Risk management in rainfed agriculture: An analysis of strategies and adaptations followed by farmers in Madhya Pradesh

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Risk management in rainfed agriculture: An analysis of strategies and adaptations followed by farmers in Madhya Pradesh

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ABSTRACT

Madhya Pradesh is the major producer of soybean in India. Being predominantly rainfed, the state faces high risks in its cultivation. The study undertook a primary survey in Madhya Pradesh to analyze the risk perception of farmers, elucidate the strategies followed by farmers to adapt with the risk and to identify the factors influencing their adoption. The results infer that late onset of monsoon, erratic rainfall and pest and diseases were the major risks. The major risks were related to untimely rainfall, drought and biotic factors like diseases and pest. The major adaptation strategies adopted were intercropping (49%), crop insurance (45%), micro irrigation (17%) and varietal diversification (39%). The study discerns need to develop drought tolerant varieties for rainfed regions, low cost micro-irrigation systems, enhanced credit availability to the farmers and promotion of crop insurance to adapt with production risks.

Key words: Adaptation, Climate change, Rainfed, Risk, Strategies, Varietal diversity

Rainfed agriculture is practised on 80% of the world's agricultural area and its importance in agriculture varies regionally. A large part of food production in developing countries depends on it. In India, rainfed areas currently constitute 55% of net sown area, supporting 40% human population, around two-third of livestock population and contributing 40% to the food grain production of the country (Venkateswarlu and Prasad 2012).However, rainfed agriculture is risky, vulnerable, diverse, and complex, and is under-invested (NRAA 2012). In this context, Suresh *et al.* (2014) have noticed that the growth in value of production has been lower than the growth in cost of cultivation for the rainfed crops during the post-liberalization period (1995-96).The risks in agriculture affects all the farmers in rainfed regions in certain ways, but the impacts are more on the marginal and small farmers (Birthal *et al*. 2014). The adaptive capacity of the small and resource poor farmers are lower compared to their counterparts, which accentuates their vulnerability to various risks of rainfed agriculture.

Asha *et al.* (2012) concluded that the small and medium rainfed farmers were highly vulnerable to climate change, and to a larger extent they adopted coping mechanisms. The temperature rise of 1 and 2^{o}C caused reduction in soybean yield by 1.3 and 4.5 percent, respectively (Rana *et al.* 2014). Farmers' generally practice different adaptation measures over the period to mitigate and prevent the effect of risks like fluctuations in monsoon, prices, weather, policy etc. Some commonly followed prodiction risk management strategies are timely planting of crops, adoption of improved crop varieties, efficient crops and cropping systems, nutrient management, integrated pest mangement (IPM) and resource conservation measures. Despite the difficulties posed by the highly heterogeneous and variable nature of rainfed environments that have slowed progress in the past, opportunities for scientific progress in the future appear promising (Pandey *et al.* 2007).

Soybean is called as "miracle bean", due to its immense potential as food, fodder, feed, fuel and industrial production. Soybean contains 36% protein, 30% carbohydrate and 20% fat, which can be utilized for nutritional security. Despite the deliberate efforts to boost the production of oilseeds domestically, it has not succeeded much in meeting the domestic oilseed demand (Jha *et al.* 2012). Soybean in India is cultivated pre-dominantly under the rainfed conditions. The high level of production risks and consequent low growth of total factor productivity (TFP) of the crop are major concerns (Suresh *et al*. 2014). In India, the crop is predominantly cultivated in Madhya Pradesh, mostly under rainfed conditions. Identifying and addressing the source of risk is important to advice strategies and policies in the cultivation of the crops. The knowledge emanating from the study would help devising suitable policies for promotion of risk adaptions that could address the risk induced farm income shocks. In this backdrop, it becomes essential to analyses the perception of farmers on various risks in

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soybean production and elucidates the factors that affect the major risk adaptation strategies.

MATERIALS AND METHODS

Madhya Pradesh is leading producer of soybean in India, accounting for 56% of total production. In the state, around 78% of soybean area is under rainfed cultivation. The present study utilizes primary data collected purposively from Indore district since it constitutes around 92% of net sown area in *kharif* season. Multistage sampling technique was used for selection of samples. From Indore, two tehsils were randomly selected. From each tehsil two villages were selected randomly. From each village, 30 farmers were selected. Thus total sample size is of 120 farmers. The data were collected through personal interview of the randomly selected farmers with the help of structured pre-tested interview schedule. The data pertains to the time period January 2015.

In understanding farmer response to risk, a useful distinction can be made between risk-reducing strategies that the farmers adopt *ex-ante* and risk coping strategies that the farmers *ex post* the shock (Ramaswami *et al*. 2004). The choice of strategies depends on several social and economic factors, and risk orientation of the farmers. Some of the important adaptation strategies undertaken by the farmers were important from technology and policy point of view. They include adoption of drought tolerant varieties of soybean, varietal diversification, and resource management strategies like micro-irrigation (sprinkler and drip irrigation) and risk transfer mechanism like crop insurance. Therefore, these strategies were selected for detailed adoption analysis.

The factors affecting the adoption of the selected risk management strategies were identified by using regression analyses, viz. logit and tobit models. Logit is a technique in which the probability of a dichotomous outcome is related to a set of independent variables. It has been widely used to study the adoption behaviour.The behaviour of the household towards adoption of a management practice was defined as :

Prob (adoption) = Prob (Y, 1 represents i^{th} farmer adopted, and 0, otherwise)

Suppose X_i represents the set of variables that influence the adoption decisions of the i^{th} household. For a household, the indirect utility (Z_i) derived from the adoption, is a linear function of k independent or explanatory variables (X). This can be stated as:

$$Z_i = \beta_0 + \sum_{i=1}^{\eta} \beta_i X_{ki}$$

where, β_0 represents the intercept term and β_is are the coefficients associated with the explanatory variables X_{ki}. These factors explain the adoption behaviour and the probability that i^{th} household decides to adopt a certain practice.

The probability of adoption is modeled as:

$$P_i = \frac{e^{Z_i}}{1 + e^{Z_i}}$$

where, P_i is the probability of i^{th} household's adoption decision and ($1-P_i$) denotes the probability that household does not adopt the variety. In the analysis, four important risk management mechanisms have emerged as most prominent. They include adoption of drought tolerant varieties, crop insurance, micro-irrigation, and varietal diversification. Logit model was applied to the first three strategies, viz adoption of drought tolerant varieties, adoption of crop insurance and adoption of micro-irrigation.

Herfindahl index (HI) is a measure of the concentration. In a market context, HI accounts for the number of firms in a market, as well as concentration, by incorporating the relative size (i.e market share) of all firms in a market. In present study, the index is used to calculate the crop varietal diversification. It is computed by taking sum of squares of acreage proportion of each variety in the total area occupied by the crop.

Mathematically the index is expressed as:

$$HI = \sum_{i=1}^{\eta} P_i^2$$

where N is the total number of varieties of the crop (soybean), and P_i represents the area proportion of the i^{th} variety in total area under the crop. The value of the index ranges between zero and one. Herfindahl index approaches a value of one when there is complete concentration, and take a value of zero otherwise, when there is perfect diversification. Thus, the value of the index is positively related with the extent of concentration. To make the index a direct indicator of diversification, the HI was deducted from a value 1. Thus, a value of 1 would indicate diversification, and 0 would indicate concentration.

Tobit model (Tobin 1958), also called censored regression model, is designed to estimate linear relationships between variables when there is either left- or right-censoring in the dependent variable. Tobit model was employed to identify the factors which influence the farmers' decision on the extent of varietal diversification, measured by using Herfindahl index. Tobit model is a statistical model to describe the relationship between the non-negative censored dependent variable Yi and independent variable Xi.

Tobit model can be described in terms of a latent variable Y*. Yi* is observed when Yi*>0 and Yi* is not observed when Yi*≤0. So the observed Yi is defined as:

$$Yi = \begin{cases} Yi^* = \beta Xi + Ui, & \text{if } Yi^*>0 \\ 0, & \text{if } Yi^* \leq 0 \end{cases}$$

Tobit model is also called as censored regression model because some observation are censored, i.e. Yi*≤0.

RESULTS AND DISCUSSION

Farm and family characters

Details of social and economic characteristics of the farm households are provided in Table 1.The study indicated that majority of the farmers belonged to medium to large farm category. The mean age of the farmers was about 50 years and the average family size was 7 members. The mean number of years of education was about 8.6, indicating a secondary level. Many farmers with higher education were observed in large farm size category. They could be targeted to work as change agents for spreading the adoptions of modern and high production technology and farming practices. The mean number of years of experience in farming was about 35 years in case of large farmers and 33 years in case of small farms. Out of SC/ST farmers, about 53% were small and 47% were large farmers, in terms of operational size of holding. The average size of operational land holding was 4.9 ha,1.7 ha for small holders and 5.9 for large holders. The average area under irrigation was quite low, only 7.8% of the area was irrigated. The status of availing credit through Kisan Credit Card (KCC) Scheme was around 77% for large farmers. Small farmers were numerically more in Gram Panchayat and co-operative societies, while large farmers dominated in marketing society and SHGs. About 57% of the farmers adopted crop insurance. The mean level of cropping intensity was 163%, with the small farmers with asignificantly higher level.

Table 1 Social and economic status of sampled farmers

Particulars	Small farmers (<2 ha)	Large farmers (>2 ha)	Total farmers
Numbers of farmers (no.)	30	90	120
Age (years)	50.9	51.3	51.2
Education (number of years of schooling)	8.5	8.7	8.6
Family size (mean no.)	7.4	7.1	7.2
Farming experience (years)	33	35.3	34.8
Caste			
SC/ST (%)	53.3	46.7	100
Others (%)	46.6	53.4	100
Mean land holding (ha)			
owned land	1.84	5.9	4.9
leased-in land	0.08	0.09	0.09
leased-out land	0.06	0.12	0.1
operational holding	1.7	5.9	4.9
Mean irrigated area (ha)	0.1	0.4	0.3
Area irrigated (%)	9.4	7.7	7.8
Possession of Kisan Credit Card (KCC) (%)	76.6	77.7	77.5
Membership in organizations			
Gram Panchayat (%)	13.3	12.2	12.5
Co-operative society (%)	40.0	37.8	38.3
Marketing society (%)	33.3	43.3	40.8
SHG's (%)	56.6	65.5	63.3
Adoption of micro-irrigation (%)	10.0	20.0	17.5
Adoption of crop insurance (%)	53.3	57.7	56.6
Cropping intensity (%)	177	157.7	162.5

Farmer's perception

The perception of the farmers on various risks faced was recorded by using Likert scale with a 5 point scale continuum starting from "strongly agree" to "strongly disagree". The mean values of the perceptions were arrived at by aggregation of the values reported by the farmers. The share of farmers who have agreed with the statements (taken average of both "agree" and "strongly agree") and the mean scores are reported in Table 2. Of the total farmers, almost 50 % large and small farmers perceived untimely rainfall as main risk factor in soybean cultivation with a mean score of 4.7. Also, 50% of both small and large farmers perceived drought condition as major source of risk, which was followed by late onset of monsoon agreed upon by 48 % of the farmers. The abiotic risks are closely followed by the biotic risks, namely diseases and pests. Close to 47 % of farmers (both strongly agree and agree) reported disease and pests, as a risk. The mean score at 4.3 was higher for diseases compared to pests (4.0).

Risk adaption strategies

To cope up with the risk, the farmers adopted many strategies (Table 3). The frequency values is the total of those reported them as "very frequent" and "frequent" in the Lykert scale. The results showed that the major strategy to cope up with the risk was intercropping. The major crops grown along with soybean were maize and some other pulse crops. Intercropping seems to help in avoiding complete crop failure in case of a risk. Intercropping lowers yield risks because of lower disease and insect pest incidence

Table 2 Farmers perception about various sources of risk

Statements	Small farmers		Large farmers		Total farmers	
	Agree %	Mean score	Agree %	Mean score	Agree %	Mean score
Untimely rainfall	50	4.7	50	4.7	50	4.7
Late onset of monsoon	46.5	4.3	43.5	4.5	48	4.5
Drought condition	50	4.6	50	4.4	50	4.4
High variability in temperature	43.5	4.1	47	4.4	46	4.3
Disease	47	4.3	47	4.3	47.5	4.3
Pest	33	4.1	46	4	45.5	4
Wild animals problem	10	2.5	14.5	2.6	13.5	2.6
Flood condition	10	2.5	13	2.7	12.5	2.6

Table 3 Strategies adopted by the farmers under risk situation

Strategy	Small farmers		Large farmers		Total farmers	
	Frequent %	Mean	Frequent %	Mean	Frequent %	Mean
Intercropping	50	4.67	48.5	4.63	49	4.64
Crop insurance scheme	45	4.37	45.5	4.36	45.5	4.36
Soil and water conservation techniques	48.5	4.43	49.5	4.28	49	4.32
Drought tolerant varieties	42	3.97	38	3.74	39	3.8
Varietal diversification	38	3.67	38	3.78	38	3.75
Disease resistant varieties	28.5	3.17	39	3.63	36.5	3.52
Pest resistant varieties	20	2.87	15.5	2.74	17	2.78
Micro-irrigation	11.5	2.43	9.5	2.36	10	2.38
Contract farming	6.5	1.9	8.5	2.08	8	2.03

and greater potential for yield compensation (Walker and Ryan 1990). Next alternative strategy was the adoption of crop insurance. The importance of crop insurance as an important risk transfer mechanism is gradually getting more policy attention. According to Venkateswarlu and Shanker (2009) a sound policy framework should address the issues of redesigning social sector with focus on vulnerable areas/populations. This would introduction of new credit instruments during extreme weather events, and weather insurance as a major vehicle to transfer risk. Almost 49 % of small farmers and 50 % of large farmers "frequently" adopt soil and water conservation techniques. About 42% of small farmers points to adoption of drought tolerant variety with a mean value of 3.97. Another important strategy was micro-irrigation. However, relatively less number of farmers adopted it. One major reason for its non-adoption is reported to be high costs involved. Climate change is also a factor which influences newer adaptation strategies. Aggarwal (2008) notes that simple adaptation strategies such as change in varieties and planting dates could help in reducing impact of climate change to some extent.

Farmers adopted some distinct strategies to manage risk (Table 4). About 71 % farmers adopted varietal diversification as a strategy. About 53 % small farmers and 58 % large farmers adopted crop insurance. Only a few farmers (about 25 %) adopted the drought tolerant variety.

Table 4 Major distinct strategies adopted by farmers to adapt with risk

Strategy	Small farmers (%)	Large farmers (%)	Total farmers (%)
Varietal diversification	73	68	71
Crop insurance	53	58	57
Drought tolerant variety	27	24	25
Micro irrigation	10	20	17

Lipton and Longhurst (1989) suggest small farmers are likely to know less about them than about traditional varieties and in particular about the resistance of new varieties to pest and disease. Finally, 17% farmers consisting of 10 % of small farmers and 20 % large farmers adopted micro irrigation, mainly sprinkler irrigation, as a risk management strategy.

Factors affecting adoption decisions

Drought tolerant varieties: As noted earlier, adoption of drought tolerant variety was one of the strategy followed by the soybean cultivators. Lipton and Longhurst (1989) point out that under the present state of technology, improved varieties have been successful in coping with moisture stress in some instances, but not all. To identify the factors that determine adoption of drought tolerant variety, logit regression was carried out and the results are provided in Table 5. The result indicates that caste of the farmer, membership in cooperatives and marketing society, soil quality and risk perception of farmers had significant effect on the adoption of drought tolerant variety. Cavatassi *et al.*(2011) and Kalinda *et al.* (2014) reported that the probability and degree of adoption of improved varieties is directly related to the size of the farm holding and participation in farmer-organizations. All significant variables were of positive sign except soil type. In case of soil type, the result suggested that the field with good quality soil, the odds of adoption of the drought tolerant variety declined. This could be probably due to the fact that there was a trade-off between yield and drought tolerance. Ghimire *et al.* (2015) reported that education, extension services and seed access play significant roles in adoption decisions of improved rice varieties. The risk perception of farmers captured by average risk score exhibited significant and positive influence. It clearly points to the need to develop varieties that can tolerate abiotic stress catering to the need of the farmers.

Micro-irrigation: Micro-irrigation was one of the effective strategies under semi-arid agriculture. Farmers' decisions to adopt the micro-irrigation, both drip and sprinkler irrigation were affected by many social and economic factors (Table 6). The logit regression results showed that the size of land holding, share of irrigation, and membership in various farmer-organizations turned out to be significant factors. Similar results were reported by Chandran and Surendran (2016) and Koshti and Mankar

Table 5 Logit regression estimates of factors influencing adoption of drought tolerant variety

Farmers adopting drought tolerant variety	Coefficient	SE	P>z
Age (years)	-0.02	0.02	0.40
Education (years)	0.06	0.09	0.49
Caste (dummy variable)	0.74	0.40	0.06**
Land holding (ha)	-0.03	0.15	0.83
Membership in cooperative societies (dummy)	2.07	0.67	<0.01*
Membership in marketing societies (dummy)	2.48	0.65	<0.01*
Membership in SHGs (dummy)	0.93	0.65	0.15
Presence of irrigation (%)	-1.38	2.45	0.57
Soil type (dummy variable for good quality and others)	-1.53	0.72	0.03*
Availability of non-farm income (dummy)	-0.46	0.78	0.55
Current value of assets (Rs)	0.00	0.00	0.58
Risk perception (Score)	15.96	6.48	<0.01*
Constant	-16.37	5.21	0.00

* and** significance at 5 and 10% level respectively.

(2016). All these factors influenced adoption of micro-irrigation positively. Kumar (2008) reported that the age, education, farm size and off-farm incomes were factors influencing the adoption of drip irrigation. The lower level of the adoption of the farmers, as indicated in the regression estimates, is mainly due to the capital constraints (as proxied by the positive sign of operational holding).

Crop insurance: Crop insurance was an important risk transfer strategy adopted by the farmers. Walker *et al.* (1986) noted that crop insurance is most likely to be adopted in dryland farming where most farmers face the same dominant risk of inadequate rainfall. Logit regression was used to identify the factors influencing the adoption of crop insurance (Table 7). The results suggested that the accessing of institutional credit, risk perception of the farmers and availability of the non-farm income were the important factors that affected the adoption of the crop insurance. Kumar *et al.* (2011)reported off farm income and risk presence as important factors that affect the adoption of crop insurance. Velandia *et al.* (2009) reported that higher off-farm income has a negative relation with the adoption of crop insurance.

Table 6 Logit regression of factors influencing adoption of micro-irrigation

Micro irrigation	Coefficient	SE	P>z
Land holding (ha)	-0.11	0.15	0.45
Presence of irrigation (%)	1.26	0.31	0.00*
Current value of asset (₹)	0.00	0.00	0.20
Availability of non-farm income (dummy variable)	-0.53	0.88	0.54
Membership in (cooperatives, marketing society, SHGs,) farmer organization (mean score)	3.15	1.51	0.03**
Risk perception (Score)	13.14	8.70	0.13
Constant	-15.55	8.02	0.05

* and** significance at 1 and 5% level respectively.

Varietal diversification: The determinants of the varietal diversification were identified using tobit regression analysis. The result of the Tobit regression analysis is presented in Table 8. The dependent variable was varietal diversification (1-HHI). The value of the diversification ranged between zero and one. The factors that were hypothesized to influence the diversification included eleven variables, out of which four variables showed statistically significant influence. They were size of land holding, availability of non-farm income, caste and status of being a share cropper. Mandal and Bezbaruah (2013) reported that farm size, irrigation, access to institutional credit were major factors that influence diversification in Assam plains. Of these, all except the dummy for sharecropper were positively influencing varietal diversification. Ali (2015) and Suersh (2005) indicated that age, education, income, landholdings, ability to irrigate, participation in the market, use of farm credit, and marketable surplus were important factors affecting adoption of diversification for risk management in agriculture.

Untimely rainfall and late onset of monsoons were the major abiotic stresses. The other major risks of biotic sources include diseases and pests. Majority of farmers were unaware of the new technologies available. In this context study points out the need to facilitate greater flow of information to the farmers. The adaptation strategies followed by the farmers include intercropping, varietal diversification, crop insurance, and soil and water

Table 7 Logit regression of factors influencing the adoption of crop insurance

Insurance adoption	Coefficient	Standard error	P>z
Land holding (ha)	0.19	0.14	0.17
Irrigated area (%)	-0.08	0.26	0.73
Current value of asset (Rs)	0.00	0.00	0.71
Availability of non-farm income (dummy variable)	1.47	0.7	0.03**
Risk perception (Score)	17.71	6.37	0.00*
Institutional credit (dummy variable)	4.03	0.73	0.00*
Constant	-12.4	4.80	0.01

* and** significance at 1 and 5% level respectively.

Table 8 Tobit regression of factors influencing the varietal diversification

1-HHI	Coefficient	S.E	P>t
Land holding (ha)	0.02	0.00	<0.01*
Irrigated area (%)	-0.09	0.07	0.21
Current value of asset (Rs)	0.00	0.00	0.96
Availability of non-farm income (dummy variable)	-0.06	0.03	0.04**
Share cropper (dummy variable)	-0.11	0.03	0.00*
Adult family members	0.00	0.00	0.20
Risk perception (Score)	-0.10	0.25	0.66
Soil type (dummy variable for good quality and others)	0.02	0.03	0.46
Membership in farmer organization (cooperatives, marketing society, SHGs) (mean score)	-0.01	0.06	0.78
Caste (dummy variable)	0.03	0.01	0.05**
Constant	0.43	0.23	0.06

* and** significance at 1 and 5% level respectively.

conservation methods, adoption of drought tolerant varieties and creation of irrigation potential. Intercropping, followed by close to half of total sample size acts as a cushioning strategy for farmers at time of low rainfall. The intercrops generate some income along with the providing food and nutritional security to the families. Soil and water conservation techniques like reduction of surface run-off by structures help to reduce erosion and increase water infiltration. Factors like membership in farmer organization, soil type and risk faced by farmers, non-farm income and off-farm incomes, accessibility to institutional credit and wealth of the farmers were some of the important factors that affect major adoption decisions. This points to the importance of institutional facilitations in insulating against risks and enabling farmers to adapt with it. Though the crop insurance was an important risk transfer strategy adopted by the farmers, its adoption was not impressive. This needs immediate attention. Development of abiotic stress tolerant varieties of soybean, creation of awareness about drought management strategies, increased flow of information, and facilitating access to credit and insurance are important strategies to popularize risk management strategies to stabilize farm income.

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