Financing for adaptation to climate change and variability in Tanzania: Evidence from smallholder farmers in Dodoma and Pwani Regions

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ABSTRACT

A study was conducted to examine cost effective climate change and variability adaptation strategies in Tanzania. Specifically, it aimed at identifying adaptation strategies and quantifying the financing requirements for effective adaptation and, identifying factors influencing the choice of adaptation strategies by smallholder farmers. Primary data was collected from 400 households in Dodoma and Pwani regions representing Central and Eastern zones respectively. Propensity score matching (PSM) was employed to examine the covariates that influence smallholder farmers' decision to practice interventions under climate change adaptation and variability strategies (CCVAS) and their contribution to crop productivity and income to the farmers. Adaptation costs which are proxy for the financing needs were estimated through descriptive analysis. Results indicate that four adaptation strategies (varying planting dates, land tilling, planting short variety seed and use of organic manure) were selected by the majority of households. The main factors influencing household adaptation to climate change and variability strategies are income, household size, type of occupation, farm size while the financing needs range between TZS 1.6 million and 4.2 million per household or TZS 0.39 million to 0.86 million per hectare(ha). It is recommended that, the financing strategy of CCVAS should focus on sustainable methods and their combinations with less cost and high positive impact on sustainable productivity and environmental conservation.

Keywords: Climate change and variability; adaptation strategies, cost effective, smallholder farmer

INTRODUCTION

Globally, climate change is not only a challenge to sustainable natural resources, ecosystem services, livelihood and economic development but its impact is real and nobody is immune to it (Ehrhart and Twena 2006). Climate change and variability pose serious risks to poverty reduction and threaten the effectiveness of development efforts in many developing countries. The impacts of climate change and variability are not likely to be uniform across and within countries. Climate change affects low latitude countries more heavily (McCarthy *et al.* 2001). Low latitude countries including Tanzania are expected to be more vulnerable to climate change because they are already warm, they rely on low-capital technology, and agriculture is a large and sensitive component of their economies (Mendelsohn *et al.* 2003). Climate change and variability are a threat to food security as they affect food availability, access to food, stability of food supplies, and food utilization. Climate change and variability affect agriculture and food production directly through changes in agro-ecological conditions and indirectly by influencing growth and distribution of incomes, and thus demand for agricultural products (Edame *et al.* 2011). Communities in rural areas are the most vulnerable to climate change and variability due to their high dependence on rain fed agriculture and due to the low capacity to adapt to the impacts of climate change.

The agricultural sector, which is mainly dominated by smallholder farmers, is one of the largest and important sectors to the national economy in Tanzania. About71% of the population lives in rural areas and their livelihood and income significantly depend on agriculture (URT 2011; URT 2015; URT 2016). The sector is more than 95% dependent on rainfall and is characterized by traditional technologies (URT 2013). This implies that a large population in the country and the economy at large are vulnerable to climatic change and variability as the climate change and variability affect agriculture (IPCC 2007; 2014). Thus, the need to address challenges and problems afflicting smallholder agricultural farmers due to impacts associated with climate change and variability is both developmental, academic and policy oriented. In the same vein, there is a need to explore smallholder farmers' activities or practices and how they contribute to climate change and variability adaptation as it has been highlighted in some policies and strategies such as National Agricultural Policy (2013) and National Climate Change Strategy (2012) that have direct link to climate change and variability in Tanzania.

At the national level, various programme documents and strategies acknowledge that interventions in the agriculture sector will facilitate increased efficiency and productivity, thereby making it possible to increase food production and hence achieve food security. The National Adaptation Programme of Action (NAPA) and the second five-year development plan (FYDP II) (2016/17 – 2020/21) document well strategic interventions where core priorities include issues related to agriculture and water and sanitation. The National Strategy for Growth and Poverty Reduction (NSGPR) II (2010/11-2014/15) and the first Five Year Development Plan (FYDP I) (2011/12 – 2015/16) echoed similar sentiments with regard to the effects of climate change and variability on agriculture and food security in the country. However, cost effective adaptation strategies to cushion smallholder farmers from the adverse effects of climate change and variability are missing.

The implementation of adaptation strategies to cushion from the climate change and variability risks requires significant funding and proper coordination. This study arises out of the apparent knowledge gap on the extent to which policy statements by the government are being translated into actual investments and actions to address climate change and variability at household level. Funding is needed to implement activities that vary in scale, location and technological adoption. There is considerable complexity to adaptation and careful analysis is needed to identify the appropriate financial instruments that meet the needs of recipients' households in different geographic locations in the country. It is also recognized that climate change and variability affect the households differently in different agro-ecological zones of the country. This situation makes most households, especially in rural areas; suffer from lack of proper means of adapting to different climate change and variability strategies. Since the effect of climate change and variability is location specific based on agro-ecological zones of the country, it entails heterogeneity of the adaptation strategies and therefore different funding mechanisms are needed by households. Thus, implementation of effective adaptation strategies could only be achieved through scientific and proper identification of the spatial (location) impacts of each strategy by local inhabitants in the country. The effectiveness of the advice on the adaptation of the cost effective strategy would therefore depend to large extent on the integration of the site specific attributes and the socio-economic factors of households in each area.

This paper examined adaptation and the cost effective adaptation strategies in Dodoma and Pwani regions of Tanzania. Specifically, it identifies adaptation strategies and quantifies the financing requirements for effective adaptation. It also identifies factors that influence the choice of adaptation by smallholder farmers.

METHODOLOGY

Study area and sampling

The study was conducted in Dodoma and Pwani regions of Tanzania that represent two major agro-ecological zones, i.e. central and eastern zones respectively. Dodoma region lies between latitudes $4^0$and 6^0Sand between longitudes 35^0 to 37^0E while Pwani region lies between latitudes $6^0$and 8^0 Sand between longitudes 37^0 to$40^0 30''$E.

Bahi and Chamwino districts in the central zone and Rufiji and Kisarawe districts in the eastern zone were sampled purposively for study. The districts were sampled based on the extent of awareness on and presence of climate change and variability adaptation initiatives. Using stratified random sampling basing on agricultural activities done in the district, five villages were sampled from each district[1]. The village register formed the sampling frame. From each village, 20 households were randomly selected from village register to make a study sample of 400 households for the two zones. We also sampled from each village 5 key informants (village chairperson, village executive officer, two members from village environment and natural resources committee, and one key informant from community) for focus group discussion (FGD). Furthermore, at district level, we sampled at least two officers from agriculture and environment departments for interviews.

Data collection methods

Primary data were collected using structured and semi structured questionnaire administered to 400 sampled rural farming households through filed visits. The socio-economic, biophysical information and the adaptation costs which are proxy of the financing needs by the households were also collected through questionnaire and were complemented by information from focus group discussion at village level using a checklist. Variables which were mainly focused by the study include household size, education, age, gender, marital status, income, main occupation, investment on agriculture (expenditure on fertilizer, improved seeds, hired labour), access to credit, asset owned (value by type of asset). Also, information on the perception on the climate change and variability, perceived impact of adaptation strategies (changes in crop production, income and food security), cost of adaptation strategies (estimated cost, proportion of cost mate for each adaptation method) etc. were collected.

We also made interviews with agricultural and environment officers in each district using a checklist to gain more understanding of the extent of impact of

[1]The villages covered in each district are Idifu, Ilolo, Muungano, Itiso and Haneti (Chamwino District); Makanda, Bankolo, Chikola, Mzogole and Bahi Sokoni (Bahi district), Nyanda Katundu and Mitengwe (Kisarawe district)

climate change and variability and present or possible initiatives and financing options to reduce the impact. This information collected from these interviews assisted the researchers to verify the information collected using questionnaire at the household level.

Data analysis

Analytical framework

The challenge of modeling climate change and variability impacts arises in the wide-ranging nature of processes that underlie the working of markets, ecosystems, and human behavior. The analytical framework used in this research is the integration of modeling components that range from the processes that are driven by the household economics to those that are essentially biological in nature. Thus the methodology for this study is based on a combination of the socioeconomic information obtained from the field survey). In this study, we adopted the sustainable livelihood framework (Chambers and Conway 1992) in understanding the importance of resources and transformation structures in realizing welfare goals (Figure 1). The sustainable livelihood framework is one of the most common diagnostic tools employed in development and interventions. It promotes poverty reduction, protection and better management of the environment and places emphasis on people and resources (Carney 1998).The framework explains how complex issues of rural development could be approached and successfully addressed (Chambers and Conway 1992). The sustainable livelihoods adapted from Chambers and Conway (1992) is a framework showing the relationship among the context of the farmers' assets (represented by different forms of capital), transformation structures, livelihood strategies, and livelihood outcomes.

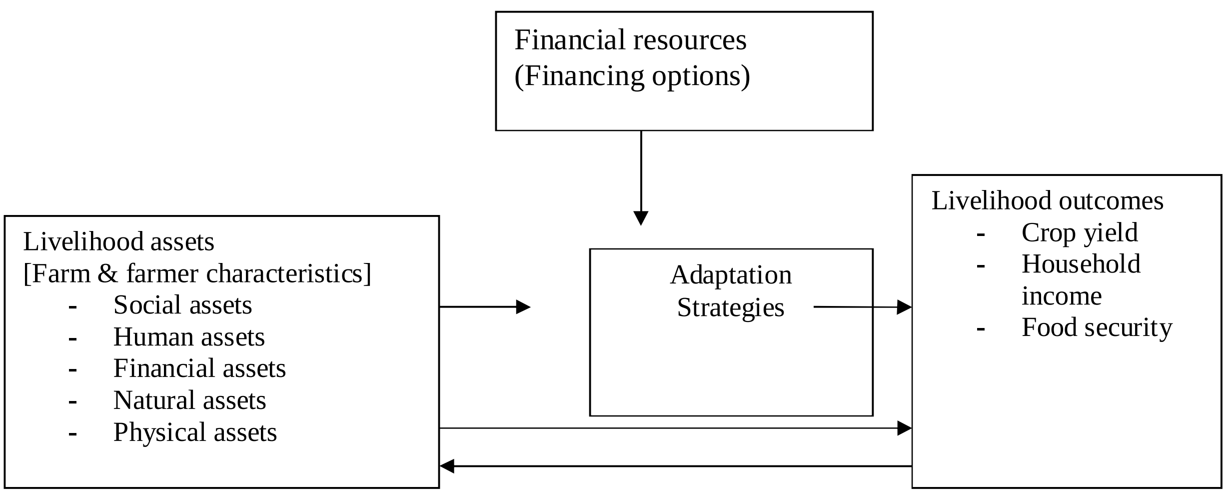

Figure 1. Modified sustainable livelihoods framework for this study

The framework shows the indirect relationship between livelihood outcomes and households' assets and the role of transformation structures and adaptation strategies. The assets comprise natural (climate, land and its resources), financial (savings, credit supplies and financial support), physical (infrastructure such as roads), social (social networks), and human forms of capital (skills and education levels). Assets form building blocks of sustainable livelihoods, impacting household capacity to withstand challenges of shocks encountered in improving livelihoods. Given asset endowments, households make decisions regarding adaptation to climate change and variability perceived by farmers to generate positive social and economic outcomes.

We extended the investigation on the link between the climate change on one hand and crop productivity and rural income on the other hand by exploring spatially what happens to major household economic activity (crop cultivation) given climate change adaptation strategies. We expect that rural income, food security and crop productivity are related to climate. Specifically, we anticipate that areas with low agricultural productivity caused by climate change and variability are more likely to harbour the rural poor. If climate conditions are not favorable, agricultural productivity will be low. Since agricultural returns are the main source of rural income, we anticipate that rural poverty will be linked with adverse climate conditions. Climate change and variability affects directly agriculture and food production through changes in agro-ecological conditions and indirectly by influencing growth and distribution of incomes. Farmers have always adapted to changing weather conditions by using a variety of production methods[2]. The poorest communities are assumed to be the most vulnerable to climate change and variability because of low capacity to adapt to the impacts of climate change. The major factors constraining farmers' adapting to climate change and variability are inadequate financial resources, lack of access to credit and lack of government support. Since most smallholder farmers have low income; this affects negatively the effectiveness of the most adaptation strategies chosen.

Specification

In this study we employed a probit model to examine the covariates that influence the farmers' decision to practice climate change adaptation, and to assess the impact of adaptation on livelihood outcomes[3]. The central goal here is to estimate the contribution of various CCVAS on the improved crop productivity and income to smallholder farmers. The estimation of the contribution is based on the Propensity Score Matching (PSM) technique suggested by Ronsenbaum and Rubin (1983). PSM is a semiparametric method that gives an average treatment effect on the treated (ATT), which is considered a better indicator of whether to continue promoting programmes that target specific groups of interest like poor farmers than population-wide average treatment effects given by probit models (Rosenbaum and Rubin 1983; Rosenbaum 2002). The basic idea behind PSM is to match each adapter of CCVAS (participant) with an identical non adapter (non-participant) and then measure the average difference in the outcome variable between the participants and the non-participants. The estimation was made through comparing the reported improved agricultural output and income of two groups of households in the study area. The first group included all households who report to have adopted a particular CCVAS strategy (participants) and the second group was one with households which have not adopted any CCVAS (non-participants). We followed the standard matching procedure described in Heckman *et al.* (1997), Heckman *et al.* (1998) and Bento *et al.* (2007) and estimated the probability of adapting strategy given some observed variables. The climate change adaptation is the treatment variable, while reported improvement in crop productivity and household income

[2]such as switching crop varieties, introducing more suitable crops, shifting agricultural production from one location to another, and shifting from crops to grazing, planting trees, soil conservation, changing planting dates, and irrigation

[3]Probit model analysis is the first part of the analysis of the propensity score matching method (PSM) with aim of establishing the propensity scores

are the outcomes of interest. On the other hand, farmers who did not adapt a particular CCVAS were the control group. PSM is based on the assumption that it is not possible for each farmer to be both in the climate change adaptation group as well as the group of those who did not adapt. This strategy considers the possibility that households who adapts and households who did not adapt might exhibit systematic differences.

We define $Di = 1$ if CCVAS is adopted by household i and $Di = 0$i f not adapted. The probability of one households belong to one group is affected by factors (Xi). It is also important to note that one household to adapt a particular CCVAS can be influenced by other households in the area. That is the decision by one household to adapt or not adapt is likely to be influenced by others in the neighborhood. This fact introduces the selection bias in comparing the households with different sets of possibilities and hence different best responses (Caliendo and Kopeinig 2008). The possibility of encountering the selection bias reminds us the use of appropriate technique which is capable to get out of this problem. The PSM is one of the popular methods to solve the selection bias as cited in many studies (Ronsenbaum and Rubin1983; Dehejia and Wahba 1999; Caliendo and Kopeining 2008). The method controls selection bias of different individuals adapting CCVAS by estimating the probability of strategy given some observable variables. We define this probability as $\Pr(Di = 1|Xi)$ as propensity score.

We utilize the PSM framework by first estimating the contribution of the CCVAS on the increased crop productivity and income. On the basis of this, we define the contribution, C_{AS} as:

$$C_{AS} = Y(1) - Y(0) \text{....................equation (1)}$$

Where $Y(1)$ is the potential outcome in the treated which is improved crop production and income of the households adopted CCVAS; and $Y(0)$ is the potential outcome that would have happened in these households had they not adopted CCVAS.

From equation (1), we observed only one potential outcome for each individual i and fail to account for unobserved outcome. This implies that estimating the individual contribution is not possible and therefore one has to concentrate on average contribution. Because of this, we consider average contribution as a parameter of interest on the individuals adopted CCVAS. Taking these into account, we formed the following contribution equation:

$$C_{AS} = E[Y(1)|D=1] - E[Y(0)|D=1] \text{..equation.(2)}$$

From equation (2), $E[Y(0)|D = 1]$ is not observable, so we need a substitute for this in order to be able to measure the average contribution, C_{AS}. In this case, we need an average outcome of the non-adapter individual say,$E[Y(0)|D = 0]$. Therefore, we followed Ronsenbaum and Rubin (1983) and estimated the average contribution by performing PSM in the following three steps:

(i) Performed a probit or logit regression by calculating the household propensity to adapt a particular strategy. The estimated coefficients are used to predict the CCVAS probability for each observation (the propensity score). In this case, the dependent variable takes the value 1 if there households adapted a particular CCVAS and 0, otherwise. The probit estimate was done on three categories. First is on the overall (model 1) and second is on a particular adaptation strategy (model 2 and 3) reported by households in the survey. The identified explanatory variables through literature and common in the study were included in each model. The model fit was assessed using the Likelihood Ratio statistic and the individual variables were assed based on the p-value at 5% level of significance. The data are divided into the treatment group (the households adapted certain CCVAS and the control group (the households that are not under CCVAS but have similar characteristics to the households that have adapted CCVAS), using the propensity scores.

(ii) We estimated a counterfactual for each treated observation $Y(1)|D = 1, P[X]$ based on $Y(0)|D = 0, P[X]$ using the kernel matching. The average effect of treatment on the treated (the conditional mean difference), e.g., what impact CCVAS has on farmers who actually adopted CCVAS is

$$C_{AS} = \{Y(1) - Y(0) \mid D = 1\} = E[E\{Y(1) - Y(0) \mid D = 1, P[X]\}] = E[E\{Y(1) \mid D = 1, P[X]\} - E[E\{Y(0) \mid D = 0, P[X]\} D = 1] \quad \text{equation(3)}$$

Primary livelihood outcomes of interest are the reported changes in crop productivity and household income. Each of these outcomes is binary, recorded as one for improvement in the indicator and zero otherwise.

The study used the demographic, economic and environmental data such as age, gender, household size, education, wealth, farm size, markets, soil type etc. as variables that influences a household to adapt a particular climate change adaptation strategy. To the large extent, the selection of variables to be included in the model was guided by the economic theory and other empirical studies. The study employs one of the strategies for selection of variables to be used in estimating the propensity score namely statistical significance[4]. With the statistical significance, we start by the parsimonious specification of the model and then test up by iteratively adding variables to the specification. A new variable is kept if it is statistically significant at the conventional levels.

Assessment of the quality of matching process

Since the propensity score matching method is based only on the propensity score, there was a need therefore to assess the quality of the matching process by performing balancing tests that examine the standardized bias for all covariates used in the matching process. This checks whether the matching procedure is able to balance the distribution of the covariates in both the participants and non-participants groups. In the case of a successful

[4] Other strategies found in the literature include Hit or Miss method, Leave-One_outCross_Validation

matching process, the differences should not exist after matching. Testing of the comparability of the selected groups was done using a "balancing test" (Dehejia and Wahba1999), which tests for statistically significant differences in the means of the explanatory variables used in the model between the matched groups of CCVAS participants and nonparticipants. Absence of statistically significant differences in observable characteristics between the matched groups implies that the PSM ensures the comparability of the comparison groups.

Cost of adaptation

The adaptation costs which are proxy for the financing needs by the households in the study area were estimated though descriptive analysis using STATA. They were analyzed by considering different combination of methods by households. Analysis of the cost of adaptation is done by estimating the average cost and maximum cost per household with one, two, three, four and more than methods or CCVAS.

RESULTS

Climate change and variability adaptation methods

Results reveal that 13 different adaptation strategies were identified in the study areas (Table 1) of which four were found to be selected by the majority of the households in the study areas. The strategies are varying planting dates (41%), land tilling (39%), planting short variety seed (32%) and use of the organic manure (32%). Other strategies were adapted by less than 10% of the sampled households (Table 2). Table 2 also show that some households have abandoned crop cultivation, instead they are engaged with non –farm activities (9.5%) as adaptation strategy for climate change and variability.

Table 1. Identified climate change and variability adaption methods in study area

S/N	Variable	Description of adaptation method	% households	Average farm size	Average cost
1	q32_i	Shifting cultivation	2.6	5.5	215,000
2	q32_ii	crop switching to grazing	0.3	9.0	20,500
3	q32_iii0	crop rotation	11.2	29.0	283,982
4	q32_iv	vary planting dates	41.1	12.0	175,300
5	q32_v	Irrigation	3.0	7.0	203,375
6	q32_i	increased farm	2.6	13.0	411,555
7	q32_vi	drought resistance seed	6.6	11.0	191,800
8	q32_vii0	short varieties	31.9	10.0	461,800
9	q32_viii0	switch to non-farm activities	9.5	7.4	438,114
10	q32_x	tree planting	4.3	8.7	392,076
11	q32_xi0	land tilling	39.1	10.0	165,363
12	q32_xii0	use of manure	31.6	11.0	164,340
13	q32_xiii0	land fallowing	3.6	16.0	315,750

Figure 2 further shows that the majority of the households adapted more than one method. More than 50% of adapters of the climate change and variability strategies adapted a combination of two to three methods.

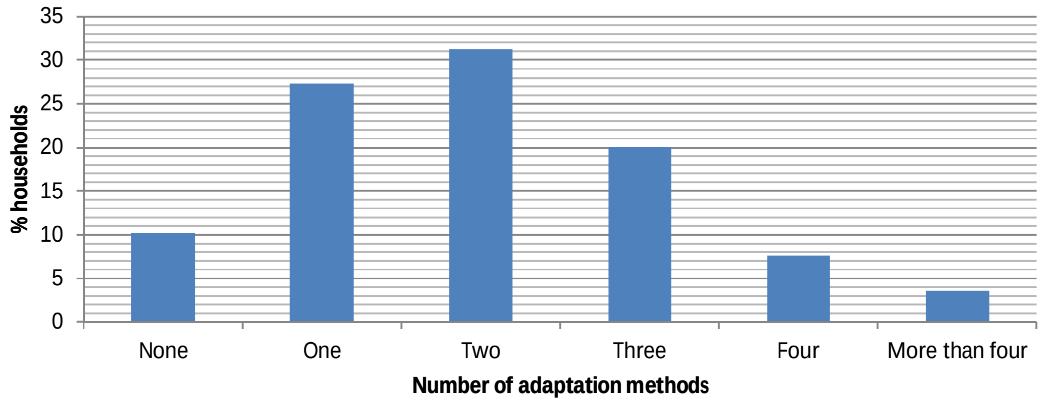

Figure 2. Number of adaptation methods per household

Factors influencing adaptation to climate change and variability

As mentioned in the methodology section, the first part of the PSM analysis estimates a probit model in order to obtain the propensity score. Table 2 presents the probit results which indicate the covariates that influence household decision on CCVAS. The probit estimate results are presented for three categories/models: the overall (model 1) and a particular adaptation strategy i.e. variation of planting dates (model 2) and land tilling as a strategy (model 3) as reported by households in the survey. The model fit was assessed using the Likelihood Ratio statistic and the individual variables were assed based on the p-value at 5% level of significance[5].

It was found that factors influencing household adaptation to climate change and variability strategies include income, household size, type of occupation, farm size, whether a farmer is migrant, characteristic of the land (poor soil), perceived increased income after adaptation, and the knowledge about climate change. These factors were found to be significant when analysis was done first for overall (model 1) and on a specific adaptation strategy (models 2 and 3) as indicated in Table 2.

Cost of adaptation and impact on crop harvest

Descriptive analysis results on the cost of adaptation proxy to financing needs by household are shown (Table 3). The results of the cost of adaptation indicate the estimate of the maximum cost per household and the average cost per ha that are incurred or needed for adapting one, two, three, four and more than four methods. The results reveal that cost of adaptation to farmers range between TZS 1.6 to 4.2 million per household while the average cost per ha is TZS 0.39 to 0.86 million.

Table 4 presents the results from PSM on the impact of the adaptation strategies to the variables of interest which are quantity harvested and the household income. It is clearly seen that adapters of the climate strategies have on average more income and harvests than the non adapters for all models or CCVAS. The highest income and yield difference (effect) is noted between the adapters and non adapters of land tilling strategy (Model 3) which is TZS 1.06 million per household and 1960.3 kg/ha.

Assessment of the quality of matching process results

[5] Note the short varieties strategy resulted to only one significant explanatory variable and therefore was not used for further analysis

Results in Table 5 show that there were no statistically significant differences in the means of the explanatory variables between the matched treated and control groups (adapters and non adapters). This implies that the propensity score matching model has estimated very well the average effect of climate change adaptation strategies on the household income and the maize harvest discussed above. In addition, we define the standardized bias as the difference between the sample means in the adapters of CCVAS and the matched non-adapters sub-samples as a percentage of the square root of the average of the sample variances in both groups (Nkala *et al.* 2011). The results show that % bias for the matched observation is low for all explanatory variables used in the analysis. This implies that there was satisfactory matching of observations for the adapters and non adapters, hence the accuracy of the models in predicting the impact of adaptation strategies on income and crop harvest.

Table 2. Probit estimates for adaption to CCVAS

Variable	Obs	Mean	Std	Model 1	Model 2	Model 3
Household size (hhsize)	304	7.51	7.26	0.10*	0.03*	0.03
Age of the head of household (age)	304	46.66	14.57	0.67	0.33*	-0.01
Log of income per capita (lycapital)	283	11.64	1.35	0.14	0.09*	0.160*
Livestock ownership	304	0.09	0.28	-0.88*	0.37	0.16
Male gender of the head of household (sex)	304	0.85	0.36	-0.47	0.32	0.01
Farm size cultivated (fsize)	296	11.94	28.83	-0.02*	0.01*	-0.013*
Migration (proportion of natives) (born_vil)	304	0.57	0.50	0.84*	0.22	0.680*
Knowing causes of climate change (pr)	303	0.85	0.36	-0.27	0.33	0.692*
Perceived effect of climate change on livelihoods (q27)	214	0.86	0.35	-0.32	0.29	0.43
Perceived increase in income due adaptation (q34)	290	0.88	0.33	0.78*	0.30	0.44
Land characteristic (gentle slope) (land_char)	304	0.59	0.49	0.61*	0.19*	0.22

*Means a covariate influences adaption to climate change and variability significantly

Legend:
Model 1 = Overall (household have adapted one or all strategies- 2 and 3)
Model 2 = Household vary planting dates as a strategy
Model 3 = Household started land tilling as a strategy

Table 3. Number and cost of adaptation methods

Number of adaptation methods	Maximum cost (TZS)	Average cost (TZS/ha)
One	1,620,000	385,493.3
Two	1,700,000	395,639.2
Three	2,450,000	536,403.6
Four	3,710,000	590,166.3
More than four	4,240,000	856,565.7

Note: 1 USD = TZS 1,650 (during field work in 2014)

Table 4.Estimated average contribution from propensity score matching

	Household income (TZS)			Maize yield(kg/ha)		
	Adapters	**Non adapters**	**Effect**	**Adapters**	**Non adapters**	**Effect**
Model 1	1,339,675.8	1,305,802	33,873.80	2,616.8	1,948.5	668.6
Model 2	275,411.90	234,398.00	41,013.90	3,341.1	1,445.0	1,896.3
Model 3	1,860,798.00	803,923.00	1,056,875	3,775.5	1,815.2	1,960.3

Legend:
Model 1 = Overall (household have adapted any of the strategies)
Model 2 = Household vary planting dates as a strategy
Model 3 = Household started land tilling as a strategy

Table 5. Balancing tests for all matching variables

Variable	Sample	Treated	Control	%bias	t-value	p>t
Hhsize	Unmatched	8.3129	5.4444	48.6	1.08	0.28
	Matched	7.8182	6.0606	29.8	1.09	0.279
lage	Unmatched	3.7901	3.7014	28.3	0.82	0.411
	Matched	3.7544	3.7648	-3.3	-0.16	0.875
lycapita	Unmatched	11.764	12.136	-29.6	-0.96	0.338
	Matched	11.64	11.613	2.1	0.08	0.934
sex	Unmatched	0.89796	0.88889	2.8	0.09	0.931
	Matched	0.84848	0.93939	-28.5	-1.19	0.237
fsize	Unmatched	13.289	22.444	-22.2	-0.81	0.418
	Matched	16.324	8.8485	18.2	1.16	0.249
pr	Unmatched	0.80272	0.66667	30.1	0.98	0.33
	Matched	0.75758	0.90909	-33.5	-1.66	0.102
born_vil	Unmatched	0.60544	0.33333	54.9	1.61	0.109
	Matched	0.30303	0.36364	-12.2	-0.52	0.608
q27	Unmatched	0.84354	0.88889	-13	-0.36	0.716
	Matched	0.84848	0.72727	34.7	1.2	0.235
q34a	Unmatched	0.90476	0.66667	58	2.25	0.026
	Matched	0.84848	0.81818	7.4	0.33	0.746
land_char	Unmatched	0.52381	0.22222	63.9	1.76	0.08
	Matched	0.27273	0.18182	19.3	0.87	0.386

DISCUSSION

Climate change and variability adaptation methods

The study revealed that the majority of the households in the study areas adapted mainly four climate change and variability adaptation strategies (planting dates, land tilling, planting short variety seeds, and use of the organic manure). Some of households abandoned crop cultivation, instead they were engaged with non –farm activities as adaptation strategy for climate change and variability. The commonly adapted CCVAS in the study areas have been also reported in other studies (Kabubo-Mariara 2008; Bryan *et al*.2009; Komba and Mchapwondwa 2012). The choice of the CCVAS has been attributed to the low cost, farmers' long experience with the strategy since it is a traditional practice and easy adaptability of the strategies (Kulindwa*etal*.2016; Tissema *et al.* 2018). However, some of the reported adaption methods were not green methods (e.g. shifting cultivation and increased farm size) since they have negative impact to the environment). Although the strategies are not recommended, they were being adapted by many rural farming households because the methods are less cost and lead to high yield in a short run but undermine conservation efforts (Tissema *et al.* 2018).

The study further showed that households adapted a combination of climate change and variability adaptation strategies whereby more than a half of adapters adapted two to three methods. Adapting more than one CCVAS has been a common practice in Tanzania and other developing countries in order to raise a chance of increasing crop yield in unpredictable weather and climate (Kulindwa *et al.* 2016).

Factors influencing adaptation to climate change and variability

The main factors that influence household adaptation to climate change and variability strategies in the current study are household socio-economic characteristics, land and soil characteristic, and perception of increased income after adaptation and the awareness of climate change problem. The socio-economic characteristics such as household income and farm size matter a lot for household to adapt the costly CCVAS since most of rural farming households are poor. Generally, the factors that were revealed by this study have been also reported in other studies such as Gebrehiwot and van der Veen (2013) and Tessema *et al.* (2018). Their results indicate that financing/income and land characteristics influence farmers' adaptation to climate change and variability significantly as revealed in the current study.

Cost of adaptation and impact on crop harvest

Results have shown that the cost of adaptation proxy to financing needs increases with increase in the number of adapted climate change and variability adaptation strategies. The results suggest that most poor rural farming households cannot afford the cost of adaptation and they opt to adapt the low cost traditional strategies as reported by Tessema *et al.* (2018).

However, it has been found that adapters of the climate change and variability strategies have on average more income and harvests than the non adapters for all mainly adapted CCVAS. The highest income and yield difference is noted between the adapters and non-adapters of land tilling strategy. This is because land tillage improves the soil structure which increases water percolation, soil moisture retention capacity and root development (Nicou and Charreau 1985). The current study findings concur to that of Kabamba and Muimba-Kankolongo (2009) and Kassie *et al.* (2010) who found that conservation farming and minimum tillage adoption increases maize yield up to three times more than the yield from conventional farming in Zambia and Ethiopia low productive areas respectively.

CONCLUSION

The study has found that smallholder farmers implement various climate change and variability adaptation methods. Four adaptation methods (planting dates, land tilling, planting short variety seeds, and use of the organic manure) out of thirteen identified methods were mostly adapted in the study areas. Some of farmers also adapted methods detrimental to environment such as shifting cultivation, which undermines conservation efforts. Most adapted methods were traditional methods and majority households adapted two to three adaptation methods or CCVAS in order to reduce risk against climate change and variability. However, the cost of adaptation increased with an increase in the number of CCVAS.

PSM results have revealed that household socio-economic and characteristics including level of income influence adaption decisions implying that most poor household do not afford the cost of adaptation and thus opt for less cost traditional methods. The PSM analysis further confirmed that adaptation of CCVAS contribute to crop productivity and smallholder farmers' income. Land tilling appears to have highest impact on both crop yield and household income. The financing needs for adapting CCVAS and their combinations seem to be high for poor households. Therefore, financing strategy of climate change and variability adaptation should focus on the sustainable methods and their combinations which are less costly but with high positive impact on productivity, household income and environmental conservation.

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