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Factors Influencing Smallholder Farmers' Adaptation to Climate Change and Variability in Chiredzi District of Zimbabwe

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Abstract
The study sought to understand household adaptation strategies to climate variability and analyse socioeconomic factors influencing smallholder farmers' adaptation. A binary logit model was used to analyse the factors influencing household decision to adapt to climate variability. Results show that at farm level, the adaptation techniques employed included dry planting, conservation agriculture, planting short season crop varieties, holding prayers and religious festivals and crop diversification. From the binary logit model, access to extension , number of members fit to work, livestock holding, access to credit, neatively age of household head positively influenced adaptation decision while age of household head and farm income negatively influenced adaptation decision.
Keywords: Climate change, Adaptation, binomial logit, smallholder farmers, resources, technology

1. Introduction

Climate change has been regarded as a silent crisis or enemy as the effects of climate change are not immediately visible (Kgakatsi, 2006; Global Humanitarian Forum, 2009, Maponya, et al, 2012). The Intergovernmental Panel on Climate Change (IPCC) points out that scientific evidence strongly suggests that global climatic conditions are changing mostly for the worst (CGAIR 2000). Climate change is envisioned to threaten sustainable development and all eight Millennium Development Goals (Global Humanitarian Forum, 2009). Climate change has altered hydrological cycles and weather patterns, raised sea levels and increased the intensity and frequency of extreme weather conditions all of which have a significant impact on the livelihoods and living conditions of the poor in developing countries (Riziki, 2011).

Like most countries, Zimbabwe has already started experiencing the impacts of climate change. The Meteorological Department in Zimbabwe indicates that evidence is showing that there are changes in precipitation amounts and precipitation patterns all over the country as indicated by change of the following parameters: rainfall patterns, first day of rain commencement, occurrence of dry spells, rainfall intensity, rainfall amounts. Flood and cyclone occurrences have become more frequent e.g. cyclone Bonita 1996, Eline 2000, Japheth 2003 and another one in 2007 (Russell, 2008).

The harsh seasonal variations in rainfall and temperature that have come as a result of climate change expose farmers to intense risks and this in turn has a major bearing on the production outcome. Considering that 70% of the local population in Zimbabwe operates under rain fed agriculture, rainfall and temperature variations have severe implications on production and food security. Using the 1961-1990 baselines, Lobell, et al, (2008) suggested that by 2050, average temperatures over Southern Africa (where Zimbabwe is located) will be 2-40C higher and rainfall 10-20% less and this will consequently significantly reduce maize yields. Climate gurus have pointed out that the Zimbabwe production levels might drop by around 30% due to climate variation (Mano and Nhemachena, 2006).

The high rainfall variability, unreliability and uncertainty have prompted farming communities to engage in measures to adapt to dynamic climatic, environmental and weather conditions. Nhemachena and

Hassan (2008), postulate that adaptation is important in helping communities mitigate and cope with the changes associated with climate variations. On the other hand, the speed of current climate change is greatly feared to exceed the limits of adaptation in many parts of the world (Adger and Vincent, 2005).

Adaptation to climate change is the adjustment in natural or human systems in response to actual or expected climatic stimuli and their effects which moderates harm or exploits beneficial opportunities (IPCC, 2001). Smith and Lenhart (1996) and Fankhauser (1996), Smit et al 2002 note that adaptation is an essential part of climatic change impact and vulnerability assessment and a policy option in response to climatic change impacts. Adaptation in agriculture is expected to help farmers achieve household food, income and livelihood security objectives in the face of changing climatic and socio-economic conditions including climatic variability, extreme weather conditions such as droughts and floods and volatile short term changes in local and large-scale markets (Kandlinkar and Risbey, 2000). Adaptation moderates vulnerability to climate change and helps farmers guard against losses due to increasing temperatures and decreasing precipitation (Spittlehouse, 2003; Nemachena and Hassan 2008). Hence understanding household adaptation to climate change is important so as to develop and implement effective adaptation measures.

The objective of this paper is to understand household adaptation strategies to climate variability and analyse socioeconomic factors influencing smallholder farmers' adaptation decisions to climate change in Chiredzi.

2 Methodology

2.1 Project area

The study was conducted in Chiredzi district which is located south east of Zimbabwe. Chiredzi district lies in Masvingo province. Chiredzi town is located 365 km from the capital of Zimbabwe, Harare. Due to intensive irrigation, Chiredzi town together with its sister town of Triangle, are the major centres of sugar production in the country. However, the rest of the district where smallholder farmers derive their livelihoods is arid. The greater part of the district is found in natural regions five while some parts lie in natural region four. In Zimbabwe, natural regions four and five are characterized by aridity and uncertain rainfall patterns. Chiredzi receives mean annual rainfall of 450 - 600 mm with mean annual evaporation exceeding 1800 mm. Historical data shows that surface temperatures in the district have warmed by 0.6°C from 1966 to 2005, and is projected to rise to 1.5 – 3.5°C by about 2050. Despite the aridity of the district, the main source of livelihood for households in Chiredzi is agriculture.

2.2 Data collection

Both qualitative and quantitative techniques were used to collect data. Some key informants interviews were conducted in which local district government personnel were interviewed to get an overview of the district. Primary data was collected using a household survey. A total of 97 household respondents were randomly selected from the district and interviewed and in-depth interviews with heads of households using a structured questionnaire were held. The sample size was mainly a factor of limited availability of funds. Data on household demographics, socioeconomic, perception and adaptation to climate change was collected using the questionnaire.

2.3 Binary Logit Model

The study uses a binomial logit model to analyse the socioeconomic factors affecting the households' decision to adapt to climate change or not to adapt. This method has been used by several authors to study household decision to adapt to climate change (Seo and Mendelsohn, 2006, Apata et al. 2009; Fosu-Mensah et al., 2010; Acquah-de Graft and Onumah 2011; Mandleni and Anim 2011;). The dependent variable is dichotomous i.e. households decision to adapt or not adapt to climate change and variability. The binary logit model in this case is appropriate because it considers the relationship between a binary dependent variable and a set of independent variables (Fosuu-Mensah, 2010).

The model uses a logit curve to transform binary responses into probabilities within the 0 - 1 interval. In the logit model the parameter estimates are linear and assume a normally distributed error term (μ). The logit model is specified as:

$$\mathrm{Prob}(Y_i = j) = \frac{\exp(\beta_j' X_i)}{\sum_{k=o}^{j} \exp(\beta_k' X_i)} \quad (1)$$

Where β_j is a vector of coefficients on each of the independent variables Xi. Equation (1) can be normalized to remove indeterminacy in the model by assuming that $\beta_0 = 0$ and the probabilities can be estimated as:

$$\Pr ob\ (Y_i = j|x_i') = \frac{\exp(\beta_j x_i)}{1+\sum_{k=1}^{j}\exp(\beta_k x_i)}, j = 0,1,2\cdots J, \beta_0 = 0 \quad (2)$$

The general form of the logit model is presented below

$$Prob(Y_i = 1) = F(\beta'\ x) \quad (3)$$

$$Prob(Y_i = 0) = 1 - F(\beta'\ x) \quad (4)$$

The binary logit estimate is expressed in its implicit form as follows:

$$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}) \quad (5)$$

Where Y is the adaptation status (1= farmers who adapted, 0= farmers who did not adapt; X_1 is age of household head; X_2 is access to extension (1=accessed extension 0=no access to extension; X_3 is the number of individuals fit to work; X_4 is Access to credit 1= access to credit, 0= no access to credit); X_5 is farm income; X_6 is livestock holding; X_7 is total dryland area; X_8 is employment status (1=full time, 0=otherwise), X_9 is literacy level ($1 =$ literate, $0 = otherwise$); The a priori expected relationship between the dependent variable and explanatory variables is given in Table 1.

Table 1: Description of variables and expected signs

Variable	Relationship with dependent variable	Expected sign
Age of household head	Young farmers are quick to understand and accept new ideas and are therefore more likely to be willing to adapt to climate change than older	negative
Level of education of the household head	Education increases the probability of adapting to climate change as it is associated with being open minded and the ability to embrace positive change.	Positive
Number of people fit to work	A larger household is expected to have a better labour endowment therefore enabling achievement of farm activities. The consumption pressure as a result of a large household size may result in diversion to off-farm activities to generate more income therefore crippling ability to adapt	Negative or positive
Credit finance	Use of credit facilities enables farmer to fund farm operations therefore enhancing the probability of a farmer to adapt strategies	Positive
Employment status or time awarded to farming	A fulltime farmer primarily seeks to be productive in his farm activity and thus more likely to adapt.	Positive
Total dryland farm area	The larger the farm size, the greater the proportion of land allocated to other crop varieties.	Positive
Farm income	High income enables farmer to be able to finance different activities	Positive
Livestock holding	Livestock ownership represent wealth and therefore households with better livestock endowment adapt better.	positive
Extension advice	Access to extension advice is expected to increase one's choice to adapt. Extension increase access to useful knowledge meant to bring change and growth.	positive

3 Results and discussion

3.1 Socio- demographic characteristics of households

Table 2 provides a comparative analysis of socioeconomic variables of households according to their adaptation status. The proportion of the farmers that adapted to climate change and variability was 65%. From the sample 61.9% farmers who have adapted to climate change and variability were male while 38.1% were female. On the other hand, 67.6% of non-adapters were male and 32.4% were female. A chi-square shows that there is no significant association between the gender concentration for adapters and non-adapters. However, there was a significant difference in the mean age of adapters (43 years) and non-adapters (57). Households adapting to climate change tended to be younger. Incomes of adapters were significantly higher and adapters had access to credit. A significant difference was also noted between the literacy status of farmers 74.6% of the farmers who adapted to climate change were literate and while 55.9% of the households that did not adapt were literate. The chi-square analysis showed the presence of systematic association between the literacy status of farmers and adaptation to climate change.

Table 2 Household characteristics

Characteristics		**Adapters to climate change**	**Non adapters to climate change**
Proportion		65%	35%
Age of household head (mean)		43	57
Gender	Male (%)	61.9	67.6
	Female (%)	38.1	32.4
Level of education of the household head	Literate (%)	74.6	55.9
	Illiterate (%)	25.4	44.1
Number of people fit to work (mean)		6	3
Credit finance	Access to credit (%)	41.3	6
	Lack of access to credit (%)	58.7	94
Farm income (mean)		USD 154	USD 27
Livestock holding (mean)		4	2.5
Extension advice	Accessed extension (%)	63.5	
	No access to extension (%)	36.5	

3.2 Farmer Adaptation strategies

The adaptation strategies included dry planting, planting short season crop varieties, moisture preserving techniques, holding prayers and religious festivals, and crop diversification (Table 3). Of these adaptation techniques the most common adaptation techniques was dry planting (26.8%) followed by conservation agriculture (17.5%) and planting short season varieties.

Table 3 Adaptation techniques

Adaptation technique	**Percentage of farmers**
Dry planting	26.8
Prayers and religious festivals	5.2
Planting short season varieties	12.4
Conservation farming	17.5
Crop diversification	3.1
Nothing	35.1

3.3 Results of the empirical analysis

Table 4 provides results of the binary logit regression. The model had a 91.4 % correct prediction value. The Likelihood Ratio Chi2 value was 85.5 implying that the model is fit very well to the data, that is, the likelihood of the null hypothesis which states that the coefficients are equal to zero being correct is extremely low.

Most of the variables tested had the expected hypothesized signs. From the logit regression results, draught power, access to credit, extension education and number of members fit to work positively and significantly influence farmers' decision to adapt to climate variability. At the same time, age of household head and farm income negatively and significantly influence farmers' decision to adapt.

Age of household head: The estimated parameter for age of the household head is negative and is statistically significant at 1% showing that the age of the household head has a strong influence on farmers' decision to adapt to climate change. The Exp (B) value shows that the odds of adapting to climate change decrease by a factor of 0.815 for a unit increase in age. Young farmers were more likely to take up adaptation strategies to climate change and variability than older ones. In general, as people grow older, they are reluctant to adopt new techniques and let go of the conventional way of doing things. However, the influence of age on adaptation has been mixed, with some studies showing no influence others showing positive or negative influence (Nhemachena and Hassan, 2008). The results from a study by Deressa (2009), showed a positive relationship between age of household head and adaptation to climate change, with more mature and experienced farmers adapting to climate. In a studies done by Nhemachena and Hassan (2008) and Fosu-Mensah et al (2010) age did not significantly influence adaptation. The results of the study agree with a study by Seo et al (2005), who also found that the head of the household age negatively influenced adaptation. Adesina and Zinnah (1993) on the other suggested the possibility of older farmers being less amenable to change from their old practices.

Table 4 Adaptation to climate change logit regression model

Variable	β	S.E	P value	Exp (β)
Age of household head	-.205	.075	.006***	.815
Extension advice	5.347	1.963	.006***	210.044
Members fit to work	.986	.385	.010**	2.682
Credit	2.572	1.377	.062*	13.098
Farm income	-.011	.006	.085*	.989
Livestock holding	.553	.287	.054*	1.739
Total dryland area	.240	.308	.437	1.271
Employment status	.998	1.968	.612	2.713
Literacy level	1.692	1.272	.183	5.433
Constant	-.686	2.936	.815	.504
Number of observations = 97				
Pseudo R^2 = 0.835				
Log likelihood = 32.828				
LR chi^2 = 85.564				
Prob > chi^2 =0.0000				
Overall Percent correct 91.4%				

***Significant at 1% level; **Significant at 5% level; * Significant at 10% level

Members fit to work: The number of household members fit to work positively and significantly influenced adaptation decision. For a unit increase in farm household size, the odds that farmers will adapt to climate change are expected to rise by a factor of 2.68. This implies that the bigger the family size the higher the probability of adapting to climate change. Considering that some of the adaptation strategies such as conservation agriculture and dry planting are labour intensive, households with large families are able to take up labour intensive adaptive measures than smaller households (Mudzonga, 2012). The results are consistent with findings of a study by Gbetibouo (2009), Nhemachena and Hassan (2008). On the other hand Apata et al (2009) found that an increase in household size negatively influenced farmers' adaptation to climate change and variability maybe because in this case as postulated by Mano and Nhemachena (2006) as household size increased households are inclined to divert part of its labour force towards off farm activities. However, in this study this was not the case because in Chiredzi agriculture dominants and households have fewer sources of livelihoods, so households have limited alternatives to divert to. So this forces them to adapt their agricultural activities which is their main source of livelihood.

Access to credit: The results show that, the odds of a farmer adapting to climate change is expected to increase by a factor of 13 if a farmer gains access to credit. Several studies conducted on the determinants of adaptation show a positive relationship between adaptation and credit (Vogel, 2000; Below et al, 2010; Hassan and Nhemachena 2008; Deressa, 2009, Nabikolo et al, 2012; Gbetibuo, 2009; Faosu-Mensah et al, 2010; Tazeze et al, 2012). With access to credit farmers are able to purchase of appropriate crop seed varieties and fertilisers, plant early, and incorporate other farming practices such as crop diversification, in response to changes in climate. In addition with financial resources households can make use of the available information and the numerous adaptation options to respond to climate variability. Therefore, access to credit is a very important factor in determining whether a household adapt to the adverse effects of climate change and variability.

Livestock holding: As per expectation, livestock holding had a positive relationship with adaptation to climate change and variability. An increase in total livestock holding by one unit is likely to give an increase in the odds of adaptation to climate change by a factor of 1.74. Ibrahim et al (2011) and Deressa et al (2009), found that livestock endowment positively affects farmers choice to adapt to climate change or not. Possession of livestock in a rural setting in Zimbabwe signifies better off households or in other words wealthy households. This implies that households that are better off are likely to adapt to climate change and variability since they have resources to enable them to adopt other means of livelihoods than those households without or with few resources at their disposal.

Access to extension services: This positively influenced a household's decision to adapt to climate change and variability. It is expected that with increased information on climate change and adaptation techniques, farmers would choose to adapt. The results are consistent with findings by Hassan and Nhemachena (2008); Deressa (2009) and Mudzonga (2012), Legesse et al (2013) who found that access to extension influenced farmer adaptation found access to extension to strongly and significantly affect adaptation to climate change. Gbetibouo (2009) noted that with access to extension households are aware of the climatic conditions and the various management practices to adapt to climate change.

Farm income: Contrary to apriori expectation and empirical evidence the results show a negative relationship between farm income and the choice to adapt to climate change. This is an interesting finding. The most probable reason is that farmers who are still engaging in the conventional agricultural system and realising high farm incomes probably see no reason to take up new activities as they could be comfortable with what they are getting. This is contrary to studies by Fosu-Mensah et al. (2010); Deressa et al (2009) and Aymone (2009) income positively influenced household decision to adapt to climate change as availability of income would allow farmers to purchase enough inputs and better varieties. This might seem contradictory to the insertion that was made already earlier on that farmers who are better off (more livestock) are more likely to adapt to climate change. Farmers with more farm income indicate farmers who are already have better income from farming. This means these farmers with higher farm incomes have no incentives of adapting than those farmers with falling or lower farm incomes. In other words, lower farm income is an incentive to adapt. Those households realizing already higher farm income have lesser incentives to adapt to newer ways of farming since their current farming practices might already be optimum. This means that if the available methods promise no better off incentives, farmers are not willing to adopt or adapt.

The education level of the household head, farm size and employment status of the household had no significant influence of adaptation to climate change.

4 Conclusion

Given that most of the households (65%) that participated in the survey adopted some strategies to mitigate the adverse effects of climate change signifies the importance of addressing and enabling the smallholder farmers' capabilities to overcome obstacles that stand in their way of raising their livelihoods. The results show that younger farmers were likely to adapt to climate change and variability than older ones. In addition, larger households were found to have higher probability of adapting to climate change. This can be attributed to the fact that most of the adaptation strategies are labour intensive, households with adequate resources are able to cope with the increased labour requirements of the new adaptation techniques.

Furthermore, access to credit was found to be a very important factor in assisting household's adaptation to the adverse effects of climate change. Households with more livestock are likely to adapt to climate change since these resources enable them to adopt other means of agricultural livelihoods than households without or with few resources at their disposal. Households with increased access to information on climate change and adaptation techniques through access to extension services were likely to adapt climate change mitigation strategies. However, the study revealed that households realizing already higher farm incomes have lesser incentives to adapt to newer ways of farming since their current farm practices might already be optimum. This means that if the available methods and technologies offer no better incentives, farmers are not willing to adopt them.

The findings underscore the importance of improving farmer's access to resources such as information and better technologies that would enable them to realize optimum benefits in their mitigation efforts to climate change. There is need for farmers to have access to financial resources to increase adaptation to climate change. Policies aiming at promoting farm level adaptation must improve households' access to affordable lines of credit so that farmers may utilise adaptation techniques. Furthermore with access to financial resources households can purchase quality inputs on time. In addition the results also underpin the importance of access to information and extension services. Improved access to extension will increase household knowledge on climate conditions, the adaptation strategies and the benefits of adaptation techniques. Extension plays an important role in farmer adoption of technologies. There is therefore need to strengthen the existing extension service provision and also bring in the private sector on board.

Given that households are labour constrained and most adaptation strategies employed by households are labour intensive there is a need for research and development of labour saving technologies. The development of labour saving technologies, improved access to credit and extension will increase the likelihood of adaption of climate change by vulnerable farmer such as women and the elderly farmers.

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