Determinants of Rural Farmers' Adoption of Climate Change Adaptation Strategies: Evidence from the Amathole District Municipality, Eastern Cape Province, South Africa

A. Taruvinga, M. Visser, and L. Zhou

***Abstract*—There is consensus that rural farmers' livelihoods are vulnerable to climate change. Also, literature suggests that locally driven adaptations are critical complementary strategies that can be targeted to reduce the negative effects of climate change in the short-run. Thus far, through using a cross sectional survey sample of 200 rural farmers from the Amathole district municipality of the Eastern Cape Province of South Africa, the paper estimated farmers' climate change adaptation strategies, adaptation portfolio diversity and factors that condition farmers' adoption behavior. The results reveal several crop, livestock and non-farm based adaptation strategies skewed in favour of crop and non-farm floral based techniques. The results further indicate that rural farmers in general are low adopters of climate change adaptation strategies with poor adaptation portfolio diversity. Regression estimates reveal several socio-economic and institutional factors as drivers of adoption and adaptation portfolio diversity worth targeting to promote the ability of rural farmers to cope with climate change.**

***Index Terms*—Climate change, adaptation strategies.**

I. Introduction

The generic view when it comes to the rural sector in Africa is that of a region driven by agriculture [1] and several natural resource-based non-farm and off-farm livelihood activities [2]. Against this background, in response to climate change, rural communities have managed to align their livelihood strategies in various available livelihood portfolios, hoping to spread and minimize the risk associated with climate change.

This has created interesting rural resilience strategies in response to climate change [3], [4] which are worth understanding, given that farmer driven adaptations may be more sustainable for Africa than sponsored external mitigations [5], [6]. Thus far, growing research is therefore seeking to understand the drivers of climate change adaptation and mitigation strategies among farmers [7]-[9]. This is mainly motivated by the fact that adaptation strategies and farmer responses to climate change are heterogeneous, depending on region [10], the socio-economic attributes of farmers [11] and existing institutional support and infrastructure [12]. This study was therefore undertaken to identify various crop, livestock, non-farm fauna and non-farm floral based climate change adaptation techniques implemented by rural farmers and important factors affecting their implementation behaviors.

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II. Objectives

- To assess rural farmers' adaptation strategies to climate change.
- To estimate factors that influence rural farmers' implementation of climate change adaptation strategies.

III. Literature Review

This section presents literature on adaptation strategies to climate change and factors that influence adaptations. The following adaptation strategies are reported in literature: 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 [6], agro-forestry, use of compost and fertilizers, destocking, fallowing [13], 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 [4]-[15].

Literature also suggests that adaptation in general is conditioned by several socio-economic (gender, education, family size, age), institutional (access to extension, credit, markets) and location (temperature and rainfall) factors [4]-[17]. A few studies also report "no adaptation" as an adaptation strategy [4]-[18], yet such scenarios are very popular which suggests the desperate nature often faced by rural households when exposed to climate change and variability shocks.

IV. Methodology

The study was conducted inthe Amathole District Municipality of the Eastern Cape Province of South Africa, using cross sectional survey data (*N*=200).

A. Theoretical Framework

Rural farmers reside in different geographical locations across Africa. They also have different socio-economic and institutional attributes. These three conditions (geographical location, socio-economic and institutional attributes)

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influence their selection choices of adaptation strategies to climate change [5]-[18] based on the utility associated with each choice [13].

Thus far, the utility associated with each choice by the i^{th} rural farmer is not directly observable, while the adaptation choices made are observable, and unordered thus suggesting that an adaptation strategy to climate change may be explained by the random utility maximization theory [13]-[18]. A rural farmer from the Amathole District Municipality of the Eastern Cape Province of South Africa would therefore choose adaptation strategy *j* over adaptation strategy "*k*" if, and only if,the perceived utility from adaptation strategy "*j*" is greater than that of "*k*", as illustra , [19].

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

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)

Using econometric models it becomes possible to relate observable socio-economic, institutional and climate variables to adaptation selection choices made by rural i^{th} farmer from the Amathole District Municipality.

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 [6]-[20]. However, if a variable is measured by counting, which is the case in this paper; it is treated as a continuous variable [21]. Generalised linear regression models would therefore best represent the dependent variable. The Poisson count regression model (PCRM), negative binomial model and simple linear regression (OLS) can be used. The first two models have strict requirements that give them operational problems as follows: for the Poisson distribution, it assumes that the mean and variance of the dependent variable(s) are equal, but normally as a result of over-dispersion; the conditional variance of the dependent variable exceeds the conditional mean [22].

A simple linear regression model was developed to identify factors affecting rural farmers' implementation (adoption) of climate change adaptation techniques. Frequency of use of various climate change adaptation techniques across a range of adaptation portfolios - that is, count of adaptation techniques implemented by rural farmers was treated as the dependent variable in the first equation. In the second equation the frequency of adaptation portfolios used by farmers – thus, count of adaptation portfolios used, was treated as the dependent variable. The analysis considered setting simple linear regression equations to estimate the reduced form models of rural farmers' climate change adaptation strategies, as illustrated in equation 2.

$$Y_j = \beta_0 + \beta_i X_i + u \qquad (2)$$

where:

y_j = the dependent variable representing count of adaptation techniques implemented in equation 1 and count of adaptation portfolios used in equation 2, explained by,

b_i = the vector of parameters and

X_i = the vector of exogenous explanatory variables with

b_0 = the constant term and

u = the error term.

V. Results and Discussion

This section presents the results and discussion of the study. Rural farmers' adaptation strategies and adaptation portfolios to climate change are presented as summarized in Fig. 1, Fig. 2, Fig. 3 and Table I, followed by factors that influence adoption and adaptation portfolio diversity (Table II).

A. Rural Farmers' Adaptation Strategies to Climate Change

Fig. 1 presents a summary of the reported adaptation strategies to climate change from the study area. Results indicate that with respect to climate change from a crop husbandry point of view, a majority of rural farmers resort to: changing crop varieties (77%), intercropping (69%), staggering planting dates (69%), supplementary irrigation (62%), use of compost and fertilizer (80%) and shifting cultivation (60%). Similar comparable results are reported in literature [6]-[13]. To enhance these strategies access, size and ownership of arable land may be an important factor.

Available livestock coping strategies, though very limited and practiced by only a few farmers, include: destocking (18%) and crop-livestock switching (5%). Previous literature reports similar adaptations [4]-[15]. Non-farm floral adaptation strategies include: use of indigenous leaf vegetables (71%), use of indigenous fruits (63%), indigenous timber (35%) and selling fire wood (26%). Non-farm fauna adaptation strategies includes: hunting mammals (18%) and bird shooting (17%). Recent studies suggest the emerging importance of indigenous foods towards supplementing household food security, dietary diversity and dietary quality [23], [24].

These findings suggest an overreliance on crop based adaptations at the expense of other portfolio activities, thus, poor adaptation portfolio diversity for rural farmers. This observation may suggest barriers to entry to these other portfolio activities worth understanding in order to improve adaptation options for rural farmers. In the next section, the paper compares the share of different adaptation portfolios available to rural farmers.

Fig. 2 summarizes the share of various climate change adaptation portfolios. Results reveal that crop based adaptations have the highest share (61%) followed by non-farm floral based adaptations (25%), non-farm fauna strategies (5%), other adaptations (6%) and, lastly, livestock based adaptations (3%).

Two messages are suggested by these results. Firstly, the results suggest that rural farmers from the study area may have mastered more crop husbandry and non-farm floral adaptation strategies, possibly as a result of the availability of such activities and easy entry. To avoid a scramble fornatural floral resources as a result of the emerging interests of rural farmers to use them as a climate change safety net, more research, investment and policy may be required to guide sustainable harvesting and boost availability in the face of potential overuse.

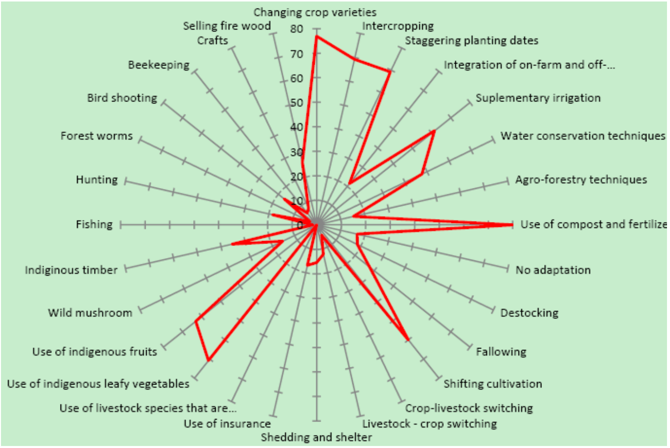

Fig. 1. Reported rural farmers' adaptation strategies to climate change.

Secondly, livestock and non-farm fauna adaptation strategies are very limited in terms of the activities that farmers can pursue and their willingness to adopt them. These observations suggest possible limitations and barriers to entry worth understanding to promote a wider climate change adaptation selection pool for rural farmers.

The next section uncovers climate change adaptation diversification based on the count of adaptation strategies adopted by farmers.

B. Rural farmers' Adaptation Diversity across Portfolios

Table I and Fig. 3 present the observed climate change adaptation diversity from the study area. Results indicate that, on average, 62.5% of the respondents were classified in the low adopter category, 37% in the medium adopter category and 0.5% in the high adopter category with a mean frequency of 9 adaptations per farmer.

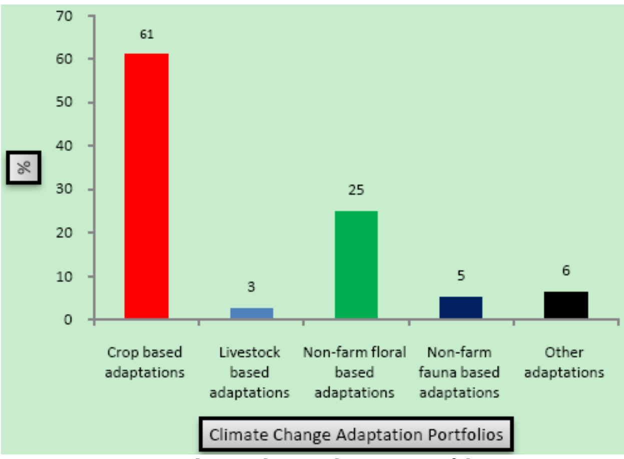

Fig. 2. Climate change adaptation portfolios.

TABLE I: COUNT OF ADAPTATION TECHNIQUES IMPLEMENTED BY FARMERS

Count of adaptation techniques implemented		
0-10 counts	11-20 counts	> 20 counts
62.5%	37%	0.5%
Low adopters	Average adopters	High adopters

Besides the frequency of adaptations, the diversity of adaptation portfolios is also critical because if all of the adaptations are derived from one portfolio, like crop husbandry, in the event of bad weather, most of the adaptations will be adversely affected. Thus far, the observed dominance of the respondents in the low adopter category is seriously affected by their poor adaptation portfolio diversity, as summarized in Fig. 2 (above half of their adaptations defined in one portfolio – 61% crop based adaptations).

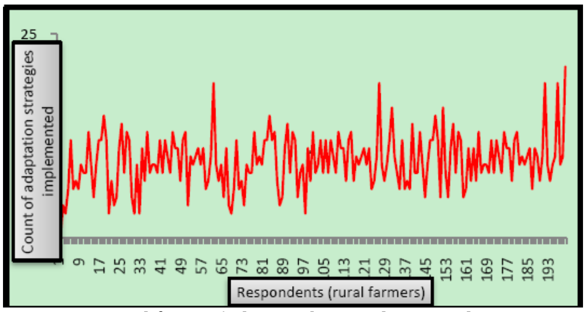

Fig. 3. Rural farmers' climate change adaptation diversity.

These findings reveal low adaptation capacity for rural farmers, possibly as a result of limited adaptation options, barriers to entry and overreliance on crop husbandry activities. This scenario presents rural farmers who are very vulnerable to climate change effects, faced with limited adaptation options which are confined in one adaptation portfolio. For the purpose of understanding drivers of climate change adaptation strategies, in the next section, the paper estimates the determinants of adaptation strategies among rural farmers.

C. Factors that Influence Adoption Frequency and Adaptation Portfolio Diversity

In this section, the paper estimated factors that influence rural farmers' adoption frequency and the adaptation portfolio diversity of climate change adaptation strategies. Table 2presents linear regression estimates for determinants of adoption frequency and adaptation portfolio diversity. With reference to the overall fit of the models, the obtained R^2 (0.791: 0.541) suggests that the weighted combination of predictor variables was jointly significant in explaining each of the dependent variables.

The results reveal that a one standard deviation positive change in the age of rural farmers, holding other predictor variables constant, yields an increase of 0.48 standard deviations for adopting climate change adaptation strategies. These results suggest that age positively conditions the probability of farmers to adopt climate change adaptation strategies [25], possibly as a result of earned experience [26], broad social networks and accumulation of wealth.

As expected, a one standard deviation positive change in the level of education holding other predictor variables constant increases adoption frequency and adaptation portfolio diversity by 1.43 and 0.260 standard deviations respectively. These findings suggest that education positively influences rural farmers' ability to adopt more climate change adaptation strategies and their ability to spread adaptation strategies across various adaptation portfolios. This may be explained by a high level of awareness (general appreciation of benefits of adapting to climate change) and access to adaptation information common with educated farmers. Similar comparable observations were noted by several authors [14]-[29].

TABLE II: FACTORS THAT INFLUENCE ADOPTION FREQUENCY AND ADAPTATION PORTFOLIO DIVERSITY OF CLIMATE CHANGE ADAPTATION STRATEGIES

Variables	**Adoption frequency** (count of adaptation strategies implemented across portfolios)			**Adaptation portfolio diversity** (count of adaptation portfolios implemented)		
	B	*Std. E*	*t*	*B*	*Std. E*	*t*
(Constant)	1.261	1.097	1.150	1.912	.376	5.087**
1) Age	.048	.015	3.249*	.006	.005	1.166
2) Gender	.540	.483	1.116	.180	.176	1.024
3) Education	1.430	.337	4.238**	.260	.124	2.097*
4) Family Size	-.247	.112	-2.202*	-.143	.041	-3.477*
5) Wealth Status	2.180	.603	3.614*	.017	.219	.079
6) Land Ownership	2.569	.620	4.143**	.017	.219	2.068*
7) Land Size	.148	.310	.478	.148	.113	1.304
8) Access to formal credit	.445	.777	.573	.724	.286	2.532*
9) Access to informal credit	.682	.554	1.230	.458	.204	2.248*
10) Membership to CBOs	-.016	.599	-.027	.121	.215	.564
11) Access to extension	.669	.527	1.270	.409	.193	2.117*
a) No. of observations			200			200
b) F.			18.199			6.353
c) Sig. F.			.000			.000
d) R^2			.791			.541

Notes: ** and * indicate significance at 0.01 and 0.05 probability level, respectively.

For a one standard deviation positive change in family size holding other predictor variables constant, the results reveal a decrease in both adoption and adaptation portfolio diversity by 0.427 and 0.143 standard deviations respectively. The observed results suggest that larger family size negatively conditions the ability of rural farmers to adopt and spread climate change adaptation strategies. Similar negative influences of household size on adaptation to climate change are also shared in literature [27]-[30]. Adoption costs may hinder larger households who normally focus their resources on sustaining immediate family members' needs at the expense of adaptation strategies. The assumed potential of large families to diversify their labor force into other non-farming activities [31], hence improving adaptation portfolio diversity, may be limited in rural areas where off-farm opportunities are poorly defined and very limited [4].

A one standard deviation positive change in the level of wealth status of rural farmers holding other predictor variables constant, increases adoption by 2.180 standard deviations. The observed positive effect may be a result of the ability to finance adaptation techniques like supplementary irrigation that involves high initial injection and operational capital, use of fertilizers and changing crop varieties.

Land ownership also explains rural farmers' adoption and adaptation portfolio diversity, where a one standard deviation positive change in land ownership holding other things constant increases adoption and adaptation portfolio diversity by 2.569 and 0.017 standard deviations respectively. Descriptive results reveal overreliance on crop based adaptations from the study area that require ownership of land. Thus far, the observed positive correlation uncovers the importance of land for promotion of crop and livestock based adaptations and, possibly, other non-farm land based adaptation activities like harvesting indigenous leafy vegetables and indigenous fruits.

Both, access to formal and informal credit to finance adaptation activities positively explain adaptation portfolio diversity. The results reveal that a one standard deviation positive change in access to either formal or informal credit will increase adaptation portfolio diversity by 0.286 and 0.204 standard deviations, respectively. The availability of credit gives rural farmers several options to finance adaptation strategies like supplementary irrigation, improved hybrids and fertilizer applications. Similar positive effects are also reported in literature [25]-[32].

Lastly, the results further indicate that access to extension services by rural farmers positively conditions their ability to spread their climate change adaptation strategies across various adaptation portfolios. Previously [4], it was argued that access to information about climate change forecasting and adaptation options remain a crucial factor which contributes promotes farmers' use of various adaptation strategies.

VI. CONCLUSION

The paper concludes that with reference to climate change adaptations, rural farmers primarily rely on crop (changing crop varieties, intercropping, staggering planting dates, supplementary irrigation, use of compost and fertilizer, shifting cultivation) and non-farm floral adaptations (use of indigenous leafy vegetables, use of indigenous fruits, use of indigenous timber) seriously affecting their adoption and adaptation portfolio diversity. The paper also concludes that the ability of rural farmers to adapt is conditioned by socio-economic (age, household size, education, wealth status and land ownership) and institutional (access to credit and extension) factors.

VII. Policy Insights

To enhance rural farmers' awareness and adoption of climate change adaptation techniques, more focus should therefore be given to socio-economic (age, education, household size, wealth, land ownership) factors as suggested by model results. For the purpose of promoting rural farmers' ability to spread their adaptation techniques across a range of adaptation portfolios, the following institutional factors should be targeted as suggested by model results (access to formal and informal credit and extension services). Public policy that creates a supportive rural institutional framework and promotes rural education, rural income initiatives and climate change awareness campaigns may promote the ability of rural farmers to adapt.

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Leo Zhou is the head of the Risk and Vulnerability Science Centre (RVSC) at the University of Fort Hare, Eastern Cape, South Africa. Dr. Zhou has recently participated in the START project on climate change impact on food security among the coastal community of the Eastern Cape. Leo Zhou has produced a book chapter and documentary film for the START project, and has published papers on food security in international refereed journals. Dr Zhou is actively involved as a project steering committee member of the Eastern Cape Anti-Poverty Food Security committee. She also supervises Masters and PhD students recruited under the RVSC.