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

P.K. Viswanathan

Chandra S. Bahinipati

Gujarat Institute of Development Research

GGKP Annual Conference 2014-2015 - "Fiscal Policies and the Green Economy Transition: Generating Knowledge – Creating Impact" San Giobbe, Ca' Foscari University of Venice, Venice, Italy

29 -30 January 2015

Presentation outline

- Background - MIS interventions in India
- Status of MIS across various agro-climatic regions in Gujarat
- Factors influencing MIS adoption & benefits
- Future perspectives on promotion of MIS

I. Background

- The national report on groundwater (GW) resource assessment and irrigation potential in India (GOI, 2005) highlighted the alarming scenario of groundwater overdraft across regions.

- In states mostly benefited by green revolution, growth in farm output was contingent upon intense use of GW along with energisation of pumpsets, causing a sharp decline in GW table with rise in agricultural power consumption in states: Punjab, Haryana, Andhra Pradesh, Gujarat, Maharashtra, Madhya Pradesh, Rajasthan, Karnataka and Tamil Nadu.

- Many regions facing water scarcity , report GW extraction becoming highly expensive, mainly due to: (i) low groundwater potential in the hard rock areas of the southern and western India; and (ii) groundwater aquifers becoming over-exploited in parts of the south Indian peninsula, western India and alluvial north-western India.

I. Background: MIS Interventions in India

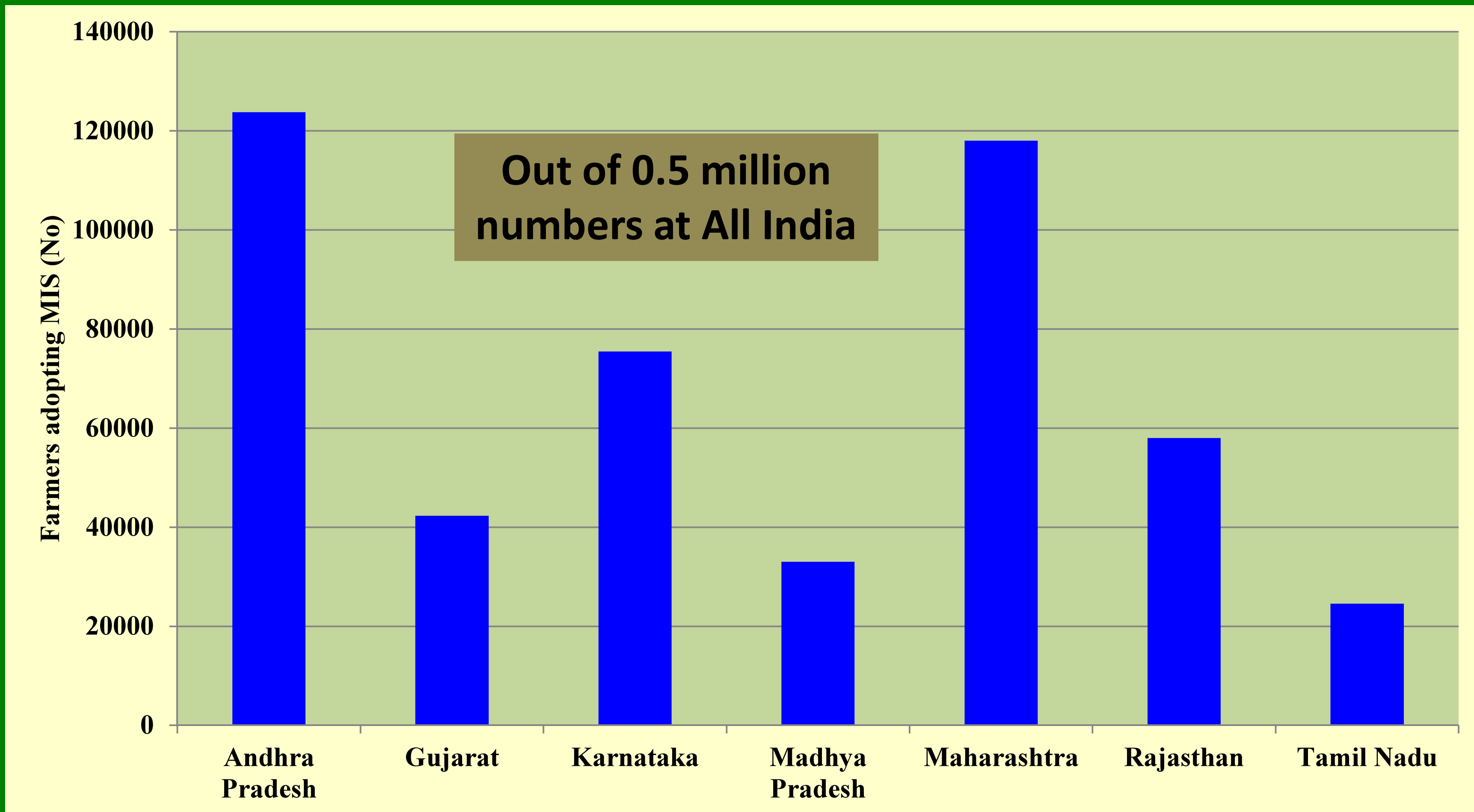
- The extent of GW extraction has even far exceeded the net annual groundwater availability in some states, like Punjab, Haryana and Rajasthan

- The stage of groundwater development (SGWD) is fast approaching the critical limits (SGWD>68%) in states, viz., Gujarat, Karnataka, Uttar Pradesh, etc. (GOI, 2014)

- It was in this context of the grim scenario of GW that the potential of water saving technologies (WSTs) such as micro irrigation system (MIS) assume importance as environmentally benign technology (EBT) especially in the groundwater over-exploited regions/ states in India

- Taking cue from international experiences, the strategies for promoting MIS in India are built on expectations that the WSTs (sprinklers and drips) while enhancing the productivity of crops also ensure water use efficiency (WUE) and optimal allocation and use of scarce water resources

Farmers adopting MIS in Indian states (2011-12)



Source: Government of India, NMMI

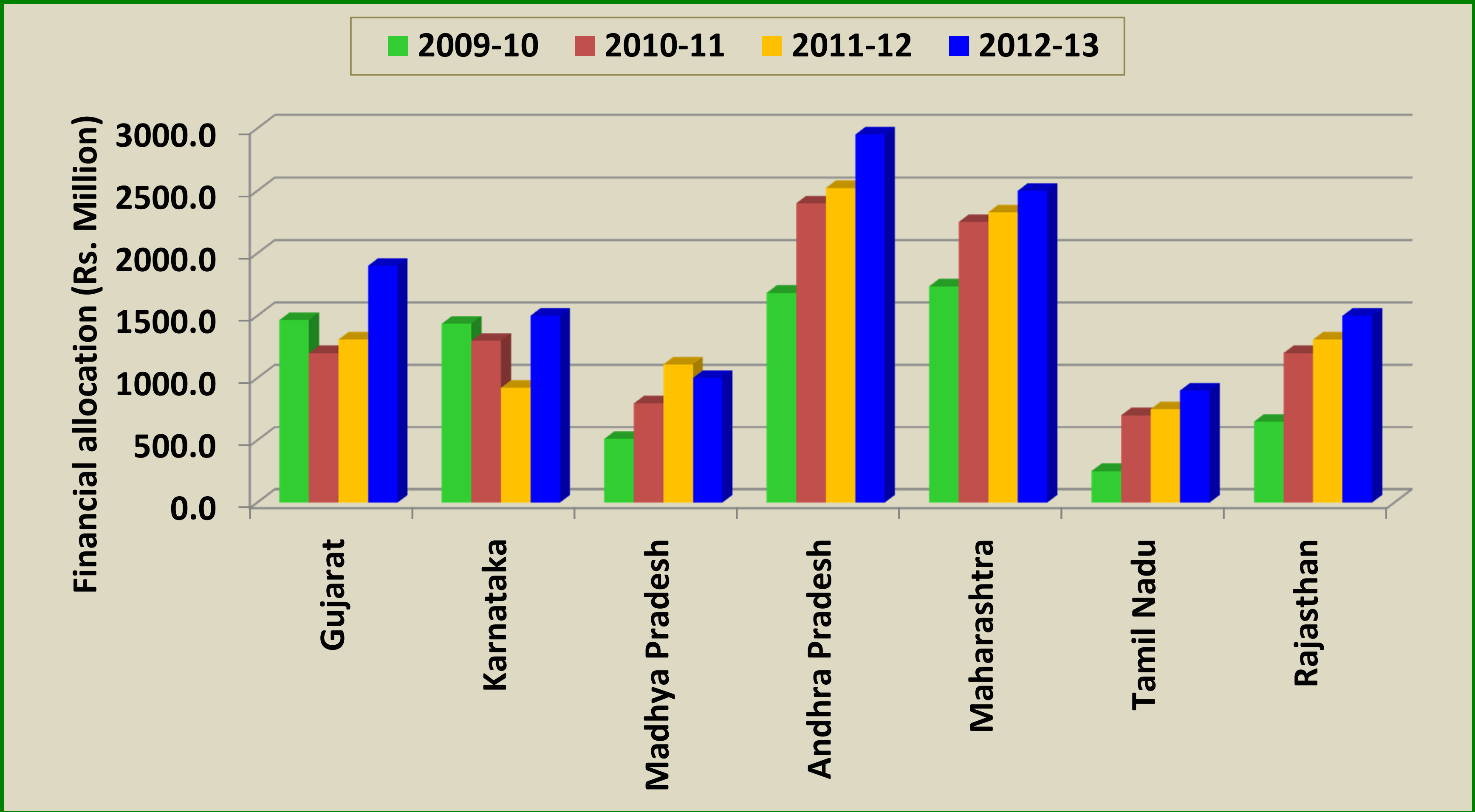
Development and potential of Micro Irrigation Systems in major states in India, 2010

States	Area under MI ('000 ha)			% share	Total potential	
	Drip	Sprinkler	Total		'000 ha	Achieved (%)
Andhra Pradesh	363.07	200.95	564.02	14.57	1117	50.5
Gujarat	169.69	136.28	305.97	7.9	3278	9.3
Maharashtra	482.34	214.67	697.01	18.01	2714	25.7
Rajasthan	17.00	706.81	723.81	18.70	5658	12.8
Karnataka	177.33	228.62	405.95	10.49	1442	28.2
Tamilnadu	131.34	27.19	158.53	4.1	702	22.6
All India	1428.46	2442.41	3870.87	100	42237	9.2

Source: Raman (2010) and Indiastat as cited in Palanisami, *et al.*, 2011.

Six states account for almost 74% of the total area covered under the MIS (sprinkler & drip systems) in India, with huge potential yet to be achieved.

Financial allocation under National Mission on Micro Irrigation (NMMI) in major states, India



Source: Government of India, NMMI

I. MIS in India: Major Impacts reported

- **Majority of the studies have been based on farm/ plot level assessments of the physical, economic, hydrological benefits/ outcomes of the MIS across States: Rajasthan, Gujarat, Karnataka, Andhra Pradesh, Rajasthan, Maharashtra and Tamilnadu.**

- **Impact Studies broadly looked at: (a) the physical impact of MIS on irrigation water use (Narayanamoorthy, 2004); (b) the use of water-efficient crops and crop water productivity in physical terms (kg/m^3) (Kumar, 2007; Singh 2013; Kumar and van Dam 2013); (c) the benefit-cost analysis of MIS (Palanisami *et al*., 2002; Kumar *et al*., 2004; Narayanamoorthy, 2004); (d) the comparative economics of the cultivation of water-efficient and high valued crops; and (e) analysis of the economic and social costs and benefits of MISs (Suresh Kumar and Palanisami, 2011).**

- **Studies also reveal that MIS can bring forth dynamic changes in smallholder farming system in terms of crop-diversification in favour of high valued cash/ horticultural crops (Kumar *et al*., 2008; Kumar, 2009) as well as an increase in milk production due mostly to the increase in area covered under the fodder crops, such as alfalfa [Singh and Kumar (2013)].**

I. MIS adoption in India: lukewarm response

- **But, despite beneficial outcomes as reported by the studies, the progress in adoption of MIS has been much slow.**

- **The total area covered under MIS in India was about 4.94 million ha during 2010, which is a little less than 5% of the total irrigated area at the national level.**

- **Six states, *viz.*, Maharashtra (18.2%), Rajasthan (18.1%), Andhra Pradesh (15.4%), Karnataka (12%), Haryana (11%) and Gujarat (8.2%) together account for about 83% of the total area under MIS in India.**

- **By and large, several factors and constraints affecting adoption, including physical, socio-economic, financial, institutional (pricing, subsidies) extension service and policy-related.**

- **Poor adoption of MIS despite financial incentives (50-75%) in states, including Gujarat**

II. MIS adoption in Gujarat: critical questions explored

- Will MIS render as a Environmentally Benign Technology, reducing the water footprint in agriculture in water scarce regions of Gujarat?
- Under what conditions MIS get widely adopted? - Do financial incentives matter?
- Whether seasonality and cropping pattern matter in accessing the benefits of MIS?
- Empirical assessment of a state government scheme of MIS implementation on public tubewells implemented by the Gujarat Water Resource Development Corporation (GWRDC) since 2009
- Covering 143 MIS installed public tubewells in Banaskantha district- a water scarce region located in the northern Gujarat. Included a farm HH survey covering 355 farmers randomly selected out of 650 beneficiaries.

Agro-climatic Regions of Gujarat

Gujarat state: Mostly arid and semi-arid agro-climatic zones

Agro-climatic regions of Gujarat

Agro-climatic zone	District s	Rainfall (in mm)	Rainy Days	CV (%)	Soil	Major Crop
North-west arid	Kachchh	340	18	60.3	Grey brown, deltaic alluvium	Bajra, Groundnut, Jowar, Cotton
North Gujarat	Banas Kantha, Mahesana, Sabar Kantha, Gandhinagar, Ahmedabad and Patan	735	30	49.7	Grey brown, Coastal alluvium	Bajra, Cotton, Jowar, Wheat
Middle Gujarat	Vadodara, Panch Mahals, Kheda, Dahod and Anand	904	36	43.9	Medium black	Rice, Maize, Bajra, Cotton
North Saurashtra	Amreli, Bhavnagar, Jamnagar, Rajkot and Surendranagar	537	24	51.6	Medium black	Bajra, Jowar, Groundnut, Cotton
South Gujarat	Surat, Bharuch, Narmada and Tapi	974	45	43.6	Deep black, coastal alluvium	Jowar, Arhar, Cotton, Wheat
Southern Hills	Dangs, Valsad and Navsari	1793	63	40.0	Deep black, Coastal alluvium	Rice, Ragi, Sugarcane, Jowar
South Saurashtra	Junagadh and Porbandar	844	29	55.6	Coastal alluvium, medium black	Groundnut, Wheat, Bajra, Cotton

Source: Varshneya et al. (2009)

II. Status of MIS adoption in Gujarat

- 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, due to two major factors.

- First, fresh water availability 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) with high variability.

- 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.

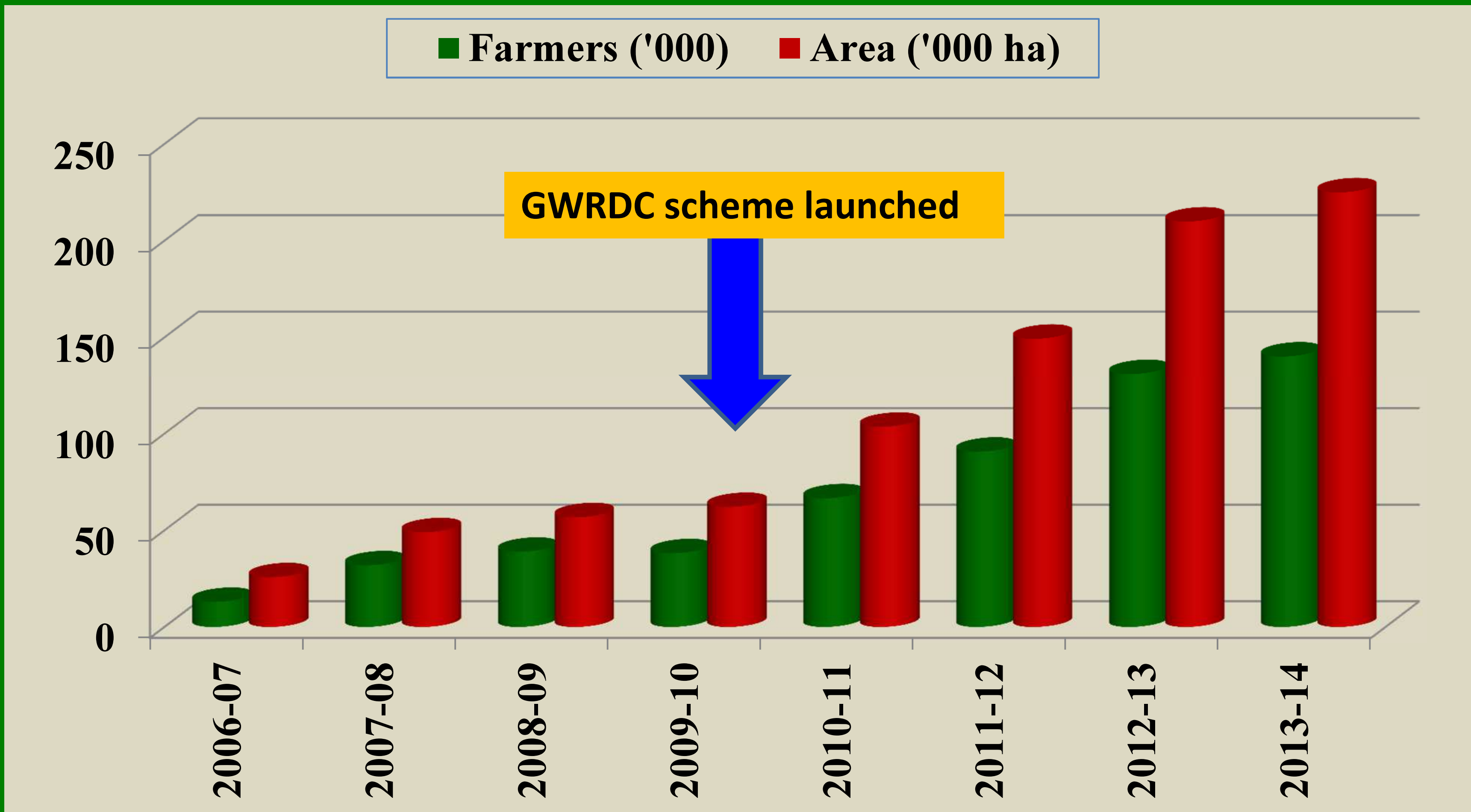
II. MIS implementation in Gujarat

- The Gujarat Water Resources Development Corporation (GWRDC) has been implementing the ‘pressurized irrigation network system (PINS) & micro irrigation system (MIS)’ since 2009

- The scheme has been implemented on the public tubewells operated by farmers, majority of them being small and marginal farmers

- Present an overview of the status of adoption of MIS and its socio-economic impacts on agriculture in Gujarat

Trends in Number of farmers and Area covered under MIS in Gujarat



An overwhelming majority of farmers (around 66%) adopting MIS belong to marginal (< 1ha) and small (1-2 ha) landholding classes

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

Agro Climatic Region	2006-07	2009-10	2011-12	2012-13	2013-14	Total	CAGR (%)
North-West Arid	0.59	0.81	0.8	4.84	5.82	15.62	33.27
North Gujarat	2.43	13.89	25.9	44.22	47.65	168.51	45.04
Middle Gujarat	1.05	3.32	15.58	17.08	13.39	62.02	37.55
North Saurashtra	2.73	12.22	27.67	30.96	37.52	153.5	38.75
South Gujarat	1.69	1.81	7.29	10.94	8.00	44.6	21.47
Southern Hills	0.86	0	3.62	5.53	3.65	20.55	19.75
South Saurashtra	3.61	6.06	9.8	17.46	24.08	85.42	26.75
Gujarat	12.96	38.13	90.65	131.02	140.1	550.21	34.66

Source: Authors' compilation from GGRC

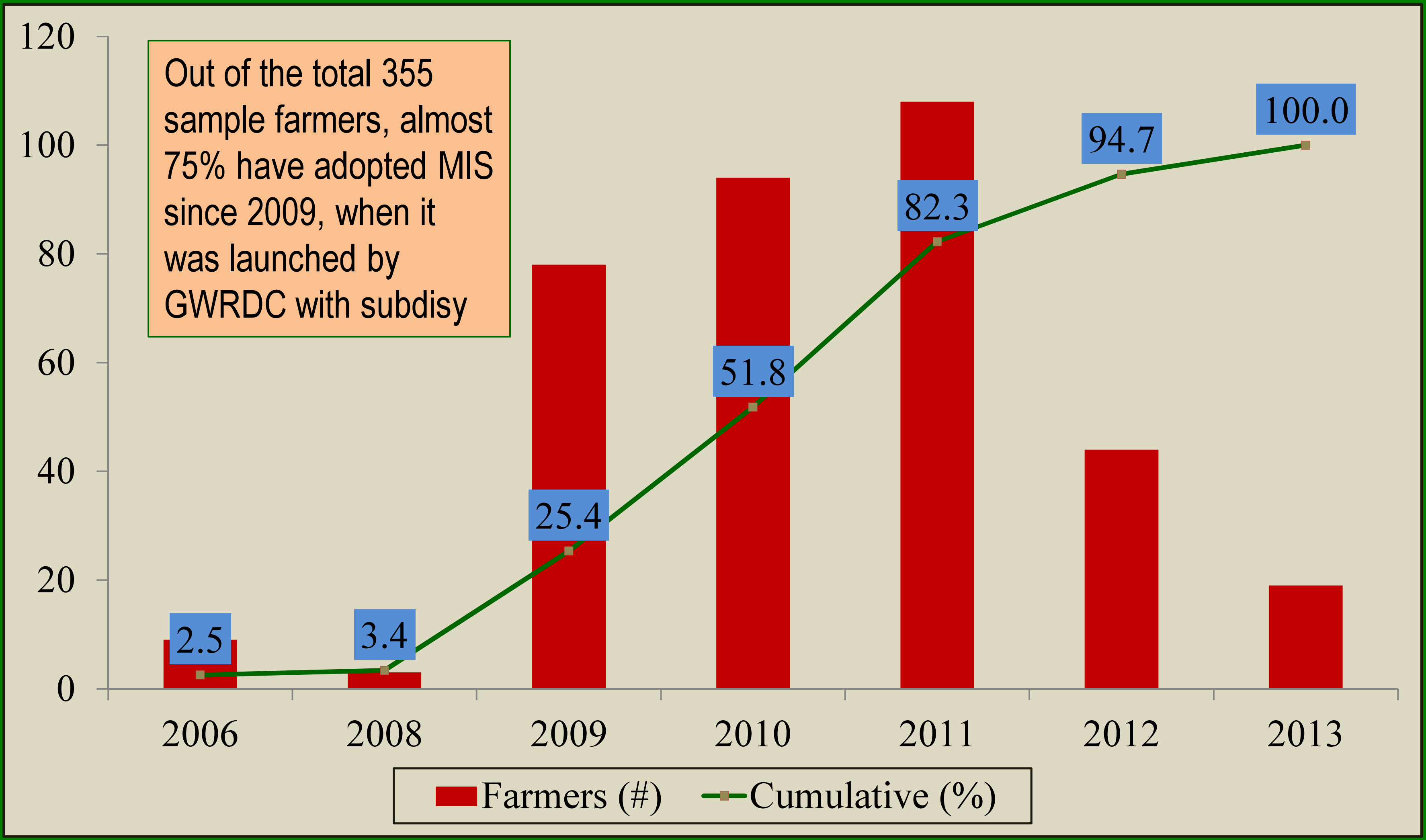
Area under MIS in Gujarat, Agro-climatic zone wise: 2006-07 to 2013-14 (in '000 ha)

Agro Climatic Region	2006-07	2009-10	2011-12	2012-13	2013-14	Total	CAGR (%)
North-West Arid	2.11	2.4	2.19	9.68	12.06	36.7	24.37
North Gujarat	5.98	24.38	48.64	75.92	78.68	293.53	38.02
Middle Gujarat	2.27	6.04	24.88	23.55	17.52	94.68	29.09
North Saurashtra	4.62	17.16	43.41	52.21	63.98	238.26	38.91
South Gujarat	3.92	3.04	10.55	15.55	12.27	66.09	15.32
Southern Hills	1.56	0	5.05	6.62	4.35	27.34	13.64
South Saurashtra	5.25	9.04	14.53	26.34	36.09	124.52	27.26
Gujarat	25.7	62.06	149.26	209.88	224.95	881.11	31.15

Source: Authors' compilation from GGRC

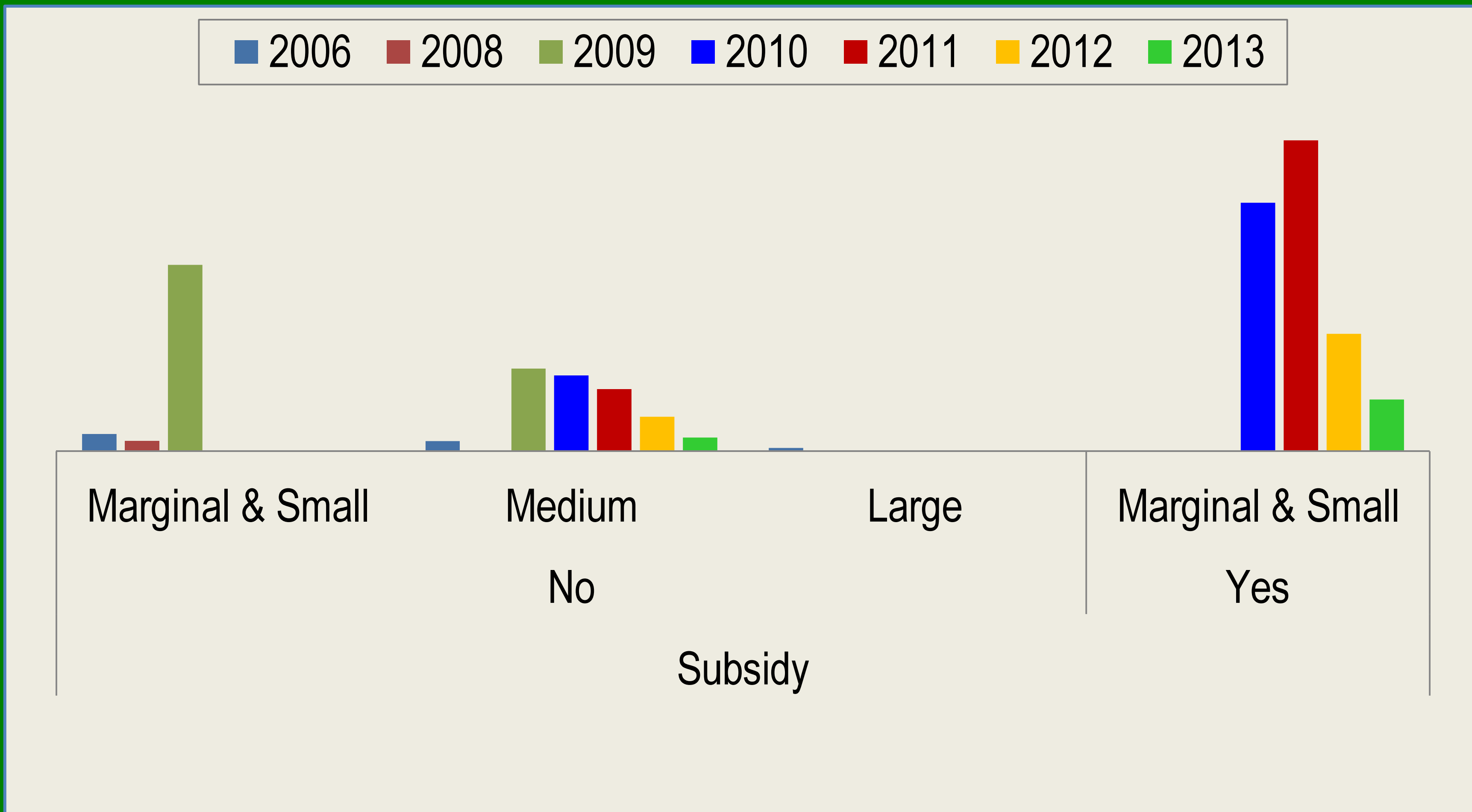
Notable increase in MIS adoption in North Gujarat, North Saurashtra and South Saurashtra regions while Middle and South Gujarat reported a decline over the years

Financial incentives impacting MIS adoption



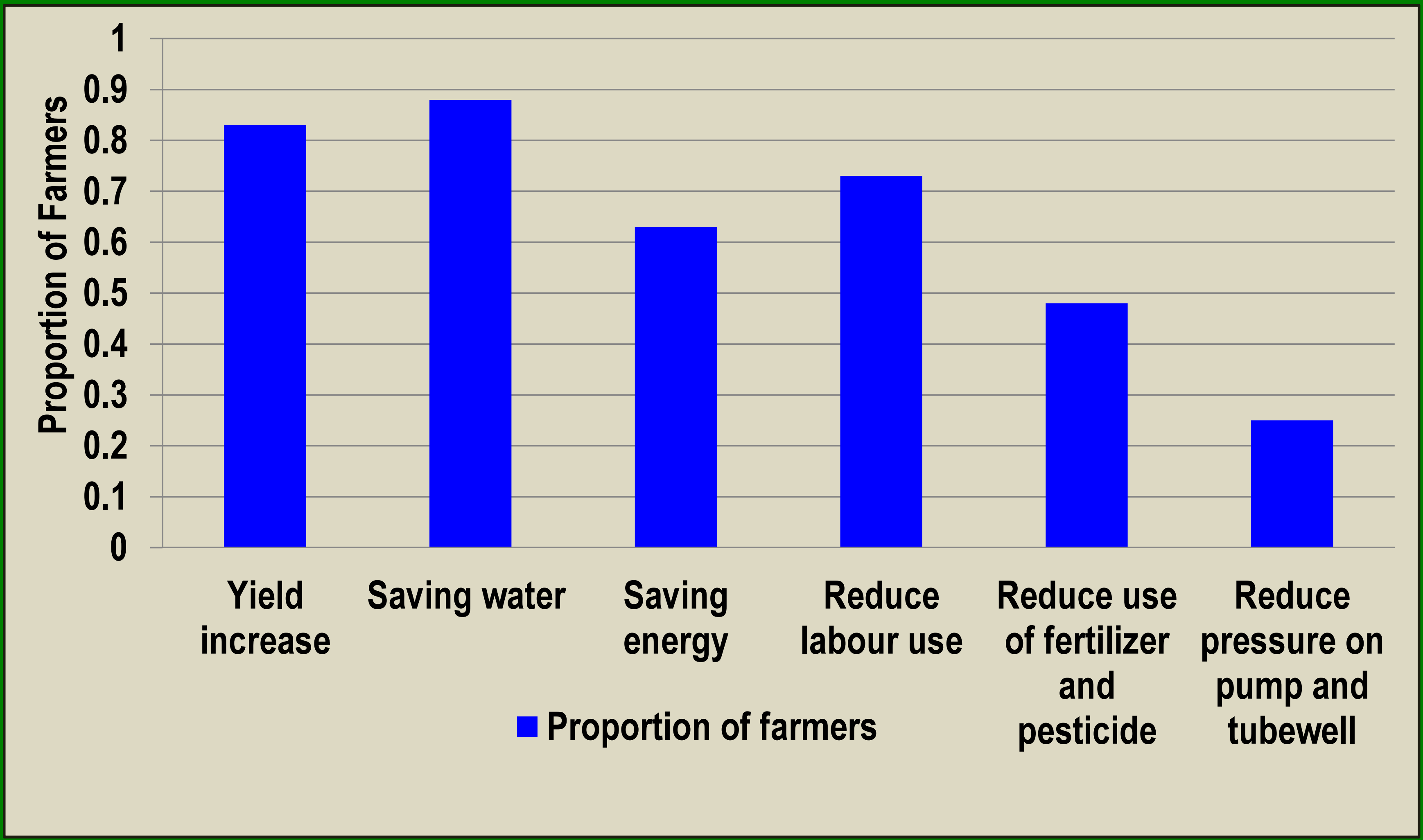
Source: Farm Household Survey of 355 MIS adopted farmers

Impact of subsidy policy on adoption behaviour of marginal and small farmers



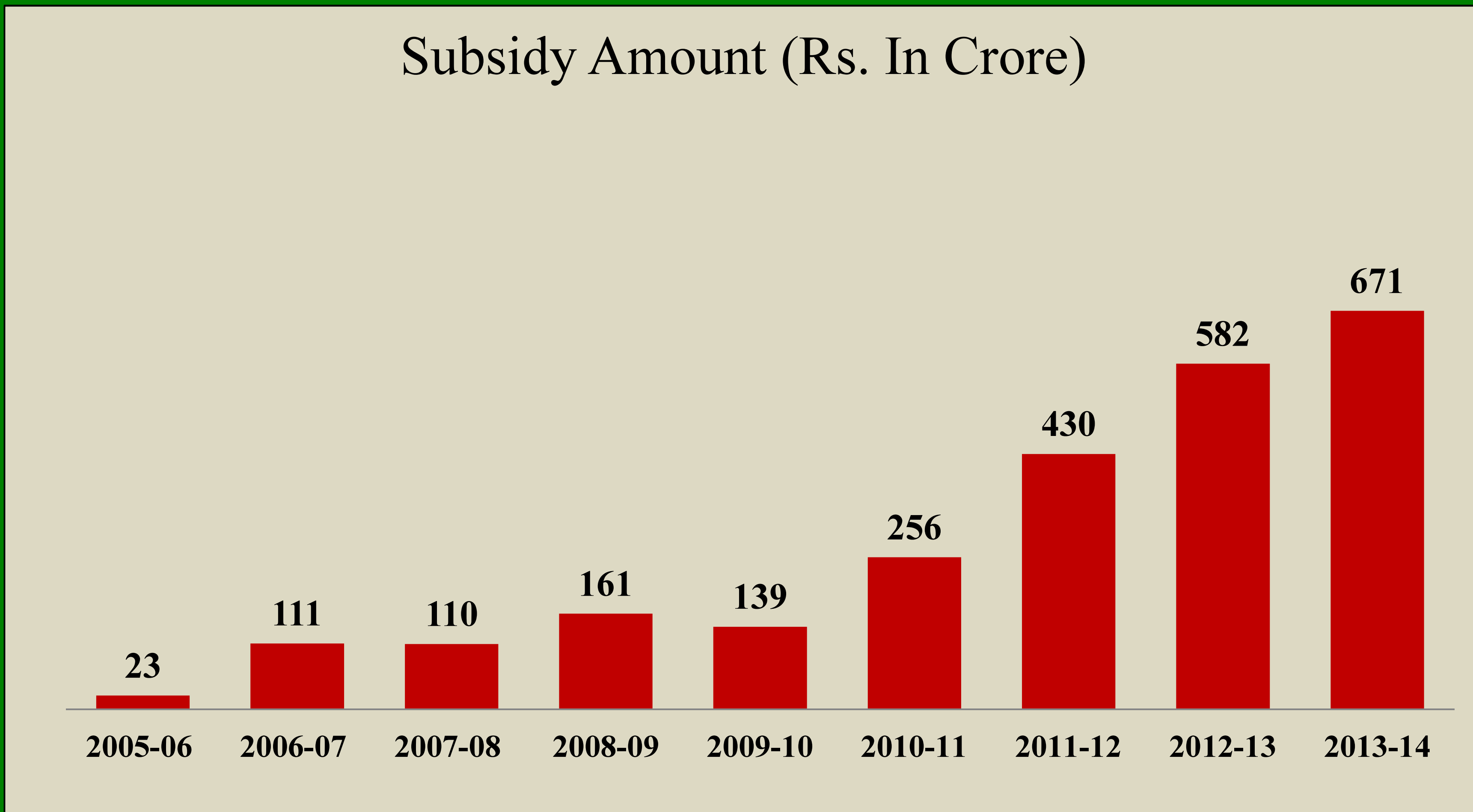
Source: Farm Household Survey of 355 MIS adopted farmers

Benefits of MIS: Farmer perceptions



Source: Farm Household Survey of 355 MIS adopted farmers

Financial subsidy for MIS in Gujarat



Source: **GGRC**

III. Determinants of accessing benefits of MIS

- To analyse the determinants of accessing various benefits of MIS, a discrete choice model was used as the dependent variables are binary in choice.

- We used a probit model to assess the effects of seasonality and cropping patterns in accessing the benefits of MIS.

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

- Further to interpret the effects of explanatory variables on the probabilities, the marginal effects of both continuous and discrete explanatory variables were estimated.

- 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), suggesting no problems of multicollinearity.

Determinants of Benefits of MIS: Results of probit analysis (Odds ratios)

	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	70.14***	49.60***	24.64**	39.48***	46.69***	27.13**
Pseudo	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

Results of probit analysis

- The values of Wald are found as significant, which indicate that the independent variables taken as a group are quite significant in explaining the farmers' perception on benefits of adopting MIS.
- 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.

Results of probit analysis

- 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.

IV. Conclusions and future perspectives

- **The results 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.**

- **It demonstrates that the farmers who have adopted the MIS under the subsidy programme by the state government have been compensated for the investments that they made into MIS.**

- **By and large, farmers reported growing a range of crops especially during the kharif and Rabi seasons and most of these crops have been brought under the MIS.**

IV. Conclusions and future perspectives

- While 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, due mainly to the water scarcity in the regions.
- Though MIS seems to be beneficial from individual farmers point of view, social benefits are largely ignored, as MIS is not promoted with an objective of making real water savings for environmental/ ecosystem functions
- The emerging local dynamics of management of MIS installed public tubewells is yet another major concern, needing careful interventions
- While adoption of MIS by the farmers has been quite impressive during the kharif and Rabi seasons, its use for growing summer crops has been found to be much lower and very much restricted to few crops.

IV. Conclusions and future perspectives

- The 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.

Thank you all…

Distribution of public tubewells with MIS in Gujarat districts, 2012-13

District	Public Tubewells (No)	(%) share	Farmers (No)	(%) share	Total Area (ha)	Avg. no of farmers/ 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
All districts	250	100	1365	100.0	1271.14	5.46	5.08	1.20

Source: Gujarat Water Resources Development Corporation, Government of Gujarat

Comparative analysis of impact of MIS on season-wise crop yield

Season/ crops	Average Yield before MIS[1] (kg/ha)	Average yield After MIS[2] (kg/ha)	Average yield under Non-MIS (kg/ha)	(%) difference in yield under MIS compared to	
				Before MIS	Non-MIS (flood irrigation)
A. Kharif season					
1. Cotton	3577.5	3456.2	3318.8	-3.4	4.1
2. Groundnut	3137.5	4013.7	3088.8	27.9	29.9
3. Bajra	3131.2	3250.0	3328.8	3.8	-2.4
4. Jowar	1982.5	2075.0	1610.0	4.7	28.9
5. Castor	3043.7	3507.5	3270.0	15.2	7.3
6. Guvar	1832.5	1992.5	1597.5	8.7	24.7
7. Fodder	3170.0	4062.5	4687.5	28.2	-13.3
8. Sesame	1166.2	1478.7	868.7	26.8	70.2
9. Green Gram	1200.0	937.5	625.0	-21.9	50.0
10. Vegetables	3593.7	5833.7	NA	62.3	NA
Average	2583.5	3060.7	2488.3	18.5	23.0
B. Rabi season					
1. Castor	2957.5	3411.2	3295.0	15.3	3.5
2. Mustard	2537.5	2935.0	3151.3	15.7	-6.9
3. Wheat	3808.7	4976.2	4196.3	30.7	18.6
4. Fodder	2812.5	2500.0	4375.0	-11.1	-42.9
5. Rajgaro	2348.7	2466.2	2911.2	5.0	-15.3
6. Fenugreek	3958.7	4166.2	3228.7	5.2	29.0
7. Potato	14548.7	21283.7	15000	46.3	41.9
8. Cumin	1031.2	1625.0	1812.5	57.6	-10.3
Average	4250.4	5420.5	4746.2	27.5	14.2
C. Summer season					
1. Bajra	3333.7	4103.7	3655.0	23.1	12.3
2. Fodder	2250.0	2571.2	2375.0	14.3	8.3
3. Guar	1625.0	1771.2	1312.5	9.0	35.0
Average	2402.9	2815.4	2447.5	17.2	15.0

MIS: Economic, environmental and social benefits

Econ/ environ/ social benefits	Responses (No.)	(%) of positive response
A. Economic and environmental benefits		
1. Increase in yield of crops	107	87.7
2. Saving of water use	108	88.5
3. Reduces over-extraction of ground water	74	60.7
4. Reduces use of pesticides	67	54.9
5. Reduction in fertilizer use	67	54.9
6. Reduction in pest and diseases	85	69.7
7. Reduces weeding cost	85	69.7
B. Social benefits		
1. Saving of energy consumption	81	66.4
2. Efficient allocation of water among farmers	114	93.4
3. Reduced water scarcity induced labour migration	43	35.3