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Adopting Climate-Smart Strategies and their Implications for Food Security in Tanzania

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Introduction

In order to provide food for an increasing population in Tanzania, the demand for agricultural output is high. In the light of climate change, some farmers find and adapt strategies to sustain their food production. Climate-smart adaptation strategies are responses to observed current or past climatic triggers and their effects, which are intended to alleviate or avoid the perceived negative effects of climate change (Hisali et al. 2011). Climate change is defined here as the long term change in mean annual temperature and precipitation as reported by the IPCC (2007). Droughts and dry spell are more frequent, rainfall becomes more erratic, which causes the soil to erode and vegetation to runoff more easily (Below et al. 2010). Due to predictions published by the IPCC (2007), by 2100 the increase in global average surface temperature could range between 1.8°C and 4.0°C. Already an increase of 1.5°C to 2.5°C could possibly risk the extinction of 20 to 30 per cent of plant and animal species, thus further aggravating the food security status in developing countries (FAO 2007). Small-scale agriculture is the main source of income for about 80 percent of those households that live below the poverty line (Cleaver et al. 2010). The rural poverty levels are estimated to be about 87% and are thus much higher than compared to levels in urban areas. About one fifth of the population in rural mainland of Tanzania is estimated to not meet the minimum food requirement of 2.200 kcal per day (ADF 2007). In order to enhance food security, agricultural production systems have to become more capable of keeping the yield stable even in extreme events caused by climate change, which are likely to shift or shorten production seasons, modify pest and disease patterns or change the portfolio of feasible crops (FAO 2010). Rain fed agriculture is common practice in rural Tanzania, thus the farmers will suffer more from these changes in climatic conditions. Small-scale farmers are directly affected, since soil erosion and loss of biodiversity through runoff have a negative effect on agriculture and sustainable livelihoods. An increase in mean temperature also leads to the risk of losing more soil moisture, an increasing frequency of droughts and lays the cornerstone for diseases and pests to spread (Hoffmann 2009).

The objective in the present paper is to explore first which adaptation strategies in response to climatic changes do small-scale farmers in rural Tanzania adopt and what are the drivers of adoption. Second, the impact of adoption of climate-smart strategies on food security using different food security indicators will be analyzed.

Data and Methods

The results are based on a household survey conducted in 2014 with small-scale farmers in rural Tanzania, located in a semi-arid and a semi-humid regional setting respectively.

The selection of households was based on a two-step random sampling procedure. A team of local enumerators visited the farmers at their homesteads and asked them questions on sociodemographic issues such as age, education and health of all the family members. The questionnaire also included questions about the households' economic activities concerning their agricultural and off-farm income generation. In order to get information on the households' food security, detailed questions were asked about their regular food consumption patterns, food preparation, food diversity and food group quantities. The average land-holding size by the farmers in our sample is about two hectares (or five acres). Thus, 900 farm households in two different agro-ecological regions have been the basis for this sample. One region, close to the capital of Dodoma, is characterized by a semi-arid climate status and an overall relatively low food security status, whereas the other region around Kilosa, is considered as semi-humid and contains areas with a lower and areas with higher food security levels. A section on land also includes the farmers' perception on how they perceived changes in their lands' soil fertility compared to the time of acquisition of the land. Information on land tenure and the perception of land safety can also give a better picture of the institutional landscape within the study sites. The survey also contains information on the farmers' perception of climatic changes in the last twenty years. If changes were perceived in the form of precipitation, temperature or wind, then follow-up questions were asked to find out about what consequences they felt these changes made in relation to their agricultural and non-agricultural activities. They were also asked to indicate, in which way they responded to these changes, i.e. in which way they altered their agricultural practices. Thus, the main climate-smart adaptation strategies identified in the sample, were the diversification of the crop portfolio, the adjustment of the crop portfolio and tree planting.

A first identification of drivers of adaptation is done using a binary choice model, in particular a logistic regression. (D'Souza et al. 1993) In this context, it tells, if adaptation has taken place (y=1) with the probability *p* or rather the alternative, to not adopt (y=0), with the probability of *1-p*. (Cameron and Trivedi, 2009)

In a next step, the objective is to find out what determines the adoption of a specific climate-smart strategy using a multinomial logit regression (MNL).

The influence of a change in one or more of the covariates on the response probabilities p is in the focus of attention at the MNL, with *j* as the identifier for the group of the non-adopter (0), and of the groups of adapter, i.e. the diversifier (1), the portfolio shifter (2) and the tree planter (3). The identification of households is represented by *i*. (Cameron and Trivedi, 2009)

$$p_{ij} = \Pr(y_i = j|x_i), \qquad j=0,1,2,3, \qquad i=1,2,\dots, N.$$

Since households self-selected themselves into the adopter or non-adopter group themselves, the so-called "self-selection bias" has to be accounted for in order to compare the outcomes across the different adaptation groups. Therefore, the average treatment effect (ATT) is estimated using "Propensity Score Matching" (PSM). (Caliendo and Kopeinig, 2008)

$$ATT = E\ (y_1|T=1) + E\ (y_0|T=0)$$

The outcome indicators were chosen in order to provide insights on the outcome of food security in its different dimensions, when adopting one of the climate-smart strategies compared to the group of non-adopters. The indicators used in this analysis are a) food security indicators, namely the Food Consumption Score (FCS), The Coping Strategies Index (CSI) and the indicator for the number of months of adequate household food provisioning (MAHFP), and b) also household survey based measures of the households total annual net income and annual net crop income. In the end Rosenbaum bounds were computed to control for hidden bias, possibly caused by unobserved heterogeneity (Becker and Caliendo, 2007).

Results and Discussion

As expected, household characteristics play a role in the decision whether to adopt a climate-smart strategy or not. Here, the education of the household head, represented by a dummy whether the head can read and write, increases the likelihood of the household to adopt in general. The level of education can enable the smallholder farmer to be open to receive, understand and implement the information relevant for the adoption of a new technology (Namara et al. 2003).

The estimation of the different adoption schemes compared to the group of non-adopters was performed using the multinomial logistic regression. Individual land ownership also increases the likelihood to adopt a climate-smart strategy, i.e. diversification and planting trees. The likelihood to shift the portfolio, for example, towards more drought resistant crops or varieties, is much higher, if the farmer is located in the semi-arid region of Dodoma.

Table 1. Multinomial logistic regression estimates and marginal effects on adoption of climate-smart strategies

	Diversification		Portfolio shift		Tree planting	
Variables	Coef.	m.e.	Coef.	m.e.	Coef.	m.e.
Adoption (base=0)						
If Household head is female	0.197	0.017	0.307	0.028	0.136	-0.001
Age	0.032	0.006	-0.001	-0.002	0.003	-0.001
Age squared	-0.000	-0.000	0.000	0.000	-0.000	0.000
If household head can read & write	0.341	0.031	0.509*	0.046	0.244	-0.001
Household size	-0.037	-0.007	0.025	0.007	-0.081	-0.005
If livestock keeping	-0.240	-0.034	-0.476*	-0.060**	0.556	0.051**
If off-farm wage employment	-0.866***	-0.005	-1.847***	-0.169***	-2.078***	-0.087***
If non-farm self-employment	-0.352	0.024	-1.203***	-0.133***	-0.771*	-0.023
Awareness effect	0.160	-0.031	0.310	0.007	1.638***	0.101***
If access to credit	-0.357	0.027	-1.672***	-0.212***	0.157	0.047
Prepared to take risk/avoid taking risk	0.182***	0.029***	0.102**	0.002	0.061	-0.002
If participate(d) in on-farm trials	0.787**	0.114**	0.441	0.003	0.626	0.014
If located in Dodoma	-0.487*	-0.170***	0.876***	0.139***	0.707*	0.047*
Perceived land security	-0.018	-0.002	0.132	0.025*	-0.351**	-0.025**
If land individually owned	0.824***	0.157***	-0.529	-0.148***	1.514***	0.088***
Distance to village center (km)	-0.069	-0.005	-0.013	0.007	-0.295**	-0.018*
Constant	-1.238		-1.398		-1.701	
Pseudo R^2	0.142					
Wald Chi squared (48)	240.90***					
Log likelihood	-727.38					
Observations	672					

Notes: The base category consists of farmers who chose not to adopt; *p*-values: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; marginal effects: m.e.

For the determination of the impact of the different adaptation strategies in terms of food security, the farmers have been compared on the basis of different food security and income indicators using PSM. First, a general comparison of the adopter versus the non-adopter in the sample reveals that the average FCS per year of a randomly drawn person would be almost 3 points higher because of the adaptation of one of the climate risk reducing strategies, thus indicating a better status quo in terms of food diversity (Maxwell et al. 2014). This increase varies a little, but not substantially and stays significant using different matching approaches, i.e. Nearest-Neighbour (NNM), Kernel (KM) and Radius matching (RM). (Caliendo and Kopeinig, 2008)

The outcome for the CSI is significantly lower for adopters (KM and RM) and also indicates that adopters are on average more food-secure than non-adopters.

Table 2. *Average treatment effects on the treated for household food security*

	Nearest neighbor matching		Kernel matching		Radius matching		Γ
	ATT	S.E.	ATT	S.E.	ATT	S.E.	
Adopter vs. Non-adopter							
FCS (Average of year)	2.93**	1.36	2.84**	1.20	2.56**	1.11	1.2
CSI (Average of year)	-4.18	3.34	-4.91*	2.71	-4.54*	2.68	2
MAHFP	-0.32	0.45	-0.39	0.42	-0.37	0.42	-
Household net income	171.79	122.38	169.27	110.58	158.09	102.45	-
Household net crop income	63.82	76.59	54.22	72.27	56.41	87.20	-

*Notes: ATT: average treatment effect on the treated;**p<0.1, **p<0.05, ***p<0.01 when compared to non-adopting farmers; S.E.: bootstrapped standard errors; Γ: Rosenbaum bounds (critical level for hidden bias).

In a next step, the different adoption schemes are compared to the group of non-adopters. The group of portfolio shifters appears to benefit most from adoption compared to non-adopters in terms of food security on different dimensions.

Conclusion

Overall, the findings suggest that the decision to adopt a climate-smart strategy leads to an increase in food security in terms of food diversity and stability.

The results support the farmers' application of locally adjusted crops and varieties, since portfolio-shifters are on average significantly less food insecure on various dimensions, but especially in terms of stability, compared to non-adopters.

Based on the results, an investment into education and raising awareness seems to be a recommendable task to be further followed by policy makers to reduce the pressure on natural resources including public forests. Information distribution through a strengthened net of extension service offices should be more in focus of attention. Given the results of the empirical analysis, the establishment of clear property rights can also contribute to adaptation of climate-smart strategies. Finally, a development of formal financial institutions can increase the possibilities to invest into climate-smart agricultural activities and also to realize more investment-intensive adaptation strategies to climate change such as planting trees.

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