Determinants of Farmers' Adoption of Drought Resistant Crops in Adapting to Drought Impacts on Crop Production in Same District, Kilimanjaro Region

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Abstract

Droughts' intensity, duration, spatial coverage and frequency have been increasing with current climate change. This has been especially the case with arid and semi-arid tropical areas. Yet, farmers in such areas have persistently growing water intensive crops like maize, leading to poor production. Consequently, food insecurity and unsustainable livelihoods have been rampant. There is a broad scientific and political consensus that growing drought resistant crops (DRCs) is a sustainable drought adaptation strategy. The crops have anatomical and physiological characteristics enabling drought toleration, hence, improve water productivity (increase crop output per water input). Besides, adoption of DRCs is simple, cheap, easy and feasible for farmers to adopt compared to other strategies. Studies have shown that adoption of DRCs, even in drought prone areas, is very low. However, causes of low adoption of these crops are not adequately understood. This study aimed at analyzing determinants of farmers' adoption of DRCs as an adaptation strategy to drought impacts. Data were collected from 281 farmers from four villages in Same district (a semi-arid and drought prone district in Tanzania). The study deployed logistic regression analysis and descriptive statistics to analyze such determinants. It was observed that adoption of DRCs is determined by a number of factors, including, access to climate information, access to agricultural extension services, food preference, location, sex of head of the household and farm size. Besides, adoption of DRCs is hampered by various barriers, including, cultural constraints, lack of knowledge, unpredictable rainfall, lack of access to climate information and lack of market. Other barriers were lack of seeds, lack of capital, destructive birds and forceful motivation approaches.

Keywords: *Drought, Drought resistant crops, Adoption, Logistic regression analysis, Same district*

Introduction

Drought is a natural hazard which has been recurring in all climatic regions since time immemorial (Wilhite, 2000; Masih, *et. al.*, 2014). However, its frequency and severity have been increasing substantially since the last half of the 1800s. This has been attributed to unprecedented climate change (CC) due to high rate of greenhouse gas emissions since industrial revolution in 1850s (IPCC, 2007). Agriculture, which is the leading sector in the economy of many developing countries and Sub-Saharan Africa in particular, is severely impacted due to over-dependence on rainfall (Madiyazhagan *et. al.,* 2004; Prasad, 2011). As a result, decline in crop production has been reported in various places, and is more pronounced in arid and semiarid areas (Hatibu *et. al.,* 2003). This poses adverse impacts on food security and general farming livelihood.

The question of *how to adapt sustainably* to changes in earth's climate system in all social-economic sectors is the most current debate in the field of CC (Nabikolo *et. al.*, 2012; Schiermeier, 2007; Wilby, 2007). It is highly agreed that adoption of drought resistant crops (DRCs) is a sustainable strategy to adapt to drought impacts (Deressa, *et. al.,* 2009; Njau, *et al.,* 2005; Augustino, *et. al.,* 2012). The strategy is simple, easy, cheap and feasible adaptation strategy (Oo, *et. al.,* 2015; Augustino, *et. al.*, 2012 and has improved crop production where they have been adopted (Njau, *et al.,* 2005). Drought resistant crops include,

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inter alia, cassava (*manihot esculenta*), sweet potatoes (*solanum tuberosum*), wheat (*triticum aestivam*), millet (*Pennisetum glaucum* L.), sorghum (*sorghum bicolor* L.), barley (*hordeum vulgare* L.) and hyacinth bean *(lablab purpureus L.)* (El-Sharkawy, 2007; Saleem *et al.*, 2011; Nezhadahmadi *et al.*, 2013).

Despite the existence of knowledge on DRCs and their usefulness in adapting to drought impacts, their adoption is still very low. Factors for low adoption of these crops are not well understood. Understanding such factors would inform policies, strategies and plans aiming at enhancing adaptability to drought impacts from local, national, regional to global levels. Using the case study of Same District in the North-Eastern zone of Tanzania, this study aimed at gaining better understanding of determinants of adoption of DRCs.

Materials and Methods

The Study Area: An Overview

This study was conducted in Same district in Tanzania. The district is located within 3^0 47` and $4^0$ 36` south and 37^0 29` and $38^0$ 24`east and covers an areas of 5,186 sq. km (URT, 1998). According to 2012 population and housing census, the district's total population was 269,807 people. Out of them, 131,515 were males and 138,292 were females (URT, 2013). The growth rate was 1.8 and average household size was 4.5 (URT, 2013). Agriculture is the main source of livelihoods and farmers are mostly smallholders. Rain-fed farming is the dominant agricultural practice in this district. However, the district is located in a semi-aridity climatic region with average annual precipitation of 562 mm only. Worse still, is highly variable with high frequency of severe droughts (Enfors and Gordon, 2007; Afifi, *et al.,* 2014). Semi-aridity climatic conditions coupled with frequent droughts have adversely impacted crop production in Same district.

Target Population and Sampling Unit

Targeted population for this study was crop farmers in Same district. These farmers form a group of individuals who have been experiencing impacts of CC induced droughts on crop production. Sampling unit was farmer households because farming activities are organized at the household level. Besides, this is the level where production threats are mostly felt and adaptation decisions are basically made. The study took heads of households as sampling elements because of their greater influence on household's adaptation behaviors, including adoption of DRCs.

Determination of Sample Size

In order to draw sample reasonable for valid statistical analysis, the scientific procedures for determining sample size were applied. The sample size was determined using formula for estimating sample size from a finite population by Kothari, (2004:179), given as:

$$n = \frac{z^2 \cdot p \cdot q \cdot N}{e^2 (N-1) + z^2 \cdot p \cdot q}$$

Where: n = Sample size,

$\boldsymbol{z}$ = Standard variant at a given confidence level

p = Sample proportion

q = 1 - p

N = Size of population (number of farmer households in the studied villages)

$\boldsymbol{e}$ = Acceptable error (the precision)

Data for calculation of sample size were: $\boldsymbol{z}$ = 1.96, p = 0.3, q = 0.7, N = 2117 and $\boldsymbol{e}$ = 5% (0.05)

$$\text{Thus: } n = \frac{(1.96)^2 (.3)\ (.7)\ (2{,}117)}{(.05)\ (2{,}116) + (1.96)^2 (.3)\ (.7)} = 281$$

Thus, questionnaires were administered to **281** head of households who were drawn systematically from the list of head of the households for the four studied villages.

Sampling Procedures

Stratified Sampling was deployed at the first stage of sampling procedures. The technique is useful in drawing representative sample where the study population is heterogeneous (Kumar, 2011). Crop farmers in Same district (the population) are from highland and lowland ecological zones, which have different climatic characteristics. The highlands are more humid and cool than the lowland areas, leading to differences in crops grown. Thus, stratified sampling was the appropriate sampling technique and the two zones were the strata.

Simple Random Sampling through fishbowl draw method was used to select two wards from each stratum and one village from each of the selected wards. According to Kumar, (2011) fishbowl draw involves numbering each element using separate slips of paper, putting them into a box and picking blindly one slip after another until the sample size is reached. Accordingly, fishbowl draw is useful where total population is small. Since number of wards in each stratum were small, and so was the number of villages in each ward, the method was used to select wards from each zone and a village from each ward. The selected villages were Malindi and Idaru from highland zone and Njoro and Saweni from lowland.

Systematic Sampling was deployed in selection of 281 head of households, proportionally from the four sampled villages. These were selected from lists of head of farmer households (sampling frame) provided by village executive officers. Systematic sampling is effective where sampling frame can be obtained or established (Kumar, 2011; Kothari, 2004).

Data Collection and Analysis Methods

Questionnaire survey was deployed as a tool of data collection in this study. Questionnaires were administered to respondents by the researchers themselves. The researchers found a questionnaire to be a convenient tool in collecting large quantitative data within a short period of time. Quantitative data were the mostly required data for this study. Besides, documentary review was used to collect secondary data from the university of Dar es Salaam library and online sources. These data were used during discussion of primary data in order to substantiate researchers' arguments (corroborative evidence).

Logistic regression analysis was used to determine factors influencing farmers' adoption of DRCs. The dependent variable was adoption of DRCs in a dichotomous scale specified as: adopting any DRC = 1 and otherwise = 0. The covariates were the independent variables hypothesized to influencing farmers' adoption of DRCs. The selection of possible independent variables was informed by adoption theories like adoption perception model, economic constraints model and diffusion of innovation theory (Rogers, 2003; Wossink *et al.*, 1997; Uaiene *et al.*, 2009) together with empirical studies on the field. Basing on that, the study hypothesized that access to climate information, access to agricultural extension services; farm size, food preference, education of head of the household, location; household income and sex of head of the household have significant influence on adoption of DRCs. IBM SPSS statistics version 23 was used in this analysis. SPSS was selected because logit model (the model for logistic regression analysis) can be easily accessed and used. The model is given as:

$$Y_i = \beta_0 + \beta_1 X_1 + \ldots\ldots\ldots\ldots \beta_n X_n$$

Where: Y_i = Dichotomous dependent variable

β_0 = Y-intercept

$\beta_1 - \beta_n$ = A set of coefficients to be estimated

$X_1 - X_n$ = Hypothesized explanatory/ independent variables.

Besides, descriptive statistics were used to analyze barriers to adoption of DRCs.

Results and discussion

Factors Determining Adoption of Drought Resistant Crops

Results from logistic regression analysis for the factors hypothesized to determine adoption of DRCs are presented in Table 1. Covariates whose influence on adoption of such crops were found to be significant included access to climate information (as indicated by the significance value of .048), access to agricultural extension services (.001), food preference (.029), location (.000) and sex of head of the household (.013) (Table 1). Farm size, education and income were found to be insignificant in this model. The results were corroborated with results from chi-square test (X^2) which indicated the significance value of 0.460 and 0.443 for income and education respectively. Since these values are greater than 0.05 (at 95% confidence level), it follows that there is no association between those independent variables and adoption of DRCs. Thus, these results from X^2 were consistent with results from logistic model. Findings for farm size indicated that there is association between this variable and adoption of DRCs basing on the significance value of 0.001.

Table 1: Results from Logistic Regression Analysis for Factors Determining Farmers' Adoption of DRCs in Same District (N=281)

	B	S.E.	Wald	Df	Sig.	Exp(B)
Access to Climate Information	-.817	.413	3.913	1	.048	.442
Access to Agricultural extension services	-1.390	.423	10.804	1	.001	.249
Farm Size	.075	.247	.093	1	.760	1.078
Food Preference	.876	.401	4.765	1	.029	2.402
Education of Head of the Household	.651	.501	1.684	1	.194	1.917
Location	-3.717	.614	36.711	1	.000	.024
Household Income	-.215	.173	1.536	1	.215	.807
Sex of Head of the Household	-1.020	.410	6.202	1	.013	.360
Constant	-1.083	2.499	.188	1	.665	.338

IBM-SPSS Output for Logistic Regression Analysis
Source: Field Data (2016)

Odds ratio for access to climate information as a covariate in the logit model was 0.442 (Table 1). The reference category in this model was *last option* (which in this case was "*no access to climate information*"). Thus, odds ratio of 0.442 which is less than 1 indicates that adoption of DRCs among farmers who do not access climate information is less than that of farmers who have access to climate information. Similar findings were also reported by a number of previous studies, including, Gbetibouo, 2009 and Kebede and Adane, 2011. This current study found that farmers with access to climate information (e.g. predictions of low rainfall or drought) adopt DRCs than farmers without such information. Climate information is necessary for farmers to make informed decisions to adapt to changes in the climate system.

Just like access to climate information, so was access to agricultural extension services. Odds ratio for access to agricultural extension services was 0.249. This indicates that farmers without such services were less likely to adopt DRCs by 0.249 times that of those who access such information. In this study presence of agriculture officers in a village or ward was considered important factor for access to agricultural extension services. It was found that farmers in wards with such officers and who visit farmers regularly adopted DRCs more than their counterparts without such officers.

Further, food preferences among members of the household was another independent variable hypothesized to influence adoption of DRCs. Odds ratio for this covariate was 2.402 indicating that adoption of DRCs among farmers who prefer foods prepared by those crops is over 2.4 times that of those who do not prefer such foods. It was observed that crop farming in Same district was basically

for subsistence. Thus, farmers tended to cultivate crops which they prefer for food, including maize and beans. This tendency posed negative impacts on adoption of DRCs, like millet, cassava and sweet potatoes which are not preferred as food in many households.

Moreover, adoption of DRCs was influenced by location of the farm. The study area is divided into two ecological zones, namely, lowland and highland areas. Odds ratio for location as a covariate in the logit model was 0.024. This indicates that adoption of DRCs among farmers at the highland areas is less than those at the lowland areas. This odds ratio is far less than 1 indicating big difference in adoption among farmers from the two zones. It was observed that cultivation of hyacinth bean which is one of DRCs at the lowland areas increased adoption of DRCs among farmers in the lowland areas. Hyacinth bean, which is cash crop was found to have been adopted by 94.9% of the respondents at the lowland areas. The crop does not favor highland conditions. As such, the only DRCs possible at highland areas are food crops like cassava, millet and sweet potatoes which are not preferred by many households for food.

Besides, sex of head of the household was one of the covariates analyzed. Results show odds ratio of 0.360 (Table 1), indicating that female headed households are less likely to adopt DRCs compared to their male counterparts. These findings concur with most studies on CC adaptation which reported differences between male and female headed households in adoption of adaptation strategies (Mwamfupe, 2014; Nabikolo *et al.*, 2012; Tenge *et al.*, 2004). All of these studies have found that females are, generally, less likely to adapt than males. Findings of these studies have attributed this disparity to traditional social barriers that prevent females from easy access to land, capital and other important resources. Current study has found that hyacinth bean was the dominant DRC grown in the study area. This is cash crop which requires large capital. Thus, male headed households have more capital to invest in this crop than female headed households.

Regarding farm size, logistic regression analysis (Table 1) found that it had no significant influence on adoption of DRCs. However, chi-square test indicted existence of association between the two. That association was indicated by the significance value of .001 at 95% confidence level. These finding concur with those by Kasenge, (1998) as well as Anik and Salam, (2015) which showed positive relationships between farm size and adoption. Unlike findings of these studies, Ndamani and Watanabe, (2015) found inverse relationship between farm size and adaptation in Lawra district of Ghana. In this current study, it was found that farmers with large farms have adopted DRCs more than their counterparts with small farms. It was found that DRCs are not the first priority in the farmers' list of crops. As such those with large farms grow their priority crops like maize and beans and grow DRCs at the remaining part of the farm.

Results from logit model (Table 1) have suggested that the influence of education on adoption of DRCs is insignificant. Likewise, chi-square test indicated the significance value of 0.443. Since this value is greater than 0.05, it follows that there is no significant association between education and adoption of DRCs. These findings differ from previous studies on adoption of improved agricultural technologies (Igodan, et al., 1990; Anik and Salam, 2015). These studies have shown that educated farmers are more likely to adopt improved technologies because they are able to access information than their lowly educated counterparts. Lack of association between education and adoption of DRCs in the current study may result from the fact that majority of the respondents (86.8%) were from one education category (primary). Studying such association using another sample which is more heterogeneous in education may provide different results.

Results from logit model regarding income showed that influence of this covariate on adoption of DRCs is insignificant. Likewise, results from chi-square test indicated the significance value of 0.460 which is greater than 0.05, suggesting lack of association between income and adoption of DRCs in general. These findings differ from most studies on adoption of CC adaptation strategies, which have found that income is positively related to adaptation (Gbetibuou, 2009; Nhemachena and Hassan, 2007). However, income seems to has impact which vary from one adaptation strategy to another. To some strategies, income has positive impact while to some it has negative impact. For instance, a study by Anik and Salam (2015) conducted in Bangladesh found that farmers with high income (especially off-farm income) were less attracted to improved onion variety because the variety required more effort and time than traditional varieties. Such farmers preferred to invest much efforts and time on their off-farm activities and use less time and efforts on farming activities, hence grow traditional onion varieties.

Barriers to Adoption of Drought Resistant Crops

The findings showed that cultural constraints, lack of knowledge, unpredictable rainfall, lack of access to climate information, lack of seeds of DRCs, lack of capital, market constraints, destructive birds and forceful motivation approaches are the barriers to adoption of DRCs. Respondents ranked the barriers basing on importance and results in percent are shown in Figure (2) 1

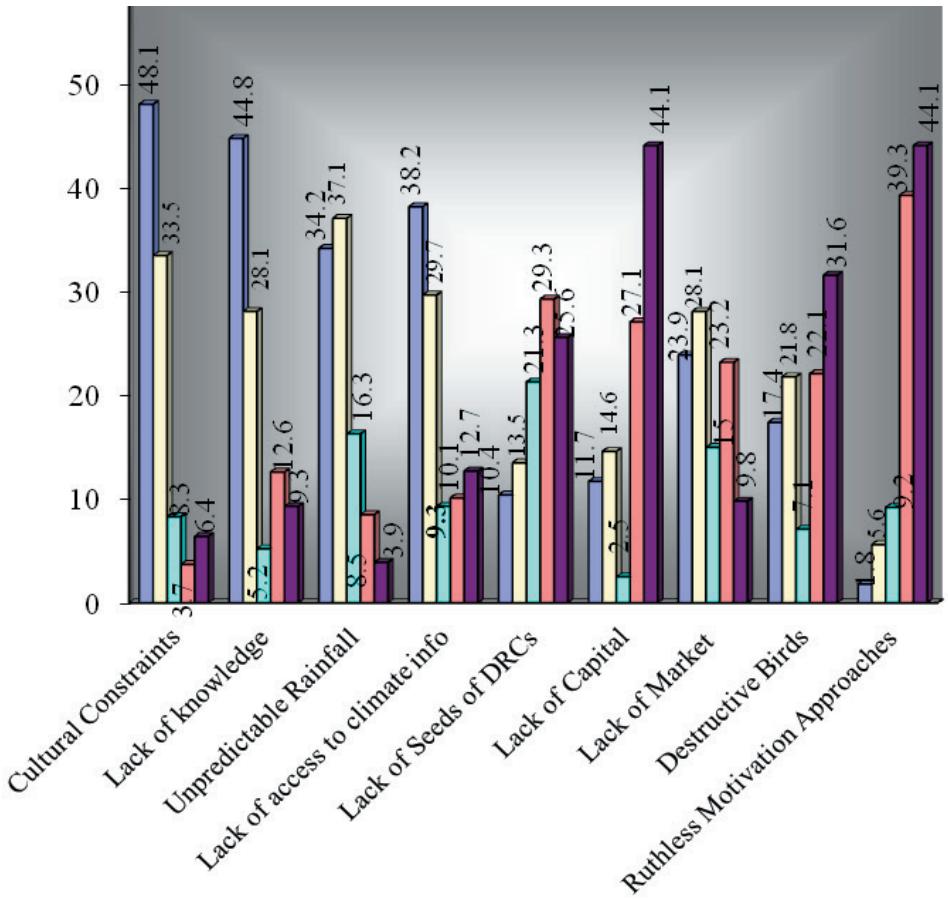


Figure 1: Barriers to Adoption of DRCs

Source: Field Data, 2016

Some barriers were considered important by majority of the respondents while others were considered unimportant by the majority (Figure 2). This study categorized them into two groups, viz. *major* and *minor* barriers. Major barriers were cultural constraints, lack of knowledge, unpredictable rainfall, lack of access to climate information, and market constraints whereas minor barriers were lack of seeds, lack of capital, destructive birds and forceful motivation approaches.

Major Barriers to Adoption of DRCs

Nearly half of the respondents (48.1%) perceived *cultural constraints* as very important barrier to adoption of DRCs (Figure 1). Cumulatively, respondents who viewed cultural constraints to be very important and fairly important amount to 81.6%. It is worth noting that, majority of the population in Same district belong to *Pare* ethnicity whose staple foods are *Makande* and *Ugali. Makande* is made from maize and beans while *Ugali* is made of maize flour and is normally eaten with beans. Thus, maize and beans (which are non-DRCs) have become the main crops grown in the district. The fact that foods prepared

using DRCs, like millet, cassava and sweat potatoes, are not preferred by the majority in Same district has become a barrier to growing such crops. Indeed, such foods are regarded by the majority as foods for hunger periods or for the poor. These findings concur with Chivenge, et al., (2015) who found that although DRCs provided food for ancestors, they are currently neglected as a result of promotion of the so called major crops. Worse still, major crops which are generally non-DRCs are promoted even in drought prone areas and periods.

Lack of knowledge about DRCs and their importance on adapting to drought impacts was considered an important barrier to their adoption by **72.9%** of the respondents (**44.8%** very important and **28.1%** fairly important). These respondents showed that they didn't know about some DRCs, such as sorghum, barley and sunflower. These farmers would not grow crops which they don't know. DRCs such as cassava and sweat potatoes were well known. However, they were less grown due to other barriers, like cultural constraints. It is important that farmers are well informed about DRCs that can be grown in their areas along with their importance in adapting to drought impact. This knowledge can be provided by ward agricultural officers.

Unpredictable rainfall was yet another major barrier to adoption of DRCs. This barrier was perceived as very important and fairly important by **34.2%** and **37.1%** of the respondents respectively (Figure 1). Thus, **71.3%** of the respondents considered unpredictability of rainfall as an important barrier. Studies have shown that rainfall in Same district is highly variable (Enfors and Gordon, 2007; Afifi, et al., 2014). This rainfall characteristic makes it difficult for farmers to plan for adaptation strategies including adoption of DRCs.

Lack of access to climate information was perceived very important and fairly important barrier to adoption of DRCs by **38.2%** and **29.7%** of the respondents respectively. Overall, this factor was perceived an important barrier by **67.9%** of the respondents. When asked about access to climate information, only **16%** of the respondents said that they were accessing climate information frequently and **33%** responded that their access to climate information was just occasionally. **51%** of the respondent said that they had no access to climate information. These findings concur with findings of many studies pertaining to CC adaptations. Such studies have reported access to climate information as vital in adaptations and lack of one has resulted into poor adaptation (Deressa, et al., 2009; Nhemachena and Hassan, 2008; Anik and Salam, 2015).

Market constraints was considered very important and fairly important barrier to adoption of DRCs by **23.9%** and **28.1%** of the respondents respectively. Market conditions, like distance from the farm, mode of transport, demand, price and knowledge about market existence are very important factor for farmers' choice of crops to grow. It was found that the price of crops such as millet, cassava and sweat potatoes were very low. Besides, farmers were not certain on markets of crops such as sunflower, wheat and millet. These situations were reported to discourage adoption of those crops.

Minor Barriers to Adoption of DRCs

Apart from major barriers discussed in the preceding sections, some other barriers to adoption of DRCs were also recognized, though by relatively few respondents. Since these barriers were identified by few respondents, we regarded them as minor barriers. Such barriers were lack of seeds of DRCs, lack of capital, destructive birds and forceful motivation approaches.

Lack of seeds of *DRCs* was perceived very important and fairly important barrier to adoption of DRCs by **10.4%** and **13.5%** of the respondents respectively (Figure 1). Respondents were of the opinion that seeds of crops like millet, wheat and sunflower were not available in their areas, something which hampered their growth. Instead, seed companies and business men concentrate on supply of maize seeds even in driest areas and seasons. Although this barrier was considered important by the minority in Same, other studies have reported the same findings. Chivenge, *et al.,* (2015) reported that one way through which

drought resistant crops are discouraged in many places of the Sub- Saharan Africa is lack of seeds of such crops at local areas.

Lack of capital was identified as very important and fairly important barrier to adoption of DRCs by **11.7%** and **14.6%** of the respondents respectively (Figure 1). However, majority of the respondents (71.1%) viewed that lack of capital was very unimportant barrier to adoption of such crops. These respondents were of the opinion that growing DRCs is more or less the same as growing non-DRCs like maize and beans. Thus, no additional costs on growing DRCs.

Besides, the study found that millet, wheat and sunflower are among the DRCs grown in the study area, though by relatively few farmers. However, these crops were reported to be eaten by birds before ripening. **39.2%** of the respondents perceived *destructive birds* to be important barrier to adoption of DRCs. Accordingly, this increased labour as farmers have to spend over a month chasing birds. This was especially the case with farmers at Saweni village where relatively large number of farmers had tried growing millet and sunflower but many of them ceased due to this problem. Instead farmers grow these crops at very small plots around their homes where birds can be easily chased away while doing other activities. Other methods to protect birds for sunflower and millet include the use of plastic bags and bottles to cover the crops (Plate 1). However, these methods are possible for just small plots.



Plate 1: Millet covered by plastic bottles to protect them from being eaten by birds

Source: Field Data (2016).

Forceful motivation approach was reported to be very important and fairly important barrier to adoption of DRCs by **1.8%** and **5.6%** of the respondents. Thus, generally only **7.4%** of the respondents perceived this factor to be an important barrier. Although these respondents were relatively few, they were of the opinion that leaders have been using forceful approaches to motivate farmers grow DRCs. These forceful approaches have long history in the district, since periods of traditional leaders (*Wafumwa)*. These leaders used to force residents to grow crops such as cassava, millet and sweat potatoes to combat hunger in their areas. Current leaders are still using such approaches as they sometimes order every household to have a

piece of land grown a selected drought resistant crop. Farmers in the studied villages were of the opinion that provision of education about DRCs should take the position of forceful orders.

Conclusion

This study examined determinants of farmers' adoption of DRCs in Same – a semiarid district in North-east Tanzania. The study has shown access to climate information and agricultural extension services to be among the determinants of adoption of DRCs. It was found that adoption of these crops is a process which is influenced by farmers' knowledge about the possibility and probability of drought outbreak in their local areas together with efficacy of DRCs in adapting to drought impacts. Results have also shown that food preferences, farm size, sex of head of the household and location influence farmers' decisions to adopt DRCs. Other factors, including households' income and education of head of the households were found to have no significant influence. Lack of relationships between these variables and adoption of DRCs may result from nature of sampled farmers who were more homogeneous in term of income and education levels. Besides, the study found various barriers to adoption of DRCs. Basing on relative importance of those barriers, this study has categorized them into major and minor barriers.

Results of this study emphasize the need to provide knowledge to farmers regarding agricultural practices which best suit their localities instead of practicing traditional farming which does not match current changes in the climate system. It is also suggested that presence of seeds of DRCs at the onset of seasons and at the affordable price will motivate farmers to grow DRCs to increase production even in case of drought outbreak. Such efforts will help insure food security among farming households.

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