WATER AND ENERGY CONSUMPTION IN HIGH-VALUE FRUITS

Towards Integrated Solutions

T. P. Munaweerage
W.H.A. Shantha
M.A.C.S. Bandara

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Hector Kobbekaduwa Agrarian Research and Training Institute
114, Wijerama Mawatha
Colombo 07
Sri Lanka

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Hector Kobbekaduwa Agrarian Research and Training Institute
114, Wijerama Mawatha, Colombo 07
Sri Lanka

Final typesetting and lay-out by : Niluka Priyadarshani de Silva
Cover page designed by : Udeni Karunarathna

Tel. Phone : +94 11 2696981
+94 11 2696437

Fax : +94 11 2692423

Email : librarian@harti.gov.lk

Web page : www.harti.gov.lk

FOREWORD

Water scarcities, exacerbated by vulnerabilities unleashed by climate change, obviously call for methodologies that are marked by greater efficiency. This paper, which discusses the ground situation of selected high value fruit crops, compares and contrasts conventional irrigation practices and what are now called green technologies, underlines the importance of a shift towards the latter and, as crucially, the need for more concerted communications exercises to ensure the adoption of the same.

It is clear that there is scientific evidence supporting such a move. It is also clear that such technologies would be more cost-effective. Awareness, however, seems to be the main stumbling block, making for inefficiency as well as compromising climate-resilience.

Although this study covers just five fruit crops, the findings point to the possibility that integrated solutions related to water and energy in general, i.e. across all crops, need to be given more serious consideration as well. This of course calls for a more comprehensive study covering the entire agriculture sector. For now, however, at least in terms of this particular study and the results it has yielded, communication and training emerge as key deliverables.

I congratulate the research team for completing the task it has set itself despite numerous obstacles engendered by the pandemic. It is hoped that the findings and the policy implications thereto would received the attention of relevant agencies in institutional regime of the agriculture sector.

Malinda Seneviratne
Director/Chief Executive Officer

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T.P. Munaweerage
W.H.A. Shantha
M.A.C.S. Bandara

EXECUTIVE SUMMARY

Water scarcity and issues related to water management have been key detrimental factors for agricultural production and livelihoods of rural communities in Sri Lanka. Considering the fact that the agriculture sector is the largest consumer of available fresh water, many government policies focus and promote efficient irrigation methods by converting gravity-fed to pressurised irrigation methods as a way of reducing water consumption in the sector. However, such programs only consider optimized water use, which is only one aspect of a system, and therefore can have unintended resource and environmental consequences such as an increase in energy consumption patterns of irrigated crops. Therefore, this study was carried out to examine the relative importance and the comparative advantage of efficient irrigation systems such as drip and sprinkler methods which contrast with the conventional types of irrigation in terms of water and energy use for selected high value fruit crops in Sri Lanka. The study used primary and secondary data related to five high value fruit crops largely cultivated in the climate vulnerable dry and intermediate zone of the country: Mango, Banana, Guava, Papaya and Pomegranate.

In spite of scientific evidence regarding water and energy saving and incremental change in crop yield of irrigation of perennial crops, findings of the research highlighted that the rate of irrigation application is still minimal. Even among the farmers who practiced irrigation (either conventional type of irrigation systems or micro irrigation systems), the awareness of daily crop water requirement depending on the stage of the crop, capacity of pumping devices, number of hours of operation (pumping devices) is lacking. There should be an awareness program for farmers on the advantages of irrigation, particularly the micro irrigation (MI) systems, as a means of climate adaptation.

Farmers mainly rely on diesel, kerosene and electric pumps to lift surface water and shallow groundwater. The majority of farmers use electric water motors with the efficiency ranging between 1 – 1.5 kw/h. Though the majority of farmers use water pumping devices which have only been used for less than 10 years regular service and maintenance of such is very poor causing long run efficiency issues while compromising durability. The high fuel costs and limited access to grid electricity limit expansion of MI. By considering the cost effectiveness and environment friendly aspects, promotion of Green Technologies (GT) including solar-powered water

pumps coupled with MI systems, would help farmers overcome energy-related access and cost constraints to adopting and benefiting from irrigation.

For many of the crops studied, the irrigation cost under conventional type irrigation is higher than that of MI systems. Further, lack of awareness of farmers regarding crop water requirement and other related technical information of crop irrigation has caused excess water application, resulting in additional cost for energy and labour. It has also caused inadequate water supply for some crops and subsequent poor performances by such crops. Therefore, it is recommended to conduct awareness creation training programs for farmers on irrigation practices and meeting daily crop water requirements

The financial analyses show that the investment on MI systems for all the crops studied makes sense since the investments can be recovered within a shorter period of time compared to the lifespan of respective crop varieties. The main conclusion is that adoption of MI is unlikely to be driven by water savings. Overall changes in energy costs and specifically savings in fertilizer and labor costs may be more important incentives for adoption. Therefore, it is recommended to promote micro irrigation systems as a green technology to increase crop yield, water and energy saving and as a technology for increased resilience to climate change.

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LIST OF ABBREVIATIONS

ADA	-	Agrarian Development Authority
ARPA	-	Agriculture Research Production Assistant
ASC	-	Agrarian Services Center
CES	-	Constant Elasticity of Substitution
COP	-	Cost of Production
DAD	-	Department of Agrarian Development
DCBR	-	Discounted Cost-Benefit Ratio
DOA	-	Department of Agriculture
DPBT	-	Discounted Pay-Back Time
FAO	-	Food and Agriculture Organization
FO	-	Farmer Organization
GCE	-	General Certificate Examination
GHG	-	Green House Gas
GT	-	Green Technologies
HARTI	-	Hector Kobbekaduwa Agrarian Research and Training Institute
HP	-	Horse Power
IRR	-	Internal Rate of Return
IWMI	-	International Water Management Institute
MASL	-	Mahaweli Authority of Sri Lanka
MI	-	Micro Irrigation
NGO	-	Non-Government Organizations
NPV	-	Net Present Value
OFC	-	Other Field Crops

CHAPTER ONE

Introduction

1.1 Background

At the global level, agriculture consumes 70 percent of fresh water available, while industrial sector and domestic use account for 15 percent each (Sivakumar, 2015; World Bank, 2017). In the developing world, the fresh water share claimed by agricultural sector is much higher than the global average. The unparalleled growth in different sectors and their relative importance in different regions have aggravated the water scarcity leading to water stress and conflicts (Aheeyar *et al*, 2008; Lecler, 2004). Estimates for Asia predict a 65 percent increase in industrial water use, 30 percent increase in domestic use, and a five percent increase in agriculture use by 2030 (Rodriguez *et al.*, 2013). This illustrates the growing and acute competition among principal water users. Further, in facing climate change, the agriculture sector has encountered several challenges, including irrigation water provision. Climate change may impact the irrigation sector directly with the spatial and temporal changes in the rainfall, availability of surface and ground water and frequency of extreme climatic events.

In Sri Lanka, the agricultural sector is considered to be the single key activity that consumes the largest portion of available water resources of the country (IPS, 2016) while the economic development with industrialization, population pressure and urbanization have created an ever-rising demand for water (IWMI, 2010). Prioritized water allocation for higher water use in some selected sub-sectors like irrigation and domestic water use, has been coupled with a series of different state institutions mandated to develop sub-sectorial uses. This has created a process of allocating water to respective users without any concern to other sub-sectorial uses. It has created higher competition among different sub-sectors. As a result, water for environmental needs such as wildlife, eco-system maintenance and water for marginalized poor have been neglected. Further, water-allocation related frictions and conflicts have also been evolved over the last few decades in different geographical areas vulnerable to seasonal water shortage and with poor water distribution mechanisms. (Aheeyar & Smith, 1999; Aheeyar, *et al*., 2008; Gunatilake, 2008; Molle *et al.,* 2008; Nanayakkara, 2009; Aheeyar, *et al.,* 2012; Sivakumar, 2015; Saumyarathne, *et al.,* 2016). The threats posed by the adverse impacts of changing climate has also been aggravating the situation, placing increasing pressure on limited water resources from different sectors.

Being the subsector that consumes the largest portion, nearly 87 percent of water resource of the country, the agriculture sector (Government of Sri Lanka, 2019) has always drawn much attention in the subject of sustainable water resource management. The excessive withdrawals of groundwater and surface water leading to issues in water quality, quantity for the use of other subsectors and resultant water pollution has been a concern. This further escalates the growing trends of stress in terms of water availability (both in quality and quantity) subjected to seasonal variation and competition among sub-sectorial water users.

Moreover, the excessive water use in the irrigation (agriculture) sector by applying conventional types of irrigation (flood irrigation, furrow irrigation and watering plant hills) has created issues such as high energy and labour consumption leading for higher cost of production, land degradation in the form of soil erosion, yield loss due to limitation of water during the crucial stage/s of the crops and etc. even within the crop production sector. The *Yala* season especially experiences this situation, compelling farmers to grow less resulting in lower productivity and production levels of the crops.

In order to overcome the issues associated with the conventional irrigation methods mentioned above, the efficient irrigation methods including Micro Irrigation (MI) systems such as drip and sprinkler irrigation have been introduced to the different crop production systems. This is especially for the fruit and vegetable sector and other field crop sector (OFC) of the country, allowing for efficient water management and increased crop yields at lower production cost. However, the efficient water management strategies introduced to the agriculture sector has a very poor popularity among the farming community owing to the issues associated with individual farmers as well as institutional setups. Whereas the micro irrigation methods introduced to some crop production systems (fruit and vegetables, OFCs and other perennials) have become popular in different parts of the country.

The micro irrigation systems were first introduced to the agriculture sector in 1990s by then Agriculture Development Authority (ADA) to promote this technology as water and labour saving initiative. Later, different initiatives and activities have been taken by Southern Development Authority (SDA), Mahaweli Authority of Sri Lanka (MASL), Food and Agriculture Organization of the United Nations (FAO) and local non-governmental organizations

(NGOs) to popularize this technology. The crop diversification strategies of the government institutes such as Ministry of Agriculture, MASL, and Irrigation Department were well supported by such initiatives in introducing and promotion of micro irrigation systems. Efficient irrigation systems have considerably been utilized for seasonal crop cultivation (vegetables and OFCs) in commercial level small-scale farms in key producing areas such as Nuwaraeliya, Kalpitiya, Thelulla, Dambulla, Jaffna and Mahaweli System H. Mostly vegetables, potato and big onion are grown under these systems. In addition, the perennial fruit crop production (guava, mango, pomegranate, and banana) in specified areas is also equipped with efficient irrigation systems such as drip and sprinkler methods. Coconut is also one of the prominent plantation crops cultivated under drip irrigation system especially in selected plantations in dry and intermediate regions (Puttalam & Kurunegala districts).

Though it has almost been three decades since introducing efficient irrigation systems the adoption level and continuation of this technology among the farming communities is not at a satisfactory level (Aheyaar *et al*., 2005; Aheeyar *et al.,* 2011; Bandara & Padmajani, 2014; Udagedara & Sugirtharan, 2018). The supply-driven nature of the irrigation systems, less applicability of the technology to given soil and water qualities, difficulties in collapsing to ease the agronomic practices such as ploughing in the following season/s, less or no affordability for the majority of the small-scale farmers, lack of technical know-how on repair and maintenance and poor service network etc. have become the impediments for this technology, limiting its use in many parts of the country. Admittedly, the challenge of improving water use efficiency and productivity is complicated by the fact that it is not necessarily a high priority for farmers.

Access to water for irrigation is of utmost importance to farmers particularly in order to sustain their livelihoods and food security. However, operating irrigation systems efficiently often calls for the adoption of local irrigation techniques and this in turn requires a source of energy. Agriculture irrigation is one of the primary consumers of energy (Naylor, 1996) and the level of energy consumption directly related with the irrigation technology adopted and the level of production (Hatirli *et al.,* 2006). In the absence of a reliable electricity supply, in many rural areas in several developing countries, farmers have to resort to diesel-based pumping systems. These systems create high operating costs particularly in remote areas, require frequent servicing, which is not always available, contribute to GHG emissions, and contribute to the energy bill in countries that do not produce such fuels. In the irrigation subsector, energy use is primarily for ground or surface water pumping and use of petroleum for on-farm irrigation technologies and other farm machinery. Continued expansion of groundwater use, its impact on water tables, the growing demand for energy and the cost to the power sector are highly relevant for Sri Lanka where energy prices often do not reflect the true cost of supply. In such circumstances solar-powered irrigation systems are increasingly in demand in developing countries as they can provide a cost-effective and "clean" solution to increase agricultural productivity.

The evidence from research and field measurements shows the huge advantages of adopting micro irrigation technologies in terms of farmer income and water conservation. However, the actual situation of farmers in the field is different. In other words, in conceptual terms agriculture should consume less water and whatever water is available must be used as productively as possible. However, in real world these solutions are far from simple because choices have to be made on who should reduce water at to what extent. Attention needs to be paid to the social, economic and food security implications of those decisions (Molle & Closas, 2017).

1.2 Rationale of the Study

Implementing a particular technology successfully in ground is not just a technology fix or a financial solution. It must consider farmers' livelihood conditions and strategies, impacts on farming systems (e.g. crop pattern, income, costs) as well as social acceptance. Integrated approaches such as the water-energy-food nexus and sustainable livelihoods should also be used to help fill the information gaps regarding micro irrigation performance and feasibility.

In literature, the importance of adhering to improved water management technologies by smallholder farmers to increase their livelihood and also to ensure the food security particularly with expected future food demands and climate variability has been discussed at length. Though micro irrigation systems have been proved to be an efficient method in saving water and increasing water use efficiency as compared to the conventional methods of irrigation, the benefits in energy saving (in the form of farm-labour and fuel/electricity required for irrigation) have not properly highlighted in the studies conducted in this field.

On the other hand, the balance between crop production and environmental sustainability involves improving water productivity (Molden *et al.*, 2007) and energy productivity (de Fraiture *et al.*, 2007) through a range of measures. The energy required for installation and operation of improved and efficient irrigation systems like drip irrigation is significantly higher than traditional systems of gravitational irrigation and, the associated greenhouse gas emissions are considerably high. Although internal and external environmental and economic benefits increase with improvement in irrigation efficiency (Beare & Heaney, 2001), a balanced use of water and energy resources is vital in terms of productivity of agriculture and for environmental sustainability. Unless energy requirement aspects are considered, the improvement in irrigation efficiency is a partial solution for minimizing the environmental footprint of consumptive use of water.

In this background, lack of scientific evidence on relative importance and the comparative advantage of micro irrigation systems over the conventional methods of irrigation has also been an impediment for small-scale farmers and other agricultural entrepreneurs/investors to adopt and invest on micro irrigation systems. Thus, understanding and portraying the costs and benefits associated with each system (conventional methods and micro irrigation systems) in monetary terms is essential to attract and motivate the majority of small-scale farmers to apply efficient irrigation systems for different crop production systems in different geographical locations of the country.

Further, the State Ministry of Paddy and Grains, Organic Food, Vegetables, Fruits, Chilies, Onion and Potato Cultivation Promotion, Seed Production and Advanced Technology Agriculture is keen on finding ways of providing higher incomes through improved water management and this has been identified as one of the priority areas of the ministry.

1.3 Objectives

In this background, this study will be carried out with the primary objective of examining the relative importance and the comparative advantage of efficient irrigation systems such as drip and sprinkler irrigation methods against the conventional types of irrigation in terms of water and energy use of selected high value fruit crops in Sri Lanka.

Specific objectives of the study are;

- To identify types of irrigation systems used in selected fruit crops production and investigate the volume of water applied and energy consumption (including human labour) under different irrigation systems.

- To portray costs and benefits (in monetary form) associated with different irrigation systems and examine the financial viability of adopting micro irrigation systems for selected fruit crops.

CHAPTER TWO

Methodology

2.1 Crops, Sample Selection and Data

As the need for assessing the water and energy savings through application of high efficient irrigation systems such as drip and sprinkler irrigation for high value perennial crops is higher than of for seasonal crops such as vegetables and other field crops, in this study the attention was drawn for five high values fruit crops largely cultivated in climate vulnerable dry and intermediate zone of the country. Even though at the initial stage eight fruit crops were selected to study, pineapple and orange was dropped from the list as micro irrigation is not commonly practiced for those crops.

The study was conducted by using both primary and secondary data and information collected from various sources. The primary data was mainly collected from the farming community practicing respective crop cultivation in the given producing areas. The secondary data was mainly obtained from the publications and other materials on respective perennial crop varieties available at the Department of Agriculture (DoA).

The survey locations

The District, Divisional Secretariat Division (DSD) and the Agrarian Service Center (ASC) area for each fruit crop variety were selected taking the land extent cultivated under each crop in the particular location into consideration. Respondent farmers were selected using the information available in the district agriculture office. Purposive sampling technique was employed to select micro irrigation farmers since there is no conclusive information on the status of micro irrigation technologies adoption in Sri Lanka basically because of not having an institute tasked with collecting information on this subject. Primary data collection was carried out using a questionnaire-based telephone survey of farmers who are cultivating selected fruit crops in selected crop production areas. It included comprehensive data set related to the farmer associated socio-economic conditions, as well as input, irrigation methods and pump characteristics.

The number of farmer households surveyed under each crop in respective districts is described in the Table 2.1.

Table 2.1: Distribution of Sample

Crop	District	Sample size
Guava	Matale	1
	Anuradhapura	10
Mango	Matale	9
Banana	Hambantota	10
Papaya	Hambantota	10
Pomegranate	Puttalam	10
Total		50

2.2 Data Analysis

The quantitative data and information on costs of application of different irrigation methods for different fruit crops and associated cost of cultivation pertaining to agronomic practices and input used as well as crop yield and farmer income were analyzed to achieve the study objectives. Further, economic viability of investment in micro irrigation for high values fruit crops was assessed by employing a financial analysis for each crop type.

2.2.1 Financial Analysis

Saving water and energy alone would not encourage farmers to adopt micro irrigation. In order to better understand the sustainability of application of micro irrigation systems for selected fruit crops, it is necessary to assess not only the profitability of the crops cultivated under efficient irrigation systems against the conventional method/s of irrigation but also the financial sustainability of the business cycle, applying appropriate indexes (Tudisca, Sgroi & Testa 2011; Bonazzi & Iotti 2014). A financial analysis was carried out determining the Net Present Value (NPV), the Internal Rate of Return (IRR), the Discounted Cost-Benefit Ratio (DCBR) and the Discounted Pay-Back Time (DPBT). Thus, for a given crop cultivation under micro irrigation system/s, to be financially sustainable, the DCBR should be greater than one and NPV is positive. Further, DPBT should be less than the lifetime of the particular crop.

The standard cost concepts were used for financial analysis. The total costs were divided into two broad categories: a) Variable Costs and b) Fixed Costs.

Variable Costs

Variable costs are the costs incurred by the farmers for the enterprise to be productive. Broadly, these are the actual costs along with incidental charges incurred towards labour and material costs.

Fixed Costs

The life span of the crops, as well as the micro irrigation systems, was considered according to the actual lifetime of the said items. Thus, the cost structure for relevant number of years was calculated by compounding and discounting the costs. Costs already incurred were compounded and future costs will be discounted to present time for a reference year as 2020.

- Rental value of own land: prevailing land rent in the study area.
- Interest on fixed capital: interest on fixed capital (market price of micro irrigation systems; material cost and installation charges) will be calculated at prevailing rate of investment credit.

NPV included the diversity of perspective according to which economic convenience is analyzed in investment context, with respect to long-term theoretical analysis (Tudisca, Sgroi & Testa 2011; Keča, Keča & Pantić 2012). In fact, NPV does not base its judgment on maximizing incomes, but on maximizing wealth, represented by the difference between discounted gross income values generated during the investment life and the corresponding fixed costs (FC).

NPV was calculated with the following formula:

$$NPV = \sum_{t=1}^{t=n} \frac{Bt - Ct}{(1+i)t}$$

Where *Bt* is the gross income (that is equal to the difference between gross production value and variable costs), *Ct* represents the fixed costs, *n* corresponds to the lifetime of the investment, *t* represents the year considered and *i* is the discount rate (in this analysis it is equal to 12 percent, considering market conditions). The considered investment is convenient if NPV is positive. Thus, choosing between two investments, the one with higher NPV value is more convenient (Tudisca *et al.,* 2013). The IRR is the discount rate at which the discounted benefits are equal to the discounted costs, determining a NPV equal to zero.

$$NPV = \sum_{t=1}^{t=n} \frac{Bt - Ct}{(1 + i)t} = 0$$

According to IRR, an investment is convenient if its IRR is higher than chosen discount rate (Kelleher & MacCormack, 2004). DCBR is defined as the ratio between the discounted gross income values generated during the investment life and the corresponding fixed costs. It has been calculated with the following formula.

$$DCBR = \sum_{t=1}^{t=n} \frac{Bt}{(1 + i)^t} / \sum_{t=1}^{t=n} \frac{Ct}{(1 + i)^t}$$

In this case, the investment will be convenient if the ratio it is higher than one (Zunino, Borgert & Schultz 2012). The Discounted Pay-Back Time (DPBT) is a financial indicator that corresponds to the number of years occurred equating initial investment and it is not a measure of the economic convenience of the investment. DPBT corresponds to the year in which the sum of discounted benefits exceeds the costs (Bedecarratz *et al.,* 2011). The costs and benefits presented in this analysis are in Sri Lankan Rupees (LKR).

2.2.2 Water and Energy Consumption Estimation

Not all water applied to the field is reaches the root zone of the plants. While part of the water utilized by plants efficiently and rest is lost by different means. In technical terms, field application efficiency measures the efficiency in application of water in the field. It mainly depends on the irrigation method and nature of the farmer practices.

Information on water use reported by farmers was used for the analysis. Further, required input data including energy inputs was selected based on common categories used in previous studies (Hatirli *et al*., 2006; Ozkan *et al.*, 2007), and it include information on fuel and electricity, machinery, agrochemicals, fertilizer and pesticides, seed and human labour. This data was integrated in an accounting model run on Microsoft Excel. The analysis was carried out to model water application and energy consumption at the field scale that describes the relationships between water (source and application rate), energy, irrigation method, and climate and soil characteristics.

In order to compare the potential effects of converting to other irrigation methods, the model combines operational data reported by farmers with accepted water use data for alternative irrigation methods not currently installed on the farm or not optimally operated in the field. The irrigation methods considered were surface, drip and sprinkler.

For this calculation average indicative field application efficiency values given by the FAO (Brouwer *et al.*, 1989) were used (Table 2.2).

Table 2.2: Indicative Values of the Field Application Efficiency

Irrigation method	Field application efficiency
Surface irrigation (border, furrow, basin)	60%
Sprinkler irrigation	75%
Drip irrigation	90%

Source: Brouwer *et al*., 1989

The Table 2.3 shows the cropping pattern and plant densities of the fruit crops studied and all the water requirements were calculated based on those figures.

Table 2.3: Cropping Pattern and Plant Density

Fruit crop	Cropping pattern	Plant density per acre
Mango	Mono crop	40
Banana	Mono crop	640
Guava	Mono crop	160
Papaya	Mono crop	640
Pomegranate	Mono crop	444

CHAPTER THREE

Socio Economic Features and Pattern of Water and Energy Use at Farmlands

Adoption of improved technologies and sustainable use of it highly depend on farmer level characteristics and level of discipline. This chapter discusses the demographic features of the fruit crop producing farmers and pattern of water and energy use at farm level.

3.1 Demographic Characteristics of the Fruit Crop Producers

This subsection summarizes the demographic characteristics of the sample fruit crop farmers including age, educational level, income, land and employment profile.

3.1.1 Age and Gender Distribution of Respondent Farmers

As far as the age of the respondent farmers are concerned, it could be observed that the majority of the farmers belong to the age categories over 40 years contributing approximately 70 percent to the total sample (Table 3.1). This indicates the general scenario of less youth involvement in the agriculture sector of the country. The youth below 30 years involvement in farming is reported to be around six percent.

Table 3.1: Age Distribution of Respondent Farmers

Age category	Number	Percentage (%)
<31	3	6.0
31-40	12	24.0
41-50	23	46.0
51-60	8	16.0
60<	4	8.0
Total	50	100.0

Source: HARTI survey data, 2021

The majority of the respondent farmers are males accounting for over 95 percent to the total sample. This information reflects general set-up of the male dominant farmer households in the dry zone area of Sri Lanka. The female respondents are mostly representing the female-headed households.

3.1.2 Education Level of the Sample Farmers

The Table 3.2 presents the level of education of the respondent farmers. It highlights that the farmers having higher education qualification is minimal in the sample. The majority of 58 percent of the respondents are confined to secondary education while over four percent of the sample fruit crop farmers have obtained no formal education or only primary level education. Another 32 percent have studied up to GCE advanced level but percentage of farmers who have passed the GCE advanced level exam is only 6 per cent. This situation in the subsistence agriculture sector of Sri Lanka has been highlighted as one of the reasons for farmers not to be convinced in adopting novel technologies.

Table 3.2: Level of Education of the Respondent Farmers

Education category	Number	Percentage (%)
No formal education	1	2
Primary education	1	2
Up to grade 10	24	48
Passed GCE O/L exam	3	6
Up to GCE A/L	16	32
Passed GCE A/L exam	3	6
Higher education	2	4
Total	50	100

Source: HARTI survey data, 2021

3.1.3 Primary Income Source of the Sample Farmers

Among the respondent farmers, 91 per cent are involved in farming in full-time basis while the rest is belonging to the part time category. This information is correctly projecting the importance of agriculture sector in rural economies where the majority of the labour force is largely involved in agriculture for their primary and/or sole source of income. Among the farmers who involved on agriculture as the key livelihood on full time basis 94 percent of them engaged in crop cultivation.

3.1.4 Farming Experience of the Sample Fruit Crop Farmers

The experience in farming, in many studies, has been proved to be a key factor determining the farmer's willingness to adopt new technologies (including application of MI systems). As presented in the Table 3.2, it can be observed in the sample of this study, that the majority, over two-third is having farming experience more than 10 years in the particular crop/s. This information further describes the age composition of the farmers in the sample, that the majority is represented by the age category over 40 years.

Table 3.3: Farming Experience of the Respondent Farmers

Farming experience	No	Percentage (%)
≤10 years	7	14
11 - 30 years	32	64
> 30 years	11	22
Total	50	100

Source: HARTI survey data, 2021

3.1.5 Land Size Distribution and Ownership Status under Different Fruit Crop Varieties

Size and the ownership status of the land where crop cultivation is undertaken are mostly linked to the investments made on land development including building/installing irrigation infrastructure on the particular land. Table 3.4 shows the land size distribution under different fruit crop varieties considered in the study.

It can be observed that almost all the farmers undertake crop cultivation on relatively smaller land parcels less than 5 ac. Majority of the farmers irrespective of the crop type cultivate land extend in between 1 – 2 ac. This information is compatible with the national level information generated through the latest Agricultural Census as well (DCS, 2002).

Table 3.4: Land Size Distribution under Different Fruit Crops

Crop	Land size category (Ac)			
	<1	1.0 – 2.0	2.1 – 5.0	5<
Mango	2	4	2	1
Guava	2	8	1	-
Banana	-	5	5	-
Papaya	2	8	-	-
Pomegranate	4	6	-	-
Total	10	31	8	1

Source: HARTI survey data, 2021

Considering the ownership status of the lands cultivated with fruit crops, more than 94 percent of the respondent farmers are cultivating their own land plots. Few of others cultivated in encroached lands or lands under tenurial arrangements or shared ownership.

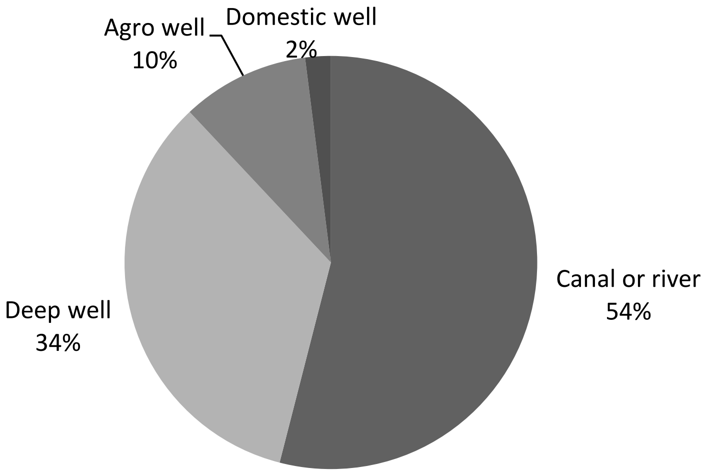
3.2 Pattern on Water and Energy Use in Farmlands

Assured source of water and energy is important for sustainable and economical use of micro irrigation and adaptation. The following section discusses the sources of water and energy for agriculture, the type of equipment used and adoption of different micro irrigation systems by sample fruit growing farmers.

3.2.1 Source of Water

Changing rainfall pattern and shifting of monsoonal weather resulting water scarcity and prolonged dry spells and droughts have adversely affected crop production in the drier parts of the country. Therefore, the importance of irrigation application is emphasized for uninterrupted crop yield while maintaining the optimum productivity levels and quality of the products. However, owing to many reasons such as lack of awareness, financial constraints, inadequate access to continuous water/irrigation source/s, lack of knowledge in novel technologies etc. the level of irrigation application is still at relatively lower levels.

As illustrated in Figure 3.1, majority of farmers use water flowing through open canals and rivers (54%) as the source for their irrigation facilities. Another 34 percent of the fruit growers use deep wells as supplementary irrigation source and the farmers using agro wells is ten percent. Agro-wells and domestic wells are used for irrigation purposes mainly by small scale farmers while deep tube wells are mostly used by the large-scale farmers growing capital-intensive and highly profitable crops such as mango and pomegranate.

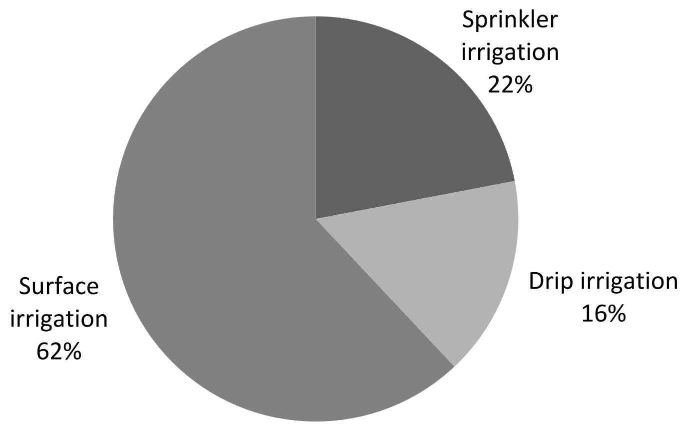


Source: HARTI survey data, 2021

Figure 3.1: Source of Irrigation

3.2.2 Method of Irrigation

Further portraying the relatively lower level of application of MI systems in agriculture sector, as illustrated in Figure 3.2 only 38 percent of the respondents in the sample are practicing either sprinkler or drip irrigation systems (22% and 16% respectively) for crop cultivation while the others are following conventional methods (62%) such as surface irrigation including furrow and basin irrigation and diverting water through ditches (for banana).



Source: HARTI survey data, 2021

Figure 3.2: Method of Irrigation

As presented in Table 3.5 the drip irrigation systems have mostly been installed with the crops such as guava and papaya whereas the sprinkler systems are used for banana and mango. It has been extensively experimented and reportedly found that drip irrigation is especially suitable for banana, coconut and most of perennial crops including fruits (Chandaragiri, 2002; Saxena & Rao, 2018;).

Table 3.5: Irrigation Methods Applied in different Crop Varieties

Crop	Sprinkler irrigation	Drip irrigation	Surface irrigation
Mango	3	0	6
Banana	3	1	6
Guava	1	3	7
Papaya	2	5	3
Pomegranate	1	0	9
Total	10	9	31

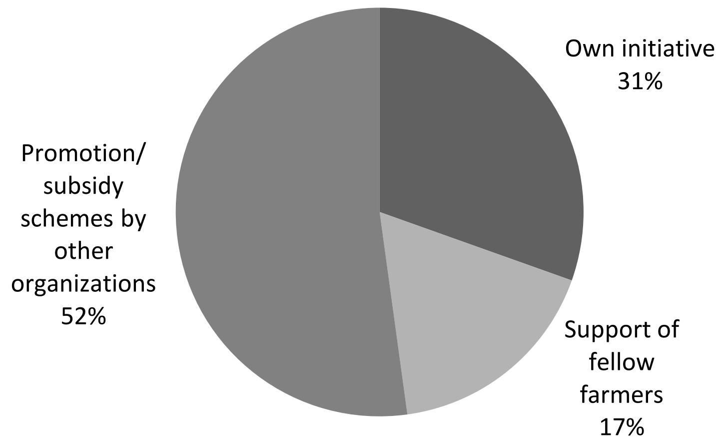
Source: HARTI survey data, 2021

As far as the different irrigation methods applied in respective crops are concerned, it is observed that irrigation water application is not practiced for some perennial crops such as orange and pineapple. In pineapple, which is mostly grown at commercial scale in wet zone district Gampaha and in intermediate zone district Kurunegala as an inter-crop in coconut plantations, the soil moisture levels are maintained with natural mulch in the dry spells. Thus, irrigation water application is hardly practiced by farmers.

In the case of orange, which is largely cultivated in the areas coming under the intermediate zone in Monaragala district, the irrigation application is practiced very rarely as farmers reckon that the crop can survive in relatively short dry spells experienced in the area. Therefore, irrigation application for the respective crop is not vastly promoted and popular among the farming communities. However, when extreme drought incidents occur farmers tend to water plant hills using buckets to avoid the damage to the crop.

3.2.3 Adoption of Micro Irrigation by Fruit Farmers

In general, similar to adopting any of the novel technologies related crop cultivation and post-harvesting handling, the innovative and early adopting farmers tend to, and are pioneers in, applying MI systems. Such enthusiastic farmers are likely to take risk of applying novel technologies. However, the awareness of such farmers on respective innovations must be made and increased, and provision of technical assistance and incentive/subsidy schemes should be promoted either through government or private sector mechanism/s.



Source: HARTI survey data, 2021

Figure 3.3: Motivation behind Farmers to Adopt MI Systems

In case of MI systems installed in the farmer fields of the respondent farmers as illustrated in Figure 3.3, less than one third has taken initiatives with their own while the majority of farmers (52%) have adopted the technology through the promotion and subsidy schemes provided by private companies. The success stories learnt by fellow farmers with practicing MI systems have also been reasons for some respondents to adopt the MI technology in their crop fields.

3.2.4 Source of Energy and Type of Machinery Used for Irrigation

Pumping and directly delivering water through pipes either to the soil surface or through drip or sprinkler systems are the widely practiced method of irrigation water supply by respondent fruit growing farmers. Table 3.6 presents the type of energy used by farmers in delivering irrigation water to crop fields. Without using any machinery for water pumping, diversion and conveying water flowing in the canal/river into the fields through ditches is also practiced by farmers as a means of irrigation, specially for banana cultivation.

Table 3.6: Source of Energy Used for Irrigation

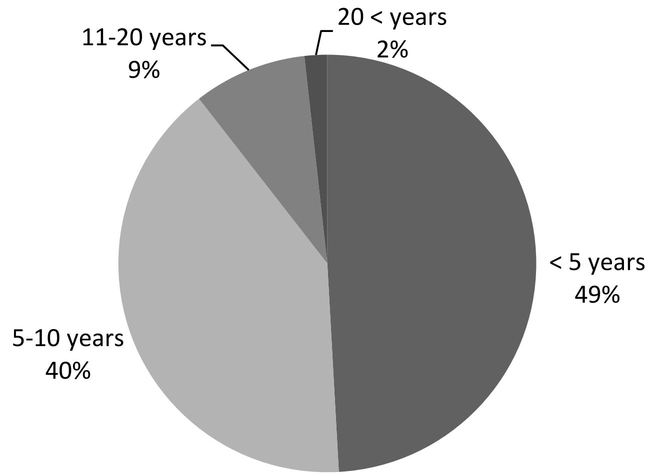
Crop	Source of Energy					
	Diesel/Kerosene		Electricity		Gravity	
	N	%	N	%	N	%
Guava	3	27	8	73	-	-
Mango	3	33	6	67	-	-
Banana	4	40	-	-	6	60
Papaya	6	60	4	40	-	-
Pomegranate	-	-	10	100		
Total	16	32	28	56	6	12

Source: HARTI survey data, 2021

Water pumps running with kerosene (ranging from 1.5 – 3.3 HP) or water motors (with 1 – 1.5 kW energy consumption) operated with electricity are mostly used by farmers for irrigation activities. However, owing to lack of regular service and other maintenance the energy efficiency of the water pumps and water motors have become low, and hence, this has negative impacts on energy consumption and the functionality as well as the durability of the machine.

It shows that electric water pumps are widely been used for irrigation water supply by the majority of farmers accounting for 56 percent. Water pumps running with diesel/kerosene are used as the machinery for pumping account for one third of the irrigating fields. It further reflects the lower levels of diffusion of Green Technologies (GT) such as solar powered MI systems even into the commercial level crop cultivation sector of Sri Lanka.

A worn out pump can be inefficient in its energy use. Many research studies conducted on pump performance in irrigated agriculture has revealed that pump efficiency was poor in most of the systems and substantial energy saving can be achieved through restored specifications (Jessen, 2008; Smith *et al.,* 2013). In general, the older the water pumping devises/machinery, the lower the fuel consumption efficiency as well as functionality of the respective machinery. It incurs additional cost for energy (electricity/kerosene) and labour. Figure 3.4 presents the age of water pumps/motors used by the farmers in the sample.



Source: HARTI Survey Data, 2021

Figure 3.4: Age of Pumping Devises/Machinery Used for Irrigation

Though the majority (approximately 90 percent) of pumping devises/machinery have been used for less than 10 years since their first use, in a situation which such machinery are poorly maintained, there is damage caused to the environment in the form of excess Carbon Dioxide (CO_2) emission causes climate change (Jackson *et al.,* 2011; Mushtaq *et al.,* 2013;). Therefore, it is important to educate farmers on carrying out periodical service and proper maintenance for improved energy efficiency of the pumping machinery. Such a mechanism will deliver positive results towards climate change mitigation (Smith *et al.,* 2013).

CHAPTER FOUR

Water and Energy Consumption and Economic Viability of Irrigation

Water and energy are intrinsically linked. Water efficient irrigation systems are generally more energy intensive and expensive to operate than water inefficient systems. A water efficient system is a major capital investment and entails taking on the additional operating energy costs and exposure to energy prices. Therefore, this chapter evaluates trade-offs associated with the adoption of more water-efficient, but energy-intensive, micro irrigation technologies and economic viability of investment in micro irrigation.

4.1 Water and Energy Consumption in Fruit Crop Production under Different Irrigation Methods

This section presents the results of the analysis of water, energy and labour usage under different irrigation methods based on the farm level data.

The energy and man-days required for irrigating cultivation lands vary depending on a number of factors including crop variety, stage of the crop (either vegetative stage or the reproductive stage), season or the time of the year (rainy *Maha* or dry *Yala*), geographical location and the agro-ecological region to which the land area belongs and etc. Since, in this study, the data and information for the selected crop varieties collected from the farmers in different parts of the country, mostly in low-country dry zone areas, a common assumption was adopted in calculating and presenting information related to cost of irrigation.

Thus, as commonly practiced by farmers, irrigation interval for surface irrigation was considered as 6 days while it is taken as 3 days for MI systems. The total duration of irrigation per annum was assumed to be 7 months. Further, the average fuel consumption for water pumping was considered as 1.3 l/h (with the capacity of 8000l/h). Based on these assumptions, the irrigation cost was calculated for selected high value fruit crops viz; Mango, Guava, Papaya, Banana and Pomegranate described in the following sections.

4.1.1 Water and Energy Consumption in Mango

Based on the field data collected from mango growers, on average 0.625 - 1 man-day required for irrigating a unit area (1 acre) of mango field under the conventional method of surface irrigation whereas less than 2 man-hours (effective labour) are used for irrigation with MI systems (sprinkler systems). As Table 4.1 shows the operating hours of water pumping devises/machinery is also slightly higher for surface irrigation methods in comparison to the MI systems. The overall operational cost of irrigation with MI systems is comparatively higher than that of conventional irrigation system. It is mainly because of short irrigation intervals practiced with MI systems.

As described in the previous section, the longer the machine operating time, the higher the amount of CO_2 emitted to the atmosphere contributing to climate change. Further, providing irrigation water for the actual water requirement of the particular crop through the MI systems can save more water. Therefore, had farmers been aware of actual water requirement, the irrigation interval can be further increased, saving energy, labour and water. Therefore, it is evident that the application of MI systems for crop irrigation with a deeper understanding of the system would have multiple benefits such as low cost, less labour demand, water and energy savings.

However, in farmers' irrigation practices (in both surface and MI systems), it can be seen that farmers are not aware of the actual water requirement of the crop. Thus, farmers apply excess water to the field, consuming excess labour and energy. Table 4.2 shows the energy consumption and water discharge per one irrigation cycle.

Table 4.1: The Cost for Irrigation of Unit Area (Ac) under Different Types of Irrigation in Mango

Irrigation method	Labour		Energy			Cost per irrigation cycle (LKR)	Total cost (LKR/yr)
	Man days	Labour cost (LKR)	Operation hours	Fuel consumption (l/hr)	Fuel cost (LKR)		
Surface irrigation	0.625	937.5	5	1.3	565.5	1,503	45,090
Drip irrigation	0.25	375	4	1.3	452.4	827.4	49,644

Note: Plant density – 40 plants /ac
Source: HARTI survey data, 2021

Table 4.2: Water Discharge and Fuel Consumption with Different Types of Irrigation in Mango

Irrigation method	Operation hours	Kerosene consumption		Water discharge	
		Fuel consumption (l/hr)	Fuel consumption (l)	Pump capacity (l/hr)	Total discharge (l)
Surface irrigation	5	1.3	5.2	8000	40000
Drip irrigation	4	1.3	5.2	8000	32000

Source: HARTI survey data, 2021

4.1.2 Water and Energy Consumption in Guava

As recorded by the guava producing farmers typically one person takes six hours to irrigate an acre of guava land. The labour requirement for the same purpose with MI systems is less than 2 hours. For guava also, the average irrigation interval for surface irrigation is 5 days while that for MI systems is 3 days. Similar to the mango crop, the guava fields assumed to be irrigated 210 days per annum.

As per Yadav *et al.,* (2017), the daily crop water requirement for guava is 74 l/plant. The recommended irrigation interval for guava under drip irrigation system is 4 days. It can be observed that, when the actual crop water requirement of guava is concerned, the farming practices in irrigation do not meet the irrigation requirement of the crop except for drip irrigation system. Therefore, excess water application does not occur for this crop under surface and sprinkler irrigation systems as given in the Table 4.4.

Table 4.3: The Cost for Irrigation of Unit Area (Ac) under Different Types of Irrigation in Guava

Irrigation method	Labour		Energy			Cost per irrigation cycle (LKR)	Total cost (LKR/yr)
	Man days	Labour cost (LKR)	Operation hours	Fuel consumption (l/hr)	Fuel cost (LKR)		
Surface irrigation	0.875	937.5	7	1.3	791.7	1,729	51,876
Drip irrigation	0.25	375	5	1.3	565.5	941	65,835
Sprinkler irrigation	0.25	375	4	1.3	452.4	827	57,918

Note:Plant density – 160 plants /ac

Source: HARTI survey data, 2021

Table 4.4: Water Discharge and Fuel Consumption with Different Types of Irrigation in Guava

Irrigation method	Operation hours	Kerosene consumption		Water discharge	
		Fuel consumption (l/hr)	Fuel consumption (l)	Pump capacity (l/hr)	Total discharge (l)
Surface irrigation	7	1.3	9.1	8000	56000
Drip irrigation	5	1.3	6.5	8000	40000
Sprinkler irrigation	4	1.3	5.2	8000	32000

Source: HARTI survey data, 2021

4.1.3 Water and Energy Consumption in Papaya

The recommended plant density for papaya is 1600 plants/ha however, the plant density is increased in drier areas up to 2000 plants/ha whereas the lower plant density is maintained in relatively wet areas. Owing to the higher plant density, irrigating a unit area of papaya field (an acre) requires higher labour accounting 2 man-days as per the farmer-based information. However, similar to the other crops, the labour requirement can be cut down by 75 percent with the MI systems, saving a significant amount of money.

Papaya is considered as a crop which is highly sensitive to moisture content. The sensitivity of this crop to varying soil moisture levels, which may be lethal to the plant or may change its morphology, necessitates the use of precise standardized technologies like drip irrigation and fertigation (Singh & Singh, 2019).

The Table 4.5 shows the calculated energy and water consumption values based on farmer observations. However, it also highlighted that drip method of irrigation gives lowest energy cost even without operating under optimum field management conditions.

It is evident that, farmers are applying excess water for papaya as well, under all the irrigation systems, though under the MI systems, the water discharge is lower than the surface irrigation system. Thus, the CO_2 emission can also be reduced with MI systems with providing actual water requirement, if farmers are aware of the actual crop water requirement. The fuel consumption and average water discharge under each irrigation method is given in the Table 4.6.

Table 4.5: The Cost for Irrigation of Unit Area (Ac) under Different Types of Irrigation in Papaya

Irrigation method	Labour		Energy			Cost per irrigation cycle (LKR)	Total cost (LKR/yr)
	Man days	Labour cost (LKR)	Operation hours	Fuel consumption (l/hr)	Fuel cost (LKR)		
Surface irrigation	1.75	2625	14	1.3	1583.4	4208.4	126,252
Drip irrigation	0.5	750	8	1.3	904.8	1654.8	115,836
Sprinkler irrigation	0.5	750	6	1.3	678.6	1428.6	100,002

Note:Plant density – 640 plants /ac

Source: HARTI survey data, 2021

Table 4.6: Water Discharge and Fuel Consumption with Different Types of Irrigation in Papaya

Irrigation method	Operation hours	Kerosene consumption		Water discharge	
		Fuel consumption (l/hr)	Fuel consumption (l)	Pump capacity (l/hr)	Total discharge (l)
Surface irrigation	14	1.3	18.2	8000	112000
Drip irrigation	8	1.3	10.4	8000	64000
Sprinkler irrigation	6	1.3	7.8	8000	48000

Source: HARTI survey data, 2021

4.1.4 Water and Energy Consumption in Banana

Banana (*Musa* spp.) is not only the most widely cultivated and consumed fruit in Sri Lanka but it has been an attractive perennial fruit crop for farmers because of its high economic benefits year around. Banana is one of the key crops used in crop diversification of paddy fields. Banana cultivation in paddy fields provides more economic benefits, with less crop water requirement and less input and labour than rice. Despite this, it gives higher returns than conventional type of paddy cultivation.

In total, 28 local cultivars of banana have been identified in Sri Lanka. Among them, the cultivar *Ambul* is in the highest demand. The cultivar *Kolikuttu* is with higher market price throughout the year. Cultivar *Ambon* grown especially in the mid country wet zone is also in considerable demand (Hirimburegama *et al.*, 2001). The recommended spacing for banana varies depending on the cultivar, agro-ecological region and type of cultivation (either mono crop or intercrop and other). Thus, the average yields under the given plant densities are also vary due to the one or more of the reasons mentioned above.

Information related to banana in this study was mainly collected from farmers who have cultivated banana in lowland paddy fields with *Kolikuttu* cultivar provided either surface irrigation (diverting water flowing in canal to the field through ditches and in this method of irrigation no use of any pumping devise/machinery) or MI system, the sprinkler system.

Table 4.7 and 4.8 shows the details of labour and energy costs with sprinkler irrigation systems. As the surface irrigation for banana requires only labour to divert water from open canals to the field through ditches, the irrigation cost is very low compared to surface irrigation in other crops. Since it does not incur any cost for energy to run devises/machinery, the total cost of surface irrigation is lower than that of MI systems. However, water discharge cannot be calculated for surface irrigation since there is no mechanism to measure the volume of water flowing into the banana fields through ditches.

Table 4.7: The Cost for Irrigation of Unit Area (Ac) under Different Types of Irrigation in Banana

Irrigation method	Labour		Energy			Cost per irrigation cycle (LKR)	Total cost (LKR/yr)
	Man days	Labour cost (LKR)	Operation hours	Fuel consumption (l/hr)	Fuel cost (LKR)		
Surface irrigation	0.5	750	NA	NA	NA	750	22500
Drip irrigation	0.125	187.5	3	1.3	339.3	526.8	36876

Note:Plant density – 640 plants /ac

Source: HARTI survey data, 2021

Table 4.8: Water Discharge and Fuel Consumption with Different Types of Irrigation in Banana

Irrigation method	Operation hours	Kerosene consumption		Water discharge	
		Fuel consumption (l/hr)	Fuel consumption (l)	Pump capacity (l/hr)	Total discharge (l)
Surface irrigation	NA	NA	NA	NA	NA
Drip irrigation	3	1.3	3.9	8000	24000

Source: HARTI survey data, 2021

4.1.5 Water and Energy Consumption in Pomegranate

In this study, data and information on pomegranate cultivation was collected from the farming community in Kalpitiya area in Puttalam district, where the farm fields are constituted with sandy soils that have higher infiltration, so that the crop water requirement is much higher than that of in other pomegranate cultivating areas of the country.

With the application of MI systems (drip irrigation systems) farmers have cut down the irrigation cost more than 50 percent in pomegranate cultivation in Puttalam district. As depicted in the Table 4.9, the annual irrigation cost with drip irrigation systems is recorded as 49,644 LKR whereas the cost for surface irrigation is 101,001.60 LKR.

With the drip irrigation systems, farmers are saving half of the water used in conventional type of surface irrigation (hose irrigation) in pomegranate Table 4.10). This water saving is very important for the farmers undertaking crop cultivation in sandy fields in drier part of Puttalam district.

Table 4.9: The Cost for Irrigation of Unit Area (Ac) under Different Types of Irrigation in Pomegranate

Irrigation method	Labour		Energy			Cost per irrigation cycle (LKR)	Total cost (LKR/yr)
	Man days	Labour Cost (LKR)	Operation hours	Fuel consumption (l/hr)	Fuel cost (LKR)		
Surface irrigation	1	1500	8	1.3	904.8	2404.8	101,001.6
Drip irrigation	0.25	375	4	1.3	452.4	827.4	49,644

Note: Plant density – 444 plants /ac
Source: HARTI survey data, 2021

Table 4.10: Water Discharge and Fuel Consumption with Different Types of Irrigation in Pomegranate

Irrigation method	Operation hours	Kerosene consumption		Water discharge	
		Fuel consumption (l/hr)	Fuel consumption (l)	Pump capacity (l/hr)	Total discharge (l)
Surface irrigation	8	1.3	10.4	8000	64000
Drip irrigation	4	1.3	5.2	8000	32000

Source: HARTI survey data, 2021

4.2 Comparative Analysis on Water and Energy Saving under Different Irrigation Methods

The previous section discussed the difference in energy and water consumption under different irrigation methods practiced by the respondent fruit crops farmers and its results emphasized that even though farmers have adopted micro irrigation technologies, they are not operating under optimal conditions to derive maximum benefit of the technology. Therefore, this section illustrates the potential water and energy saving under optimal operational circumstances.

The energy required for pumping depends on crop water requirement, total dynamic head, flow rate and system efficiency (Lal, 2004). Crops with a higher water requirement have a larger amount of water being pumped and increased energy consumption. Where groundwater is used for irrigation, converting to micro-irrigation systems can decrease energy consumption if the conversion also means that operating pressures (and therefore total dynamic head) and pumping volumes are reduced (Hodges *et al*., 1994; Srivastava *et al*., 2003).

On-farm water application rates reported by farmers were used for the analysis in previous section. However, for the purposes of simulating the potential maximum benefit of using micro irrigation methods, the quantity of water applied and energy used was determined separately for each crop. In this study, it was assumed that the use of sprinkler and drip irrigation methods would result in a reduction in water application of 15 percent and 30 percent respectively in perennial crops compared to surface irrigation (Jensen *et al.*, 2004).

These reductions in water application and energy and labour consumption have been extrapolated and used to explore the likely impacts of converting to micro irrigation systems. Following assumptions on crop water requirement were made in the analysis adopting from different research studies (Bharati, 2015; Yadav *et al.,* 2017):

- Crop water requirement of mango is 80l/plant
- Crop water requirement of guava is 74l/plant
- Crop water requirement of papaya is 18l/plant
- Crop water requirement of banana is 21l/plant
- Crop water requirement of pomegranate is 15l/plant

Table 4.11 presents the potential water, energy and labour savings by operating micro irrigation technologies such as sprinkler and drip under optimal management conditions. It is evident that water use efficiency of micro irrigation technologies is substantially high compared to surface irrigation methods. It is important to highlight that even among the farmers those who are practicing irrigation (either conventional type of irrigation systems or MI systems), the awareness of daily crop water requirement depending on the stage of the crop, capacity of pumping devises, number of hours of operation (pumping devises) are lacking. Therefore, energy and water wastage are high at the field level even with micro irrigation systems.

Water savings for banana is highest among the crops examined in the study, followed by papaya and guava with drip and sprinkler irrigation comparing to surface irrigation. Among the five crops considered for analysis, water saving in terms of HP hours is much higher for banana crop compared to papaya. As mentioned earlier drip irrigation method of water application save a great deal of water by eliminating evaporation and distribution losses and targeting the water to root zone.

In order to assess the impact of micro irrigation on energy use, energy consumption is estimated based on operating hours of pump sets for both drip and sprinkler and surface irrigated crops. The estimated consumption of energy presented in Table 4.11 shows that drip and sprinkler used a lot less energy compared to surface irrigation for all the crops.

Since most of the farmlands do not have access to grid electricity farmers, must rely more on kerosene or diesel pumps. Even though electricity tariffs in Sri Lanka is at concession rates it is more sustainable and economical to shift from fuel/electrically operated pump sets to solar powered pump sets. Irrigation systems fitted with solar pump sets generate less CO_2 emission as compared to electrically operated pumpsets. However, none of the sample farmers (both DMI-adopters and non-adopters) in this study used solar pumpsets. This indicates the need for concerted efforts by the government, academia, civil society and financial institutions to disseminate the advantages of solar pumpsets over electrically operated pumpsets. Further, adopting solar pumpsets must be made financially attractive for farmers in view of the much higher upfront investment compared to electrically operated pumpsets. However, it is also possible that solar pumpsets may not meet the irrigation frequency needed for some crops since it operates at capacity only for limited number of hours (Otoo *et al.,* 2018).

Table 4.11: Potential Water and Energy Saving with Micro Irrigation in Selected Fruit Crop

Crop		Units	Surface	Drip	Sprinkler	Net saving drip	Net saving sprinkler
Guava	Water consumption/month	Litres	592000	473600	394666.7	**197333.3**	**118400**
	Fuel consumption/operation	Litres	4.93	3.95	3.29	**1.64**	**0.99**
	Fuel consumption/annum	Litres	90132	72105.6	60088	**30044**	**18026.4**
	Labour consumption/annum	LKR	630000	78750	78750	**551250**	**551250**
	Total operation cost	LKR	720132	150855.6	138838	**581294**	**569276.4**
Mango	Water consumption/month	Litres	160000	128000	106666.7	**53333.33**	**32000**
	Fuel consumption/operation	Litres	1.33	1.07	0.89	**0.44**	**0.27**
	Fuel consumption/annum	Litres	24360	19488	16240	**8120**	**4872**
	Labour consumption/annum	LKR	630000	78750	78750	**551250**	**551250**
	Total operation cost	LKR	654360	98238	94990	**559370**	**556122**
Banana	Water consumption/month	Litres	672000	537600	448000	**224000**	**134400**
	Fuel consumption/operation	Litres	5.60	4.48	3.73	**1.87**	**1.12**
	Fuel consumption/annum	Litres	102312	81849.6	68208	**34104**	**20462.4**
	Labour consumption/annum	LKR	630000	78750	78750	**551250**	**551250**
	Total operation cost	LKR	732312	160599.6	146958	**585354**	**571712.4**
Papaya	Water consumption/month	Litres	576000	460800	384000	**192000**	**115200**
	Fuel consumption/operation	Litres	4.80	3.84	3.20	**1.60**	**0.96**
	Fuel consumption/ annum	Litres	87696	70156.8	58464	**29232**	**17539.2**
	Labour consumption/annum	LKR	630000	78750	78750	**551250**	**551250**
	Total operation cost	LKR	717696	148906.8	137214	**580482**	**568789.2**
Pomegranate	Water consumption/month	Litres	333000	266400	222000	**111000**	**66600**
	Fuel consumption/operation	Litres	2.78	2.22	1.85	**0.93**	**0.56**
	Fuel consumption/ annum	Litres	50699.25	40559.40	33799.50	**16899.75**	**10139.85**
	Labour consumption/annum	LKR	630000	78750	78750	**551250**	**551250**
	Total operation cost	LKR	680699.3	119309.4	112549.5	**568149.8**	**561389.9**

Source: HARTI Survey data, 2021

4.3 Economic Viability of Adopting Micro Irrigation Fruit Crop Production

Although micro irrigation helps save irrigation water and energy while reducing the contribution to the climate change, micro irrigation technologies come with higher initial investment. Therefore, economic viability of adopting micro irrigation technologies within a systematic framework is essential for drawing policy inferences. The following section presents the results of financial analysis related to micro irrigation with reference to selected high value fruit crops.

As per the results given in the Table 4.12, application of MI systems in mango cultivation will be a profitable in long-run. The investment in application of MI system can be recovered in 8 years (4 years from initiation of crop harvest). For guava crop, the investment on application of MI system (drip irrigation) can be recovered within a shorter period of time (in the fourth year). Being a crop that produce yield from the second year and bearing fruits year-round, which always has a good price in the market, guava has been a profitable crop to be cultivated under MI systems. Papaya the investment made on installation and application of MI systems can be recovered within the first year of the crop. The payback period for the irrigation investment for banana is between second and third year of the crop. Finally, how many years are needed to recover the capital costs of installing MI is an important decision point for farmers as well as financing institutes that finance MI investments. The year-wise computation of net present worth for all five studied crops suggests that farmers could recover the entire capital cost of the drip-set from their net profit in the first two years itself for the crops like guava and papaya which can be harvested within first two years.

Table 4.12: The Results of the Financial Analysis for Application of MI System for Selected Fruit Crops

	NPV	IRR	DCBR	DPBP
Guava	2,829,042.74	65%	8.38	3.25
Mango	832,242.73	23%	3.05	7.96
Banana	1,162,864.96	53%	3.64	2.66
Papaya	1,808,671.72	188%	5.1	0.71
Pomegranate	7,866,971.46	62%	18.83	3.79

Source: HARTI survey data, 2021

CHAPTER FIVE

Findings and Recommendations

5.1 Major Findings

1. The results in this research paper highlight the links between irrigation water use and energy consumption, and the influence of water source and irrigation method on these relationships. Of particular note is the confirmation that micro irrigation methods reduce energy consumption in regions where groundwater is used.

2. In spite of the scientific evidence on water and energy saving and the incremental change in crop yield of irrigation of perennial crops, the rate of irrigation application is still minimal. Even among farmers who practice irrigation (either conventional type of irrigation systems or MI systems), the awareness of daily crop water requirement depending on the stage of the crop, capacity of pumping devises, number of hours of operation (pumping devises) is lacking.

3. The majority of farmers use electric water motors with the efficiency ranging between 1 – 1.5 kW/h. The water pumps running with kerosene is with the power of 1.5 – 3.3 HP. Though the majority of farmers use water pumping devises which have been used for less than 10 years since their first use, regular service and maintenance of such devises are very poor causing long-run efficiency issues and minimum durability.

4. For many of the crops studied, the irrigation cost under conventional type irrigation is higher than that of MI systems. Further, lack of awareness of farmers on crop water requirement and other related technical information of crop irrigation has caused excess water application resulting additional cost for energy and labour. It has also caused inadequate water supply for some crops and subsequent poor performances by such crops.

5. The financial analyses show that the investment on MI systems for all the crops studied are worth to made as the investment can be recovered within a shorter period of time compared to the lifespan of respective crop varieties.

6. There is a significant lack of practical information regarding energy efficiency in irrigation and opportunities for renewable energy which is delaying innovation and is a drag on both water efficiency programmes and farm productivity.
7. Farmers are generally aware of the increased energy consumption associated with water-efficient irrigation. They are largely unaware of how this increased energy consumption can be minimized and controlled.
8. The main conclusion is that adoption of MI is unlikely to be driven by water savings. Overall changes in energy costs and specifically savings in fertilizer and labour costs may be more important incentives for adoption.

5.2 Recommendations

1. The results of this study demonstrate the factors affecting water application and energy consumption at the irrigated farm scale in high value fruit crops and the complex interrelationships between these factors. The implications of these results are important at the policy, irrigation water provider and farming levels. Any policy designed to optimize water use must also consider the energy impacts of the policy.
2. The study highlighted that there should be awareness programme for farmers to teach them the advantages of irrigation particularly, the MI systems and as a means of climate adaptation.
3. It is recommended to promote MI systems as a GT to increase crop yield, water and energy saving and as a technology for increased climate resilience in the face of changing climate.
4. Farmers generally lack of incentives to adopt MI because of limited lack of water shortage, electricity costs are not high enough to incentivize and no water chargers are implementing in the field. Therefore, blanket subsidies to promote this technology are not recommended. Moreover, considering the high initial investment associated with MI, “smart” subsidies for target farmers can be designed, it should be clear from the beginning that they are a temporary solution and should lead to market-based financial mechanisms.

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