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Barriers and opportunities to climate change adaptation in rural Africa: Evidence from the Eastern Cape Province of South Africa

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Abstract

Smallholder farmers operate in highly sensitive farming environments in rural Africa. They are also highly vulnerable to climate change shocks for most of their livelihoods are derived from land-based natural resources sensitive to climate change. Of interest to note, is the fact that, most smallholder farmers have managed to cope with such climate change shocks using their indigenous knowledge, past experience and tacit knowledge, although their copping experiences has received minor attention. This paper used cross sectional survey data (n = 250) from the Eastern Cape Province of South Africa to estimate smallholder farmers' adaptation strategies to climate change and factors that conditions their choices. Results reveal several adaptation strategies used by smallholder farmers in response to climate change (changing crop varieties, intercropping, staggering planting dates, supplementary irrigation, water conservation techniques, shifting cultivation, use of indigenous vegetables and fruits) poorly defined in one adaptation portfolio – on-farm activities. These adaptation options are also influenced by socio-economic, institutional and climate variables worth targeting to enhance smallholder farmers' resilience to climate change shocks. The paper therefore makes several policy insights given the poor portfolio adaptation diversity revealed under the smallholder farming sector.

Keywords: Climate Change, Smallholder Farmers, Adaptation Strategies, South Africa

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1. Introduction

Climate change, has presented multiple detrimental challenges to societies in rural Africa (Juana et al., 2013; Mabe et al., 2014), most importantly their livelihood strategies (Hiremath and Shiyani, 2013) which are mainly natural resource-based (Deressa et al., 2008; Heltberg and Bonch-Osmolovskiy, 2011; Zeleke and Aberra, 2014). In the process rural smallholder farmers have adopted several adaptation strategies (important resilience factors) in response to climate change (Ellis, 2000; Lipton, 2004; Morton, 2007; Hassan and Nhemachena, 2008; Zeleke and Aberra, 2014). Of interest to note are the "emerging new complex livelihoods trends" (Morton, 2007) pursued by rural communities worth understanding given that adaptation may be a more realistic alternative for Africa (Hassan and Nhemachena, 2008; Taruvinga et al., 2013; Nhemachena et al., 2014).

Unfortunately literature has paid little attention to such rural farmer driven adaptation strategies (Morton, 2007) for the main focus has been centred on large scale commercial farmers and projections of future impacts (Hiremath and Shiyani, 2013). Thus far, not much is therefore known about the vulnerability status of smallholder rural farmers and their tried location specific adaptation strategies to climate change (Morton, 2007; Kurukulasuriya and Medelsohn, 2008; Mabe et al., 2014).

With that background, the study focused on such gaps (adaptation strategies of rural smallholder farmers to climate change) for purposes of understanding rural community driven, user friendly and tried adaptation strategies that can be supported or enhanced through public policy, investments and further research.

2. Problem statement

Several studies of climate change in Africa focus on medium to large scale commercial farmers at the expense of rural smallholder farmers (Hiremath and Shiyani, 2013) who are a major victim (Thornton et al., 2008) of, and minor contributor to, climate change. Also, several studies on climate change focus on projected impacts on crop and livestock performance at the expense of tried adaptation strategies to mitigate such challenges (Morton, 2007; Kurukulasuriya and Medelsohn, 2008). For the few studies that focus on adaptation strategies (Morton, 2007; Kurukulasuriya and Mendelsohn, 2008), not much is also said about factors that influence farmers to make such choices (Mabe et al., 2014; Nhemachena et al., 2014).

With that background, the paper was motivated by the quest to understand rural smallholder farmers` locally tried successful adaptation strategies and factors that influence such choices as potential barriers and incentives to adaptation. The motivation as it were, was based on the "emerging new complex livelihoods trends" (Morton, 2007) created in response to climate change impacts worth understanding as practical adaptations strategies available for rural communities (Nhemachena et al., 2014).

2.1. Objective

- To assess smallholder farmers' adaptation strategies to climate change
- To estimate factors that influence smallholder farmers' adaptation choices to climate change

3. Literature review

This section presents literature on adaptation strategies to climate change and factors that influence adaptations. Literature reports several climate change adaptation strategies to include: changing crop varieties, intercropping, staggering planting dates, integration of on-farm and off-farm livelihoods activities, supplementary irrigation, use of water conservation techniques/water harvesting (Nhemachena et al., 2014), agro-forestry, use of compost and fertilizers (Zeleke and Aberra, 2014), destocking, fallowing (Mabe et al., 2014), shifting cultivation, crop-livestock and livestock-crop switching, shading and shelter, use of insurance and use of livestock species that are more suited to drier conditions (Maddison, 2006; Nhemachena and Hassan, 2007; Hassan and Nhemachena, 2008; Taruvinga et al., 2016). With regards to factors that influence farmers' selection choices of climate change adaptation strategies, literature suggests several socio-economic (gender, education, family size, age), institutional (access to extension, credit, markets) and climatic (temperature and rainfall) factors (Deressa, 2007; Hassan and Nhemachena, 2008; Bryan et al., 2013; Nhemachena et al., 2014; Taruvinga et al., 2016). This paper therefore seeks to understand household level adaptation strategies to climate change as significant local indigenous knowledge and factors that condition such choices.

4. Methodology

4.1. Study area

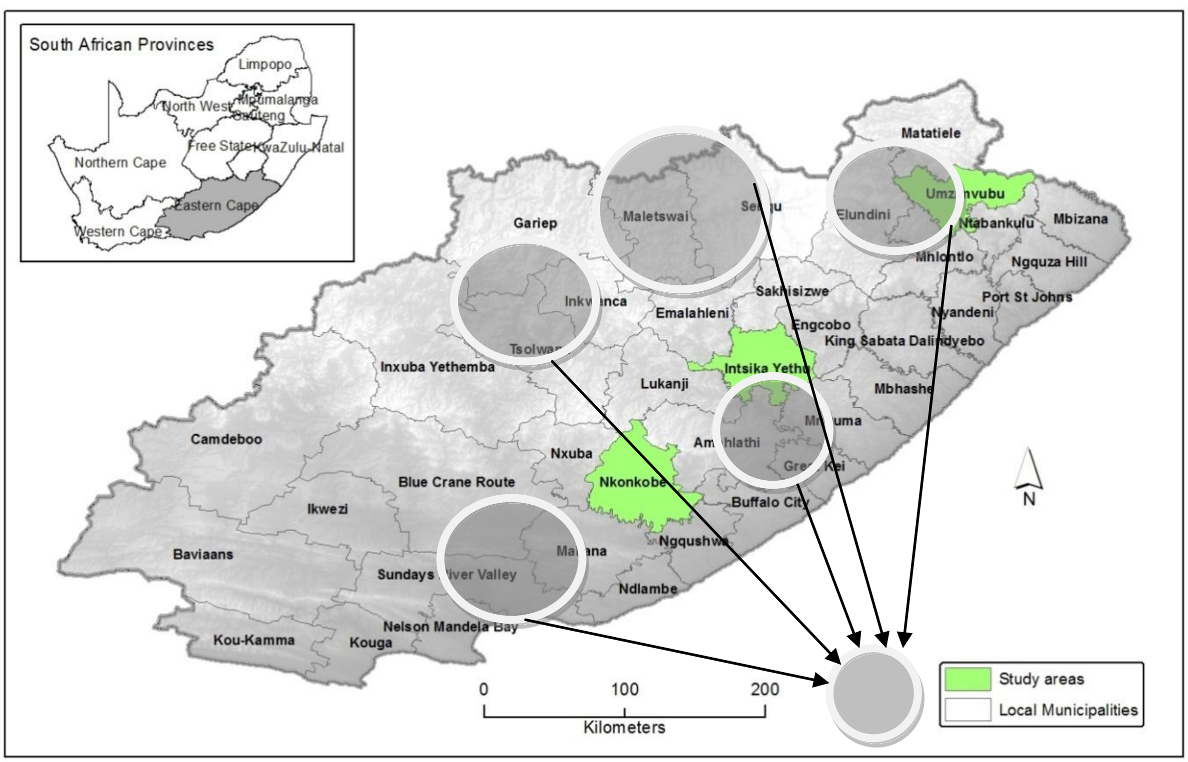

Figure 1. Study sampling frame location map

This study was conducted in five purposively selected Local Municipalities of the Eastern Cape Province of South Africa located in different agro-ecological positions to enhance estimation of the impact of temperature and rainfall variations on adaptation strategies selected by rural households. Figure 1 presents 5 Local Municipalities that were used as the sample frame.

Using a cross-sectional survey approach 50 respondents from each of the above five Local Municipalities were randomly selected for interviews to give a total of 250 respondents.

4.2. Analysis

4.2.1. Theoretical framework

Rural smallholder farmers have different socio-economic and institutional attributes and are also exposed to different climatic conditions. Literature argue that these conditions may influence how farmers select adaptation strategies to climate change available to them (Deressa et al., 2008; Taruvinga et al., 2013) in line with the utility associated with each choice (Mabe et al., 2014).

With that background, the utility associated with each choice by the "i"th smallholder farmer are not directly observable, while adaptation choices made are observable, and unordered (Deressa et al., 2008). Adaptation strategy to climate change may therefore be explained by the random utility maximisation theory (Mabe et al., 2014). A smallholder farmer would therefore choose adaptation strategy "j" over adaptation strategy "k" if and only the perceived utility from adaptation strategy "j" is greater than of "k" as illustrated in equation 1 (Falco et al., 2007; Deressa et al., 2008).

$$U_{ij}\left(\grave{\beta_j} X_i + \varepsilon_j\right) > \left(U_{ik}\left(\grave{\beta_k} X_i + \varepsilon_i\right)\right), \forall\ k \neq j \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where;

- U_{jk} = denotes perceived utilities of adaptation strategies "j" and "k"
- X_i = vector of explanatory variables that condition the perceived adaptation strategy
- β_{jk} = parameters to be estimated
- e_{ik} = error terms [assumed to be independently and identically distributed (Greene, 2000)]

Thus far, using econometric models it becomes possible to relate observable socio-economic, institutional and climate variables to adaptation selection choices made by rural "i"th smallholder farmer as detailed in the econometric model presented in the next section.

4.2.2. Empirical model

Several econometric models have been used to estimate the relationship between farmers' identified adaptation strategies and a set of predictor independent variables. They range from univariate techniques, multivariate techniques to multinomial discrete choice models (Seo and Mendelsohn, 2006; Nhemachena et al., 2014). For this study a binary logit model was used.

The approach allows each adaptation strategy to be analysed separately and independently, thus eliminating the challenge of the independence of irrelevant alternatives (IIA) assumption (Mabe et al., 2014) generic with multinomial logit (MNL) model (Bryan et al., 2013), given the true reality that a household can choose more than two adaptation strategies. Previous literature argues that univariate techniques ignore potential correlations among the unobserved disturbances in adaptation strategies (Belderbos at al., 2004). In this paper we maintained the binary logit model to avoid misrepresentation of originally reported adaptation strategies possible through grouping of researcher perceived similar adaptation strategies to create categories (Bryan et al., 2013; Zeleke and Aberra, 2014; Mabe et al., 2014).

Each farmer was therefore faced with a binary choice dummied as 1 if a farmer chooses "j"th adaptation strategy in response to climate change and 0 otherwise (Bryan et al., 2013). Assuming Y to be an adaptation strategy likely to be pursued by "i"th farmer and X are the socio-economic, climate and institutional factors likely to affect Y, a logistic model can be used to analyse the expected relationship (Fosu-Mensah et al., 2007; Zeleke and Aberra, 2014). Following an approach by Acquah (2011) the effects of X on the response probability, P(y=j/x) can be estimated using a binary logit model as illustrated in equation 2 to 5:

$$P\left(\frac{Y_i}{X}\right) = F(Z_j) = \frac{e^{Zi}}{1+e^{Zi}} = \frac{1}{1+e^{-Zi}} \quad (2)$$

$$P\left(Y_i = \frac{j}{X_i}\right) = F(Z_j) = \frac{e^{Zi}}{1+e^{Zj}} = \frac{1}{1+e^{-Zj}} \quad (3)$$

$$Z_i = \beta_0 + \beta_1 X_{1i} +, \dots, + \beta_{ni} X_{ni} + \mu_i \quad (4)$$

with the specific binary logit model expressed as follows (Apata et al., 2009);

$$ln\left[\frac{P_j}{1-P_j}\right] = \beta_0 + \beta_1 X_{1i} +, \dots, +\beta_{ni} + \mu_i \quad (5)$$

n = 1,2, ... , 17.

4.2.3. Dependent and independent variables

The dependent variables for the model were the reported major adaptation strategies by the respondents (dummied as 1 if the respondent adopts that particular adaptation option and 0 otherwise).

4.2.4. Independent variables

Different socio-economic, institutional and climate variables were included as independent variables in the estimation procedure, whose choice was based on experience, previous studies and availability of data.

5. Results and discussion

This section presents the research findings of this study, based on descriptive and econometric results.

5.1. Basic sample statistics summary

Table 1 provides the basic sample characteristics from the study area. A total of 250 respondents were considered for this study, with a mean household-head age of 54 years. The mean education level was 1; this implies that, on average, respondents were educated up to the level of primary schooling. Basic sample statistics also suggest that the considered sample had more males than females with an average household size of 6 family members. A majority of the respondents did not have access to extension, market and both formal and informal credit services. With reference to arable land results indicates that a majority were land owners of 0.5 – 2ha under communal ownership.

Table 1. Basic sample statistics of the sample population

Descriptive Statistics						
Variables	N	Minimum	Maximum	Mean	Std. Deviation	Skewness
1. Rainfall	250	484	1032	839.52	162.438	-.608
2. Max Temp	250	23.9	28.9	26.039	1.4215	.331
3. Min Temp	250	4.7	11.6	7.763	2.1589	.521
4. Marital status	250	0	2	1.02	.679	-.026
5. Age	250	24	87	54.12	14.550	.040
6. Gender	250	0	1	.46	.500	.150
7. Education	250	0	3	1.14	.791	-.214
8. Family size	250	0	15	5.50	2.496	.412
9. Wealth status	250	0	1	.30	.508	.089
10. Land ownership	250	0	1	.90	.349	-.913
11. Land size	250	1	3	1.61	.898	.117
12. Type of land ownership	250	0	2	.42	.864	1.112
13. Access to formal credit	250	0	1	.14	.372	2.436
14. Access to informal credit	250	0	1	.24	.426	1.245
15. Membership to CBOs	250	0	1	.38	.494	.579
16. Access to markets	250	0	1	.43	.496	.294
17. Access to extension	250	0	1	.33	.472	.717

Lastly the sample statistic reveals that a majority of the respondents were classified as poor families who didn't belong to any community based farming organisation. The asymmetry of distribution was both positively and negatively skewed, as shown in Table 1. Most of the variables had skewness values below and close to 1 (with the exception of access to formal credit); this suggests that the distribution did not differ significantly from a normal symmetric distribution.

5.2. On-farm crop-based adaptation strategies to climate change

Several on-farm crop-based adaptation strategies to climate change were reported as summarised in Figure 1. Intercropping was reported across all study sites, respondents citing microclimate advantages and potential to spread risk in the event of extreme temperatures that would affect other crops. Similar comparable observations were earlier shared by Lithourgidis et al. (2011) arguing that, intercropping brings partial restoration of diversity lost under mono-cropping and provide high insurance against crop failure in areas subject to extreme weather conditions such as frost, drought and floods.

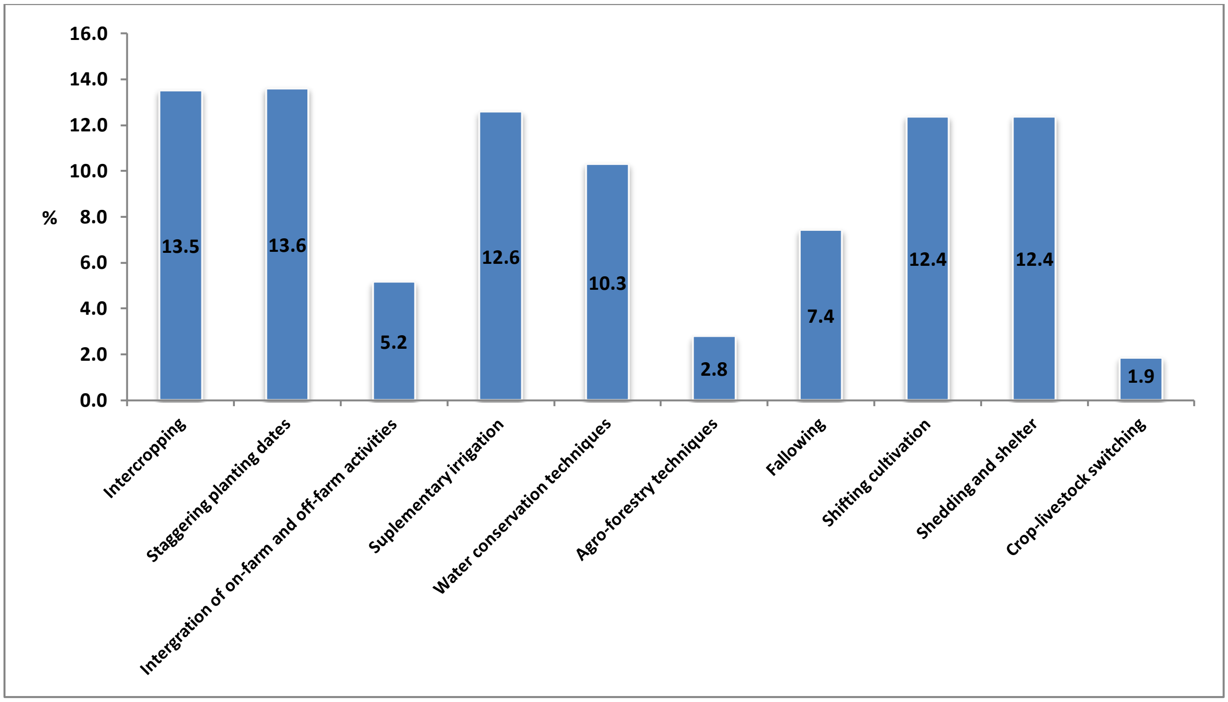

Figure 1. Reported crop based adaptation strategies from the study area

Staggering plantings dates was also a common adaptation strategy used my local farmers in response to climate change. Changing planting dates is viewed as an effective low cost strategy capable of avoiding crop exposure to extreme climate like high temperatures and low rainfall assuming these adverse conditions can be predicted.

Crop water demand is likely to increase with warming. In response smallholder farmers consider supplementary irrigation (more commonly under home gardens), adoption of infield water conservation techniques, shedding and mulching. Respondents noted that although supplementary irrigation was effective, establishment and running costs were the main limiting factor. Water conservation techniques, shedding and mulching were therefore viewed as user friendly and cost effective adaptations in response to increased crop water demand than supplementary irrigation from the study area.

Shifting cultivation was also commonly used by respondents in response to climate change. Farmers reported shifting their cultivation from one field to another with a general trend of moving away from uplands towards wetlands in search of high moisture content and fertile soils. Other reported adaptation strategies include; integration of on-farm and off-farm activities, agro-forestry and crop-livestock switching.

5.3. On-farm livestock-based adaptation strategies to climate change

This section presents results on farmer reported on-farm livestock-based adaptation strategies to climate change as summarised in Figure 2. Three main adaptations were reported in this category namely; destocking, use of drought tolerant species and livestock-crop switching.

Destocking was the main adaptation strategy used by local farmers contrary to the general cultural norms of keeping large heard of cattle. Farmers noted that climate change was forcing them to reduce their livestock (cattle and sheep) in line with low carrying capacity of their grazing land.

Farmers also switched livestock species in response to climate change. Both inter and intra species swaps were very common. Drought resistant species like beef cattle, goats, donkeys and indigenous chicken were targeted by most farmers. Intra species swaps were skewed in favour of indigenous breeds like the Nguni cattle and indigenous goats and chickens breeds.

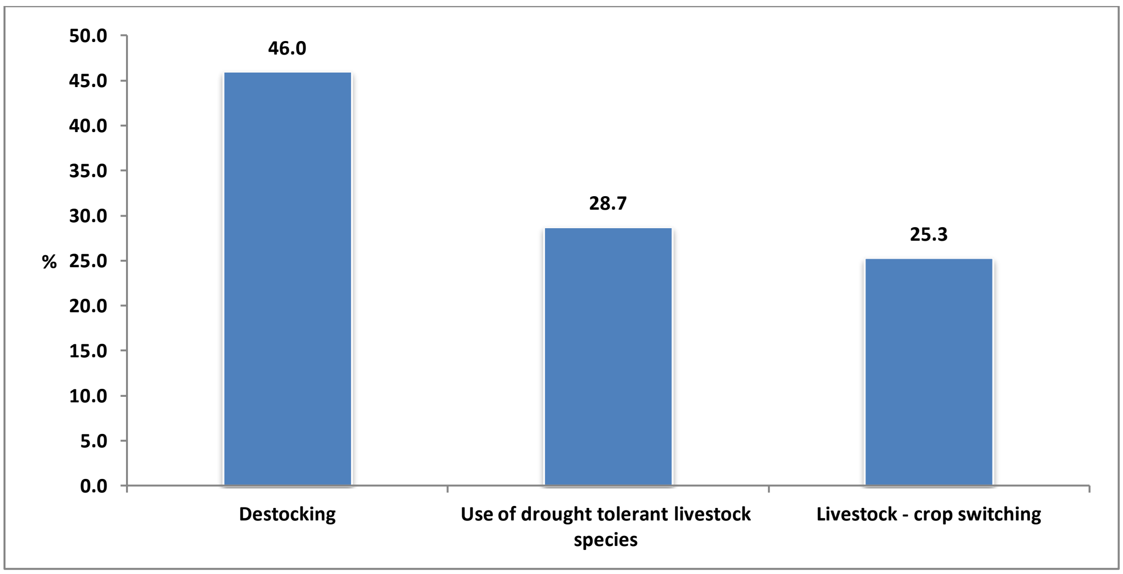

Figure 2. Reported livestock based adaptation strategies from the study area

Other farmers also reported switching from livestock to crop production more common with wet conditions. They argued that under high rainfall conditions crop production was more productive and easier to manage than livestock normally associated with high disease challenges in the absence of adequate extension support services.

These findings reveal limited livestock adaptation strategies more defined in the use of indigenous drought tolerant species rarely supported by research, extension and markets. Thus far, smallholder rural farmers face very limited livestock-based adaptation options a significant factor that is likely to reduce livestock populations in rural areas with climate change and negatively impact on their livelihoods which traditionally have been shaped around livestock.

5.4. Off- farm natural resource-based adaptation strategies to climate change

In this section farmer off-farm natural resource-based adaptation strategies are reported as summarised in Figure 3. Rural farmers have relied on the natural environment since long back although research and available institutional support frameworks (extension, policy, funding) have not adequately supported them. Several natural flora and fauna adaptations were reported from the study area.

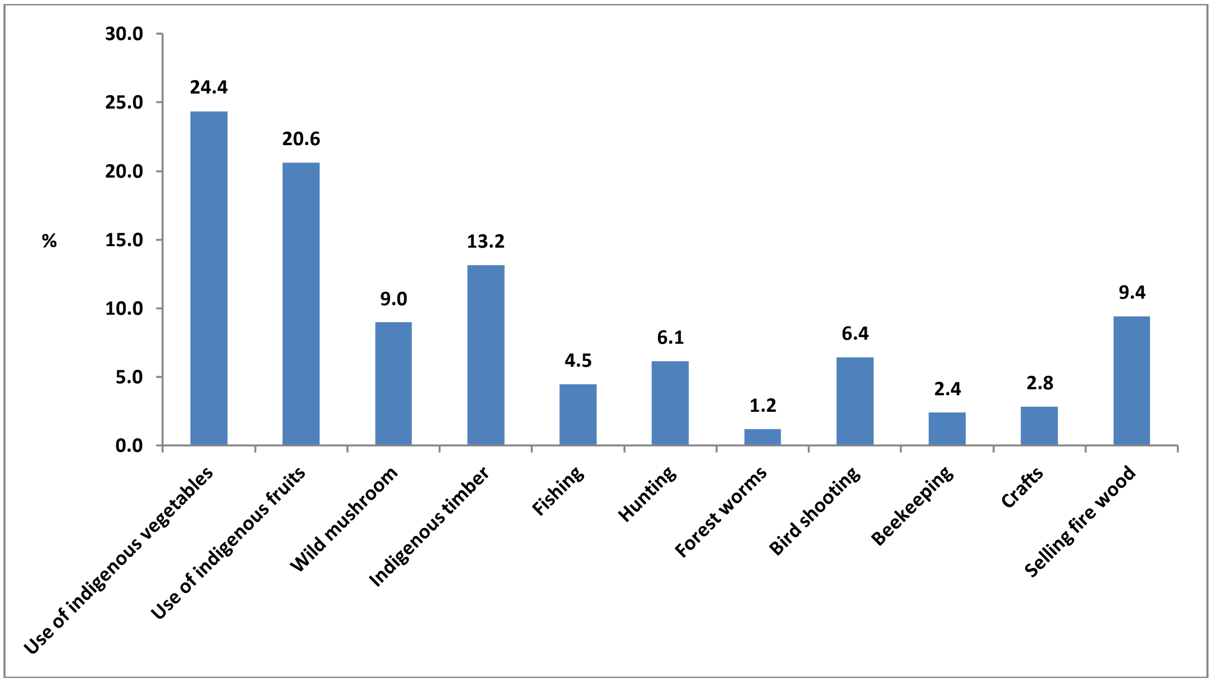

Figure 3: Reported off-farm natural resources adaptation strategies from the study area

With respect to climate change respondents reported frequent use of the following floral natural resources: indigenous vegetables (Jews mallow: *Corchorus olitorius* L.), indigenous fruits (Num-num: *Carissa macrocarpa*; Kei apple: *Dovyalis caffra*; Monkey orange: *Strychnos spinosa*) and wild mushroom. The following fauna were reported from the study area: bird shooting (6.4%), hunting (6.1%), fishing (4.5%) and forest worms (1.2%). Indigenous timber was also a significant adaptation strategy (13.2%) as well as selling fire wood (9.4%) and crafts (2.8%). These finding suggests adaptation strategies skewed in favour of floral natural resources (indigenous vegetables and fruits, wild mushroom and selling firewood) and indigenous timber than fauna resources.

Combining all adaptations, the paper estimated dominant strategies pursued by rural farmers as summarised in Figure 4. Results reveal that, in response to climate change rural smallholder farmers adapt the following strategies; changing crop varieties (9%), intercropping (8%), staggering planting dates (8%), supplementary irrigation (7%), water conservation techniques (5%), shifting cultivation (7%), use of indigenous vegetables (9%) and fruits (8).

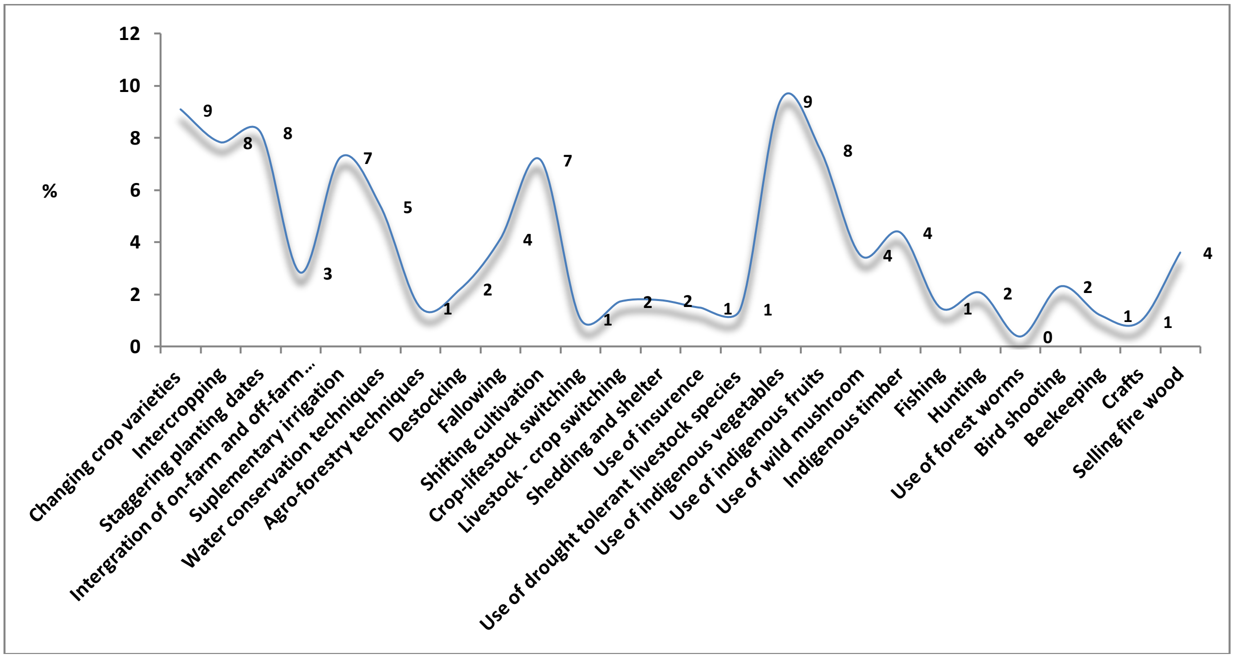

Figure 4: Farmer adaptation strategies to climate change

These findings suggests that when it comes to adaptation to climate change in rural areas, smallholder farmers rely more on on-farm crop based adaptation strategies (changing crop varieties, intercropping, staggering planting dates, supplementary irrigation, water conservation techniques, shifting cultivation) followed by limited off-farm floral adaptations (use of indigenous vegetables and fruits). This suggests poor climate change adaptation portfolio diversity for rural smallholder farmers (Taruvinga et al., 2016) more defined in one portfolio (on-farm crop based adaptations). With that background, in the next section, the paper explores potential barriers and opportunities faced by smallholder farmers as they try to adopt the above main coping strategies.

5.5. Factors that influence rural households` adaptation choices to climate change

For purposes of eliminating the possibility of interactions among the adaptation decisions of farmers, eight different binary logit regression models were ran for each adaptation strategy as summarised in Table 2. With regards to the model fit, the Lemeshow Goodness-of-Fit test statistics for the overall fit of the models showed that the explanatory variables were jointly significant in explaining each of the dependent variables at an acceptable level. The following *Nagelkerke* R^2 were obtained 0.541, 0.621, 0.511, 0.600, 0.587, 0.741, 0.644, and 0.631, suggesting that more of the variation was explained by the models with overall prediction percentages of 68.2%, 66.8%, 75.6% 71.0%, 69.6%, 76.3%, 71.4%, and 67.5%, respectively.

5.5.1. Changing crop varieties

Wealth status, type of land ownership and access to informal credit were statistically significant in explaining the selection of changing crop varieties in response to climate change. Results reveal a positive association between wealth status of smallholder farmers and changing crop varieties. Wealth plays a crucial role in rural areas when it comes to selection of adaptation strategies. Changing crop varieties has cost implications (Nhemachena et al., 2014) if moving from landraces to improved Open Pollinated Varieties (OPVs) or hybrids with drought tolerance.

As expected model results confirm a positive relationship between secure land tenure and changing crop varieties as an adaptation strategy to climate change. This suggest that smallholder farmers prefer to use improved varieties (OPVs and hybrids) that require more inputs for owned plots with secure tenure. Comparable observations are suggested in previous literature arguing that farmers prefer to use inorganic fertilizer on less secure land and reserve other inputs for owned plots with long-term security (Birungi and Hassan, 2010). More recently Nhemachena et al., (2014) highlighted the importance of secure private property especially in rural areas to promote uptake of long-term climate change adaptations investments by farmers. Similarly, Herath and Takeya (2003) argue that a more secure land ownership may have positive technology adoption incentives through lengthening planning horizons and the share of benefits accruing to adopters while lowering the rates of time preferences.

Lastly in this adaptation portfolio, a positive association between access to informal credit and changing crop varieties was confirmed. Nhemachena et al. (2014) noted that access to cheap credit improves financial resources of farmers and their ability to choose different adaptation techniques like buying new varieties. Thus far, to promote smallholder rural farmers' ability to change crop varieties in response to climate change the following socio-economic and institutional factors may be targeted; improving their general wealth status, more secure land tenure systems and access to cheap informal credit facilities.

5.5.2. Intercropping

The following predictor variables were statistically significant towards conditioning the probability of smallholder rural farmers to select intercropping as an adaption strategy in response to climate change; wealth status, type of land ownership and access to extension. Results reveal that a one standard deviation positive change in wealth status, holding other predictor variables constant, yield a decrease of 0.483 standard deviations for the selection of the intercropping adaptation choice. This suggests that the more smallholder rural farmers become wealthy the more they are likely to abandon intercropping, normally targeting monocroping typical for cash crops. To that end, intercropping may be an adaptation strategy for poor smallholder rural farmers, who wish to spread the risk of individual crop failure by growing two or more crops in one field, although this may compromise individual crop yields.

With reference to type of land ownership, results indicate that a one standard deviation change in favour of private land ownership holding other predictor variables constant result in a decrease of 0.300 standard deviations for the selection of intercropping as an adaptation choice. Nhemachena et al. (2014) previously noted the importance of secure private property especially in rural areas to promote uptake of long-term climate change adaptations investments, like irrigation facilities, organic fertilizers (Birungi and Hassan, 2010) and use of hybrids. Such kind of investments normally promotes mono-cropping systems like Ht maize cultivars (herbicide – round-up tolerant) than intercropping. Similar observations were also noted by Herath and Takeya (2003) in the smallholder rubber sector in Sri Lanka.

Table 2. Determinants of adaptation to climate change at household level

Variables		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
		Changing crop varieties	Intercropping	Staggering planting dates	Supplementary irrigation	Water conservation techniques	Shifting cultivation	Use of indigenous vegetables	Use of indigenous fruits
Constant	β_0	[-1.947] .0018	[7.475] .0061	[-.917] .3967	[-6.291] .1354	[2.603] .0000	[-9.145] .0371	[9.303] .0032	[2.581] .5051
Climate variables									
Rainfall	β_1	[.002] .112	[.001] .216	[.000] .751	[.000] .822	[-.002] .033**	[-.002] .090*	[.001] .655	[.000] .961
Max Temp	β_2	[.079] .559	[-.212] .103	[.051] .727	[.226] .099*	[.103] .438	[.250] .074*	[.337] .019**	[-.147] .238
Socio-economic and institutional variables									
Marital Status	β_4	[-.128] .575	[.295] .168	[.089] .713	[.442] .052*	[-.004] .987	[.387] .094*	[.422] .085*	[-.078] .710
Age	β_5	[.001] .962	[-.016] .113	[.010] .423	[.000] .989	[.015] .180	[-.003] .775	[.034] .004***	[.008] .425
Gender	β_6	[.100] .751	[.212] .484	[-.008] .981	[-.666] .034**	[-.281] .374	[-.451] .148	[.441] .208	[-.288] .333
Education	β_7	[.288] .153	[.220] .261	[.609] .005***	[.289] .147	[.278] .169	[.310] .128	[-.199] .371	[-.105] .581
Family Size	β_8	[.064] .282	[.021] .708	[.066] .298	[-.039] .502	[-.017] .768	[.100] .101	[.096] .138	[.037] .509
Wealth Status	β_9	[.510] .082*	[-.843] .003***	[.977] .002***	[.328] .255	[.097] .745	[1.085] .000***	[-.524] .102	[-.167] .546
Landownership	β_{10}	[-.464] .295	[.587] .178	[.026] .949	[.310] .429	[.588] .150	[.051] .901	[.737] .127	[-.087] .826
Land Size	β_{11}	[-.220] .216	[-.256] .134	[.061] .749	[-.195] .277	[-.415] .028**	[.157] .393	[.429] .133**	[.341] .383**
Type of landownership	β_{12}	[.363] .033**	[-.300] .082*	[-.928] .000***	[-.259] .147	[.599] .001***	[-.493] .007***	[-.903] .200***	[-.269] .108
Access to formal credit	β_{13}	[-.610] .123	[-.577] .134	[.305] .486	[-.319] .423	[-.132] .744	[.439] .294	[-.091] .830	[-.151] .691
Access to informal credit	β_{14}	[.670] .071*	[.319] .340	[1.246] .002***	[1.050] .004***	[.087] .801	[1.460] .000***	[.143] .705	[.053] .870
Membership to CBOs	β_{15}	[.409] .212	[.447] .153	[.553] .099*	[.458] .142	[-.456] .162	[.436] .171	[-.009] .980	[.253] .403
Access to markets	β_{16}	[.237] .481	[-.125] .698	[.106] .761	[-.542] .108	[.722] .033**	[.098] .769	[-.543] .132	[.872] .006***
Access to extension	β_{17}	[.464] .181	[.652] .044**	[.575] .107	[1.177] .001***	[1.427] .000***	[.620] .065*	[.583] .121	[.734] .022**
Model Summary									
Chi-Square (df = 17)		37.975	40.845	88.587	61.640	54.255	64.578	77.224	32.587
(-2) Log Likelihood		321.828	344.918	291.343	329.405	325.675	284.656	314.302	356.332
Accuracy (%)		68.2	66.8	75.6	71.0	69.6	76.3	71.4	67.5
Nagelkerke R^2		.541	.621	.511	.600	.587	.741	.644	.631

***Notes: ***,** ** and * indicates significance at 0.01, 0.05 and 0.1 probability level respectively*

For a one standard deviation positive change in access to extension by household heads holding other predictor variables constant, results reveal an increase in the probability of selecting intercropping as an adaptation strategy by 0.562 standard deviations. Extension services provide an important source of information on climate change, and different mitigation agricultural production and management techniques (Nhemachena et al., 2014) like intercropping. Herath and Takeya (2003) suggest the innovation diffusion theory as a possible explanation for the positive effect of extension on adoption.

We therefore argue that, wealth and more secure land ownership may discourage the probability of smallholder rural farmers to select intercropping mainly because of the failure of the system to accommodate cash crops normally targeted by the wealthy farmers with access to secure land focusing on mono-crops. To that end, for promoting intercropping as an adaptation strategy in response to climate change under smallholder farming sector, access to extension may be targeted.

5.5.3. Staggering planting dates

Staggering planting dates as an adaptation strategy to climate change is conditioned by the following factors; education, wealth status, type of land ownership, access to informal credit and membership to community farming groups. Results reveal that education positively conditions the probability of smallholder farmers to choose staggering planting dates in response to climate change. The success of using staggering planting dates in response to climate change is based on selection of correct crop varieties normally short seasoned improved varieties which coincide their flowering period with the short wet periods. Education therefore plays a critical role for purposes of mastering varietal choices and timing. Similarly the revealed positive association between wealth status, access to informal credit and staggering plant dates may be explained by the cost implications of using improved short seasoned varieties (improved OPVs and hybrids).

As expected a negative association between secure land tenure and selection of staggering planting dates was revealed, suggesting that the more smallholder farmers have access to secure land tenure the more they are likely to invest in long-term climate change adaptations investments (irrigation, water conservation techniques) on their land properties (Nhemachena et al., 2014) so as to accommodate medium to long seasoned high yielding varieties hence abandon staggering planting dates typical with short seasoned low yielding varieties and intercropping systems.

Membership to local farming groups was positively related to the likelihood of adopting staggering planting dates. These findings reinforce the importance of social capital as suggested by the innovation diffusion theory in explaining the positive influence of social participation and adoption (Herath and Takeya, 2003). To promote staggering planting dates as an adaption strategy the following socio-economic attributes of smallholder farmers may be targeted; social networking, access to informal credits, farmer education and improvements in their wealth status.

5.5.4. Supplementary irrigation

Results indicate that supplementary irrigation as an adaptation strategy in response to climate change may be conditioned by the following factors: temperature, marital status, gender, access to informal credit and extension services. As expected a positive association between temperature and selection of supplementary irrigation was revealed. High temperature affects plant water requirements to an extent that supplementary irrigation becomes necessary.

A positive association was revealed between marital status and selection of supplementary irrigation. These findings may be explained by age, more labour, experience and accumulation of wealth more pronounced in the married and divorced categories compared to single headed households for supplementary irrigation require capital and experience.

Model results also indicate a negative influence of gender on selection of supplementary irrigation as an adaptation strategy to climate change. These findings suggest that female headed households are more likely to choice supplementary irrigation in response to climate change compared to males. Nhemachena et al., (2014) argue that in most rural smallholder farming communities in Africa, much of the agricultural work is done by women; hence they may have more farming experience and information on how to respond to climate change. To the contrary, Muhammad-Lawal et al. (2013) argued that due to labour and energy requiring activities associated with irrigation farming a positive association is more likely.

The confirmed positive association between access to informal credit, extension services and selection of supplementary irrigation reinforce the relevance of capital and access to information towards promoting adoption.

5.5.5. Water conservation techniques

Model results reveal that water conservation techniques as an adaptation strategy may be influenced by the following factors; rainfall, land size, type of land ownership, access to markets and extension. Results confirm a negative association between rainfall and water conservation techniques. These findings suggest that as rainfall decreases smallholder farmers increase their water conservation techniques. Interestingly, this is true (intensification of water conservation techniques) for small pieces of land with more secure ownership where such farmers will be having access to markets and extension services. Several previous studies endorse the relevance of secure land ownership (Birungi and Hassan, 2010, Nhemachena et al., 2014) and extension services (Herath and Takeya, 2003) towards promoting uptake of adaptation strategies to climate change under smallholder farming sectors.

5.5.6. Shifting cultivation

With reference to shifting cultivation as an adaptation strategy to climate change, model results reveal the influence of the following factors; rainfall, temperature, marital status, wealth status, type of land ownership, access to credit and extension services. With warming, results indicate that smallholder farmers consider shifting cultivation in search of areas with high moisture content (wetlands). However as rainfall increases the probability of shifting cultivation decreases an observation that may suggests that shifting cultivation is entertained more in response to moisture stress than otherwise. Results further reveal that such an adaptation strategy is more likely to be considered by married and wealth households with insecure land ownership but having access to informal credit and extension services.

5.5.7. Use of indigenous vegetables

The use of indigenous vegetables is conditioned by the following factors; temperature, marital status and age. With warming, results indicate that smallholder farmers consider the use of indigenous vegetables for most indigenous vegetables can tolerate high temperatures compared to most exotic cultivated crops. Results also indicate a positive association between age and use of indigenous vegetables as an adaption strategy to climate change. Previous studies suggest that the youth of today perceive African Leaf Vegetables negatively, considering them as weeds or food consumed by the poor (Faber et al., 2010; Taruvinga and Nengovhela, 2015). The observed positive association may therefore be explained by the negative attitude common among the youth. The confirmed positive association between marital status and selection of indigenous vegetables could be largely due to the fact that the married farmers have more responsibilities to shoulder in terms of meeting at least the basic needs of their family members especially feeding.

5.5.8. Use of indigenous fruits

Model results reveal that selection of indigenous fruits as an adaptation strategy to climate change may be positively conditioned by; access to markets and extension. Smallholder farmers frequently sell indigenous fruits in local markets to generate household income. Access to such markets supported by access to extension is likely to trigger use of indigenous fruits as an adaptation strategy to climate change.

6. Conclusion

The study was based on household level adaptations strategies pursued by rural smallholder farmers in response to climate change and factors that influence their choices. Several adaptation strategies were reported from the study area to include the following; changing crop varieties, intercropping, staggering planting dates, supplementary irrigation, water conservation techniques, shifting cultivation, use of indigenous vegetables and fruits. The paper also investigated factors that influence rural smallholder farmers' adaptation choices to climate change concluding that several socio-economic (age, gender, education, wealth status and land size), institutional (land ownership, type of land ownership, access to informal credit, membership to CBOs, access to markets and extension), and climate variables (rainfall and temperature) condition the choice made by these farmers. The paper therefore argues that smallholder farmers' adaptation options to climate change are more defined in one portfolio (on-farm cropping activities) seriously affecting their adaptation diversity critical for purposes of spreading risk. Public policy, investments and further research that promote other adaptation portfolios (on-farm livestock and off-farm natural resources) will enhance smallholder farmers' resilience to climate changes shocks. For purposes of promoting different adaptations, caution should be exercised for they are conditioned by a diverse of farmer socio-economic and institutional attributes and climatic variables.

7. Policy

The following policy insights are suggested based on the research findings;

- To promote the selection of off-farm natural resources as an adaptation portfolio to climate change institutional factors like access to markets and extension plays a critical role. Also, results suggest that awareness campaigns dispelling the "food for the poor" tag associated with indigenous vegetables and fruits among the youth should be targeted.
- With reference to most on-farm cropping adaptations considered by a majority of smallholder farmers, factors like access to extension, wealth, social cohesion, secure land properties and access to informal credit may be targeted.
- More research is however required on more adaptation strategies related to on-farm livestock and of-farm natural fauna, given the multiple direct and indirect contribution of livestock to smallholder farmers' livelihoods.

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