Determinants of adaptation practices to climate change: insights from soybean growers in Central India

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ABSTRACT

The study analyzed the determinants of adaptation practices of soybean growers toward climate change in Central India using primary data collected through household survey from 280 soybean growers. The influence of a set of explanatory variables on each of the different adaptation strategies was simultaneously modeled using multivariate probit analysis. The most widely practiced adaptation measure was change in the variety (71% farmers) followed by the change in time of farm operations and crop change or crop diversification. To cope with the insect-pest and disease attack on the crops, farmers adopted resistant varieties to minimize the cost of chemical spray. More than one-third of the sampled farmers practiced change in input application, while soil and water management practices were practiced by nearly 28% of the farmers. Analysis of results indicated that the change in varieties of crops is significantly more likely to be adopted by households with larger family size, higher involvement in extension activities, having a tractor, higher educated head of household. Households with higher family income, possessing mobile phones and other infrastructure are more likely to adopt the change in varieties, whereas farmers having higher social participation, extension contact, larger land holding, and belonging to ethnic origin other than scheduled caste or scheduled tribe do not necessarily do so. The government should frame out policies towards the promotion of technological and institutional measures suitable to various categories of farmers so that the adaptation strategies could be helpful in maintaining and/or increasing the sustainability of the production systems.

Keywords: Adaptation practices, Climate change, Determinants, Multivariate probit analysis

Climate change is one of the major environmental concerns and will have serious implications on all the stakeholders *viz*., farmers, industries, and policymakers alike in the 21st century. Climate change is likely to impact more on the rainfed agricultural economies (McCarthy *et al.*, 2018), and consequently the food security, access, and utilization of food as well as price stability (Porter et al., 2014). Therefore, climate change is expected to further complicate the millennium goal of meeting the demand for food and nutrition considering the global population and rising consumer incomes (UN, 2015). To minimize the negative impact as well as realize the positive impact of climate changes, it is pertinent to make suitable adjustments and changes in the agricultural production system. Since the local actors are worst affected by the severity of climate change, farm-level adaptation measures deserve significance for sustaining the productivity and profitability of agricultural production systems (UNFCCC, 2009; Singh *et al.,* 2015). According to UNFCCC, "Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. In simple terms, countries and communities need to develop adaptation solution and implement action to respond to the impacts of climate change that are already happening, as well as prepare for future impacts" (UNFCCC, 2020).

The adaptation involves correctly perceiving the consequences of climate change and applying measures to minimize the impact. Perception is a cognitive process involving exposure to sensory information and its interpretation for choosing available appropriate solutions. But due lack of information or resources or capacity to use the alternatives, some people do not respond to the effect of climate changes despite perceiving correctly. The earlier studies have indicated that farmers rely on farm level strategies like change in crop and/or variety, changing the agronomic practices, adoption of resource conservation technologies as well as soil and water management practices, and some risk management strategies for minimizing the losses due to climate change (Sharma, 2013; Pathak *et al.*, 2014; Tripathi and Mishra, 2017).

The major challenge is adapting agriculture to climate change, especially in a developing country like India, where a vast majority of farmers are marginal and small holders having small and fragmented land holdings, less educated, and have a significantly lower adaptive capacity. Autonomous adoption of farm-level adaptation strategies is the order of the day but maybe insufficient to offset the losses caused by climate change (McCarthy, 2001). In this situation, adaptation strategies with incentives and policy-driven support can help the farming community to sustain the productivity and profitability of their farming enterprise. The major challenge in study of adaptation by small holders identifying the actual adaptation (Lobell, 2014), as the adaptation strategies varies with the variation in climatic, economic, social and institutional factors (Below *et al.*, 2012).

The climate change impact on Indian agriculture is well researched and documented by various studies including in major soybean producing region, i.e. Central India (accounting for more than 90 per cent share, also major producer of wheat, pulses and other oilseed crops) having policy implications considering the country's economic situation. Studies available on the adaptation to climate change in India as well as elsewhere, mainly focus on adaptation strategies at the regional or national level, crucial for macro level planning (Singh *et al.,* 2015; Singh *et al.,* 2019). Nevertheless, the studies focusing on the micro level adaptation strategies, at farm or household level, are inevitable to identify and design effective measures for adaptation at the local level. The study aims to understand strategies followed by growers of soybean based cropping system in Central India along with the factors determining the decision of adopting the adaptation strategy. In this study, we assessed the actual adaptation measures adopted by soybean growing farmers and the determining factors. In order to minimize the impact of climate change on the soybean-based cropping system, it is high time to devise appropriate local level adaptation strategies and prioritize them for the benefit of the farming community.

MATERIALS AND METHODS

Data and collection method: Three states in central India *viz.,* Madhya Pradesh, Maharashtra, and Rajasthan together account for more than 90 percent of area and production of soybean in India. Looking into the importance of the area, the study was conducted in Malwa and adjoining regions of Central India with farmers practicing mainly soybean based cropping system. The study was mainly based on the primary data collected through a household survey conducted during the period 2016-17. The data were collected with the help of a pre-structured interview schedule developed specifically for the purpose which was divided into two parts. The first part of the survey schedule focused on demographics, livelihood activities, assets, and income, etc. The second part focused on seeking information on farmers' perceptions of climate change; the resultant impacts of climate change including the extreme climate events on the crop; and the households' adaptation or coping strategies in response to these events. The focused group discussions were conducted in selected villages in order to assess the gradual changes witnessed by the farmers in local climate involving a time line of climate-related extreme events.

Survey instrument was also pre-tested in two villages. Based on the pre-testing, the schedule was revised before conducting a household survey with a provision of seeking the information on farmers' perception of changes in the local climate as well as open ended questions related to the agronomic practices/adaptation strategies being followed by them consequent to their perception of change in climate. The interview schedule was numbered, coded, and scored using standard procedures. The present study was conducted in three major soybean growing districts covering Malwa (Dewas and Indore districts) and Nimar Plateau (Dhar district) of Madhya Pradesh state in Central India, popular for soybean revolution in the country. The sample for the study consisted of 280 soybean growers drawn randomly from selected six villages (50 farmers from each of four villages from Indore and Dewas districts under Malwa Plateau and 40 from each of two villages of Dhar district in Nimar Plateau). Open-ended questions were also included in the interview schedule relating to long-term changes in rainfall and temperature, farmers adaptations in response to climate changes they experienced.

Empirical model: Since the adaptation measures practiced by sample farmers are not mutually exclusive, the present study used a multivariate probit (MVP) model to analyze the determinants of adaptation measures. The influence of a set of explanatory variables on each of the different adaptation strategies was simultaneously modeled using multivariate probit analysis. MVP allows the unobserved and unmeasured factors (error term) to be freely correlated. Substitutability (negative correlation) and complementarities (positive correlation) among different adaptation measures may be the source of the correlation between error terms, which are taken into account in the MVP model. The MVP econometric model used in this study is characterized by a set of n binary dependent variables *yi*, such that;

$$y_i = 1 \; if \; x'\beta_i + \varepsilon_i > 0,$$
$$= 0 \; if \; x'\beta_i + \varepsilon_i \leq 0, i = 1,2,\dots,n. \qquad \dots(1)$$

Where x is a vector of explanatory variables, βi are the vector of parameters to be estimated, and the random error terms εi are distributed as a multivariate normal distribution with zero means, unitary variance, and an n x n contemporaneous correlation matrix R=[ ], with density ?(ε1, ε2, ….., εn; R). The likelihood contribution for an observation is the *n*-variate standard normal probability

$$\Pr(y_1,\dots,y_n \mid x) = \int_{-\infty}^{(2y_1-1)x'\beta_1}\int_{-\infty}^{(2y_2-1)x'\beta_2}\dots\times\int_{-\infty}^{(2y_n-1)x'\beta_n}\phi(\varepsilon_1,\varepsilon_2,\dots,\varepsilon_n;\, Z'RZ)\,d\varepsilon_n\dots\varepsilon_2\varepsilon_1 \quad \text{..... (2)}$$

Where, Z= diag [2y1 -1, …, 2yn -1]. The maximum-likelihood estimation maximizes the sample likelihood function, which is the product of probabilities (eq. 2) across sample observations. The present study used the estimation process developed by Cappellari and Jenkins (2003) to estimate the MVP model in STATA using the simulated maximum likelihood using Geweke-Hajivassiliou-Keane (GHK) simulator approach. The simulated maximum likelihood is consistent as the number of observations and number of draws tends to infinity. In this study, the number of draws (R) was set to 100 (default R = 5) in order to ensure consistent estimates.

The multicollinearity in explanatory variables and heteroscedasticity in the model are major problems in econometric analysis of survey data, which can lead to imprecise estimates. The multicollinearity was diagnosed by estimating individual ordinary least squares (OLS) regression for each individual choice variable against the same set of explanatory variables and running the variation inflation factor (VIF) test, and results found VIF values less than 5.0 for all explanatory variables, below threshold level, with an average of 2.05. The heteroscedasticity in the model was addressed through model estimation using robust standard errors that compute a robust variance estimator based on a variable list of equation level scores and covariance matrix. The use of robust standard errors is an effective way of dealing with heteroscedasticity (Wooldridge 2006) and does not change the significance of the model and the coefficients but gives relatively accurate P values.

Model variables: Based on the literature review and location-specific characteristics, thirteen independent variables were selected for analysis in the study and presented in Table 1. Both positive, as well as the negative influence of the age of household head on adaptation choices, was reported in the literature (Seo and Mendelsohn, 2008a; Hassan and Nhemachena, 2008; Deressa *et al.,* 2009). It is hypothesized in this study that older farmers, in the productive age group, have more farming experience and are better able to perceive climate change and assess the characteristics of technology, positively influence climate change adaptation. The access to improved production technology and information on crop management aspects under changing climatic situations which helps farmers to utilize the suitable adaptation strategies is facilitated by the education of the household head (Maddison, 2007; Deressa *et al.,* 2009), mobile phone connectivity, and households with higher extension participation index. A positive relationship between years of education of household head, having mobile connectivity and higher extension participation, and various farm-level adaptation mechanism was hypothesized in this study.

The size of household influences farmers' adoption behavior and the required amount of labor for adopting labor-intensive adaptation measures could be met through the availability of family labor (Deressa, 2010) and thus, a positive relation is anticipated between the household size and adaptation measures which are labor-intensive in nature (Bryan *et al.,* 2009; Gbetibouo, 2009; Di Falco *et al.,* 2011; Bahinipati, 2015). It is evident that the adoption of various adaptation strategies involves cost and thus, requires financial resources and availability of farm machines and equipment. Hence, the rich households and farmers having farm machines and equipment are expected to undertake a greater number of different adaptation measures (Hassan and Nhemachena, 2008; Panda *et al.,* 2013; Bahinipati, 2015). The size of landholding is reported to influence the adaptation positively (Maddison, 2007; Seo and Mendelsohn, 2008b; Hassan and Nhemachena, 2008; Gbetibouo, 2009; Below *et al.,* 2012). It was hypothesized, in this study, that larger farms are more likely to adopt all the adaptation practices except traditional strategies. Since, majority of the sample farmers, more than 90 per cent, responded positively for the variables such as the change in pattern and spread of rainfall, increasing incidences of weather abnormalities, and temperature changes, hence not included as explanatory variables.

The institutional representation factors, formal or informal, included in the study are social participation, extension contact, and extension participation. Agricultural extension is anticipated to be a reliable and better source of agricultural technology information for farmers. Some of the studies stated that farmers getting climate change information through contacting extension agents or participation in extension activities govern the decision on adaptation choices (Patt *et al.,* 2005; Deressa *et al.,* 2009; De Falco *et al.,* 2011 and 2012; Arimi, 2013). In the present study, it was hypothesized that farmers having higher social participation, contact with extension agencies, and/or participation in extension activities, are positively related to the adoption of farm-level adaptation measures.

The descriptive statistics for the independent variables used in the study are presented in Table 1. The average age of the head of households was nearly 45 years, and the mean years of the schooling of farmers were about 8 years indicating that farmers in the study area were middle-aged and fairly educated. The mean family size was about 4 having on an average 8.53 hectares of cultivable land. About 85 per cent of the farmers were connected through mobile phones and majority of them belonged to other backward castes. The mean family income of the sample households from all sources reported was the ₹2.06 lakhs/annum/family. Nearly three-fourths of the respondents were actively involved in social activities. About 42 per cent possessed tractor, nearly half of the respondents had farm machines and implements, and about half possessed irrigation infrastructure. More than 80 per cent of the sample farmers participated in one or the other extension activities such as farmers' fairs, field days, institute visits, training, etc. About 57 per cent of the respondents had regular contact with the extension agents.

RESULTS AND DISCUSSION

Farm-level adaptation strategies followed by farmers in the study area: The analyses presented in this study identified the important determinants of adoption of various adaptation measures to provide policy information on which factors to target and how so as to encourage farmers to increase their use of different adaptation measures. Farmers in the study area had adopted one or a combination of adaptation measures to cope with the effect of climate change in the crop sector. The sample farmers were specifically probed to state the farm-level adaptation measures which the farmers have been undertaking to mitigate the impact from previous climate extreme events. The farmers of the study area reported various adaption measures practiced and the widely practiced farm-level adaptation measures were included for empirical analysis in the present study as presented in Table 2. The most widely practiced adaptation measure was the change in the variety (by nearly 71 % of the sample farmers) followed by the change in time of farm operations and crop change or crop diversification (about half of the respondent farmers). As has been observed in the study area, majority of the farmers in Central India changed their cropping pattern from soybean-wheat cropping system to soybean in the rainy season followed by potato/onion/garlic followed by wheat in the late *rabi* season in irrigated conditions. In the case of rainfed conditions, farmers have changed to soybean-gram. Therefore, short-duration crops and varieties of crops are more prevalent in the area. To cope with the insect-pest and disease attack on the crops, farmers prefer to go for resistant varieties to minimize the cost of chemical spray. In Central India, more than one-third of the sample farmers practiced change in input application, while soil and water management practices were adopted by nearly 28% of the farmers. Aggarwal (2008) reported that most common adaptation measures like change in varieties and altering sowing time could help in reducing the impact of climate change to some extent.

Farmer group discussions revealed that majority of farmers perceive the increase in incidence of climatic disturbances such as increase in maximum temperature, disturbances in quantum and duration of rainfall - increase in frequency of high rainfall in short span of time, long dry spells, etc. leading to increased incidences of insect and diseases and in turn decline/ high variability in yield of soybean and other rainfed crops. The discussions further revealed that the area under short duration crops like soybean and pulses, has increased and along with increase in demand of short duration varieties of crops to minimize the effect of harvest period weather disturbances.

Determinants of adaptation to climate change results from the MVP model: The factors determining the adaptation strategies to climate change were analyzed using a multivariate probit (MVP) model and the results are presented in Table 3. The results indicated a number of location-specific insights into the determinants of adaptation choices for the crop sector. The results of the MVP model indicated that the direction of influence for most of the explanatory variables was as expected with some exceptions. The Wald χ^2 (likelihood ratio statistics) was highly significant (P=0.0000), showing that the variables included adequately explained the model. Further, the estimation of all equations simultaneously by the MVP model instead of individual equation is validated as the likelihood ratio test for the null hypothesis of the absence of correlation between the individual equations is strongly rejected (P=0.0005). The complementarities (positive correlation) and substitutability (negative correlation) among different adaptation measures was indicated by the significant correlation coefficients (t-test statistics) of the error terms for any pair of equations. Also, substantial differences are there in estimated coefficients across equations which further support the aptness of multivariate analysis of adaption options.

Results of the multivariate probit analysis indicated that the change in varieties of crops was significantly more likely to be adopted by farmers with the higher educated head of household and larger family size, having a tractor and higher involvement in extension activities. Surprisingly, the direction of influence of extension contact and the age of household head were significantly negative, contrary to our hypothesis, on the farmers' option to choose for change in varieties as an adaptation strategy. Households with higher family income, having mobile phones, and possessing other infrastructure are more likely to adopt the change in varieties, whereas farmers having higher social participation, extension contact, larger land holding, and belonging to ethnic origin other than scheduled caste or scheduled tribe do not necessarily do so.

Households with larger land holding, having mobile phone, belong to other backward caste or general caste, possessed tractor and farm machines & implements, and with higher extension participation are significantly more likely to adopt change in crops or crop diversification option of adaptation to climate change. Whereas, households with higher social participation and possessed other infrastructures are significantly less likely to go for crop diversification of change in crop selection. The direction of influence of age was positive, but contrary to hypotheses the household family income, family size, and extension contact are negatively influencing the option of crop diversification.

The change in the use of inputs as an adaption option was significantly more likely to be adopted by the farmers with larger land holding, higher family income, higher educated head, and in possession of farm machines and implements. Contrary to the hypothesis, the relationship between the age of the head of household, mobile phone connectivity, and change in inputs use was found to be negative and significant. The direction of influence of number of family members and social participation was as expected, whereas the influence of ethnic origin, households in possession of tractor and other infrastructure, extension participation, and contact on change in input use were not as per our hypothesis. Soil and water conservation measure as an adaptation measure to mitigate the effect of climate change in the crops sector significantly increases with the age and education of the head, land holding, and family income. Mobile phone connectivity does not have any influence on the adoption of this adaptation choice, whereas the influence of extension contact and ethnic origin with SC/ST as reference class was not as hypothesized. Social participation, possession of tractor, farm machines and implements and other infrastructure, and higher extension participation increases the propensity to adopt the soil and water conservation measure.

Change in timing of farm operations is significantly and positively influenced by larger land holdings, education of head, family size, extension participation, ethnic origin other than SC and ST category, and possession of tractor. Contrary to our hypothesis, this adaptation option was significantly less likely to be adopted by households with higher income, higher social participation, and in possession of other infrastructure. The direction of influence of extension contact, possession of farm machines and implements was as expected, while the influence of mobile connectivity on change in timing of farm operationswas not as hypothesized. The age of the head of household does not have any influence on the adoption of the change in timing of farm operations.

Table 1 Explanatory variables selected for the model

Variables	Unit	Mean (%)	Standard deviation	Expected sign
Age of head of household	Years	45.21	14.16	±
Education of household head	Years of schooling	7.65	4.66	+
No. of family members	Number	3.88	1.27	±
Land holding	Hectares	5.83	6.90	±
Mobile phone	Dummy; 1=Yes, 0= No	0.85	0.36	+
Family Income	₹ 2.06 lakhs/HH	2.92	2.64	±
Ethnic origin	1= Scheduled caste/tribe	18.57	0.54	±
	2= Other backward caste	70.71		
	3= General	10.71		
Social participation	0= No participation	17.14	1.16	+
	1= member of any coop. society/ institution	5.00		
	2= office bearer of any coop. society/ institution	5.00		
	3= Active involvement in social activities	72.86		
Have tractor	Dummy; 1=Yes, 0= No	0.42	0.49	+
Have farm machines and implements	Dummy; 1=Yes, 0= No	0.49	0.50	+
Have irrigation infrastructure	Dummy; 1=Yes, 0= No	0.27	0.44	+
Extension participation index	Index ranging 0 to 1	0.84	0.18	+
Extension contact index	Index ranging 0 to 1	0.57	0.24	+

Table 2. Adaptation strategies practiced by soybean growers in Central India

Adaptation measures	Details of adaptation practice	Percentage of household adopting the practice (n=280)
Change in variety	Use of short duration/ drought/ pest/ disease resistant variety	70.71
Change in time of farm operations	Change in sowing/ harvesting/ weeding/ pesticide application time	48.57
Crop diversification/ change	Shifted to short duration crop/ crop rotation/ intercropping	47.86
Change in input application	Increased use of organic manure/ fertilizers/ plant protection chemicals/ use of herbicides	35.71
Soil and water management	Creation of irrigation facility/ use of BBF/ FIRBS for sowing/ rain water harvesting/ drainage of excess water	28.57
No adaptation		10.71

Table 3 Parameter estimates of the multivariate probit model

Explanatory variable	Change in variety		Change in crop		Change in inputs		Soil & water conservation		Change in sowing time	
	Coeff.	Prob	Coeff.	Prob	Coeff.	Prob	Coeff.	Prob	Coeff.	Prob
Age	-0.022	0.002***	0.010	0.182	-0.030	0.007***	0.018	0.056*	-0.004	0.575
Land	-0.022	0.145	0.067	0.006***	0.134	0.000***	0.066	0.003***	0.056	0.002***
Income	0.223	0.146	-0.056	0.765	0.852	0.000***	1.008	0.002***	-0.434	0.008***
Education	0.069	0.004***	0.138	0.000***	0.056	0.040**	0.136	0.000***	0.056	0.017**
Family members	0.192	0.005***	-0.063	0.380	0.027	0.751	0.121	0.152	0.157	0.027**
Mobile	0.130	0.597	0.544	0.023**	-1.086	0.001***	0.007	0.982	-0.138	0.639
Tractor	0.575	0.058*	1.025	0.002***	-0.274	0.473	0.132	0.719	1.779	0.000***
Machine & implements	-0.376	0.209	0.998	0.003***	1.193	0.001***	0.350	0.353	0.383	0.312
Other infrastructure	0.175	0.493	-0.761	0.006***	-0.231	0.381	0.210	0.416	-1.137	0.000***
Caste	-0.124	0.472	0.392	0.062*	-0.208	0.318	-0.569	0.127	0.306	0.080*
Social participation	-0.172	0.122	-0.783	0.000***	0.116	0.364	0.214	0.129	-0.596	0.000***
EPI	2.208	0.001***	2.422	0.001***	-0.741	0.263	0.206	0.798	2.609	0.001***
ECI	-0.827	0.057*	-0.464	0.294	-0.368	0.412	-0.596	0.199	0.509	0.202
Constant	-3.092	0.088*	-2.986	0.148	-9.100	0.000***	-15.356	0.000***	1.703	0.350
Correlation			Coeff.		Prob.					
$\hat{\rho}_{21}$			-0.380		0.001***					
$\hat{\rho}_{31}$			0.067		0.615					
$\hat{\rho}_{41}$			-0.066		0.680					
$\hat{\rho}_{51}$			-0.080		0.505					
$\hat{\rho}_{32}$			-0.206		0.094*					
$\hat{\rho}_{42}$			0.091		0.497					
$\hat{\rho}_{52}$			0.399		0.000***					
$\hat{\rho}_{43}$			0.342		0.028**					
$\hat{\rho}_{53}$			-0.070		0.684					
$\hat{\rho}_{54}$			0.460		0.001***					
Draws			100							
Observations			280							
Wald $\chi 2$ (65)			1065.63							
P value			0.000***							
Log Likelihood			-536.82							

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0:
χ^2 (10) = 30.2053 Prob > χ^2 = 0.0008***; *; **; *** Significant at 10%, 5%, and 1%, respectively

The educated younger farmers are more likely to adopt these adaptation measures as compared to their older counterparts, possibly for being innovative, having the higher risk-taking capacity and keen to try new methods and technologies to improve farming (Sharma *et al*., 2018). The size of landholding has significantly increased the propensity to adopt the adaptation strategies, as farmers with larger landholdings can afford to make the necessary investments (Maddison, 2007; Gbetibouo, 2009; Below *et al.,* 2012; Sharma *et al.,* 2018). Households with higher income also have money to invest in improved technologies and thus, are more likely to adapt to change in the input application and soil and water conservation measures. It was also possible to reduce the further reduction in grain yield by adopting new management practices or through replacement of new varieties which could sustain the growth under increased temperature (Mohanty *et al.,* 2015).

The size of the household, on the other hand, influences the choice of the crop as well as the application of required inputs and decision of planting the crop at right time. The larger the size of the household, there are better the chances of adopting various measures (Bahinipati and Venkatachalan, 2015). The possession of mobile phone connection helps the farmers to access the relevant and updated information on various farming enterprises and helps the farmers in the decision-making process (Mittal and Hariharan, 2018) about which variety to be grown under the prevailing circumstances along with specific practices to be followed for aversion of risk. Similarly, it was seen that the possession of tractors, machines, and improved farming implements helped the farmers to adopt suitable crop, soil and moisture conservation practices, and time of planting to cope up with the climatic adversities. It was also observed that the factors like farmers' participation in social activities, possession of tractor/agricultural machines and implements as well as other infrastructure, and higher extension participation increased the propensity to adopt the soil and water conservation measure.

The estimated correlation coefficients (Þ$_{kj}$) among the various adaptation strategies were found to be significant for five out of ten combinations. Change in variety was negatively correlated with crop diversification/ change in crops, soil and water conservation, and change in timing of farm operations, while it was positively correlated with change in inputs. This implies that the change in a variety of the crop minimizes the vulnerability to climate change for the crop sector and thus, reduces the dependence on other adaptation options but complements with the change in input application. Crop diversification or change in the crop was complemented with soil and water conservation and change in sowing time of the crops, while negatively correlated with change in input application. Change in input application was positively correlated with soil and water conservation, whereas negatively with the change in sowing time. A complementary relation was found between soil and water conservation and change in the sowing time of the crops.

Results from the study indicated that the change in varieties of crops was significantly more likely to be adopted by households with more number of family members, having higher involvement in extension activities, having a tractor, higher educated head of household. Households with higher family income, having mobile phones, and possessing other infrastructure are more likely to adopt the change in varieties, whereas farmers having higher social participation, extension contact, larger land holding, and belonging to ethnic origin other than scheduled caste or scheduled tribe do not necessarily do so.

As a follow up, the work on the development and dissemination of climate-smart technologies and practices including varieties resistant to various biotic and abiotic factors may be strengthened. Efforts are also needed for studying the vulnerability as well as validation and assessment of technologies and practices in the prevailing climatic situations. The officers belonging to extension services should be sensitized to create awareness among the farming community about the climate changes and its overall impact on agricultural production and processes. Organization of skill-oriented programs may be planned for the field level extension personnel for promoting the access, utilization, and dissemination of weather-specific advisories as well as adaptation strategies in order to achieve the yields in the changed climatic situations. To do this, the extension services need to be upgraded through the provision of additional manpower and climate-smart policies like crop insurance schemes considering the increased risk of adverse climate particularly successive drought situations as well as crop damage due to biotic factors.

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REFERENCES

Aggarwal P K 2008. Global climate change and Indian agriculture: impacts, adaptation and mitigation. *Indian Journal of Agricultural Sciences*, **78**(10): 911.

Arimi K S 2013. Determinants of climate change adaptation strategies used by fish farmers in Epe local government Area of Lagos state, Nigeria. *Journal of the Science of Food and Agriculture*, **94**: 1470-1476.

Bahinipati C S 2015. Determinants of farm-level adaptation diversity to cyclone and flood: Insights from a farm household-level survey in Eastern India. *Water Policy*, **17**(4): 742-761. doi: 10.2166/wp.2014.121.

Bahinipati C S and Venkatachalam L 2015. What drives farmers to adopt farm-level adaptation practices to climate extremes: empirical evidence from Odisha, India, *International Journal of Disaster Risk Reduction*, **14**(4): 347-356.

Bal S K and Minhas P S 2017. Atmospheric stressors: challenges and coping strategies. In: Minhas *et al.* (Ed) *Abiotic stress management for resilient agriculture.* Springer Nature, Singapore, pp. 9-50.

Below T B, Mutabazi K D, Kirschke D, Franke C, Sieber S, Siebert R and Tscherning K 2012. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental Change*, **22**: 223-235.

Birthal P S, Parthasarathy Rao P, Nigam S N, Bantilan M C S and Bhagavatula S 2010. Groundnut and soybean economies of Asia facts, trends and outlook. International Crops Research Institute for the Semi-Arid Tropics, Patancheru, Andhra Pradesh, India.

Bisaliah S 1986. *Soybean Development in India.* CGPRT Paper No.5. UN/ESCAP CGPRT Centre: Bogor, Indonesia.

Bryan E, Deressa T T, Gbetibouo G A and Ringler C 2009. Adaptation to climate change in Ethiopia and South Africa: Options and constraints. *Environmental Science & Policy,* **12**(4): 413-426.

Cappellari L and Jenkins S P 2003. Multivariate probit regression using simulated maximum likelihood. *The Stata Journal*, **3**(3): 278-294.

Deressa T T 2010. Assessment of the vulnerability of Ethiopian agriculture to climate change and farmers' adaptation strategies, Ph.D. dissertation, Department of Agricultural Economics, Extension and Rural Development, University of Pretoria, South Africa.

Deressa T T, Hassan R M and Ringler C 2011. Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia. *Journal of Agriculture Science*, **149**: 23-31.

Deressa T T, Hassan R M, Ringler C, Alemu T and Yesuf M 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile basin of Ethiopia. *Global Environmental Change*, **19**: 248-255.

Di Falco S, Veronesi M and Yesuf M 2011. Does adaptation to climate change provide food security? A micro-perspective from Ethiopia. *American Journal of Agricultural Economics*, **93**(3): 829-846.

Di Falco S, Yesuf M, Kohlin G and Ringler C. 2012. Estimating the impact of climate change on agriculture in low-income countries: household level evidence from the Nile basin, Ethiopia. *Environmental and Resource Economics*, **52**(4): 457-478.

Dupare B U, Sharma P, Billore S D and Verma S K 2020. Impact of climate change on soybean cultivation in Malwa and Nimar region of Madhya Pradesh: farmers' perspective. *Soybean Research*, **18**(1): 87-97.

Gbetibouo G A 2009. Understanding farmers' perceptions and adaptations to climate change and variability. The case of the Limpopo basin, South Africa. IFPRI discussion paper 00849. International food policy research institute, Washington DC.

Golob T F and Regan A C 2002. Trucking industry adoption of information technology: a structural multivariate discrete choice model. *Transportation Research Part C: Emerging Technologies*, **10**: 205-228.

Hassan R and Nhemachena C 2008. Determinants of African farmers' strategies for adapting to climate change: multinomial choice analysis. *African Journal of Agricultural Resource Economics*, **2**(1): 83-104.

Lin C T J, Jensen K L and Yen S T 2005. Awareness of Food-Borne Pathogens among US consumers. *Food Quality and Preference*, **16**(5): 401-412.

Maddison D 2007. The perception of and adaptation to climate change in Africa. Policy Research Working Paper 4308. The World Bank, Washington DC.

Mall R K, Bhatt D, Sonkar G and Banerjee T 2014. Simulation modelling and climate change: issues and challenges. *Environmental Science and Pollution Research,* **21**(19): 11605-11608.

Mall R K, Singh R, Gupta A, Srinivasan G and Rathore L S 2006. Impact of climate change on Indian agriculture: a review. *Climatic Change,* **78**(2-4): 445-478.

McCarthy N, Lipper L and Zilberman D. 2018. Economics of Climate Smart Agriculture: An Overview. In: Lipper N, McCarthy N, Zilberman D, Asfaw D, Branca S (Ed) *Climate Smart Agriculture.* Springer Verlag.

McCarthy James J 2001. Climate Change 2001. Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Mittal S and Hariharan V K 2018. Mobile-based climate services impact on farmers risk management ability in India. *Climate Risk Management*, **22**: 42-51.

Mohanty M, Sinha N K, Lenka S, Hati K M, Somasundaram J, Saha R, Singh R K, Chaudhary R S and Subba Rao A 2015. Climate change impacts on rainfed soybean yield of Central India: management strategies through simulation modelling. In: Singh *et al.* (Ed.) *Climate Change Modelling, Planning and Policy for Agriculture.* DOI 10.1007/978-81-322-2157-9-5, Springer India, pp. 39-44.

Mohanty M, Sinha N K, McDermid S, Chaudhary R S, Sammireddy K, Hati K M, Somasundaram J, Lenka S, Patidar R K, Prabhakar M and Cherukumalli S R 2017. Climate change impacts *vis-à-vis* productivity of soybean in Vertisol of Madhya Pradesh. *Journal of Agrometeorology*, **19**(1): 10-16.

Nhemachena C and Hassan R 2007. Micro-level analysis of farmers' adaptation to climate change in southern Africa. IFPRI discussion paper 00714. International Food Policy Research Institute, Washington DC.

NRAA 2012. Prioritization of rainfed areas in India. Study Report 4. National Rainfed Area Authority, New Delhi.

Panda A, Sharma U, Ninan K N and Patt A 2013. Adaptive capacity contributing to improved agricultural productivity at the household level: empirical findings highlighting the importance of crop insurance. *Global Environmental Change,* **23**(4): 782-790.

Pathak H, Pramanik P, Khanna M and Kumar A 2014. Climate change and water availability in Indian agriculture: impacts and adaptation. *Indian Journal of Agricultural Sciences*, **84**: 671-679.

Patt A, Suarez P and Gwata C 2005. Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe. *Proceedings of the National Academy of Sciences*, **102**(35): 12623-12628.

Piya L, Maharajan K L and Joshi N P 2013 Determinants of adaptation practices to climate change by Chepang households in the rural mid-hills of Nepal. *Regional Environmental Change*, **13**: 437-447.

Porter J R, Xie L, Challinor A J, Cochrane K, Howden S M, Iqbal M M, Lobell D B and Travasso M I 2014. Food security and food production systems. In: Field et al. (Ed) Climate Change 2014: Impacts, adaptation, and vulnerability Part A: Global and sectoral aspects, pp. 485-533. Contribution of Working Group II to the Fifth Assessment 31 Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, Cambridge University Press, New York, U.S.

Seo S N and Mendelsohn R 2006. Climate change adaptation in Africa: a microeconomic analysis of livestock choice. CEEPA Discussion Paper No. 19. Center for Environmental Economics and Policy in Africa, University of Pretoria.

Seo S N and Mendelsohn R 2008a. An analysis of crop choice: adapting to climate change in South American farms. *Ecological Economics*, **67**: 109-116.

Seo S N and Mendelsohn R 2008b. Animal husbandry in Africa: climate change impacts and adaptations. *African Journal of Agricultural Resource Economics*, **2**(1): 65-82.

Sharma B 2013. Impact of climate change on water resources and potential adaptations for Indian agriculture. *Annals of Agricultural Research*, **34**(1):1-14.

Sharma P 2016. Dynamics of growth of soybean in India: role of income and risk. *Agricultural Situation in India*, **73**(6): 37-46.

Sharma P, Dupare B U and Patel R M 2016. Soybean improvement through research in India and socio-economic changes. *Legume Research*, **39**(6): 935-945.

Sharma P, Patel R M and Dupare B U 2015. Profitability of soybean *vis-a-vis* major *kharif* crops in Madhya Pradesh. *Soybean Research*, **13**(2): 65-77.

Sharma P, Dupare B U and Patel R M 2018. Technology adoption, its impact and determinants: the case of soybean in Madhya Pradesh. *Agricultural Economics Research Review*, **31**(2): 281-289.

Singh N P, Anand B, Singh S and Khan MA 2019. Mainstreaming climate change adaptation in Indian rural development agenda: a micro-level convergence. *Climate Risk Management*, **24**: 30-41.

Singh N P, Byjesh K and Bantilan C 2015. Climate change vulnerability and adaptation strategies with a rural-farm level perspective: A retrospection. In: Singh NP, Bantilan C, Byjesh K, Nedumaran S (Eds.), *Climate Change Challenges and Adaptations at Farm-level: Case Studies from Asia and Africa.* CABI Private Limited, pp. 1-10.

Tripathi A and Mishra A K 2017. Knowledge and passive adaptation to climate change: An example from Indian farmers. *Climate Risk Management*, **16**: 195-207.

UN 2015. UN Sustainable Development Goals. http://www.un.org/sustainabledevelopment/sustainable-development-goals.

UNFCCC 2009. Climate change: impacts, vulnerabilities and adaptation in developing countries. Retrieved Oct Feb 2019, www.unfccc.int/resource/docs/publications/impacts.pdf.

UNFCCC 2020. What do adaption to climate change and climate resilience mean? https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean, accessed on October, 2020.

Venkateswarlu B and Prasad J V N S 2012. Carrying capacity of Indian agriculture: issues related to rainfed agriculture. *Current Science*, **102**(6): 882-888.

Wooldridge J M 2006. *Introductory Econometrics, A Modern Approach.* Thomson South Western.