THE APPLICATION OF MICRO IRRIGATION TECHNOLOGIES IN THE SMALL FARMING SECTOR IN SRI LANKA: POTENTIAL AND CONSTRAINTS

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FOREWORD

We have before us a disciplined and well-researched study on micro-irrigation in Sri Lanka. It is perhaps the first such study in which the application of new technologies has been assessed in relation to land and water use systems that have a long history here. Its basic assumptions flow from the point of approach chosen and that complement, in a fundamental way, the parameters adopted in the study for analysis in 'economic' terms.

It also corresponds to a dominant paradigm based on notions of human development that are defined in relation to industrialisation or the adoption of machinery as being the key also to 'civilisation'. It is sufficient, at this point, to record that the transfer of responsibility for maintaining and erecting systems of water management to Civil Engineers who had not been given, as a part of their training, a knowledge of the productive bonding of water with land, has created distortions in the management of both.

The development of the dry zones in the north-central, north-western and south-eastern segments of this island could not have occurred in the absence, of an appreciation of the water resources that could be harnessed for crop production and of the most efficient ways for doing that. In other words, 'micro-irrigation', in so far as it refers to the use of quantities of water that are near enough the minimum required for the cultivation of food crops, is not unknown to our traditional farmer, - indeed it is not new or 'news' to him. What is new is the particular 'technology' the applications of which have been recently introduced to the Lankan market.

Our farmers have long known what crops to grow under the rainfall or water supply regime that determines crop production in their locality. It is when fresh demands are made on them to respond to 'economic imperatives' at macro level that 'problems' of changes in land use and the attempts to promote the adoption of new technologies come into focus. They have a bearing not only on the 'efficiency' of water use but on the capacity of the farmer, big or small, to bear the cost of such a change within a cash economy. The relationships that have been here examined, for 'cash crops' that are important for the balance of payments at national level, typically take the form of advocacy in terms of the (private) profitability for the farmer of a change in crop and in the technology, including cultivation practices, that are said to be required to support such a positive development.

In the context of the large-scale devastation of our forests, especially in the central highlands, for private profit particularly in coffee and tea, and its continuing adverse impact on our water resources, among others, Deduru Oya, Mahaweli Ganga, Maha Oya, Kirindi Oya, Walawe Ganga, Kalu Ganga, Kelani Ganga, Kumbukkan Oya and their feeder streams - the need to conserve this primary resource has become acute. However, this study does not seek to address that 'macro' problem: such a project was beyond its scope.

It shows that the technology for micro-irrigation here has been supply-driven. Companies with such hardware for sale have sought to operate via NGOs and other less informal agencies. A question that arises is whether the "Seva Lanka Foundation" or the Agricultural Development Authority had evaluated the hardware on offer in terms of its applicability in specific locations in relation to specific crops or of the prices quoted. This study shows also that a major constraint to the micro-irrigation programme has been the inappropriateness of the equipment that has been foisted on such agencies. It also brings out the fact that farmers were opting out of the technology brought to them. It is a technology, presumably as advocated by its vendors that required further investments by its clients in high-priced chemical fertilizers and other agro-chemicals.

As it has been noted in this report, further investigation into the factors, that would determine the adoption of the technologies examined here and of their use for our farmers is needed. There can be no doubt that hydraulic-mechanical systems designed to optimise the use of the depleted water resources we still have, need to be developed by our scientists. Such an exercise must necessarily complement further studies of the socio-economic features that will determine the uses of micro-irrigation in application that have been documented here.

D.G.P. Seneviratne
Director

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Authors

EXECUTIVE SUMMARY

Compared to other forms of irrigation, micro irrigation plays an important role in the management of crops to obtain the maximum yield from lesser quantities of water, chemicals and fertilizer. The agricultural sector in Sri Lanka, as the largest user of water faces the difficult challenge of increasing the efficiency of use of water to increase or maintain crop yield while at the same time allowing re-allocation of water from agriculture for rapidly growing urban, domestic and industrial uses. One of the technical methods available to improve the efficiency of water usage is the adoption of micro irrigation (MI) technologies to reduce losses during distribution and on-farm water management.

The government of Sri Lanka and various donor agencies have invested considerable sums of money on the development of micro irrigation on a pilot basis since late 1990s. The Agricultural Development Authority in association with various micro irrigation-supplying companies played a pioneering role in promoting MI technology among small farmers from 1998 onwards. Various companies under different intervention programmes together with private investments by individual farmers have so far provided MI units to cover an estimated extent of about 6,000 acres island wide. The degree of adoption of the supplied/installed MI systems is not yet known.

As the introduction of MI technology to small farmers has been relatively new, no comprehensive studies have been done so far with regard to the social and economic feasibility of these technologies. For the dissemination and further promotion of the new technology among small farmers, we need to address the farmers' risk taking capacity in the cultivation of cash crops under the new technology; their attitudes, knowledge and skills in using micro irrigation systems, and the economic feasibility of MI technology at smallholders' level are important areas for investigation.

The major objective of this study was to find out the potential of promoting micro irrigation systems in Sri Lanka and to identify the existing problems and constraints experienced by small-scale farmers, using this new technology. Study locations were selected from DL_1 agro-ecological zone in the North Central dry zone area and in the Southern dry zone area. The total sample size was 69, which was not less than 10% of the total population in the selected study sites. Samples were selected on a cluster basis in order to minimize the traveling between farms, since they are highly scattered. All sample farmers were small farmers (less than 1 acre MI capacity) and the majority of them had some kind of subsidy or a total grant. Key informant interviews, questionnaire surveys, literature research and the case study method were used to obtain the necessary data and information for the study.

The age profile of MI farmers showed that, 60-75% of them were over 40 years and only 6% of the beneficiaries were women farmers. The primary employment of 87% of owners in Southern DL_1 and 69% in Northern DL_1 is farming. The availability of land to the farmers ranges from 0.25 to 5 ac in the study area for both the lowland and highland areas. However, the farm size under MI varies from 0.125 to 2 ac with the majority of the farmers cultivating 0.25-0.5 ac using MI technology. The source of water for 77% of MI farmers is groundwater. The Sewa Lanka Foundation (as one of the MI suppliers) has supplied 50% of MI units in sample locations. The majority of MI farmers had not changed their traditional crops with the availability of MI technology. The crops cultivated under sprinkler irrigation are big onions, red onions, chillies, cabbage, beetroot, brinjal, okra and other vegetables. Drip irrigation has been used to cultivate coconut, papaya, gherkin and fruits.

The main benefit of using MI as seen by farmers is the saving of water. The majority of farmers are still to realize the various other benefits in the use of MI units. The major drawback of sprinkler irrigation is the non-uniform provision of water as experienced by 52% of farmers. The use of low-pressure high volume pumps for MI has resulted in the high cost of fuel due to the speedy operation of pumps to generate the necessary pressure for the rotation of MI units. The above finding illustrates the inappropriateness of the technology introduced among the sample farmers. One of the factors hindering the promotion of MI is the mis-conception among farmers that the small quantity of water supplied by MI is not sufficient for a satisfactory crop growth.

The study reveals that, the degree of adoption of MI by existing micro-irrigation owners is very poor. For example only 5-10% of farmers in the study areas had utilized MI technology and 100% in all seasons since receiving the MI units, upto 2002. The findings also indicate the non-use of available MI systems by 57% of MI owners who owned MI systems upto 2002 is mainly due to two reasons. Firstly, poor targeting of beneficiaries and secondly, lack of training and awareness of the use of MI technology. It is also noteworthy to mention that, about 13% of MI owners (1998-2002) had already sold their systems.

Farmers have realized that the use of the provided MI to cover just 0.25 – 0.5 ac is futile, while cultivating a 1-2 ac extent by surface methods of irrigation, unless there is a severe water scarcity to cultivate the entire extent. The services provided by suppliers were found to be very poor and farmers faced difficulties in obtaining the necessary spare-parts and technical know how. It is recommended to promote MI by targeting at least 10 or more farmers in a locality as a solution to provide affordable after sales services by the suppliers. The level of usage of drip in *yala* 2003 was comparatively higher than that of sprinkler irrigation.

Economic analysis was conducted for red-onion, big-onion, gherkin and papaya cultivations among selected entrepreneurial micro irrigation farmers. The assessment results indicate that, the selected crops provided sufficient returns to recover the capital investment cost within one to two years.

The case study results of papaya cultivation under drip irrigation show the economic viability of MI systems even at a 20% discount rate. The outcomes of the sensitivity analysis conducted for papaya cultivation under different scenarios (10% increase in cost of cultivation, 10% decrease in benefits, and 10% increase in cost and 10% decrease in benefits) and at different interest rates also show the viability of micro irrigation and the great potential of adopting MI technology.

MI programme can be implemented successfully by proper targeting of the beneficiaries, providing adequate knowledge and skills on the use of MI technology and by determining the minimum land size to be used by individual farmers using the MI system. There is a need to conduct research to find out an ideal size of farm plot to be developed under MI. The choice of a suitable area and suitable crops for MI and the introduction of appropriate MI technology considering specificity of the area, available resources and farmer capacity are essential before the commencement of large scale promotion among small farmers. The study recommends that the government intervention on MI promotion must be done as an integrated approach with the support of all line agencies and the MI package should include all components including filter and fertigation equipments. It is important to develop low cost technology at an affordable price to attract investment by smallholders.

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LIST OF ABBREVIATIONS

ADA	Agricultural Development Authority
AI	Agricultural Instructors
ARPA	Agricultural Research and Production Assistants
BCR	Benefit-Cost Ratio
DO	Divisional Officer
DOA	Department of Agriculture
DS Division	Divisional Secretariat Division
FAO	Food & Agriculture Organization
HARTI	Hector Kobbekaduwa Agrarian Research & Training Institute
HNB	Hatton National Bank
IDE	International Development Enterprises
IRR	Internal Rate of Return
JICA	Japanese International Co-operation Agency
MI	Micro Irrigation
MIS	Micro Irrigation Systems
NGOs	Non Government Organizations
NPV	Net Present Value
NPW	Net Present Worth
Rs	Sri Lankan Rupees

CHAPTER ONE

INTRODUCTION

1.1. Background

Despite a large amount of public investment on irrigation infrastructure, Sri Lanka suffers from acute water shortages resulting mainly from a mis-management of water resources. Most of the dry zone districts in Sri Lanka face either seasonal or year round severe water scarcities (Amarasinghe et-al, 1999). Research findings also show that, if the current trend of water use continues, there will be a severe scarcity of water in several districts of the country in the near future (ibid). The difficult challenge is to improve the efficiency of agricultural water use so as to increase or maintain crop yield while at the same time allowing the reallocation of water from agriculture for increased urban, domestic and industrial use. The growing challenge facing agriculture development is how to grow more food for an increasing population using less water for agriculture.

Increasing water scarcity in Sri Lanka, together with evidence of its inefficient use in many instances have made it imperative to treat water as an economic good. Managing scarcity by supply augmentation is increasingly difficult due to the fact that, almost all potential water sources are already fully developed, and the new sources which could be developed in the future are technologically more complex, economically less attractive and often less environment friendly. Mechanisms for demand management are therefore becoming increasingly important.

Surface irrigation or open canal irrigation (gravity irrigation) is the conventional and major method of irrigation in Sri Lanka. Water use efficiency under the gravity method of irrigation is generally less than 50% due to conveyance losses and poor farm water management. Efficiency of the gravity method of irrigation can be improved by proper land leveling and preparation, the planning of advanced techniques in the determination of irrigation (irrigation frequency, quantities and stream size, installation of water measurement and regulation systems, supply of water according to crop requirement etc.) and by re-using water for irrigation (Sivanappan, 1994). Improved facilities, skills and scientifically planned irrigation are therefore important to improve efficiency in the gravity method of irrigation.

One of the methods available to improve the efficiency of water usage is the adoption of micro irrigation technologies to reduce losses at distribution and at the farm water management level. In India, it was found that the efficiency of the farm irrigation system was about 90 percent under a properly designed and managed drip irrigation system, 70 percent under sprinkler irrigation and only about 45 percent in the case of surface irrigation methods (Sivanappan, 1994).

Micro irrigation includes all methods of frequent water application, in small flow rates, on or below the soil surface. Ideally, the volume of water is applied directly to the root zone in quantities that approach the needs of the plants. Micro Irrigation Systems (MIS) are more efficient in terms of water use and thus more land can be brought under irrigation with a given quantity of water.

Micro irrigation systems can be broadly classified into two groups, namely drip and sprinkler irrigation systems. Drip irrigation applies water at a regulated and slow pace directly to the soil surface or sub-surfaces through emitters or orifices at frequent intervals and allows the water to dissipate under low pressure in a pre-determined pattern. A wetted profile develops in the plant's root zone beneath each dripper. Drip irrigation can supply water from one L to 20 L per hour. With a peak water utilization rate of 95%, this method is suitable for intensive cultivation. Drip irrigation is also practically unaffected by wind conditions or soil surface conditions.

The method of applying water to the plants as a spray is known as sprinkling. Micro sprinkler or mini-sprinkler emission devices are generally simple orifices and include small, low-pressure mini-sprinklers, foggers, splitters, jets and sprayers that are installed in the field on tubing. These sprinklers typically apply water to larger areas than drip emitters, but do not uniformly cover the entire cropped area. The sprinklers achieve a water utilization rate of 70-80% as compared to open irrigation, which achieves only a 40% water utilization rate. Sprinklers are generally used to irrigate tree crops, shrubs, widely spaced plants and localized grass areas with extensive root systems.

The government of Sri Lanka and various donor agencies have invested considerable sums of money on the development of micro irrigation projects on a pilot basis. However, the success of these investments primarily depends on the amount of incentives received for both the government and the private users to save water and increase farm income. Micro irrigation can play an integral role in the management of crops to obtain maximum yield from lesser quantities of water, chemicals and fertilizers compared to other forms of irrigation. Another objective of the micro irrigation programmes implemented by various agencies is to protect groundwater depletion through excessive extraction of water for irrigation.

The Agricultural Development Authority (ADA) alone has invested over Rs. 10 million in the introduction of minor irrigation technologies in its first phase (1999-2001) of the project. In additions a number of pilot programmes on micro irrigation is in progress in various parts of the country by private sector organizations and various donor agencies including the FAO, Mahaweli Authority of Sri Lanka, Southern Development Authority, Samurdhi Authority of Sri Lanka and NGOs.

1.2 Problem

As the introduction of micro irrigation system has been relatively new, beginning of late 1990s, no comprehensive studies have yet been done with regard to the social and economic feasibility of these technologies. A rapid appraisal conducted by HARTI shows that the installation of micro irrigation systems in the small farmers' fields has led to various problems such as the use of the mechanical weeders and other machinery. The damage caused by wild animals to these systems, seriously affect their life span.

Proper training and awareness are essential to use the technology effectively. In the Sri Lankan context, where the topography and farming practices are very diverse in nature, farmers are usually not familiar with the use of micro irrigation or other water efficient technologies.

For dissemination of the new technologies among farmers, their risk taking capacity in the cultivation of cash crops under this new technology as well as farmers' attitudes, knowledge and skills in using micro irrigation systems need to be addressed. Also for further promotion of this technology among the Sri Lankan farming community, conducting an economic appraisal of these investments is relevant and timely.

1.3 Study Objectives

The major objective of this study was to find out the prospects of promoting micro irrigation systems in Sri Lanka and to identify the existing problems and constraints experienced by farmers in using this new technology.

The specific objectives of this study are as follows:

1. To assess the level of success of micro irrigation in saving water and improving farmers' income.
2. To identify problems and constraints in adopting existing micro irrigation technologies.
3. To conduct an economic appraisal for micro irrigation investment.
4. To make necessary recommendations for the future promotion of micro irrigation programmes in Sri Lanka.

1.4 Research Methodology

1.4.1 Study Sites

Study sites were selected from DL_1 agro ecological region in the north central dry zone (part of Kurunegala and Anuradhapura districts) and DL_1 Agro-ecological region in the southern dry zone (part of Hambantota, and Ratnapura districts), where the largest number of micro irrigation systems were installed by ADA. Since the farm locations of the micro irrigation farmers are scattered very widely within the agro-climatic zone, 3-4 Divisional Secretariat Divisions (DS Divisions) which have the largest number of micro irrigation farmers from each part of the DL_1 agro ecological region were selected for the detailed study. The details of the study sites are given in figure 1.1 and table 1.1.

1.4.2 Sample Size

The sample frame was basically prepared by using the micro irrigation farmers' database of ADA. After selecting the sample sites, micro irrigation farmers other than ADA beneficiaries were also included in the sample frame in consultation with grass root level officers (AI, DO, ARPA) in the respective sites. Beneficiaries who received MI units before 2002 were selected for the study. The total sample size was 69, which was not less than 10% of the total population. Samples were selected on a cluster basis in order to minimize travel between farms, since they are widely scattered.

Table 1.1: Study Locations

Agro-Ecological Region	District	DS Division	Sample Size
DL_1 (North Central Dry Zone)	Anuradhapura	Medawachchiya Thirappane	
	Kurunegala	Ambanpola Galgamuwa Polpithigama	39
DL_1 (Southern Dry Zone)	Ratnapura	Godakawela Embilipitiya	30
	Hambantota	Lunugamwehera Sooriyawewa	

1.4.3 Data Collection Procedures

(a) Key Informant Interviews

The research team visited line agencies relevant to agriculture, micro irrigation equipment supply companies, farmer leaders and selected micro irrigation farmers in order to understand the prospects of micro irrigation and constraints in the application of the systems. The perceptions and experiences obtained from various stakeholders were later used to prepare the questionnaire for the survey.

(b) Questionnaire Survey

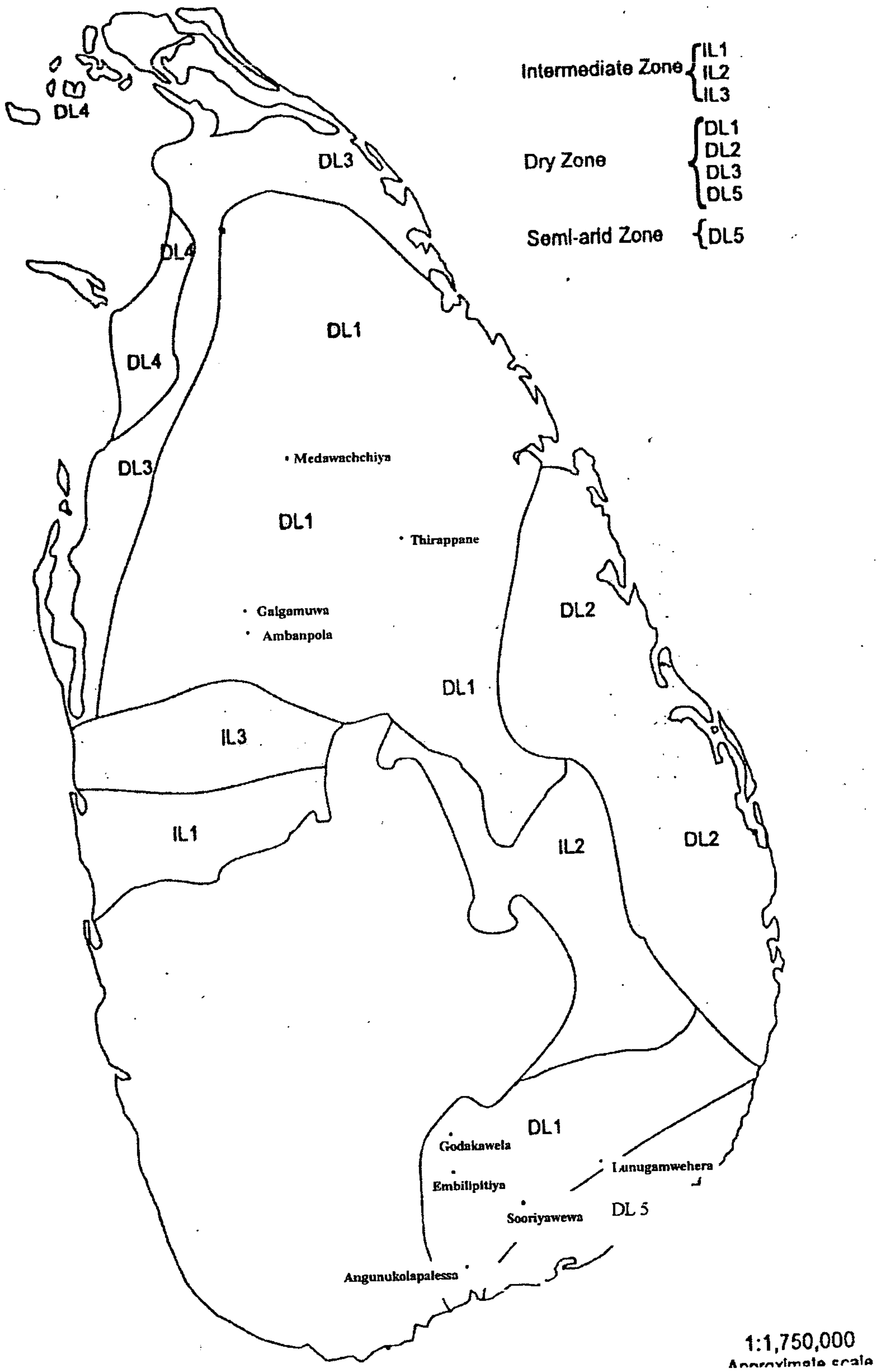
The major source of information of this research report was an in-depth questionnaire survey administered in nine locations selected from two parts of the DL_1 agro-ecological zone. The questionnaire was developed by the research team and pre-tested in the field before the sample survey. It aimed to elicit information on the general socio-economic status of farmers, the extent of cultivation, cropping calendars, cropping pattern, degree of use of MI and merits and de-merits of micro irrigation. The survey was conducted during May to September of 2003.

(c) Case Studies

The purpose of the case studies was to generate necessary data to conduct economic appraisal of drip and sprinkler irrigation systems to understand the viability of MI development and the potential for further promotion. The selected farmers were requested to record the information and data on cost of production, quantity of water issued, yield and farm gate price of the product during *yala* 2003.

The case study locations were Polpithigama (gherkin under drip irrigation), Abakolawewa, (big-onion under sprinkler), Sooriyawewa (red onion under sprinkler) and Mahaweli-H (papaya under drip irrigation). One entrepreneur farmer from each location was selected for the case study.

Figure 1.1: Map of the Study Locations



1.4.4 Data Analysis

The data gathered from primary and secondary sources were analysed using descriptive methods to assess the reasons for the success or failure of micro irrigation, its possibilities and limitations. Net Present Worth (NPW) and cost-benefit ratio were calculated to assess the economics of investment and return.

Benefit-Cost Ratio and Net Present Worth were calculated as follows;

$$NPW = \sum_{i=1}^{i=n} \frac{B_t - C_t}{(1+i)^t}$$

$$BCR = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}}$$

B_t	=	Benefit in year t
C_t	=	Cost in year t
t	=	1, 2, 3...........n
n	=	Life of the project in years
i	=	Opportunity cost of capital/rate of interest

The benefit item identified was the income earned from crop yield and cost items were the cost of cultivation and maintenance incurred for MI systems. All costs and benefits were calculated at the present value at the interest rates of 6%, 8%, 10%, 12%, 15%, and 20%. In terms of the NPW criterion, the investment on micro irrigation can be treated as economically viable if the present value of benefit is greater than the present value of cost. Similarly, if the BCR is greater than 1, the project is considered economically viable.

Sensitivity analysis was carried out to understand the level of sensitiveness of the investment on MI with uncertainties such as increase in cost of production and decrease in expected benefits. Sensitivity analysis is done with three scenarios including 10% increase in costs of cultivation, 10% decrease in benefits and 10% increase in cost and 10% decrease in benefits.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Experiences of Micro Irrigation

Micro irrigation technologies, first perfected in Israel during the 1960s, have spread to many other parts of the world. Based on 1991 data, on a global basis, USA ranked first in area covered under micro irrigation (0.6 million hectares) followed by Spain (0.16 million ha), Australia (0.147 million ha), South Africa (0.144 million ha), and Israel (0.1 million ha) (INCID, 1994). However, according to Misra and Mody (1998), the area coverage under micro irrigation in India is 0.225 million ha (Table 2.1).

The application of modern irrigation technologies in Israel led to a significant reduction of water required per unit of production by 1990, compared to conventional irrigation used in 1984. The below table Nc. 2.2 illustrates the level of water reduction for different crops achieved by modern irrigation technologies in Israel.

Table No. 2.2: Comparison of Water Requirement in Israel (L/kg yield)

Crop	1984	1990	% Reduction
Potato	250	100	60
Cotton	1400	1000	29
Citrus	240	200	17
Avocado	1220	800	34
Apple	550	250	55
Banana	1700	650	62

Source: Schwarz (1991)

The major motivational factors behind the adoption of high cost sophisticated irrigation technologies in Israel were the high cost of fresh water, opportunity cost of waste water and the availability of state of the art technology locally. Magen (1986) states that, sophisticated irrigation has led to a decrease in water consumption in Israel from an average of 8700 m^3/ha in 1951 to 5600 m^3/ha in 1999. In addition, Israeli farmers apply approximately 50% of N and P_2O_5 and 65% of the K_2O through fertigation.

Micro irrigation is popular in India for widely spaced crops like coconut, grapes and fruit crops. Drip irrigation for citrus and orange orchards and grapes in Maharashtra is a big success. It is also very effective for coconut in Tamil Nadu and for mulberry in Karnataka (Shah and Keller, 2002). In the world scenario, almost 54% of the drip irrigation is applied to orchard crops with citrus as a major crop (Kareem, 1999). Drip irrigation trials conducted on a full bearing coconut plantation in Gujarat, India, helped to save water upto 40-50% compared to surface irrigation, without any significant reduction in yield. It was possible to irrigate an additional one-hectare of land from the saved water and thereby increasing net income (Raina et-al, 1998).

International Development Enterprises (IDE) of India made pioneering efforts to promote micro irrigation technologies among poor farmers by cutting the cost of technology to affordable levels. IDE's micro-irrigation programmes for poor women vegetable farmers were studied by Bilgi (1999) in Maharashtra state. He found that, a typical micro irrigation kit resulted in 55 percent reduction in water use, 58 percent reduction in labour use, 16 percent savings in fertilizer and agro chemical use, 97 percent increase in production and 142 percent increase in gross income. The micro irrigation concept among poor women vegetable farmers in the hilly areas of Nepal is already established where the main inducing factor for the new micro irrigation investment decision is not so much based on water scarcity but on generating significant household income (Shah and Keller, 2002). IDE Nepal is working hard towards micro irrigation intervention, developing appropriate technology to suit poor households and providing intensive after sales service.

A study conducted in the desert areas of Haryana state, India, with sprinkler irrigation shows that, irrigation efficiency could be increased three fold and gross income from crops by 40 percent (Tomer et-al, 1989). They also pointed out that, the increase in farm income was mainly due to the increase of area under the sprinkler irrigation system, resulting in higher yield of crops as well as area wise shift to cash crops. However, the total annual cost of irrigation increased by 70% due to the sprinkler system, compared to surface irrigation. This was mainly due to an increase in fixed costs.

Field experiments conducted in India for different crops under the conventional method of irrigation and drip irrigation show a significant saving of water under the drip method of irrigation. The results are given in table 2.3. Results obtained in USA in this regard comparing gravity irrigation and sprinkler irrigation is given in table 2.4.

Table 2.3: Water Used for Various Crops in Drip and Conventional Irrigation Methods in India

Crop	Water Supplied (cm)		
	Conventional	Drip	Water Saving (%)
Banana	176.00	97.00	45
Grapes	53.20	27.80	48
Sugarcane	215.00	94.00	65
Tomato	30.00	18.40	39
Ladies finger	53.68	32.44	40
Brinjal	90.00	42.00	53
Bitter gourd	24.50	11.55	53
Ridge gourd	42.00	17.20	59
Cabbage	66.00	26.67	60
Papaya	228.00	73.30	68
Raddish	46.41	10.81	77
Beetroot	88.71	17.73	79
Chillies	109.71	41.77	62
Sweet Potato	63.14	25.20	60

Source: Adopted from Sivanappan (1994)

Table 2.4: Water Used for Various Crops in Gravity and Sprinkler Irrigation in USA

Crop	Water Supplied (acre feet)		
	Gravity	Sprinkler	Water Saving (%)
Corn	1.6	1.1	31.3
Wheat	1.5	1.2	20.0
Cotton	2.3	1.0	56.5
Peanut	2.5	0.8	68.0
Vegetables	2.8	1.5	46.4
Orchards	2.9	2.2	24.1

Source: Adopted from Kimmell (1999)

Sugarcane is the major agricultural crop in Hawai and the sugar industry alone uses more fresh water than all other users combined, where 82% of sugarcane cultivation is irrigated by drip systems by 1986 (Shrestha and Gopalakrishnan, 1993). The adoption rate of drip in Hawai was very rapid since water use efficiency was as high as 85-95% compared to 50% for furrow irrigation and the yield increase was as high as 20%. A study conducted by Illangathilake (1992) showed that, drip irrigation for sugarcane gave water saving of 50-55%, increase in yield by 12-37% and 2.7 times higher water use efficiency compared to conventional furrow irrigation.

2.2 Advantages of Micro Irrigation Systems

i) **Water Saving:** Water saving up to 70% is observed in various crops. This is due to the irrigation of a smaller portion of the soil, as seepage, percolation, evaporation and conveyance losses are reduced or eliminated. Evaporation from the soil is significantly reduced since only a small surface area under the plant is moistened and it is usually well shaded by the foliage.

ii) **Application of Fertilizers and Agro-chemicals:** Micro irrigation systems allow a high level of control of chemical applications. The plants can be supplied with the precise amount of nutrients required at a given time. Usually nitrogen, potassium, sulfate and micronutrients such as iron, zinc, copper and manganese can be injected as chlorates or sulfates using drip irrigation system.

Fertigation reduces fertilizer cost by 30-50% compared to conventional methods since they are applied directly to the root zone by this method. Other chemicals such as herbicides, insecticides, fungicides, nematicides and growth regulators can be efficiently applied through micro irrigation systems to improve crop production. This application method is more economical and decreases groundwater pollution due to the high concentration of chemicals that could not move with deep percolated water.

iii) **Improved Quality of the Crop and Increased Yield:** The root zone moisture content can be maintained near field capacity through-out the season provided that there is a level of water and air balance close to optimum for plant growth. This results in preventing moisture stress or shocks associated with other methods of irrigation. The above conditions promote optimum plant performance resulting in higher yield and better quality produce. There is also a reduction of bacteria and fungi diseases and infestation of other pests that require a moist environment, and also gives a higher yield.

iv) **Suited for Difficult Terrains:** Micro irrigation can be used over a wide range of terrain conditions. Vast areas of land with difficult terrains and wastelands can be brought under productive cultivation as they can be easily irrigated without costly land leveling and removal of valuable top soil.

v) **Suited for Problematic Soils and Water:** A significant advantage of micro irrigation is that water with a relatively high salt content can be used by the system. Drip irrigation is a suitable irrigation practice for irrigation with saline water (Bielorai, 1985; Siefert et-al, 1975). Micro irrigation systems can be used in saline and alkaline soils as well.

vi) **Improved Disease Control:** Disease control is enhanced by the application of micro irrigation systems, since the soil moisture and chemicals additive levels can be closely controlled. Further, the spread of pathogens through runoff is controlled or eliminated.

vii) **Other Advantages of Micro Irrigation Systems:** Micro irrigation systems can be extensively automated decreasing labour and operating costs.

- Less energy consumption since less amount of water is used.
- Enables fertilization at high water table conditions.

viii) **Additional Advantages of Drip Irrigation**

- Fertilizer can be applied effectively through the drip systems since placement of fertilizer is more accurate.
- Since only a small portion of the soil surface is watered, field operations can be continued during irrigation.
- Since irrigation water is not applied to the foliage, foliar applied chemicals are more effective since they are not washed off by irrigation water.
- Another social benefit of drip irrigation is that it reduces soil erosion and non-point pollution, where surface irrigation can cause severe soil erosion and pollution of the water table through percolation of fertilizers and pesticide residues.

Table No: 2.5: Comparative Advantages of Drip over Flood Irrigation

Variable	Drip method	Flood method
Water saving	High 40-100%	Less due to evaporation
Irrigation efficiency	80-90%	30-50%
Input cost	Less in labour, fertilizer, pesticides	Comparatively high
Weed problem	Almost nil	High
Suitable water	Even saline water can be used	Only normal water
Diseases and pest problems	Relatively less	High
Water logging	Nil	About 8.5 mh under water logging
Water control	High and easy	Less
Evaporation and Transportation	Very low	High seepages
Efficiency of fertilizer use	Very high and regulated supply	Heavy losses due to leaching
Increase in yield	20-100 %	Less compared to drip

Source: Naryanamoorthy (1996)

2.3 Potential Problems in Micro Irrigation

i) **Requirement of Skills and Managerial Capacity:** To operate satisfactorily, a micro irrigation system should be correctly designed and managed considering the physical properties of the soil, the quality of irrigation water and water requirements of the plants. Skills are also necessary to prepare an irrigation schedule considering soil properties and plant growth stage.

ii) **Clogging:** Clogging of the emitters is one of the biggest problems in micro irrigation. The small openings can be easily clogged by soil particles, organic matter, bacterial slime, algae or chemical precipitates. The micro irrigation system requires very good filtration (most often recommended is 200 mesh screen) even with a good quality water supply. Water conditioning and cleaning agents are normally applied through most micro irrigation systems to enhance crop growth and to prevent emitter clogging.

iii) **Moisture Distribution:** Moisture distribution depends largely on the soil type being irrigated by this system. Micro irrigation system wets only a limited portion of the potential soil root volume. However, there is a minimum volume of roots, which have to be moistened, or a reduction in yield will be observed. The optimum wetted zone has to be achieved by adjusting the number of emitters and the spacing between the emitters.

iv) **Initial Cost:** The initial investment and maintenance cost of a micro irrigation system may be higher than for some other irrigation methods. Filters, chemical injectors and possible automation components add to the cost of a micro irrigation system. Actual costs will vary considerably depending on the selection of a particular micro irrigation system, required filtration equipment, water quality, water treatment and selection of automation equipment.

v) **Salt Buildup:** Micro irrigation systems can use saline water. However, a problem may occur from salt accumulating at the edges of the wetted zone during prolonged dry periods.

vi) **Problems Created by Rodents and Wild Animals:** Insects and animals, especially rodents can create additional maintenance problems by chewing holes in the laterals. Pest control methods may be necessary. Burying irrigation lines is a desirable preventive step. In addition, persons or animals unaware of their locations can easily damage some components of the system.

vii) **Additional Drawbacks:**

- Because micro irrigation systems normally irrigate only a fraction of the crop root zone and if soils have a very low water holding capacity, irrigation must be scheduled frequently, sometimes more often than daily.
- Maintenance requirements and the need to manage high frequency irrigation increased labour requirements and the quality of labour needed to use micro irrigation.
- Sprinklers cannot be used to irrigate cut flowers because of diseases or quality problems resulting from frequent wetting of the foliage.
- Micro irrigation is not adaptable to some ornamental and landscape plants such as ornamental fern because the water application characteristics of micro irrigation are not adaptable to their production systems.
- Micro irrigation is not suited to closely planted crops such as small grains, and has been used only to a limited extent on field crops such as cotton.

2.4 Cost-benefits of Micro Irrigation

The cost of MI systems depends on the selection of the micro irrigation type (mini sprinkler, sprinkler, drip etc.), kind of crop, spacing, quantity of water required, type and discharge capacity of emitters, distance to a water source, extent of farm and country of manufacture of MI system.

The cost for larger areas will be lower since certain essential components remains the same irrespective of extend of the farm.

Sivanappan (1994) calculated Benefit-Cost Ration (BCR) for selected crops cultivated in 1-2 acre fields under drip systems in India. He found that BCR for coconut, banana, sugarcane, mango, papaya, citrus spp. and vegetables varies from 1.31 to 2.60. The BCR for grapes was 13.35, which is tremendously higher compared to other crops. According to Nagaraj (1989) 12 ha coconut plantation installed with drip system was evaluated in India over a 40 year time period at 12 percent interest rate considering with and without scenario. The BCR was 1.92 and 1.69 and Internal Rate of Return (IRR) was 26 percent and 21.4 percent with drip and without drip respectively. It was observed that, drip installed plantation yielded better quality coconuts in terms of size, copra content and quality.

A study conducted in orange growing farmers' field in Maharashtra state of India showed that, drip irrigation required 33 percent higher cost of cultivation compared to the conventional system, but the, cost of labour was reduced by Indian Rs. 500 per hectare. The return from drip-installed orchard increased slightly (by 4 percent) compared to conventional systems, which did not compensate adequately for added cost. However, the water requirement was reduced by 60 percent due to drip system indicating a wide scope for extending the area under irrigation (Mahalle et-al, 1989). However, the assessment conducted by Deshpande and Autkai (1989) in India based on data maintained by research stations during 1986/87 for drip installed orange orchards showed that area under orchard can be increased by 2.5 times when irrigated with limited water, 37 percent increase in productivity compared to traditional irrigation systems and BCR was 3.91 against 0.44 in basin irrigation system.

An economic analysis conducted in Haryana state of India for the cultivation of mustard, wheat and barley under sprinkler irrigation gave NPW, BCR, IRR and the pay back period of Rs. 6,066, 1: 1.41, 14 percent and 6 years respectively at a 10 percent interest rate (Gangwar et-al, 1989).

Banana and grapes cultivated under drip irrigation in Maharashtra, India, BCR of 2.253 and 1.778 respectively at 10% discount rate without capital subsidy for drip set were obtained (Narayanamoorthy, 1997). The same crops provided a BCR of 2.361 and 1.802 respectively after deducting capital subsidy. Shrestha and Gopalakrishnan (1993) found an yield increase of 1.7 tons of sugar per acre or a net gain in revenue of US $ 578 per acre and 12% saving in water and considerable saving in labour use as the major benefit through the rapid adoption of drip irrigation.

Economic analysis conducted for banana and sugarcane cultivation under drip method of irrigation in the Haryana state of India shows that investment on drip irrigation is economically viable even without a subsidy (Narayanamoorthy, 2003). He found that, the BCR for sugarcane varies from 2.02 to 2.05 with subsidy and from 1.83 to 1.87 without subsidy, while for the banana crop the same ranges from 2.34 to 2.36 with subsidy and from 2.23 to 2.25 without subsidy.

Indian experience in MI technology adoption highlights that, high capital cost, absence of subsidy or inadequate subsidy, poor MI product quality, lack of farmer awareness and knowledge and relatively expensive MI products mainly targeting commercial farmers are the reasons for the slow spreading of MI technology, despite its many advantages (Narayanamoorthy, 1986, 2003).

CHAPTER THREE

INSTITUTIONAL AND SOCIAL ASPECTS OF MICRO IRRIGATION

3.1 Demographic Characteristics

From the data gathered on the age profile of farmers who have either drip or sprinkler units, about 60-75% of beneficiaries are over 40 years. In Southern DL_1 area, 50% of MI owners are over 50 years of age. Of the 69 farmers from the total sample only 04 were females, and out of them 03 were from the North Central DL_1, and below 40 years, while the other was from the Southern DL_1 and was above 50 years of age.

Across the study sites, the sample farmers' profile of educational level showed that the largest number of owners of micro-irrigation had an education of at least ordinary level or advanced level certificates. 40% of farmers in the Southern parts of DL_1 and 82% of farmers in the North Central part of DL_1 had education above G.C.E. (O/L). Data also shows (Table 3.1) that only 02 owners of micro-irrigation have had no schooling. These findings indicate that the new technology is used more by educated farmers than by the less educated farmers.

Table 3.1: Educational Level of Farmers by District (as a percentage)

	Southern DL_1		Northern DL_1	
	No.	%	No.	%
No-schooling	1	3.3	1	2.6
Grade 1-5	9	30.0	1	2.6
Grade 6-10	8	26.7	5	12.8
O/L	6	20.0	20	51.3
A/L	5	16.7	10	25.6
Higher studies	1	3.3	2	5.1

Source: Survey Data, 2003

Employment patterns show that 87% and 69% of owners in Southern DL_1 and North Central DL_1 regions respectively are primarily farmers, while rest of the people are involved in government sector employment, business/self employment and skilled jobs. Self-employment is mostly in the area of trade, eg. running small kiosks or selling at the weekly market (*pola*). One farmer/micro-irrigator who was self employed was using the technology for a plant nursery which she was operating. Owners who are permanent or temporary employees in the government or private sector, who own this technology, were only 14% of the population and were using micro-irrigation in their homegarden or small plots of cultivated land close to their homes.

Size or availability of land to the farmers range from 0.25 acres to 5 acres in the study areas for both lowland and highland. Most of the lowlands cultivated by the farmers are irrigated while only 19% farmers cultivate rainfed paddy. Most of the highlands in the study locations are cultivated with water from agro-wells. The North Central DL_1, which has the highest percentage of agro-wells, also has the largest number of farmers cultivating with water from agro-wells.

Farmers across the two regions have access to varying amounts of land both lowland and highland under different ownership patterns. Most of the farmers are owner cultivators, while

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25% are tenant farmers. Also seen from the data is the fact that 26% farmers are encroached settlers. Of the sample, only 13 have leased or mortgaged lands.

3.2 Agricultural Practices and Purchase of MI Units

3.2.1 Awareness on Micro-irrigation Units

From the sample, 68% of the farmers had first become aware of this technology through the ADA in the two regions, while projects initiated by the Department of Agriculture, JICA and FAO have been the other sources of information to the farmers. Only 03 farmers had learnt about this technology from other farmers, which is also a method by which farmers learn new technologies. School education and media have played a very small part in dissemination of information through which farmers have learnt about these systems.

Data from the sample sites (Figure 3.1) point to the years 1999 to 2001 as being the years when farmers became aware of the system of micro-irrigation and had purchased these units.

Figure 3.1: Year of the Farmers' First Awareness of Micro Irrigation Technology

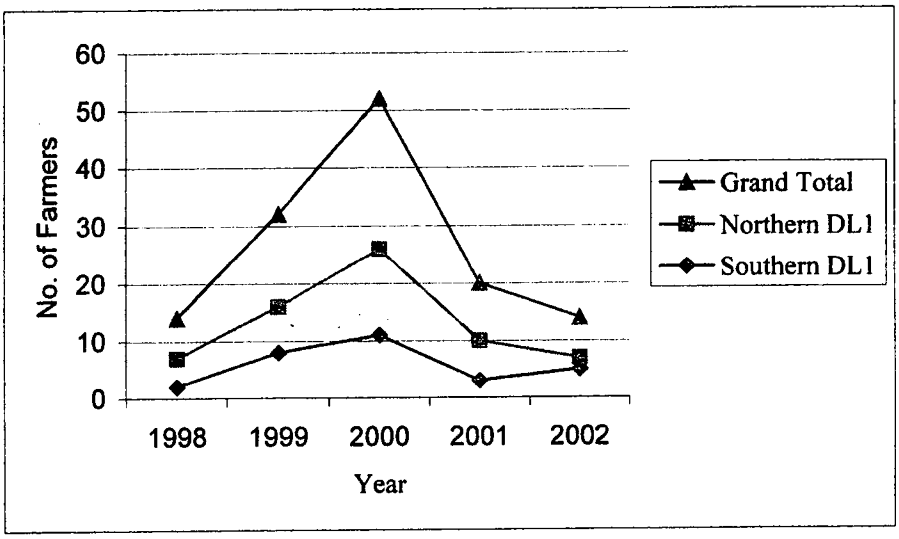


Table 3.2: Organizations Through which Familiarization on Micro Irrigation is given to Farmers

	No. of Farmers	
	Southern DL_1	**Northern DL_1**
ADA	19	28
World Vision	2	1
DOA/FAO	3	6
Other farmers	1	2
Sun-frost/Nippon Kohir (NGO)	2	1
School Education	-	1
Media	2	-

Source: Survey Data (2003)

3.2.2 Farmer Investment on Micro Irrigation Units

Farmers under ADA micro-irrigation projects had to pay Rs.10,000/= to Rs.12,500/=, as a farmer equity in the purchase of MI units. Only 02 farmers had got loans to pay for the unit. The beneficiaries under the FAO project had to payback the cost of MI unit on an installment basis (Rs.2500 per season). The contract farmers of Sunfrost (Hayleys Ltd) have been provided micro irrigation units on a credit basis (Rs. 20,000 per 0.25 acre of extent), which they have to payback on an installment basis without interest. The values of the installments are determined by the company seasonally depending on the income earned in the respective season. A farmer in Mahaweli-H area has invested Rs. 144,000 for drip irrigation to cultivate hi-breed papaya in one ha of land, where he has obtained Rs.56,000 as a subsidy

The reason for the farmers' investment in MI unit is to gain an economic benefit by minimizing the use of fuel, labour and water (Table 3.3). The major reason given by farmers in Southern DL_1 area was the saving in water, while the North Central DL_1 farmers perceived an expectation of a higher economic return. Another reason as quoted by a small percentage of farmers, has been the provision of the subsidy, for the purchasing of the unit. Although, the majority of farmers did not mention the subsidy as a reason for the purchase of MI systems, 94% of sample farmers were not ready to invest on MI without a subsidy.

Table No 3.3: Reasons for the Investment on Micro Irrigation Units

Reasons	No. of Farmers	% of Farmers
Obtain high economic benefit	26	38
Save water	21	31
Provision of subsidy	14	20
Labour saving	05	07
Convenience in cultivation	03	04
Total	**69**	**100**

Source: Survey Data (2003)

Table 3.4 shows that a majority among the sample farmers has invested in sprinkler irrigation. 84% of the sample across the sample area has sprinkler units; with only 16% having purchased drip irrigation units. The reasons for the choice of sprinkler system by the majority are that, farmers were not satisfied with the smaller quantity of water supplied by drip systems and they also experienced greater difficulties in shifting the drip system from one field to another during a season, than the sprinkler irrigation units. Farmers were supplied MI units to cover ¼ to ½ acre of land. They wanted to cover a wider extent by shifting MI systems from one place to the other. The types of tubes used in MI units have been polycon since they are flexible and can withstand the high temperature stress.

Table 3.4: Type of Micro Irrigation among Farmers

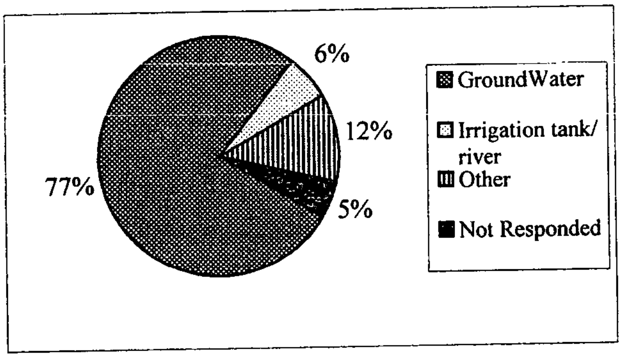
Location	Method		Grand Total
	Drip	Sprinkler	
Southern DL_1	7	23	30
Northern DL_1	4	35	39
Grand Total	**11**	**58**	**69**

Source: Survey Data (2003)

3.2.3 Source of Water for Micro Irrigation Cultivation

The main source of water for the micro irrigation units was groundwater mainly from agro-wells (Figure 3.2), across the locations with a few farmers obtaining water either from the irrigation tanks or rivers, drainage canals and sources like overhead tanks and domestic pipe borne drinking water supplies. Since ADA MI programme was targeted to agro-well farmers in order to minimize groundwater extraction, most of the sample farmers use groundwater as a source of irrigation.

Figure 3.2: Source of Water for Micro Irrigation



3.2.4 Agricultural Practices

The types of crops grown using MI system are varied within the two regions. In Southern DL_1 the crops range from chillies, where seven farmers have cultivated 2.125 acres for 2002 and 2003 *yala*, to tomatoes and banana and other varieties. Banana cultivation has been continued from 2002 to date where the farmers use drip irrigation to irrigate the fields. Another farmer whose secondary occupation is animal husbandry uses the sprinkler system to irrigate pasture, which has been grown to feed his herd of cattle. Other crops as shown in Annex Table 3.1 are red onions, b'onions, beans, knohkhol and perennial crops. Two farmers in Embilipitya area (Southern DL_1) have started using drip irrigation system for perennial crops.

In North Central DL_1 area, the units have been mainly used for crops such as vegetables, chillies and big onion (Annex Table 3.2). The combinations of plants have varied from cabbage/ b'onion, cabbage/brinjal, vegetable/big onion, beetroot/chillies, big onion and brinjal. About 33% of farmers have chosen vegetables for the cultivation under MI during 1998-2003 in both DL1 areas in *yala* seasons.

A new addition to this list not found in the Southern DL_1 is gherkin (Annex Table 3.2) for which micro irrigation units are used in many other countries. Across the two DL_1 areas, use of MI units in *maha* is greatly reduced except in the Embilipitiya area where farmers use their units due to convenience and scarcity of water even in the *maha* season. In North Central DL_1, a farmer in Medawachchiya has used sprinkler unit to grow potato crop, which failed due to a disease. Green gram is another crop, which is grown also in North Central DL_1 using MI units.

3.2.5 Water Usage

Data shows that frequency of water usage varies from twice a day in the case of some farmers, to once only every 2-3 days (Table 3.5). There are, however, a few farmers who have irrigated these fields only once a week, mainly through sprinkler irrigation. A majority of farmers irrigate their fields twice a day or at least once every day.

Table 3.5: Water Usage by Different Systems in Districts

Frequency of Water Application	Southern DL_1		Northern DL_1		Grand Total
	Drip	Sprinkler	Drip	Sprinkler	
Twice a day	-	3	2	11	16
Once a day	4	9	2	11	26
Every other day	2	5	-	8	15
Once a week	1	3	-	-	4
N/A	-	3	-	5	8
Grand total	7	23	4	35	69

Source: Survey Data, 2003

When data on the time taken for water issue was calculated on an average, under drip irrigation, water was issued for 2 - 8½ hrs, while with sprinkler irrigation, it ranged from 2 - 2½ hrs. Even with the issue of water through MI units, a majority of farmers still follow the traditional system of manually irrigating the fields. This is either done by irrigating the whole field once every 3-5 days or manually the non- wetted areas by the MI units. Misconceptions regarding the technology have led to the belief that the amount of the water provided is insufficient. Farmers who for long years have got used to the speedy surface irrigation methods, which require large quantities of water, feel the water distributed at a more leisurely pace through either drip/sprinkler systems is not sufficient for the crops.

Use of water by gherkin farmers with MI (drip) and without MI was recorded in Polpithigama area (North Central DL_1). The requirement of water to cultivate gherkin in 0.5-acre extent under drip irrigation was only 240,000 L, while surface method of irrigation water requirement was 600,000 L.

Water levels of agro-wells after a pumping cycle before adoption of micro irrigation and after the adoption of micro irrigation as perceived by farmers based on eye estimates are given below in Figure 3.3-3.6 for the 04 districts in two parts of DL_1 agro climatic zones. All show a drastic decrease in the number of feet of water used with MI technology. In most cases, more than half the quantity of water has been saved.

Figure 3.3: Decrease of Water Levels in Wells (Hambantota)

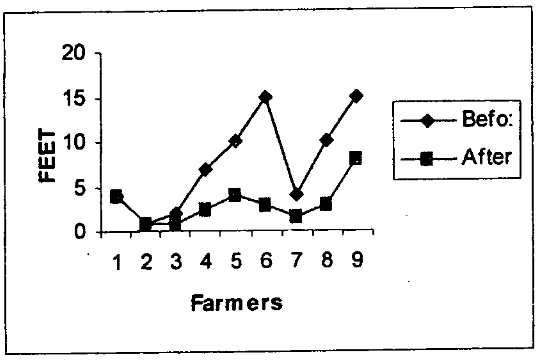


Figure 3.4 : Decrease of Water Levels in Wells (Anuradhapura)

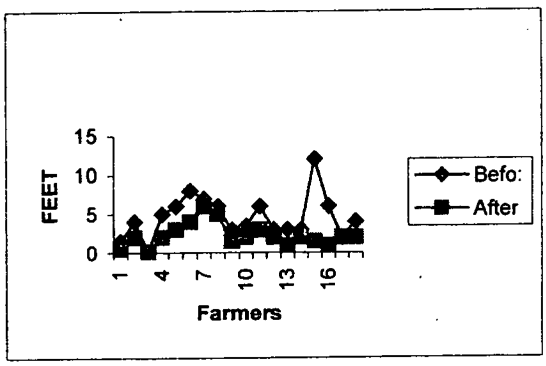


Figure 3.5. Decrease of Water Levels in Wells (Kurunegala)

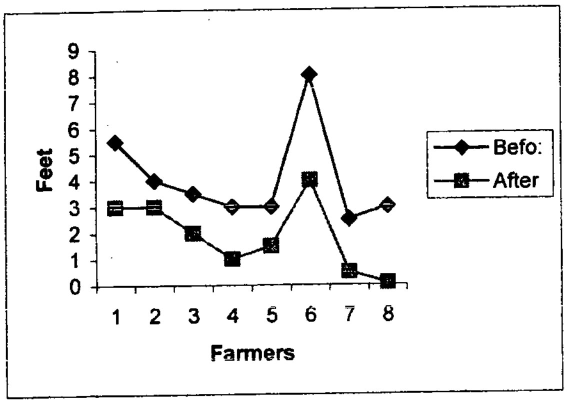
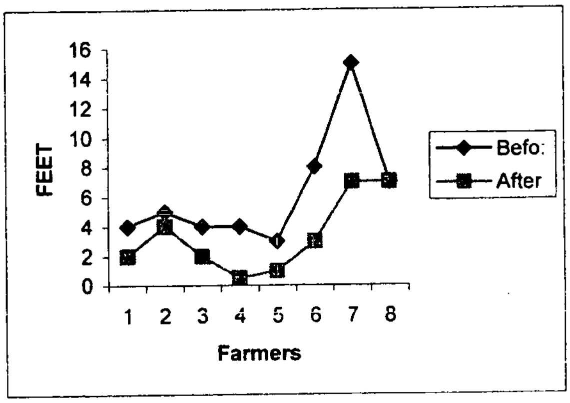


Figure 3.6. Decrease of Water Levels in Wells (Ratnapura)



3.3 Benefits and Drawbacks of Micro-irrigation

The benefits from the use of micro irrigation to farmers have been many and varied. Sprinkler and drip irrigation methods have been proven as having increased water use efficiency compared to the traditional surface irrigation methods (discussed in detail in Chapter Two). Survey data (Tables 3.6 and 3.7) gives a list of reasons given by micro-irrigators about the advantages and constraints in the use of this technology.

The requirement of a lesser quantity of water to irrigate crops and labour saving was cited as the main advantage of the system. Even in times of less water where crops have had insufficient water from surface irrigation, the farmers using micro-irrigation systems have been successful in obtaining a good harvest. Another advantage is the less time required and thereby less labour required to irrigate crops. A farmer in Mahaweli-H area (North Central DL_1) explained that, he has used 3 labourers once in 3 days to irrigate his one-hectare papaya cultivation without drip irrigation. After adoption of drip irrigation, the farmer himself can manage the irrigation, which incurred only 2 ½ hours of time in the morning and 2 hours in the afternoon everyday. This labour saving provides him a saving of Rs. 900 per week (Rs. 150 per labour day X 6 labour days per week).

The other advantage is the less amount of fuel required in operating the water pump, as the time span required is shorter. For example, gherkin cultivating farmers in Polpithigama in North Central DL_1, spend 9 L of kerosene per week for pumping of water to cultivate 0.25 ac without MI, while, they use only 30 L kerosene to cultivate the same extent for the entire season with MI. The total saving of kerosene during 2 months crop life is about 42 L for 0.25 acre.

It has been proved that micro-irrigation especially the use of sprinklers is effective in the control of pests and diseases, especially sprinkler irrigation that has improved the yield in onion cultivation among sample farmers by controlling leaf-tip burn disorder. As such, among the sample farmers', data shows that this has been one of the advantages. Use of drip irrigation has shown that it is an effective means of weed control since only a section of the soil is wetted. The use of MI has also helped farmers in the sample districts to improve soil properties by reducing soil compaction and erosion.

Cultivation of crops during inter season/mid season is possible with micro-irrigation provided the other climatic conditions are suitable. Other studies have shown that off-season cultivation has attempted to gain relief from marketing problems such as low production prices and seasonal fluctuations (Sharmini D., et.al, 2000). A few farmers also quoted this factor as an advantage across the regions.

Investment in agro-chemicals and fertilizer usage is low, due to the method of using these chemicals through the micro-irrigation systems, clear examples of which have been given in Chapter Four. But, among the sample farmers, only 03 farmers in the Southern DL_1 have the fertigation unit, though about 40% are aware of it. A drip irrigation farmer in Southern DL_1 said that, he is now applying 12 kg of Urea and Murate of Potassium once in 2weeks for his one-acre chillie cultivation, when he had to use 25 kg of the same per week, before installing the drip system. An increased yield obtained by the use of this technology has also been a further advantage to farmers.

Table 3.6: Advantages/Benefits in Using Micro Irrigation

Advantages/ benefits	Number of Farmers	
	Southern DL_1	Northern DL_1
1. Less water requirement	22	31
2. Less labour	23	32
3. Less fuel	7	11
4. Control of disease, weed and pests	5	4
5. Less soil erosion and no compaction of soil	4	-
6. Low investment for land preparation, and agro-chemical and fertilizer	3	10
7. Cultivation of cash crops/high value crops	5	6
8. Increased yield	13	3
9. Low risk	3	3

Source: Survey Data (2003)

The main constraint faced by farmers in the North Central DL_1 has been the lack of uniformity in the provision of water to the crop. These are technical problems associated with units of different brands of product, problems related to spray of water, not wetting the outer circumference of the crop due to lack of water pressure, deficiency in nozzle sizes and height of spray. The other problems with the units are the obstruction of nozzles and tubes with dirt, salt, slime, which depends on the quality of water available and the non-use of a filter by the farmers.

Farmers complain of insufficient supply of water for the crops, the reasons for which are many and varied. Factors such as the pressure from water pumps being insufficient for certain types of soil in the area, such as sandy soil and during very dry weather conditions and mainly the attitudinal biases among the farmers. Most of the farmers use low-pressure high volume water pumps, which were previously used to lift the water from agro-wells. However, MI requires high pressure, low volume pumps for an efficient spread of water.

Other problem faced by farmers in the use of sprinklers is in the falling of flowers, especially chllie, due to the pressure of water through the sprinkler and in some cases even the breaking of tender plants. This particular problem was observed in the sprinklers, which were supplied by Sewa Lanka Foundation. The sprinkler system supplied by Sewa Lanka Foundation consists of eight sprinkler heads to cover 0.5 acre extent and therefore, each sprinkler head had to cover a larger circumference with high pressure water which has lead to the above problem. Some farmers have noted that moving the unit, specially sprinkler unit from one field to another has proved to be a problem since it requires a certain amount of labour and skill in refitting of the unit. Another factor noted is that when the wind velocity is high, the spray from the sprinklers sways in the direction of the wind. This was a serious problem especially in the Medawachchiya area (North Central DL_1) during *yala* seasons, when water scarcity was severe and need of MI comparatively higher.

Another belief among a few farmers is that drip/sprinkler units irrigation compared to surface irrigation is less effective since moisture levels in surface irrigation are maintained for a couple of days though it requires more labour, water and fuel. Though, farmers are aware of the vast quantity of water, which is required for surface irrigation methods, they believe that new irrigation does not provide sufficient water for the crops. Damage by wild animals in certain areas and thefts are complaints made by farmers. This is due to the fact that these units are laid in the field and not removed after use, and during the night most of the tubes/pipes are not visible, and have a high risk of being damaged by animals.

Table 3.7: Problems/Constraints in Using Micro Irrigation

Problem/Constraint	Number of Farmers	
	Southern DL_1	**Northern DL_1**
1. Non uniform provision of water (no wetting border area)	10	26
2. Maintenance related problems (blockage of nozzles and tubes, breaking of tubes, leakage from joints, frequent filter changing)	12	9
3. Insufficient pressure of water pumps.	11	19
4. Falling of flowers, breaking of plants	2	1
5. Difficulties in moving system and usage during windy season	-	5
6. Increase in the expenditure	8	5
7. Damage by wild animals/thieves	3	3
8. Non awareness of usage of equipment	1	-

Source: Survey Data (2003)

3.4 Institutional Issues in Use of MI

Micro irrigation systems were supplied to farmers by a number of companies. The major organization involved with small-scale farmers in supply of MI is an NGO called Sewa Lanka Foundation. They have supplied the MI units to about 50% of sample farmers (Table No. 3.8). The major attraction of Sewa Lanka MI units for farmers was the large sprinkler head, of which 8 of them were sufficient to cover 0.5 ac extent. Farmers were satisfied with this model, because, it was easier to handle and easily movable from one field to another. However, as discussed in the previous section, with time, farmers realized that, to operate this sprinkler, there is a need of a high-pressure water pump and water sprayed from these units is powerful enough to break tender plants and also cause the falling of flowers.

Table No. 3.8: Suppliers of MI in Sample Districts

Company	No. of farmers	% of farmers
Sewa Lanka Foundation	34	49
Brown & Company	13	19
Irritech Ltd	08	12
CIC Fertilizer	04	06
Hayleys (Sunfrost)	02	03
Agri World	02	03
Rainbird International	01	01
Jinasena Ltd.	01	01
Not reported	04	06
Total	**69**	**100**

Source: Survey Data (2003)

Further training in the use of the units was not in great demand among the sample farmers (Table 3.9). Only 13% of farmers felt the need for further training in the practical aspects of using the system, such as what kind of crops could be grown, installation of the system and maintenance and operation. From the 03 who had fertigation units, there was a request for training in the application of fertilizer and agro-chemicals through the units.

Table 3.9: Training Required by Farmers using of MI, by District

	Number of Responses		Grand Total
	Southern DL_1	**Northern DL_1**	
Installment of the system	-	3	3
Practical knowledge in using the system successfully	1	8	9
Application of fertilizer and chemicals through the system	1	1	2

Source: Survey Data (2003)

The low level of requests for training should not lead one to conclude that the initial training given to farmers who are using units at present has been sufficient. According to key informant discussion, farmers were not given a proper training other than a demonstration of the use of MI equipments by different companies and also through field demonstrations. Farmers were tested about their knowledge of filters and fertigation equipment, which are two important components of MI systems. About 45% of the farmers had never heard of filters and 61% were unaware of fertigation units. Only 23% farmers had filters, while only 6% of farmers were using fertigation units. Furthermore, some of the constraints explained by farmers in applying MI such as insufficient supply of water by MI, difficulties in operating and moving MI system and use of manual water application methods while practicing MI imply lack of knowledge in the proper use of MI systems and the need for an attitude change through proper training. Out of 69 sample farmers, only 12 farmers have changed their traditional farming system to market oriented cash crop cultivation.

Maintenance difficulties experienced by the farmers in using MI are lack of availability of MI spare parts in the area or neighbouring areas. Farmers have to rely on suppliers, who are mainly operating from Colombo without any dealers even at provincial level. Therefore, some farmers have to reduce the original extent of MI due to damages already caused at joints, sprinkler heads, drip lines and nozzles. Maintenance of units is mainly in the cleaning of nozzles due to blockage by particles or slime and in the cleaning of the tube system. Cost of which on an average for an year is around Rs.400-500. A small percentage of farmers have had problems with the water pump for which repairs cost around Rs.1000/=. This has been the one item the maintenance cost of which has been high. Since farmers have no experience in replacing damaged components of MI, the maintenance cost is not reflected in this regard.

After sales service provided by the organization for the units have been either insufficient or lacking. Only 14% of the sample farmers were satisfied with the after sales service. Across the study areas, 45% complained about complete lack of service without being able to meet any official after the initial installment of the unit, while 34% complained of insufficient services provided by the suppliers (Table No. 3.10). This factor has led farmers to be disgruntled with the purchase of units. The main difficulty of providing a routine or on call after sales service by the suppliers is the scattered nature of farm locations within a 0.25-0.5 acre extent, which is highly inconvenient for the companies and economically unviable.

Table 3.10: Services of Organizations, which Provided MI, by District

Level of Service	Number of Responses		Grand Total	%
	Southern DL_1	Northern DL_1		
No service	13	18	31	45
Service not sufficient	9	14	23	34
Good service	5	5	10	14
Not responded	3	2	5	7

Source: Survey Data (2003)

Targeting of Beneficiaries – Lessons for the Future

Ataweeragollawa is a village located in Madawachchiya Divisional Secretariat in Anuradhapura dry zone district. The research team conducted a case study in the village on the application of MI technology, since the village had a large number of MI beneficiaries. Information for the case study was collected by interviewing MI farmers and key informants in the village. About 18 villagers have received micro irrigation units under the ADA subsidy programme. Out of these 18 subsidized farmers, 15 farmers had been manipulated by a rich farmer to obtain the benefit of ADA subsidy, who paid the farmer equity of Rs. 10,000 for 15 farmers and received the Rs. 35,000 value of MI units on behalf of each farmer. Finally the rich farmer received 15 MI units under other neighbouring farmers' names and in addition to the one under his name. The total extent covered by MI was 8 acres.

However, during the first season of MI cultivation, he had difficulty in using sprinklers provided by the company, which needed high pressure – low volume water pumps. The farmer tried to operate existing high volume low-pressure water pumps, which were previously used for agro-well water lifting with high acceleration for MI operation, which consumed higher amounts of fuel. Also the farmer felt that, the water applied to the crops was not sufficient and non-uniform causing wilting of plants and uneven growth within the field. High velocity uni-directional wind conditions prevailing in the Medawachchiya area during *yala* seasons is another constraint in using MI. The unidirectional wind does not allow the proper spray of water. Therefore, he removed the sprinkler heads from MI systems in order to use the pipe system supplied with MI units just to supply water from his agro-wells under the furrow irrigation method. The rich farmer has realized now that, drip irrigation is the suitable method for the area, not the sprinkler. The sprinkler head provided by the company is quite large, which is not appropriate for the area and the farming system.

The case study highlights that subsidizing programmes must be targeted properly considering the need of MI, availability of farm resources, farming system, skill development, appropriateness of MI and cost and benefits. The development of appropriate technology and modification of the technology with farmer participation and experimentation is also being highlighted in the study. Village based pilot demonstration projects coupled with proper monitoring and evaluation would provide many lessons for the diffusion of technology in a large scale.

3.5 Degree of Utilization/Adoption of MI Technology

As discussed elsewhere in this report, MI technology in Sri Lanka was mainly backed by subsidies provided by the government and various other organizations. The objective of the policy was to popularize the technology among small farmers and to phase out the subsidy gradually and diffuse the technology via demonstration effect. Therefore, to achieve these objectives, farmers should accept the technology and adopt it by themselves. The realized benefits should be sufficient to motivate farmers to self-finance for a further expansion of the technology.

The level of adoption of MI technology was assessed by estimating the numbers of seasons, the units used by farmers after receiving MI technology and number of seasons they cultivated using MI technology from the inception to *yala* 2003. A realistic assumption was made as the potential number of seasons per year is two and adjustments were also made for any drought seasons that may have prevailed during the reference period. The results are illustrated in figure No. 3.7. The results clearly indicate that 38% of sample farmers in North Central DL_1 have utilized the technology for less than 25% during the past seasons. Only 5-10% of farmers both from North Central DL_1 and Southern DL_1 have utilized MI technology throughout the past seasons. The findings also show that no farmers in Anuradhapura administrative district (part of North Central DL_1) have used the technology for 100% of the past seasons.

The data across the two parts of DL_1 agro ecological zones indicates that, 57% of farmers, who owned MI systems by 2002, have not used their MI for cultivation purposes after 2002. The details in this regard are given in Table No. 3.11.

Figure 3.7: Degree of MI Usage during 1998-2003

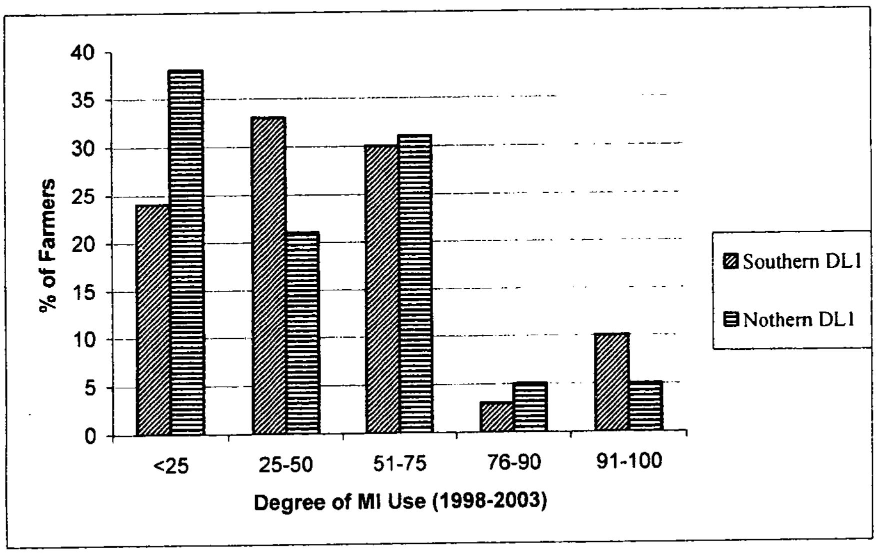


Table No. 3.11: Level of Adoption of Micro Irrigation during 1998-2002

Year	First cultivation year (No. of farmers)	Last cultivation year (No. of farmers)	% of farmers who stopped the use of MI
1998	10	02	20
1999	14	01	13
2000	11	01	11
2001	15	10	28
2002	10	20	57

Source: Survey data (2003)

The owners of MI, who were not using the system for cultivation, were investigated to find out the reasons for non-use of units. The results are setout in Table No. 3.12. The reasons given by farmers for not using MI system were that the MI system was sold out, availability of abundant water for the successful cultivation even without MI, and lack of proper water source for cultivation or use of MI technology. All this highlights the weakness of targeting or selecting the beneficiaries for the programme. Difficulties encountered in using of MI systems and the lack of substantial benefits of using the technology (42% of total farmers) demonstrates the need for training and awareness creation on various aspects of MI technology.

Table No. 3.12: Reasons for not using Micro Irrigation System

Reasons	Number of Farmers		% of Total Farmers
	Southern DL_1	Northern DL_1	
1.MI system is already sold out or planning to sell	3	6	13
2.No substantial benefits	5	9	20
3.Difficulties encountered in application/using of MI system	6	9	22
4.Availability of sufficient water for cultivation without using MI	5	5	14
5.Lack of a proper water source for cultivation	2	-	3

Source: Survey Data (2003)

One of the major difficulties of using MI by smallholder farmers is the capacity of MI units covering just ¼ - ½ ac extent, while cultivating 1-2 ac. Therefore, it is not worthwhile for a farmer to utilize MI for just ¼ - ½ ac, while he is doing a cultivation of 1-2 ac extent by surface method of irrigation, unless there is a severe water scarcity to do the cultivation of the entire extent.

The survey data also indicates that only 24 farmers (35% of total farmers) across two parts of DL_1 agro ecological zones have utilized their MI systems for cultivation during *yala* 2003 which included 17 sprinkler farmers and 7 drip irrigation farmers. These figures indicate that only 30% of the farmers, who owned the sprinkler irrigation have used the technology for cultivation, while, the drip irrigation system has been used for cultivation by 63% of the drip farmers in year 2003. The level of education and age groups of the farmers who were continuously using MI technology upto last *yala* (2003) season were investigated. The results show that, about 60% of these farmers who have adopted MI had educational qualifications, either G.C.E. (O/L) or G.C.E. (A/L) and about 40% of farmers are in the age group of less than 45 years. This finding shows the positive relationship between high level of education and lower age groups in adopting MI technology.

When MI farmers were questioned about the increase of land under the micro irrigation, 74% of them mentioned their unwillingness to invest on further expansion of micro irrigation. Farmers generally stated that MI investment was too high, thus to purchase a new unit with the income of the investment was insufficient. While another major reason was the lack of water and the lack of suitable land even if water was available. Therefore, these findings indicate that, subsidy provided for MI to cover 0.25 ac to 0.5 ac land on a demonstration basis to promote and diffuse the technology has not been successful.

CHAPTER FOUR

PROSPECTS OF MICRO IRRIGATION IN SRI LANKA

4.1 Status of Micro Irrigation in Sri Lanka

Micro irrigation promotion was started by ADA as a nation-wide programme in late 1990s. Until then the micro irrigation was tested in private and state experimental farms to realize its potentials and benefits. Micro irrigation systems in the past were mainly utilized for landscaping, floriculture and controlled agriculture.

The government of Sri Lanka has not yet formulated a specific policy document for the development and promotion of micro irrigation. However, technology for the efficient use of water resource for agriculture in the dry zone is a long felt need of the country. National policy on agriculture and livestock (2003) stresses the importance of using new irrigation technology in order to produce more crops with less water. The government official policy document, "Regaining Sri Lanka" (GOSL, 2003) also emphasizes the necessity of adopting micro irrigation technology in order to prepare the farmers to be ready for a more competitive market situation.

The use of Micro irrigation in Sri Lanka is still in an infant stage, especially among small farmers. The majority of small-scale micro irrigation farmers in Sri Lanka are helped with a subsidy or total grant. Agricultural Development Authority (ADA), Samurdhi Authority of Sri Lanka and Coconut Cultivation Board provided subsidies for micro irrigation. In addition, there were several pilot projects and demonstration plots implemented in the farmers' fields by the Southern Development Authority, Japanese International Co-operation Agency (JICA) and the Mahaweli Authority of Sri Lanka. Among these various projects and programmes, the ADA's micro irrigation development programme played a pioneering role in the relevant field.

4.2 ADA's Micro Irrigation Programme

The Agricultural Development Authority (ADA) obtained a cabinet approval in July 2000, for a subsidy scheme for agro-well farmers to install micro irrigation units to irrigate ½ acre of highland. Under phase -1 of the programme, which commenced in 2000, 540 units were distributed among selected agro-well farmers, where the farmers' equity was Rs. 10,000, while government subsidy was Rs. 20,000. Phase-2 of the programme commenced in 2002, where farmers' contribution increased to Rs. 12,500 and government subsidy was Rs. 25,000. The target of the phase 2 was to provide about 375 MI units among small farmers.

The selection criteria for micro irrigation subsidy scheme were based on the following considerations as specified by the ADA.

1. The farmer must be a beneficiary of ADA agro-well subsidy programme and an agro-well cultivator.
2. Agro-well of the farmer must have a minimum water level of 10 feet in their agro-well during the months of July-August to ensure *yala* season cultivation.
3. The farmer must have a 2-inch water pump, horsepower of which is not less than two and water height of not less than 70 feet.
4. The farmer must be able to deposit his equity at the ADA micro irrigation account within 10 days of notice.

5. Beneficiary farmer must have knowledge of the new agricultural technology and be a suitable candidate to receive a subsidy.
6. The farmer must be a permanent resident around the agro-well area.
7. Land extent under the agro-well must be not less than one acre.

ADA selected a list of leading companies involved in the micro irrigation equipment business and NGOs as micro irrigation equipment suppliers for this programme, and farmers had the opportunity to choose among these organizations/companies according to their preference. According to beneficiaries, companies conducted the demonstration and interactive sessions for farmers at provincial level to explain the specific features and advantages of their company products and services provided by them. After a discussion with the companies, farmers selected the system based on the demonstration given by the company and entered into an agreement with the supplier. The agreement included the provision of all items required to irrigate ½ acre of crops (sprinkler or drip), cost of installation, and commissioning and after sales services for one season.

The progress of the first phase of ADA micro irrigation programme is given in table 4.1. The major districts covered by the programme are Kurunegala, Anuradhapura, Matale, Hambantota and Moneragala.

Table No. 4.1: ADA Micro Irrigation Subsidy Programme

District	No. of Units of Micro-irrigation Installed	
	Phase I (2000-2001)	Phase II (2002-2003)
Kurunegala	214	62
Anuradhapura	151	99
Matale	41	34
Ratnapura	40	35
Hambantota	36	26
Moneragala	34	6
Puttalam	13	14
Polonnaruwa	10	20
Batticaloa	01	8
Badulla	-	36
Vavuniya	-	25
Ampara	-	11
TOTAL	**540**	**376**

Source: ADA Records

4.3 Progress of Micro Irrigation Promotion by Other Organizations

FAO in collaboration with JICA has provided about 40 micro irrigation kits to selected small farmers in North Western Province to irrigate ¼ acre extent as a pilot project for demonstration purposes and a subsequent diffusion purpose in year 2000. The Social Service Ministry of North Central Province also distributed micro irrigation kits for about 500 small-scale farmers to cultivate 0.25 ac upland without any farmer equity in 1998. Southern Development Authority granted 300 micro irrigation units, each covered 0.25 ac for the benefit of the farmers in Galle, Matara, Hambantota and Moneragala districts. The total extent covered by the project is about 75 ac. However, the adoption rate and success of these various interventions are not known.

Hayleys, a leading business company in Sri Lanka has an agricultural subsidiary called Sun frost Lanka Ltd. The company has introduced drip irrigation for their contract farmers, who cultivated gherkin. The cost of the drip irrigation has to be paid back on an installment basis. The installment is determined depending on their gherkin yield and total income without adversely affecting the livelihood of farmers. They found that the yield increase by using drip irrigation was marginal, but there was a possibility of cultivating a third season using limited water, which provides a substantial gain to the farmers.

The Hatton National Bank (HNB), Trincomalee branch, has introduced sprinkler irrigation in Nilaveli area for onion cultivation with the assistance of the Provincial Department of Agriculture under a loan scheme. About 25-30 farmers received loan upto Rs. 50,000 – 100,000 under this scheme. The crop cutting survey conducted in 2002 indicates a doubling of onion yield from 10 cwt to 20 cwt (Personal communication, HNB Trincomalee branch manager). However, recent visits to Nilaveli indicates that farmers are reluctant to use micro irrigation units, because they believed that use of micro irrigation has spread some diseases to their onion crops during the last couple of seasons and reduced the yield. Whether the farmers' perception on yield reduction is a myth or a reality is unknown. Some farmers in the area have shifted from onion to chillie cultivation.

Largest micro irrigation extent in Sri Lanka is located in the Aralaganvila area in the Mahaweli System B, which is under new coconut cultivation. The extent under this coconut farm is 629 ha. In 2002, the Coconut Cultivation Board commenced a subsidy programme to promote adoption of micro irrigation in coconut cultivation. Under the subsidy programme, coconut growers can obtain a subsidy of Rs. 7500/= per acre starting from 0.5 acre to maximum of 10 acre per year to install drip irrigation. As eligibility criteria, coconut lands must consist of coconut trees not less than 50 per acre and located in climatically suitable areas.

Wijesekara (2003) reported that, cultivation of cucumber under drip irrigation provided a yield three times higher compared to surface irrigation and pineapple, papaya, capsicum and beans provided a yield twice as high. In addition to the yield increase, use of drip irrigation technology helps to save the irrigation water requirement by 48% and 90% of labour in water management and fertilizer application respectively. The utility time of a water pump has also been reduced by 50% and thereby reduction in the cost of fuel.

The major crops cultivated under drip irrigation in Sri Lanka are, coconut, banana, papaya, citrus, timber plants (eg. teak), pineapple and other fruit crops. The crops covered by sprinkler irrigation are chillie, onion, timber plants, floriculture, tomato, brinjal, okra, corn, cucumber, cabbage, leafy vegetables, capsicum and other vegetables.

The cost of micro irrigation equipment varies depending on the brand of the product and type of crop to be covered. Drip irrigation for coconut ranges from Rs. 18,000 to 30,000 per acre (depending on the extent to be supplied, larger the extent lesser the unit cost); for papaya and banana Rs 75, 000 to 80,000 per acre; for tea Rs 120,000 per acre; and for rambutan Rs. 65,000 per acre in year 2003. The price includes drippers, head control unit, mesh filter, fertigation unit, PVC pipe for main lines, lateral pipes, valves and all applicable accessories. The cost of sprinkler irrigation system for vegetable crops varies from Rs.75, 000 to 120,000.

There are more than 10 companies involved in the micro irrigation business as suppliers in Sri Lanka. They are: Brown & Company, Irritech (Pvt.) Ltd., Sewa Lanka Foundation (NGO), Wimaladharma Brothers, Citi Gardens, CIC Fertilizer (Pvt.) Ltd., Agri World (Pvt.) Ltd., Transpack International (Pvt.) Ltd., Piyadasa & Sons (Pvt.) Ltd., Sun frost (Ltd), Jinasena (Pvt.)

Ltd. and St. Anthony's Industries (Pvt.) Ltd (annex 4.1). The extent of coverage by micro irrigation is given in table No. 4.2. The figures in the table include both privately invested micro irrigation extents and micro irrigation supplied by different MI promotion programmes. The total estimated coverage under micro irrigation in Sri Lanka by already supplied systems is about 6,500 acres.

Table No. 4.2 Estimates of Number of Micro Irrigation Units Supplied by Different Companies

Name of the Company	No. of units				
	Less than 2 ac extent		More than 2 ac extent		Total extent under micro irrigation (ac)
	Drip	Sprinkler	Drip	Sprinkler	
CIC Fertilizers (Pvt) Ltd.	12	25	19	04	1200
Piyadasa & Sons (Pvt) Ltd.	400	32	10	05	184
Citi Gardens	01	153	-	-	94
Transpac International (Pvt) Ltd.	37	21	03	02	115
St. Anthony's Group (Pvt.) Ltd.	01	02	01	-	15
Irritech (Pvt.) Ltd.	100	540	30	05	900
Brown & Company	-	-	-	-	700
Sewa Lanka Foundation	-	420	10	-	400
Sun frost (Ltd.)	13	-	-	-	15
Agri World (Pvt.) Ltd.	17	17	27	07	2787

Source: Data Collected from the records of Listed Companies.

4.4 Economics of Micro Irrigation

The economic analysis was conducted for small onion (red onion), papaya, gherkin and big onion using the cost and return data collected from selected micro irrigation farmers. The analysis was conducted comparing the cost-benefits of micro irrigation farmers and surface irrigation farmers in the neighbouring area except for papayas. The selected farmers were entrepreneur farmers, who do the cultivation systematically adopting recommended agronomic practices.

The findings from the economic viability of the reference crops indicate the viability of micro irrigation investments. The selected crops provide sufficient return to recover the capital cost within one to two years. This contradicts the general belief of a long time requirement to recover the capital investment made for micro irrigation. Narayanamoorthy (1997) also found similar results for banana and grape cultivation under drip irrigation in India.

1. Economics of Red Onion Cultivation under Sprinkler Irrigation verses Surface (furrow) Irrigation

Location – Sooriyawewa
Extent - 0.25 acre
Season - *Yala* 2003

No.	Particulars	Amount (Rs/ac)	
		Drip	Furrow
1	Fixed cost of sprinkler irrigation	80,000	0
	(a) Life Period	10 years	-
	(b) Depreciation	8,000	0
	(c) Interest @ 12%	9,600	0
	(d) Maintenance cost	500	0
	(e) Sub total (b + c + d)	18,100	0
2	Irrigation system cost spread over 2 crops per year	9,050	0
3	Cost of cultivation per season	65,350	84,400
4	Seasonal total cost (2 + 3)	74,400	84,400
5	Yield (Kg/ac)	6,120	4,200
6	Average price (Rs./Kg)	26	26
7	Gross income (5 X 6)	159,120	109,200
8	Net income (7 – 4)	**84,720**	24,800
9	Incremental benefit from sprinkler irrigation per acre per season	**59,920**	

The analysis shows that, the net return from one cultivated acre within a season is more than the capital investment. The net return obtained from cultivation without sprinkler irrigation is Rs. 60,000 less than with sprinkler irrigation. Therefore, incremental net benefit from red onion cultivation itself is sufficient to recover the capital cost within an year. Therefore, discounted cash flow analysis to capture the time preference of the investment is not necessary for this case study.

2. Economics of Big-onion Cultivation under Sprinkler Irrigation versus Surface Irrigation

Location - Abakolawewa
Season - *Yala* 2003
Extent - 0.5 acre
Variety - Beraly Red

No.	Particulars	Amount (Rs/ac)	
		Drip	Furrow
1	Fixed cost of irrigation (a) Life Period (b) Depreciation (c) Interest @ 12% (d) Annual maintenance cost (e) Sub total (b + c + d)	80,000 10 years 8,000 9,600 500 18,100	0 - 0 0 0 0
2	Irrigation system cost spread over 2 crops per year	9,050	-
3	Cost of cultivation per acre	69,360	78,280
4	Seasonal total cost (2 + 3)	78,410	78,280
5	Yield (kg/ac)	8,720	6,900
6	Average producer price (Rs./kg)	18.50	18.50
7	Gross income (5 X 6)	161,320	127,650
8	Net income (7 – 4)	82,910	49,370
9	Incremental benefit with sprinkler irrigation per acre per season	33,540	

The incremental benefit from big onion cultivation with sprinkler irrigation is very impressive. The net return obtained within an year (two season cultivation) is sufficient to recover the sprinkler investment cost.

According to the farmers, sprinkler irrigation helps to increase their yields in both big-onion and red onion not only by reducing water stress, but also through minimizing the leaf tip burning disorder by washing away of salt accumulation on the leaf surface and of mist. Minimization of leaf burning increases the photosynthesis area and thereby improves the yield.

3. Economics of Gherkin Cultivation under Drip Irrigation Verses Surface Irrigation

Location - Hiriyala
Season - *Yala* 2003
Extent - 0.25 ac

No.	Particulars	Amount (Rs/ac)	
		Drip	Furrow
1	Fixed cost of irrigation	80,000	0
	(a) Life Period	10 years	-
	(b) Depreciation	8,000	0
	(c) Interest @ 12%	9,600	0
	(d) Maintenance cost	1,000	0
	(e) Sub total (b + c + d)	18,600	0
2	Irrigation system cost spread over 3 crops per year	6,200	0
3	Cost of cultivation per acre/per season	49,418	65,430
4	Seasonal total cost (2 + 3)	55,618	65,430
5	Annual total cost of cultivation	166,854	130,860
6	Yield * price = Gross Income		
	Grade – I	7,466	6,000
	Grade – II	800	2,500
	Grade – III	1,066	0
	Large fruit	1,066	1,300
7	Price (Rs/kg)		
	Grade – I	10	10
	Grade – II	7	4
	Grade – III	2	0
	Large fruit	1	1
8	Gross Income	81,858	71300
9	Annual Gross Income	245,574	142,600
10	Annual Net Income	78,720	11,740
11	Incremental Benefit with drip per acre per year	66,980	

Although the difference between gross incomes with and without drip is only about Rs.10,000, the possibility of cultivating a third season by saving of water, gherkin cultivation gives substantial incremental benefit within an year. The return from drip application is sufficient to cover the investment cost within two years.

4. Economics of Papaya Cultivation under Drip Irrigation

Location - Mahaweli H (Bulnewa area)
Variety - Red lady
Year - 2003
Extent - One hectare

No.	Particulars	Amount (Rs/ac) Drip
1	Fixed cost of irrigation (a) Life Period (b) Depreciation (c) Interest @ 12% (d) Maintenance cost (e) Sub total (b + c + d)	100,000 10 years 10,000 12,000 1,000 23,000
2	Irrigation system cost for 4 year crop life (e x 4)	92,000
3	Cost of cultivation per acre (a) Cost incurred during first year (b) Cost during rest of the period/year (c) Average yield period (d) Cost during 3 year yield period (e) Total cost (a+d)	 130072 325,920 3 years 977,760 1107832
4	(a) Average yield (kg/ac)-first year (b) Average yield (kg/ac)-second year (c) Average yield (kg/ac)-third year (d) Average yield (kg/ac)-fourth year (d) Total yield	5,600 38,400 30,800 28,400 103200
5	Average price (Rs/kg)	20
6	Gross Income (d X 5)	2,064,000
7	Net Income for 4 years (6 – 3e) per acre	1,010,488

Drip irrigation with good agronomic practices provides a remarkable yield increase for papaya cultivation compared to surface irrigation. Cash flow analysis and sensitivity analysis were conducted to find out the BCR and NPW for papaya cultivation under different scenarios. The results are given in the following section.

Benefit –Cost Analysis

Cash flow analysis for the papaya cultivation under drip irrigation was conducted with the following assumptions:

1. Life cycle of the drip unit is 10 years.
2. The income stream from drip is treated as uniform over its entire life (Due to lack of temporal information).
3. Crop cultivation practices are uniform over the period.
4. Differential rates of interest rates (6%, 8%, 10%, 12%, 15% and 20%) were assumed to represent the opportunity cost of capital.

The sensitivity analysis of NPW and BCR shows that, the project is viable even at 20% discount rate, if there is no change in the cost of production and gross income during the life period (Table No. 4.3). The policy-wise important economic issues which can be substantiated from the analysis of the adoption of drip irrigation is that, farmers can recover the full capital cost in less than a two years. Therefore in this context, the role of discount rate to capture the time preference of capital investment is of lesser importance. In addition, incorporation of social benefits such as water saving, less ground water pollution, labour saving, convenience of farming, additional irrigation benefits and lower soil degradation would indicate much more benefits to society than the estimated value.

The results of the sensitivity analysis (Table No. 4.4) show that BCR decrease with a discount rate but the change is not significant. The lowest BCR observed is 1.38 with discount rate 20% and cost rising of 10% and benefit falling of 10%. The sensitivity analysis also shows that reduction in NPW and BCR is much higher when expected benefits are decreased by 10% than a 10% increase in cost of cultivation. The rate of return is higher than the cost involved. Overall, the sensitivity analysis under various scenarios indicates, that the MI (drip) investment remains economically viable in all instances.

Table No. 4.3: Sensitivity Analysis of NPW and BCR* for Papaya

Description	Value
1. Net Present Worth	
At 06 percent discount rate	1342346
At 08 percent discount rate	1231256
At 10 percent discount rate	1126560
At 12 percent discount rate	1028999
At 15 percent discount rate	913571.3
At 20 percent discount rate	750720.2
2. Benefit-Cost Ratio	
At 06 percent discount rate	1.75
At 08 percent discount rate	1.74
At 10 percent discount rate	1.73
At 12 percent discount rate	1.72
At 15 percent discount rate	1.70
At 20 percent discount rate	1.67

* Assumption – No change in the cost of production and gross income during the life period.

Table No. 4.4: Sensitivity Analysis of NPW and BCR under Different Scenarios for Papaya

Description	Scenario 1	Scenario II	Scenario III
1. Net Present Worth			
At 06 percent discount rate	1173120	1028264	859038
At 08 percent discount rate	1075390	941689	785823
At 10 percent discount rate	982679	859489	715608
At 12 percent discount rate	895676	782279	648956
At 15 percent discount rate	794070	692264	572764
At 20 percent discount rate	649852	564396	463528
2. Benefit-Cost Ratio			
At 06 percent discount rate	1.61	1.57	1.44
At 08 percent discount rate	1.59	1.56	1.43
At 10 percent discount rate	1.58	1.55	1.42
At 12 percent discount rate	1.57	1.54	1.41
At 15 percent discount rate	1.56	1.53	1.40
At 20 percent discount rate	1.54	1.50	1.38

Note :

Scenario – I : 10 percent increase in cost of cultivation

Scenario – II : 10 percent decrease in benefits

Scenario – III : 10 percent increase in cost and 10 percent decrease in benefit

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Major Findings

Micro irrigation technology has been spreading in Sri Lanka since the late 1990s among small farmers. The rate of spread is fairly low considering the time and resources spent in this regard. MI units have been supplied by various companies under different subsidy projects and also private investments to cover about 6,000 acres of land in Sri Lanka. The level of acceptability and adoption of this new technology by small-scale subsistence farmers are not yet known. However, experiments conducted on MI technology shows positive results in terms of yield increase, water saving, labour saving and improvement of income.

The field survey results showed that, the largest numbers of MI farmers had at least an ordinary level or advanced level education, except 2 farmers who had had no schooling. Only 6% of MI farmers were women and a majority of them were from North-Central DL_1. The primary employment of the majority of the beneficiaries was farming and they are mainly owner cultivators in the low lands.

About 68% of farmers have learnt about MI technology through the Agricultural Development Authority (ADA). Rest of the farmers got their information from the Department of Agriculture, FAO, schools and the media. The main purpose of the investment on MI technology as perceived by farmers is to gain an economic benefit through saving in fuel, labour and application of small amounts of water. Provision of subsidy has also been a great incentive for farmers to purchase MI units.

The main source of water for micro irrigation for about 78% of farmers is from groundwater. About 84% of farmers owned sprinkler irrigation and the rest have drip irrigation units. The extent cultivated under MI varies from 0.125 ac to 2 ac. The majority of farmers cultivate 0.25 – 0.5 ac extents. The types of crops grown using MI system varied within two parts of DL_1 agro-ecological zone. The main use of sprinkler irrigation has been for chillies, big-onions, small onions and vegetables (cabbage, brinjal, beet-root, okra and cucumber). Drip irrigation is widely used by small farmers for banana, papaya and coconut cultivation. Some contract farmers in the Kurunegala district (part of North Central DL_1) use drip irrigation for gherkin cultivation.

Water use information by MI technology shows that the majority of farmers irrigate once a day. Under drip irrigation, water has been issued 2-8½ hrs per day, while with sprinkler irrigation it ranges from 2 – 2½ hrs per day. However, most of the MI farmers still follow the traditional system of manually irrigating fields either by surface irrigation of whole field once in 3-5 days or manually wetting non-wetted areas of micro irrigation. The major reason behind this situation is the slow distribution of water through MI, which has failed to satisfy the farmers who are used to speedy irrigation methods that demand a larger quantity of water. This mis-conception has led to the belief among farmers that water provided by MI is insufficient for healthy plant growth.

The main benefit of micro irrigation to farmers is saving of water, especially during water scarce periods, which helps to avoid crop failure. Ability to cultivate using small quantities of water also has created a possibility of off-season cultivation among enterprising farmers. The other advantages are labour saving, minimizing the damages from pest and diseases by sprinkler irrigation and less weed problem by drip irrigation. The sprinkler irrigation is very useful for onion cultivation, which minimizes leaf tip burning disorder and there by increasing the yield. Drip irrigation is being successfully implemented for papaya, banana and fruit crops

The major constraint of sprinkler irrigation is non-uniform provision of water as experienced by 52% of the farmers. The other problem is the obstruction of nozzles and tubes with dirt, salt and slime, which is caused by the quality of available water and the non-use of a filter by 77% of farmers. Another major difficulty of using MI is the insufficient horsepower of existing water pumps, which were previously used to lift water from agro-wells. Pumps used for agro-wells were generally low pressure-high volume pumps, but MI technology provided to farmers required high pressure-low volume pumps. The use of existing low-pressure pumps for MI incurred a high fuel cost to farmers.

An NGO called Sewa Lanka Foundation supplied the MI units to about 50% of sample farmers, followed by Brown and Company and Irritech Ltd. Various MI supplying companies have provided farmers with only product demonstrations. The level of farmers' knowledge, attitude and perception of various aspects of MI use showed that, awareness on MI operation and possible benefits were not sufficiently known among small farmers. For instance, about 45% of farmers had never heard about filters, while 61% of farmers did not know the availability of fertigation equipment. This also indicates that, farmers are not provided the opportunity to receive full benefits from the MI technology. Farmers' mis-conception on insufficient water supply by MI units and their inability to operate MI systems also highlights the lack of knowledge among farmers on micro irrigation.

The lack of spare parts of MI at least at provincial level is another drawback faced by existing MI farmers. About 79% of farmers are not satisfied with the services provided by MI companies, in which 45% of them have not received any services after the installation of MI systems.

The findings highlight that, the degree of adoption of MI by existing MI owners is very poor. For examples, 38% of farmers in North Central DL_1 have utilized MI technology for cultivation of less than 25% of seasons until 2002 after receiving the technology. Among the owners of MI units until 2002, 57% of them have not used their MI for cultivation after 2002. The reasons given by 30% of farmers for not using MI technology are; MI system was sold out, availability of sufficient water for a successful cultivation without using MI and unavailability of a regular water source to use MI technology. The given reasons for non-utilization of MI highlight the poor targeting of beneficiaries by MI intervention programmes. Another set of reasons provided by 42% of total farmers for not using the technology were difficulties encountered in using the MI system and lack of substantial return in using the technology, which shows lack of training and awareness on various aspects of MI technology.

5.2 Lessons Learned and Policy Implications

1. Awareness creation and provision of technical skills to farmers are a key aspect in introducing a breakthrough in technology for subsistence farmers. Farmers must be convinced about the technology and practically realize the benefits before adopting the technology.
2. Micro irrigation technology is being successfully used by skillful enterprising farmers in Sri Lanka, who suffer from water scarcity in their cultivation and who have sufficient knowledge of the benefits of MI technology.

3. The success stories of MI show that the economic viability of the technology is very high and is capable of generating a sufficient return to pay back the capital investment within 1-2 years.
4. Provision of MI systems under subsidy scheme to cover the extent of 0.25-0.5 acre is not sufficient to motivate the farmers to adopt the technology. Farmers normally do cultivation of 1-2 acre in a season. In these circumstances, the use of MI technology just for 0.5 acre or less and the use of surface irrigation for the rest of the land area is not feasible for farmers unless there is a severe water scarcity.
5. The majority of farmers are not convinced of the many benefits they could gain from using MI, other than saving water. Therefore, farmers are not willing to adopt the technology, if there is no real water scarcity. The majority of the farmers do not realize the benefits of filters and fertigation equipment and therefore the ultimate benefits are not achieved/gained.
6. Targeting the beneficiaries for MI subsidy programme should be done more carefully considering farmers' entrepreneurship, level of education, willingness to use new technology, commercial orientation, degree of water scarcity, environmental condition of the area and the farming system.
7. Demonstration projects are useful to disseminate the technology, but it should be done systematically with an integrated approach rather than merely providing subsidized MI systems.
8. There are varieties of MI products imported from different companies available in the market. For instance, the type of sprinkler irrigation provided for about 50% of sample farmers, is not appropriate for small scale farmers, which also needed replacement of existing water pumps from low pressure-high volume pumps to high pressure –low volume pumps. Therefore, the government has to intervene in the import market of MI by establishing quality standard and formulating regulatory framework in order to guarantee the quality of imported products and also to protect the customers.
9. The present scattered nature of farms is logistically difficult and economically not feasible to provide a satisfactory service by the intervention agencies and the suppliers. However, MI programme implementer must ensure that, there is a reliable after sales service at least during the guarantee period.
10. Micro irrigation technology is not suitable for all areas and for all crops. Therefore, studies should be done to identify the areas and crops before conducting a large-scale promotion of the technology.
11. Compared to India, the investment on MI is relatively high which small farmers find it difficult to afford.
12. The level of adoption of drip irrigation is comparatively higher than sprinkler, although popularity of sprinklers was high at the initial stages.

5.3 Recommendations and Future Actions

1. Micro irrigation technology should be introduced to farmers through a series of steps: feasibility analysis; technology demonstration and training; appointment of area based MI supervisors to guide farmers on the technology use, operation and repairs; and routine visits of MI supervisors and agriculture officials to the farmers' fields.
2. MI technology must be promoted in selected villages/localities to cover a considerable extent rather than isolated farms in dispersed localities, to ensure a routine after sales service from MI companies and agricultural officials.
3. The development of low cost, appropriate MI technology at an affordable level to small farmers is very important to attract the farmers and to induce them to invest. Appropriate

technology should consider the cost of the product, suitable water pump pressure and the environment of the locality (wind velocity, evapo-transpiration and soil condition).

4. MI spare parts should be made available at local markets like other products.
5. MI technology should be introduced with an integrated approach providing support services from Agricultural Department and other line agencies. This should also include the assessment of the available water sources of the farmer and his other agricultural resources such as the capacity of the water pump and availability of a overhead tank (for drip). A comprehensive capacity development programme for target farmers to develop their knowledge and skills in farming systems, market linkages and MI technology are a necessity.
6. Government intervention for the MI promotion must intend to develop a feasible extent of land per beneficiary for MI use. Research need to be conducted to find the ideal size of a farm plot under MI.
7. Government should provide subsidies or other forms of intervention to diffuse the technology concentrating on targeted villages. The selected localities must have at least 10-15 users, which will be helpful to provide support services, extension support and after sales services easily without much cost.
8. MI introduction should be promoted as a package, which must include filter, fertigation unit, suitable water pump and overhead tank (for drip).

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Annexes

Annex Table 3.1: Cultivated Crops and Extents in last *Yala* Season* in Southern DL_1 (in acre)

Crop	Year						Total	
	2001		2002		2003			
	No. of Farmers	Extent	No. of Farmers	Extent	No. of Farmers	Extent	No. of Farmers	Extent
Pasture/grass	-	-	-	-	1	0.5	1	0.5
Chillie	-	-	2	1	5	1.125	7	2.125
B'onion	-	-	-	-	1	0.5	1	0.5
Knohkhol	1	0.5	-	-	-	-	1	0.5
Perennial crops	-	-	-	-	3	3.87	3	3.87
Beans	1	0.5	1	1	1	0.25	3	1.75
Tomato	-	-	2	1.5	1	0.5	3	2
Banana	-	-	-	-	2	1.0	2	1.0
Red Onion	1	0.5	-	-	1	0.125	2	0.625
Brinjal	1	0.5	3	3.25	-		4	3.75
Mix vegetables	-	-	2	0.75	-		2	0.75
Cucumber	-	-	1	2	-		1	2
Beetroot					1	1	1	1
Cabbage					2	3	2	3
Okra						0.25	1	0.25

Source: Survey Data, 2003.

*** Latest cultivation season indicates the last cultivation season practiced by the farmer using MI**

Annex Table 3.2: Cultivated Crops and Extents in Last *Yala* Season in North Central DL_1 (in acre)

Crop	Year												Total	
	1998		1999		2000		2001		2002		2003			
	No. of Far.	Ext.	No. of Far.	Ext.	No. of Far.	Ext.	No. of Far.	Ext.	No. of Far.	Ext.	No. of Far.	Ext.	No. of Far.	Ext.
Chillie	-	-	-	-	-	-	2	0.5	2	0.25	2	2.25	6	3
B'onion	-	-	1	0.5	-	-	1	0.5	2	0.25	3	5	5	5.75
Perennial crops	-	-	-	-	-	-	-	-	-	-	1	1	1	1
Beans	-	-	-	-	-	-	1	0.5	-	-	-	-	1	0.5
Red Onion	-	-	-	-	-	-	-	-	1	0.25	-	-	1	0.25
Mix Vegetables	-	-	-	-	-	-	-	-	4	1.5	1	0.5	5	2
Brinjal	1	2	-	-	-	-	-	-	3	3.5	1	2.5	4	7.5
Beetroot	-	-	-	-	-	-	-	-	3	0.75	-	-	3	0.75
Cabbage	1	2	-	-	1	4	2	0.75	1	0.25	1	2	6	9
Tomato	-	-	-	-	-	-	-	-	1	0.25	-	-	1	0.25
Okra	-	-	-	-	-	-	1	0.25	-	-	1	0.1	2	0.35
Cucumber	-	-	-	-	-	-	-	-	1	0.25	-	-	1	0.25
Gherkin		-	-	-	-	-	-	-	-	-	2	0.75	2	0.75

Source: Survey Data, 2003.

Annex Table 3.3: Number of Farmers Cultivating a Combination of Crops During the Latest *Yala/Maha* Season (1998 – 2003)

Crops	Southern DL_1		Northern DL_1	
	Yala	*Maha*	*Yala*	*Maha*
Pasture/grass	1	-	-	-
Chille	6	4	4	1
Chillie/tomato/banana	1	-	-	-
B'onion	1	-	3	-
B'onion/chillie/cabbage	-	-	1	-
B'onion/brinjal	-	-	1	-
Knohkhol	1	-	-	-
Perennial crops	3	-	1	1
Beans	2	-	1	-
Tomato/red onion	1	1	-	-
Tomato/beans/brinjal	1	-	-	-
Tomato/cabbage/capsicum	-	-	1	-
Banana	2	-	-	-
Red onion	2	-	1	-
Vegetable	1	1	3	1
Vegetable/b'onion	-	-	1	-
Brinjal	2	1	3	1
Brinjal/cucumber	1	-	-	-
Brinjal/chillie	-	1	-	-
Beetroot/chillie	-	-	2	-
Beetroot/other vegetables	-	-	1	-
Cabbage	1	-	2	1
Cabbage/b'onion	-	-	1	-
Cabbage/brinjal	-	--	1	-
Cabbage/beetroot/capsicum	1	-	-	-
Okra	1	1	2	-
Cucumber	-	-	1	-
Gherkin	-	-	2	-
Potato	-	-	-	1
Paddy	-	-	-	1
Green gram	-	-	-	2
Not Cultivated	2	18	7	30
Total	***30***	***15***	***39***	***39***

Source: Survey Data, 2003

Annex 4.1 List of Micro Irrigation Suppliers

Name of Company	Address	Contact Telephone No.
PIYADASA & SONS	No. 34, Quarry Road Colombo 12	011-2435871
IRRITECH (Pvt) LTD.	No. 382/1, Maitripala Senanayake Mawatha New Bus Stand Anuradhapura	025-2224653
CITIGARDENS	No. 173A, Galle Road Dehiwela	011-2730896
SEWA LANKA FOUNDATION	No. 128, Highlevel Road, Nugegoda	011-2821018
BROWN & COMPANY LTD	No. 75, Dewanampiyathissa Mawatha Colombo 10	011-2693097
C.I.C. FERTILIZER (Pvt) LTD	No. 205 1/1, D.R. Wijewardene Mawatha Colombo 10	011-2688200
WIMALADHARMA BROTHERS (Pvt.) LTD	P.O. Box 44 No. 120, Main Street Colombo 01	011-2325613
AGRIWORLD (Pvt.) LTD	No. 46, Narahenpita Road Nawala	011-2806461
TRANSPACK INTERNATIONAL (PVT) LTD	5th Flow, Loyds Building Sir Baron Jayathilaka Mawatha, Colombo	011-2332400
ST. ANTHONY'S INDUSTRIES GROUP (PVT) LTD.	516, 1st Floor, Sri Sangaraja Mawatha Colombo 10	011-2320622
JINASENA LIMITED	No. 2, Hunupitiya Road, Colombo 02	011-2326558

Annex 4.2 Cash Flow Analysis - Papaya Cultivation using Drip Irrigation

Description	Year 0	Y 1	Y 2	Y 3	Y 4	Y 5	Y 6	Y 7	Y 8	TOTAL
Costs										
1. Capital cost for drip	100,000	0	0	0	0	0	0	0	0	
2. Drip maintenance	0	1000	1000	1000	1000	1000	1000	1000	1000	
3. Cost of cultivation	0	130,072	325,920	325,920	325,920	130,072	325,920	325,920	325,920	
TOTAL COST	100,000	131,072	326,920	326,920	326,920	131,072	326,920	326,920	326,920	
DCF @ 6%	1	0.943	0.89	0.84	0.792	0.744	0.705	0.665	0.627	
Present value of costs	100000	123600.9	290958.8	274612.8	258920.6	97517.57	230478.6	217401.8	204978.8	1798470
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF@6%	1	0.943	0.89	0.84	0.792	0.744	0.705	0.655	0.627	
	0	105616	683520	517440	449856	83328	541440	403480	356136	3140816
									(1) NPV	**1342346**
									(2) B/C ratio	**1.746382**
DCF @ 8%	1	0.926	0.857	0.794	0.735	0.681	0.63	0.585	0.54	
Present value of costs	100000	121372.7	280170.4	259574.5	240286.2	89260.03	205959.6	191248.2	176536.8	1664408
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF@ 8%	1	0.926	0.857	0.794	0.735	0.681	0.63	0.585	0.54	
Present Value of Benefits	0	103712	658176	489104	417480	76272	483840	360360	306720	2895664
									(1) NPV	**1231256**
									(2) B/C ratio	**1.739756**
DCF 10%	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	
Present value of costs	100000	119144.4	270035.9	245516.9	223286.4	81395.71	184382.9	167710	152671.6	1544144
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF 10%	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	
Present value of benefit	0	101808	634368	462616	387944	69552	433152	316008	265256	2670704
									(1) NPV	1126560
									(2) B/C ratio	1.729569

Sensitivity analysis

DCF@ 12%	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	
Present value of costs	100000	117047.3	260555.2	232767	207921.1	74317.82	165748.4	147767.8	132075.7	1438200.5
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF@ 12%	1	0.89	0.79	0.71	0.64	0.57	0.51	0.45	0.4	
Present value of benefit	0	99680	606720	437360	363520	63840	391680	277200	227200	2467200
									(1) NPV	**1028999.5**
									(2) B/C ratio	**1.7154771**
DCF 15%	1	0.87	0.756	0.658	0.572	0.497	0.432	0.376	0.327	
Present value of costs	100000	114032.6	247151.5	215113.4	186998.2	65142.78	141229.4	122921.9	106902.8	1299493
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF 15%	1	0.87	0.756	0.658	0.572	0.497	0.432	0.376	0.327	
Present value of benefit	0	97440	580608	405328	324896	55664	331776	231616	185736	2213064
									(1) NPV	**913571.3**
									(2) B/C ratio	**1.703021**
DCF 20%	1	0.833	0.694	0.579	0.482	0.402	0.335	0.279	0.233	
Present value of costs	100000	109183	226882.5	189286.7	157575.4	52690.94	109518.2	91210.68	76172.36	1112520
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF 20%	1	0.833	0.694	0.579	0.482	0.402	0.335	0.279	0.233	
Present value of benefit	0	93296	532992	356664	273776	45024	257280	171864	132344	1863240
									(1) NPV	**750720.2**
									(2) B/C ratio	**1.674793**

Annex 4.3 Sensitivity Analysis - Papaya Cultivation using Drip Irrigation (10% Increase in Cost of Cultivation)

Description	Year 0	Y 1	Y 2	Y 3	Y 4	Y 5	Y 6	Y 7	Y 8	TOTAL
Costs										
1. Capital cost for drip	100,000	0	0	0	0	0	0	0	0	
2. Drip maintenance	0	1000	1000	1000	1000	1000	1000	1000	1000	
3. Cost of cultivation		143,079	358,512	358,512	358,512	143,079	358,512	358,512	358,512	
TOTAL COST	100,000	144,079	359,512	359,512	359,512	144,079	359,512	359,512	359,512	
DCF @ 6%	1	0.943	0.89	0.84	0.792	0.744	0.705	0.665	0.627	
Present value of costs	100000	135961	320054.7	302074.1	284812.7	107269.3	253526.5	239142	225476.7	1968317
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF@6%	1	0.943	0.89	0.84	0.792	0.744	0.705	0.655	0.627	
	0	105616	683520	517440	449856	83328	541440	403480	356136	3140816
									(1) NPV	**1172499**
									(2) B/C ratio	**1.595686**
DCF @ 8%	1	0.926	0.857	0.794	0.735	0.681	0.63	0.585	0.54	
Present value of costs	110000	133509.9	308187.5	285531.9	264314.8	98186.04	226555.6	210373	194190.5	1830849
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF@ 8%	1	0.926	0.857	0.794	0.735	0.681	0.63	0.585	0.54	
Present Value of Benefits	0	103712	658176	489104	417480	76272	483840	360360	306720	2895664
									(1) NPV	**1064815**
									(2) B/C ratio	**1.581596**
DCF 10%	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	
Present value of costs	100000	130968	296956.9	269993.5	245546.7	89473.18	202764.8	184429.7	167892.1	1688025
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF 10%	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	
Present value of benefit	0	101808	634368	462616	387944	69552	433152	316008	265256	2670704
									(1) NPV	**982679.2**
									(2) B/C ratio	**1.582147**

DCF@ 12%	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	
Present value of costs	100000	128662.7	286531.1	255972.5	228649.6	81692.91	182272.6	162499.4	145242.8	1571523.7
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF@ 12%	1	0.89	0.79	0.71	0.64	0.57	0.51	0.45	0.4	
Present value of benefit	0	99680	606720	437360	363520	63840	391680	277200	227200	2467200
									(1) NPV	**895676.27**
									(2) B/C ratio	**1.5699413**
DCF 15%	1	0.87	0.756	0.658	0.572	0.497	0.432	0.376	0.327	
Present value of costs	100000	125348.9	271791.1	236558.9	205640.9	71607.36	155309.2	135176.5	117560.4	1418993
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF 15%	1	0.87	0.756	0.658	0.572	0.497	0.432	0.376	0.327	
Present value of benefit	0	97440	580608	405328	324896	55664	331776	231616	185736	2213064
									(1) NPV	**794070.8**
									(2) B/C ratio	**1.559602**
DCF 20%	1	0.833	0.694	0.579	0.482	0.402	0.335	0.279	0.233	
Present value of costs	100000	120018	249501.3	208157.4	173284.8	57919.84	120436.5	100303.8	83766.3	1213388
TOTAL BENEFIT	0	112,000	768,000	616,000	568,000	112,000	768,000	616,000	568,000	
DCF 20%	1	0.833	0.694	0.579	0.482	0.402	0.335	0.279	0.233	
Present value of benefit	0	93296	532992	356664	273776	45024	257280	171864	132344	1863240
									(1) NPV	**649852**
									(2) B/C ratio	**1.535568**

Annex 4.4 Sensitivity Analysis - Papaya Cultivation using Drip Irrigation (10 percent decrease in benefits)

Description	Year 0	Y 1	Y 2	Y 3	Y 4	Y 5	Y 6	Y 7	Y 8	TOTAL
Costs										
1. Capital cost for drip	100,000	0	0	0	0	0	0	0	0	
2. Drip maintenance	0	1000	1000	1000	1000	1000	1000	1000	1000	
3. Cost of cultivation	0	130,072	325,920	325,920	325,920	130,072	325,920	325,920	325,920	
TOTAL COST	100,000	131,072	326,920	326,920	326,920	131,072	326,920	326,920	326,920	
DCF @ 6%	1	0.943	0.89	0.84	0.792	0.744	0.705	0.665	0.627	
Present value of costs	100000	123600.9	290958.8	274612.8	258920.6	97517.57	230478.6	217401.8	204978.8	1798470
TOTAL BENEFIT	0	100800	691200	554400	511200	100800	691200	554400	511200	
DCF@6%	1	0.943	0.89	0.84	0.792	0.744	0.705	0.655	0.627	
	0	95054.4	615168	465696	404870.4	74995.2	487296	363132	320522.4	2826734
									(1) NPV	**1028264**
									(2) B/C ratio	**1.571744**
DCF @ 8%	1	0.926	0.857	0.794	0.735	0.681	0.63	0.585	0.54	
Present value of costs	100000	121372.7	280170.4	259574.5	240286.2	89260.03	205959.6	191248.2	176536.8	1664408
TOTAL BENEFIT	0	100800	691200	554400	511200	100800	691200	554400	511200	
DCF@ 8%	1	0.926	0.857	0.794	0.735	0.681	0.63	0.585	0.54	
Present Value of Benefits	0	93340.8	592358.4	440193.6	375732	68644.8	435456	324324	276048	2606098
									(1) NPV	**941689.2**
									(2) B/C ratio	**1.56578**
DCF 10%	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	
Present value of costs	100000	119144.4	270035.9	245516.9	223286.4	81395.71	184382.9	167710	152671.6	1544144
TOTAL BENEFIT		100800	691200	554400	511200	100800	691200	554400	511200	
DCF 10%	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	
Present value of benefit	0	91627.2	570931.2	416354.4	349149.6	62596.8	389836.8	284407.2	238730.4	2403634
									(1) NPV	**859489.8**
									(2) B/C ratio	**1.556612**

DCF@ 12%	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	
Present value of costs	100000	117047.3	260555.2	232767	207921.1	74317.82	165748.4	147767.8	132075.7	1438200.5
TOTAL BENEFIT		100800	691200	554400	511200	100800	691200	554400	511200	
DCF@ 12%	1	0.89	0.79	0.71	0.64	0.57	0.51	0.45	0.4	
Present value of benefit	0	89712	546048	393624	327168	57456	352512	249480	204480	2220480
									(1) NPV	**782279.52**
									(2) B/C ratio	**1.5439294**
DCF 15%	1	0.87	0.756	0.658	0.572	0.497	0.432	0.376	0.327	
Present value of costs	100000	114032.6	247151.5	215113.4	186998.2	65142.78	141229.4	122921.9	106902.8	1299493
TOTAL BENEFIT		100800	691200	554400	511200	100800	691200	554400	511200	
DCF 15%	1	0.87	0.756	0.658	0.572	0.497	0.432	0.376	0.327	
Present value of benefit	0	87696	522547.2	364795.2	292406.4	50097.6	298598.4	208454.4	167162.4	1991758
									(1) NPV	**692264.9**
									(2) B/C ratio	**1.532719**
DCF 20%	1	0.833	0.694	0.579	0.482	0.402	0.335	0.279	0.233	
Present value of costs	100000	109183	226882.5	189286.7	157575.4	52690.94	109518.2	91210.68	76172.36	1112520
TOTAL BENEFIT	0	100800	691200	554400	511200	100800	691200	554400	511200	
DCF 20%	1	0.833	0.694	0.579	0.482	0.402	0.335	0.279	0.233	
Present value of benefit	0	83966.4	479692.8	320997.6	246398.4	40521.6	231552	154677.6	119109.6	1676916
									(1) NPV	**564396.2**
									(2) B/C ratio	**1.507313**

Annex 4.5 Sensitivity Analysis - Papaya Cultivation using Drip Irrigation (10 percent increase in cost and 10 percent decrease in benefit)

Description	Year 0	Y 1	Y 2	Y 3	Y 4	Y 5	Y 6	Y 7	Y 8	TOTAL
Costs										
1. Capital cost for drip	100,000	0	0	0	0	0	0	0	0	
2. Drip maintenance	0	1000	1000	1000	1000	1000	1000	1000	1000	
3. Cost of cultivation	0	143079.2	358512	358512	358512	143079.2	358512	358512	358512	
TOTAL COST	100,000	144,079	359,512	359,512	359,512	144,079	359,512	359,512	359,512	
DCF @ 6%	1	0.943	0.89	0.84	0.792	0.744	0.705	0.665	0.627	
Present value of costs	110000	135961	320054.7	302074.1	284812.7	107269.3	253526.5	239142	225476.7	1978317
TOTAL BENEFIT	0	100800	691200	554400	511200	100800	691200	554400	511200	
DCF@6%	1	0.943	0.89	0.84	0.792	0.744	0.705	0.655	0.627	
	0	95054.4	615168	465696	404870.4	74995.2	487296	363132	320522.4	2826734
									(1) NPV	**848417.5**
									(2) B/C ratio	**1.428858**
DCF @ 8%	1	0.926	0.857	0.794	0.735	0.681	0.63	0.585	0.54	
Present value of costs	110000	133509.9	308187.5	285531.9	264314.8	98186.04	226555.6	210373	194190.5	1830849
TOTAL BENEFIT	0	100800	691200	554400	511200	100800	691200	554400	511200	
DCF@ 8%	1	0.926	0.857	0.794	0.735	0.681	0.63	0.585	0.54	
Present Value of Benefits	0	93340.8	592358.4	440193.6	375732	68644.8	435456	324324	276048	2606098
									(1) NPV	**775248.3**
									(2) B/C ratio	**1.423436**
DCF 10%	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	
Present value of costs	100000	130968	296956.9	269993.5	245546.7	89473.18	202764.8	184429.7	167892.1	1688025
TOTAL BENEFIT	0	100800	691200	554400	511200	100800	691200	554400	511200	
DCF 10%	1	0.909	0.826	0.751	0.683	0.621	0.564	0.513	0.467	
Present value of benefit	0	91627.2	570931.2	416354.4	349149.6	62596.8	389836.8	284407.2	238730.4	2403634
									(1) NPV	**715608.8**
									(2) B/C ratio	**1.423933**

DCF@ 12%	1	0.893	0.797	0.712	0.636	0.567	0.507	0.452	0.404	
Present value of costs	100000	128662.7	286531.1	255972.5	228649.6	81692.91	182272.6	162499.4	145242.8	1571523.7
TOTAL BENEFIT		100800	691200	554400	511200	100800	691200	554400	511200	
DCF@ 12%	1	0.89	0.79	0.71	0.64	0.57	0.51	0.45	0.4	
Present value of benefit	0	89712	546048	393624	327168	57456	352512	249480	204480	2220480
									(1) NPV	**648956.27**
									(2) B/C ratio	**1.4129472**
DCF 15%	1	0.87	0.756	0.658	0.572	0.497	0.432	0.376	0.327	
Present value of costs	100000	125348.9	271791.1	236558.9	205640.9	71607.36	155309.2	135176.5	117560.4	1418993
TOTAL BENEFIT	0	100800	691200	554400	511200	100800	691200	554400	511200	
DCF 15%	1	0.87	0.756	0.658	0.572	0.497	0.432	0.376	0.327	
Present value of benefit	0	87696	522547.2	364795.2	292406.4	50097.6	298598.4	208454.4	167162.4	1991758
									(1) NPV	**572764.4**
									(2) B/C ratio	**1.403641**
DCF 20%	1	0.833	0.694	0.579	0.482	0.402	0.335	0.279	0.233	
Present value of costs	100000	120018	249501.3	208157.4	173284.8	57919.84	120436.5	100303.8	83766.3	1213388
TOTAL BENEFIT	0	100800	691200	554400	511200	100800	691200	554400	511200	
DCF 20%	1	0.833	0.694	0.579	0.482	0.402	0.335	0.279	0.233	
Present value of benefit	0	83966.4	479692.8	320997.6	246398.4	40521.6	231552	154677.6	119109.6	1676916
									(1) NPV	**463528**
									(2) B/C ratio	**1.382011**