Factors affecting and farmers' perception of the adoption of water-saving irrigation technologies in semi-arid states in India

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Abstract

Water deficiency poses a severe threat to food security, and it creates an uncertainty that has to be overwhelmed in the process of socio-economic development of India. Therefore, it is needed to adopt water-saving irrigation technologies to avoid water scarcity in the future. This study explores the determinants influencing the adoption of water-saving irrigation technologies including drip and sprinklers is estimated using a probit model and data from India Human Development Survey-II, 2011-12, a selected sample of 2912 households in semi-arid states of India. The results exhibit that the factors of farmers' income, size of landholding, Kisan Credit Card (KCC) and education were statistically significant and positive impact with the adoption of drip and sprinkler irrigation technologies. Besides, the outcomes indicate that the efficiency of water use is considerably higher under these water-saving technologies would benefit to reducing the cost of cultivation for large farmers, improving productivity of crops and as well as the socio-economic conditions of the farmers compare with non-adoption farmers. Lastly, the study concludes that these water-saving irrigation technologies must be expanded to other regions to elucidate the advantages of these irrigation technologies through proper extension services, so that they can be get higher crop productivity using limited resources of water and also economically benefit.

Keywords: Water saving, technologies, adoption, agriculture, economic benefit

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1.Introduction

Water scarcity is currently a global issue and it severely affects the arid and semi-arid regions and countries in the world. The studies of global climate models (GCM) projected that there is a significant change in rainfall pattern and air temperature leads negative impact on crop production and water resources (Kurylyk and MacQuarrie, 2013). Specifically, it will threaten the rural livelihoods dependent on rainfed agriculture and overall food security in the countries (Singh et. al 2018; Gosling & Arnell 2016). The country like India where agriculture is playing a vital role in the upliftment of rural livelihoods and it reports 50 percent of the total work force is involved in the agriculture sector (CIA, 2017). The semi-arid regions (SARs) of India face dynamic climatic and non-climatic risks, makes farmers and communities in these areas are highly vulnerable. Further, the climate change has the potential threat to the water resources and agriculture sector where 75 percent of the cropped areas is in semi-arid areas in the country. Therefore, a proper and long-term resilience solutions such as an innovative technology options are required to tackle these risks and to enable the efficient and sustainable utilization of water resources. The micro-irrigation (MI) technologies are believed to be one of such innovative interventions drip and sprinkler irrigation methods are increasing in the recent past.

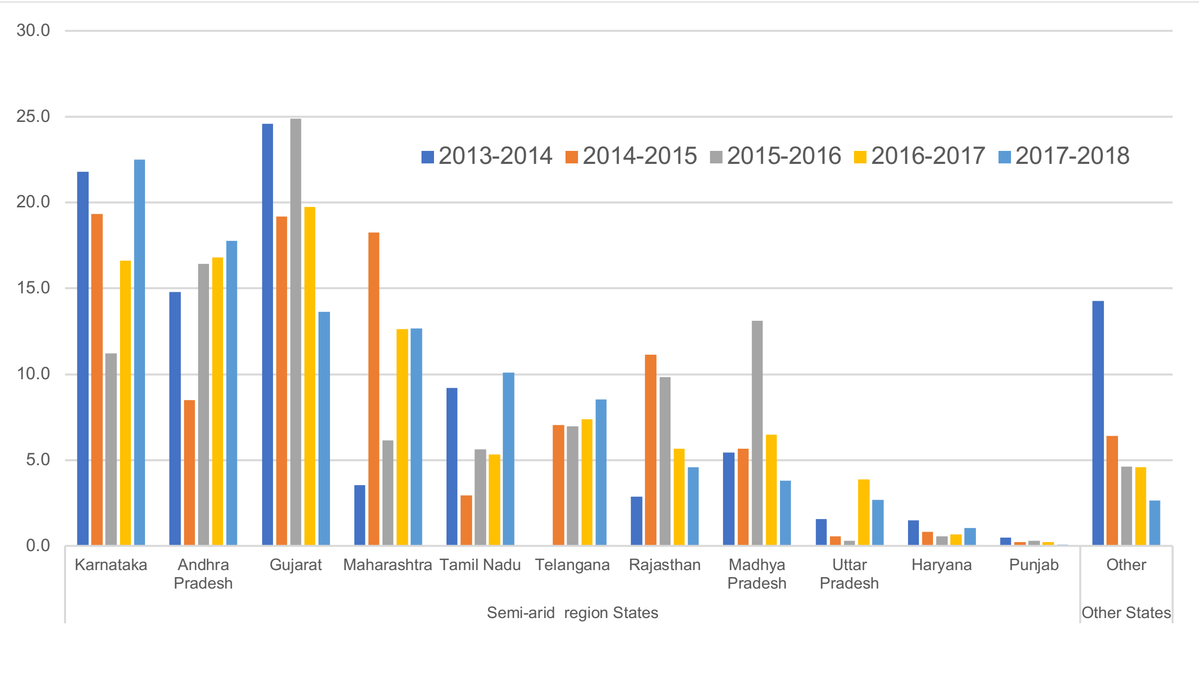
Several studies have attempted to study the impact of micro-irrigation technologies (drip irrigation) and have found that MI technologies produces the anticipated positive impacts (Kumar and Palanisami, 2010; Narayanamoorthy, 1997, 2003, 2005, 2007; Namara et. al. 2005; Dhawan, 2002; Verma et. al. 2004; Magar et. al. 1988). It is shown that the MI technologies are technically viable and environmentally feasible, particularly when the farmers depend on groundwater sources (Kumar and Palanisami, 2010; Dhawan, 2000). In many parts of the country and elsewhere, these have yet to be adopted extensively. Keeping these concerns in view, the present paper has focused the following important issues: (1) what the factors are influencing to adopt MI technologies in semi-arid area states in India? (2) what are the difficulties and causes to not to adopt the MI technologies. At the macro level, very few studies attempted to study the potential and prospects of drip and sprinkler irrigation, covering various states in India (Narayanamoorthy, 2007). But, for this paper, we have attempted to study the semi-arid area of top ten states in India that are highly dependent on agricultural farming. The primary objectives of this study are to estimate the total area covered under drip and sprinkler irrigation in semi-arid area states. To identify the significant factors that are influencing farmers' adoption of irrigation technologies. Finally, to determine the farmers' perception and experiences through focus group discussion (FGD) on MI technologies semi-arid southern state of Andhra Pradesh.

The paper is organized into seven sections. Following the introduction, section two presents the current situation of the area under MI technologies in India. A potential and actual area under MI technologies in semi-arid states showed in section three. The methodology is present in section four, and the research results are presented in section five. Focus Group Discussion (FGD) on MI technologies in section six. A brief conclusion is presented in the last section.

2. Current Situation of Micro-Irrigation Technologies in India

Micro-irrigation (MI) is introduced mainly to save water and increase water use efficiency in agriculture and indirectly brings various other economic and social benefits of the society. Both drip and sprinkler irrigation technologies are treated as MI. These MI technology leads to gain the productivity ranges of 20 to 90 percent for different crops (INCID, 1994; 1998, Narayanamoorthy, 2007). Besides, the expansion of drip irrigation was extremely slow in the earlier years and from the 1990s, it has been achieved significant development due to several schemes introduced by the government of India and states like Maharashtra followed by other semi-arid states Andhra Pradesh, Karnataka, and Tamil Nadu.

Figure-2: State-wise Area Covered under Micro-Irrigation Technologies (Drip and Sprinkler) in India, 2013-14 to 2017-18



Source: http://indiastat.com

Nevertheless, having immense potential for the development of MI technologies does not match the expectations in a maximum number of the semi-arid states. Earlier studies clearly stated that the drip-irrigated area had improved significantly between 1991-92 and 2000-01 in all the semi-arid states of India (Narayanamoorthy, 2007; Saleth, 2009). However, the share

of area under drip-irrigated to gross irrigated area was only 0.48 percent throughout the year 2000-01. Figure-2 presents the state-wise area covered under micro-irrigation technologies in India between 2013-14 to 2017-2018. It is witnessed that the micro irrigated area has been increased significantly in Telangana state (8.5 %) between 2014-15 to 2017-18. The southern semi-arid state Karnataka obtained top spot and expanded their micro irrigated area about 22.5 in 2017-18 followed by Andhra Pradesh (17.8 %), Maharashtra (12.7 %) and Haryana (1.0 %). The other semi-arid states like Gujarat (13.6 %), Madhya Pradesh (3.8 %) and Punjab (0.1 %) are shown to decrease their micro irrigated area. Remarkably, the semi-arid state of Tamil Nadu registers variation trend from (5.6 %) in 2015-2016 to (5.3 %) in 2016-2017. However, it has been ranked fifth in the position to expand the micro irrigated area (10.1 %) in 2017-18.

3. Potential and Actual Area under Micro-Irrigation Technologies in Semi-arid States

The importance of micro-irrigation technologies has been assessed that there is a potential of carrying around 37 million ha under drip and sprinkler irrigation in the semi-arid states in India (Table-1). For the sprinkler irrigation, the potential area of 27 million ha is appropriate for crops include cereals, pulses, oilseeds, and fodder crops. For drip irrigation, the potential area around 10 million ha under commercial crops and fruits and vegetables and pulse crops (Palanisami et al. 2010).

Table-1: Potential and Actual Area under MI in Semi-arid States (Area in 000' ha)

State	Drip			Sprinkler			Total		
	Potential	Actual	%	Potential	Actual	%	Potential	Actual	%
1. Andhra Pradesh	730	363.07	49.7	387	200.95	51.9	1117	564.02	50.5
2. Karnataka	745	177.33	23.8	697	228.62	32.8	1442	405.95	28.2
3. Maharashtra	1116	482.34	43.2	1598	214.67	13.4	2714	697.01	25.7
4. Tamil Nadu	544	131.34	24.1	158	27.19	17.2	702	158.53	22.6
5. Haryana	398	7.14	1.8	1992	518.37	26.0	2390	525.51	22.0
6. Rajasthan	727	17.00	2.3	4931	706.81	14.3	5658	723.81	12.8
7. Gujarat	1599	169.69	10.6	1679	136.28	8.1	3278	305.97	9.3
8. Madhya Pradesh	1376	20.43	1.5	5015	117.69	2.3	6391	138.12	2.2
9. Punjab	559	11.73	2.1	2819	10.51	0.4	3378	22.24	0.7
10. Uttar Pradesh	2207	10.68	0.5	8582	10.59	0.1	10789	21.27	0.2
Other States	1658	37.71	2.3	2720	270.73	10.0	4378	308.44	7.0
Semi-arid States (1-10)	**10001**	**1390.75**	**13.9**	**27858**	**2171.68**	**7.8**	**37859**	**3562.43**	**9.4**
All India	**11659**	**1428.46**	**12.3**	**30578**	**2442.41**	**8.0**	**42237**	**3870.87**	**9.2**

Source: Palanisami et. al (2011); Raman (2010) and Indiastat 2010

The actual area under drip and sprinkler irrigation are still less than below 50 percent to meet with potential area and however it is varying between one state from other states, compare

with other semi-arid states, Andhra Pradesh (49.7 %) performs well followed by Maharashtra (43.2 %), Tamil Nadu (24.1); Karnataka (23.8 %), Gujarat (10.6). On the other hand, the actual area under sprinkler irrigation was performed well by the semi-arid state Andhra Pradesh (51.9 %), followed by Karnataka (32.8 %), Haryana (26.0 %), Tamil Nadu (17.2 %) and Rajasthan (14.3 %). The semi-arid state of Uttar Pradesh is underachieved in both drip and sprinkler technologies. The possible cause could be the central schemes on MI technologies did not get decent response during the Seventh Plan because the subsidy was limited to only small and marginal farmers. Moreover, due to lack of proper investment, these farmers could not afford the MI technologies (drip irrigation) even at the subsided price.

4. Methodology

4.1. Sampling Framework

According to the CWC report, most of the drought-prone districts spread over 14 states in India. But, the record vulnerable areas are concentrated in the states like Rajasthan, Karnataka, Andhra Pradesh, Maharashtra and Tamil Nadu. For this paper, we attempted to identify the factors affecting the adoption of different MI technologies in the semi-arid states Gujarat, Madhya Pradesh, Punjab, Uttar Pradesh, and Haryana, including states as mentioned above. Altogether we have selected ten semi-arid states (Figure-2) for the study.

Figure-2: Selected Semi-arid States in India

Both secondary and primary data were collected. The secondary (farming household) data collected from the India Human Development Report (IHDP) survey 2011-12 carried out by

the University of Maryland, USA and the National Council of Applied Economic Research (NCAER), New Delhi containing information on socio-economic, size of landholding, farming practices and combine it with information of the head of the household from the individual. The selected farming households from only those villages where there is an identified case of at least having drip or sprinkler technology, and other farming households from the same village were selected as the control group (Table-1). On the other side, the primary data is mainly on selected focus group discussion among farmers in East Godavari district, Andhra Pradesh, India. For this paper, we consider only the farming households reporting their land holdings and engagement in the farm cultivation in the last one year.

Table 1: Sampling distribution across the semi-arid states

State	No. of Treated Households			No. of Control Households	Total No. of Households
	Drip	Sprinkler	Micro irrigation (both)	Non-Adopters	
Punjab	11	7	18	88	106
Haryana	14	11	25	159	184
Rajasthan	14	83	97	507	604
Uttar Pradesh	12	8	20	172	192
Madhya Pradesh	32	19	51	265	316
Gujarat	6	3	9	88	97
Maharashtra	72	57	129	589	718
Andhra Pradesh	8	6	14	71	85
Karnataka	37	63	100	504	604
Tamil Nadu	7	1	8	7	15
Semi-Arid Region	213	258	471	2450	2921

Source: Author's computations from India Human Development Survey-II, 2011-12

4.2. Study area and Data Collection

4.2.1. Data Analysis

To enable the selection of an appropriate econometric model for analyzing the factors influencing the adoption of different micro-irrigation technologies (drip, sprinkler and drip & irrigation) by farming households. The MI technologies adoption variable is a discrete-dichotomous variable; a farming household is either having these MI technologies such as drip, sprinkler and both considered as (adopter) and not having any MI technology is non-adopter. The probit and logit models are most commonly used to estimate the technology adoption methods (Feder et. al. 1985; Namara et. al. 2005; Chuchird et. al. 2017; and Oladeji et. al 2005). In this paper, a probit model was employed for the study.

$Y_i = \beta_o + \sum_{i=1}^{10} \beta_i X_i + \epsilon$ ---------- (1)

Where Y_i is the micro irrigation technology adoption (1 if adopted and 0 otherwise); β_o is the intercept; β_i is the vector of the parameter estimates; X_i is a vector of the explanatory variables; and ϵ is the random disturbance term. Table-2 exhibits the explanatory variables (X1-X10) that are comprised of gender education, caste, farmers' income, orchard plantation, benefit from government, size of landholding, KCC, source of water, and semi-arid States.

Table-2: Variables of the probit model used to determine the influencing factors of the adoption of micro-irrigation technologies

Representation	Variable Name	Description	Variable Type/Criteria
Y	Adoption (Dependent Variable)	Farmer's adoption of micro irrigation technology	Dummy: 1 if adopted, 0 otherwise
X1	Education	Years of education	Continuous variable
X2	Gender	Respondent's Gender	Dummy: 1=Male, 2=Female
X3	Caste	Respondent's Caste	1= Forward, 2=OBC, 3=SC & ST, 4=EBC or others
X4	Farmers' Income	Farmers' annual household income	Categorized the farmers' income by percentile
X5	Orchard Plantation	Area under plantation/orchards	Dummy: 1 if have plantation, 0 otherwise
X6	Government Benefit	Drought/flood compensation from government	Dummy: 1 if receive, 0 otherwise
X7	Size of Landholding	Total cultivated area in (ha)	1=Marginal (<1.0 ha), 2=Small (1.0-2.0 ha), 3=Semi-Medium (2.0-4.0 ha), 4=Medium (4.0- 10.0 ha); 5=Large (above 10.0 ha)
X8	KCC	Kisan Credit Card	Dummy:1 to have card, 0 is otherwise
X9	Source of water	Types of water sources	1= Rainfed, 2=Tube well, 3=River or Canal, 4=Other water bodies
X10	State ID	Semi-arid states	Punjab, Haryana, Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu

5. Results and Discussions

The table-3, presents the probit model results for three micro-irrigation technologies (drip, sprinkler, drip and sprinkler) influencing the factors of the adoption of MI technologies of the farming households across top ten semi-arid states India. Particularly, model-1, the drip irrigation adoption was statistically associated with level of education, household income, size of landholding (large farmers), Kisan Credit Card, source of irrigation: tube well, other water bodies, and river or canal); and the states Andhra Pradesh, Karnataka and Tamil Nadu. In model-2, the adoption of sprinkler irrigation is statistically related to the medium size of landholding farmers other than the same as other factors linked with the adoption of drip irrigation except the determinant of orchard. Interestingly, the model-3 shows that the factors of education, household income, KCC, large farmers, and tube wells are statistically significant with the adoption of both drip and sprinkler irrigation.

Table-3: The probit model results of the factor influencing the adoption of variable micro irrigation technologies

Factors	Model1: Drip Irrigation		Model2: Sprinkle Irrigation		Model3: Drip & Sprinkle Irrigation	
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
Education	0.03**	0.01	0.02**	0.01	0.03**	0.02
Gender (Male)	0.09	0.16	0.08	0.14	0.26	0.26
Caste (Forward)						
OBC	-0.07	0.10	0.08	0.10	-0.04	0.15
SC & ST	-0.31**	0.15	-0.26***	0.15	-0.26	0.27
Others	-0.34	0.36	0.08	0.25	-0.30	0.60
Household Income	0.07*	0.02	0.08*	0.02	0.05***	0.03
Orchard	0.36*	0.12	0.01	0.11	0.33***	0.19
Benefit from Government	0.13	0.18	0.20	0.17	0.13	0.26
Size of Landholding, ha (Marginal Farmers)						
Small	-0.34***	0.19	0.02	0.16	-0.20	0.30
Semi-medium	-0.11	0.17	0.07	0.15	-0.46	0.33
Medium	0.15	0.17	0.34**	0.15	-0.04	0.28
Large	0.60*	0.18	0.73*	0.17	0.60**	0.30
Kisan Credit Card (KCC)	0.36*	0.11	0.28*	0.10	0.48*	0.18
Source of Irrigation (Rainfed)						
Tube well	0.89*	0.13	0.92*	0.10	1.07*	0.24
River or Canal	0.51**	0.21	0.85*	0.18	0.26	0.48
Other water bodies	0.78*	0.22	0.61*	0.22	1.07*	0.36
State ID (Punjab)						
Haryana	0.05	0.23	0.11	0.26	0.11	0.33
Rajasthan	-0.27	0.22	1.00*	0.23	-0.14	0.33
Uttar Pradesh	0.35	0.24	0.36	0.27	-	-
Madhya Pradesh	0.30	0.22	0.19	0.25	-0.67*	0.38
Gujarat	0.23	0.31	0.03	0.36	-	-
Maharashtra	0.44	0.20	0.54**	0.22	0.39	0.30
Andhra Pradesh	0.64**	0.28	0.69**	0.31	0.81**	0.40
Karnataka	0.37***	0.23	1.13*	0.24	0.28	0.36
Tamil Nadu	1.81*	0.47	0.39	0.58	-	-
Constant	-3.25	0.35	-3.74	0.35	-4.06	0.58
Log pseudolikelihood	-571.88		-690.07		-203.48	
Wald Chi2	307.10		277.66		168.05	
Prob>Chi2	0.0000		0.0000		0.0000	
Pseudo R-Squared	0.2496		0.2082		0.2781	
Number of Observations	2912		2912		2609	

* Significant at the 0.01 level, **significant at the 0.05 level, and *** significant at the 0.10 level

The socio-economic indicators of education, caste, and income are important factors to determine the adoption of micro-irrigation technologies. In all the three MI models, education exhibits positive and statistically significant, which indicates the level of education creates much awareness and the importance of usage of technologies. Furthermore, the caste indicator, particularly SC & ST had negative and significant effect on probability adoption of MI technologies due to lack of proper investment this group could not afford the MI The farm income was statistically significant and positively correlated in all the three models, which suggested that the increased income from their crop contributed to the better likelihood of the MI technology options. The size of landholding medium and large farmers were significantly positively and associated with the adoption of MI technologies. Thus, an increase in the landholding contributed to an increased probability of the MI technologies in semi-arid areas.

On the other hand, the adoption of drip irrigation and small farmers' size of landholding were significantly negatively correlated, which clearly suggests that small farmers have difficulty in adopting drip irrigation technology. According to the previous studies, access to credit and subsidy increases the adoption of MI technologies among small and marginal farmers (Kumar 2016). The positive association between Kisan credit card and MI technologies are statistically significant and positive, which shows that the KCC is offered to the small and marginal farmers for allied activities such as pump sets, plantation and drip irrigation. As expected, the source of irrigation tube well, river or canal and other water bodies was significantly and positively correlated with the MI technologies drip and sprinkler irrigation. The state of Andhra Pradesh, Karnataka and Tamil Nadu shows statistically significant and positively associated with micro-irrigation technologies. Earlier studies revealed that the adoption of MI technologies: drip irrigation is largely found in semi-arid states like Maharashtra, Andhra Pradesh and Tamil Nadu; and the sprinkler irrigation technology mostly adopted in semi-arid states Madhya Pradesh and Rajasthan (Narayanamoorthy, 2007; INCID, 1994; 1998, and GOI, 2004).

6. Focus group discussion on MI technology

The data for this quantitative part of our study were collected as part of the project water for sustainable development, funded by Ministry of Environment, Japan. The study used data collected through five focus group discussion (FGDs) in East Godavari districts of Andhra Pradesh during June 2019. The FGDs were conducted using an FGD guide for covering barriers and facilitating factors affecting the adaptation of drip and sprinkler irrigation. The FGDs were conducted in local languages and were audio-recorded. Audio recordings were translated into English, taking care to convey the feelings of the participants and to avoid bias due to different grammatical structure of the language. The resulting transcripts were analyzed and arranged under different themes using QSR International's NVivo 11 qualitative data analysis software.

6.1. Perceived barriers to an adaptation of micro-irrigation technology

The analysis of the FGDs exhibits that there are four main barriers suggested by adopters and non-adopters of drip and sprinkler irrigation.

6.1.1 Land Tenure

In our selected villages, the majority of the farmers had leased land, whereas the subsidy scheme for micro-irrigation, particularly drip irrigation is primarily focused on land ownership as an important criterion for getting the subsidy.

"I am a small farmer cultivating on leased land, I cannot get government support for installing drip irrigation in my farm". R Rama Suresh, 33, Vangala Pudi village

6.1.2 Type of crop grown

Drip irrigation seems to be working well for the farmers having plantations like palm tree as the majority of them are found to be satisfied with the drip irrigation. Notably, the sample village Ramavaram village, Jaggampeta where farmers were growing palm trees, the majority of them were pleased with it. They reported the technique to be easy to handle and labor-saving. However, in Raghavapuram village, the majority of the farmers said growing cereals and not willing to diversify into horticulture. The primary reason behind this unwillingness is, first, the subsistence nature of agriculture; they want to plant enough cereals to secure the availability of food for the family round the year. Secondly, they reported the incidence of wild monkeys destroy the horticulture crops.

"I have a four acres plot where I have planted palm trees, drip irrigation is a boon for me, as it helps me manage the entire farm alone". P Srinivasulu, 48, Ramavaram Village

"We are small farmers, we mostly grow rice where we find drip irrigation not useful at all…in spite of suitability of soil and climate it is difficult to grow fruits and vegetable in this area because there are monkeys and other wild animals. They often attack our farms".
Perarapu Koteswara Rao, 47, Raghavapuram village

6.1.3 Prevalent agriculture practices

The choice of irrigation technique also depends on the agriculture practices in the area. The village Srikrishna Patnam is predominantly grown horticulture crops like lemon, cashew and custard apple crops. All these three crops are grown by the farmer within one plot with an average size of landholding around 5 acres. They specified that the handling of drip irrigation is a burden every time by plowing the field before harvesting the crop.

"Before harvesting the fruits, we usually plough the fields to make the ground loose, this minimizes the crop damage during its harvesting. Drip irrigation does not allow us to plough the field swiftly, therefore, we prefer surface irrigation".
Rajamandrapu Lakshmana Rao, 45, Srikrishnapatnam village

6.1.4 Lack of coherence between agriculture scheme

The drip irrigation technology is suitable for the farmers how are having their own borewell. Farmers described that getting drip irrigation is not an issue, but their primary concern is

getting their own tube well. As the water level is below 150-500 feet, it is quite expensive to get a borewell. The government is giving subsidy for installing drip irrigation not for a bore well. Therefore, small farmers in this region found the subsidies not substantive enough to fulfill.

"Getting drip irrigation is not an issue as it is highly subsidised, our main concern is getting water in the field. The water table in the area is very low and it is very expensive to get a borewell in the field. We do not get any support from the government for that".
Bottala Vishnu,60, Sri Rangapatnam

7. Conclusions

The study provides insights into the current situation and potential adoption of MI technology in the semi-arid states in India. The adoption rate of MI technology is still very low compared with potential area. However, the semi-arid state like Andhra Pradesh, Maharashtra and Tamil Nadu expanded potential area progressively under this technology, but, the state like Uttar Pradesh and Madhya Pradesh least expanded in both drip and sprinkler technology due to lack of extension services and other motivating factors. The poor adoption could be credited with various determinants such as size of landholding, access of credit, farmers' income, availability of water resources, the subsidy from the government. The empirical estimation based on the probit model reveals the factors: socio-economic indicators of education, caste, income, landholding (large farmers), kisan credit card have a positive and statistically significant in influencing the adoption of MI technologies in semi-arid states. With support to the previous studies, the semi-arid state of Andhra Pradesh, Karnataka, and Tamil Nadu have statistically significant and positively associated with drip irrigation technology and the states like Maharashtra, Karnataka and Rajasthan was significantly correlated with adoption of sprinkler irrigation technology (Narayanamoorthy, 2007; INCID, 1994; 1998).

Lastly, from the results of farmers' focus group discussion (FGD), one of the farmers expressed about MI technology, drip irrigation is not an issue to adopt as it is highly subsidized. Still, the primary concern for them is to access water in the field. The water table in some parts of East Godavari district, Andhra Pradesh is very low, and it is very expensive to get a borewell in the field. It undoubtedly exhibits that the farmers are willing to adopt MI technologies, but, due to lack of proper investment, the small and marginal farmers could not afford these technologies even at the high subsided price (Palanisami et al 2010), predominantly in the dominant semi-arid states.

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