Technical and Socio-Economic Assessment of Micro Irrigation Systems in the Small Scale Farming Sector of Sri Lanka

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ABSTRACT. *Micro Irrigation Systems (MIS) has been introduced to the small farmers in Sri Lanka since 2000 mainly to increase the crop productivity and water use efficiency. Although there has been a continuous support to upscale this intervention both by the government and donor agencies, anecdotal evidences indicate that the intended benefits were not fully achieved. Therefore, this study was conducted to determine whether the objectives of introducing MIS have been achieved and to understand the factors influencing its success and failure so as to formulate guidelines for future investments in the micro irrigation sector.*

A comprehensive field survey was conducted with 300 MIS receivers who were randomly selected from dry and intermediate zones of Sri Lanka. Technical, socio-economic and production information on MIS receivers were collected during the period, November 2003 to September 2004. Net farm income, land productivity, technical efficiency and factors affecting successful adoption of the technology were computed for different MIS user level and compared.

The results indicated that the net income of farmers who used MIS in the dry zone has increased whilst there is hardly any impact in the intermediate zone. The technical efficiency computed based on the Cobb-Douglas production model indicated that continuous use of MIS has increased the technical efficiency substantially during the period 2000 - 2003 in all user farmers compared to non-users. A 19% technical efficiency improvement was recorded by high intensity MIS user farmers. Land productivity based on chillie cultivation was found to be the highest with high intensity MIS users in the dry zone. The Logit regression analysis revealed that selection of drip over sprinkler irrigation systems was the most affected factor for the success of MIS in both dry and intermediate zones. Farmer satisfaction and land extent of the MIS were also found to be important factors for better adoption.

INTRODUCTION

In order to improve the agricultural productivity in the dry zone, the concept of large diameter wells (agro-wells) was introduced by the Agricultural Development Authority (ADA) in 1989 with a pilot project of 200 wells (Karunarathna, 2002a).

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With the success of this technology, a large number of organizations as well as individuals have heavily invested in constructing agro-wells during the subsequent period. At the end of year 2000, 18,338 agro-wells had been built in the dry zone, of which 10,178 were completed while others were under different stages of construction. This uncontrolled development of agro-wells created problems of excessive extraction of water from the limited shallow ground water table. In order to circumvent this problem of excessive use of groundwater, ADA submitted a cabinet memorandum in July 2000 to obtain special cabinet approval for providing subsidies to introduce micro irrigation systems (MIS) for agro-well farmers as a strategy of achieving higher water use efficiency and higher production potential (Karunarathna, 2002b). Micro irrigation technology which is one of the improved irrigation technologies used in many parts of the world, includes both drip and sprinkler irrigation technologies. Investment on micro irrigation as a policy was also taken in view of its potential to increase productivity and alleviate poverty.

By the end of 2001, ADA had given subsidies to 540 farmers to irrigate 0.5 acres of highland using MIS. In addition, Department of Agriculture, Samurdhi Authority, Provincial Ministries of Agriculture and several Non-governmental Organizations also granted loans and subsidies to install MIS in the dry zone as a strategy to alleviate poverty and improve food security. The numbers of companies marketing micro irrigation equipment has also increased over the years to meet the increased demand. By the year 2004, there were more than 15 registered companies in the MIS business.

Since MIS has been identified as a technique to increase the productivity and a tool for poverty alleviation, the Government of Sri Lanka is continuing its policy support to increase the investment in this sector. However, some of the anecdotal evidences indicate that the intended benefits were not fully achieved. Therefore, it is of paramount importance to investigate the present status of MIS together with the identification of constraints for its use which will help to plan strategies to improve the adoption of this technology. Investing substantial amount of funds without identifying the constraints, both technical and socio economic, will be wasteful and even counter productive to the farming community and to the national economy.

Therefore, this study was conducted to determine whether the intended benefits of introducing MIS to the small-scale farming systems have been achieved and to understand the factors influencing its success/failure so as to formulate guidelines for future investment of the micro irrigation sector.

METERIALS AND METHODS

Data collection

A stratified randomized sample of 300 farmers was drawn covering 21 agro ecological zones on a proportional basis according to the number of MIS given for each zone, as shown in Table 1. Selected farmers were interviewed using a pre-tested structured questionnaire during the period from November 2003 to September 2004. The questionnaire included information on family details, land use, water source and irrigation system, services provided by the private and government sector, cultivation and marketing, and socio-economic information.

Table 1. Number of farmers selected for the study.

Agro Ecological Zone	Number of MIS farmers	Number of farmers selected
DL 1b	278	112
DL 1c	25	10
DL 1e	7	3
DL 1f	2	1
DL 2b	2	1
DL 3	2	1
DL 5	22	9
IL 1a	117	47
IL 1b	45	18
IL 2	7	3
IL 3	154	62
IL 1a	7	3
IM 1a	2	1
IM 2a	15	6
IM 2b	10	4
IM 3b	20	8
IU 2	2	1
IU 3a	5	2
IU 3b	5	2
IU 3e	7	3
WL 2a	7	3
Total	744	300

Data analysis

The MS Excel software package was used to process the primary data collected through the questionnaire survey. This data were processed into different formats to facilitate a range of analyses using software Minitab 11 and Frontier 4.1. The farmers were first grouped into two categories, as users and non-users. User farmers were again grouped into four categories as depicted in Table 2 depending on the level of use. This grouping was based on the number of seasons during which MIS was used out of the total number of seasons.

Table 2. User levels of micro irrigation system (MIS) by farmers.

User level (%)	Farmer category
0	Non users
01-25	Very low users
26-50	Low users
51-75	Moderate users
76-100	High users

Note: The farm income, land productivity, technical efficiency and identification of factors influencing the success of MIS were analysed during the study.

Farm income

Farm income in each season, i.e. gross income per crop, was first calculated by multiplying production by the farm gate price. This was then extended for all cultivated crops to obtain the total gross income. The net farm income was calculated by subtracting the cost of cultivation from the gross farm income. The net farm income values thus calculated for each farmer were aggregated and divided by the number of farmers to estimate the mean annual net farm income. This was carried out separately for different user levels and for non-users in the dry zone and intermediate zones. A comparison of net farm income between different user levels and non-users was made using pooled 't' test. Then this was extended to all climatic zones.

Land productivity

In order to calculate the mean land productivity, one field crop (i.e. chillies) was selected since that was the most widely cultivated crop by the farmers surveyed. The land productivity was calculated by dividing the total production of chillie crop by the cultivated extent.

Technical efficiency (TE)

Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977) independently proposed the estimation of a stochastic frontier production function, where noise is accounted for by adding symmetric error term (v_i) to the non negative error term (u_i) as;

$$Y_i = f(x_i;\beta) + \varepsilon_i; \tag{1}$$

$$\varepsilon_i = v_i - u_i \quad i = 1, \ldots, N$$

Where Y_i denotes production level of the i^{th} farm, x_i is input level and β is vector of unknown parameter to be estimated; ε_i is the composed error term; f (x_i:β) is a suitable production functional form; v_i is independently and identically distributed random error N (0, σ_i). u_i is non negative random variable which represents the Farell (1957) technical inefficiency i.e. the distribution of u_i is half normal. Aigner *et al.* (1977) suggested that the maximum likelihood estimates of the parameters can be obtained by parameterization of $\sigma^2_v + \sigma^2_u = \sigma^2$ where σ_v and σ_u are standard deviation of v_i and u_i, respectively. Following Aigner and Chu (1968), a Cobb-Douglas production function can be estimated as shown in Equation 2.

$$\ln Y_i = \ln x_i^{'} \beta + u_i \tag{2}$$

Where, ln Y_i is logarithm of output Y in i^{th} farm; ln $x_i^{'}$ is logarithm of input vector. Then,

$$TE = Y_i / \exp(\ln x_i^{'} \beta) \tag{3}$$

The Cobb-Douglass production model was used for the empirical estimation of the technical efficiency. The main reason of using the Cobb-Douglass functional form is its wider use in farm efficiency studies (Bravo-Ureta and Pinheiro, 1993). Further, there are more flexible forms such as translog are associated with the high degree of multicollinearity. The model used for the estimation was,

$$\ln y = \beta_0 + \sum^k \beta_1 \ln x_i + v_i - u_i \tag{4}$$

Where, y is the value of crop output in rupees; x_i are the inputs in the production process namely land, seeds, fertilizers, agro-chemicals, labor and cost of irrigation. The software *FRONTIER* (Version 4.1) developed by Coelli (1994) was used to estimate the technical efficiency.

Success of adoption

The farmers who have used MIS for more than 75% of the cultivated seasons and those who have not used MIS though they were given the MIS during the period from 2000 to 2003 were used for this analysis. Those who used MIS for more than 75% of seasons were identified as the most successful adopters while those who did not use MIS was identified as unsuccessful adopters.

Factors affecting success of MIS adoption were identified by fitting a binary logistic regression model at different user levels (Gujarati, 2004), as given in Equation 5.

$$\ln[P_i/(1-P_i)] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ..\beta_k X_k + \varepsilon_1. \tag{5}$$

Where, P_i in the probability of adoption of MIS and $P_i/(1-P_i)$ is the odds ratio. $X_{1,} X_{2,...}X_k$ are explanatory variables such as socio economic factors, farm-specific characteristics, and MIS related variables. The socio economic variables include education level and farming status while farm-specific variables were extent of cultivation, slope of the land, soil type and water availability. The MIS related variables include exposure to practical training, type of system, technology transfer and farmer satisfaction.

RESULTS AND DISCUSSION

Mean annual net income

As described in the materials and methods section, mean annual net income of non-users and all four user levels were obtained by calculating total net income values for each group in each year and dividing it by the number of farmers in each group. Figure 1 indicates that the net income has increased with the intensity of user level for all years thus giving the highest mean income for 76-100% user level. It is also noticeable that non-users have received a higher income compared to some of the farmers with low user levels in each year. In order to compare the performance of different user levels with non-users, a pooled 't' test was employed to compare each level with non-users (Table 3). Since there was a high variability of net farm incomes, no significant differences between users and non-users within year, were observed in most cases. However, with respect to mean aggregate net income for the study period of 2000-2003, users had a significantly higher income than the non-users.

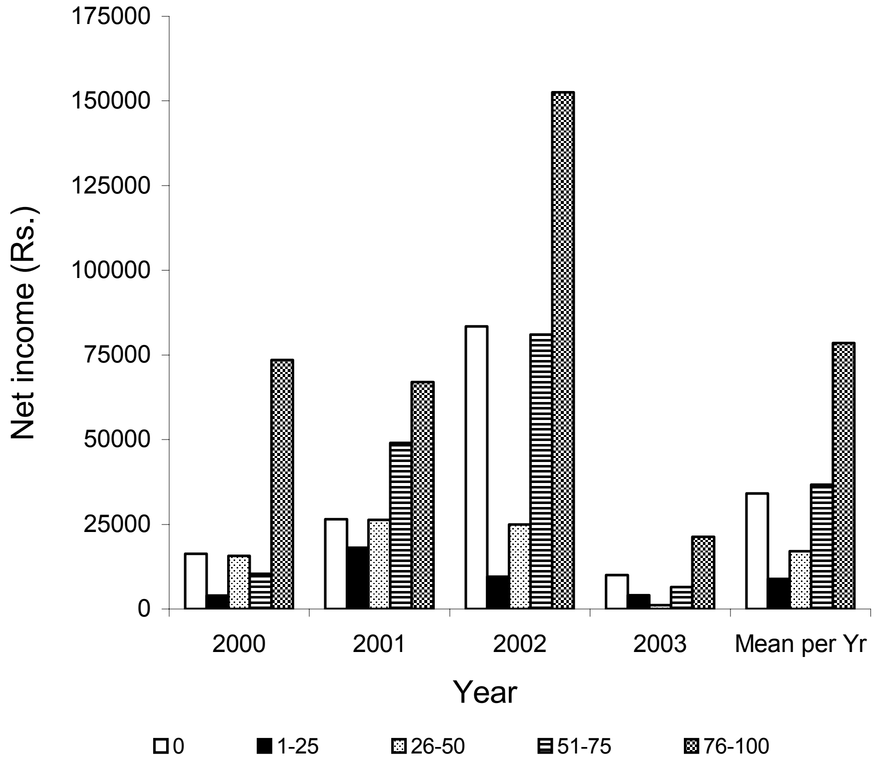

Fig. 1. Mean annual net income at different user levels.

Table 3. Comparison of mean net farm income against non-users using 't' test.

User level (%)	P value				
	2000	**2001**	**2002**	**2003**	**Per year**
01 - 25	0.4804	0.4946	0.0643*	0.1282	0.0611*
26 - 50	0.2880	0.1245	0.4787	0.3126	0.4184
51 - 75	0.1004*	0.0805*	0.1329	0.2704	0.0179**
76 - 100	0.4944	0.3946	0.1212	0.2026	0.1416
All user farmers	0.0887*	0.2883	0.0256**	0.1787	0.0087**

Note: **Significant at 5%; *Significant at 10%.

This information was further divided as dry and intermediate zones. Figure 2 and Table 4 show the details on net income data for the dry and intermediate zones for different user levels. According to the results, users in the dry zone have received a significantly higher net farm income than non-users in years 2001 and 2003. However, the mean income per year of users was significantly higher than that of non-users in the dry zone. In the intermediate zone, only the high users of MIS had significantly high net farm income over the non-users.

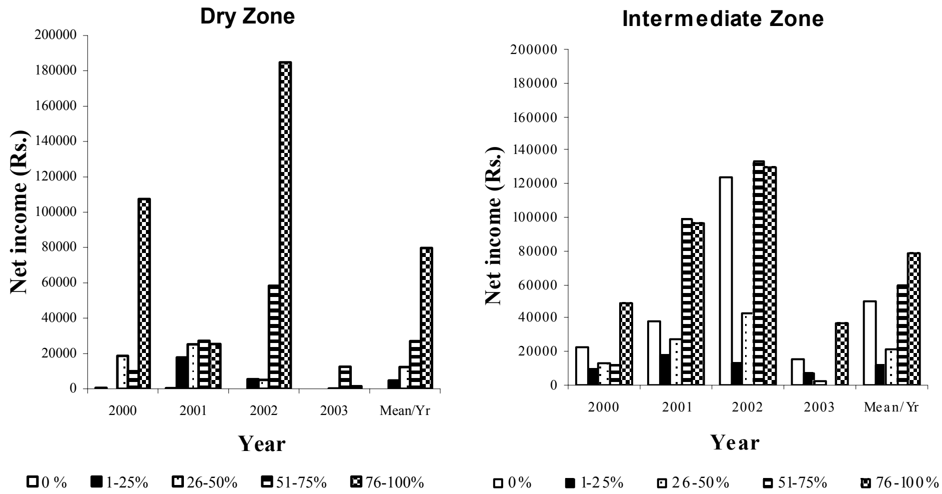

Fig. 2. Mean annual net incomes at different user levels in dry and intermediate zones.

Table 4. Comparison of mean net farm income against non-users in dry and intermediate zones using 't' test.

User level (%)	P value				
	2000	**2001**	**2002**	**2003**	**Per year**
Dry zone					
01-25	0.1895	0.0088**	0.0551*	0.3141	0.0188**
26-50	0.1296	0.0355**	0.0409**	0.3497	0.0055**
51- 75	0.1610	0.0070**	0.0011**	0.0234**	0.0000**
76- 100	0.1550	0.1229	0.0439**	0.4692	0.0157**
All user farmers	0.0716*	0.0004**	0.0002**	0.1555	0.0000**
Intermediate zone					
01-25	0.2346	0.3149	0.0689*	0.1070*	0.0322**
26-50	0.2124	0.0762*	0.4577	0.0079**	0.3622
51- 75	0.1644	0.0932*	0.4662	0.2043	0.1065*
76- 100	0.2768	0.4908	0.0732*	0.1623	0.0589*
All user farmers	0.1592	0.1880	0.0180**	0.1703	0.0054**

Note: **Significant at 5%; *Significant at 10%.

Technical efficiency

The changes of individual technical efficiencies which measure the ability to achieve the best production level at a given set of inputs, is a good indicator of the performance of MIS. The Cobb-Douglas production frontier was fitted using maximum likelihood estimation method to compute technical efficiencies of individual farmers in each year. The technical efficiencies obtained were grouped according to the MIS user levels.

Table 5. Mean technical efficiency of MIS adopting farmers.

User level (%)	Mean technical efficiency of each year (%)				
	2000	2001	2002	2003	Mean
0	55.86	66.86	66.56	71.00	65.07
01-25	98.02	62.01	98.91	61.52	80.11
26-50	53.14	98.92	72.62	97.41	80.52
51-75	98.19	69.42	64.73	56.42	72.19
76-100	80.54	96.02	95.85	99.73	93.03
Overall mean	88.90	93.09	92.54	92.31	92.16

The mean technical efficiency of high users (76-100% level) has continuously increased during the 2000 to 2003 as shown in Table 5. According to Table 6, there is a significant difference between mean technical efficiency of non-user farmers and user farmers (in all user levels) implying that adoption of MIS has helped the farmers to increase the technical efficiency of their farming operations.

Table 6. Comparison of mean technical efficiency against non-users.

User level (%)	P values				
	2000	2001	2002	2003	Annual mean
01-25	0.000**	0.179	0.000**	0.055*	0.000**
26-50	0.366	0.000**	0.110*	0.000**	0.000**
51-75	0.000**	0.315	0.388	0.016**	0.429
76-100	0.101*	0.099*	0.098*	0.101*	0.006**
All users	0.005**	0.010**	0.017**	0.045**	0.000**

Note : **Significant at 5%; *Significant at 10%.

High users (76-100%) recorded the highest mean technical efficiency of 93% compared to other user levels. They have obtained 19% efficiency increment over the period 2000-2003. Though there was no systematic increase of technical efficiency of other users groups, the technical efficiencies were comparatively higher than that of non-users. The technical efficiency of non-users and all users was also significantly different (Table 6).

Since there was a clear impact of MIS in the dry zone, as shown by the increase of net income, a Cobb-Douglas production function was fit using maximum likelihood estimation to estimate the technical efficiency only for the dry zone. The results are given in Tables 7 and 8. Improvement of technical efficiency is much more pronounced for the dry zone compared to the aggregated analysis for both dry and intermediate zones. This was clearly indicated by the results given in Table 7, where comparisons of technical efficiency between non-users and all user levels were significant, except for 51-75% user level.

Table 7. Mean technical efficiency of the MIS adopted farmers in the dry zone.

User level (%)	Mean technical efficiency of each year (%)				
	2000	**2001**	**2002**	**2003**	**Mean**
0	63.76	73.02	65.11	67.18	67.71
01-25	95.82	59.32	99.91	59.20	76.20
26-50	52.84	93.94	73.14	99.49	81.88
51-75	98.19	68.71	70.15	52.36	73.09
76-100	86.79	95.66	95.82	99.73	94.48
All users	78.61	82.61	83.22	78.45	80.82

Table 8. Comparison of mean technical efficiencies against non-users in dry zone.

User level (%)	P values				
	2000	**2001**	**2002**	**2003**	**Annual Mean**
01-25	0.0020**	0.0759*	0.0052**	0.2205	0.0574*
26-50	0.0018**	0.0002**	0.0060**	0.0029**	0.0018**
51-75	0.1754	0.2137	0.2723	0.1170*	0.1754
76-100	0.0000**	0.0000**	0.0001**	0.0028**	0.0000**
All users	0.0022**	0.0077**	0.0243**	0.1370*	0.0022**

Note : **Significant at 5%; *Significant at 10%

Land productivity

Although farmers have cultivated different crops including vegetables, fruits, cereals and ornamental plants, chillie is the most widely cultivated crop under the MIS. Therefore, farmers who cultivated chillie were selected to calculate the land productivity. A total of 110 farmers cultivating chillie were identified from both dry (55 farmers) and intermediate (55 farmers) zones, where at least one chillie crop was cultivated during 2000 and 2003. Mean land productivities were calculated only for the *Yala* season because there were very few farmers who cultivated chillie during the *Maha* season.

Figure 3 shows the distribution pattern of the mean land productivity where chillie was cultivated during the Yala season in the dry zone. High users (76-100%) have recorded significantly higher mean land productivity values than the non-users in each year as shown in Table 9. Except for 2001 and 2003, 51-75% user groups also have obtained higher productivity levels compared to non-users. These results indicate that farmers who used MIS intensively (>50% level) have achieved the highest productivity levels in each year than the non-users. Therefore, the continuous usage of MIS is appeared to be helpful in improving the land productivity.

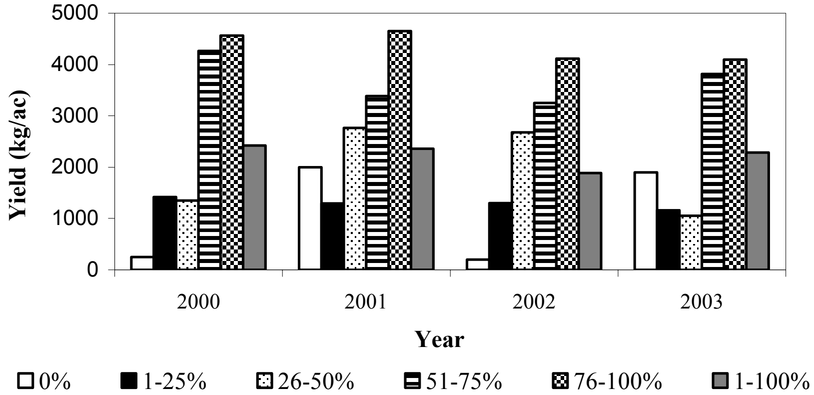

Fig. 3. Mean land productivity of Chillie farmers in *Yala* (Dry Zone).

Table 9. Comparison of the land productivity of users against non-users in Yala (Dry Zone).

Farmer level (%)	**P values**				
	2000	**2001**	**2002**	**2003**	**Per year**
01-25	0.4535	0.3463	0.4253	0.1597	0.1120*
26-50	0.4656	0.3059	0.1630	0.4570	0.2413
51-75	0.0270**	0.2766	0.0501**	0.2106	0.0180**
76-100	0.0163**	0.0036**	0.0522**	0.0470*	0.0000**
All user groups	0.1901	0.2493	0.1832	0.4594	0.1371*

Note : **Significant at 5%; *Significant at 10%.

Factors affecting the successful adoption of MIS

As described in the Materials and Methods, a Logit model was fit to identify the factors affecting the successful adoption of the MIS technology. As shown in Table 10, the type of the MIS, farmers' satisfaction and cultivated land extent were the only factors, which affected the successful adoption of the MIS.

The analysis revealed that the successful farmers have used drip irrigation systems although majority of farmers surveyed in this study used sprinkler irrigation systems. Before selling the MIS, a demonstration of drip and sprinkler irrigation systems was given to farmers and they were asked to select the system. Based on their decisions, MIS were given to them by the private sector companies. Most of the farmers preferred sprinkler systems compared to drip systems because the former was more impressive, especially with regard to the mode of water delivery to the crop like simulated rain. However, drip systems were found to be more suitable compared to sprinkler systems in both dry and intermediate zones. There were many reasons for the poor adoption of MIS as previously reported (Prathapasinghe, 2002; Aheeyar *et al.*, 2003; Ekanayake *et al.*, 2004). However, those who were satisfied with the MIS were found to be more resourceful and innovative farmers with good knowledge of practical agriculture. They also showed better access to market than the others. Some of the innovation included modified emitters, placing burned rice husk ash around plants for good water distribution, placing water containers in the field to prevent rodent/squirrel attacks on the irrigation system *etc*.

Table 10. Factors affecting success in adoption.

Tested Factor	P value
Education level (educated =1/no= 0)	0.915
Practical training of MIS (trained =1/no =0)	0.812
Farmer profession (farming= 1/other= 0)	0.547
Cultivated extent (0.5Ac=<,1/other= 0)	0.130*
Land slope (not sloppy =1/other =0)	0.474
Soil type (clay = 1/other =0)	0.710
Water availability over year (available= 1/no 0)	0.424
Water quality by appearance (good =1/no =0)	0.620
Well type (agro well =1/no= 0)	0.432
MI technology transfer (Extension =1/other= 0)	0.235
Farmer satisfaction (satisfied= 1/not satisfy =0)	0.057*
Type of MI system (drip= 1/sprinkler =0)	0.001**
Log – likelihood	-62.909
G	24.434

Note : **Significant at 5%; *Significant at 10%.

CONCLUSIONS

The MIS given to farmers under various subsidy programs has increased the net income of farmers in the dry zone despite high variability. Annual mean technical efficiencies were found to be improved in high MIS users. The inefficient MIS farmers improved over the time especially with the continuously use of the technique. Land productivity has increased due to MIS when level of use is more than 50%. Drip irrigation is found to be more adoptable compared to sprinkler irrigation systems. Farmer satisfaction and cultivated land extent of the MIS was also found to be a reason for better adoptation. Proper identification of farmers (i.e. satisfied and enthusiastic) for this type of subsidy program is a must for successful adoption.

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