Indian Journal of Traditional Knowledge
Vol 19(1), January 2020, pp 192-196

Dynamics of socio-economic factors affecting climate vulnerability and technology adoption: Evidence from Jodhpur district of Rajasthan

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Received 07 May 2019; revised 21 August 2019

Climate change and extreme weather fluctuations are the most threatening challenges to the farming communities especially in semi-arid tropics. The paper investigates socio-economic factors affecting vulnerability and adoption of innovations using micro-level survey data of 100 systematically selected farmers in the Jodhpur district of Rajasthan, India. The results reveal that higher income, irrigation and provision of seeds reduce climate vulnerability to a great extent. Several farm level strategies have been adopted by the farmers against climate induced stress, including change in cropping pattern, reduction in irrigation usage, use of drips and sprinklers and water conservation. In case of pearl millet cropping system, we found that adoption of wide row spacing is significantly influenced by the level of the farmer's education, land size category, climate awareness and trainings programs. The study suggests that diversified crop sequence involving pearl millet-wheat-cluster bean-barley-onion, farmers' adoption of suitable adaptation strategies and climate resilient technologies will improve with better awareness, education and farm governance with regard to climate change. Moreover, technologies especially indigenous ones suitable to the local contextual needs must be developed or fine-tuned and disseminated for reducing climate-induced vulnerability.

Keywords: Adaptation, Agriculture, Climate change, Technology, Vulnerability
IPC Code: Int. Cl.[20]: A01D 91/00, A61K 36/00

Globally climate risks pose formidable challenges to the agriculture sector. It is now widely recognized that higher intensity and frequency of extreme weather events such as cyclones, droughts, floods and desertification adversely impact agriculture production and sustainability of farm livelihoods. Semi-arid ecosystems which are characterized by erratic rainfall pattern, higher temperature and recurrence of droughts are particularly more vulnerable to climate induced changes[1]. Efficient and effective adaptation is thus essential in offsetting the vulnerability of farm households to the harmful effects of climate change[2,3]. Moreover, adoption of appropriate agriculture technologies that reduce cost of production and enhance agriculture productivity can significantly reduce poverty levels and environmental degradation. However, the extent of climate vulnerability and adoption of technologies differs across regions. The existing literature emphasizes the importance of non-climatic (socio-economic) factors amongst the major drivers influencing the magnitude of vulnerability and in modifying the impact of climatic shocks[4-5]. In this context, our study examines the socio-economic determinants of farm vulnerability to climate variation, strategies adopted to mitigate climatic risks and drivers of wide row spacing technique in case of pearl millet (*Pennisetum glaucum*) cropping system by the farmers in Jodhpur district, Rajasthan, India.

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Materials and methods

Study area

Jodhpur District, situated between the latitude 26°16'57.11" N and longitude 73°1'25.23"E, lies in the agro-climatic zone of the Western Dry Region. Located in the state of Rajasthan, the district covers a total geographical area of 22850 sq. km, with 66% of the population living in rural areas, primarily dependent on agriculture and allied activities for their livelihoods. Millets, jowar, pulses, groundnut and guar are the major crops of *kharif* season while wheat, barley, isabgol and mustard are some of main crops sown during *rabi* season. The climate conditions in Jodhpur vary from arid to semi-arid with average annual rainfall of 371 mm, most of which occurs during the south-west monsoon. The mean temperature in the district ranges from 49°C in summers to nearly 1°C in winters. Only 0.46% of Jodhpur's total geographical area is covered with forest[6]. Groundwater extracted through tube-wells is responsible for more than 90% of the total irrigation in the region. Moreover, in an assessment of vulnerability of agriculture to climate change, Jodhpur has been classified as *highly* vulnerable district[7].

Methods

Data collection method

In this study, field survey was conducted to assess determinants of household vulnerability to climate change, strategies adopted in response to climatic risks and factor influencing adoption of wide row spacing technology in case of pearl millet cropping system. The data on socio-economic status, input-output, agricultural technologies in practice and climate conditions were elicited using a well-structured and pre-tested schedule. A multi-stage sampling technique was adopted in selecting the farm households, where in the first stage, Jodhpur district, lying in the arid western zone of Rajasthan was purposively selected. In the second stage, Bhopalgarh block and in the third, two villages (*Mailana* and *Lawera*) were chosen for the study. Further, 50 respondents from each village were randomly selected for the grass-roots enquiry. Thus, the sample included a total of 100 farmers with different farm and socio-economic attributes.

Informal interviews and focused group discussions (FGDs) with 8-10 stakeholders were organised in the selected villages. During the field investigation farmers were asked open-ended questions about the changes they observed in rainfall and temperature over the few past years, frequency/magnitude of droughts and floods during sowing and harvesting of crop and whether there was infiltration of pest during wet/dry seasons. Moreover, respondents were asked to delineate the measures adopted to cope up against the climatic aberrations.

Empirical strategy

Factors that explain vulnerability were examined using the following model;

$$Y_j = \beta_0 + \beta D_{ij} + \gamma X_{ij} + u_{ij} \quad \text{... (1)}$$
$$i = 1, \ldots, n \ and \ j = 1, \ldots . J$$

Where, Y_j is the vulnerability index for the j^{th} farmer respectively. D_{ij}, represents dummies for education, land size, social group, seed and wide row spacing and X_{ij} is income and irrigation. The vulnerability index was computed using information on six different variables elicited through field investigation: flooding before end of growing or harvest season; drought after planting of crops; prolonged rainfall or flood during wet season; prolonged drought during dry season; pest and diseases during wet season; and pest and diseases during dry season. The selected variables were first normalized to the scale of 0 and 1 as follows,

$$Z_{ij} = \frac{A_{ij} - Min_{ij}}{Max_{ij} - Min_{ij}} \quad \text{... (2)}$$
$$i = 1,2, \ldots, I \ and \ j = 1,2, \ldots . J$$

Where Z_{ij} is the index for the i^{th} variable related to the j^{th} farmer; A_{ij} is the actual value; Max_{ij} is the maximum value and Min_{ij} is the minimum value respectively. Note that since the responses were binary, minimum and maximum values could only be 0 and1. The vulnerability index was aggregated as the weighted average of the variable indices using equation (3);

$$V_j = \frac{\sum_{i=1}^{I} w_{ij} Z_{ij}}{I} \quad \text{... (3)}$$

Where V_j is the vulnerability index for each farmer and w_{ij} are weights assigned to each of the variable, with the assumption that equal weights are allocated among the selected variables.

Further, a binary logistic regression was employed to analyse determinants that influence farmer's decision towards adoption of wide row technology in pearl millet cropping system. The estimated logit model is expressed as;

$$\log\left(\frac{P_i}{1 - P_i}\right) = \beta_0 + \sum \beta_i X_i + u_i \quad \text{... (4)}$$
$$i = 1, \ldots, k$$

where the term$\left(\frac{P_i}{1-P_i}\right)$, indicates the odds ratio in favour of technology adoption. β_0 is the intercept term and $\beta_1 \ldots \ldots \beta_k$ are the regression coefficients associated with each explanatory variable $X_1 \ldots \ldots X_k$,which were estimated using maximum likelihood method.

Results and discussion

Socio-economic profile of the surveyed farmers

The choice and adoption of technology and climate adaptation strategies are widely influenced by the socio-economic and demographic characteristics of the farm household[8]. As shown in Table 1, majority of the sampled farmers were in the age group of 36 to 50 years and thus experienced enough to understand the agriculture nuances and take technology adoption decisions. The average size of family and land holding in the study area was six members and about 4 ha per household. On an average, 44% of the farmers were illiterate, while 22% and 27% were qualified with primary and secondary education. Large proportion of the farm households belong to the marginalized section of the society. Nearly one-third of the cultivated area in the region was irrigated. However, due to extreme aridity, 0.28 ha of land was reported as permanent fallow. Moreover the sampled households on an average possessed three livestock per household, which indicates significance of cattle rearing in sustenance of local livelihoods in arid and semi-arid regions.

Determinants of vulnerability to climate change

Table 2, shows that illiterate farmers are at a greater risk due to climatic aberrations compared to educated ones. Farmers with marginal landholdings were more vulnerable to climate shock due to their lesser capacity to make suitable agriculture and livelihood diversifications. The coefficients for income, irrigation, obtaining seeds from institutional sources and wide row spacing were negative and statistically significant. This indicates that higher income and better irrigation infrastructure reduces the farmers' vulnerability to climatic aberrations. Further, institutional support for certified and climate tolerant seeds and adoption of wide row spacing can help in reducing the climate induced vulnerability of farm households.

Table 1 — Summary statistics: Demographic and socioeconomic characteristics of farm household

Characteristics	Jodhpur
Average age (in years)	25
Average family size (in numbers)	6
Social composition	
General (in %)	15
Backward Caste (in %)	79
Scheduled Caste (in %)	6
Education level	
Illiterate (in %)	44
Primary (in %)	22
Secondary (in %)	27
Graduate and above (in %)	7
Land assets	
Average owned land (in hectares)	4.33
Average leased-in (in hectares)	3.20
Average permanent fallow (in hectares)	0.28
Irrigated area (in %)	30.11
Average number of farm equipment (in numbers)	1.34
Average number of livestock (in numbers)	3
Household income	
Farm income (in Rs.)	161974
Non-farm income (in Rs.)	162920
Household expenditure	
Farm expenditure (in Rs.)	128248
Household consumption expenditure (in Rs.)	154231

Farm level adaptation measures to climate change

Our grass-roots enquiry revealed that farmers were adopting several mechanisms to mitigate the harmful effects of climate variations (Fig. 1). About 33% of the farmers were making appropriate changes in their cropping pattern and 25% were adopting ground water recharge techniques and soil conservation methods. 81% of the farmers were reducing the number of irrigation sessions. Further, more than 50% were adopting micro-irrigation technology, conserving water through conventional methods and construction of watershed structures. On the contrary, a substantial proportion of the respondents were digging new bore wells and further deepening the existing ones to extract groundwater. We also found that migration (seasonal or permanent) was emerging as a significant strategy against increasing climate uncertainty and dwindling farm profitability.

Determinants of technology adoption in the pearl millet cropping system

Pearl millet is a major coarse grain cereal grown in arid and semi-arid regions due to its greater tolerance to withstand wide range of soils, droughts and harsh environment conditions (higher temperature and lower rainfall). Table 3, represents the estimates of the variables influencing farmer's decisions to adopt

Table 2 — Determinants of vulnerability

Explanatory Variables	Coefficient
Education (illiterates= 1, otherwise= 0)	0.0123*
Land size (marginal= 1, otherwise= 0)	0.0447*
Social group (schedule caste and scheduled tribe= 1, otherwise= 0)	0.2454*
Income (continuous)	-0.0450
Irrigation (continuous)	-0.8954*
Seeds (from institutional source= 1, otherwise= 0)	-0.4562*
Wide row spacing (Yes= 1, otherwise= 0)	-0.6452*
Constant	0.2764*
R-Square	0.654
Adj. R-square	0.721
No. of Observations	100

Source: Estimated from field survey data, 2018
Note: *indicate 1 percent level of significance

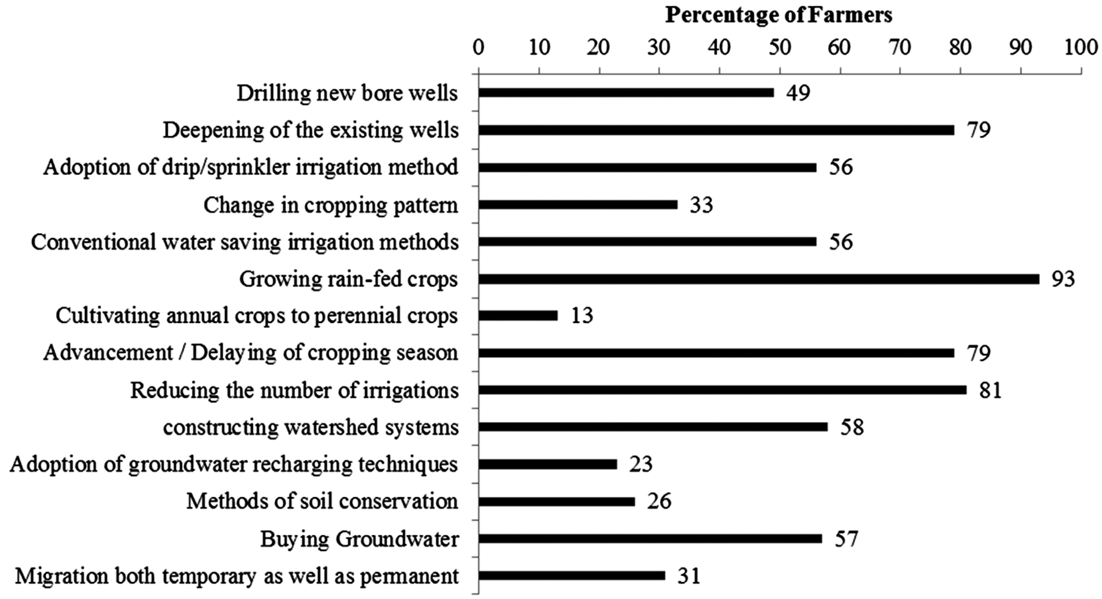

Fig. 1 — Adaptation strategies adopted by surveyed farmers

Table 3 — Determinants of wide row spacing technology in pearl millet cropping system

Explanatory Variables	Coefficient	Odds Ratio
Education (Illiterates= 1, otherwise= 0)	-0.0457*	1.25
Land size (Marginal= 1, otherwise= 0)	-0.0954*	0.21
Social group (Schedule caste and scheduled tribe= 1, otherwise= 0)	-0.5470*	0.28
Infrastructure (Warehouse= 1, otherwise= 0)	0.0421*	3.21
Irrigation (continuous)	0.8095*	2.23
Seeds (institutional source= 1, otherwise= 0)	0.4516*	4.21
Awareness of Climate Change (Yes= 1, otherwise= 0)	0.0457*	3.41
Agricultural training (Yes= 1, otherwise= 0)	0.4721*	4.24
Agriculture insurance (Yes= 1, otherwise= 0)	0.2415*	3.25
Improved and hybrid seed varieties (Yes= 1, otherwise= 0)	0.4571*	2.32
Constant	0.2764*	0.25
LR chi2	23.64	
Prob> chi^2	0.0041	
Pseudo R^2	0.1642	
Log likelihood	-78.24	
No. Observation	100	

Source: Estimated from field survey data, 2018
Note: * indicate 1 percent level of significance

wide row spacing technique for pearl millet crop. The results reveal that adoption of technology is significantly influenced by all the explanatory variables in the model. The probability of adopting technology was lower for illiterate farmers, as compared to educated farmers, who are better equipped to understand the social costs and benefits of the prescribed technologies and also the influence of changing weather and market conditions. This is consistent with the literature indicating positive correlation between a household's education level and coherent adaptation strategies[10,11]. Compared to the other land size categories, it was found that marginal farmers were 0.21 times less likely to adopt wide row spacing method in growing pearl millet. Better access to irrigation facilities positively influenced farmer's technology adoption decision. Farmers with information on changing climatic conditions were 3.41 times and those skilled with training programs were 4.24 times more likely to choose innovation. Further provision of institutional seeds significantly influences farmers' decision towards adoption of wide row spacing technology against climatic changes.

Conclusions

The study through assessment of pearl millet based cropping system examined the socio-economic factors that determine farm-level vulnerability and adaptation to climate change in arid region of Rajasthan. Field level surveys revealed that several agronomic management and water and soil conservation measures are being practised by pearl millet farmers against climate variations and uncertainty. Our empirical estimations indicate that the existence of irrigation facilities, access to agri-inputs, higher education and farm size reduces climate vulnerability of farmers, whilst also encourages the adoption of technology such as wide row spacing. Activities facilitating livelihood diversification at the grass-root level improves farmers' capacity for managing risks. Moreover, dissemination of climate knowledge and climate resilient technologies by local institutions will enhance resiliency of farm households. With the changes in climate impacting overall water availability in semi-arid regions, collective efforts are needed in development of water harvesting structures and ground water recharge to enhance resilience of local communities.

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