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Determinants of Adopting and Accessing Benefits of Environmentally Benign Technologies: A study of Micro Irrigation Systems in North Gujarat, Western India

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Determinants of Adopting and Accessing Benefits of Environmentally Benign Technologies: A study of Micro Irrigation Systems in North Gujarat, Western India

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Abstract

The state of Gujarat in western India is mostly covered by arid and/or semi-arid regions, where half of the rural households depend on agriculture. The state receives the monsoon rainfall for about 30-35 days in a year with high variation in temperature and rainfall. Therefore, irrigation, mainly through groundwater sources, has been promoted over the years, which acts as an insurance against drought. Intensive use of groundwater driven by tubewells had resulted in depletion and contamination of groundwater sources. To address the worsening groundwater scenario, the state government has been promoting the adoption of micro irrigation system as an environmentally benign technology among the farmers especially in water scarce regions in recent years. The Gujarat Green Revolution Company (GGRC) Limited acts as a nodal agency to implement micro-irrigation in the state, and the government provides financial incentive in the form of subsidy in a range of 50-75% of the total investment costs. In the context of India, the studies so far address two broad issues: (i) farmers' adoption behaviour, and (ii) socio-economic and physical benefits of adopting micro-irrigation. It may be noted that hardly a few studies have investigated the role of subsidy in enhancing the adoption rate in the recent years. Nevertheless, there is a gap in the literature examining the importance of factors, such as seasonality and cropping patterns in accessing the benefits of micro-irrigation in the Indian context. This paper tries to address this by exploring two key objectives, namely: (i) the influence of subsidy in enhancing adoption rate, particularly in the recent years; and (ii) the effects of seasonality and cropping patterns on accessing the benefits. For empirical assessment, Banaskantha district was selected as the study area, which is a water scarce region located in the northern Gujarat. The study covered 143 public tubewells on which micro-irrigation system was implemented by the Gujarat Water Resource Development Corporation (GWRDC), and in total, 355 farmers were randomly selected out of 650 beneficiaries. The results suggest that: (a) subsidy significantly influenced the increasing adoption of MIS in recent years; and (b) the benefits of MIS largely confined to the specific season and cropping patterns adopted by the farmers. From a policy perspective, this analysis could help in terms of identifying and promoting specific crops/ cropping patterns that show better outcome impacts of investments in micro-irrigation.

Keywords: Micro-Irrigation, Subsidy, Seasonality, Cropping Patterns, Gujarat, India
JEL: D12, Q12, Q55, Q58

1. Introduction

Water scarce regions in India are highly constrained by high cost of water extraction for agriculture and any other competing uses, including industry, urban water provision, etc. This is mainly due to two important factors: (i) groundwater potential is very low in the hard rock areas of the southern and western India; and (ii) groundwater aquifers are already over-exploited in most parts of the south Indian peninsula, western India and alluvial north-western India (Kumar, 2014). While the extent of groundwater extraction, for instance, has even far exceeded the net annual groundwater availability in some states of India, like Punjab, Haryana and Rajasthan, the stage of groundwater development (SGWD) is fast approaching the critical limits (SGWD>68%) in other states, such as Gujarat, Karnataka, Uttar Pradesh, etc. (Government of India, hereafter GoI, 2014). The over exploitation and the resultant depletion of groundwater had caused lowering of water levels, desertification of agricultural lands, increase in cost of construction of wells/ bore wells, installation of pumps [mostly, submersible]; and the already declined well yields increase the cost per unit of water pumped (Kumar, 2007).

Gujarat state in western India is one of the water scarce regions with unique agro-climatic features, characterised mostly by arid and semi-arid areas that experience acute scarcity of water. Two major factors are identified responsible for this. First, the distribution and availability of freshwater across the agro-climatic regions is highly skewed, i.e., almost 70% of the state's fresh water resources are confined only to 30% of its geographical area, mostly located in South Gujarat (Kishore, 2013). Second, the state receives rainfall for about 30-35 days in a year, and around 95% of it occurs during the monsoon season (Mehta, 2013). In addition, high variations in temperature and rainfall are observed across the eight agro-climatic regions (Ray *et al.*, 2009; Hiremath and Shiyani, 2012; Mehta, 2013). Hence, the state experiences frequent droughts (Mall *et al.*, 2006; Kishore, 2013). Almost half of the rural households of the state depend on agriculture (Census, 2011), where intensive agricultural operations are distinctly influenced by the availability of rainwater and groundwater. Considering irrigation as the major insurance against drought (Shah, 2009), the proportion of irrigated area in the state had increased over the years from 7% of the gross cropped area (GCA) in 1960-61 to 40% by 2011-12 (Government of Gujarat, hereafter GoG, 2008, 2013); but, around 80-85% was irrigated through groundwater sources (Kishore, 2013; Viswanathan and Pathak, 2014).

It is reported that the large scale adoption of water intensive cropping pattern acts as one of the major determinants in achieving higher agricultural growth rate in the state and increasing the cropping intensity (Shah, 2009; Viswanathan and Pathak, 2014). However, this leads to the over-extraction and contamination of groundwater. For example, in the six states (Gujarat, Haryana, Maharashtra, Punjab, Rajasthan and Tamil Nadu), around 54% of the total assessment units were identified as semi-critical, critical or overexploited, compared with a national average of 29% in the year 2005 (GoI, 2007). In Gujarat, the overall level of development of groundwater resources was around 67% as of 2011, with four districts (Banaskantha, Gandhinagar, Mahesana and Patan) showing over-exploitation (i.e., SGWD>100%) and five districts (Ahmedabad, Kutch, Porbandar, Rajkot and Sabarkantha) falling in grey or semi-critical categories (65-85%) (GoI, 2014). While the groundwater development scenario has been a matter of great concern, it is also critical to consider that the over-exploitation of groundwater resources has been contingent upon energisation and intensive use of pump sets, causing a sharp rise in agricultural power consumption in various states of India, including Gujarat (Viswanathan and Bahinipati, 2015).

Hard-pressed by the multifaceted challenges affecting agricultural development, many of the states in India, including Gujarat have been devising strategies and programmes for popularizing the adoption of environmentally benign policies and technologies that help in releasing the pressure of agriculture on water and energy, which got intensified by the unscrupulous agricultural practices promoted during the green revolution (GR) era. Apparently, it may be argued that the technological interventions, like the micro irrigation systems (MIS), currently being promoted at the national and state levels, bear the testimony of environmentally benign means of doing away with the environmental, agro-ecological and hydrological damages caused by the wider adoption of the GR technologies[1].

Thus, the impending water crisis along with potential challenges of adverse environmental and climatic uncertainties in a way motivated many of the Indian states, including Gujarat to adopt prudent strategies and technological interventions for saving the precious water resources from being depleted and degraded further. Since the mid of last decade, the GoI has, therefore, been promoting the micro-irrigation systems (MIS) under the National Mission on Micro-Irrigation (NMMI); the prime objective is to reduce water footprint and increase yield. In order to enhance the adoption rate, both the GoI and individual state governments provide subsidy that varies with respect to landholding, caste and geographical location (IRAP, 2012). Being a water scarce state, the Government of Gujarat (GoG) has been taking a special initiative to enhance the wide scale adoption through instituting a special purpose vehicle (SPV), named as Gujarat Green Revolution Company Limited (GGRC), which is the nodal agency for implementing the MIS programme in the state. The amount of subsidy given to farmers range from 50-75% (Indian Rupee (INR) 60,000 to 90,000; a detailed explanation is given in the next section) depending on the status of beneficiaries with respect to caste, landholding and geographical locations (IRAP, 2012).

In the Indian context, the empirical literature on MIS so far looks into two aspects: (i) determinants of adoption (Namara *et al.*, 2007; Palanisami *et al.*, 2011), and (ii) socio-economic and physical benefits of MIS adoption (Palanisami *et al.*, 2002; Kumar *et al.*, 2004;

[1] The popularization and adoption of Green Revolution technologies in India has been stimulated under the subsidy policy regime (called as 'environmentally damaging subsidies' in the current parlance), by which the national and state governments offered fertilizer, irrigation and power subsidies to the farmers across states. Estimates show that there has been almost threefold increase in the agricultural subsidies provided by the Government of India from US$ 9700 million during 2000-01 to US$ 28500 million during 2008-09. Of this, the three major subsidies, viz., fertilizer, irrigation and power together accounted for almost 70% of the total agricultural subsidies (Government of India, Ministry of Agriculture).

Narayanamoorthy, 2004; Kumar, 2007; Kumar and Palanisami, 2011; Kumar and van Dam, 2013). Since MIS adoption rate is much lower, ie., only 10% of the total MIS potential area in India as of 2010 (Palanisami *et al.*, 2011), a few studies investigated the socio-economic and physical constraints in adopting MIS. However, it is now observed that a large number of farmers adopted MIS in the current decade, particularly in the Gujarat state. Such enhanced adoption trend needs to be examined, particularly, to confirm *'whether subsidy has any impact on increasing the adoption rate in the recent years?'*. In fact, to our knowledge, this remains a grey area needing further empirical investigations across regions/ states. Further, specific studies on the impact of MIS in India as undertaken by various scholars broadly looked at: (a) the physical impact of water-saving technologies (WSTs) on irrigation water use (Narayanamoorthy, 2004); (b) the impact of WSTs and water-efficient crops on crop water productivity in physical terms [kg/m^3 of water consumed] (Kumar, 2007; Singh 2013; Kumar and van Dam 2013); (c) the benefit-cost analysis of MIS, such as drips and sprinklers (Palanisami *et al*., 2002; Kumar *et al*., 2004; Narayanamoorthy, 2004); (d) analysis of the economic and social costs and benefits of MIS (Suresh Kumar and Palanisami, 2011). However, none of the studies seems to have looked into *whether seasonal and cropping patterns matter in assessing the benefits of MIS*.

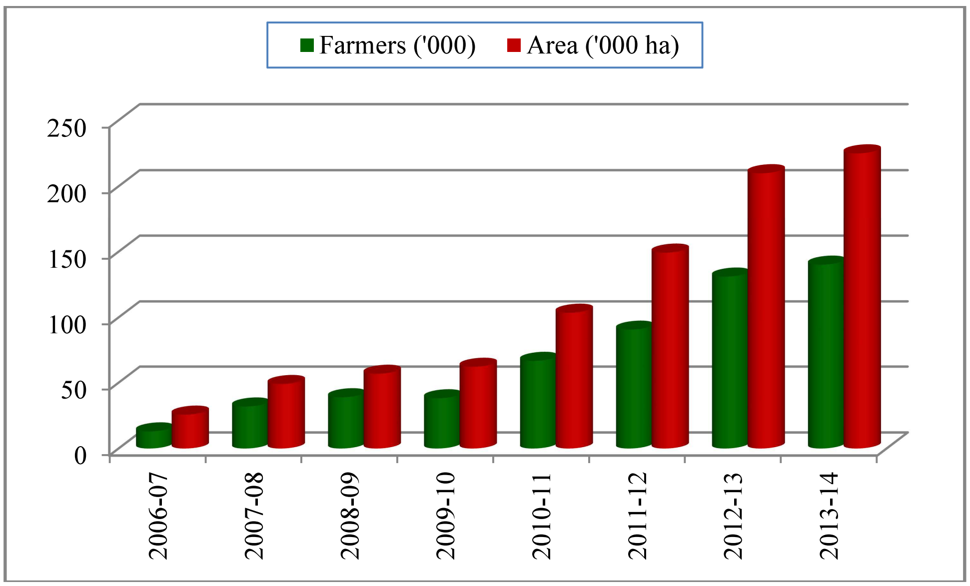
In this backdrop, this paper aims to investigate the role of subsidy in enhancing the adoption rate of MIS and identify the determinants of accessing the benefits of MIS, which is increasingly reckoned as an 'Environmentally Benign Technology' in reducing the water foot print in agriculture especially in water scarce regions. For empirical assessment, a farm-household survey was undertaken in the Banaskantha district in North Gujarat [detailed explanation about the survey design is given in data and methods section].

The paper is organized into five sections, including introduction and conclusions. The second section presents a brief description about the status of MIS across various agro-climatic regions in Gujarat. The third section outlines data and methods. Section four presents the results and discussion, where we discuss about the role of subsidy in enhancing adoption rate among the farmers in recent years; and the socio-economic impacts and the determinants of accessing various benefits of MIS. The fifth section concludes the paper highlighting the future perspectives on the promotion and scaling up of MIS.

2. Status of MIS in Gujarat State

Studies point out that there is a high probability of adopting MIS when water is a scarce resource in a particular region and/or when a large number of farmers depend on groundwater for irrigation purposes (Caswell and Zilberman, 1983; Palanisami *et al.*, 2011). Since both the situations coexist in the state of Gujarat, an increasing trend was observed in the number of farmers adopting MIS and area under MIS[2] (see Figure 1). For instance, about 13,000 farmers had adopted MIS in the year 2006-07, which increased more than 10 times by 2013-14 (i.e., 140.1 thousand farmers). Similarly, 25.7 thousand ha land was under MIS during 2006-07, which had gone up by 9 times to 224.95 thousand ha during 2013-14. It is observed that both the number of farmers and the area under MIS have significantly increased since 2009-10, when the programme was launched by the Government of Gujarat. This could be because of the awareness about MIS systems and the subsidy policy, introduction of extra subsidy for tribal farmers in tribal talukas and farmers in dark-zone talukas, etc.

Figure 1: Trends of Number of MIS Adopted farmers and Area under MIS

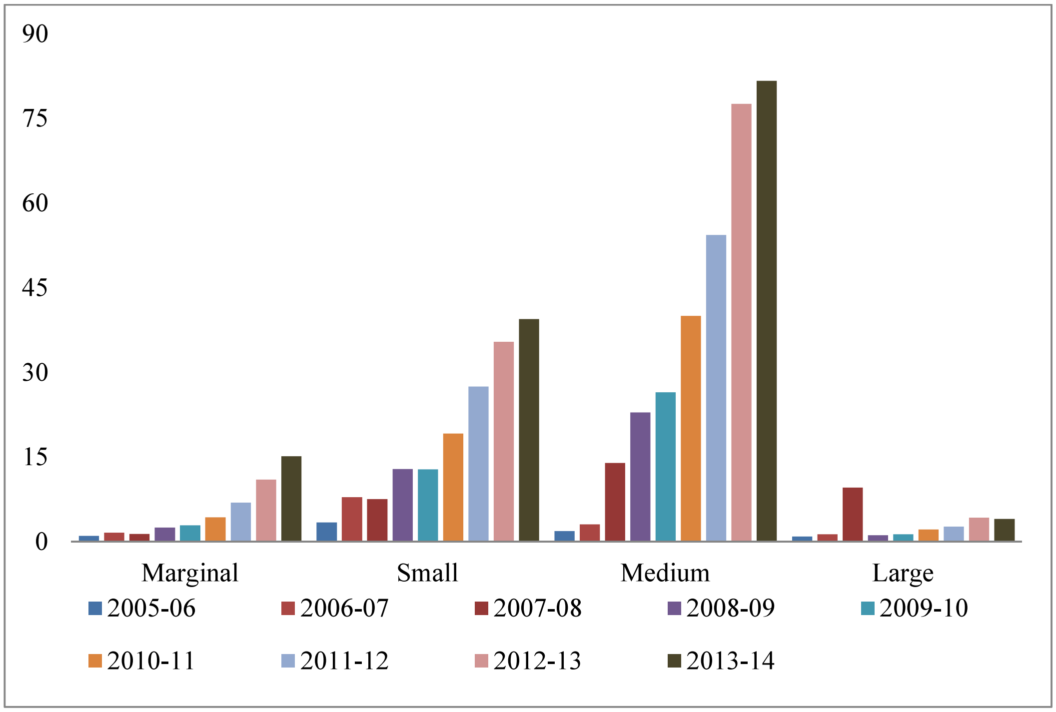


Source: Gujarat Green Revolution Company Ltd., Gujarat.

Therefore, it is imperative to investigate the role of subsidy in encouraging adoption of MIS in the state. While looking at the number of farmers adopting MIS by land holding categories, it is found that a large number of medium farmers (2-10 ha) adopt it (see Figure 2), while an overwhelming majority of farmers (around 66%) adopting MIS belong to marginal (< 1ha) and small (1-2 ha) landholding classes, as of 2010-11 (GoG, 2011). This reveals that there is still a potential for increasing MIS adoption particularly among the small and marginal farmers in the state.

[2] The information presented in this study were collected from GGRC between 2006-07 and 2013-14. But, some farmers could have adopted MIS before GGRC was formed and some may have adopted MIS without the support of GGRC (e.g., farmers under the GWRDC scheme) – Those figures are not included in the analysis presented in this section.

Figure 2: MIS Adopted Farmers by Landholding Categories (in '000 nos.)



Source: Gujarat Green Revolution Company Ltd., Gujarat.

The agro-climatic region-wise distribution of farmers adopting and area covered under MIS in the state during 2006-07 to 2013-14 is presented in Tables 1 and 2, respectively. It is observed that both the indicators (i.e., number of farmers adopting MIS and total area under MIS) have seen an increasing trend over the years. There was a notable increase in the number of farmers and area brought under MIS between 2006-07 and 2013-14 in the state across the agro-climatic regions. For instance, the CAGR of number of MIS adopted farmers was 34.7% (Table 1), and it was 31.2% in the case of area under MIS during the reference period (Table 2).

In other words, this signifies that the proactive state policy of providing subsidy in a range of 50-75% would have motivated a large number of farmers to adopt MIS over the years, in addition to the perceived socio-economic and physical benefits of adopting MIS. Within the state, a large number of farmers adopted MIS in the three agro-climatic regions, namely, north Gujarat, north Saurashtra and south Saurashtra, as these regions are experiencing severe water scarcity. Reportedly, the SGWD in these three agro-climatic regions are 102%, 63.4% and 67%, respectively as of 2011 (GoI, 2014). These three regions together cover around 74% of the total number of farmers adopting MIS and 75% of the total area under MIS in the state. Among them, north Gujarat occupy the first position in terms of number of farmers adopting MIS (i.e., 168.51 thousand farmers which consist of around 31% of total farmers adopting MIS in the state between 2006-07 and 2013-14) and total area under MIS, i.e., 293.53 thousand ha which is around 33% of total area under MIS in the state. The lower growth rate was observed in the southern hills, which receive the highest rainfall across all the agro-climatic regions of Gujarat, i.e., 1793 mm per year; the variability of rainfall also less in these regions (Mehta, 2013).

Table 1: Farmers adopting MIS in Gujarat, Agro-climatic zone wise: 2006-07 to 2013-14 (# in '000)

Agro Climatic Region	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	Total	CAGR (%)
North-West Arid	0.59 (4.52)	0.75 (2.36)	0.76 (1.95)	0.81 (2.12)	1.26 (1.89)	0.80 (0.88)	4.84 (3.69)	5.82 (4.16)	15.62 (2.84)	33.27
North Gujarat	2.43 (18.78)	6.6 (20.70)	6.35 (16.33)	13.89 (36.44)	21.46 (32.25)	25.90 (28.57)	44.22 (33.75)	47.65 (34.01)	168.51 (30.63)	45.04
Middle Gujarat	1.05 (8.07)	1.62 (5.08)	2.15 (5.53)	3.32 (8.73)	7.83 (11.76)	15.58 (17.18)	17.08 (13.03)	13.39 (9.56)	62.02 (11.27)	37.55
North Saurashtra	2.73 (21.08)	9.95 (31.20)	18.78 (48.27)	12.22 (32.06)	13.67 (20.54)	27.67 (30.52)	30.96 (23.63)	37.52 (26.78)	153.50 (27.90)	38.75
South Gujarat	1.69 (13.02)	2.11 (6.63)	2.13 (5.48)	1.81 (4.75)	10.62 (15.95)	7.29 (8.04)	10.94 (8.35)	8.00 (5.71)	44.60 (8.11)	21.47
Southern Hills	0.86 (6.65)	0.94 (2.95)	1.17 (3.00)	0 (0)	4.78 (7.19)	3.62 (3.99)	5.53 (4.22)	3.65 (2.60)	20.55 (3.74)	19.75
South Saurashtra	3.61 (27.89)	9.91 (31.08)	7.56 (19.43)	6.06 (15.90)	6.93 (10.42)	9.80 (10.81)	17.46 (13.33)	24.08 (17.18)	85.42 (15.52)	26.75
Gujarat	12.96	31.89	38.90	38.13	66.56	90.65	131.02	140.10	550.21	34.66

Note: Figures in parentheses indicate percentage; CAGR – Compound Annual Growth Rate.
Source: Authors' compilation from GGRC

Table 2: Area under MIS in Gujarat, Agro-climatic zone wise: 2006-07 to 2013-14 (in '000 ha)

Agro Climatic Region	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	Total	CAGR (%)
North-West Arid	2.11 (8.2)	2.46 (5.0)	2.30 (4.0)	2.40 (3.8)	3.50 (3.4)	2.19 (1.5)	9.68 (4.6)	12.06 (5.4)	36.70 (4.2)	24.37
North Gujarat	5.98 (23.3)	12.78 (26.1)	13.08 (23.0)	24.38 (39.3)	34.08 (32.9)	48.64 (32.6)	75.92 (36.2)	78.68 (35.0)	293.53 (33.3)	38.02
Middle Gujarat	2.27 (8.8)	3.00 (6.1)	3.67 (6.5)	6.04 (9.7)	13.74 (13.3)	24.88 (16.7)	23.55 (11.2)	17.52 (7.8)	94.68 (10.7)	29.09
North Saurashtra	4.62 (17.9)	13.01 (26.6)	22.06 (38.9)	17.16 (27.6)	21.81 (21.1)	43.41 (29.1)	52.21 (24.8)	63.98 (28.4)	238.26 (27.0)	38.91
South Gujarat	3.92 (15.2)	3.49 (7.1)	3.54 (6.2)	3.04 (4.9)	13.73 (13.3)	10.55 (7.1)	15.55 (7.4)	12.27 (5.4)	66.09 (7.5)	15.32
Southern Hills	1.56 (6.1)	1.59 (3.2)	1.81 (3.2)	0 (0)	6.36 (6.1)	5.05 (3.4)	6.62 (3.2)	4.35 (1.9)	27.34 (3.1)	13.64
South Saurashtra	5.25 (20.4)	12.63 (25.8)	10.31 (18.2)	9.04 (14.6)	10.32 (9.9)	14.53 (9.7)	26.34 (12.5)	36.09 (16.0)	124.52 (14.1)	27.26
Gujarat	25.70	48.97	56.76	62.06	103.53	149.26	209.88	224.95	881.11	31.15

Note: Figures in parentheses indicate percentage; CAGR – Compound Annual Growth Rate
Source: Authors' compilation from GGRC

3. Data and Methods

The Gujarat Water Resource Development Corporation (GWRDC) has been involved in implementing MIS in the water scarce districts of North Gujarat, viz., Banaskantha, Mehsana, Patan, Sabarkantha and Gandhinagar. So far, GWRDC has implemented MIS in about 250 tubewells covering about 1365 farmers and 1271 ha of area (see Appendix 1); the average number of farmers benefited under each tubewell is 5 with a range of 1 to 18 (Viswanathan and Bahinipati, 2014, 2015). As is evident, Banaskantha district accounts for almost 60% of the total number of tubewells on which the MIS has been installed, i.e., 143 tubewells. The district also has the corresponding highest share in the number of beneficiary farmers (i.e., 48%) (Viswanathan and Bahinipati, 2014, 2015; see Appendix 1). Patan and Mehsana are the other two districts showing highest number of tubewells and farmers adopting MIS (Viswanathan and Bahinipati, 2014, 2015). In view of the larger coverage, we selected the Banaskantha district for the field survey, which is a water scarce region with a groundwater development status of 107% during 2011 (GoI, 2014). Out of the total beneficiary farmers under GWRDC scheme in the Banaskantha district (i.e., 650 households), the study surveyed at most 5 households under each tubewell, and these households were selected randomly: 355 farmers were interviewed in total. A structured questionnaire was used to gather information from the sample farm households, which included the information on various impacts and benefits of MIS, household characteristics and cropping patterns.

A simple descriptive analysis was undertaken to understand the role of subsidy in enhancing the adoption rate of MIS and the socio-economic impacts of it. Further, to analyse the determinants of accessing various benefits of MIS, a discrete choice model was used as the dependent variables are binary in choice. There are two options for this analysis: logit and probit. Logit and probit models can be derived from an underlying latent variable model (Wooldridge, 2002):

$$y^* = x\beta + e \quad y = 1\left[y^* > 0\right] \cdots\cdots (1)$$

Where, y^* is the unobserved latent variable, x denotes the set of explanatory variables, β represents the vector of parameters to be estimated and e is the error term. The main difference between probit and logit models lies in the assumption of the distribution of the error term. While the error term has standard logistic distribution in the context of logit model, it has standard normal distribution in the case of probit model. Understandably, most studies prefer using probit model because of normality assumption (Wooldridge, 2002). This study also used a probit model to assess the effects of seasonality and cropping patterns in accessing the benefits of MIS. Further to interpret the effects of explanatory variables on the probabilities, the marginal effects of both continuous and discrete explanatory variables are estimated.

The marginal impact for each continuous explanatory variable on the probability level is given by (Wooldridge, 2002):

$$\frac{\partial p\left(y=1|\mathrm{x}\right)}{\partial x_k}=g\left(x\beta\right)\beta_j\cdots\cdots(2)$$

Further, the marginal effect for a dummy variable, say x_k, is the difference between two derivatives evaluated at the possible values of the dummy, i.e., 1 and 0, thus (Wooldridge, 2002):

$$\frac{\partial p\left(y=1|\mathrm{x}\right)}{\partial x_k}=G\left(\beta_1+\beta_2x_2+\cdots+\beta_{K-1}x_{K-1}+\beta_k\right)-G\left(\beta_1+\beta_2x_2+\cdots+\beta_{K-1}x_{K-1}\right)\cdots\cdots(3)$$

The cross-section econometric analysis is associated with the problem of multicollinearity and heteroskedasticity. A variance inflation factor (VIF) for each of the explanatory variable was estimated to check multicollinearity, and a robust standard error was calculated to address the possibility of heteroskedasticity (Wooldridge, 2002). The VIF value for all the independent variables is below 10 (i.e., 1.51 with a range of 1.12 to 4.7; see Appendix 2), suggesting no problems of multicollinearity. The descriptive statistics of both dependent and explanatory variables used in the analysis are reported in Appendix 3.

4. Results and Discussions

4.1. Role of Subsidy Policy in Enhancing MIS Adoption Rate

As outlined in the previous section, both national and state governments provide financial incentives (subsidy) to enhance the adoption rate of MIS. In the context of Gujarat, the government gives subsidy of 50% of the cost of MIS installation or INR 60,000 per ha, whichever is lower, to the farmers (IRAP, 2012). Besides, the farmers in the 57 notified dark zone talukas (as per GoG norms) of Gujarat get additional 10% subsidy for MIS installation on any crop[3]. Whereas, the small and marginal farmers can get a higher amount of subsidy, ie., 75% for installation of MIS on the public tubewell, as per the GWRDC MIS scheme launched since 2009 (Viswanathan and Bahinipati, 2014). Similarly, the farmers in the tribal talukas are entitled to get a subsidy of 75% or INR 90,000 per ha, whichever is lower (GGRC, 2013).

[3] http://www.ggrc.co.in/pdf%20files/FAQ%20(13-14).pdf; accessed on 25th August 2014.

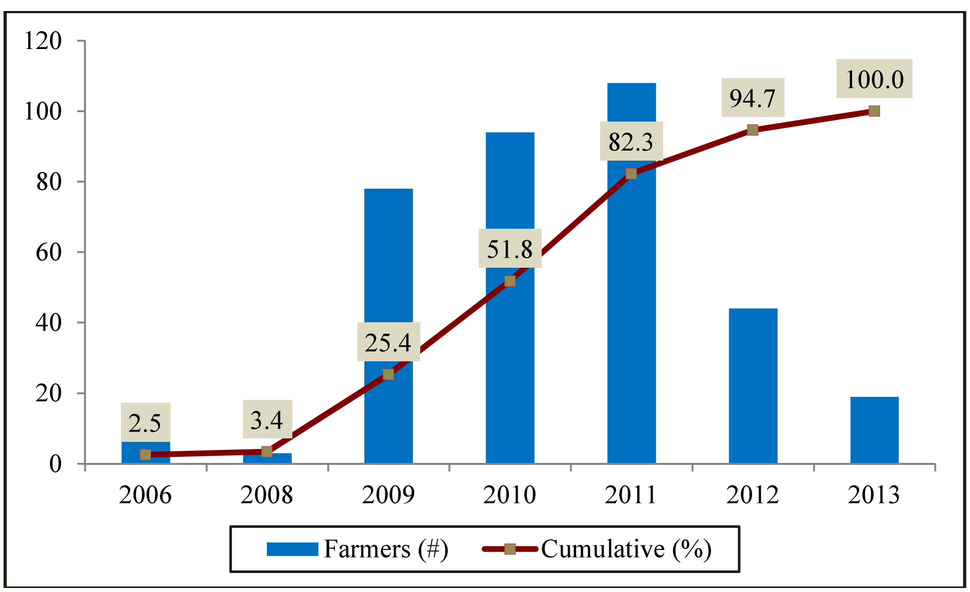
Since all the farmers are eligible for 50% subsidy, this section briefly describes the impact of additional 25% subsidy provided by the GWRDC to marginal and small farmers on the MIS adoption. In this context, Table 3 reports MIS adopted farmers based on year of adoption and availing extra subsidy. Out of the total 355 sample farmers, almost 75% of the farmers have adopted MIS since 2009, when it was launched by the GWRDC (Figure 3). The curve showing cumulative percentage of MIS adoption has increased from 25% during 2009 to 52% during 2010 and almost 95% by 2013.

Table 3: Status of MIS Adoption among farmers, by Year of Adoption and Availing Extra Subsidy

	Extra Subsidy[1]		
Year adopted	No	Yes	Total
2006	9 (100)	0 (0)	9 (2.54)
2008	3 (100)	0 (0)	3 (0.85)
2009	78 (100)	0 (0)	78 (21.97)
2010	22 (23.4)	72 (76.6)	94 (26.48)
2011	18 (16.67)	90 (83.33)	108 (30.42)
2012	10 (22.73)	34 (77.27)	44 (12.39)
2013	4 (21.05)	15 (78.95)	19 (5.35)
Total	144 (40.05)	211 (59.44)	355 (100)

Note: 1 – the extra 25% subsidy is given to the small and marginal farmers in the year 2009 onwards by GWRDC, otherwise all the farmers are eligible to get 50% subsidy under GGRC
Source: Computed from Primary Data.

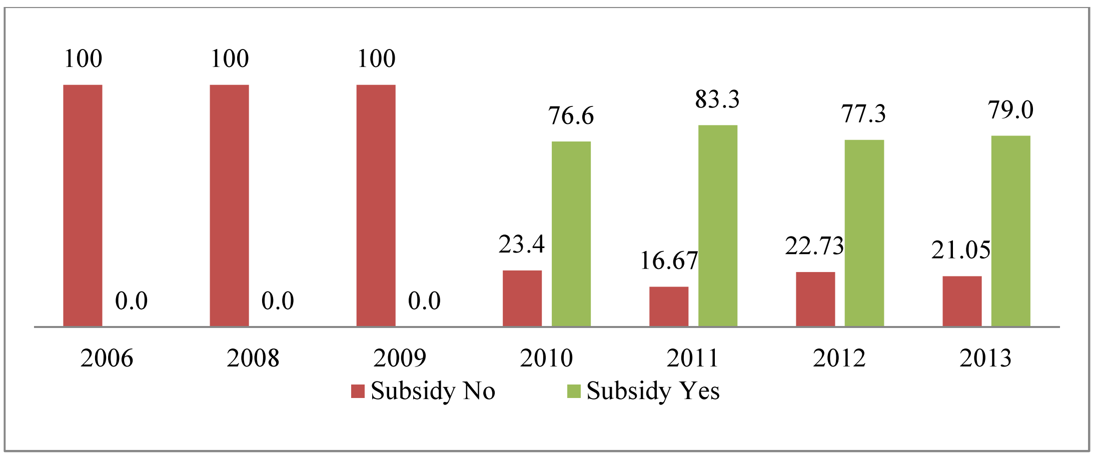
Figure 3: Trend of MIS Adopted Farmers



Source: Table 3.

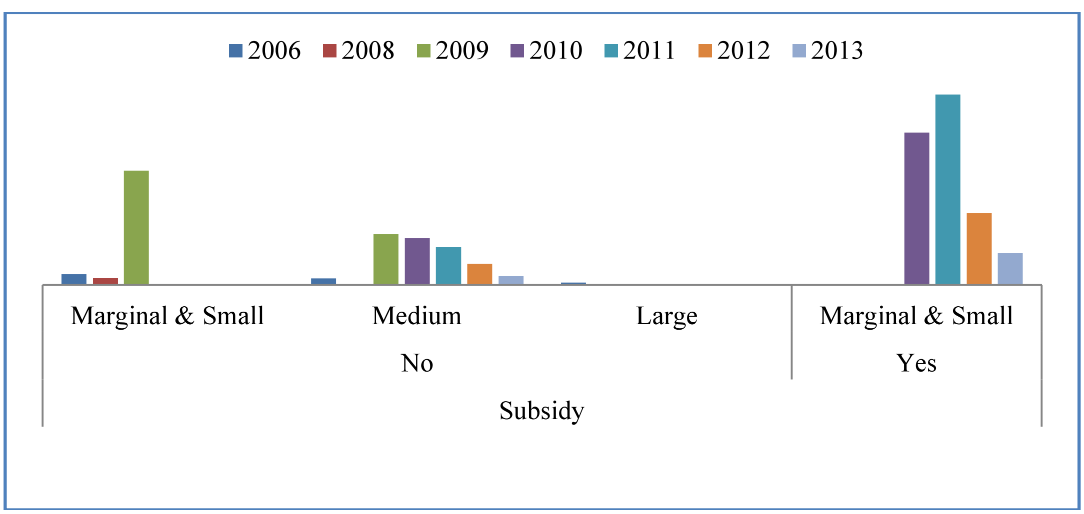
It is also observed from Table 3 that a large percentage of farmers, who have availed extra subsidy under GWRDC scheme, have undertaken MIS since 2010 (see Figure 4). While looking at the MIS adopted farmers by landholding category (Figure 5), it is found that larger number of marginal and small farmers have adopted MIS since 2010, as they are entitle to get additional 25% subsidy. This reveals that the subsidy plays an important role in enhancing adoption rate of MIS in the study area. There are also other confounding factors such as awareness about MIS, learning effect, benefits of MIS, etc that could have influenced better adoption. The future research should control all these factors to see to what extent subsidy alone influences the MIS adoption rate.

Figure 4: Percentage of MIS Adopted Farmers, by Availing Extra Subsidy



Source: Table 3

Figure 5: Impact of subsidy policy on adoption behaviour of marginal and small farmers

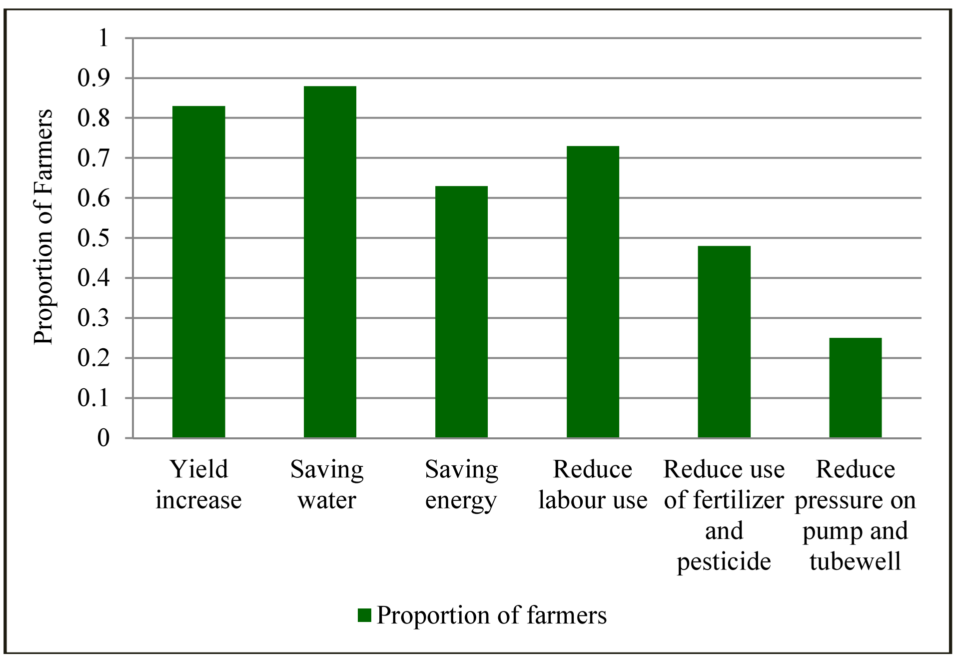


Source: Table 3

4.2. Farmers' perceptions about economic and social benefits of MIS

An assessment of the economic and social benefits of the MIS is presented here based on the perceptions of farmers as regards some of the visible benefits that emerge from MIS adoption. In this respect, it was found that majority of responses are highly appreciative of the overall benefits accrued from the use of MIS for irrigation. As per the farmers' perception, the major benefits, which are not mutually exclusive, they realise from adopting MIS are: (i) yield increase, (ii) saving water, (iii) saving energy, (iv) reduced labour use, (v) reduced use of fertilizer and pesticides, and (vi) reduced pressure on pump and tubewell. Figure 6 shows farmers' perception on benefits of MIS. Among them, two benefits (e.g., yield increase and saving water) were observed by more than 80% of the farmers. While around 60-70% of the farmers reported reduction in labour use and energy saving after adopting MIS, around half of the farmers have reported that use of MIS reduced the use of fertilizer and pesticide. Moreover, about one-fourth of the farmers experienced the positive impact of MIS in reducing pressure on pump and tubewell.

Figure 6: Farmers' Perception on benefits of MIS



Source: Computed from primary data (n=355)

4.3. Determinants of accessing the Benefits from MIS

Table 4 reports the marginal effects of the determinants of accessing benefits of micro-irrigation (MIS). The results show that all the coefficients included in the model had the expected signs.

The values of Wald $x^2(15)$ are found as significant in all the models, which indicate that the independent variables taken as a group are quite significant in explaining the farmers' perception on benefits of adopting MIS. Further, it is also found that there are no missing variables in the model as the coefficients of 'Ramsey test' are not significant, and as a result, we can't reject the null hypothesis as there is no missing variable in the model (see Appendix 4). In addition, there are no specification errors in all the models (see Appendix 4). Since the objective of this study is to investigate the effects of seasonality and cropping patterns in accessing the benefits of MIS, this study first discusses about the coefficient of variables undertaken under these two categories.

The variables representing seasonality are area under MIS during kharif, rabi and summer seasons. Among them, it is found that the coefficients of area under MIS during kharif season are positive and significant for the benefits like yield increase, reduced labour use and reduced use of fertilizer and pesticides. For instance, a 1% increase in area under MIS during kharif season enhances farmers' perception on yield increase by 9.1%; reduce labour use by 11.5% and reduce use of fertilizer and pesticides by 18.5%. The coefficients of other two variables representing seasonality such as area under MIS during rabi and summer seasons, are not significant for any of the benefits of MIS. This indicates that farmers' perceived various socio-economic benefits of adopting MIS when they adopt it during the kharif season and not in the other seasons like rabi and summer. This could be because of two reasons: one being the scarcity of water itself during rabi and summer due to lack of rainfall. Second, they have a strong preference for growing water intensive high valued crops during rabi and summer seasons, so that they do not perceive any benefits during such seasons. The indicators representing cropping patterns are share of cereals and pulses, share of cotton and oil crops and share of vegetables. The coefficient of share of cereals and pulses is significant in the context of yield increase. Further, the coefficients of share of cotton and oil crops are positive and also significant for benefits like yield increase, saving energy and reduce labour use. The other indicator representing share of vegetables has positive association with three benefits of MIS, such as yield increase, saving water and saving energy.

Table 4: Odd ratio of Determinants of Benefits of Micro-Irrigation

	Yield increase	Saving water	Saving energy	Reduce labour use	Reduce use of fertilizer and pesticide	Reduce pressure on pump and tubewell
Age of HH	-0.002 (0.001)	-0.001 (0.001)	-0.002 (0.002)	-0.003* (0.002)	-0.004* (0.002)	-0.002 (0.002)
Years of schooling of HH	0.002 (0.005)	-0.003 (0.004)	-0.007 (0.007)	-0.005 (0.006)	-0.001 (0.006)	-0.003 (0.006)
Ownership of land (in ha)	-0.009 (0.013)	0.006 (0.013)	0.006 (0.023)	-0.008 (0.021)	0.060** (0.026)	-0.009 (0.018)
Share of land under MIS	0.001* (0.001)	0.001 (0.001)	-0.001 (0.001)	0.001 (0.001)	-0.001 (0.001)	-0.002** (0.001)
Area under MIS during kharif	0.091* (0.051)	-0.041 (0.032)	-0.071 (0.061)	0.115** (0.058)	0.185*** (0.062)	0.067 (0.054)
Area under MIS during rabi	0.007 (0.095)	0.054 (0.135)	-0.151 (0.132)	0.103 (0.155)	0.094 (0.158)	0.002 (0.139)
Area under MIS during summer	0.037 (0.048)	0.042 (0.042)	0.079 (0.068)	-0.003 (0.058)	-0.058 (0.071)	0.022 (0.058)
Years completed of MIS adopted	-0.012 (0.017)	-0.029** (0.014)	0.011 (0.024)	-0.032 (0.023)	-0.011 (0.026)	0.043** (0.020)
Number of farmers in a tubewell	0.007 (0.004)	0.008** (0.004)	-0.007 (0.007)	0.011* (0.006)	0.008 (0.006)	-0.006 (0.005)
Ln(Depth of tubewell)	0.021 (0.041)	0.042 (0.033)	0.051 (0.060)	0.137*** (0.053)	0.222*** (0.067)	0.081 (0.054)
Deepened in the last five years	0.001 (0.050)	0.093* (0.054)	-0.057 (0.069)	-0.007 (0.063)	0.048 (0.072)	-0.102 (0.069)
Horsepower of pump	-0.004*** (0.001)	-0.004*** (0.001)	-0.003 (0.002)	-0.006*** (0.002)	-0.004* (0.002)	-0.0003 (0.002)
Share of cereals and pulses	0.002** (0.001)	0.0001 (0.001)	0.002 (0.002)	0.0002 (0.001)	0.001 (0.002)	-0.0003 (0.001)
Share of cotton and oil crops	0.005*** (0.001)	0.001 (0.001)	0.004** (0.002)	0.003* (0.002)	0.002 (0.002)	0.001 (0.001)
Share of vegetables	0.004*** (0.001)	0.003** (0.001)	0.005** (0.002)	0.002 (0.002)	-0.002 (0.002)	0.002 (0.002)
Number of Observations	355	355	355	355	355	355
Wald $\chi^2(15)$	70.14***	49.60***	24.64**	39.48***	46.69***	27.13**
Pseudo R^2	0.198	0.157	0.052	0.097	0.105	0.063

Note: figures in the parentheses indicate robust standard error; ** p<0.05 and * p<0.1 respectively
Source: Computed from primary data

From the above discussion, it is understood that farmers are accessing various benefits of adopting MIS, if they are cultivating cotton and oil crops as well as vegetables. Therefore, these crops should be promoted in the region where a large number of farmers have already taken up MIS. In sum, it could be said that farmers' perception about various socio-economic benefits of adopting MIS varies with respect to seasonality and cropping patterns.

While the coefficient of share of land under MIS is positive and significant for yield increase, it shows negative association with reduced pressure on pump and tubewell. The coefficients of number of farmers in a tubewell are positive as well as significant for yield increase and reduced labour use. The coefficient for 'deepening of wells in the last five years' is positive and significant in case of water saving. The coefficients of horsepower (HP) of pump have negative relationship with yield increase, saving water, reduce labour use and reduce use of fertilizer and pesticides.

5. Conclusions and future perspectives

This paper presents the results of the techno-economic analysis of the performance of MIS installed on a sample of 122 public tubewells in the Banaskantha district in Gujarat. Based on an empirical survey of 355 farmers, it also brings out the important financial (subsidy) socio-economic as well hydrological factors that significantly contribute towards accessing the benefits of MIS among the farmers. The results of the techno-economic analysis bring forth significant economic and social benefits to the beneficiary farmers in terms of: (a) increase in crop yields during kharif, rabi and summer seasons; (b) considerable savings in energy consumption; (c) reduction in the use of chemical fertilizers and pesticides; (d) reduction in cost of weeding; (f) reduction in groundwater over-extraction; and (f) reduction in water scarcity induced labour migration, etc to mention a few.

The analysis demonstrates that the farmers who have adopted the MIS as offered under a subsidy programme by the state government have been compensated for the investments that they made to adopt the MIS. By and large, farmers have reported to grow a range of crops especially during the kharif and Rabi seasons and most of these crops have been brought under the MIS. However, while the adoption of MIS by the farmers has been quite impressive during the kharif and Rabi seasons, the use of MIS for growing summer crops has been found to be much lower and very much restricted to few crops. This lack of a greater adoption of the MIS during the summer season could be attributed to a host of factors, including the persistent scarcity of ground water in the drier months, which in turn pre-empt the farmers to grow any crops during the summer using MIS. This raises an important constraint that comes up in the way of scaling up of the MIS in the specific context of Gujarat, where the farmers are heavily promoted to adopt new agricultural practices, especially such innovative water saving technologies. While the study brings forth the significant positive economic, social and environmental outcomes of the MIS, efforts in terms of extension support and institutional interventions for facilitating wider adoption of the MIS through bringing more crops under the ambit of the scheme. More efforts are needed to rejuvenate the local water harvesting structures through artificial groundwater recharge programmes wherever such potentials exist and this in turn may help increase the adoption of MIS during the summer.

At the same time, the implementation of MIS also creates issues of local conflicts, mostly triggered by the local dynamics in the villages. Our interactions with villagers revealed that in view of the emerging shortage of water, the access to the benefits of MIS is mostly determined by who holds the control over the public tubewell on which MIS is installed. This in other words creates more rooms for division of the local village communities on caste or other lines. It was noticed in several places that the water from the bore wells was earlier utilized by larger number farmers (2 to 15), irrespective of their socio-economic or caste affiliations. But with increased scarcity due to depletion of water in the borewells, the extent of area as well as farmers benefited under such innovative water saving technologies are getting shrunk across villages. Adding more to the water woes, in majority of cases, the public tubewells or borewells are at least 20-30 years old with shrinking water levels. In very many of such situations, the benefits of MIS are found to be mostly appropriated by few family members, who incidentally happen to be the listed beneficiaries at a public tubewell on which MIS has been installed. What type of policies and institutional measures could help resolve such dilemmas is a major issue to be resolved to enhance the social viability and sustenance of the MIS interventions in the specific context of Gujarat.

A much more serious issue is achieving the fuller potentials of the MI technology and taking forward its broad goals of water saving along with inter as well as intra-generational equitable distribution, especially when the rural scenario is fast changing with respect to ageing farming population and the declining interests in farming amongst the younger generations. The implication here is that the ultimate long-term success of a technology, such as MIS would depend upon how innovative are the farmers in terms of devising new methods of water application and new cropping and agro-management practices that would lead to 'real water savings' following the adoption of the technology. This essentially requires the enhancement of assimilative capacities and skill levels of the farmers, which can yield better results mostly when the farmers are 'younger enough' to learn and adapt the new water management practices on the field. Given the empirical reality that the average age of a vast majority of the sample farmers is

50 years and above, it may be quite unlikely that the fuller potential of the MIS would be explored in the emerging scenario of growing water shortages.

The above facts bring out two major issues of topical relevance, ie., the need for regulatory systems or institutions for addressing the market prices for crops grown under MIS on the one hand and the regulation of over-extraction of groundwater through appropriate pricing policies to reflect the scarcity value of water. It emerges from the study that there are no real incentives for the farmers to grow more water efficient and market friendly crops to address these concerns. Moreover, the energy pricing policy of the state has also been least responsive to the serious problem of over-extraction of groundwater through the use of submersible pumpsets installed on the deeper tubewells/ borewells all across the state. Given this reality, the adoption or non-adoption of MIS does not contribute much towards conserving the scarce water resources in a water-stressed state like Gujarat.

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Appendix Tables:

Appendix 1: Distribution of public Tubewells with MIS in Gujarat (up to 2012-13)

District Name	Tubewells (No)	(%) share	Farmers (No)	(%) share	Total Area (ha)	Avg. no of farmers per tubewell	Area (ha) per tubewell	Avg. farm size (ha)
1. Banaskantha	143	57.2	650	47.6	642.55	4.55	4.49	1.28
2. Gandhinagar	24	9.6	131	9.6	122.99	5.46	5.12	1.19
3. Mehsana	32	12.8	244	17.9	214.43	7.63	6.70	1.11
4. Patan	42	16.8	285	20.9	204.02	6.79	4.86	0.91
5. Sabar Kantha	9	3.6	55	4.0	87.15	6.11	9.68	1.76
Total	250	100	1365	100.0	1271.14	5.46	5.08	1.20

Source: Adopted from Viswanathan and Bahinipati (2015)

Appendix 2: Collinearity test for Independent variables

Variable	VIF	1/VIF
Age of Household Head (HH)	1.10	0.91
Years of schooling of HH	1.02	0.98
Ownership of land (in ha)	1,41	0.71
Share of land under MIS	1.42	0.71
Area under MIS during kharif	1.29	0.77
Area under MIS during rabi	1.27	0.79
Area under MIS during summer	1.17	0.86
Years completed of MIS adopted	1.21	0.82
Number of farmers in a tubewell	1.63	0.61
Ln(Depth of tubewell)	1.45	0.69
Deepened in the last five years	1.12	0.89
Horsepower of pump	2.09	0.48
Share of cereals and pulses	1.99	0.50
Share of cotton and oil crops	2.54	0.39
Share of vegetables	2.00	0.51
Mean VIF	1.51	

Source: Authors' computation

Appendix 3: Descriptive Statistics of the variables

Sl. No.	Variables	Mean	SD	Min	Max	Description
	Dependent variables					
1	Yield increase	0.83	0.38	0	1	Binary (Yes, No)
2	Saving water	0.88	0.33	0	1	Binary (Yes, No)
3	Saving energy	0.63	0.48	0	1	Binary (Yes, No)
4	Reduce labour use	0.73	0.44	0	1	Binary (Yes, No)
5	Reduce use of fertilizer and pesticide	0.48	0.50	0	1	Binary (Yes, No)
6	Reduce pressure on pump and tubewell	0.25	0.43	0	1	Binary (Yes, No)
	Independent Variables					
7	Age of Household Head (HH)	48.91	13.12	21	85	Numerical
8	Years of schooling of HH	9.03	3.96	1	18	Numerical
9	Ownership of land (in ha)	1.49	1.32	0.2	16.2	Continuous
10	Share of land under MIS	77.99	30.59	6.7	100	Numerical
11	Area under MIS during kharif	0.67	0.47	0	1	Binary (Yes, No)
12	Area under MIS during rabi	0.97	0.18	0	1	Binary (Yes, No)
13	Area under MIS during summer	0.77	0.42	0	1	Binary (Yes, No)
14	Years completed of MIS adopted	3.54	1.15	1	5	Numerical
15	Number of farmers in a tubewell	7.48	5.10	1	27	Numerical
16	Ln (Depth of tubewell)	6.29	0.52	4.70	6.91	Numerical
17	Deepened in the last five years	0.83	0.38	0	1	Binary (Yes, No)
18	Horsepower of pump	44.18	17.52	10	85	Numerical
19	Share of cereals and pulses	38.26	22.16	0	100	Numerical
20	Share of cotton and oil crops	32.12	24.10	0	100	Numerical
21	Share of vegetables	17.94	18.39	0	87.5	Numerical

Source: Computed from primary data (n=355)

Appendix 4: Test for Omitted Variable Bias and Specification Error

Dependent variable	Ramsey test for Omitted variable bias (H_0: model has no omitted variables)		Specification Error Test	
	F (3, 336)	Prob. > F	Coefficient of $\hat{Y}^2$	P value
Yield increase	1.38	0.248	-0.390 (0.524)	0.456
Saving water	0.66	0.579	-0.625 (0.970)	0.520
Saving energy	0.86	0.464	-0.116 (1.160)	0.921
Reduce labour use	0.23	0.874	-0.058 (0.871)	0.947
Reduce use of fertilizer and pesticide	0.47	0.704	0.457 (0.498)	0.359
Reduce pressure on pump and tubewell	0.10	0.959	0.190 (1.443)	0.895

Source: Authors' computation