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Determinants of adaptation strategies to climate change impact on major field crops in Saurashtra region, Gujarat

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Abstract
The implications of climate variability, be it the delay in seasonal rainfall; its unexpected arrival during the reproductive phase of the crops, or even the increase in night temperature, continue to strike the farmers financially, forcing them to rethink farming as a viable proposition. Nevertheless, the farmers try to cope with or counter climate change effects with adaptation strategies. The present study involving a sample size of 240 farmers from Gujarat, India, employed the multinomial logit model to determine the factors influencing their adaptation strategies to climate change. The findings revealed that among the socio-economic variables, the age of the farmers influenced all the adaptation strategies except the practice of inter/mixed cropping in the study area. For instance, the older the farmers the more they were prone to adopt 'digging/deepening of wells' as a climate change adaptation strategy when compared with that of a base strategy of no adaptation. Farm income was also found to be significantly triggering all the adaptation strategies. For every one-unit increase in farm income, the probability of changing the cropping calendar increased by 2.005 times; taking up of micro-irrigation by 1.379 times; practicing inter/mixed cropping by 1.093 times, and digging / deepening of wells by 1.058 times. The study offers the scope to understand why and how farmers continue to take up farming despite facing complications imposed by climate change.

Keywords: Climate change, adaptation strategies, multinomial logit model, India

Introduction

Climate change refers to a statistically significant variation, often irreversible, in either the mean state of the climate or in its variability due to anthropogenic factors in addition to the natural factors, persisting for an extended period. On the other hand, climate variability refers to the deviations of climatic statistics over a given time period (usually less than a year) when compared to that of base year statistics. Climate change has emerged as one greatest environmental challenge facing the world today.

Climate variability and change represent significant risks for farmers in agriculture. Implementing climatic adaptation measures at the farm level is an effective strategy to reduce climatic vulnerability, allowing rural households and communities to mitigate adverse effects of climate change. Studies demonstrate that agriculture is generally adversely affected by climate change without adaptation strategies, but the negative impacts can be partially offset through various adaptation measures at the farm level. The impact of climate change on the agricultural sector is contingent upon the adaptive capacity of farming communities. A comprehensive understanding of farmers' concerns and their perceptions of climate change is crucial for designing effective policies that support successful adaptation in agriculture. Accurate knowledge about the types and extent of adaptation methods adopted by farmers is equally important. Therefore, gaining insights into how farmers perceive climate changes and the factors that shape their adaptive behavior is essential for robust adaptation research. The choice of adaptation methods by farmers depends on various social, economic and environmental factors. This knowledge will ultimately enhance the credibility of policies and their strength to tackle the challenges being imposed by climate change on. A great number of studies have been done on farm-level adaptation to climate change across different disciplines in various countries which explored farmers' adaptive behavior and its determinants.

While there has been extensive global research on adaptation in the agricultural sector concerning climate change, there has been a notable scarcity of such work in South Asia. In Gujarat, very few studies have explored the factors influencing adaptation measures to climate change. The current study was specifically designed to gain insights into farmers' perceptions, adaptation strategies, and the determinants shaping their responses to climate change.

Methodology

This study investigates farmers' perceptions of climate change and adaptation choices in Gujarat's Junagadh, Rajkot, Jamnagar, and Amreli districts. A sample of 240 farmers was selected using multistage random sampling. Personal interviews explored cropping patterns, input utilization, output yields, and farmers' awareness of climate change. The study employed the multinomial logit (MNL) model to analyse adaptation strategies, providing a nuanced understanding. MNL was chosen over multinomial probit for its precision and practicality. The research aims to identify determinants influencing farmers' grassroots adaptation strategies to climate change.

Farmers' coping strategies for climate variability were evaluated using a multinomial logit model. The discrete and independent strategies considered were: (i) Digging/deepening wells; (ii) Drip/sprinkler irrigation; (iii) Changing cropping patterns; (iv) Adjusting sowing/harvesting dates; (v) Adopting short-duration varieties; (vi) Practicing inter-cropping/mixed cropping; (vii) Adopting soil moisture conservation; and (viii) No adaptation. Farmers selected one strategy they have followed or are willing to follow. 'No adaptation' served as the base strategy, and the farmer's unique strategy was compared with it, allowing for potential modifications based on feedback.

Farmers' choices among alternatives are grounded in the theory of random utility, where the utility of each option is modeled as a linear function of observed characteristics, along with an additive error term. The 'i'th farmer opts for the 'j'th adaptation option if the perceived benefit from option 'j' exceeds the utility from all other options ('K'). This decision is based on selecting the alternative with the highest utility.

$$U_i(\beta_j x_i+\varepsilon_{ij}) > U_{ik}(\beta_k x_i+\varepsilon ik), \text{ for all } k \neq j \quad \text{........(1)}$$

Where:

U_{ij} and U_{ik} = Perceived values of the ith farmer for adaptation options j and k, res.;

x_i = Vector of explanatory variables that influence the choice of the adaptation option;

β_j and β_k = Parameters to be estimated; and

εij and εik = Error terms referring to the stochastic component to account uncertainty.

This study examined how socio-economic factors, such as education, family size, and farm income, impact farmers' adaptation strategies to climate change. Key factors received positive signs, indicating a positive impact, while distance to market was considered negatively. Utilizing existing literature and expert opinions, the research assessed individual effects of these variables on adaptation strategies, contributing to a nuanced understanding of the relationship between socio-economic characteristics and farmers' responses to climate change.

Table 1: Explanatory variable hypothesized to impact farmers' coping strategies in face of climate change

Variables	Value	Expected Sign
Age of the farm household head	No. of years	+/ -
Education of the household head	No. of years	+
Family size	Number	+
Farm Income	Rs./ha	+
Farm Size	In ha	+
Farm Experience	No. of years	+/-
Livestock Ownership	1 = Yes, 0 = Otherwise	+
Extension Agency Contact	1 = Yes, 0 = Otherwise	+
Access to weather information	1 = Yes, 0 = Otherwise	+
Access to credit	1 = Yes, 0 = Otherwise	+
Distance to market	km	-

In the MNL model, it is usual to designate one of the adaptation strategies as the reference strategy. The probability of adaptation of other strategies is compared with the probability of adaptation of the reference strategy. Thereby, the observable choice of strategies can be related to the unobservable continuous net gain variable as:

$$Yi = 1 \text{ if } Uij > 0 \text{ and } Yi = 0 \text{ if } Uij < 0 \quad \text{… (2)}$$

In this formation, Y is a dichotomous dependent variable taking the value of 1 when the farmer chooses an adaptation option and 0 otherwise.

The probability that farmer 'i' will choose adaptation strategy 'j' among the set of adaptation strategies was defined as:

$$\text{Prob}[Yi=j|x] = \text{Prob}\,[Uij>Uik] \quad \text{….(3)}$$
$$= \text{Prob}\,[xi\beta j+\varepsilon ij-xi\beta k-\varepsilon ik>0|x]$$
$$= \text{Prob}\,[x(\beta\text{j}-\beta k)+\varepsilon ij-\varepsilon ik>0|x]$$
$$= \text{Prob}\,[xi\beta+\varepsilon^*>0|x] = \text{F}\,(\beta^* xi) \quad \text{… (4)}$$

Where:

ε^* = Random disturbance term;

β^* = Vector of unknown parameters that can be interpreted as the net influence of the vector of explanatory variables influencing adaptation;

F ($\beta^* xi$) = Cumulative distribution of ε^* evaluated at $\beta^* xi$.

Thus, the probability that a farmer 'i' with socio-economic characteristics 'X' will choose alternative 'j' was specified as:

$$\Pr\left(Y_i = \frac{i}{j}\right) = Pr_{ij} = \left(\frac{exp(x_i\beta_j)}{1+\sum_{j=2}^{8}(exp(x_1\beta_k)}\right) \ldots\ldots(5)$$

The parameter estimates of the MNL model can only provide the direction of the effect of the independent variable on the dependent variable. Thereby, the actual magnitude of change of the probability of change can be estimated only with the help of marginal effect.

Results and Discussions

Perception and adaptation behaviour of farmers *vis-à-vis* climate change

Perception and adaptation are intertwined in addressing agrarian issues. Farmers' awareness and understanding of issues, such as climate change, shape their perceptions, influencing the urgency to adopt adaptation strategies. Farmers' perceptions serve as feedback, indicating economic implications. Adaptation, occurring over various timescales, involves measures implemented by farmers to align with changing conditions. Incremental adaptations, like crop management changes, can occur autonomously, while practices such as technology adoption and sustainable resource management reduce climate-induced yield risks. Access to irrigation is a notable adaptation strategy. Analysing farmers' perceptions and adaptation choices is crucial for regional policy development. Farmers' decisions are influenced by their resources and decision-making power. Recognizing climate variability is essential for farmers to adopt necessary adaptation strategies. This study, conducted from October 2019 to January 2020 among 240 farmers, explores their perceptions, implications of climate change, and key adaptation strategies. Results shed light on farmers' adaptation behaviour.

Socio-economic characteristics of farm respondents

Socio-economic characteristics play a vital role in defining the perceptions as well as the adaptation strategies of the farmers. In addition, the crops under cultivation may also considerably influence in shaping up of both perception and adaptation. Thereby, it is critical to ensure commonality among the socio-characteristics of the farmers. Besides, the effect of crop under cultivation should also be neutral in terms of the underlying socio-economic characteristics of the farmers. Accordingly, in this study, the socio-economic characteristics of the farmers are analyzed. For the sake of convenience, the farmers surveyed are in turn classified in to two groups, *viz.* groundnut farmers and cotton farmers. These two crops were employed as indicator crops since surveyed all the farm respondents were found to allocate a significant portion of the landholdings to these crops. Besides, a t-test was also conducted to see whether there is any significant difference among the socio-economic characteristics of the two groups of farmers.

Table 2: Descriptive statistics of respondents

No.	Determinant variables	Cotton farmers (n = 120)		Groundnut farmers (n = 120)		t-test	
		Mean	Std. Dev.	Mean	Std. Dev.	t-stat	p-value
1.	Age (years)	48.23	11.52	48.63	10.07	-0.28	0.78
2.	Education (years)	9.91	2.77	9.75	2.62	0.46	0.65
3.	Family size (no.)	5.29	1.69	5.18	1.77	0.52	0.61
4.	Farm income (Rs. lakh / ha)	1.06	1.17	1.13	0.96	-0.99	0.32
5.	Land holding (ha)	3.19	1.40	3.48	1.41	-1.59	0.11
6.	Farm size under i^{th} crop	2.75	2.05	3.12	1.98	-0.26	0.79
7.	Farm experience (years)	26.74	11.88	24.35	11.75	0.13	0.89
8.	Distance to market (km)	15.21	7.78	14.68	7.47	-0.04	0.96

As furnished in Table 2, the mean age of both the groups were found to be more than 48 years and the farmers in general were found to have an average experience of about 25 years. In this connection, the farmer’s perceptions on climate change can be ascertained to be valid as the responses are given in general after prolonged exposure to climate change and its field level implications which in turn can be inferred from the farm experience of the farmers. The average farm income was also found to be more the same around Rs. 1 lakh per annum in case of both the farmers. In addition, the t-test statistics reveal no significant mean difference among any socio-economic characteristic between the two groups of farmers. Thereby, the perceptions and the adaptation strategies obtained can be generalized for the study area and need not be ascertained as farmer specific or crop specific strategies.

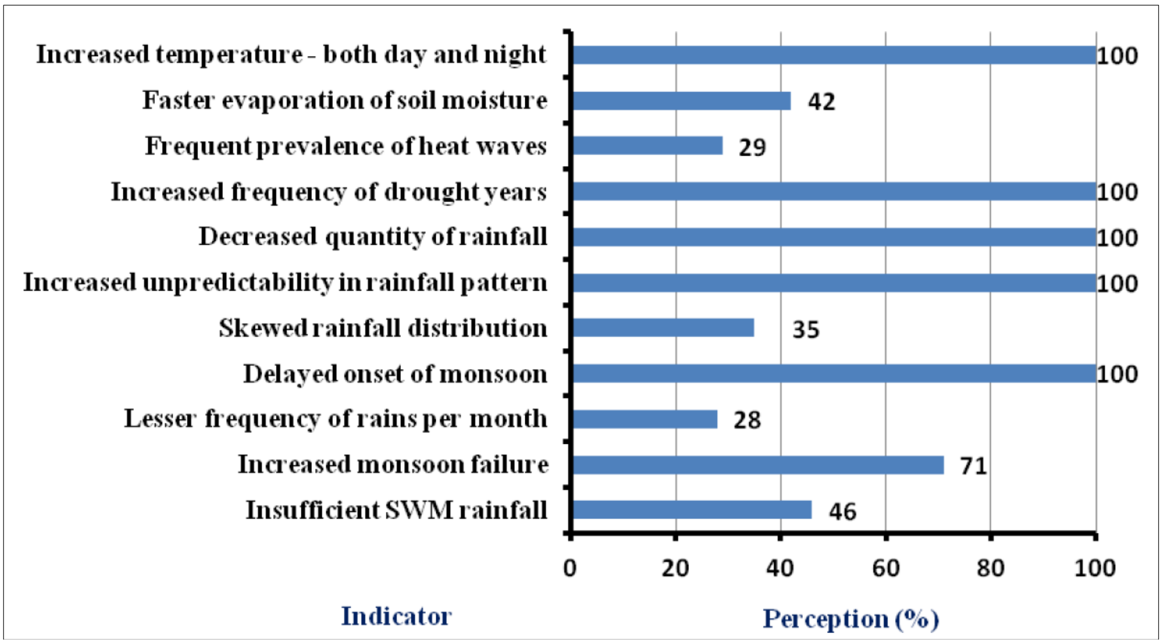
Farm level perceptions with respect to climate variability and change

The success of any adaptation strategy practiced by farmers or implemented by the institutional agencies depends on their tendency to perceive and react favourably towards changes in climate and environment. In the study area, all the respondents have perceived climate change in terms of various meteorological indicators. Among the indictors of perception, 100 per cent of farmers observed that the quantity of rainfall has been decreasing over the years.

Further, the delayed onset of monsoon was perceived by 100 per cent of farmers. Even as 100 per cent of farmers reported increasing temperature, few among them felt that summer is extending. Another 100 per cent were of the opinion was that the rainfall pattern has become more erratic and unpredictable than before whereas 100 per cent of farmers had perceived increased frequency of drought years. The perception of increased monsoon failure was reported by 71 per cent of the farmers followed by insufficient south west monsoon (46%), faster evaporation of soil moisture (42%) and prevalence of heat waves (29%). These results are in conformity with the studies of and Deressa *et al*. (2009) [7] who reported that the farmers perceived climate change in the form of severe changes in rainfall pattern and variations in average annual minimum and maximum temperatures.

Determinants of farmers’ climate change adaptation strategies

The study examined farmers' adaptations to climate change using a 30-year average climate as a baseline. Coping methods included digging wells, micro-irrigation, changing cropping patterns, adjusting calendars, adopting short-duration varieties, and practicing inter/mixed cropping. The Multinomial Logit Model considered seven coping strategy categories, with "No Adaptation" as the reference. Explanatory variables, selected from relevant literature, encompassed farm, farmer, social, and institutional characteristics, such as age, education, gender, family size, farm income, farming experience, land ownership, livestock ownership, household assets, extension agency contact, organizational membership, climate change awareness, credit access, irrigated land, agricultural inputs access, governmental support access, and distance to market.



Note: Multiple responses; (n=240)

Fig 1: Farm level perceptions with respect to climate change

Hausman test for testing IIA assumption

The MNL model, with seven adaptation choice categories, underwent a Hausman test to assess the Independence of Irrelevant Alternatives (IIA) assumption. Table 3 displays P-values for omitted variables, all at 1.00, indicating the model satisfies the assumption. Negative test statistics, common in empirical work, support the validity of the MNL model for adaptation strategies, as noted by Hausman and McFadden (1984). Positive probabilities for chi-square values further confirm the model's validity.

Table 3: Hausman-McFadden test of IIA Assumption of the MNL Model

Variable	Chi-square	d.f.	*p*> Chi-squaress	Evidence for H_o
Digging / deepening of wells	-55.568	64	1.000	Yes
Adoption of micro irrigation	-0.247	62	1.000	Yes
Changing cropping pattern	-0.635	64	1.000	Yes
Changes in crop calendar	-0.114	49	1.000	Yes
Adopting short duration varieties	-1.279	64	1.000	Yes
Practicing inter/ mixed cropping	-2.263	65	1.000	Yes
No adaptation strategy	-2.672	65	1.000	Yes

H_o= odds (outcome- J vs, Outcome-K) are independent of other alternative

Direction of influencing factors of climate change adaptation

The multinomial logit model was employed in the present study to obtain the determinants of climate change adaptation strategies among the farmers in the study area. The study analysed the adaptation of six different strategies *viz.* (i) digging / deepening of wells; (ii) adoption of micro irrigation; (iii) changing cropping pattern; (iv) changes in crop calendar; (v) adopting short duration varieties; (vi) practicing inter/ mixed cropping and compared all their adaptation with that of (vii) no adaptation strategy in face of climate change. The influences of socio-economic characteristics over the adaptation strategies of farmers were further analyzed for their significant effects and are presented in Table 4.

The coefficients presented can suggest only the direction of the effect of the influencing variables and not their concerned magnitude as such. Among the socio-economic variables taken up, the age of the respondent was found to significantly cast a positive effect in the adaptation of all the strategies except practicing inter/mixed cropping when compared with that of adaptation strategy. Similarly, education was found to have positive and significant effect in influencing the farmers' adaptation of all the climate change strategies when compared with that of the base strategy. The effect of family size was not found to influence any of the adaptation strategy except that of 'changing crop calendar'. In the same vein, the effect of farm income was not observed on 'changing cropping pattern' and otherwise it was found to be positively influencing all the adaptation strategies when compared to that of base strategy.

Farm size was yet another least influencing variable and its limiting effect was noticed only on the 'adoption of micro-irrigation' among farmers when compared with that of adaptation of no strategy. In similar terms, the influence of farming years was also found to be negative on 'practicing inter/mixed cropping' strategy. Livestock ownership and distance to market did not influence the adaptation of any climate change adaptation strategy among the farmers in the study area. On the contrary, extension agency contact; governmental support and access to credit influence a whole lot of adaptation strategies among farmers when compared to that of base strategy. The effect of crop was minimal in decision of the adaptation strategy by the farmers and the strategies were found to be less crop-centric and more farm-centric.

Table 4: Direction of influencing factors of climate change adaptation among farmers in study area

Explanatory variables /Coping Strategies	Digging / deepening of wells		Adoption of micro irrigation		Changing cropping pattern		Changes in crop calendar		Adopting short duration varieties		Practicing inter/ mixed cropping	
	Coeff. (SE)	P value	Coeff. (SE)	P value	Coeff. (SE)	P value	Coeff. (SE)	P value	Coeff. (SE)	P value	Coeff. (SE)	P value
Age (in years)	0.202* (0.104)	0.053	0.215** (0.105)	0.041	0.186* (0.107)	0.082	0.197* (0.103)	0.055	0.199* (0.110)	0.070	0.126 (0.110)	0.251
Education (in years)	0.572** (0.247)	0.021	0.711*** (0.252)	0.005	0.673*** (0.257)	0.009	0.482** (0.242)	0.046	0.512* (0.266)	0.054	0.722*** (0.261)	0.006
Family size (in nos.)	-0.271 (0.332)	0.415	-0.302 (0.339)	0.373	-0.130 (0.346)	0.708	0.088*** (0.025)	0.001	-0.124 (0.358)	0.729	-0.013 (0.353)	0.970
Farm income (Rs. /ha)	0.056* (0.029)	0.068	0.321*** (0.050)	0.001	0.011 (0.127)	0.613	0.696** (0.296)	0.050	0.023* (0.011)	0.056	0.089** (0.035)	0.012
Farm size (ha)	0.035 (0.453)	0.939	-0.208*** (0.068)	0.001	-0.306 (0.477)	0.521	-0.189 (0.443)	0.670	0.272 (0.469)	0.563	0.026 (0.485)	0.958
Farming Exp. (in years)	-0.073 (0.074)	0.329	-0.034 (0.074)	0.649	-0.055 (0.077)	0.479	-0.082 (0.073)	0.263	-0.064 (0.079)	0.422	-0.144* (0.087)	0.098
Livestock Ownership (Yes / No)	1.175 (1.180)	0.319	0.715 (1.202)	0.552	0.298 (1.224)	0.808	-0.303 (1.158)	0.794	0.749 (1.273)	0.556	0.829 (1.246)	0.506
Extension Agency Contact (Yes / No)	2.713** (1.243)	0.029	2.528** (1.264)	0.046	3.363** (1.336)	0.012	4.445*** (1.237)	0.000	3.194** (1.393)	0.022	4.662*** (1.614)	0.004
Weather information (Yes / No)	1.132 (1.345)	0.400	1.040 (1.385)	0.453	1.016 (1.406)	0.470	2.182* (1.323)	0.099	1.107 (1.501)	0.461	0.592 (1.396)	0.671
Governmental support (Yes / No)	2.629* (1.380)	0.057	2.440* (1.466)	0.096	1.597 (1.373)	0.245	2.727** (1.278)	0.033	2.508* (1.290)	0.097	3.195* (1.640)	0.051
Access to credit (Yes / No)	2.895 (1.155)	0.012	2.309** (1.147)	0.044	2.411* (1.235)	0.051	1.877* (1.027)	0.068	2.235* (1.129)	0.083	2.391* (1.332)	0.073
Crop under cultivation (cotton/ groundnut)	-1.856 (1.032)	0.072	-1.219 (1.052)	0.247	-1.262 (1.079)	0.242	-1.830* (1.003)	0.068	-1.255 (0.075)	0.266	-1.120 (1.105)	0.311
Distance to market (km)	0.026* (0.066)	0.695	0.054 (0.067)	0.424	0.050 (0.070)	0.471	-0.065 (0.066)	0.329	-0.001 (6.720)	0.992	0.008 (0.074)	0.908
Constant	-21.412 (6.135)	0.000	-24.30 (6.318)	0.000	-22.545 (6.371)	0.000	-19.851 (5.949)	0.001	-24.700 (4.321)	0.000	-22.301*** (6.537)	0.001
Base outcome	: No adaptation			LR chi-square		: 246.92		Log likelihood		: -295.74642		

Note: ***, **, and * indicate significance at 1%, 5% and 10% probability levels.

Conclusion

Among the socio-economic variables, age of the farmers was found to be most influencing all the adaptation strategies except practicing inter/ mixed cropping among the farmers in the study area. The effect was also found to be more or less the same across different adaptation strategies. For instance, for every one unit increase in age the probability of a farmer incorporating 'digging / deepening of wells' as a climate change adaptation strategy significantly increases by 1.224 times when compared with that of a base strategy of no adaptation. Along with age and education, farm income was also found to be significantly influencing all the adaptation strategies in the study area. For every one unit increase in farm income, the probability of adaptation of changes in cropping calendar increased by 2.005 times when compared to that of no adaptation strategy. Farm income was also found to be an influencing factor in deciding the adaptation of all the strategies such as adoption of micro irrigation to the tune of 1.379 times followed by practicing inter/ mixed cropping (1.093 times); digging / deepening of wells (1.058 times) and changing cropping pattern (1.011 times).

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