieties that they are currently growing or what they consider to be resilient to the recurrent droughts and irregular rainfall. There is need for identification and characterization of such crop varieties available at farmers' level and testing their suitability in various climatic conditions. Researchers can work with farmers to characterize such crops, and develop an inventory of seed types for specific conditions. In addition, researchers need to identify germplasm suited for different climate zones which can be promoted among the farmers. Participatory variety selection with farmers, and availing appropriate information about alternative crop varieties will facilitate promotion of such crops amongst farmers. National agricultural research system need to invest more resources in promoting their varieties and helping to stimulate commercial seed production.

This study also revealed that much as farmers were aware and can mention the crops they consider resilient to climate change, they are not the ones that were most commonly grown. For example millet was grown at two sites while sorghum was grown at five of the 13 sites. The proportion of farmers growing these crops was also small (<10%). This may relate to the value attached to these crops such as yield, commercialization, and contribution to food security and household incomes. Development of viable value chains enhancing productivity, processing and value addition of such crops will facilitate increased adoption and integration in farming systems. Wambugu and Mburu (2014) note that through improved access to high-quality certified seed technology, intensification of production, transfer of good agronomic skills and use of inputs, and stronger market links, farmers could increase productivity of sorghum by two fold as well as volumes traded.

Given that farmer seed production is part of general farming practices by households, actions aimed at enhancing crop production would also go a long way in ensuring seed security. Provision of climate information and advisories, and promotion of climate smart agricultural practices to enhance adaptation of the farming system in general to the perceived climate stresses, drought in this case are recommended. This study recommends wide promotion of sustainable production measures that hold substantial mitigation potential, and that contribute to adapt agriculture and food production systems to extreme events. These may include; farmers maintaining broad crop genetic base, use of new cultivars and crop varieties, shift in sowing/planting dates, use of cover crop, soil fertility management and reduced tillage practices. Extension agents should include climate messages in their delivery system.

#### **4.2 *Broadening seed supply and distribution***

A consistent finding from this study and other studies in Africa is that farmers use multiple sources of seed, but often dominated by own seed and local markets. The formal sector also plays an important role in delivering mainly improved and hybrid seed especially for maize and other non-traditional food crops such as soy bean, sesame and sunflower. Farmer seed systems are considered important in maintaining crop varieties that are considered resilient to various biotic and abiotic factors faced by farming communities. This therefore highlights the need for existence of multiple channels from which farmers can make choices based on their preferences. This will also ensure seed affordability, inclusion of diversity, geographical reach and information transfer.

This assertion is supported by previous studies (Bellon et al. 2010; Louwaars and de Boef 2012; McGuire and Sperling 2013). Linking formal and informal seed sector is presumed to give a degree of stability along with production gains. Louwaars and de Boef (2012) and McGuire and Sperling (2013) detail the architecture of how this integration of multiple channels can be achieved in practice. Proposed actions that are relevant to this study as well include; expanding formal distribution outlets to more vulnerable locations and providing information with regard to new crop varieties. This may be combined with demonstrations of new varieties and provision of seed in small packs to allow farmer access and own testing. The role of agro-dealers and marketing networks is also being recognized in seed sector development, thereby enforcing market forces for dissemination at a local level (MacRobert 2009; Louwaars and de Boef 2012).

This study wants to place more emphasis on strengthening the role of farmers in producing and distributing quality seed of desired varieties in their communities. Local seed production emerges as an important strategy for seed production and supply to local communities. Wiggins (1995) groups local level seed production into three categories; seed production using contract growers, seed exchange schemes and farmer seed enterprises. Previous studies have demonstrated that farmer seed enterprises being commercially oriented, appear to be the most sustainable (Anderson and Singh 1990; David 2004). Developing farmer seed entrepreneurs is suggested by many studies as a strategy for meeting dual objectives; to establish a regular source of clean seed of either local or modern varieties, and to sustainably distribute and promoted modern crop varieties (David, 2004). Some experiences have been documented in Ethiopia, Uganda and Ghana on farmer seed entrepreneurship with promising results in terms of quantities and quality of seed produced and supplied to farmers. Most of these seed entrepreneurs deal in food crops of importance to farmers where the formal sector has limited interest. These may include crops that are valued by farmers because of their yield stability, resilience, or cultural attachments. Enhancing skills of farmers to produce seed of resilient crop varieties will go a long way in providing quality seed in a timely manner to their communities.

However, the questions posed in agricultural planning circles, and in most reports therefrom, are how the quality of available planting material can be improved (Joughin 2014), more so in the informal sector where seed quality control is based on internal mechanisms within groups/communities producing seed. Concerns about seed quality need to be addressed as seed trade develops, including farmer seed entrepreneurs. The National Seed Certification Services (NSCS) is responsible for enforcing seed standards, including inspecting seeds at the retail level, as well as inspecting fields growing seeds and seed testing before packaging. Development of seed entrepreneurs implies expanded portfolio for the NSCS thus requiring effective mechanisms to ensure quality assurance. Previous studies in Uganda have suggested wider use of the FAO's Quality Declared Seed System to help avoid bottlenecks during certification (Joughin 2014). This would be a practical way to improve on the current situation in which many farmers have no choice but to rely on uncertified and potentially counterfeit seed sold in open markets.

## **5 Conclusions and policy implications**

Using a combination of sociological and ecological approaches, this study has documented farmers' perceptions of climate change and how their awareness conditions the functioning of their seed systems. Drought or irregular rainfall patterns were considered the most important climate factors affecting livelihoods and seed system functions. While the seed system in the study area consists of both formal and informal elements, the informal elements were the most important supply channels for farmers' seed. Farmers selected their seed based on a combination of factors, which included perceived adaptability to climate conditions, marketability and yield. These seed attributes were believed to be met by the informal seed system, given its flexibility and speed in providing a wider selection of crops and varieties. Practical options for enhancing resilience of farmer seed systems include; participatory (research and farmers) identification and promotion of climate resilient crop varieties of important food crops, development of farmer seed entrepreneurs as a strategy of enhancing production and distribution of quality seed of locally adapted crops/varieties, promotion of climate smart agriculture practices, and dissemination of climate advisories to farmers to help adapt their farming practices to current climate.

Results and recommendations from this study have the following policy implications. First, development of farmer seed entrepreneurs means that farmers will be recognized as legal producers and sellers of seed. This requires an effective quality assurance mechanism to ensure that seed produced by farmers meets seed quality standards, and it's not just grain sold as seed. Secondly, farmers need to be recognized as custodians of genetic materials that can feed into modern breeding programs, and effectively supported to maintain the genetic resource they have. And lastly, policies and development strategies by the



government need to recognize the important role of crop diversity in building resilience to climate change as opposed to focus on market-oriented crops alone.

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### **References**

- AGRA (Alliance for a Green Revolution in Africa), 2014. Africa agriculture status report: Climate change and smallholder agriculture in Sub-Saharan Africa, Nairobi, Kenya.
- Agrawala, S., Moehner, A., Hemp, A., van Aalst, M., Hitz, S., Smith, J., Meena, H., Mwakifwamba, S.M., Hyera, T., Mwaipopo, O.U., 2003. Development and Climate Change in Tanzania: Focus on Mount Kilimanjaro. OECD, Paris.
- Allara, M., Kugbei, S., Dusunceli, F., Gbehounou, G., 2012. Coping with changes in cropping systems: Plant pests and seeds. In: A. Meybeck, J. Lankoski, S. Redfern, N. Azzu and V. Gitz (Eds.), Building resilience for adaptation to climate change in the agriculture sector. Proceedings of a Joint FAO/OECD Workshop 23–24 April 2012. Food and Agriculture Organization of the United Nations and Organisation for Economic Co-Operation and Development, Rome, Italy. Pp347.
- Almekinders, C. J. M., Louwaars, N.P., 1999. Farmers' seed production: New approaches and practices. London, UK: Intermediate Technology.
- Anderson, P., Singh, R., 1990. NGO-Government links in seed production: Case studies from the Gambia and Ethiopia. ODI Agricultural Administration (Research and Extension) Network, Network paper 14. London: ODI.
- Bellon, M., Anderson, C.L., Lipper, L., Dalton, T., Keleman, A., Grum, M., 2010. Synthesis: Markets, seed systems and crop diversity. In: L. Lipper, T. Dalton, C.L. Anderson, (Eds.) Seed Trade in Rural Markets: Implications for Crop Diversity and Rural Development. Earthscan, Sterling, VA, pp. 189-208.

- Bellon, M.R., Adato, M., Becerril, J., Mindek, D., 2006. Poor farmers' perceived benefits from different types of maize germplasm: the case of creolization in lowland tropical Mexico. *World Development*, 34(1):113–129.
- Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo R., Yanda, P., 2007. Africa climate change 2007: Impacts, adaptation and vulnerability. In: Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. and Hanson, C.E. (Eds.). *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.
- Brown, O., Crawford, A., 2007. Climate change: A new threat to stability in West Africa? Evidence from Ghana and Burkina Faso. International Institute for Sustainable Development (IISD). *African Security Review*, 17 (3): 39–57.
- Cabell, J.F., Oelofse, M., 2012. An indicator framework for assessing agroecosystem resilience. *Ecological and Society*, 17(1):18.
- Cooper, P. J. M., Coe, R., 2011. Assessing and addressing climate-induced risk in Sub-Saharan rainfed agriculture. Foreword to a special issue of experimental agriculture. *Experimental Agriculture*, 47(2):179-184.
- David, S., 2004. Farmer seed entrepreneurship: A sustainable approach to seed delivery? *Agriculture and Human Values*, 21:387-397.
- Deschênes, O., Greenstone, M. 2007. The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather. *The American Economic Review*, 97 (1): 354-385. Accessed online at [http://www.econ.ucsb.edu/~olivier/DG\\_AER\\_2007.pdf](http://www.econ.ucsb.edu/~olivier/DG_AER_2007.pdf), on 22<sup>nd</sup> January 2014.
- Di Falco, S., Chavas, J.P., Smale, M., 2006. Farmer Management of Production Risk on Degraded Lands: The Role of Wheat Genetic Diversity in Tigray Region, Ethiopia. Environmental and Production Technology Division, Discussion Paper 153 IFPRI, Washington DC, USA.
- Ferris, S., and R. Laker-Ojok. 2006. “Growth Prospects for Services within Selected Agricultural Sectors in Uganda.” International Center for Tropical Agriculture.
- Gareeba-Gaso, E., Gisselquist, D. 2012. Operationalization of the non-ATAAS component of the development strategy and investment plan. Final analytical report on seeds and planting materials. Ministry of Agriculture, Animal Industry and Fisheries, Kampala, Uganda.

- Ghimire, S., Mehar, M., Mittal, S. 2012. Influence of Sources of Seed on Varietal Adoption Behavior of Wheat Farmers in Indo-Gangetic Plains of India. *Agricultural Economics Research Review*, 25: 399-408
- Gibson-Graham, J.K., 2006. *A Post-capitalist Politics*. University of Minnesota Press, Minneapolis.
- GOU, 2004. Increasing incomes through exports: A plan for zonal agricultural production, agro-processing and marketing. Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and Ministry of Finance, Planning and Economic Development (MFPED), Entebbe, Uganda.
- GOU, 2010. National development plan 2010/2011-2014/2015. Accessed on October 1, 2014 at [http://www.finance.go.ug/docs/NDP\\_April\\_2010-Prot.pdf](http://www.finance.go.ug/docs/NDP_April_2010-Prot.pdf). Government of Uganda (GOU), Kampala, Uganda
- Goulden, M., 2008. Building resilience to climate change in lake fisheries and lake-shore populations in Uganda. Policy briefing note, Tyndall Centre for Climate Change Research, University of East Anglia, UK (unpublished).
- Greene, W.H., 2003. *Econometric Analysis*. Prentice Hall International, Inc, New York University, New York, USA.
- Hart, K., 2006. Bureaucratic form and the informal economy. In: B. Guha-Kahsnobis, R. Kanbur, E. Ostrom, (Eds.) *Linking the Formal and Informal Economy*. Oxford University Press, Oxford, pp. 21-35.
- Hirpa, A., Meuwissen, M.P.M., Tesfaye, A., Lommen, W.J.M., Lansink, A.O., Tsegaye, A., Struik, P.C., 2010. Analysis of seed potato system in Ethiopia. *American Journal of Potato Research*, 87: 537-552.
- Hodgkin, T., Jarvis, D.I., 2003. Seed systems and the maintenance of diversity on farm: Introductory remarks. In: D.I. Jarvis, R. Sevilla-Panizo, J.L, Chávez-Servia and T. Hodgkin (Eds.), *Seed systems and crop genetic diversity on farm*. Proceedings of a workshop, 16-20 September, 2003, Pucallpa, Peru. International Plant Genetic Resources Institute, Rome, Italy.
- IPCC, 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Annex I: M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (Eds.), Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, UK, 976pp.
- ISSD Africa, 2013. ISSD Uganda briefing note.

- ISSD Uganda, 2014. Farmers' access to seed and other planting materials in Uganda. Baseline report, Kampala Uganda.
- Jassogne, L., Läderach, P., van Asten, P., 2013. The impact of climate change on coffee in Uganda: Lessons from a case study in the Rwenzori Mountains. *Oxfam research reports*, April 2013.
- Jones, K., 2013. The political ecology of market-oriented seed system development and emergent alternatives. Paper presented at the International Conference Yale University, September 14-15, 2013. Conference paper no. 54.
- Joughin, J., 2014. The Political Economy of Seed Reform in Uganda: Promoting a Regional Seed Trade Market. Africa Trade Practice Working Paper Series, Number 3, the World Bank.
- Kurukulasuriya, P., Mendelsohn, R., 2006. Crop selection: Adapting to climate change in Africa. Centre for Environmental Economics and Policy in Africa (CEEPA) Discussion Paper No. 26, University of Pretoria, South Africa.
- Lipper, L., Anderson, C.L., Dalton, T.J., (Eds.) 2010. Seed trade in rural markets. Implications for crop diversity and agricultural development. London, UK: Earthscan.
- Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P., Naylor, R.L., 2008. Prioritizing climate change adaptation needs for food security in 2030. *Science*, 319(5863):607-610.
- Longley, C., 2000. Farmer Seed Systems under Stress. In: Targeted seed aid and seed system interventions: strengthening small farmer seed systems in East and Central Africa. Proceedings of a workshop held in Kampala, Uganda, 21–24 June 2000. 451 p.
- Louwaars, N.P., 1994. Connecting formal and local seed systems in development: integrated seed supply systems. In: P. Stolp (Ed.), Organisation and Management of National Seed Programmes", ICARDA, Aleppo, Syria, DSE Feldafing, Germany. pp. 10-17.
- Louwaars, N.P., de Boef, W.S., 2012. Integrated seed sector development in Africa: a conceptual framework for creating coherence between practices, programs, and policies. *Journal of Crop Improvement*, 26: 39–59.
- Lunduka, R., Fisher, M., Snapp, S., 2012. Could farmer interest in a diversity of seed attributes explain adoption plateaus for modern maize varieties in Malawi? *Food Policy*, 37(5): 504–510.
- MacRobert, J. F., 2009. Seed business management in Africa. Harare, Zimbabwe: CIMMYT.

- McGuire, S., 2001. Seed system health indicators: A note. In: L. Sperling (Ed.), Targeting seed aid and seed system interventions: Strengthening small farmer seed systems in East and Central Africa. Proceedings of a workshop held in Kampala, Uganda, 21-24 June, 2000. CIAT, Kampala, Uganda.
- McGuire, S., Sperling, L., 2013. Making seed systems more resilient to stress. *Global Environmental Change*, 23: 644–653.
- Mgonja, M.A., Shiferaw, B.S., Mitaru, B., Obare, G., 2012. An assessment of the sorghum and millet sub-sector in ECA: Towards better integration and exploitation of productivity enhancement and market opportunities. In: B.N. Mitaru, M.A. Mgonja, I. Rwomushana, F. Opio (Eds), Integrated sorghum and millet sector for increased economic growth and improved livelihoods in Eastern and Central Africa. Proceedings of the ECARSAM Stakeholders Conference, 20–22 November 2006, Dar es Salaam, Tanzania. ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa), Entebbe.
- Mulder, C., Uliassi, D., Doak, D., 2001. Physical stress and diversity-productivity relationships: the role of positive interactions. *Proceedings of the National Academy of Sciences*, 98: 6704–6708.
- Mwadalu, R., Mwangi, M., 2013. The potential role of sorghum in enhancing food security in semi-arid eastern Kenya: A review. *Journal of Applied Biosciences*, 71:5786– 5799.
- Nzuma, J.M., Waithaka, M., Mulwa, R.M., Kyotalimye, M., Nelson, G., 2010. Strategies for Adapting to Climate Change in Rural Sub-Saharan Africa A Review of Data Sources, Poverty Reduction Strategy Programs (PRSPs) and National Adaptation Plans for Agriculture (NAPAs) in ASARECA Member Countries. IFPRI Discussion Paper 01013, July 2010.
- Osbah, H., Dorward, P., Stern, R., Cooper, S., 2011. Supporting agricultural innovations in Uganda to respond to climate risk: Linking climate change and variability with farmer perceptions. *Experimental Agriculture* 47 (2): 293–316.
- Oxfam, 2008. Turning Up the Heat: Climate Change and Poverty in Uganda, July 2008, Oxfam GB.
- Scott J., Kambewa, P., Chirwa, R., Aggarwal, V., 2003. Local seed systems for beans in Malawi. Network on Bean Research in Africa, Occasional Publications Series, No. 40. CIAT, Kampala, Uganda.
- Thornton, P.K., Jones, P.G., Ericksen, P.J., Challinor, A.J., 2011. Agriculture and food systems in sub-Saharan Africa in a 4°C + world. *Philosophical Transactions of the Royal Society A*, 369: 117–36.

- USAID, 2013. Uganda climate change vulnerability assessment report. USAID African and Latin American Resilience to Climate Change (ARCC), August, 2013, Kampala, Uganda.
- van de Steeg, J.A., Herrero, M., Kinyangi, J., Thornton, P.K., Rao, K.P.C, Stern, R., Cooper, P., 2009. *The influence of current and future climate-induced risk on the agricultural sector in East and Central Africa: Sensitizing the ASARECA strategic plan to climate change*. Research report 22. ILRI (International Livestock Research Institute), Nairobi, Kenya, ICRISAT (International Crop Research Institute for the Semi-Arid Tropics), Nairobi, Kenya, and ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa), Entebbe, Uganda.
- Wambugu, F., Mburu, N., 2014. Potential for sorghum in food security and economic development among communities in arid and semi-arid lands in Africa. Research report, Technical Centre for Agricultural and Rural Cooperation ACP-EU (CTA). Accessed at <http://knowledge.cta.int>, on October 21, 2014.
- Weltzien, E., vom Brocke, K., 2001. Seed systems and their potential for innovation: Conceptual framework for analysis. In: L. Sperling (Ed.), Targeted seed aid and seed system interventions: Strengthening small farmer seed systems in East and Central Africa. Proceedings of a workshop held in Kampala, Uganda, 21-24 June 2000. Kampala, p9-13
- Westengen, O.T., Brysting, A.K., 2014. Crop adaptation to climate change in the semi-arid zone of Tanzania: the role of genetic resources and seed systems. *Agriculture and Food Security*, 3(3):1-12.
- Wiggins S. 1992. NGOs and local level seed supply in The Gambia. Overseas Development Institute, London, UK

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