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Effectiveness of Smallholder Farmers adaptation to climate extremes: Evidence from the Southern Province of Zambia

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ABSTRACT

Climate extreme is one of Zambia's most pressing issues impacting socio-economic development. This paper assessed the impact of adaptation to climate extremes, as well as the effectiveness of adaptation strategies to mitigate the negative impact on food production. A total of 270 smallholder farmers were sampled. Descriptive analysis, and, the endogenous switching regression model were applied. According to the study's findings, adaptors and non-adaptors have a number of different characteristics. Furthermore, based on the estimates of the endogenous switching regression model, radio ownership, seed quantity and farming experience, had a positive relationship with adaptation. Also, the results showed that adaptors are 'better producers' than the non-adaptors. In light of the findings, some policy recommendations were made. When drafting policies (a) it is necessary to draw on the expertise and experience of farmers and local institutions, (b) consider the assets of the farmers and (c) enhance farmers' access to more affordable agricultural inputs.

Keywords: Adaptation, climate extreme, Smallholder Farmers, Zambia

1. INTRODUCTION

Floods, droughts and other severe weather events are becoming more common around the world due to climate change. In addition, the economic implications are large, with losses totaling about USD 300 billion per year, according to the World Bank estimates. The countries in the south are particularly hard-hit by the change, especially when it comes to agriculture. Crop failures, particularly among small-scale farmers, are threatening their economic livelihoods (GIZ, 2018).

Zambia is increasingly susceptible to climate change and variability, as demonstrated by increased frequencies related to extreme events. Incidences related to climate, such as seasonal floods, droughts, dry spells and extreme temperatures, have continued to affect Zambia's socio-economic

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development(Mwitwa, 2018). These are the most serious threats to Zambia's agriculture sector (Braimoh et al., 2018). Zambia has endured six droughts in the last 16 years from 1990 to 2005: 1991/1992, 1994/1995, 1997/1998, 2000/2001, 2001/2002 and 2004/2005. In addition, the 2007/08 floods [5,8], and the droughts of 2018/19 farming season. The occurrence of these extreme events increased the vulnerability of smallholder farmers.

Adaptation acts as a crucial part of any policy response to climate extreme (e.g., droughts and floods). Climate extremes, according to studies, are for the most part ad-verse to the sector of agriculture without adaptation, nonetheless, adaptation can minimise vulnerability to some extent (Smit & Skinner, 2002). The significance of the agricultural sector in Zambia's southern province cannot be over emphasised. The province is one of the predominantly agriculture producing areas in Zambia.

Agriculture in the Province is subsistence and is practiced by the majority of the smallholder farmers. The main crop is maize, which is a staple food, and an important and strategic crop. Over 70% of the urban population and businesses in the Province survive from the multiplier effect of agricultural-related activities. The contribution of the Province to the gross domestic product (GDP) is around 20%. Climate change has had a negative effect on the Province, with the steady decline of agriculture (Ngoma, 2008) .

In Zambia, little is known about whether adaptation practices by farmers support food productivity. Most of the scholarly work focuses on the impact of climate change on agriculture (Jain, 2007; Kalantary, 2010). To the best of our knowledge, there is no research in Zambia, focused on the effectiveness of adaptation and/or the impact of adaptation on food pro-duction. To ensure food security, it is important to establish how effective adaptation is to climate extremes for farmers, and whether such measures can reduce yield loss (Khanal et al., 2018). This study, therefore, investigated (a) the impact of adaptation to climate extremes on farmers' food production, and (b) the effectiveness of adaptation strategies to mitigate the negative impacts of climate extremes on food production.

2. RESEARCH METHOD

Study area and data collection

The Southern Province, one of Zambia's ten provinces, has thirteen districts. The Province's overall area is 85,283 km2, that is, four times the size of Israel. The plateau is the Province's heartland,

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with the most farmland in Zambia. The main economic activity is subsistence agriculture. Climate change extremes are most notable in this Province and have contributed to low agricultural productivity.

This study used data collected from a survey in 2020, from 270 farm households. The study adopted a two-stage sampling technique. The first stage, enumeration areas were selected and the farm households according to their size. The second stage within each enumeration area, 20 farm households were randomly selected. Owing to the sample size of 270, in one enumeration area only a random selection of 10 farm households was conducted (Figure 1).

These ten sampled farm households, suffered crop production as a result of climate extreme (drought/floods) in the immediate three years (2017, 2018 and 2019) prior to the study. Climate extreme was measured according to a farmer's own assessment. By definition, climate extreme took place based on a farmer’s indication that their crop output was significantly impacted by climate extreme. If a farmer indicated ‘Yes’ then we probed further to find out which years were deemed relatively normal, and those where serious climate extreme was experienced. The farmers in the sample considered 2017 as a ‘normal year’, whereas 2018 and 2019 were accepted as years where climate extreme was experienced. Face-to-face interviews were used in this household survey.

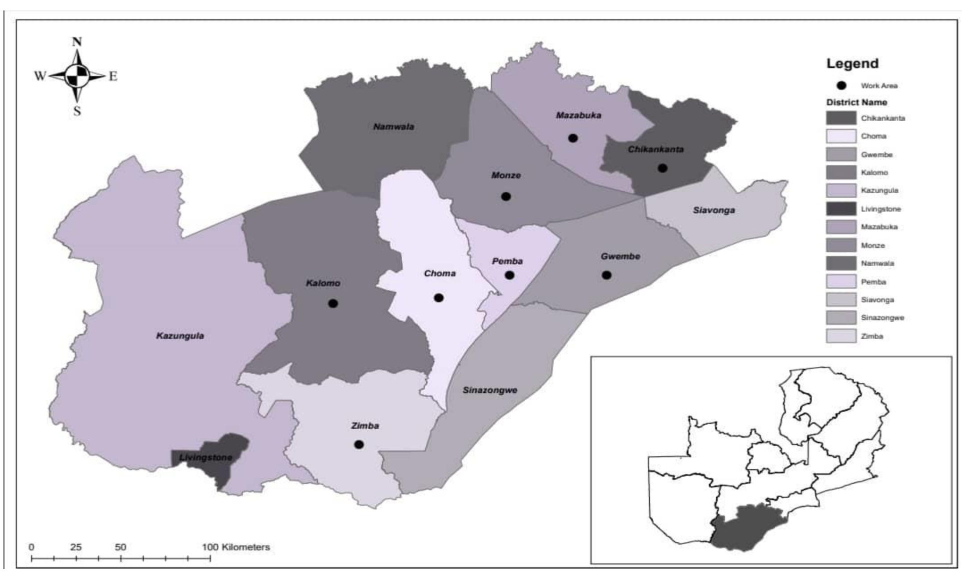

Figure 1: Map of Southern Province (Source: Author, 2021)

The dotted points are the location of the work areas

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Modelling adaptation to climate extreme and food production

Falco et al., 2010) explain that a two-stage approach can be used to simulate adaptationdecisions on climate extreme and its impact on food production. In the first step, a 'selection model' was used for climate extreme adaptation-decisions. It is assumed that a farmer will take the decision to adapt to climate extreme based on projected benefits denoted by A^*.

We specified the selection equation as:

$$A_i^* = Z_i\alpha + \eta_i \quad \text{with} \quad A_i = \begin{cases} 1 & if \quad A_i^* > 0 \\ 0 & otherwise \end{cases} \tag{1}$$

And that farmers will choose to adapt ($Ai = 1$) if $A^* > 0$, 0 otherwise, Z is a variable vector that influences whether to adapt to climate extreme.

The second step involved using the production technology to model the adaptation impact on food production. The easiest way would have been to incorporate an adaptation dummy variable in the food production equation and then use ordinary least squares (OLS). The problem with this approach is that it could have led to biased estimates since it assumes that adaptation to climate extreme is determined exogenously, though it may be endogenous in nature." Furthermore, other problems, like selection bias and inconsistent estimates, could have arisen thus invalidating the results. For this study, in determining the impact of adaptation on food production, we used an endogenous switching regression model of food production. Farmers who adapt and those who do not, have different production functions.

Regime 1: $y_{1i} = X_{1i}\beta_1 + \varepsilon_{1i} \quad if \quad A_i = 1$ (2a)

Regime 2: $y_{2i} = X_{2i}\beta_2 + \varepsilon_{2i} \quad if \quad A_i = 0$ (2b)

where y_{1i} and y_{2i} are the quantity produced per hectare, X_i denotes farmers' characteristics, input vector, asset ownership, and climatic factors, such as droughts and floods, β parameters to be estimated, ε_{1i} and ε_{2i} are stochastic terms.

Consistent with (Falco et al., 2010), we used the endogenous switching regression model to investigate the conditional expectations for food production in the four scenarios defined as

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$$E(y_{1i} \mid A_i = 1) = X_{1i}\beta_1 + \sigma_{1\eta}\lambda_{1i} \quad (3a)$$

$$E(y_{2i} \mid A_i = 0) = X_{2i}\beta_2 + \sigma_{2\eta}\lambda_{2i} \quad (3b)$$

$$E(y_{2i} \mid A_i = 1) = X_{1i}\beta_2 + \sigma_{2\eta}\lambda_{1i} \quad (3c)$$

$$E(y_{1i} \mid A_i = 0) = X_{2i}\beta_1 + \sigma_{1\eta}\lambda_{2i} \quad (3d)$$

Equations 3a and 3b denote the sample's actual expectations. The counterfactual predicted outcomes are described in Equations 3c and 3d. The difference between Equations 3a and 3c represents the effect of the treatment to adapt on the treated (TT), and depicts the effect of climate extreme adaptation on the farmers' food production. Likewise, the difference between Equations 3d and 3b measures the treatment effects on the untreated (TU) for farmers that in fact did not adapt. Besides, the effect of base heterogeneity for the farmers, who made the decision to adapt, is calculated as the difference between E 3a and 3d. Equally, the impact of base heterogeneity is the difference between Equations 3c and 3b for the farmers, who made the decision not to adapt. Lastly, we calculated transitional heterogeneity (TH) as the difference between TT and TU.

3. RESULTS AND DISCUSSION

Descriptive statistics

Before discussing the empirical results, this section discusses the features that characterise our data. Despite the fact that eight different crops were cultivated in the study area, maize crops stood out as the only one that all the farmers grew and was at the cornerstone of the local diet. Maize is the country's staple food crop, and its value de-fines food security. Other crops, such as sorghum, millet, sunflower, groundnuts, sweet potatoes, mixed beans, soyabeans were grown by a small number of farmers in the sample, depending on their location, vis-à-vis, the climatic factors. In light of this, we limit the production function estimation to maize crops. The measure of analysis was at the farm level.

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Table 1: Descriptive statistics of adaptors and non-adaptors

Variable Name	Farm households that adapted		Farm households that did not adapt		Diff.
	Mean	Std. Dev.	Mean	Std. Dev.	
ADAPTATION (Adapted=1)	1	0	0	0	1
Quantity produced per hectare(Kg/ha)	2510.796	1621.174	2143.245	2011.315	367.551*
Gender (male= 1)	1.462	0.501	1.444	0.499	0.017
Marital status(married=1)	0.923	0.268	0.948	0.223	-0.025
Age of household head (years)	42.658	8.131	44.425	8.593	-1.767**
Household size (number)	12.607	2.652	12.392	2.591	0.215
Educationof household head (years)	8.162	3.806	8.248	2.530	-0.086
Farming experience (years)	24.709	18.854	24.490	18.065	0.219
Farm size owned(ha)	7.726	4.205	7.451	3.876	0.276
Number of fields owned (number)	2.846	1.356	3.059	1.991	-0.213
Off-farm income(ZMK)	1595	4651	1657	2457	-61.891
Plough ownership (own= 1)	0.855	0.354	0.902	0.298	-0.047
Hoe ownership (own= 1)	0.863	0.345	0.758	0.430	0.105**
Oxen ownership (own= 1)	0.128	0.336	0.163	0.371	-0.035
Radio ownership (own= 1)	0.299	0.460	0.569	0.497	-0.269***
Source of extension (government=1)	0.615	0.489	0.725	0.448	-0.110
Access to extension (access=1)	0.564	0.498	0.784	0.413	-0.220***
Extension services received (number)	3.111	2.494	3.608	2.418	-0.497
Access to credit (access=1)	1.863	0.345	1.699	0.460	0.164
Source of credit(government=1)	1.060	0.238	1.124	0.331	-0.064
Seeds (Kgs)	117.539	57.383	139.673	175.709	-22.135*
Distance to the main market (Km)	20.111	14.177	20.490	13.976	-0.379

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Variable Name	Farm households that adapted		Farm households that did not adapt		Diff.
	Mean	Std. Dev.	Mean	Std. Dev.	
Labour (person-days)	6.051	2.735	6.275	3.029	-0.223
Information received on expected disasters 2018 (yes=1)	1.128	0.336	1.183	0.388	-0.055
Information received on expected disasters 2019 (yes=1)	1.171	0.378	1.242	0.430	-0.071
Information received to prevent disasters 2018 (yes=1)	1.103	0.305	1.144	0.352	-0.041
Information received to prevent disasters 2019 (yes=1)	1.154	0.362	1.222	0.417	-0.068

Note: There are 270 total observations. Significance level: *** (p ≤0.01); (p ≤0.05); ** (p ≤ 0.10)*

(Source: Author, 2021)

Based on the study, 55% of the households interviewed were male-headed homes and 45% were female-headed. From Table 1, the average age of adaptors along with non-adaptors are in the age category of economic productivity of 43years and 44years, respectively. This age gap between the two groups is confirmed by the t-test as being statistically significant. Both adaptors and non-adaptors spent an average of eight years at school. It was also observed that some farm household heads did not complete their education due to several reasons, and others did not acquire tertiary education. Overall, the farm households reported that there were no labour shortages even at the peak period of field activities.

Some households in the study area, whether adaptors or non-adaptors, own key agricultural assets, like a plough, a hoe and oxen, which they reported as being used for field purposes. Other assets owned by them included a radio. The chi-square statis-tics indicate that the ownership of a hoe and radio are significantly different among both the adaptors and the non-adaptors. Additionally, agricultural credit and extension services are available to the sampled households. The chi-square statistics indicate that credit access and access to an extension is significantly different among the adaptors and non-adaptors.

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Impact of adaptation to climate extremes on farmers food production

This section discusses the impact of adaptation to climate extremes on farmers' food production. Furthermore, the effectiveness of adaptation strategies to mitigate the negative impacts of climate extremes on food production are also considered.

Table 2: Parameters estimates of climate extreme adaptation and food production equations

	(1)		(2)		(3)		(4)	
					Endogenous Switching Regression			
Model	OLS				Adaptation = 1 (Farm households that adapted)		Adaptation = 0 (Farm households that did not adapt)	
Dependent variables	*Quantity produced per hectare*		*Adaptation 1/0*		*Quantity produced per hectare*		*Quantity produced per hectare*	
	Coef.		**Coef.**		**Coef.**		**Coef.**	
	Std. Err.	**dy/dx**	**Std. Err.**	**dy/dx**	**Std. Err.**	**dy/dx**	**Std. Err.**	**dy/dx**
Adaptation 1/0	480.626	480.611**						
	(213.3819)	(213.3819)						
Age	-3.617	-0.036	-0.003	0.025	-31.163	-0.087	1.986	0.138
	(11.768)	(11.768)	(0.012)	(0.012)	(24.508)	(24.508)	(11.489)	(11.489)
Household Size	34.368	0.034	0.043	0.041	147.048	0.099*	-1.775	0.188
	(45.850)	(45.850)	(0.045)	(0.045)	(86.197)	(86.197)	(47.420)	(47.420)
Farming experience	0.000	0.000	0.011	0.020**	0.122	0.034	0.436	0.076
	(0.000)	(0.000)	(0.005)	(0.005)	(0.000)	(0.000)	(0.000)	(0.000)
Farm size owned	46.085	0.046	-0.012	-0.051	82.574	0.043	-25.693	0.011
	(28.498)	(28.498)	(0.033)	(0.033)	(67.053)	(67.053)	(30.790)	(30.790)
Number of fields owned	60.445	0.060	0.092	0.097	74.520	-37.526	44.137	0.090
	(64.206)	(64.206)	(0.070)	(0.070)	(109.183)	(0.0109183)	(85.926)	(85.926)
Off-farm income	0.237	0.024***	0.000	-0.016	0.168	0.014**	0.177	0.097***
	(0.029)	(0.029)	(0.000)	(0.000)	(0.081)	(0.081)	(0.029)	(0.029)
Hoe ownership	0.000	0.000	-0.566	-0.057***	0.000	0.019	0.000	0.051
	(0.000)	(0.000)	(0.220)	(0.220)	(0.000)	(0.000)	(0.000)	(0.000)
Oxen ownership	881.840**	0.088	0.388	0.013	3347.235	-0.050***	631.696	0.012*
	(38.852)	(38.852)	(0.432)	(0.432)	(11.402)	(11.402)	(34.720)	(34.720)
Radio ownership	-163.854	-0.016	1.130	0.065***	-863.882	-0.077	-50.452	0.052

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	(1)		(2)		(3)		(4)	
	(26.201)	(26.201)	(0.286)	(0.286)	(82.109)	(82.109)	(27.505)	(27.505)
Source of extension	-191.968	-0.019	0.043	0.035	-759.140	-0.021*	-124.124	-0.019
	(20.768)	(20.768)	(0.216)	(0.216)	(45.047)	(45.047)	(20.367)	(20.367)
Access to extension	545.212	0.055*	0.209	0.090	3583.333	-0.022***	264.684	0.059
	(33.193)	(33.193)	(0.392)	(0.392)	(11.048)	(11.048)	(29.297)	(29.297)
Extension services received	28.982	0.029	-0.080	0.009	-214.207	-0.061	26.302	0.030
	(39.720)	(39.720)	(0.050)	(0.050)	(20.829)	(20.829)	(35.800)	(35.800)
Seeds	-0.761	-0.076	0.004	0.012**	-0.617	-0.050	13.881	0.033***
	(0.739)	(0.739)	(0.002)	(0.002)	(1.109)	(1.109)	(2.030)	(2.030)
Distance	4.753	0.048	0.000	0.082	4.221	-0.015	3.118	0.057
	(7.300)	(7.300)	(0.007)	(0.007)	(15.037)	(15.037)	(7.139)	(7.139)
Labour	0.000	0.000	-0.049	-0.026	0.000	0.045	0.000	0.148
	(0.000)	(0.000)	(0.036)	(0.036)	(0.000)	(0.000)	(0.000)	(0.000)
Radio	35.672	0.036	0.091	0.081	370.742	0.013	17.027	-0.076
	(19.733)	(19.733)	(0.200)	(0.200)	(45.141)	(45.141)	(19.595)	(19.595)
Mobile	122.748	0.012	0.001	0.000	47.773	0.014	-124.563	-0.022
	(26.074)	(26.074)	(0.247)	(0.247)	(51.771)	(51.771)	(26.743)	(26.743)
channel extension	40.333	0.040	-0.107	0.000	-305.890	0.022	-74.530	0.047
	(19.770)	(19.770)	(0.199)	(0.199)	(40.996)	(40.996)	(20.153)	(20.153)
Constant	351.946		-2.111**		-1988.546		242.467	
	(966.724)	(966.724)	(1.067)		(2818.777)		(923.345)	
σ_i					1622.110		1349.620	
					(312.075)		(67.782)	
ρ_j					0.668		0.125	
					(0.302)		(0.210)	

Standard errors appear in parentheses. σ is the square-root of the variance of the error terms εji in the outcome equations (2a) and (2b), respectively; ρjis the correlation coefficient between the error term η of the selection equation (1) and the error term εji of the outcome equations (2a) and (2b), respectively.

Note: Asterisks represents level of statistical significance level: ***(p ≤ 1%); **(p ≤ 5%); *(p ≤ 10%)
(Source: Author, 2021)

Table 2 presents the endogenous switching regression model estimates. The first column has the OLS estimates of the food production function with no switching and with an adaptation dummy variable. The second column depicts the estimated results of the adaptation selection equation (1); the third and fourth columns show, respectively, the food production functions 2a and 2b for adaptors and non-adaptors.

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The estimates from Equation 1 suggest that information on farmers possessing a hoe, radio, farming experience and seeds have a significant influence on the farm households likelihood to adapt (Table 2, Column 2). The estimated coefficient for farming experience is positive and statistically significant, suggesting that farm households with more farming experience will be willing to adapt. The quantity of seeds has a positive and significant impact on household adaptation to climate extremes. This is consistent with the findings of (Hampton et al., 2016), that seeds are one of the options to adapt to climate effects.

We now discuss the effect of adaptation on food production. The easiest approach is to employ the OLS model of food production and include an adaptation dummy variable (Table 2 Column 1). Adaptation dummy variable entails that farmers in the study area are regarded to have adapted if they adopted any of the adaptation measures. This is also true whether they used two, three, or more adaption strategies. Using this approach, we can conclude that adaptors produce more than the non-adaptors, about 481 Kg more per hectare, ceteris paribus (marginal effect of the adaptation dummy variable). This approach is problematic since it yields estimates which are biased and inconsistent. Further, potential structural differences between the production function of adaptors and non-adaptors is not explicitly accounted for.

The estimates presented in the third and fourth columns of Table 2 account for the endogenous switching in the food production function. Based on descriptive statistics, the food production function of farm households that adapted to climate extremes is significantly different from that of the farm households that did not adapt. The variable household size is an important factor in explaining an increase in the quantity produced per hectare in the adaptor group. Based on predictions from economic theory, inputs like seeds, tend to improve the quantity produced per hectare for non-adaptors to climate extreme. This argument is raised in many existing studies (Falco et al., 2010) where it is argued that seeds significantly determine the production of farm house-holds. The results further indicate that off-farm income is a significant factor in the quantity produced per hectare for the adaptors, and is less than that of the non-adaptors.

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Table 3: Average expected production per hectare; treatment and heterogeneity effects

	Decision stage		
Sub-samples	To Adapt	Not to Adapt	Treatment Effects
Farmers who adapted	(a) 2510.80	(c) 2184.02	TT= 326.78
Farmers who did not adapt	(d) 2251.02	(b) 2143.25	TU= 107.77
Heterogeneity effects	BH_1= 259.78	BH_2= 40.77	TH= 219.01

(Source: Author, 2021)

Finally, Table 3 presents the expected quantity produced per hectare under actual and counterfactual scenarios, and the estimated results of the effects of both average treatment and base heterogeneity. Cells a and b represent the expected quantity produced per hectare as observed in the sample. Cell c represents the expected quantity produced per hectare of the adaptors if they decided not to adapt. Cell d represents the expected quantity produced per hectare of the non-adaptors if they decided to adapt.

If adaptors had not adapted, their production would have been roughly 326.78 kg/ha less. Likewise, if non-adaptors had adapted, their production would have been roughly 107.77 kg/ha more. These findings suggest that adaptation to climate extreme results in increased food production. Also, the last row of Table 3 adjusts for potential heterogeneity in the sample, which shows that farm households who decided to adapt, tend to have benefits above the average. However, the issue on climate extreme, adap-tors remain better producers than the non-adaptors. The finding is consistent with those of (Khanal et al., 2018).

4. CONCLUSIONS

The study's objectives were twofold. First, to investigate the impact of adaptation to climate extremes on farmers' food production. Second, to investigate the effective-ness of adaptation strategies to mitigate the negative impacts of climate extremes on food production. The descriptive analysis showed a significant difference in output per hectare, hoe ownership, radio ownership, access to extension services and in the age of adaptors and non-adaptors. The results of the endogenous switching regression model showed that farming experience, quantity of seeds and radio ownership

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were positive and statistically significant with adaptation. Furthermore, we noted that there are some systematically different characteristics between adaptors and non-adaptors. Generally, these findings imply that adaptation increases food production. Adaptors have benefits above the average and are better producers than non-adaptors.

To determine adaptation, given the relevance of farming experience, ownership of production assets, and quantity of seeds, from the study the recommendation when drafting policies is to draw on the expertise and experience of farmers and local institutions, to consider the assets of the farmers, and to enhance farmers' access to more affordable agricultural inputs.

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