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ORIGINAL ARTICLE

MITIGATION STRATEGIES FOR COMBATING CLIMATE CHANGE IN MAHARASHTRA

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Abstract : Main focus of the present study is to analyse the current potential of various irrigation technologies adopted by farmers to mitigate crop risks in view of climate change. This also analyses important factors determining farmers' choice of specific technologies adopted by them. Findings of this study are based on the primary data collected from 116 sample farmers of Sholapur district of Maharashtra. Current study revealed that the adopted irrigation technologies have proved highly beneficial as farmers shifted from production of staple cereal food crops to demand - driven crops *viz.* vegetables and fruits. Adoption of drip or sprinkler irrigation system has significantly higher benefit-cost (B:C) ratio than conventional irrigation methodologies adopted usually by farmers. Fitting of Legit model to the data revealed that the probability of adoption of irrigation technologies by farmers depends on benefit-cost (B:C) ratio, farm size, subsidy, access to credit and collective action undertaken by farmers. Salient outcome of the study is that overexploitation of groundwater should be discouraged and water saving techniques must be adopted to improve farm level efficiency.

Key words: Climate Change, Irrigation, Benefit Cost ratio, Legit model, Subsidy, Efficiency

1. Introduction

Accumulation of greenhouse gases in the atmosphere has warmed the planet and caused changes in the global climate. In 2001, the UN sponsored Intergovernmental Panel on Climate Change (IPCC) reported that worldwide, temperatures have increased by more than 0.6°C in the past century. IPCC also reported that sea levels have risen by between 10 and 20 cm and snow and ice covers have fallen almost worldwide, while the precipitation patterns characterizing land areas of the Northern Hemisphere have progressively changed. Several research studies also confirmed that climate change has several adverse effects on major ecosystems and their services [Mohan and Sinha (2009), Hallegatte (2010)]. National Action Plan on Climate Change (NAPCC) has warned that due to rise in temperature, there will be declining freshwater availability in major river basins and occurrence of severe droughts in several Indian States by the end of 21*st* century. Recent floods in 2013 in various States of India testifies this fact. Among the several sectors, irrigation is the largest user of water as NCIWRD estimates show that irrigation has consumed about 78.45 per cent of the total water demand during 2010 and due to serious decline in per capita water availability, this scenario is projected to be reduced to 72.47 per cent and 68.38 per cent respectively during years 2025 and 2050 [Government of India (2006)]. It is also warned that farmers of India will be more vulnerable to water scarcity problems due to climate change because of widespread poverty, high dependency on natural resources and lower resilience to climate related shocks [UNICEF, FAO and SaciWATERs (2013)]. It is thus believed that making huge investments in irrigation sector to increase irrigation intensity and efficiency can significantly help agricultural sector to cope with climate variability and adopt future climate change challenges [Thomas (2008) and Yu *et al.* (2010)]. Implementation of irrigation-related adaptation strategies includes one or a combination of technologies *viz.* construction of small dams for water storage, flood control and measures to capture rainwater during the monsoon seasons, facilitating water distribution systems [O'Brien (2000)]; practising traditional water-saving techniques

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[Kurukulasuriya and Rosenthal (2003)]; construction of water harvesting structures, applying drip, sprinkler [Oweis and Hachum (2003), Pereira *et al.* (2002)] and mulching [Lal (2003)]; adopting centre pivot irrigation, dormant season irrigation, gravity irrigation and pipe irrigation [Smith (1993)]; scheduling of existing systems [Chiotti and Johnston (1995)]; changing the timing of irrigation [de Loe *et al.* (1999)]. But farmers' choice for adaptation of irrigation technology, among several factors, depends on the potential of benefits received against major costs of production [Smith and Lenhart (1996)]. In other words, farmers' adaptation strategy is driven by self-interest and underlying welfare-maximizing principles *i.e.* profit maximization, output maximization, cost minimization [Kurukulasuriya and Rosenthal (2003)] subject to various constraints such as lack of information, lack of money, shortage of labor, shortage of land and poor potential of labour. Thus, understanding the potential benefits and costs of various irrigation technologies adopted by farmers and factors determining their choice to a particular strategy merits huge attention by the policy makers for making efficient utilization of scarce resources to cope with adverse effects on climate change and achieve food and livelihood security in India. Under this background, the main objectives of the study are to estimate the potential benefits and costs of various irrigation technologies adopted by the farmers and to analyse the factors determining farmers' choice for a particular irrigation strategy.

2. Materials and Methodology

The present study pertains to Climate Change and its impact on agricultural technologies, which is a part of the ongoing National Initiatives on Climate Resilient Agriculture (NICRA) project initiated by Indian Council of Agricultural Research (ICAR) and carried out at National Academy of Agricultural Research Management (NAARM), Hyderabad, India. The present focus on primary data collected from Sholapur district of Maharashtra. Sholapur district is the victim of severe climate change and has resulted in erratic rainfall and occurrence of moderate to severe drought at regular intervals. A multi-stage purposive sampling method was adopted for collection of data at the household level. Based on the stress zone maps provided by the local district level officers, eight villages were purposively selected for the final household survey. Data on quantitative parameters was collected from 116 randomly selected farmers from eight villages and followed by several Focus Group Discussion (FGD) which yielded other useful village level information.

Data was collected as per the methodology proposed in the manual published in Cost of Production Survey, Government of India for estimating total cost of cultivation. Various types of costs incurred during crop production include monetary value of quantity of physical inputs, family and hired labour, animal and machine labour, interest on working capital, depreciation of machinery and rent. Annual rate of deprivation has been estimated using 'straight-line method'. It is noted that farmers practising mixed cropping system *i.e.* soyabean with bajra or jowar, mix of vegetables like bitter-gourd, ridge-gourd, bajra or jowar with grams, etc. to reduce the physical cost of production due to which certain costs included as a proportion of area under individual crops. Production benefits is obtained by the market value of the produce less transportation cost of produce.

Logistic model [Verbeek (2004)] has been utilised for identifying factors determining farmers' adoption of a certain irrigation technology against the adverse effects of climate change and is given by

$$P_i = \frac{1}{1+\exp\left(-\beta_0 - \sum_{j=1}^{k}\beta_j X_{ij}\right)} \qquad (1)$$

Log transformation of the model can be written as

$$L_i^* = \log\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \sum_{j=1}^{k}\beta_j X_{ij} + \varepsilon,\ i = 1, 2, 3, \ldots N \qquad (2)$$

Where, L_i^* is a latent variable ($L_i = 1$, if a farmer adapts any irrigation technology, $L_i = 0$ otherwise), ε is the error term and X_{ij} are the exogenous variables under study. Two types of irrigation strategies are mainly adopted by the farmers in the study area *i.e.* drip with mulching and sprinkler. Legit model has been estimated through maximum likelihood method [Verbeek (2004)].

Likelihood function of Legit model is

$$\log L(\beta) = \prod_{i=1}^{N} P\{y_i = 1|x_i;\beta\}^{y_i} \times P\{y_i = 0|x_i;\beta\}^{1-y_i} \qquad (3)$$

Substituting $P\{y_i = 1|x_i;\beta\} = F(x_i^*\beta)$, we obtain

Table 1 : Total investments, subsidy and extent of the benefits received from various irrigation projects.

Sl. No.	Irrigation Projects	Investments (in Rs. '000)		Support (Rs. '000)		# Benefit (%)
		Total	Average	Total	Average	
1.	Tube Well	12330	107.22	2125	18.32	68.42
2.	Well	3858	33.26	525	4.53	52.96
3.	Micro Irrigation Structure	2899	24.99	475	4.10	63.18
4.	Sprinkler	625	5.39	85	0.73	76.67
5.	Water Harvesting Structure	2924	25.21	280	2.43	33.53
6.	Mulching	1010	8.71	486	4.18	68.24
7.	Farm Pond	2100	18.10	865	7.46	54.29

Benefit during first year of instalment.

$$\log L(\beta) = \sum_{i=1}^{N} y_i \log F(x_i'\beta) + \sum_{i=1}^{N} (1-y_i)\log\left(1-F(x_i'\beta)\right) \quad (4)$$

Substituting the appropriate form for F gives an expression that can be maximised with respect to β. the first order conditions of the maximisation problem can be written by differentiating Equation (4) with respect to β as

$$\frac{\partial \log L(\beta)}{\partial \beta} = \sum_{i=1}^{N}\left[\frac{y_i - F(x_i'\beta)}{F(x_i'\beta)\left(1-F(x_i'\beta)\right)} f(x_i'\beta)\right] x_i = 0 \quad (5)$$

Where, $f = F'$ is the derivative of the distribution function.

In simple form, Legit model can be written as

$$\frac{\partial \log L(\beta)}{\partial \beta} = \sum_{i=1}^{N}\left[y_i - \frac{\exp(x_i')}{1+\exp(x_i')}\right] x_i = 0 \quad (6)$$

The solution of (6) is the maximum likelihood estimator $\hat{\beta}$. From this estimate we can estimate the probability that $y_i = 1$ for a given x_i as

$$\hat{P}_i = \frac{\exp(x_i'\hat{\beta})}{1+\exp(x_i'\hat{\beta})} \quad (7)$$

Then the first order condition imply that

$$\sum_{i=1}^{N} \hat{p}_i x_i = \sum_{i=1}^{N} y_i x_i \quad (8)$$

3. Results and Discussion

Sholapur district in Maharastra falls in low or eruptive rainfall zone, where farmers experience scanty rainfall over the whole year and moderate to severe drought once in 4 years. During last 15-20 years, farmers experience plethora problems in farming such as low groundwater availability, insufficient rainfall, damaged farming activities, low irrigation, increased soil salinity and increased disease infestation. As a result, farmers are forced to adopt some drought resistant technologies to mitigate adverse effects of climate change. But over the last several years, farmers have shifted their preferences to more beneficial market driven technologies. In the last decade, farmers made about Rs. 25747 thousands of investments in construction of tube wells (47.89 per cent), shallow wells (14.98 per cent), water harvesting structure (11.36 per cent), micro irrigation projects (11.26 per cent), farm pond (8.16 per cent), mulching (3.92 per cent) and sprinkler (2.43 per cent) (Table 1). From the table, it can be found that the highest investment was made in tube wells. Government also provided huge subsidies for digging tube wells. Growing demand for tube wells had created serious decline of the water table from 300 meter to 700 meter, which is uneconomical and is not a viable option. State government discourages digging of bore wells and subsidies (upto 50 per cent of total cost) are provided for construction of water saving technologies like micro irrigation project, water harvesting structures, farm pond, drip and mulching. Latest intervention is the construction of farm ponds on 50:50 sharing between the farmers and the State government and the beneficiaries are the farmer members of the Water User Association (WUA). Demand for farm ponds are also becoming highly

Table 2 : Area under different crops.

Crops	15-20 years ago			At present		
	Total area (acre)	Average	Std. Deviation	Total area (acre)	Average	Std. Deviation
Bajra	65	2.16	2.02	38	2.37	1.78
Bitter-gourd	-	-	-	55	4.58	3.68
Brinjal	2	2.00	-	45	4.50	1.84
Cotton	76	3.04	2.25	-	-	-
Grape	39	3.00	3.79	87	10.88	4.19
Groundnut	38.6	2.97	1.64	22	2.81	1.51
Harad	37	1.92	0.79	-	-	-
Harbara	31	1.94	1.12	28	1.96	1.25
Jowar	124	1.72	2.01	106	2.42	1.40
Maize	105.8	2.58	1.86	58	3.22	2.23
Moong	49	2.47	1.39	22	2.75	2.61
Onion	20	2.22	1.20	124	3.25	1.70
Papaya	-	-	-	29	3.69	2.87
Pomegranate	-	-	-	133	6.05	4.23
Ridge-gourd	2	2.00	-	32	2.67	1.30
Soyabean	36	2.96	1.96	75	4.17	2.45
Sugarcane	204	3.99	2.64	3	3.00	-
Sunflower	27.2	2.47	1.38	-	-	-
Tomato	6	3.00	0.00	144	4.24	3.17
Tur	52	1.91	1.30	25	1.19	0.60
Urad	25	3.57	2.76	-	-	-
Wheat	90	4.71	2.93	-	-	-

Table 3 : Costs of cultivation, profit and yield rate between the traditional and irrigation technology adopted farmers.

	Unit	Traditional farmers (N = 47)	Technology adopted farmers # (N = 69)	Mean Difference
Land preparation	Rs.	1650.21	4172.74	2522.53***
Labor	Rs.	2009.36	5203.04	3193.68***
Seed	Rs.	1085.96	2250.80	1164.84***
Fertilizer and manure	Rs.	1650.64	4136.17	2485.54***
Pesticide	Rs.	919.57	2361.59	1442.02***
Plant protection	Rs.	495.96	1308.97	813.01***
Irrigation	Rs.	2635.32	6427.46	3792.15***
Transportation	Rs.	416.96	802.32	385.36***
Interest	Rs.	912.34	1841.23	928.89***
Depreciation	Rs.	895.53	2264.64	1369.11***
Others cost	Rs.	702.55	1571.59	869.04***
Total cost	Rs.	13640.36	32340.57	18700.20***
Yield rate	Kg./Acre	30.08	48.66	18.58***
Profit	Rs.	36812.97	48986.28	12173.31***
Benefit-cost ratio	Ratio	1.82	3.01	1.19***

Note: *** significant at 0.01 percent level, # includes both Drip/mulching and sprinkler.

popular as a result a total of Rs. 2100 thousands have been invested for which on average each individual farmer in each group got Rs. 7.46 thousands as amount of subsidy.

Shortage of labour resulted in increased market demand for vegetables and horticulture crops which in turn resulted in adoption of sprinkler and mulching in these areas. These technologies are proved to save water upto 70 per cent. Table 2 shows change in cropping pattern over the past 15-20 years. Earlier farmers used to grow sugarcane, maize, jowar, wheat and cotton but growing these crops is not remunerative and hence farmers start growing vegetable crops such as tomato, onion, ridge-gourd and commercial crops such as grapes and sugarcane and vegetables like bitter-gourd and horticultural crops like pomegranate and papaya are also grown (Table 2). As growing cotton, sunflower and wheat are non-remunerative. Growing of crops such as maize, sugarcane and other staple food crops are also drastically declined. High variability is observed in these crops, which prove that these crops are limited to only few farmers.

Irrigation technology driven change in cropping pattern has increased significantly both production cost and yield. Table 3 clearly shows significant differences in irrigation, labour, fertiliser and land preparation among traditional and technology adopted farmers. It is the main reason for showing significant differences in per-acre yield rate, profit and finally benefit-cost ratio.

Results about the determinants of a particular adaptation strategy depends on various factors such as total area under cultivation, educational background of the family, access to subsidy and credit, extension services and collective action. Famers with more land ownership are more innovative and have the opportunity to adopt commercial agricultural production. It is observed that the probability of odd that a large scale farmer adapts sprinkler is more than that of drip/mulching. It is so because large scale farmers took first initiative to dig bore well and well and land was irrigated through sprinkler. Family education also

Table 4 : Determinants of Farmers' choice of a particular irrigation technology (Odd Ratios).

	Drip/Mulching with Traditional		Sprinkle with Traditional	
	B	S. E.	B	S. E.
Land (acre)	1.844***	0.234	2.483***	0.253
Family Education	1.005	0.077	1.228**	0.114
Household age	0.919	0.054	0.969	0.068
Benefit-cost Ratio	1.67*	0.296	2.968***	0.364
Access to Subsidy	34.199***	1.089	208.104***	1.545
Access to Credit	10.309**	0.976	2365.494**	3.181
Insurance Benefit	1.768	1.032	1.379	1.542
Collective Action	8.629**	1.017	7.247	1.284
Extension Service Facility	4.081	0.994	17.642**	1.302
-2 log Likelihood	88.956			
Goodness-of-Fit (Pearson)	187.945			
Pseudo R-Square Cox and Snell Nagelkerke	 0.750 0.849			

***significant 1% level, **significant at 5% level, *significant at 10% level.

significantly plays positive role for adaptation of sprinkler while that of drip and mulching is not significant. Benefit-cost ratio also increases the probability of odd of household adapts both sprinkler and drip. Provision of subsidies and credit are significantly playing most critical role because these are the main institutional mechanism widely helped the farmers to adopt new technology. It is here to be noted that while collective action has increased the probability of odd that farmer has adapted mulching, no significant role is found in case of sprinkler. It is so because collective action is found in case of construction of farm ponds and water stored is irrigated though drip and mulching. But use of sprinkler is associated with bore well and wells, adoption of which purely depend on farmer's own production decisions. Another peculiar finding of this study is that extension service does not influence significantly influences farmer's adaption of drip and mulching, even though mulching saves more water than the sprinkler.

4. Concluding Remarks

Adoption of any irrigation technology depends on level of water availability, high benefit-cost ratio and adequate institutional provisions. Limited progress of these technologies, however, observed due to unsustainable groundwater exploitation and inadequate institutional provisions. Success and failure of farm level collective action and institutional mechanism provides many important conclusion of the study. It is believed that provision of subsidies for development of groundwater recharge techniques instead of giving for digging new bore wells; rehabilitation of tanks and connecting with available perennial water sources; increase efficiency of farm ponds by reducing percolation and evaporation losses and implementation of watershed programme to reduce wastage of rainwater are some of the measures that can be adopted to improve farm level efficiency.

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