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Analyzing farmers' vulnerability and adaptation strategy to climate change in arid ecosystem of India

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Abstract
The study was conducted to assess vulnerability level of farmers toward climate change in arid ecosystems of India. A sample of hundred farmers from Jodhpur and Jaisalmer representing arid ecosystem were selected. Total twenty-nine socio-economic and psychological variables were studied and data were collected through personal interview and focused group discussion. The statistical techniques like principal component analysis and regression analysis were used to analyze the data. The findings revealed a high level of vulnerability as thirty-one per cent respondents belonged to highly vulnerable group. The findings of multiple linear regression analysis revealed that socio-economic variables like land holding, education, income, awareness level, communication pattern and psychological variables like achievement motivation, adaptive behavior, stress and pessimism were important predictors of vulnerability.

Keywords: Adaptation, Arid ecosystem, Climate change, Vulnerability

Introduction
Third Assessment Report (TAR) of Intergovernmental Panel on Climate Change (IPCC) defined vulnerability as 'the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes' and sees vulnerability to climate change as a function of exposure, sensitivity and adaptive capacity. In India, the vulnerability of farming community towards climate change is more due to its poor socio-economic status, poor infrastructural base, poor cognitive empowerment and huge technological gap at farm level. Hence, vulnerability of farming community extends beyond bio-physical impact and include multiple socio-political, economical and psychological aspects such as a sense of belonging, respect, social and cultural heritage, equality and distribution of wealth, dispersed settlement, access to information, knowledge of adaptation and control over one's own destiny. Patnaik and Narayanan (2009) similarly reported that socio-economic system of developing country was more vulnerable where economic and institutional circumstances were less favourable. In this context, a composite vulnerability index integrating all the components helped to discern the actual causes of vulnerability and reasoned out why some region or social group were more vulnerable than others. Besides measuring vulnerability, it is highly important to identify the major adaptation strategies to averse the negative effect of climate change. In this context, Rao *et al*. (2016) mentioned that adaptation is as important as mitigation, when dealing with climate change. Therefore, adaptive measures need greater attention, in terms of policy, research and institutional interventions to deal with climate change induced vulnerability and impact.

However, technological adaptations to climate change represent only one of many options and vulnerability to climate change has traditionally been studied only in technological and physical aspect. But exposure to climate in developing countries is more influenced by political, economic, and social conditions in addition to climatic factors. Although considerable research attention has examined components of biophysical vulnerability and the vulnerability of the built environment (Mileti, 1999), we currently know the least about social aspects of Vulnerability (Cutter *et al*., 2003). With this background, the present study was undertaken to assess the social vulnerability level of farmers towards climate change in arid ecosystem of India and to identify major adaptation strategies to overcome the negative effect of climate change.

Materials and Methods
***Study area and sampling plan*:** The study was conducted in 2013 in Rajasthan representing Arid ecosystem of India as the impact of climate change are most seriously felt

in this Arid belt of India. The Arid regions of India consist of South-West of Punjab and Haryana, Western part of Rajasthan, Kuchchh Peninsula region and North of Kathiawar Peninsula of Gujarat. Among these places, the Rajasthan state comes under one of the most vulnerable region under changing climatic condition due to overall reduction in rainfall, increase in temperature and evapotranspiration. Goswami and Ramesh (2008) reported that there would be significant increase in desertification over India in next 100 years due to climate change. The Inter Governmental Panel on Climate Change (IPCC, 2007) and the PRECIS model have projected hotter days and warm nights and a reduction in rainfall in Thar region by 21st century (Poonia and Rao, 2013). Rao *et al*. (2016) further reported that high to very high exposure towards climate change was observed in the district of Rajasthan with low adaptive capacity and very high vulnerability. In this regard, Goyal (2004) reported that even 1% increase in temperature may result into additional crop water requirement of 34.27 million cubic meter for Jodhpur district alone. Sarkar *et al*. (2014) in a study on impact of climate change in arid ecosystem of Rajasthan reported that 86 per cent farmers reported about delayed and irregular rainfall. Similarly, Rathore and Verma (2013) reported that duration of rainy season declined from 101 days to 46 days between 1973 to 2010 and average rainfall is declined by 1.5% in September month in Rajasthan. The impacts have been felt in all aspects of livelihood *i.e*. agriculture, livestock and health.

Hence, two districts Jodhpur and Jaisalmer from Rajasthan were purposively selected representing arid ecosystem. Luni block from Jodhpur and Jaisalmer block from Jaisalmer district were selected to see the level of vulnerability in typical arid region of India. Four villages- Lonawaskhara, porkkhawas, Bharamser and Pora were selected respectively from Luni and Jaisalmer blocks. Finally, 25 farmers were selected randomly from each village and total 100 farmers were interviewed for the present study.

***Measurement of vulnerability*:** Considering the various psychological dimensions of individual (attitudinal, knowledge, value orientation etc.), social-cultural dimension (interconnectedness and cohesiveness), demographic dimension (age, education, land holding etc.), and economic dimension (physical resources, income, size of landholding, livestock resources etc.); an attempt was made to measure the vulnerability of sample respondents. Total 29 indicators of vulnerability were studied and analyzed to find out the vulnerability level of farmers. Drawing from the approaches of Intergovernmental Panel on Climate Change (IPCC 2001; 2007), The Energy and Research Institute (TERI; 2003), Cutter *et al*. (2003), O'Brien *et al*. (2007) and United Nations Development Programme (UNDP, 2002), a composite vulnerability index was worked out and respondents were grouped under the categories of highly vulnerable, moderately vulnerable and less vulnerable. For each component of vulnerability, sub-indices were worked out using the following formula.

Sub Vulnerability Index (SVI) = (Actual value – Minimum value) / (Maximum value - Minimum value)

The high index values mean high vulnerability but the indicator such as literacy rate, income etc. had inverse functional relationship and hypothesized to decrease the vulnerability with increasing values (Anonymous, 2016). So, the index values were reversed for those factors by subtracting them from 1 *i.e*. [1-index value].

Then, weights were attached to the indicators by using principal component analysis (PCA). The assigned weights were then multiplied with each variable score to calculate each principle component score by taking their linear summation. The PCA score of first few principal components which explain more than 80 percent of total variation for final vulnerability index was taken into consideration for final vulnerability index (Suhr, 2016). The summation of average index score of those selected principal components was performed for final vulnerability index. Following formulae were formulated to calculate the final vulnerability index which is as follow-

1. Principal component score (P)= (Σ WiPi*SVIij)

Where, SVI_{ij}= index value for i^{th} variable and j^{th} individual (Here, 'i' ranges from 0 to 29 and 'j' ranges from 0 to 100)

W_i= Weightage for i^{th} principal component (here, 'i' ranges from 0 to 29)

P_i= Number of principal components (here, it ranges from 0 to 29)

2. Final vulnerability index= (Σ PCSi/n)/N

Where, PCS_i= Different principal component score

n=Number of principal components

N=Number of respondents

The respondents were then classified into three categories- high, moderate and less vulnerability group. The classification was done based on cumulative cube root frequency (CCRF) method (Dalenius and Hodges, 1959). Finally, linear regression analysis was employed to test the validity of the vulnerability level of respondents through our measurement tools**.** All statistical analyses were performed using software SAS Version 9.3 (SAS Institute, Cary NC).

Measurement of independent variables: Twenty seven socio-economic and psychological predictors of vulnerability were chosen after consultation with the experts. The socio-psychological variables like achievement orientation, pessimism, openness, stress, production orientation, and sustainability behvaiour were measured by modified scale of Austin *et a*l. (1998). Attitude of the respondents was measured by the scale of Department of Environment, Food and Rural Affairs (DEFRA, 2007) whereas respondents' fatalism and egalitarianism were measured by modified scale Leiserowitz (2006). The knowledge test of Sarkar and Padaria (2014) was used to measure the knowledge level of respondents. The famers' perception, risk perception and value orientation towards climate change was captured using the methodology of Sarkar and Padaria (2014). Primary data were collected on socio-economic variables like age, education, sex, caste, income, asset, communication behaviour, social cohesiveness and social participation using structured schedule.

Results and Discussion

Cropping pattern: The livelihood of majority of the farmers was based on agro-forestry and livestock. The major crops of *kharif* season were *Pennisetum glaucum, Vigna radiata, Lens culinaris, Cyamopsis tetragonoloba, Cyamopsis tetragonoloba* etc. The major crops of rabi season were *Triticum aestivum*, *Brassica nigra, Cuminum cyminum, Plantago ovata, Brassica napus*, etc. Besides these the vegetables grown by the farmers were *Chenopodium album, Praecitrullus sp, Solanum melongena L, Solanum lycopersicum, Capsicum annuum,* etc. The major fruit trees of the area were *Phyllanthus emblica* and *Ziziphus mauritiana*. Farmers used to follow a mixed type of farming system incorporating fruit trees (*Phyllanthus emblica, Ziziphus mauritiana, Psidium guajava*), forest trees (*Acacia nilotica, Acacia senegal, Azadirachta indica, Capparis decidua, Commiphora mukul, Prosopis spicigera, Salvadora persica, Tecomella undulata and Ziziphus mauritiana)*, and fodder (*Sorghum bicolor, Lasiurus sindicus (Sewan grass), Cyamopsis tetragonoloba, Pennisetum glaucum, Medicago sativa* etc.). The livestock resources like buffalo, sheep, cow and goat also played an important role in the livelihood security of farming communities.

Vulnerability level of farmers: The vulnerability index was calculated based on the above-mentioned socio-psychological and economic variables. From the Table 1 it is clear that 83.24 per cent of total variance is explained by first seven principal components. Therefore, the PCA score of first seven principal components only considered for calculation of final vulnerability index.

Based on the PCA score of seven components the mean vulnerability score for each respondent was finally calculated. Then overall mean vulnerability was calculated which was 0.73 indicating a very high level of vulnerability of the arid ecosystem. The respondents were then categorized into different levels of vulnerability through cumulative cube root frequency method which is a standardized tool to categorize the data for continuous variable. Following graph shows the distribution of respondents according to their level of vulnerability.

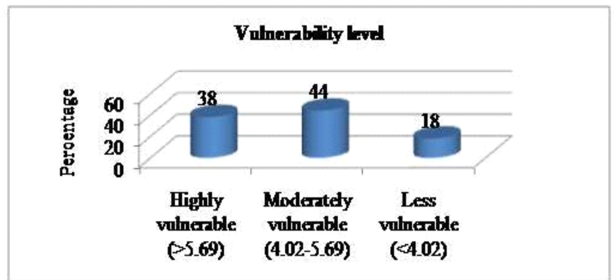

Fig 1. Distribution of respondents according to their vulnerability level (n=100)

From the Figure 1 it is gathered that 38 per cent respondents were highly vulnerable to climate change followed by moderately vulnerable (44 %) and less vulnerable category (18%). The high vulnerability level in the region may be ascribed to low socio-economic status of the farmers, poor economic condition, rough topography, low adoption of climate resilient technologies, lack of information on climate change impact and adaptation options, lack of knowledge, poor communication infrastructure and weak community initiative etc.

Multiple linear regression analysis: Multiple regression analysis was carried out to identify the factors influencing vulnerability (Table 2-4). The R^2 value of 0.8834 showed regressions fit as highly impressive. This indicated that 88.34 per cent of total variations in the dependent variable were explained by our independent variables. F test was employed to test the significance of the model, and the result is displayed in Table 3.

The P value of <0.001 indicated that the model was highly significant at 1 % level of significance. The regression coefficients for each variable were calculated to predict the future vulnerability level (Table 4). It was also tested whether the slope was significantly different from 0 or not through test. The results were as follows.

Table 1. Eigenvalues of the principal components

Variables	Eigenvalues	Difference	Proportion	Cumulative
Income	0.85208743	0.48762135	0.3536	0.3536
Size of landholding	0.36446608	0.10763864	0.1513	0.5049
Physical resources	0.25682743	0.05808570	0.1066	0.6115
Livestock resources	0.19874173	0.06970374	0.0825	0.6940
Education	0.12903799	0.01876834	0.0536	0.7475
Age	0.11026965	0.01592445	0.0458	0.7933
Adaptive behavior	0.09434520	0.01447469	0.0392	0.8324
Attitude	0.07987052	0.01946634	0.0331	0.8656
Achievement orientation	0.06040417	0.01190424	0.0251	0.8907
Risk orientation	0.04849993	0.00643788	0.0201	0.9108
Value orientation	0.04206205	0.00625643	0.0175	0.9282
Production orientation	0.03580562	0.00470683	0.0149	0.9431
Openness	0.03109879	0.00880239	0.0129	0.9560
Stress	0.02229640	0.00561764	0.0093	0.9653
Pessimism	0.01667876	0.00278178	0.0069	0.9722
Fatalism	0.01389699	0.00094255	0.0058	0.9780
Knowledge	0.01295443	0.00079799	0.0054	0.9833
Awareness	0.01215645	0.00600300	0.0050	0.9884
Perception	0.00615345	0.00179088	0.0026	0.9909
Risk perception	0.00436257	0.00069665	0.0018	0.9927
Communication behaviour	0.00366592	0.00069942	0.0015	0.9943
Social participation	0.00296650	0.00018987	0.0012	0.9955
Cohesiveness	0.00277664	0.00034859	0.0012	0.9966
Sustainability orientation	0.00242804	0.00063173	0.0010	0.9977
Family members	0.00179632	0.00046189	0.0007	0.9984
Economic motivation	0.00133442	0.00019662	0.0006	0.9990
Innovativeness	0.00113781	0.00037473	0.0005	0.9994
Egalitarianism	0.00076307	0.00014823	0.0003	0.9997
Dependency level	0.00061485		0.0003	1.0000

Table 2. Results of multiple regression analysis

Root MSE	0.01638
Dependent mean	0.53704
Coeff var	3.04915
R-Square	0.9354
Adj R-Sq	0.8834

Table 3. Findings of ANOVA

Source	DF	Sum of squares	Mean square	F value	Pr > F
Model	12	1.57431	0.13119	489.26	<.0001
Error	87	0.02333	0.00026814		
Corrected Total	99	1.59764			

Education, income, size of land holding, awareness, achievement orientation, pessimism, knowledge, value orientation and communication behavior were found to be significant predictor variables at 1 per cent level of significance whereas, age was found to be significant variables to predict the vulnerability level at 5 per cent level of significance. The colinearity statistics like tolera--nce level and VIF statistics were used to trace any presence of multicollinearity in the regression model. All the VIF score indicated the absence of any multicollinearity which shows the strength of the regression model. Thus, the regression model could express the vulnerability level in the form of following equation-

Vulnerability= 0.27742 - 0.02311 *age + 0.13374 *education + 0.15575 *income + 0.08293 *size of land holding + 0.02946 *awareness + 0.06142 *achievement orientation - 0.04218 *pessimism + 0.05534 *knowledge + 0.03434 *value orientation + 0.12798 *communication behavior

The results pointed at differential risks for farmers with different socio-economic and psychological profile. A large section of the respondents (38%) belonged to highly vulnerable group which may be due to their low adaptive capacity in terms of technological, socio-economic and psychological indicators. The findings again proved the

Table 4. Regression coefficients

Variable	DF	Parameter estimate	Standard error	t Value	Pr > |t|	Variance inflation
Intercept	1	0.27742	0.02205	12.58	<.0001	0
Age	1	-0.02311	0.01114	-2.08	0.0409	3.34286
Education	1	0.13374	0.01851	7.23	<.0001	9.54102
Income	1	0.15575	0.01236	12.60	<.0001	4.94309
Size of landholding	1	0.08293	0.01226	6.77	<.0001	4.54095
awareness	1	0.02946	0.00993	2.97	0.0039	3.37118
Achievement orientation	1	0.06142	0.01834	3.35	0.0012	8.20687
Pessimism	1	-0.04218	0.01027	-4.11	<.0001	3.97095
Openness	1	0.00479	0.01283	0.37	0.7099	4.21785
Knowledge	1	0.05534	0.01549	3.57	0.0006	7.65131
Perception	1	0.01087	0.01355	0.80	0.4246	3.88215
Value orientation	1	0.03434	0.01284	2.67	0.0090	4.91380
Communication behaviour	1	0.12798	0.00939	13.63	<.0001	1.24336

Table 5. Adaptation strategies to reduce vulnerability level

Strategies	Mean rank
Promotion of climate resilient technologies among the farmers like - short duration varieties of Pearl Millet (MH-179), Cluster bean(Maru), Moong bean (S- 8, K-851) etc.	I
Awareness building programme among the farmers about climate change and its impact in livelihood	V
Real time forecasting about climatic events and timely agro-advisory services	IV
Promotion of heat tolerant breed of cow, buffalo, sheep and goat among the dry land farmers	II
Conducting capacity building programme on climate resilient technologies (Zero tillage, DSR etc.) and agronomic practices for farmers	III
Revival of traditional water harvesting structure and indigenous practices for ecosystem management	VII
Training on better irrigation management practices, IPM, INM etc.	VI
Promotion of agro-forestry based cropping system	VIII
New extension approach like climate field school, climate smart villages need to be taken up	IX

hypothesis that social variables like education, land holding, income, communication pattern and psychological determinants like knowledge, achievement motivation, stress and fatalism were instrumental in determining the vulnerability level of people towards climate change. It was further derived from the findings that for developing adaptation strategy, emphasis must be laid upon socio-psychological empowerment of farmers besides developing competencies in acquiring knowledge and skills related to adaptation practices. The findings of Maiti *et al.* (2015) also supported this derivation who constructed a social vulnerability index to climate change of pastoralists of West Kameng and Tawang districts of Western Arunachal Pradesh and concluded that vulnerability profile of pastoralists were largely influenced by their adaptive capacity.

***Adaptation strategy to reduce vulnerability*:** Interestingly, the finding of adaptation strategy (Table 5) to reduce vulnerability towards climate change indicated that by promotion of heat tolerant breed of cow, buffalo, sheep and goat among the dry land was the most preferred adaptation strategy (Mean rank I) followed by promotion of climate resilient technologies among the farmers like - short duration varieties of Pearl Millet (MH-179), Cluster bean (Maru), Moong bean (S- 8, K-851) etc. There is little doubt that technological adaptations such as irrigation schemes, drought tolerant seed varieties, raised bridges, structural improvements in housing and so forth can decrease vulnerability to climate change in many countries. For example, Bantilan and Mohan (2014) highlighted that adaptation measure like improved technologies such as climate smart crops, credit facilities to farmers, establishment of cooperatives / associations, marketing reform etc will help in empowerment of farming communities and thus reducing vulnerabilities. Chander *et al*. (2016) reported that October (early) and January (very late) sown crop evaded aphid attack on wheat ear heads.

The findings of study on crop choice by Kurukulasuriya, and Mendelsohn (2006) also supported the fact that crop choice is climate sensitive and farmers adapt to changes in climate by switching from crops to livestock. Other major adaptation strategies were conducting capacity building programme on climate resilient technologies (Zero tillage, DSR etc.) and agronomic practices for farmers (mean rank III), real time forecasting about climatic events and timely agro-advisory services (mean rank IV), Training on better irrigation management practices, Integrated Pest Management (IPM), Integrated Nutrient Management (INM) etc. (mean rank V). Prasad *et al*. (2014) reported that farmers from the Panna district of Madhya Pradesh similarly adopted different agronomic and technological adaptation measures like change in sowing time of different crops (80%), change in cropping sequence (20%) and sowing of summer crop on arrival of monsoon to cope up with the climate change. He further reported that farmers in the area believed that adoption of agroforestry land use was best remedy for minimizing farming risk in changing climatic scenario. Rosenzweig and Hillel (1995) also reported that a wide variety of adaptive actions may be taken to lessen or overcome adverse effects of climate change on agriculture. At the level of farms, adjustments may include the introduction of later- maturing crop varieties or species, switching cropping sequences, sowing earlier, adjusting timing of field operations, conserving soil moisture through appropriate tillage methods, and improving irrigation efficiency.

Conclusion

It can be concluded from the study that the arid ecosystems were highly vulnerable towards climate change. A large section of farming community (38%) belonged to highly vulnerable group. The finding of regression analysis in the state again showed that socio-economic and psychological characteristic of individuals play an important role in determining their adaptive capacity. Income, area, education, achievement motivation, knowledge, stress, pessimism and communication pattern of respondents were the major factors in determining their vulnerability towards climate change. The index helped us to identify those characteristics and experiences of farmers that were responsible for their vulnerability. Relevant socioeconomic and psychological characteristic of the affected community must be taken into consideration before formulation of any policy. However, there is a need to integrate the social vulnerability with bio-physical vulnerability to address the challenges. The development and integration of social, environmental and climatic hazard indicators together can improve our assessment of actual vulnerability and can justify the selective group of communities for adaptation and mitigation more accurately. So, the future research should be focused in that direction.

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