IMPACT OF IRRIGATION ON CROP INCOME AND COLLECTIVE WATER MANAGEMENT ACTIVITIES UNDER PYAWT YWAR IRRIGATION PROJECT, MYINMU TOWNSHIP

MYO HTWE

DECEMBER 2019

IMPACT OF IRRIGATION ON CROP INCOME AND COLLECTIVE WATER MANAGEMENT ACTIVITIES UNDER PYAWT YWAR IRRIGATION PROJECT, MYINMU TOWNSHIP

A thesis presented by

Myo Htwe

to

The Post-graduate Committee of the Yezin Agricultural University as a requirement for the degree of Doctor of Philosophy in Agricultural Economics

Yezin Agricultural University

DECEMBER 2019

The thesis attached hereto, entitled "**Impact of Irrigation on Crop Income and Collective Water Management Activities under Pyawt Ywar Irrigation Project, Myinmu Township**" was prepared under the direction of the chairperson of the candidate supervisory committee and has been approved by all members of that committee and board of examiners as a requirement for the degree of **Doctor of Philosophy**.

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DECLARATION OF ORIGINALITY

This thesis presents the original works of the author, except where otherwise stated. It has not been submitted previously for a degree at any other university.

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DEDICATED TO MY BELOVED PARENTS,

U TIN TUN AND DAW KHIN THAN

ACKNOWLEDGEMENTS

I would like to express my deep and sincere gratitude to Dr. Nang Hseng Hom, Rector, Dr. Soe Soe Thein, Pro-Rector (Academic), Dr. Kyaw Kyaw Win, Pro-Rector (Admin.), Yezin Agricultural University (YAU) for their permission and administrative support for my research work, and the valuable suggestions to improve this thesis.

I wish to express my sincere gratitude to Dr. Cho Cho San, Professor and Head, Department of Agricultural Economics, Yezin Agricultural University, for her invaluable advice and kind assistance which helped me to complete my research work.

My sincere thanks also extend to Dr. Khin Oo, Professor and Principal (Retired), Rice Crop Specialization, Hmawbe Campus, Yezin Agricultural University, for her kind help, cooperation and the valuable suggestions she made for this manuscript.

I am deeply indebted gratitude to my supervisor Dr. Hnin Yu Lwin, Associate Professor, Department of Agricultural Economics, Yezin Agricultural University, for her willing and invaluable guidance, encouragement and helpful advice throughout this study.

Sincere appreciation and gratitude go to the Supervisory Committee members, Dr. Kyaw Kyaw Win, Pro-Rector (Admin.) and Dr. Theingi Myint, Professor, Department of Agricultural Economics, YAU for their guidance, encouragement, moral support, and kindness during the study, and their critical and patient reading, and incisive comments on this manuscript.

It is my pleasure to acknowledge International Water Management Institute (IWMI) for research grant as a partial financial support for doing research works.

My special thanks to Ms. Alisonm Boughton and Mr. Christopher Chaffe for their editing and correction of the English of this thesis.

I would also like to express my gratitude to all teaching staff from the Department of Agricultural Economics for their advice on statistical analysis, suggestions, encouragement and generous help throughout my this study.

It is a great pleasure to express my gratefulness to Dr. Ye Tint Tun, Director General, Department of Agriculture and U Myint Swe, Director, Coffee-Seasonal Crop Division, Department of Agriculture, Ministry of Agriculture, Livestock and Irrigation, for their permission and administrative support for my research work.

I would like to thank the junior master students from the Department of Agricultural Economics for their help in seminars and general support.

I am grateful to all of the staff from Department of Agriculture, Myinmu Township and members of the International Water Management Institute (IWMI) for their help in obtaining the necessary primary and secondary data for this thesis.

My special thanks are also extended to the sample farmers under in Myinmu Township for answering the questionnaires.

Finally it is a great pleasure to express my gratefulness to my mother, brothers and sister who have provided me with support, whatever and whenever was needed.

ABSTRACT

Irrigation water management is imperative in water scarce areas for livelihoods improvement. This study attempted to examine participation of farmers in collective water management under the Pyawt Ywar irrigation project and to investigate the contribution of canal water to crop income toward rural livelihood improvement in the study area. Using the proportionate stratified random sampling method, total sample farmers of 285 including 208 canal irrigation beneficiaries (95 head-end, 69 middle and 44 tail-end beneficiaries) and 77 non-beneficiaries were chosen from 3 irrigation blocks under Pwat Ywar Irrigation Project area. In data analysis, descriptive statistics, Full Information Maximum Likelihood Estimation of Endogenous Switching Regression (FIML ESR) model and Tobit model were employed. Beneficiaries possessed more acreage of lowland compared to non-beneficiaries. A large majority (80%) of family members in both farm household groups were farm labour. Annual non-farm income was significantly different between beneficiaries and non-beneficiaries. About half (46%) of beneficiaries have grown crops in three seasons while 41.6% of non-beneficiaries could only grow crops in two seasons (monsoon and winter). Onion was largely produced by non-beneficiaries as a main cash crop in winter. Monsoon crop income was the major income source for beneficiaries. The involvement of beneficiaries in social organizations was higher than that of non-beneficiary households. According to FIML ESR results, crop income was influenced by market distance, block position, livestock unit and non-farm income, and access to canal irrigation water contributed to enhance crop income. In water management activities, despite beneficiaries actively participated in canal repair, they were involved less in association by management activities. Based on Tobit regression results, participation in collective water management was influenced by irrigation experience, water source, irrigated summer crop income, social organization involvement, attending water-related meetings, conflict involvement, and farmers' perception on water management such as water distribution fairness, water availability in time and coordination of the water management committee. Farm and non-farm incomes were vital for livelihood improvement of the sample farm households. Access to canal irrigation has resulted in a positive impact on crop income of farmers with the existing use of other water sources. Farmers who had a higher economic incentive through greater investment in summer irrigation were more willing to participate in collective water management activities than those that earned less. Beneficiary households that were more involved in social organizations were more amenable to participate in collective water management activities. The system should be improved by upgrading and expanding the irrigation facilities. The water management committee should emphasize effective coordination and decision making activities with a transparent management system. Irrigation scheme can contribute positive impact on crop income. To fulfil targeted irrigation area of the scheme, appropriate rehabilitation program for irrigation infrastructure is needed. Influencing factors on collective water management are crucial for sustainability of the scheme. Therefore training and motivation programs are needed for implementing irrigation management transfer and participatory irrigation management to reduce public expenditure burden and improve efficiency, equity and sustainability of the scheme. In summary, by improving irrigation schemes and their management Myanmar will be able to create a sustainable agriculture sector, increase rural development and provide a way out of poverty for her farmers.

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LIST OF ABBREVIATIONS

ADB	= Asian Development Bank
CR	= Canal Representative
DOA	= Department of Agriculture
DOP	= Department of Population
GAD	= General Administrative Department
ha	= Hectare
ICRISAT	= International Crops Research Institute for the Semi-Arid Tropics
IWMI	= International Water Management Institute
IWUMD	= Irrigation and Water Utilizations Management Department
JICA	= Japan International Cooperation Agency
kg	= Kilogram
km	= Kilometer
LIFT	= Livelihoods and Food Security Trust Fund
mm	= Millimeter
MMK	= Myanmar Kyat
MOALI	= Ministry of Agriculture, Livestock and Irrigation
MT	= Metric Ton
NEPS	= National Engineering and Planning Services
PCA	= Principal Component Analysis
PYPIP	= Pyawt Ywar Pump Irrigation Project
SD	= Standard Deviation
SLRD	= Settlement and Land Records Department
SPSS	= Statistical Packages for Social Science
TLU	= Tropical Livestock Unit
UNOPS	= United Nations Office for Project Services
USD	= United States Dollar
WFP	= World Food Programme
WHH	= Welthungerhilfe
WMC	= Water Management Committee

LIST OF CONVERSION FACTORS

One hectare	= 2.47 acres
One basket of paddy	= 20.9 kg
One basket of wheat	= 32.7 kg
One basket of pigeon pea	= 32.7 kg
One basket of chickpea	= 31.3 kg
One basket of green gram	= 32.7 kg
One basket of black gram	= 32.7 kg
One basket of red phaseolus	= 31.2 kg
One basket of groundnut	= 11.4 kg
One basket of sesame	= 24.5 kg
One basket of sunflower	= 14.5 kg
One basket of sorghum	= 28.1 kg

CHAPTER I

INTRODUCTION

Irrigation can play a central and dynamic role in the improvement of rural livelihoods (Hasnip, Mandal, Morrison, Pradhan & Smith, 2001). There is therefore a need to develop Myanmar agriculture sector through improvement of irrigation because the majority of the population lives in rural areas and relies on agriculture (Department of Population [DOP], 2015). However, the larger proportion of Myanmar cultivated area is rain-fed and vulnerable to unpredictable rainfall patterns as only about 16.5% of the net sown area in Myanmar in 2017 was irrigated (Ministry of Agriculture, Livestock and Irrigation [MOALI], 2018). According to the Myanmar Census of Agriculture, the average land holding size is 2.6 hectares and this is declining in Myanmar (Settlement and Land Records Department [SLRD]. Hence, expansion of cultivated area is a finite option, especially in view of marginal and vulnerable characteristics of large parts of Myanmar. Moreover, the existing irrigation schemes in Myanmar are very low in efficiency (International Water Management Institute [IWMI], 2013). The larger proportion of irrigated land has provided a greater improvement in livelihoods than those depending on rainfall. As long as agriculture is largely rain-fed, irrigation has become a very crucial resource in agricultural production and livelihood improvement. There is, therefore, a need for improving irrigated agriculture to improve rural livelihoods through improving irrigation efficiency in Myanmar.

Water management is a key mechanism for the development of irrigated agriculture, particularly in the area troubled by drought and erratic rainfall (Ashraf, Kahlown & Ashfaq, 2007). Water resource management includes the activities of planning, developing, distributing and managing the optimum use of water resources. Basically, water planning and management activities are undertaken for the purpose of solving problems such as inadequate water supplies or unfair water distribution. According to Dungumaro and Madulu (2003), it is important to involve local communities in assessing and solving water problems since they are the ones who interact with their environments and conduct activities that impact the environment. Community participation in irrigation water management is important for not only efficient and effective utilization of water but also equity of upstream and downstream users.

However, farmers still have insufficient experience in collective maintenance and management of water in Myanmar (Than, 2018). Often the inefficient and inequitable system management results in conflicts between users. One way to overcome these problems is to reform the water management activities by forming well-functioning water user groups that can lead to effective irrigation system management. This is because water user groups may be able to manage water effectively (Kajisa & Dong, 2015). Users' involvement can build trust among users (Dungumaro & Madulu, 2003) and improve over all water management, including conflict resolution (Jansky & Juha, 2006). Therefore, collective active action in water management has been documented as the key instrumental task force in various developing countries Irrigated farming, therefore, is an important factor in improving the lives of rural households and in determining opportunities for generating income (Meinzen-Dick, DiGregorio & McCarthy, 2004). To this date no previous research has investigated collective water management in Myanmar.

In irrigation water management, local community participation is one way to help the system to be effective and efficient (Meinzen-Dick et al., 2004). Irrigation efficiency in Myanmar, however, is somewhat low due to the plot-to-plot irrigation practice and farmer's participation in water management in most of the irrigated areas is relatively rare in recent history (Than, 2018). In connection with this community participation in irrigation, water management is important for not only efficient and effective utilization of water but also equity of upstream and downstream users. Since farmers are the ones who interact with their environments and conduct activities, it is important to involve local communities in assessing and solving water problems (Dungumaro & Madulu, 2003). Therefore, participation in water management by the community is essential to the improvement of livelihood and income in the rural communities of Myanmar.

1.1 Background of the Study

The geography of Myanmar must have played a major determining role in the early development of irrigation techniques. Construction of irrigation works for crop cultivation started historically in the days of the Myanmar Kings. Meikhtila Lake, Kinda and Ngapyaung diversion weirs in the Kyaukse area and the old Mu Canal and Maha Nanda Lake in the Shwebo area were significant irrigation schemes in Myanmar (Than, 2018).

During the colonial period, commissioning of irrigation facilities started for agriculture and flood protection, particularly in Lower Myanmar. Since Independence in 1948, the government had been promoting irrigation schemes in the agricultural sector by raising large sums of capital required to meet development needs in the agricultural sector (Than, 2018). The government made continuous efforts in the construction of dams and reservoirs. As a result, local irrigation facilities were constructed throughout the country.

In Myanmar, agricultural irrigation has been identified as a major input in the development of the agricultural sector for a long time. In 2017-2018, the net sown area was 13,394,000 ha and the net irrigated area was 2,212,000 ha but the multiple cropping irrigated areas was only 563,000 ha which accounts for 25.5% of net irrigated area as shown in Table 1.1 (MOALI, 2018).

Until now different types of irrigation (canals, tanks, wells, and pumps) have been implemented as shown in Table 1.2. Canals, tanks, wells and pumps irrigation occupied 29.2%, 11.2%, 7.2% and 39.4% respectively of total irrigated area in 2017-2018 (MOALI, 2018). Among them, pump irrigation facilities occupied the highest proportion of total irrigated area and are being operated using diesel and electricity.

1.1.1 Irrigation infrastructure construction and condition in Myanmar

In Myanmar, irrigation schemes usually have reasonably well-structured canal layouts: main canals, distributary canals and minor canals down to watercourse outlets. There are, however, a large number of direct outlets from the main canals which tend to receive a disproportionate amount of water resulting in relative shortages further down the system.

Table 1.1 Net sown area and irrigated area in Myanmar, 1995-2018

Particulars	Unit	1995/ 1996	2010/ 2011	2012/ 2013	2013 /2014	2014/ 2015	2015/ 2016	2016/ 2017	2017/ 2018
Net sown area	000’ha	9,168	13,748	13,299	13,261	13,361	13,362	13,375	13,394
Net irrigated area	000’ha	1,757	2,292	2,115	2,133	2,170	2,137	2,150	2,212
% of irrigated area	%	19.2	16.7	15.9	16.1	16.2	16.0	16.1	16.5
Multiple cropping irrigated area	000’ha	385	642	483	577	511	555	563	563
% of multiple cropping area under irrigation	%	21.9	28.0	22.8	27.0	23.6	26.0	26.2	25.5

Source: MOALI, 2018

Table 1.2 Irrigated area based on types of irrigation in Myanmar, 2005-2018

(Unit: thousand ha)

Year	Type of irrigation					
	Canals	Tanks	Wells	Pumps	Others	Total
2005/2006	694	314	98	799	230	2,136
2006/2007	693	330	120	844	256	2,244
2007/2008	634	325	145	851	269	2,224
2008/2009	664	321	138	867	284	2,275
2009/2010	675	306	151	902	294	2,310
2010/2011	652	276	154	899	310	2,292
2011/2012	648	255	141	773	300	2,118
2012/2013	650	237	148	789	291	2,115
2013/2014	650	241	151	798	292	2,133
2014/2015	618	259	155	840	298	2,170
2015/2016	620	224	150	844	298	2,137
2016/2017	619	229	153	855	293	2,150
2017/2018	646	248	158	872	288	2,212
% of total irrigated area	29.2	11.2	7.2	39.4	13.0	100

Source: MOALI, 2018

Moreover, the design of irrigation infrastructure in Myanmar is generally suited to extensive irrigation of uniform cropping, usually paddy cultivation. In addition, many main canals do not receive their designed discharge (even during the monsoon) and they are never operated at full discharge in the summer season. Most distributary canals of irrigation schemes are quite small (typically range from 200 to 800 ha), but those of the larger systems may cover substantial areas resulting in relative difficulties in managing water supplying to those areas. Furthermore, a significant issue is that minor canals and direct outlets from the main canals are often ungated and this can substantially distort water distribution patterns (Stargardt, 1968).

At field level, watercourses/tertiary units, whether from a minor canal or directly from a distributary or main canal, are all farmer-managed. They supply water to farm ditches through a number of ungated outlets, and watercourse command areas are of the order of range from 10 to 30 ha. This irrigation is managed entirely by the farmers through informal cooperation arrangements led by an irrigation representative and field-to-field irrigation is the normal practice within tertiary units but this is only adequate for monsoon season rice cultivation (ADB, 2016).

Concerning the physical condition of irrigation infrastructure in Myanmar most canals are earthen unlined channels with masonry structures, although the main weirs may be reinforced concrete. However, standards even of original construction were not good, and thus most structures and canals are now in a very poor condition and distributary canals are generally in much worse condition than the main canals.

1.1.2 Irrigation management in Myanmar

Management of irrigation systems is based on a traditional, top-down, supply-led approach aimed at maximizing rice production. There is no single law on water resources. The development and management of irrigation is still governed by the 1905 Canal Act which does not recognize the need for modern concepts such as effective participatory irrigation management, a user-oriented service delivery approach, and sustainable arrangements for cost recovery (Than, 2018).

Although irrigation facilities have given high priority to development, irrigation efficiency was rather low due to plot-to-plot irrigation practices and most of the distributor canals were unlined. For all operations of distributaries and drainage outlets farmers generally consult and negotiate bilateral agreement with the farmers who keep the adjacent fields in the plot-to-plot irrigation (Than, 2018). Water from a branch canal flows into a field at the farthest upstream and then plot-to-plot to the lower reaches. The traditional water management is inefficient and farmers who actually use water need to be more sensitive and more serious in water management.

1.1.3 Description of Myanmar's Dry Zone

The Dry Zone lies within Myanmar's central plains, which are bounded by mountains to the east and west. It is sited between latitudes 19º to 23º North and longitudes 94º to 96º 30' East. It has a maximum length of 560 kilometers, width of 270 kilometers and a total area over 75,700 km^2. It is located within Sagaing Region (Sagaing, Shwebo and Monywa districts); Mandalay Region (Kyaukse, Myingyan, Meiktila, Yamethin and Nyaung U districts) and Magway Region (Pakokku, Magway, Minbu and Thayet districts). The population of the Dry Zone is estimated to be around 10 million people, out of a total national population of 51.4 million (LIFT 2015; Department of Population 2014).

The Dry Zone is mostly flat, with the Ayeyarwady River (joined by the Chindwin River) flowing through it from north to south. The Bago Hills range runs parallel to the Ayeyarwady River in the southern part of the Dry Zone, gaining altitude towards the north and ending in southeast Mandalay. Fertile alluvial soil is found along the banks of the major rivers, but the Bago Hills are sandstone and have less fertile sandy soil. As its name suggests, the Dry Zone is the driest region of the country, with annual rainfall between 500 and 1,000 mm (IWMI, 2015).

1.1.4 Farming community in the Dry Zone

Agriculture, primarily rain-fed, provides livelihoods for a large proportion of the rural population, including many of the country's poorest people. According to JICA (2010), 58% of those living in the region are farmers and 25% are farm laborers. Farming and casual labor in the agriculture sector are the two key livelihood activities in the Dry Zone (World Bank 2012).

The distribution of cultivable land is highly skewed. Although estimates of landlessness differ widely, most available evidence suggests that approximately half of all rural households have no rights to use any cultivable land (Haggblade et al. 2013). They rely on casual labor to earn an income, primarily from agriculture or other activities, such as raising livestock. Pronounced seasonality of agricultural employment, a paucity of alternative jobs and low wages constrain annual earnings. Faced with lower incomes and higher poverty rates than land-owning families, landless households are more likely to go hungry and borrow money to purchase food. However, because land serves as collateral in informal lending, landless households typically have less access to credit than those that own land.

Food insecurity and malnutrition are very common in the Dry Zone. A survey conducted by LIFT (2013) found that 18% of households had inadequate food for consumption, and more than a quarter of children under the age of five were underweight. Households with poor access to land and markets, and those relying on casual labor, are the most likely to have insufficient food. Farming households are more likely to be food-secure, but food security is precarious even for these families. In 2010, the food security of 41% of farming households was adversely affected by dry spells (WFP 2011).

1.1.5 Agro-ecosystems of the Dry Zone

The Dry Zone's agricultural systems are complex; farmers cultivate paddy and non-rice crops (pulses, oilseeds, cotton, tobacco, vegetables and others), as well as raising large and small livestock. Traditionally, land in Myanmar is described in terms of its suitability for different types of cultivation, with the main distinction between *le* (lowland) and *ya* (upland) lands. The Dry Zone is vital to Myanmar's agriculture sector, producing most of the country's sesame, groundnuts and pulses (a major export earner), and 22% of its rice. Almost half of all the cattle and more than two-thirds of all the sheep and goats in Myanmar are raised in the Dry Zone (IWMI, 2015).

For the majority of farmers growing rainfed crops, decision making around planting is flexible, and the cropping calendar varies from year to year. On *le* and *ya* lands, farmers prepare the land between February and May. They then plant their monsoon crop between mid-May and mid-June, when soil moisture is considered to be sufficient. Pulses, such as green gram or chickpea, and oilseeds, such as sunflower, are cultivated until August or September. A second crop, such as groundnuts, chickpea or cotton, may follow, using residual soil moisture (LIFT, 2012).

Irrigated areas with year-round access to water lie mainly within formal irrigation schemes. These include major schemes, such as those in Minbu, Kyaukse and Ye U, and smaller schemes – pumped irrigation systems, in particular – along the Ayeyawady and Chindwin Rivers. Irrigation is usually developed on lowlands that have higher agricultural potential, although some schemes report problems with sandy soils. Small-scale groundwater irrigation is found in some areas, generally supporting small-scale horticulture, which provides a high financial return and is usually implemented by wealthier households.

The farming calendar on irrigated landholdings includes a summer crop of paddy, which is fully irrigated from mid-February to May. Some farmers also plant a fast-growing crop, such as green gram or green pea, in early March or April for harvesting in May or June. This is followed by a primarily rainfed monsoon crop, such as paddy, which reaches maturity in October or November. Irrigation is used to secure the monsoon crop, protecting the plants from dry spells and low rainfall (LIFT, 2012).

1.1.6 Surface water resources of the Dry Zone

The Ayeyawady River and its tributaries dominate surface water resources in the Dry Zone. The Chindwin River is the major tributary of the Ayeyawady River; other significant tributaries are the Mu, Shweli and Myitnge. These rivers provide water for irrigation and, in some places, recession agriculture, where farmers capitalize on natural flows and sediments to irrigate and fertilize crops on floodplains. However, some of the river courses are deeply incised into the landscape, so water for irrigation can only be obtained by pumping (IWMI, 2015).

River flows are highly seasonal. The larger rivers flow all year-round, but many of the smaller streams are ephemeral. In some cases, when water levels fall below the level of the riverbed, flows continue in the sandy aquifers of the river channel, and can be accessed through shallow wells and sand dams. Cultivation in dry streambeds during the dry season is common, but carries a high risk of losing crops to early floods (IWMI, 2015).

Water levels are measured at key locations in the Dry Zone during the wet season to provide flood-warning alerts, but few measurements are made during the dry season. Seasonal variation in water flow is very high: on average, around 85% of the flow in both the Ayeyawady and Chindwin Rivers occurs during the wet season between May and October. The flow of the Ayeyawady River in February, the month with the lowest flow, is less than 2% of the total annual flow (IWMI, 2015).

In Dry Zone, until now different types of irrigation (such as canals, pumps etc.) have been implemented as shown in (Table 1.3). Pumps and canals irrigation occupied 29.4% and 35.8% respectively of 2018 Dry Zone’s total irrigated area in 2018 (IWUMD, 2018; GAD, 2018). Although the larger number of pumps irrigation project was found in Sagaing and Mandalay Regions, Sagaing Region of Dry Zone highly relied on pump irrigation for crop production.

1.1.7 Description of the Sagaing Region

Sagaing Region is in the central part of Myanmar. Its major parts fall in the dry zone. It is situated in the north-western part of Myanmar between latitude 21° 30' north and longitude 94° 97' east. It shares border with India in the north, Kachin State, Shan State and Mandalay Region in the east, Mandalay and Magway Regions in the south and Chin State and India in the west and has 94,625 km. This Region is formed with 198 wards and village-tracts, 38 townships and eight districts-Sagaing, Shwebo, Monywa, Katha, Kale, Tamu, Mawlaik and Hkamti. Sagaing is the capital of the Region. This Region has a total cultivated area of over 1214 thousand ha. Paddy is cultivated on 557 thousand ha and other crops on 607 thousand ha. Others are alluvial-land cultivation, garden farms and hillside cultivation. Irrigation water is available from canals, lakes, tube-wells and pump stations. Major crops of the Region are rice, wheat, corn, maize, edible oil crops such as sesame, groundnut and sunflower, cotton, sugarcane, beans and pulses. Over 405 thousand ha are being put under paddy in the Region annually. Eighty percent of the nation's wheat comes from Sagaing Region. Tobacco, tomato, toddy palm, and vegetables are also grown in this Region. Small amount of land is put under green tea at mountain regions in the north.

Table 1.3 Irrigated area based on types of irrigation in Dry Zone of Myanmar, 2018

Districts	Type of irrigation					Total
	Pumps [a]		Canals [b]		Others [b]	
	No.	Area (000'ha)	No.	Area (000'ha)	Area (000'ha)	Area (000'ha)
Mandalay Region						
Mandalay	8	0.8				0.8
Kyaukse	11	3.0	5	80.8	14.6	98.4
Nyaung U	5	6.7			0.1	6.8
Meiktila	1	3.2			6.6	9.8
Yemathin					0.4	0.4
Myingyan	12	19.9	5	1.4	2.0	23.3
Magway Region						
Pakokku	13	8.0			2.8	10.8
Magway	13	8.3			15.5	23.8
Minbu	1	0.6	1	13.2	5.9	19.7
Thayet	5	4.0			5.9	9.9
Sagaing Region						
Sagaing	12	9.6			7.6	17.2
Shwebo	14	1.7			11.0	12.7
Monywa	10	11.3			20.1	31.4
Yinmarpin	1	1.2				1.2
Total	106	78.3	11	95.4	92.5	226.2
% of irrigated area		29.4		35.8	34.8	100

Source: [a] IWUMD, 2018 & [b] GAD, 2018

The Ayeyawady, Chindwin, Mu Rivers dominate surface water resources in the Sagaing Region. The Ayeyawady and Chindwin Rivers as well as Mu River are the major water sources for pump irrigation projects in this Region (Table 1.4). In the Sagaing Region, thirty eight electrically driven pump irrigation stations and four diesel fuel pump stations distribute irrigation water to the cultivated area of 24.4 thousand ha (IWUMD, 2018). Among the District of the Sagaing Region, only Sagaing District has significantly utilized irrigation water with 12 pump irrigation stations from the three rivers (Ayeyawady, Chindwin and Mu).

1.1.8 Description of Myinmu Township

Myinmu Township is located 21˚ 56'N 95˚ 35'E and situated between 60.9 m and 76.2 m above sea level. It is the principal town and the town lies on the northern bank of the Ayeyawady River. Mu River flows about 7.5 kilometers (4.7 miles) away from the town. The total area of Myinmu Township is 14.5 km^2. The neighbor areas of Township are Sagaing, Chaung Oo, Monywa, Ngazun and Ayadaw Townships. Sagaing Township is located to the east, Chaung Oo and Monywa Townships are also situated to the west, Ngazun Township is located to the south and Ayadaw Township is situated to the north from Myinmu Township. The total population was about 115,621 in which 15,371 in urban and 100,250 in rural population in 2017 (General Administrative Department, [GAD], 2017).

1.1.9 Climatic conditions of Myinmu Township

In summer, the maximum temperature was 41.4 ºC and the minimum temperature was 0.91 ºC in cool season of 2018 in Myinmu Township (GAD (Myinmu), 2018). In this Township, number of rainy day and annual rainfall decreased in 2018. A maximum precipitation of 169.93 mm was found in May and minimum precipitation was 2.03 mm in November in 2018. There was no precipitation in February and March (DOA, 2018). Annual rainfall and temperature of Myinmu Township from 2015 to 2018 is indicated in Table (1.5).

Table 1.4 Pump irrigation schemes in the Sagaing Region, 2018

Districts	Irrigated area (000'ha)	Electrically driven pump stations		Diesel fuel pump stations	
		No.	Water source	No.	Water source
Sagaing	**9.6**	**12**			
	2.0	2	Chindwin River		
	1.5	1	Mu River		
	6.1	9	Ayeyawady River		
Monywa	**11.3**	**10**			
	3.3	5	Chindwin River		
	4.1	1	Mu River		
	2.8	1	Ayeyawady River		
	1.1	3	Pauk-inn Stream		
Shwebo	**1.7**	**12**		**2**	
	1.4	11	Kintat Dam left canal	2	Alaungpaya canal
	0.3	1	Thapanseik Dam		
Yinmarpin	**1.2**	**1**			
	1.2	1	Chindwin River		
Katha	**0.4**	**3**			
	0.4	3	Mu River		
Kalay	**0.2**			**2**	
	0.14			1	Pyinthar River
	0.06			1	Nayyinsayar River

Source: IWUMD, 2018

1.1.10 Land utilization of Myinmu Township

The township total area of Myinmu Township is 77,561.31 ha and the largest share of the township area is occupied by agricultural land (Table 1.6). Upland occupied 81% of the cultivable land (66797.65 ha) and followed by lowland (17%), alluvial land (2%) and orchard land (0.02%). There was fallowed land 6,774.18 ha, which was 9% of township area (GAD (Myinmu), 2017).

1.1.11 Sown area and crop production in Myinmu Township

In Myinmu Township, the production and cultivation of the major growing crops were rice, groundnut, sesame, sunflower, black gram, green gram, pigeon pea, cotton and corn in 2016-2017. In monsoon season, most cultivated crops were rice, groundnut, green gram and pigeon pea. Groundnut was highly grown in winter season and followed by sesame and sunflower. Summer rice was grown under irrigated area (GAD (Myinmu), 2017).

As Myinmu Township has abundant upland, upland crops were mostly grown under rain-fed condition. In Myinmu Township, the total sown area of rice occupied by 14.6 thousand ha and production was 11.9 thousand MT in monsoon season (DOA, 2017). Sown area, yield and production of main crops grown in Myinmu Township in 2016-2017 are indicated in Table (1.7).

1.1.12 Condition of irrigated agriculture in Myinmu Township

The Ayeyawady and Mu Rivers dominate surface water resources in Myinmu Township. The Ayeyawady and Mu River are the major water sources for irrigation scheme in this township. In this township, 7 electrically driven pumped irrigation schemes, 3 weirs and 9 river sluices provide irrigation water for crop production. The command area of 7 river pumped irrigation schemes covered to the cultivated area of 2,488.9 ha (IWUMD, 2018). Among the river pumped irrigation schemes in Myinmu Township, only Pywat Ywar irrigation scheme has significantly utilized irrigation water from the Mu River and the largest irrigation command area (Table 1.8).

Table 1.5 Annual rainfall and temperature of Myinmu Township, 2015-2018

	Rainfall		Temperature (ºC)	
Year	Rainy day (no.)	Volume (mm)	Lowest	Highest
2015	59	872.0	11.5	43.9
2016	64	1,022.1	0.9	45.0
2017	60	1,100.1	0.9	43.1
2018	24	406.9	0.9	41.4

Source: DOA, 2019

Table 1.6 Land utilization of Myinmu Township, 2016-2017

Types of land	Area	%
Cultivable land	**66797.65**	**86.12**
Lowland	11,379.60	17.04
Upland	53,880.62	80.66
Alluvial land	1,525.70	2.28
Orchard land	11.74	0.02
Gracing land	**543.91**	**0.70**
Fallowed land	**6,774.18**	**8.73**
Other	**3,445.57**	**4.44**

Source: GAD (Myinmu), 2017

Table 1.7 Seasonal main crops grown in Myinmu Township, 2016-2017

No.	Crops	Season	Sown area (000' ha)	Harvested area (000' ha)	Yield (MT/ha)	Total Production (000' MT)
1.	Rice	Summer	0.7	-	-	-
		Monsoon	14.6	14.6	0.8	11.9
2.	Groundnut	Monsoon	15.7	15.7	1.4	22.2
		Winter	11.9	11.9	1.9	23.2
3.	Sesame	Monsoon	8.4	8.4	0.4	3.3
		Winter	14.6	14.6	0.9	13.9
4.	Sunflower	Monsoon	0.8	0.8	0.6	0.5
		Winter	6.8	6.8	0.9	6.1
5.	Black gram	Pre-monsoon	0.7	0.7	1.0	0.7
6.	Green gram	Monsoon	11.8	11.8	1.4	16.2
		Winter	0.5	0.5	1.4	0.7
7.	Pigeon pea	Monsoon	14.1	14.1	1.4	20.1
8.	Cotton	Pre-monsoon	0.8	0.8	2.2	1.7
9.	Corn	Monsoon	0.3	0.3	2.6	0.9
		Winter	0.9	0.9	3.1	2.9

Source: GAD (Myinmu), 2017

Table 1.8 Irrigated area based on types of irrigation in Myinmu Township, Sagaing District, 2018

Pumps [a]			Weir [b]		River sluice [b]		
No.	Area (ha)	Water source	No.	Area (ha)	No.	Area (ha)	River
7	**2,488.9**		**3**	**230.7**	**9**	**1,942.5**	
Pyawt Ywar	1,456.9	Mu	Kantaw	109.3	1	404.7	Mu
Wunpyae	323.8	Ayeyawady	Aseintaya	60.7	8	1,537.8	Ayeyawady
Sappakone	141.6	Ayeyawady	Minkan	60.7			
Lakkapin	121.4	Ayeyawady					
Kyweyike	121.4	Ayeyawady					
Chayyartaw	101.2	Ayeyawady					
Tharyarpaung	222.6	Ayeyawady					

Source: [a] IWUMD, 2018 & [b] GAD, 2018

1.1.13 Pyawt Ywar Pump Irrigation Project in Myinmu Township

The Pyawt Ywar Pump Irrigation Project (PYPIP) is one of more than 300 pump irrigation projects constructed by Government of Myanmar as part of its strategy to increase agricultural production, particularly of rice. The scheme draws water from the Mu River through one primary and two secondary pump stations, irrigating a range of crops including paddy (monsoon and summer), green gram, chickpea, sesame, groundnut, wheat, maize and cotton. It was constructed in 2004 with a nominal command area of 2,024 ha. In common with many other pumped irrigation projects, the overall performance of the PYPIP has been limited, and the actual area irrigated has consistently been less than a half of the nominal command (IWMI, 2018). Standard information on pump capacity and number of pumps per pumping station is presented in Table 1.9.

Myanmar's Irrigation and Water Utilization Management Department (IWUMD) made strong efforts to assist farmers in the Dry Zone by expanding irrigation systems, constructing canals and reservoirs, and implementing river-pumping and groundwater systems. But no matter how extensive or advanced, the construction of infrastructure in itself could not guarantee farmers equitable access to water. Initially, issues surrounding the governance of the new schemes had been overlooked, meaning that vestigial laws dating back to Britain's Canal Act of 1905 remained in place. While Myanmar's laws were eventually updated in 2017, they have not yet been translated into a practical integrated governance structure, rendering collective or sustainable water management impossible (IWMI, 2018).

Table 1.9 Information on pump capacity and number of pumps per pumping station of Pyawt Ywar pump irrigation scheme in Myinmu Township

Items	Pumping station-1	Pumping station-2	Pumping station-3
Capacity (kW) per pump	315	132	90
Discharge (m^3/s) per pump	0.85	0.57	0.42
Number of pumps	4	4	4
Number of pumps operational	4 or 2	4 or 2	4 or 2 or 1

Source: IWMI, 2018

This lack of institutional structures facilitating water governance has led to the disrepair of canals and water conflicts between villages. In response, the Livelihoods and Food Security Trust Fund (LIFT) began implementing the Pyawt Ywar Pump Irrigation Project. In collaboration with the Irrigation and Water Utilizations Management Department (IWUMD) of the Ministry of Agriculture, Livestock and Irrigation (MOALI), LIFT had invested five million USD in the Pyawt Ywar pump irrigation rehabilitation project in Myanmar’s central Dry Zone to improve livelihoods of local communities through irrigation, as well as to improve irrigation investment decisions made by the Government, development partners and the private sector. The infrastructure and agricultural technical support project is implemented by United Nations Office for Project Services (UNOPS), and a consortium led by the International Water Management Institute (IWMI) and National Engineering and Planning Services (NEPS), with Welthungerhilfe (WHH) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

More than 30 years of IWMI’s experience in irrigation management research suggest that these projects need continued support past the introductory and implementation phases. For newly introduced institutional structures, assistance over the course of several cropping seasons is recommended to build the trust and confidence that make new systems stick. Nevertheless, stakeholders from the paddy fields to the district irrigation offices are feeling the potential for lasting change, not just in Pyawt Ywar, but throughout the rest of the country’s Dry Zone.

This project aimed to define institutional guidelines for pump based irrigation schemes in the Central Dry Zone to empower farmers and IWUMD to work together to enhance equity and efficiency in schemes, thus increasing agricultural production. This project had three main goals: 1) rehabilitate existing irrigation infrastructure, 2) facilitate the institutionalization of participatory water management and 3) educate farmers about sustainable agriculture, water usage and high-value crops.

1.2 Rationale of the Study

Dry Zone of Myanmar is the most water stressed region of the country (IWMI, 2013). Due to the climate change impacts, rainfall pattern and rainfall intensity have significantly changed in this area. Under adverse climate conditions, standing crops suffer water stress affecting the yield of the crops and household income and therefore rural households are facing shortfalls of seasonal agricultural income and employment (Mercy-Corps, 2015). Most of rural households in Dry Zone are engaged in marginally profitable agriculture-based livelihoods and are subject to shocks and stresses such as erratic rainfall patterns and price fluctuations. According to Maharjan and Myint (2015), there is a seasonal migration of households due to the lack of sufficient and year-round livelihood opportunities at the source communities in the Dry Zone. Efficient irrigation could alleviate the unpredictability of rainfall and stabilise agricultural production and rural livelihoods.

Due to the importance of irrigation in agriculture the Government of Myanmar has made considerable efforts to expand irrigation using gravity-fed canal and reservoir schemes, river pumping, and groundwater systems. However, the performance of formal irrigation schemes has been suboptimal, and the actual area irrigated is much lower than the planned command area in the Dry Zone. This is attributed to a mix of issues, including inadequate funding, communities' limited technical capacity for operating and maintaining facilities, availability and cost of energy for pumped systems and a lack of flexibility in water delivery and scheduling. As a result, the efficiency of existing irrigation schemes is very low (IWMI, 2013). There is a need to improve irrigation efficiency and crop water productivity.

Farmers' participation in system design and management is to ensure the sustainability of the system, reduce the public expenditure burden, and improve efficiency, equity, and standards of service (Meinzen-Dick et al., 2004). Without proper community participation in the water management, the expected outcome cannot be fulfilled particularly in an area of water scarcity. Greater participation by farmers, through collective water management, would provide sustainability of the water resources development and efficient and effective utilization of water for increased crops production.

Therefore, the rural livelihoods of Myanmar require the improvement of irrigation systems with community participation. By understanding the constraints and determinants of farmer participation in collective water management activities, local water management systems can be strengthened in order to produce sustainable water resources development and efficient and effective utilization of water for the improvement of rural livelihoods of Myanmar.

1.3 Objectives

The objectives of this study are as follow.

1. To observe the socio-economic characteristics of selected farm households in Pyawt Ywar pump irrigation project, Myinmu Township
2. To explore the decision making of the canal irrigation beneficiaries and non-beneficiaries on farm management and income generating activities by gender perspective
3. To analyze the impact of canal irrigation on crop income by comparing irrigation beneficiaries and non-beneficiaries in the study area
4. To observe the current collective activities of water management by canal irrigation beneficiaries in the study area
5. To examine factors influencing water management activities through collective action in the study area

CHAPTER II

LITERATURE REVIEW

2.1 Linkages between Irrigation and Income

Irrigation is a major driving factor of the increase in rural household income through agricultural growth. According to Lipton, Litchfield and Faurès (2003) and Haile (2008) the four main inter-related mechanisms to improve rural livelihood are:

1. Irrigation increases agricultural production and income, for households with access. These outcomes are observed despite the price decrease that can occur as supply increases (other factors held constant). The price decrease can allow poorer households to more easily meet their basic needs. Household level economic welfare is improved for the poor.

2. Irrigation protects from the risk of crop loss due to erratic, unreliable or insufficient rainwater supplies.

3. Irrigation enhances the use of yield-enhancing farm inputs. The use of such farm inputs improves the agricultural production and income.

4. Irrigation creates additional employment. Household and/or laborers are engaged in the irrigation farming that helps to increase the labor productivity during the dry periods and farm off-season.

Water is a valuable input for agriculture. Irrigation water appears to provide many pathways for livelihood improvement. The access to consistent irrigation water can enable farmers to adopt irrigation technologies. Irrigation facilitates the intensity of cultivation that leads to an increase in agricultural productivity and greater returns from farming. The expansion of irrigation opens up new employment opportunities in the household that increase the efficiency of labor and land. This improves farm income, livelihood, and the quality of life in rural areas (Hussain & Hanjra, 2004).

2.2 Impact of Irrigation Use on Income: The Empirical Findings

Over the past few years, many research works has been carrying out to comprehend the effect of irrigation on livelihood improvement in developing countries. Although irrigation infrastructure is believed to be the main catalyst to boosting overall growth in the agricultural sector, the probability to which this is true has not been extensively rectified (Kimsun, Socheth & Santos, 2011).

The existing literature in relation to the impact of irrigation on crop income is mixed. Some studies have confirmed a strong link between irrigation and livelihood improvement through crop income in developing countries. Nevertheless, others indicate the impact of irrigation on agricultural productivity and rural livelihood is not significant. Most studies look into consumption expenditure as a proxy indicator of the impact of irrigation. This however, indirectly accounts for income.

A number of literature sources show that irrigation has both direct and indirect impact on farm household. To start with the direct impact: Lipton et al. (2003) stated that the first direct impact is on output. Irrigation enhances farm output and thus, with prices remaining constant, raises farm incomes. Output levels may increase for any of at least three reasons. Firstly irrigation boosts yields by mitigating crop loss due to unpredictable, unreliable or inadequate rain-water supply. Secondly, irrigation permits the possibility of multiple-cropping and a boost in total output. Thirdly, irrigation enables a greater area of land to be used for crops in times where rain-fed production is not possible or insignificant. Consequently, irrigation is expected to increase output and income levels.

The second major impact of irrigation is generating employment both on and off the farm (Barker, Dawe, Tuong, Bhuiyan & Guerra, 2000). This is in offering entitlement or purchasing power for the poor. For landless laborers increased cropping intensity has the maximum impact on employment. Irrigation means extra work in more days of the year. The employment impact is felt not only in irrigated areas but also in rain-fed areas. Sometimes, landless workers in rain-fed villages migrate long distances to take advantage of employment opportunities in the irrigated areas.

The third direct effect on livelihood improvement is by means of food prices. If irrigation boosts the level of output, then this may result in lower prices of foods (Lipton et al., 2003). Lower food prices have reduced vulnerability associated with distribution of food and its access among poor and marginal communities (Bhattarai, Sakhitavadivel & Hussain, 2002). Therefore, both rural net purchasers and urban consumers will gain from the cheaper food prices. Thus, a fall in the staple price as a result of more outputs from irrigated plots is expected to be livelihood improvement.

Lipton et al. (2003) argued that access to irrigation also has (indirect) impacts through output, employment and prices on livelihood improvement. In the long-run with a dynamic general equilibrium scenario, access to irrigation will encourage farmers to adopt fertilizers, pesticides, improved seeds and other agricultural factors of production and expand farm output. This also has a positive effect in crop income.

In addition, a study by Sinyolo, Mudhara and Wale (2014) revealed that access to irrigation enabled farmers to practice double cropping, and to grow horticultural crops commercially. As a result, the irrigators were able to generate more money compared to their non-irrigating counter-parts. Several studies by Haji, Aman and Hailu (2013), Beyan, Jema and Adem (2014), and Anwar (2014) in different parts of Ethiopia supported the positive and significant effect of irrigation on crop income and household expenditure.

A more recent study by Sinyolo et al. (2014) with the treatment effect and propensity score matching model indicated that smallholder irrigation access played a significantly positive role in improving crop income in the rural areas of South Africa.

Further, Kuwornu and Owusu (2012) on their analysis on the sources of household income in Ghana revealed that non-farm income for respondents could be as much as 12 to 15% of household income. Thus, as much as 85 to 87% of household income was reinforced by farming income. For irrigators, average income from irrigation activity was about 45%. Irrigated income thus accounted for the highest proportion of total income.

Dinku (2004) studied the irrigation scheme in Eastern Oromia of Ethiopia and found that the average income obtained from irrigated agriculture for three consecutive years accounted 69%, 76%, 76% in Doni Kumbi and 0, 75%, 61% in Bato Degage as compared to other households' source of income. The study had also shown the importance of smallholder irrigation development as a key drought mitigation measure and improvement of household income.

On the contrary, Kimsun et al. (2011) concluded that irrigation had no impact on the abundance of household assets. Their results, both descriptive and analytical could not confirm a positive correlation between irrigation and accumulation of household assets. This might be due to the proxy measure of income.

A study in India has showed that access to irrigation has had a positive impact on household income (Narayanamoorthy, 2001; Shah & Singh, 2002).

Gebregziabher, Namara and Holden (2012) found that, in terms of their technical efficiency, irrigator farmers in northern Ethiopia operated on a higher production frontier with significant inefficiencies, while rain-fed farms were on a lower production frontier with high efficiency levels.

In South and South East Asia, Hussain and Hanjra (2003) showed that irrigation enabled households to improve crop productivity. A comparison between irrigators and non-irrigators in China showed that irrigation contributed to increased yields for almost all crops and higher income for farmers in all areas (Huang, Rozelle, Lohmar, Huang & Wang, 2006).

In Ethiopia, access to irrigation has had a positive and significant impact of irrigation use on the two outcome variables: income by 8.8% and asset formation by 186% as compared to non-users (Gebrehiwot, Makina & Woldu, 2017).

In Ghana, Acheampong, Balana, Nimoh and Abaidoo (2018) showed that there was only about 3% increase in the income of vegetable farmers participating in irrigated vegetable production using small reservoir irrigation against the counterfactual situation but this change was insignificant statistically.

Using the methods of propensity score matching (PSM) and switching regression, it was ascertained that improved access to irrigation in the rural savannah region of Ghana significantly improved household welfare via increase in net farm income, and there was more room for enhanced impacts (Owusu, Namara & Kuwornu, 2011).

A study by Nkhata (2014) with endogenous switching regression and propensity score matching methods indicated that irrigation had a positive impact on annual agricultural income in Malawi. The results also showed, in addition, traditionally marginalized groups (households headed by youth, female-headed households, and low-income households) earned more agricultural income than what they would have earned if they did not participate in the irrigation scheme.

In Nepal, Ghimire and Kotani (2015) studied to find the effect of irrigation on vegetable farming with the endogenous switching regression model, to take into account endogeneity and to measure the impact of irrigation via counterfactual experiments. The selection equation showed that participation in irrigation schemes was enhanced by credit access, investment, improved seeds, education and agricultural training. The regime equations found that vegetable incomes for non-adopters were affected by several factors such as age, education, livestock, land value, credit access, investment and improved seeds, while only the two determinants of livestock value and credit access were important for vegetable incomes of adopters. The counterfactual experiment demonstrated that vegetable income of non-adopters would increase by 33% if non-adopters adopt plastic ponds.

2.3 Gender Participation in Agricultural Processes and Decision Making

Gender has often been misunderstood as being about the promotion of women only, but gender focuses on the relationship between men and women, their roles, access to and control over resources, division of labour and needs. Gender relations also determine household security, well-being of the family, planning, agricultural production and many other aspects of rural life (Frischmuth, 1997). Ayoola and Odiaka (2004) described gender as a socio-economic parameter that is useful in analyzing the roles, responsibilities, opportunities and constraints of both men and women along different ethnic, religion and ecological lines. The term "gender" can also be viewed in economic, social and cultural attributes and the opportunities associated with being male or female (UN-Habitat, 2003). In almost all societies, women and men differ in their activities and undertakings, regarding access to and control over resources and participating in decision-making.

The participation of women has been increasing in agriculture, mainly as agricultural labour. This phenomenon is driven mainly by three facts. First, there are increasing numbers of small and fragmented land holdings and these households cannot afford hired labour: this finally leads to increased participation of family labour mainly by women in the fields (Satyavathi, Bharadwaj & Brahmanand, 2011). Second, due to increased migration of the male members of the household in search of jobs from rural to urban areas, there is an increase in female participation in labour and agricultural activities (Rao, 2006). Third, with the increased level of mechanization, most of the farm related mechanized activities were taken care of by men and thus other manual activities like cleaning of seeds and weeding in the farmlands are done by the women (Headey, Chiu & Kadiyala, 2012).

There are several other socio-economic factors that impact participation of women in agricultural activities. The cultural misconceptions that the men are stronger than women reduced the prospects of women as a farmer and they were confined to labour in their fields, on either simple or time consuming tasks (Rao, 2006). Increase in household income lead to a decline in the participation of women in agricultural activities. This is confined by the continued labour of women from poor households as labour on their farms (Khan, Sajjad, Hameed, Khan & Jan, 2012). In most of the studies conducted it is shown that women have a limited role in the marketing of the produce as most of their activities are at the farm level (Grace, 2005; Tiruneh, Tesfaye, Mwangi & Verkuijl, 2001). Ibrahim, Saingbe and Abdulkadir (2012) found that participation by women in agricultural activities is much higher than the males. The access to physical and human capital has a significant influence on income generating activities of rural households in Indonesia by Schwarze (2004).

Bastidas (1999) stated that women’s participation in irrigated agriculture was higher in female-headed households in Ecuador. Upadhyay, Samad and Giordano (2005) found that women extensively contributed to irrigate vegetable farming under the drip-irrigation systems in Nepal.

The other important aspect is that even if women are playing an active role in agriculture, it is often found that their involvement in the decision making process on various agricultural activities is very limited. Intra-household dynamics are often assumed to exist in isolation of the socio-economic factors, although that is not the reality (Agarwal, 1997).

Several quantitative factors might describe the bargaining power and decision among processes of women in the households and these factors might be beyond income. Aregu, Puskur and Bishop-Sambrook (2011) argued that women are often consulted in the decision process and they can influence the outcome of the decision if they have appropriate capability. In developing countries most of the activities and decisions related to livestock rearing and sale of produce are undertaken by the women (Aregu et al., 2011; Grace, 2005; Khan et al., 2012; Tiruneh et al., 2001). In most of the cases men make all the important decisions related to cropping including the cropping pattern, use of seeds and technology, and the participation of women in decision making is not appreciated (Tsegaye, Dessalegn, Yimam & Kefale, 2012).

Men in the rich and middle income households took mostly decisions alone, but in the poorest households the decisions are taken jointly by the husband and wife (Aregu et al., 2011; Damisa & Yohanna, 2007). The lack of access to information sources, new technology, credit facilities and proper training limits the decision making capacity of women (Chayal, Dhaka, Poonia, Tyagi & Verma, 2013; Rao, 2006).

2.4 The Role of Collective Action

2.4.1 Collective action: definition and characteristics

Marshall-Fratani (1998) defined collective action as “the action taken by a group (either directly or on its behalf through an organization) in pursuit of members’ perceived shared interests”. As observed by Meinzen-Dick et al. (2004), the more specific and varied definitions which have been added later have in common the following features: the involvement of a group of people, shared interests and common and voluntary actions to pursue those shared interests.

A single individual barely has any influence on an organization’s situation, but every individual is able to rejoice in every improvement, regardless of whether he or she has contributed to it. A "conflict between collectively and individually best action" exists: nobody is interested in bearing the expenses for the improvement; instead everyone is trying to profit from the public good in a greedy way (Olson, 2009).

Ostrom (2014) described two types of collective action: (i) cooperation: bottom-up, farmer-to-farmer collective action and (ii) coordination: top-down, agency-led collective action. While some bottom-up collective actions may receive government support, others may be carried out without government support.

Indeed, as emphasized by Meinzen-Dick et al. (2004) any kind of collective action for routine maintenance will likely become institutionalized or integrated into mainstream policy frameworks and, while this institutionalization has the potential of reducing the transaction costs of negotiation, on the other hand the more institutionalized the collective action becomes, the less adaptable and flexible it is. The same authors argued that all the factors which influenced the structure of groups and their organizations were relevant because they influence their conduct and then their outcomes. As shown in Figure 2.1, the many variables of interests present in collective actions usually determine feedbacks and co-movements that are likely to be very influential in determining the performance of collective action.

2.4.2 Social capital and collective action: a theoretical perspective

Social capital is often considered an intangible action asset that facilitates collective action and self-organization (Meinzen-Dick et al., 2004). Putnam (1995) refers to social capital as the "features of social organizations such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit". In this respect, Ishihara and Pascual (2009) make use of the concepts of 'common knowledge', defined as the capacity to represent individuals' preferences as community preferences, and 'symbolic power', which is related to the question of whose preferences are represented, for explaining how social capital may foster collective action. It is also worth noting that despite social capital being regarded as intrinsically positive. Pretty and Ward (2001) highlight the fact that not all forms of social capital imply higher social welfare. For instance, Adhikari and Goldey (2010) argue that rule-breaking with impunity and elites' capturing of resources affect collective action and the sustainability of community based organizations. In this respect, social capital may reinforce and sustain inequality, as well as forms of networks with negative social outcomes.

Collective action is affected by factors related to the attributes of the resource itself (such as scarcity and size), the resource users (such as heterogeneity, age and origin of the group and proximity to markets) and to the socioeconomic and institutional context, stated by Araral (2009).

Pretty and Ward (2001) identified four key aspects related to social capital: trust, reciprocity and exchanges, common rules, norms and sanctions and connectedness, networks and groups. In addition, as acknowledged in Pretty (2003), higher social capital is also related to higher levels of economic and social well-being. As argued in Marshall (2004), trust and cooperation are pivotal factors in providing collective goods.

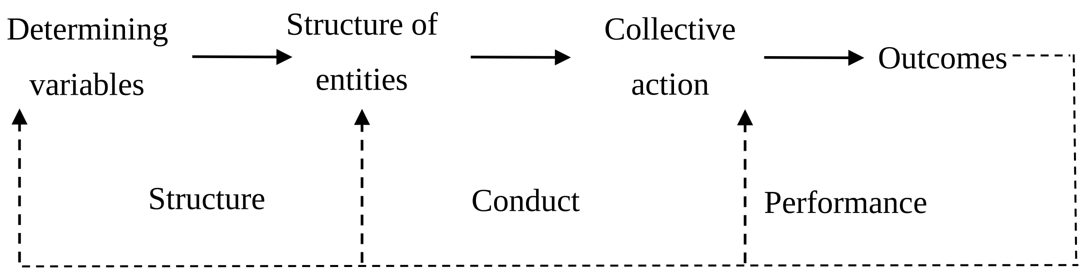

Figure 2.1 Structure, conduct and performance of collective action

Source: Meinzen-Dick et al., 2004

As suggested by Fujiie, Hayami and Kikuchi (2005), willingness to cooperate is greater in individuals who have cooperated in the past, and have obtained rewards from that cooperation. Furthermore, cooperating in any somewhat irreversible arrangement - as such would result from sharing irrigation infrastructures with a group of neighboring farmers - increases the risk of conflict, disputes and financial losses.

Although irrigation is a vital resource for agriculture, water is rarely used efficiently and effectively. Without regulation or control, water can easily be overused by those who have access to it first, resulting in shortages for tail-enders, conflicts over water allocation, and water logging, drainage and salinity problems. But where social capital is well developed, then local water users' groups with locally developed rules and sanctions are able to make more of existing resources than individuals working alone or in competition (Pretty, 2008).

2.5 Selected Studies on Water Management in Rural Community

Water management is a key mechanism for the development of irrigated agriculture, particularly in the area affected by drought and erratic rainfall (Ashraf et al., 2007). Several studies have been conducted to investigate influencing factors on farmer participation in irrigation water management. Nhundu, Mushunje, Zhou and Aghdasi (2015) investigated the institutional determinants influencing farmer participation in irrigation development with a binary regression model in Zimbabwe. The empirical results revealed the importance of training, cost recovery, participation in design and implementation, access to extension, and access to credit extension in influencing farmers to participate in irrigation development.

Wescoat, Halvorson and Mustafa (2000) attempted to ensure that participation is a systematic involvement of local people in diverse activities to manage their own problems that conveyances sustainability in Sindh Province of Pakistan. The study revealed that the majority of the farmers were averagely involved in water management activities.

Stahlberg (2006) studied local cooperation in water management with the capacity of rural communities in India to manage their water resources in a sustainable way. Theories on collective action and the commons have been used in the analysis. The study showed how the formal institutions responsible for water management in the village are perceived to have a limited role.

A study of farmers' participation in water management in Pakistan by Sheikh, Redzuan, Samah and Ahmad (2015) with multiple linear regression analysis revealed that the participation was positively influenced by age, education, residential locality, house type, lack of on-farm facilities, underground water use for irrigation purpose and location of watercourses on the canal network.

Khalkheili and Zamani (2009) found that farmers' attitudes toward participation in irrigation management, attitudes toward personnel of the State Water Authority and the Agricultural Extension Service Centers, family size, the problem perception, dependence on the dam for water, and educational background have influenced their participation in irrigation management in Iran.

Muchara, Ortmann, Wale and Mudhara (2014) studied collective action and participation in irrigation water management with the Tobit model in South Africa. The results of models suggested that collective activities were negatively affected by low farmer-literacy levels.

Deribe (2008) found that analysis showed less number of conflicts and violation of rules are associated with collective action in irrigation water management in Ethiopia. The evidence also showed that instead of higher level of education status, it is greater number of provision of training which favors collective action.

The types of activities promoted by cooperative groups and the determinants of participation intensity of members in cooperative activities in Southwestern Nigeria were investigated with Tobit model by (Agbonlahor, Enilolobo, Sodiaya, Akerele & Oke, 2012). This study had revealed the important roles of collective action in improving rural livelihoods.

A study showed that collection in canal water management was associated with resource scarcity, market distance from the resource, group size, heterogeneity in the community, and involvement of other institutions in Bangladesh. The findings implied that collective actions in common water management were being influenced by the characteristics of the resource, as well as the characteristics of the water users, and the institutional structure of the community. User associations strongly influence collective water management, while resource scarcity and group size influence negatively (Haque, Hossain, Bauer and Kuhlmann (2013).

In South Africa, Muchara, Letty, et al. (2014) found that the poor coordination of government funded activities negatively affects smallholder irrigation performance, through poor provision of public infrastructure like roads and physical asserts like tractors.

Some the socioeconomic determinants have strong relationships with dynamic participation. In a study where the farmers were involved in cleaning of irrigation channels, the participation level was associated with plot size while the farmers of larger plots were particularly active in water management (Nakano & Otsuka, 2011). Participation positively correlates to intra-personal empowerment across earnings levels, but is optimistically related to interactional empowerment only for low-income individuals (Speer, Peterson, Armstead & Allen, 2013). In Nepal, the participation of farmers is influenced by the education level and amount of training, while farm size and gross farm income are dominant economic variables influencing participation (Shivakoti & Thapa, 2005).

On the other hand Saidu, Samah, Redzuan and Ahmad (2014) conducted a study in Kano state of Nigeria and divulged that education added negatively to participation in the decision-making process as the majority of the educated people look for better job opportunities rather than agricultural activities. However, Oladele (2012) claimed that age and education level play a vital role in participation. Arun, Singh, Kumar and Kumar (2012) reported that the participation increases as farm-size increases. Shamiyulla (2010) argued that farmers' literacy level, living standards and economic factors also contribute to the success of Participatory Irrigation Management (PIM). Awortwi (2012) conducted a study in Africa and Latin America and concluded that income levels and housing categories have positive relationships with factors influencing community participation and supervision. Levels of participation in social and civic community life are significantly influenced by individual socioeconomic status and other demographic characteristics (Baum et al., 2000).

CHAPTER III

RESEARCH METHODOLOGY

3.1 Conceptual Framework of the Study

There are many reasons to draw from rural farm household data and information concerning household income. Farm households aim to receive their highest relative income from farming. To achieve this aim, they will make decisions on how to manage their resources for the best use (Figure 3.1). Hence, they will decide how to allocate resources for their livelihood through existing knowledge and social capital. In farm management, mostly they could use cooperation and collective action to perform efficient and effective water management because irrigation has a direct impact on household incomes by increasing farm revenues. Decision making continues to vary in whether women are included.

Consequently, when irrigation related activities are well-managed farm revenues increase. Irrigation can increase annual revenue per unit of land through its direct positive effect on total crop production in a given cropping season. Although input costs for crops are correspondingly higher for household in the irrigated area, irrigation water not only increases crop yields per hectare but also reduces crop yield variability. That stabilizes household incomes.

In addition, irrigation may increase farm revenue by allowing a plot to be planted for an extra crop season in a given year. Actually, irrigation induces the possibility of double cropping. The result of this increased activity leads to improved household income which in turn leads to increased household expenditure in most situations. When household income and expenditure are increased, there should be proper investment in farming, improved food security and livelihood improvement of the household.

Moreover, irrigation may lead to different employment consequences for men and women. This arises because of the pronounced gender division of labour. It may also lead to a given change in total labour requirements. Indirectly, irrigation can benefit the landless through higher wages as it results in higher marketed surpluses and increased employment opportunities. Furthermore, irrigation can benefit the poor as it may lead to lower food prices. These are especially beneficial to the poor since the poor spend a disproportionately large share of their income on food. Therefore, irrigation schemes benefit not only the participants but the non-participants as well through these spill-over effects.

However, if income from farming is insufficient for their livelihood and living standard, there will be a reallocation of family labour. As a result, off-farm or non-farm jobs become new primary jobs and eventually seasonal or cross border migration occurs. Under such circumstances, farm households receive income as remittance money which may then be reinvested in farming.

There are, of course, other external factors influencing household decision making and income. In particular, they would be political, social and economic situation at macro level environment and climate change and market shocks at micro level environment. Over all, an understanding of the determinants of farmer participation in collective activities would form the basis to strengthen local water management systems and institutional policies to ensure maximum benefits from participating in collective activities.

3.2 Description of the Study Area

The Pyawt Ywar Pump Irrigation Project (PYPIP) area is located in Myinmu Township, Central Dry Zone of Myanmar. It is one of the largest irrigation command areas in Myinmu Township, supplying water for 2,024 ha of the sown farming area. The PYPIP irrigation scheme became operational in 2005 using diesel fuel pumps to lift water from the Mu River. Pumps were upgraded in 2010-2011 to electrically driven pumps: this resulted in an expansion of irrigated land from 892 hectare in 2010 to 1,457 ha in 2016 (IWUMD, 2017). Problems occur during extremely wet years or years with extremely high rainfall when the high water levels in the river carry more debris and sediment load in the monsoon season. This has an impact on pump operation due to clogging of the filters which causes pump failures (IWMI, 2018).

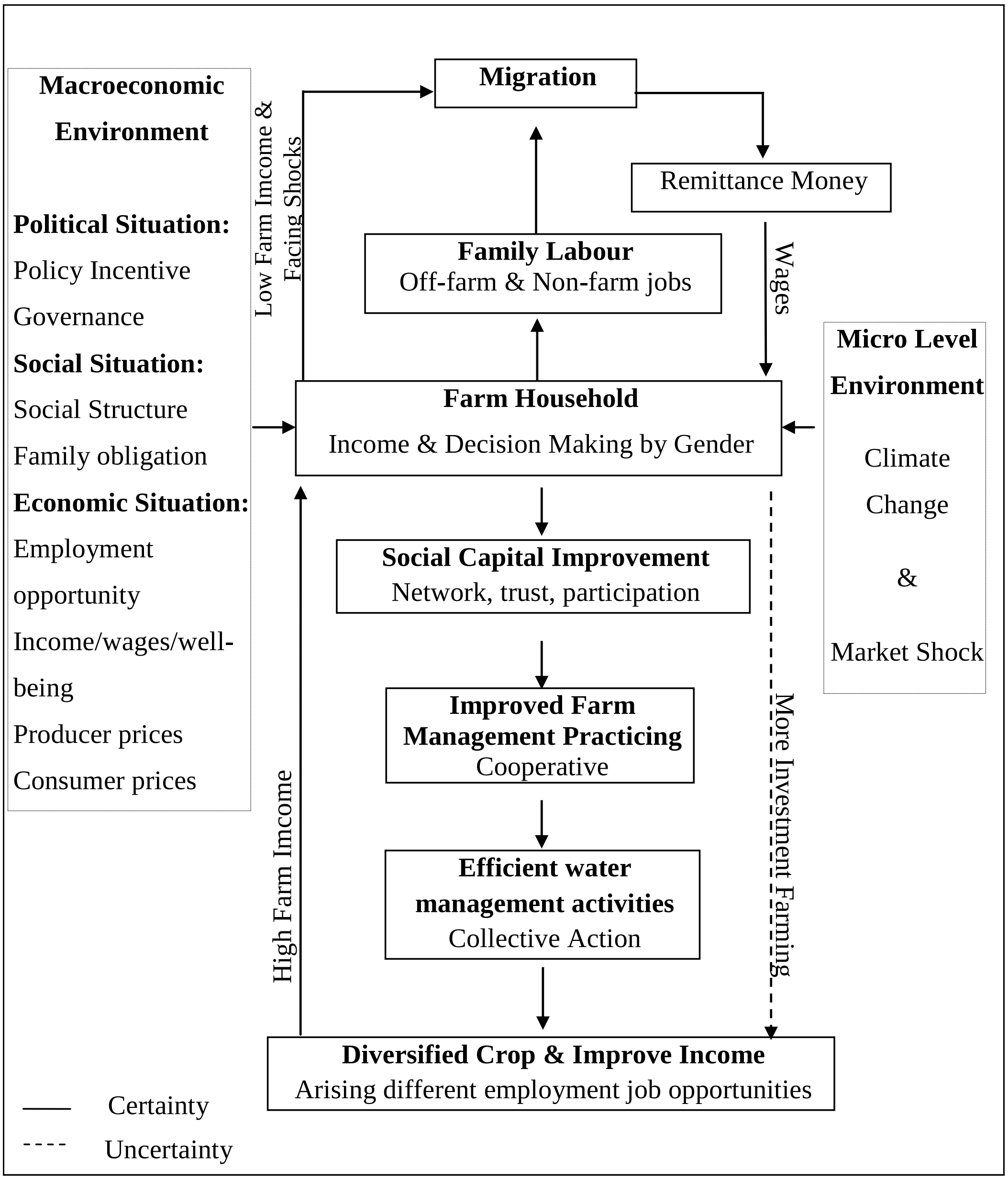

Figure 3.1 Conceptual framework of the study

Adopted from Milne (1991) & Sabatier (2007)

The command area consists of three pump stations, situated near the Mu River, and three main canals that distribute water to the cultivated areas of 7 villages. Irrigation water is lifted from the Mu River into earthen canals and then distributed to the fields. Three subsidiary pump stations service the following areas: Pump station-1 benefits the villages of Pyawt Ywar, Muwa Ywar Htaung and Hnabae Kyuu; Pump station-2 irrigates the fields of villages including Pyawt Ywar, Hnabae Kyuu, Makyee Kan and Kan Phyar; and Pump station-3 supplies irrigation water to the villages of Muwa Ywar Htaung, Nyaung Yinn and Htee Saung villages.

The irrigation scheme involves three pumping zones. Figure 3.2 shows the administrative boundary in the command area. The scheme was originally designed to have three main canals and 17 distributary canals. The three main canals have total length of 19.44 km and 17 distributary canals have total length of 31.54 km.

3.2.1 Function of communal Water Management Committee

Irrigation and Water Utilization Management Department (IWUMD) has set the official organization structure for the management, operation and maintenance for the PYPIP irrigation schemes. In the study area, there is a communal Water Management Committee (WMC) organized by Irrigation and Water Utilization Department comprising (6 representatives) from irrigation command areas (2 persons from each block) and village administrators of 7 villages.

The Scheme Manager of Pyawt Ywar Pump irrigation and the officer-in-charge of the scheme are responsible for managing the scheme. The Scheme Manager is primarily responsible for leading the seasonal planning meetings together with the agricultural coordination committee, canal representatives and the water user committee that result in the seasonal water allocation schedule. He also chairs the weekly irrigation scheduling meetings (held on Saturday) with the canal representatives to adjust the original water allocation schedule based on prevailing water availability conditions. The Scheme Manager is also responsible for submitting yearly cost estimates for pump operation and maintenance as well as maintenance of canals.

Canal Representatives (CR) are the primary representatives of the farmers, and are generally meant to represent all farmers served by a particular distributary canal. The canal representatives are appointed and they facilitate water allocation, operation and maintenance functions of main canal and branch canals. Each CR is compensated for his efforts by receiving a service fee at the rate of 2000 MMK per acre by the farmers served by the distributary canal he manages. Since irrigation representatives are elected among beneficiaries and representatives may have a bias concerning the water allocation, they are usually disrespected by the irrigation use farmers.

The village administrators are important players given their overall authority over the affairs of a village and authority to represent their respective villages in external forums. They tend to get involved especially to support CRs enforce the water allocation rules. Moreover, they play an advisory role in planning of agricultural production systems at the onset of the season to ensure proper water allocation and facilitate to resolve water- related conflicts. However, the Water Management Committees at village level are not operational (IWMI, 2018).

The beneficiary or fault will be punished by a cash fine set by the Water Management Committee if a water beneficiary does not follow regulations of the communal Water Management Committee during the irrigation time. Conflict resolution has been the duty of the Water Management Committee but it has little authority to enforce its regulations at the operational level. The Water Management Committee generally has little influence on the actual collective water management especially when water is scarce.

3.2.2 Provision of irrigation water in the scheme

In the project area, rotational irrigation is practiced. Irrigation water is not allocated according to land size per farmer or type of crops planted but is based on a roster that allocates a specific number of irrigation days per block. Actually, water distribution shifts are organised based on counting dates or complaints, instead of water needs by plants. Since the Pump station-1 command area is the first lift user of the irrigation scheme, it accesses irrigation water from the main canal. While other pump stations command areas are allocated irrigation water, the main canal serves as a temporary reservoir. Therefore, Pump station-1 command area has better access to irrigation water compared with other command areas.

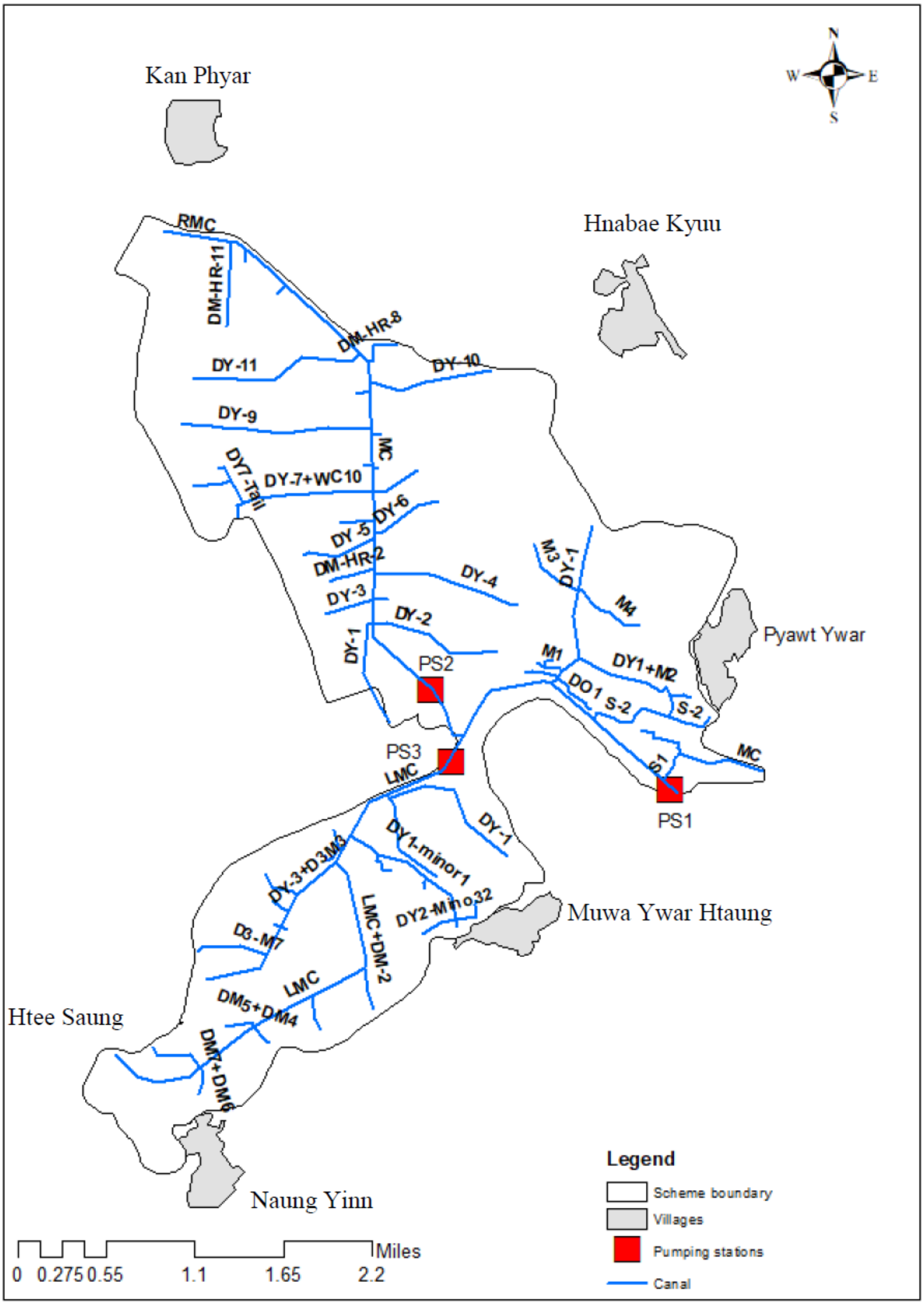

Figure 3.2 Structure and boundaries of Pyawt Ywar Pump Irrigation Scheme

Source: International Water Management Institute (IWMI), 2018

Once the water gets to the main canals, it is accessed on a 'first-come first-serve' basis with the likelihood of depriving irrigation beneficiaries who start irrigating late or are at the tail-end of the fields or canal. Maintenance is a problem with poorly maintained secondary and tertiary canals, irregular pumping activity (due to pump breakdowns and electricity failures) and canal wall collapse (IWMI, 2018).

3.2.3 Participation of farmer in water management in the study area

In the project area where more members of the water user group face water scarcity, they were less likely to choose collective water management. However some farmers were involved in complementary activities like decision making through participating in meetings, reporting undisciplined water use as well as engaging authorities to resolve water-related challenges in the scheme. Participation was influenced by farmers' plot location within the scheme. This was due to an unequal distribution of water among head and tail-end farmers.

Farmers also claimed to follow crop-water requirement rates in irrigating their plots. However their water application was without consideration of the soil type, crop type and stage of growth and they also usually over-irrigate their fields thinking that more water results in more certain yields (IWMI, 2018).

3.2.4 Sampling technique and sample size

To ensure a representative sample, the scheme was stratified into 3 segments (Block 1, Block 2 and Block 3) based on the positions of the pump stations. The Block 1 of the PYPIP comprises members farming in Pump station-1, the Block 2 comprises members farming in Pump station-2, and the Blocks 3 constitutes Pump station-3 with the basic assumption that there could be inequity in water distribution.

The stratified random sampling method was used to select irrigation beneficiaries and non-irrigation beneficiaries within the command of the PYPIP. Irrigation beneficiaries were again stratified into head-end, middle and tail-end beneficiaries based on their plot location of the main conveyance canal. The number of farmers in the study area was (1010) farmers including 736 beneficiary farmers and 274 non-beneficiary farmers (Table 3.1). A total of 285 respondents were sampled from the 3 blocks with a 0.05 confidence interval. This amounted to a total of 208 beneficiaries and 77 non-beneficiaries were proportionately selected from irrigation command area (Table 3.2). In total 285 farmers were interviewed with a structural questionnaires for primary information. STATA and SPSS were used for analysis data.

3.3 Data Analysis Methods

For Objective - 1

Descriptive statistics were used to explain objective - 1: to observe the socio-economic characteristics of selected farm households in Pyawt Ywar pump irrigation project, Myinmu Township.

Data collection was conducted on households of the canal irrigation beneficiaries and non-beneficiaries in the study area to get information on socio-economic characteristics of households.

For Objective - 2

Descriptive statistical analysis was used to explain objective - 2: to explore the decision making of the canal irrigation beneficiaries and non-beneficiaries on farm management and income generating activities and by gender perspective.

Interviews were conducted with households of beneficiaries and non-beneficiaries in the study area to get information on household livelihood and decision making participation by gender in farm management activities and income generating activities.

For Objective - 3

The Full Information Maximum Likelihood Estimation of Endogenous Switching Regression model was used to explain objective - 3: to analyze the impact of canal irrigation on the crop income by comparing irrigation beneficiaries and non-beneficiaries in the study area.

Table 3.1 Sample size of canal irrigation beneficiaries and non-beneficiaries based on block position in the study area

Items	Block 1		Block 2		Block 3		Total	
	Farmer No.[a]	Sample No.	Farmer No.[a]	Sample No.	Farmer No.[a]	Sample No.	Farmer No.[a]	Sample No.
Beneficiary	114	31	416	113	206	64	736	208
Non-beneficiary	2	2	164	44	108	31	274	77
Total	116	33	580	157	314	95	1010	285

[a]Source: WHH, Myinmu office (2017) & IWUMD, Myinmu project office (2017)

Table 3.2 Sample size of canal irrigation beneficiaries based on plot position in the study area

Block	Position	Beneficiary (No.)[a]	Sample No.
Block 1	Head-end	96	26
	Middle	8	2
	Tail-end	10	3
	Total	114	31
Block 2	Head-end	149	42
	Middle	184	48
	Tail-end	83	23
	Total	416	113
Block 3	Head-end	103	27
	Middle	45	19
	Tail-end	58	18
	Total	206	64

[a]Source: WHH, Myinmu office (2017) & IWUMD, Myinmu project office (2017)

In practice, evaluating the impact of canal irrigation on an outcome variable using linear regression analysis can lead to a biased estimate if the underlying process which governs selection into the irrigation scheme is not incorporated in the empirical framework. In this case, participation into the irrigation scheme is not only by self-selection of farmers but also non-random selection by the irrigation scheme. Hence, participation decision could be influenced by the observed (farm and household characteristics), and unobserved factors (motivation and management skills) of farmers. The reason for this is that the effect of the irrigation scheme may be over or underestimated if the beneficiaries are more (or less) able (due to certain unobservable characteristics) to derive benefits compared to eligible non-beneficiaries (Zaman, 2001).

In this study, some unobservable characteristics such as skill, innovation, and attitude in farm households may affect not only the use of agricultural irrigation but also other farming decisions, leading to endogeneity and self-selection problems in the model (Di Falco & Veronesi, 2013). Therefore, if the endogeneity that arises in farming and use of irrigation scheme is not taken into account, the true impact on farming cannot be estimated. Hence, the endogenous switching regression model that enables us to jointly consider the use of both the irrigation scheme and farming within a single framework was used. It further allows implementing counterfactual experiments for answering what the impact of irrigation is, if non-beneficiaries use irrigation or if beneficiaries do not use it.

An endogenous switching regression model was used to estimate the relationship between the access to canal water and crop income in the study area, controlling for self-selection bias. The endogenous switching regression can be used to predict expected crop income for beneficiaries if they switched to not accessing canal irrigation and vice versa for non-beneficiaries (Lokshin & Sajaia, 2004).

An endogenous switching regression model follows two steps. In the first step, it models the decision of whether or not farmers use canal irrigation. In the second step, it models the outcome of farming depending whether on farmers are beneficiaries or non-beneficiaries. Let the decision to use one of the canal irrigation be a dichotomous choice, where a farmer decides to use canal irrigation when there is a positive perceived difference between using canal irrigation and not using the canal irrigation.

Let this difference be denoted as I^* so that $I^* > 0$ corresponds to the net crop income of accessing the canal irrigation exceeding that not accessing the canal irrigation, and it is under this condition that the farmer decides to use canal irrigation. However I^* is not observable; what observed is I, which represents the observed farmer's decision choice. The expected utility of accessing canal irrigation, I_1^* (beneficiaries or regime 1) compared to the utility of not accessing canal irrigation, I_0^* (non-beneficiaries or regime 2), and the decision to use canal irrigation occurs if $I_1^* > I_0^*$. According to Lokshin and Sajaia (2004), the first-step equation (selection equation) can be expressed as:

$$I = 1 \text{ if } Z_i\,\alpha + \varepsilon_i \text{ if } I^* > 0$$

$$I = 0 \text{ if } Z_i\,\alpha + \varepsilon_i \text{ if } I^* < 0 \qquad (1)$$

Where Z_i represents variables that affect participation decisions such as socio-economic, agro-ecological characteristics and institutional characteristics for household i; α is a vector of parameters to be estimated; and ε_i is a random error term which captures the unobserved factors with mean zero and variance σ_ε^2.

The second-step equations called "regime equations" evaluate the determinants of crop income depending on whether farmers are beneficiaries or non-beneficiaries. The estimation can be made with the following specification.

$$\text{Regime 1 (for beneficiary): } Y_{1i} = \beta_1\, X_{1i} + \mu_{1i} \qquad (2)$$

$$\text{Regime 2 (for non-beneficiary): } Y_{2i} = \beta_2\, X_{2i} + \mu_{2i} \qquad (3)$$

Where Y_{1i} and Y_{2i} are the crop incomes for i^{th} beneficiary and i^{th} non-beneficiary, X_{1i} and X_{2i} are a set of the independent variables for equations (2) and (3), β_1 and β_2 are the parameters to be estimated for beneficiaries and non-beneficiaries, and μ_{1i} and μ_{2i} are random error terms with variances of σ_1^2 and σ_2^2, respectively. According to Verbeek (2012) the variables included in X_{1i} and X_{2i} should be contained in Z_i in equation (1), implying that Z_i must have at least one more variable that is not included in equations (2) and (3).

The ε_i, μ_{1i} and μ_{2i} are error terms of selection and regime equations, respectively and are assumed to have a trivariate normal distribution with zero mean vectors and the following covariance matrix (Lokshin & Sajaia, 2004).

$$\text{Cov}(\varepsilon_i, \mu_{1i}, \mu_{2i}) = \begin{bmatrix} \sigma_\varepsilon^2 \sigma_{\mu1\varepsilon} \sigma_{\mu2\varepsilon} \\ \sigma_{\mu1\varepsilon} \sigma_{\mu1}^2 \sigma_{\mu1\mu2} \\ \sigma_{\mu2\varepsilon} \sigma_{\mu1\mu2} \sigma_{\mu2}^2 \end{bmatrix} \quad (4)$$

Where σ^2_ε, $\sigma^2_{\mu1}$ and $\sigma^2_{\mu2}$ are variances of the error terms in the equations (1), (2) and (3), respectively, $\sigma_{\mu1\varepsilon}$ and $\sigma_{\mu2\varepsilon}$ are the covariance between μ_{1i} and ε_i, and μ_{2i} and ε_i respectively. The $\sigma_{\mu1\mu2}$ is the covariance between μ_{1i} and μ_{2i}, is unobservable as a farmer cannot simultaneously be a beneficiary and non-beneficiary (Maddala, 1986).

A series of these estimations for parameters α, β_1 and β_2 in equations (1) to (3) is executed in STATA using the "move-stay" command developed by Lokshin and Sajaia (2004). FIML ESR model is written as follow.

$$lnY_i = \sum_{i=1}^{n} (I_i\, w_i [ln\{F(\eta_{1i})\} + \ln\{f(\mu_{1i}/\sigma_{\mu1})/\sigma_{\mu1}\}] + (1 - I_i) w_i [\ln\{1 - F(\eta_{2i})\} + \ln\{f(\mu_{2i}/\sigma_{\mu2})/\sigma_{\mu2}\}])$$

Where F is a cumulative normal distribution function, f is a normal density function, w_i is an optimal weight for observation i and

$$\eta_{ji} = \frac{(\alpha Z_i + \rho_j \mu_{ji}/\sigma_{\mu j})}{\sqrt{1-\rho_j^2}} \quad (j = 1, 2).$$

Where, ρ_j is the correlation coefficient between the selection equation ε_i and μ_{1i} ($\rho_{beneficiary}$), and between ε_i and μ_{2i} ($\rho_{non\text{-}beneficiary}$). ρ_j are statistically significant in endogenous switching and selection bias.

Upon the estimates of β_1 and β_2, both conditional and unconditional expectation of crop incomes for both beneficiaries and non-beneficiaries of canal irrigation were calculated. In this type of study, crop incomes in counterfactual situations cannot be observed, i.e., (i) when beneficiary could not use canal irrigation and (ii) when non-beneficiary could use canal irrigation. Their counterfactual value was estimated through β_1 and β_2 considering beneficiaries using canal irrigation as a treatment group. To calculate average treatment effect on treated (ATT), the actual crop income (observed) and its counterfactual crop income for beneficiaries were differentiated. Similarly, average treatment effect on untreated (ATU) is calculated as the difference between the actual (observed) and counterfactual crop incomes for non-beneficiaries. This was done following approach by Di Falco and Veronesi (2013).

Expected crop income of beneficiaries (observed) with canal irrigation use is

$$E\,(Y_{1i}|I = 1) = X_{1i}\ \beta_1+\sigma_{\mu 1\varepsilon}\ \rho_{beneficiary} \qquad (5)$$

Expected crop income of beneficiaries without irrigation use (counterfactual) is

$$E\,(Y_{2i}|I = 1) = X_{2i}\ \beta_2+\sigma_{\mu 2\varepsilon}\ \rho_{beneficiary} \qquad (6)$$

Expected crop income of non-beneficiary without irrigation use (observed) is

$$E\,(Y_{2i}|I = 0) = X_{2i}\ \beta_2+\sigma_{\mu 2\varepsilon}\ \rho_{non\text{-}beneficiary} \qquad (7)$$

Expected crop income of non-beneficiary with irrigation use (counterfactual) is

$$E\,(Y_{1i}|I = 0) = X_{1i}\ \beta_1+\sigma_{\mu 1\varepsilon}\ \rho_{non\text{-}beneficiary} \qquad (8)$$

Where ρ_k, k = (beneficiary, non-beneficiary) are inverse Mills ratios of the two regime equations, respectively.

Using equations (5) and (6) yields ATT as follows:

$$ATT = E\,(Y_{1i}|\ I = 1) - E\,(Y_{2i}|\ I = 1) \qquad (9)$$

Likewise, using equations (7) and (8) yields ATU as follows:

$$ATU = E\,(Y_{1i}|\ I = 0) - E\,(Y_{2i}|I = 0) \qquad (10)$$

Computation of equations (9) and (10) follows the procedures introduced by Lokshin and Sajaia (2004) and gives further insight on the impact of canal irrigation scheme when non-beneficiary could use canal irrigation or when beneficiary could not use canal irrigation.

For Objective - 4

The descriptive analysis and Principal Component Analysis (PCA) were used to explain on objective - 4: to observe the current collective activities of water management by canal irrigation beneficiaries in the study area.

Data collection was conducted on households of beneficiaries in the study area to get information on the current collective activity including water management.

For Objective - 5

The Tobit model was used to explain objective - 5: to examine factors influencing on water management activities through collective action in the study area.

In the studies of collective activities, participation is considered as a choice and step-wise decision, where respondents either participate or not (Fischer & Qaim, 2012). Under such circumstances, binary choice models were applied to analyze the determinants. However, this study could not consider the binary option due to the multidimensional nature of activities involved in water management. A respondent might be participating in one activity and not in others; as such it is logical to generate a composite index that captures the greatest number of possible collective activities that farmers are expected to engage in. Participation in some activities of water management under the PYPIP command area is mandatory for all farmers. Besides, participation in canal water management in the PYPIP is multi-dimensional; hence, Principal Component Analysis (PCA) was used to generate a composite index of participation. The variables representing the various forms of farmers' participation in collective action were not orthogonal; hence PCA reduced the dimensionality of variables (Manyong, Okike & Williams, 2006) and decomposed variations in the variables included in the analysis into orthogonal components, each having a characteristic unique from the others (Dunteman, 1989; Fujiie et al., 2005).

Participation in activities, therefore, were ranked using a 5-point Likert scale from zero (0) if a farmer is not involved in a given activity, to four (4) if he or she is highly involved. The rankings were then used to compute the participation index (PI) using Principal Component Analysis (PCA) for individual farmers in water-related activities.

The forms of participation in collective activities by farmers are assumed to have equal weights. This may be queried where farmers value the forms of contribution differently; for example, one farmer might value labour contribution more than financial contribution or attending meetings. Differences in value allocation might be emanating from different socio-economic status of respondents or the characteristics of the resource. The complexity of allocating specific values to the various forms of participation resulted in the current implicit assumption about equal weights. The participation index (PI) was therefore used as a proxy to measure farmers' involvement in collective action.

Then the Tobit model was used to examine factors influencing water management activities in the study area. The model, which was first proposed by James Tobin (Tobin, 1958), involves aspects of probit analysis, and it is suitable when the response (dependent) variable is censored. Stewart (2009) reported that the Tobit model is the predominant and, seemingly, sensible approach to use as it is developed specifically for situations where the dependent variable is truncated at zero or another cutoff. Although the Tobit estimation is a regression model, it is different from the Ordinary Least Squares (OLS) regression model, as it provides one coefficient for each of the explanatory variables despite the fact that there are two distinct types of response variables (censored and uncensored). Using OLS yield asymptotically biases estimates. Estimating a model that omits the limit observations would create a bias and ignoring them would be discarding relevant information, yet including these observations as though they were ordinary observations also creates a bias. These limitations are overcome by using a censored sample Tobit model. The Tobit model has been used in studies to determine not only use/exploitation, but also the extent of use or expenditures. The Tobit procedure is a logical extension of the probit analysis model based on accumulative normal distribution. Sigelman and Zeng (1999) posited that, theoretically, the standard Tobit model is applicable only if the underlying dependent variable contains negative values censored to zero in the empirical realization of the variable.

In practice, though, the Tobit model is routinely employed when the values of the observed dependent variable are exclusively nonnegative and are clustered at zero, irrespective of whether any censoring has occurred. In economic models, this corresponds to a corner solution in the utility maximization program where the individual's optimal value of the dependent variable is negative, but non negativity constraints force the value to be zero (Stewart, 2009). The partial derivative obtained from estimation describes two effects that the explanatory variable has on the response variable. The first effect implies that a marginal change in the explanatory variable would change the response variable for those cases closer to the limit (threshold), while the second effect indicates that a marginal change in the explanatory variable would change the probability of being below the threshold.

Changes in explanatory variables also lead to changes in the cumulative standard normal distribution function, and the response variable also changes accordingly (Adesina & Zinnah, 2002; McDonald & Moffitt, 1980). In considering collective activities, members have only two options: to participate or not to participate in some or all of the activities. This gives the dependent variables a special feature: that it is either equal to zero or it is positive; since participation cannot be negative (censored in the lower tail).

The PCA-derived composite index of participation (σ) was used as the dependent variable. Given right- and left-censoring at minimum (σ_{min}) and maximum (σ_{max}) score, respectively, the 2-limit Tobit model (Maddala, 1986) was used as follows:

$\sigma_i^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i X_i + \mu_i$

$\sigma_i = \sigma_{min}$ if $\sigma_i^* \leq \sigma_{min}$ e.i farmer is not involved in collective activity,

$\sigma_i = \beta'(X_i) + u_i$ if $\sigma_{min} \leq \sigma_i^* \leq \sigma_{max}$ e.i farmer is involved in a collective activities,

$\sigma_i = \sigma_{max}$ if $\sigma_i^* \geq \sigma_{max}$ e.i farmer is highly involved in collective activities.,

where, σ_i^* is an unobservable latent response variable, and X_i is an observable vector of explanatory variables. β_i is a vector of parameters to be estimated and u_i is a vector of independently and normally distributed residuals with a common variance θ.

The vector of independent parameter estimates is embedded in the coefficient vector β (Wooldridge, 2010), consisting of demographic, institutional and socio-economic factors. The model adjusts better to a probability curve by using a normal distribution function to estimate the probability of a certain ranking (Greene & Hensher, 2010).

CHAPTER IV

RESULTS AND DISCUSSION

4.1 General Information of Sample Farm Households

4.1.1 Demographic characteristics of respondents

In this study, 285 sampled farmers from the Pyawt Ywar pump irrigation project area were divided into 208 beneficiaries who could access canal irrigation water and 77 non-beneficiaries who could not access canal irrigation water.

Table 4.1 provides demographic characteristics for beneficiary and non-beneficiary respondents. The average age of the beneficiary respondents was 50.1 years while that of the non-beneficiary respondents was 47.7 years. The t-test showed that there was no significant difference in the average age of these two groups.

Among beneficiary households, there were 85.6% of male headed households and 14.4% of female headed households. In the case of non-beneficiaries, male headed and female headed households were 87.0% and 13.0% respectively (Table 4.1).

To measure the education level of respondents, 4 categories (primary level, secondary level, high school level or university level) were used. The number of respondents in the study area who had graduated from university, was 2 in the irrigation beneficiary households, and 7 in irrigation non-beneficiary households. In terms of education level, 77.9%, 16.9%, 2.6% and 2.6% of non-beneficiary respondents had primary, secondary, high school and university graduated education level respectively, while 74.0%, 14.4%, 8.2% and 3.4% of beneficiary respondents had primary, secondary, high school and university graduated education level respectively. The average year of schooling for beneficiary respondents was 4.3 years and that of non-beneficiary respondents was 4.0 years (Table 4.1). The t-test showed that there was no significant difference in the average years of schooling of respondents between two groups.

Concerning respondents' marital status, married (85.6%), single (10.1%), and widowed (4.3%) were found in the beneficiary households whilst in the non-beneficiary households, 79.2% of respondents were married, while 15.6% were single and 5.2% were widowers (Table 4.1).

On average, the beneficiary respondents had an average farming experience of 24.8 years while the non-beneficiary respondents had 23.3 years. The t-test showed that there was no significant difference in years of farming experience between two groups (Table 4.1).

4.1.2 General information of sample farm households

The average family size for both beneficiaries and non-beneficiaries was 4.8 persons. The t-test showed that the family size was not significantly different between the two groups. In beneficiaries, 2.2 and 2.6 of average household members were males and females respectively. In non-beneficiaries, male and female members varied as 2.2 and 2.7 members. Therefore, average male and female members were similar in both groups (Table 4.2).

The average number of dependent family members for the beneficiary households was 1.5 persons and that of the non-beneficiary household was 1.9 persons. The t-test showed that there was a significant difference in the average numbers of dependent family member between two groups (Table 4.2).

The average figure for active labour force in beneficiary households was 3.2 persons and that of the non-beneficiary household was 3.0 persons. The t-test showed that there was no significant difference in the average numbers of active labour force between two groups.

The average family farm labour of the beneficiary households was 3.2 and 2.9 persons for the non-beneficiary households. The t-test showed that there was no significant difference in family farm labour between two groups. In beneficiary households, on average 1.7 and 1.5 of farm labour were males and females respectively. In non-beneficiary farm households, both male and female farm labour were 1.5 persons respectively. Therefore, average male and female family farm labour were similar in both groups (Table 4.2).

In this study, as shown in Table 4.2, the average farm size owned by beneficiaries was 3.7 ha and the non-beneficiaries owned on an average of 3.3 ha. The t-test showed that there was no significant difference in the average area of farm size owned between two groups.

Table 4.1 Demographic characteristics of respondents

Items	Unit	Farm household (n=285)		t-test
		Beneficiary (n=208)	Non-beneficiary (n=77)	
Age	year	50.1	47.7	1.8^{ns}
Gender				
Male	number	178 (85.6)	67 (87.0)	
Female	number	30 (14.4)	10 (13.0)	
Education	year	4.3	4.0	0.8^{ns}
Primary	number	154 (74.0)	60 (77.9)	
Secondary	number	30 (14.4)	13 (16.9)	
High School	number	17 (8.2)	2 (2.6)	
Graduated	number	7 (3.4)	2 (2.6)	
Marital status				
Married	number	178 (85.6)	61 (79.2)	
Single	number	21 (10.1)	12 (15.6)	
Widow	number	9 (4.3)	4 (5.2)	
Farming experience	year	24.8	23.3	0.9^{ns}

Note: Value in parentheses presents percentage. ns = not significant.

Table 4.2 General information of sample farm households

Items	Unit	Farm household (n=285)		t-test
		Beneficiary (n=208)	Non-beneficiary (n=77)	
Family member	number	4.8 (1.6)	4.8 (1.5)	0.4^{ns}
Male	number	2.2 (1.0)	2.2 (0.9)	
Female	number	2.6 (1.3)	2.7 (1.2)	
Dependent	number	1.5 (1.3)	1.9 (1.4)	
Active labour force	number	3.2 (1.3)	3.0 (1.3)	
Family farm labour	number	3.2 (1.6)	2.9 (1.5)	0.2^{ns}
Male farm labour	number	1.7 (0.9)	1.5 (0.8)	
Female farm labour	number	1.5 (1.2)	1.5 (1.2)	
Average farm size	hectare	3.7 (2.7)	3.3 (2.7)	1.2^{ns}
Upland	hectare	1.5 (1.6)	2.0 (2.1)	-2.0**
Low land	hectare	1.8 (1.5)	1.1 (0.9)	4.4***
Alluvial land	hectare	0.4 (0.9)	0.2 (0.4)	

Note: Value in parentheses presents standard deviation.

** and *** present significant at 5% and 1% levels. ns = not significant.

In the study area, sample households raised livestock including cattle, goats and sheep. The number of livestock on their holding was converted into a common unit as the Tropical Livestock Unit (TLU) which is equal to the product of animal and related animal coefficient. In this study, animal coefficients were adopted from Storck, et al., (1991) (Appendix 3). The average of livestock units were 3.42 and 3.36 for beneficiaries and non-beneficiaries, respectively. The t-test showed that there was no significant difference in the average holding livestock unit between two groups (Table 4.3).

Irrigation water is one of the inputs in farming and having sufficient water sources can reduce production risk. In the study area, there were several water sources for crop production; not only scheme canal water but also tube well, lake and the Mu River. About 30% beneficiaries additionally received irrigation water from other water sources. About half of non-beneficiaries (46.7%) relied on rain water and the rest of them had lake and tube well water sources for crop production (Table 4.4).

Table 4.3 Livestock unit asset of sample farm households

Types of animal	Livestock unit asset	
	Beneficiary (n=208)	Non-beneficiary (n=77)
Bullock/Ox	1.8 (1.5)	1.6 (1.5)
Cow	1.1 (2.2)	1.4 (3.5)
Calf	0.2 (0.4)	0.2 (0.7)
Dairy cow	0.3 (2.9)	0.1 (0.6)
Goat	0.1 (1.1)	-
Sheep	0.02 (0.3)	0.04 (0.3)
Average livestock unit	3.4 (4.6)	3.4 (4.8)
t-test	0.11^{ns}	

Note: Value in the parentheses presents standard deviation. ns = not significant.

Table 4.4 Water sources for crop production of sample farm households

Water sources	Water source asset (No. of household)	
	Beneficiary (n=208)	Non-beneficiary (n=77)
Canal	142 (68.3)	
Canal + Tube well	27 (13.0)	
Canal + Lake	26 (12.5)	
Canal + Lake + Tube well	10 (4.8)	
Canal + Lake + Mu River	2 (1.0)	
Canal + Tube well + Mu River	1 (0.5)	
Lake		22 (28.6)
Tube well		10 (13.0)
Lake + Tube well		4 (5.2)
Lake + Mu River		3 (3.9)
Mu River		2 (2.6)
Rain-fed only		36 (46.7)

Note: Value in the parentheses presents percentage.

4.1.3 Primary and secondary occupations of family members of sample farm households

Family members of all farm households in the study areas worked in their own farms as their primary occupation. There were 669 working family members in beneficiary households and 228 working family members in non-beneficiary households. In Table 4.5, the primary occupations of family members of beneficiary and non-beneficiary households are presented. Primary occupations among working family members included farmer, agricultural wage labour, self-employment such as green-grocer/vendor, weaver/tailor and traditional baker, salary earner such as company and government staff and other wage labour such as bricklayers. A majority (80%) of family members were working as farmers in both beneficiary and non-beneficiary households, followed by 9% and 14% of self-employment. Agricultural wage labour was found in 4.8% and 2.6% of beneficiary and non-beneficiary farm household members respectively. Regarding primary occupation of beneficiary household members, other occupations were salaries earner (4.8%), vending (2.8%), tailor (2.4%) and other wage labour (1.9%). However, for non-beneficiary household members, primary occupations were tailor (9.6%), salary earners (3.1%), and other wage labour (0.9%).

Table 4.6 demonstrates family members' secondary job holding condition. Secondary job holding family members of beneficiary households were 102 family members and that of non-beneficiary households were 26 family members. Among secondary occupation holders of beneficiary households, there were agricultural wage labour (41.2%), self-employment (53.9%), salary earner (2.9%) and other wage labour (2.0%). Secondary occupations of non-beneficiary farm household member were agricultural wage labour (50.0%), self-employment (42.3%), salary earner (3.8%) and other wage labour (3.8%). As results, irrigation scheme leads to different employment consequences for beneficiaries and non-beneficiaries. As it also leads to a given change in total labour requirements, family members of both groups highly engaged in irrigated farming as agricultural wage labour. It can be explained that beneficiary households had more secondary occupations due to their former jobs taken before starting pump irrigation.

Table 4.5 Primary occupations of family members of sample households

Types of primary job	Farm household member (n=897)	
	Beneficiary (n=669)	Non-beneficiary (n=228)
Farming	**532 (79.5)**	**181 (79.4)**
Agricultural wage labour	**32 (4.8)**	**6 (2.6)**
Self-employment	**60 (9.0)**	**32 (14.0)**
Green grocer/Vending	19 (2.8)	10 (4.4)
Weaver/Tailor	16 (2.4)	22 (9.6)
Vending traditional cake	12 (1.8)	
Residence cum shop	8 (1.2)	
Animal husbandry	2 (0.3)	
Other self-employments	3 (0.5)	
Salary earner	**32 (4.8)**	**7 (3.1)**
Company staff	14 (2.1)	5 (2.2)
Government staff	14 (2.1)	
Private factory labour	4 (0.6)	2 (0.9)
Other wage labour	**13 (1.9)**	**2 (0.9)**
Wage labour	5 (0.7)	1 (0.4)
Bricklayer	4 (0.6)	1 (0.4)
Car driver	4 (0.6)	

Note: Value in parentheses presents percentage.

Table 4.6 Secondary occupations of family members of sample households

Types of secondary job	Farm household member (n=128)	
	Beneficiary (n=102)	Non-beneficiary (n=26)
Agricultural wage labour	**42 (41.2)**	**13 (50.0)**
Self-employment	**55 (53.9)**	**11 (42.3)**
Weaver/Tailor	15 (14.7)	7 (26.9)
Animal husbandry	7 (6.9)	1 (3.8)
Driver	6 (5.9)	
Carpenter	5 (4.9)	1 (3.8)
Broker	5 (4.9)	
Green grocer/Vending	5 (4.9)	
Agricultural machine rental service	4 (3.9)	
Other self-employments	8 (7.8)	2 (7.7)
Salary earner	**3 (2.9)**	**1 (3.8)**
Other wage labour	**2 (2.0)**	**1 (3.8)**

Note: Value in parentheses presents percentage.

4.1.4 Income source diversification of sample farm households

Household income source diversification is related to the job opportunity and capacity of the household. Table 4.7 presents income source diversification of sample farm households. About 38% beneficiary households and 45.5% of non-beneficiary households have only one income source. This implies that those households relied only on farm earnings. The households which have a couple of income sources were found in 40.9% of beneficiary households and 41.6% of non-beneficiary households. There were three income sources in 16.3% of beneficiary households and 11.7% of non-beneficiary households. The four income sources were only found in beneficiary households (about 4%). But there were five income sources in 1% of beneficiary households and 1.3% of non-beneficiary households. It was found that both beneficiaries and non-beneficiaries relied not only on farm income but also on non-farm income.

4.1.5 Structure of non-farm income of sample farm households

Most farmers in the study area were depending largely on on-farm production for their livelihood. Farm households normally diversify incomes rather than relying on a single source. Different non-farm income generating activities of the sample households are described in Table 4.8. The highest proportion of annual nonfarm income was occupied by self-employment in both beneficiary and non-beneficiary households and amounted to approximately 50% of total annual non-farm income. In beneficiary households, as they engaged more in secondary occupations salary and wage labour earnings contributed 25% and 20% respectively to household non-farm income. However, in the proportion of non-farm income, the agricultural wage labour earning proportion of non-beneficiary households (about 11%) was higher than that of beneficiary households (about 8%). The average non-farm income of beneficiary farm households was higher than that of non-beneficiary farm households. The t-test showed that there was a significant difference in the non-farm income between two groups. In the study area, self-employment activities were much more than other income activities.

Table 4.7 Income source diversification of sample farm households

No. of job per household	Farm household (n=285)	
	Beneficiary (n=208)	Non-beneficiary (n=77)
One job	78 (37.5)	35 (45.5)
Two jobs	85 (40.9)	32 (41.6)
Three jobs	34 (16.3)	9 (11.7)
Four jobs	9 (4.3)	
Five jobs	2 (1.0)	1 (1.3)

Note: Value in parentheses presents percentage.

Table 4.8 Annual non-farm income of sample farm households

(Unit: thousand MMK)

Types of job	Non-farm income	
	Beneficiary (n=208)	Non-beneficiary (n=77)
Self-employment	609.2 (45.2)	491.4 (58.0)
Salary earner	342.9 (25.2)	176.4 (20.8)
Other wage labour	278.0 (20.6)	84.4 (10.0)
Agricultural wage labour	118.3 (8.8)	95.3 (11.2)
Average non-farm income	1,348.4 (100.0)	847.5 (100.0)
t-test	2.2^{**}	

Note: Value in parentheses presents percentage. ** presents significance at 5% level.

4.1.6 Seasonal crop grown by the sample farm households

In this study, most of beneficiaries and non-beneficiaries grew crops in the monsoon and winter (Table 4.9). About half (46%) of beneficiaries grew crops in three seasons as they received irrigation water for crop production while 41.6% of non-beneficiaries grew crops in two seasons (monsoon and winter). As the main canal of Pump station-1 had the most favorable access to irrigation water and served as a temporary reservoir of Pump station-2 and Pump station-3, the beneficiaries in this command area of Pump station-1 could grow more crops in three seasons. But due to plot position and irrigation water accessibility, some beneficiaries did not grow crops in all seasons. Only monsoon crop cultivation was found in 9.1% of beneficiaries and 6.5% of non-beneficiaries. Moreover, 5.2% of the non-beneficiaries cultivated winter crops only. As non-beneficiaries possessed more acreage of upland compared to beneficiaries and changes in rainfall pattern, they mainly cultivated upland crops in the winter for getting sufficient soil moisture by preparing land in the monsoon. Moreover they could cultivate crops in the winter because they possessed alluvial land and received irrigation water from lakes and tube wells.

4.1.7 Crop diversification of sample farm households

Crop diversification is related to water availability, farmer preference and farm resource endowment. In the summer season, 82% of beneficiaries and 89% of non-beneficiaries could produce only one type of crop. The other farmers were able to produce more than one crop (Table 4.10).

In the monsoon season the majority of farmers produced only one crop; 62.4% of beneficiary and 46% of non-beneficiary households respectively. About half that amount produced two crops. Of the households that produced three or more crops the largest amount was produced by non-beneficiary households whilst the number of beneficiary households dropped to 8.9% (Table 4.10).

In the 2017 winter crop season, one crop was cultivated by about 60% of both beneficiaries and non-beneficiaries. Two crops were grown by about 35% each of the beneficiaries and non-beneficiaries. However, three crops were grown by 4.8% of beneficiaries and 7.6% of non-beneficiaries. Only 0.6% of beneficiaries were able to grow four crops in the winter season. Non-beneficiaries could diversify more crops in winter season compared with beneficiaries (Table 4.10).

In the summer crop season, beneficiaries diversified into more crops than non-beneficiaries as they received canal irrigation water as shown in Table 4.11. In the study area, the number of summer crop growers was 126 for beneficiaries and 36 for non-beneficiaries. Among the summer crop growers, green gram was grown by 50.8% of beneficiaries only. Summer rice was grown by 43.7% of the beneficiaries compared with 66.7% of the non-beneficiaries. About 13.5% of beneficiaries and 16.7% of non-beneficiaries grew sesame on alluvial land as a summer crop. Horticultural crops such as tomato, okra, cucumber etc. were cultivated by 10.3% of the beneficiaries and 27.8% of the non-beneficiaries respectively. Beneficiaries irrigated some crops in summer using canal water, lake and tube-well water while water sources of non-beneficiaries for summer crops were lakes and tube-wells.

In the monsoon season, both beneficiaries and non-beneficiaries cultivated rice especially for home consumption and animal feed. They also grew oil seed crops, other cereal crops, cash crops and horticultural crops as 2016 monsoon crops (Table 4.12). In the study area, the number of monsoon crop growers was 202 for beneficiaries and 63 for non-beneficiaries. Although approximately 99% of beneficiaries could grow monsoon rice, 1% could not grow monsoon rice. The fact is that some of their lowlands were highly flooded resulting in fallow lands, and some farmers preferred growing cash crops which had a higher return per unit land in both winter and summer seasons of 2016-2017 cropping year. Often non-beneficiaries 87% of non-beneficiaries grew monsoon rice but the rest of beneficiaries (13%) could not grow monsoon rice as some of their lowlands did not receive enough precipitation for rice growing and some farmers much preferred growing crops in winter and summer seasons due to the rainfall pattern. About 11% of beneficiaries and 29% of non-beneficiaries produced sunflower. Non-beneficiaries grew more pigeon pea, sorghum, groundnut and horticultural crops but beneficiaries grew more green gram in the monsoon season.

The most cultivated crop in the winter season was chick pea among both groups as shown in Table 4.13. In the study area, the number of winter crop growers was 165 for the beneficiary group and 66 for the non-beneficiary. About 60% of beneficiaries and 40% of non-beneficiaries produced chick pea as a cash crop. As the second most cultivated crop, groundnut was produced by 38% of beneficiaries and 35% of non-beneficiaries on dry land. In the winter crop season, onion and red phaseolus were produced in greater numbers by non-beneficiaries than beneficiaries as cash crops. About 35% of non-beneficiaries produced onions while the beneficiary was 6%. Moreover, red phaseolus was grown as a cash crop by 12% of beneficiaries and 29% of non-beneficiaries. About 19% and 14% of beneficiaries and non-beneficiaries grew wheat on dry land respectively.

4.1.8 Cropping intensity of sample farm households

Cropping intensity can be expressed as the ratio of gross cropped area to net sown area. Increasing the cropping intensity is one way to increase agricultural production whereas the availability of land is fixed. The cropping intensity of beneficiaries and non-beneficiaries in the cropping year of 2016-2017 is shown in Table 4.14. The cropping intensity of beneficiaries ranged from 26 to 300% while that of non-beneficiaries ranged from 23 to 200%. According to the results, there was a high variation in cropping intensity in the study area, with higher levels in beneficiaries. The t-test showed that there was a highly significant difference in cropping intensity between two groups.

Table 4.9 Multiple cropping production of sample farm households

Cropping season	Farm household (n=285)	
	Beneficiary (n=208)	Non-beneficiary (n=77)
Summer - Monsoon - Winter	96 (46.2)	20 (26.0)
Monsoon - Winter	63 (30.3)	32 (41.6)
Summer - Monsoon	24 (11.5)	6 (7.8)
Summer - Winter	6 (2.9)	10 (13.0)
Only Monsoon	19 (9.1)	5 (6.5)
Only Winter	-	4 (5.2)

Note: Value in parentheses presents percentage.

Table 4.10 Seasonal crops diversified by sample farm households

Crop diversification	Farm household	
	Beneficiary	Non-beneficiary
Summer season		
One crop	103 (81.7)	32 (88.9)
Two crops	23 (18.3)	4 (11.1)
Total	126 (100.0)	36 (100.0)
Monsoon season		
One crop	126 (62.4)	29 (46.0)
Two crops	56 (27.7)	17 (27.0)
Three crops	18 (8.9)	13 (20.6)
Four crops	2 (1.0)	4 (6.4)
Total	202 (100.0)	63 (100.0)
Winter season		
One crop	98 (59.4)	38 (57.6)
Two crops	58 (35.2)	23 (34.8)
Three crops	8 (4.8)	5 (7.6)
Four crops	1 (0.6)	-
Total	165 (100.0)	66 (100.0)

Note: Value in parentheses presents percentage.

Table 4.11 Summer crops cultivated by sample farm households

Summer Crops	Frequency of farm household	
	Beneficiary (n=126)	Non-beneficiary (n=36)
Green gram	64 (50.8)	-
Summer rice	55 (43.7)	24 (66.7)
Sesame	17 (13.5)	6 (16.7)
Horticultural crops	13 (10.3)	10 (27.8)

Note: Value in parentheses presents percentage.

Table 4.12 Monsoon crops cultivated by sample farm households

Monsoon Crops	Frequency of farm household	
	Beneficiary (n=202)	Non-beneficiary (n=63)
Rice	199 (98.5)	55 (87.3)
Sunflower	22 (10.9)	18 (28.6)
Sesame	21 (10.4)	7 (11.1)
Pigeon pea	17 (8.4)	8 (12.7)
Sorghum	9 (4.5)	9 (14.3)
Horticultural crops	9 (4.5)	9 (14.3)
Green gram	7 (3.5)	1 (1.6)
Groundnut	5 (2.5)	11 (15.5)

Note: Value in parentheses presents percentage.

Table 4.13 Winter crops cultivated by sample farm households in the study area

Winter Crops	Frequency of farm household	
	Beneficiary (n=165)	Non-beneficiary (n=66)
Chickpea	96 (58.2)	24 (36.4)
Groundnut	62 (37.6)	23 (34.9)
Wheat	32 (19.4)	9 (13.6)
Red phaseolus	20 (12.1)	19 (28.8)
Onion	10 (6.1)	23 (34.9)
Green gram	16 (9.7)	1 (1.5)
Black gram	6 (3.6)	

Note: Value in parentheses presents percentage.

Table 4.14 Cropping intensity of sample farm households (2016-2017)

Items	Cropping intensity (%)		t-test
	Beneficiary (n=208)	Non-beneficiary (n=77)	
Mean	114.1	94.5	3.0^{***}
Minimum	25.8	22.7	
Maximum	300.0	200.0	
SD	52.2	39.3	

Note: *** presents significance at 1% level.

4.1.9 Summer crop income of sample farm households

The largest share of summer crop income came from green gram production for beneficiaries and summer rice production for non-beneficiaries (Table 4.15). The results showed that about 44% of the summer crop income for beneficiaries came from green gram production, followed by summer rice (about 40%) and horticultural crops production (about 12%). Non-beneficiaries had about 59% of the summer crop income from summer rice production which provided the largest share of the summer crop income, followed by horticultural crops (33%) and sesame (8.3%). As beneficiaries could produce irrigated crops in the summer using canal irrigation, their average summer crop income (553.6 thousand MMK) was higher than that of non-beneficiaries (244.0 thousand MMK).

4.1.10 Monsoon crop income of sample farm households

In the monsoon season, monsoon rice was mostly grown in the study area. The largest share of monsoon crop income came from monsoon rice and pigeon pea (Table 4.16). Monsoon rice and pigeon pea contributed 75% and 19% respectively for beneficiaries followed by sesame (2.6%) and green gram (1.2%). Non-beneficiary farmers depended more heavily on pigeon pea which provided about 52 % of their income. For non-beneficiaries, pigeon pea growing provided the largest share of monsoon crop income, followed by monsoon rice (25%) and horticultural crops (11.2%). As beneficiaries could produce monsoon rice using canal irrigation, their average monsoon crop income (1,408.6 thousand MMK) was higher than that of non-beneficiaries (996.5 thousand MMK).

4.1.11 Winter crop income of sample farm households

The largest share of winter crop income came from groundnut and onions production (Table 4.17). Onions produce the largest share of winter crop income for non-beneficiaries. The results showed 38% of winter crop income coming from groundnut followed by onions (about 24%) and wheat (about 11%) for beneficiaries. It was significant that non-beneficiaries about 88% of winter crop income from onion growing. They also got income from groundnut and red phaseolus crop production. As non-beneficiaries intensely produced onion in winter using tube-well irrigation, their average winter crop income (2,230.7 thousand MMK) was significantly higher than that of beneficiaries (439.6 thousand MMK).

Table 4.15 Summer crop income of sample farm households

(Unit: thousand MMK)

Crops	Summer crop income			
	Beneficiary (n=208)		Non-beneficiary (n=77)	
	Average	%	Average	%
Green gram	244.9	44.2	-	-
Summer rice	220.9	39.9	143.1	58.7
Horticultural crops	65.7	11.9	80.5	33.0
Sesame	21.9	4.0	20.4	8.3
Average summer crop income	553.6	100.0	244.0	100.0

Table 4.16 Monsoon crop income of sample farm households

(Unit: thousand MMK)

Crops	Monsoon crop income			
	Beneficiary (n=208)		Non-beneficiary (n=77)	
	Average	%	Average	%
Monsoon rice	1,055.7	74.9	249.3	25.0
Pigeon pea	263.8	18.7	521.6	52.3
Sesame	35.9	2.6	18.4	1.8
Green gram	17.5	1.2	6.9	0.7
Sunflower	14.5	1.0	35.3	3.5
Horticultural crops	9.7	0.7	111.8	11.2
Groundnut	6.6	0.5	41.5	4.2
Sorghum	4.9	0.4	11.8	1.2
Average monsoon crop income	1,408.6	100.0	996.5	100.0

Table 4.17 Winter crop income of sample farm households

(Unit: thousand MMK)

Crops	Winter crop income			
	Beneficiary (n=208)		Non-beneficiary (n=77)	
	Average	%	Average	%
Groundnut	167.9	38.2	131.5	5.9
Onion	105.1	23.9	1,959.4	87.8
Wheat	47.5	10.8	43.1	1.9
Green gram	41.7	9.5	6.6	0.3
Chickpea	40.1	9.1	21.3	1.0
Red phaseolus	36.5	8.3	68.8	3.1
Black gram	0.8	0.2	-	-
Average winter crop income	439.6	100.0	2,230.7	100.0

4.1.12 Crop income of sample farm households

Monsoon crops make up the largest portion of the annual crop income for beneficiary farmers, running at about 60% (Table 4.18). Conversely, non-beneficiaries received about 65% of annual crop income from winter crop production. For non-beneficiary households, winter crop production provided the highest share of annual crop income and followed by income from monsoon crop production. Although beneficiaries could produce crops in three seasons, their average annual crop income (2,401.8 thousand MMK) was less than that of non-beneficiaries (3,471.2 thousand MMK). This is because beneficiaries mainly grew rice in the summer and monsoon, but non-beneficiaries produced cash crops with a high rate of return (such as onion) in winter. Beneficiaries were confronted with a lack of choice in that they could not grow onions if the farmer in the adjacent field was growing a different crop. This is because the land is over saturated due to rice growing. In addition, production costs were relatively higher for some beneficiaries so they chose to focus on rice growing to get rice straw for animal feed. The t-test showed that there was a significant difference in the annual crop income between two groups.

Table 4.18 Annual crop income of sample farm households

(Unit: thousand MMK)

Crop income	Crop income	
	Beneficiary (n=208)	Non-beneficiary (n=77)
Monsoon crops	1,408.6 (58.6)	996.5 (28.7)
Summer crops	553.6 (23.1)	244.0 (7.0)
Winter crops	439.6 (18.3)	2,230.7 (64.3)
Average crop income	2,401.8 (100.0)	3,471.2 (100.0)
t-test	2.0^{**}	

Note: Value in parentheses presents percentage. ** presents significance at 5% level.

4.1.13 Household income composition of the sample farm household

The income share from non-farm activities such as the wages and salaries of governmental and company staff, construction works, weaving, tailoring, vending and owning grocery stores, etc. was about 36% of annual household income in beneficiary households whereas non-beneficiary households received about 20% of annual household income from non-farm activities. In household income composition, income share of crop production (80%) was higher than the share of non-farm activities (20%) in non-beneficiary households. In the study area, both beneficiaries and non-beneficiaries relied not only on farm income but also on non-farm income. The income from non-farm activities of beneficiaries contributed in household income more than that of non-beneficiaries. Moreover beneficiaries' average monsoon and summer crop income was higher than that of non-beneficiaries. Non-beneficiaries' average winter crop income was higher than that of beneficiaries. This was because beneficiaries mainly grew rice in the summer and monsoon, but non-beneficiaries produced cash crops with a high rate of return (such as onion) in winter. Therefore non-beneficiaries' crop income was higher than that of beneficiaries. Average annual household incomes were 3,750 and 4,318 thousand MMK in beneficiaries and non-beneficiaries respectively. The t-test showed that there was no significant difference in the household income between beneficiaries and non-beneficiaries (Table 4.19).

4.1.14 Involvement of the sample farm households in social organizations

The involvement of sample households in social organizations was demonstrated in Table 4.20. In the study area, some types of social and development activities were mandatory in some villages. The group activities were found as working together in religious donation ceremonies, building and repairing of roads, bridges, public buildings such as clinics, schools, and so on.

The social organization in which all households were most involved was the village social-help groups where about 36% of beneficiary households and 40% of non-beneficiary households participated. In the study area, about each 9% of beneficiary households were involved in cooperative associations, village religious groups and village development activities. However, only about 9% of non-beneficiary households were involved in the cooperative association. Moreover, the involvement of non-beneficiary households in village religious group and village development groups was relatively lower when compared with beneficiary households' involvement. About 7% of beneficiary households were involved in the village administration whereas non-beneficiary households were only about 3%. In savings and loans associations, only beneficiary households (5%) were involved. About 25% and 36% of beneficiary and non-beneficiary households respectively were not involved in any social organization. Involvement of beneficiary households in social organizations was higher than that of non-beneficiary households.

Table 4.19 Annual household income of sample farm households

(Unit: thousand MMK)

Household income	Household income	
	Beneficiary (n=208)	Non-beneficiary (n=77)
Annual crop income	2,401.8 (64.0)	3,471.2 (80.4)
Annual non-farm income	1,348.4 (36.0)	847.5 (19.6)
Average household income	3,750.2 (100.0)	4,318.7 (100.0)
t-test	1.0^{ns}	

Note: Value in parentheses presents percentage. ns = not significant.

Table 4.20 Social organization involved by sample farm households

Types of organization	Farm household (n=285)	
	Beneficiary (n=208)	Non-beneficiary (n=77)
Village social-help group	74 (35.6)	31 (40.3)
Cooperative association	19 (9.1)	7 (9.1)
Village religious group	19 (9.1)	6 (7.8)
Village development group	19 (9.1)	3 (3.9)
Village administration	15 (7.2)	2 (2.6)
Saving and loan association	10 (4.8)	-
Not involved	52 (25.0)	27 (35.5)

Note: Value in parentheses presents percentage.

4.2 Decision Making Behavior of Sample Farm Households

4.2.1 Gender participation in decision making on farming activities

In terms of gender participation in decision making about crop selection, male family members mostly dominated in both beneficiary and non-beneficiary households. Female participation in decision making about crop selection was about 15% for beneficiary households and 16% for non-beneficiary households. The respondents from beneficiary households (21%) and non-beneficiary households (16%) reported that their household members (both males and females) usually make decision together for crop selection (Table 4.21).

In decision making about seed selection, male family member (> 60%) mostly dominated in this also, followed by joint decision. In both beneficiary and non-beneficiary households, female participation in decision making about crop selection was about 18%. Joint decision of household members (males and females) was found in 20% of beneficiary households and 17% of non-beneficiary households in deciding about seed selection (Table 4.21).

In the 2016-2017 cropping season, the majority of farmers used chemical fertilizers but 2 beneficiaries and 1 non-beneficiary did not use them. In both beneficiary (69%) and non-beneficiary households (76%), male family members particularly decided about fertilizer application in crop management as household heads were male and they were employed particularly in farming. Female participation in decision about fertilizer application was about 13% in both beneficiary and non-beneficiary households. Joint decisions were made in 18% and 11% of beneficiary and non-beneficiary households respectively (Table 4.21).

For crop protection (such as fungicide and insecticide applications) male family members usually made the decision. In the 2016-2017 cropping year, 3 beneficiaries and 2 non-beneficiaries did not apply fungicide and insecticide. In the study area, female participation in the decision making of crop protection was about 14% in beneficiary and 12% in non-beneficiary households respectively. For crop protection, family members decided together in 19% of beneficiary households and 15% of non-beneficiary households (Table 4.21).

Crop marketing is an important activity of a farm household. In this study, a large number of male members in non-beneficiaries participated in decision making about crop marketing but male members and female members participated equally in decision making by beneficiary households. There was a lower participation of male family members in this decision making than other decisions. About 20% each of beneficiary and non-beneficiary household jointly decided on crop marketing (Table 4.21).

In both beneficiary and non-beneficiary households, male family members dominated on decision making in farming activities.

4.2.2 Gender participation in decision making on income generating activities

In this study, non-farm income generating activities which included wage labour occupation, self-employment and salaried occupations were crucial for sample households' livelihoods. Family members usually decided themselves about their occupations for higher skilled employment but for self-employment in business and wage labour cases, family members (males and females) decided jointly on those cases.

For wage labour occupations, about 50% of beneficiary and 46.2% of non-beneficiary households used joint decisions (Table 4.22). Male dominance in decision making was found in 29% and 31% of beneficiary and non-beneficiary households respectively.

In self-employed occupations, family members' joint decision on this occupation was found in about 66% of beneficiary and non-beneficiary households followed by female decision and male decision (Table 4.22).

In beneficiary and non-beneficiary households, male participation in the decision making about salaried occupations was found in 44% of beneficiary and 57% of non-beneficiary households respectively. Female participation in decision making on salaried occupations was found in 30% of beneficiary households and 14% of non-beneficiary households (Table 4.22).

Table 4.21 Decision making on farming activities of sample farm households

Decision maker	Farm household (n=285)	
	Beneficiary (n=208)	Non-beneficiary (n=77)
1. Crop selection		
Male	133 (63.9)	53 (68.8)
Female	31 (14.9)	12 (15.6)
Joint	44 (21.2)	12 (15.6)
2. Seed selection		
Male	129 (62.0)	50 (64.9)
Female	38 (18.3)	14 (18.2)
Joint	41 (19.7)	13 (16.9)
3. Fertilizer application		
Male	142 (68.9)	58 (76.3)
Female	28 (13.6)	10 (13.2)
Joint	36 (17.5)	8 (10.5)
4. Crop protection		
Male	139 (67.8)	55 (73.3)
Female	28 (13.7)	9 (12.0)
Joint	38 (18.5)	11 (14.7)
5. Crop marketing		
Male	82 (39.4)	36 (46.8)
Female	83 (39.9)	26 (33.7)
Joint	43 (20.7)	15 (19.5)

Note: Value in parentheses presents percentage.

Table 4.22 Decision making on income generating activities of sample farm households

Decision maker	Farm household (n=78)	
	Beneficiary (n=65)	Non-beneficiary (n=13)
1. Wage labour occupation		
Male	19 (29.2)	4 (30.8)
Female	13 (20.0)	3 (23.1)
Joint	33 (50.8)	6 (46.2)
2. Self-employment occupation		
Male	11 (15.7)	4 (13.3)
Female	13 (18.6)	6 (20.0)
Joint	46 (65.7)	20 (66.7)
3. Salary occupation		
Male	10 (43.5)	4 (57.1)
Female	7 (30.4)	1 (14.3)
Joint	6 (26.1)	2 (28.6)

Note: Value in parentheses presents percentage.

4.3 Descriptive Statistics of Variables Used in FIML ESR Model

The descriptive statistics of the data for the variables used in the model estimation are presented in Table 4.23. The average years of schooling undertaken by the respondents of the two groups were similar. There was also little difference between the averages farming experience of the two groups. The average family size and farm size were not statistically different between the two groups. However, there were differences in annual crop income and non-farm income between the two groups. The non-beneficiaries received higher crop incomes but beneficiaries earned more non-farm income. In facts, beneficiaries mainly grow rice in summer and monsoon, whereas non-beneficiaries produce high return cash crop such as onions in winter besides summer and monsoon rice.

As the results indicated, the average number of livestock held was similar for the two groups. In regard to the distance from the nearest market, beneficiaries had a far greater distance to travel than non-beneficiaries in this study area (Appendix 10). In the study area, there were several water sources, other than canal water, for crop production. These include water from tube wells, lakes and the Mu River. In the determining the number of water sources accessed it was found that beneficiaries accessed more sources than non-beneficiaries (Appendix 9). For the measurement of the female participation in family decision making in farm management activities (crop selection, seed selection, fertilizer application, crop protection and crop marketing), there was no statistical difference between the two groups (Appendix 11). Onion was the predominant cash crop produced by non-beneficiaries in the winter season. The involvement of non-beneficiary households in village development groups was relatively low compared with the involvement of beneficiary households.

4.4 Canal Irrigation Impact on Annual Crop Income

To assess the impact of irrigation on crop income, Full Information Maximum Likelihood Endogenous Switching Regression model was used. The estimated results from the maximum likelihood endogenous switching regression model were presented in Table 4.24. The Full Information Maximum Likelihood approach estimated both the selection and the outcome equations jointly. The selection equations explained the determinants of the likelihood of the sample farmer participating in irrigated farming.

The Wald χ^2 test statistics (106.43) indicated that the selected covariates provided good estimate determinants to apply to the model and they were jointly and statistically significant (pr < 0.01). The likelihood ratio test statistic for joint independence ($\chi 2$ = 8.64, pr = 0.003) showed that the equations were dependent. Also, the chi-square statistic indicated over-identification in the regression specifications of annual crops income and was significantly different from zero at 1% level. The results showed that the selectivity terms ($\rho_{beneficiary}$ and $\rho_{non\text{-}beneficiary}$) were statistically significant, indicating self-selection into irrigated farming by farmers in the study area. This also implied that participation in canal irrigation may impact differently on the non-beneficiaries if they choose to participate (Lokshin & Sajaia, 2004).

The estimation result of the irrigation selection equation was derived from running a probit regression within the endogenous switching regressions for a dichotomous choice of using a canal irrigation scheme. In the study access to water sources was administered as an instrumental variable. The second column of Table 4.24 reported the estimates for the determinants of the decision to use canal irrigation. The market distance and water source improved significantly the probability of participation in canal irrigation. This suggested that farmers were willing to select canal irrigation as it had a lower cost and required less labour compared to other water sources of the study area. Remote farm households were constrained in getting access to proper market infrastructure. The variable of cash crop growing negatively influenced the canal irrigation selection. It may be due to irrigation scheme providing water in the monsoon and summer crop seasons, and onion growers seem to prefer to use other irrigation facilities (tube well) under their self-management in winter season.

The results in the last two columns of Table 4.24 showed that annual crop income function for two groups with the natural logarithm of annual crop income as the dependent variables. The most notable results were about farm holding size and cultivator of onions as a cash crop for both groups. Farm size and cash crop growing appeared to have differential impacts on beneficiaries and non-beneficiaries. Farmers with larger farms have higher annual crop incomes compared to farmer with smaller farms, where a one hectare increase in farm size will raise annual crop income by 13% for irrigation beneficiaries and by 16% for non-beneficiaries.

Similarly, cash crop growing positively affected the annual crop income, indicating that, for beneficiaries, cash crop (onion) growers had 64% higher annual crop income than non-growers and for non-beneficiaries cash crop (onion) growers had 140% higher annual crop income than non-growers. The study showed that cash crop growers received a higher annual crop income than non-growers.

The total holding livestock unit significantly and positively affected crop income for beneficiaries. The result indicated that a one unit increase in livestock holding will raise the annual crop income by 2.1% for beneficiaries.

Non-farm income, market distance and block position were identified as having significant effects on the annual crop income of beneficiaries while such effects were not found for non-beneficiaries. The result indicated that a 100% increase in non-farm income will reduce the annual crop income by 1.3% for beneficiaries. Buying farm inputs and selling farm outputs, as well as market information, were determined by market distance and means of transportation. This implied that high transactional costs due to market distance negatively affected crop income.

Moreover, irrigation beneficiaries in downstream block position (Block 3) would have low water availability for crop production compared with irrigation beneficiaries in upstream block position (Block 1). Low water availability for crop production results in low crop income in downstream block position.

Education of respondents and family size were identified to have negatively significant effects on the crop income for non-beneficiaries while such effects were not found for beneficiaries. It implied that these variables did not contribute to welfare in terms of crop income of non-beneficiaries.

Table 4.23 Description of variables used in the FIML ESR model

Variables	Descriptions	Mean	
		Beneficiary (n=208)	Non-beneficiary (n=77)
Selection variable			
Irrigation	1 = if farm household use irrigation, 0 = farm house not use irrigation		
Outcome variables			
Crop income	Log annual crop income of household (thousand MMK)	2401.8	3471.2
Explanatory variables			
Education	Schooling years of respondent	4.3	4.0
Farming experience	Farming experience of respondent (year)	24.8	23.3
Family size	Total family members in household (no.)	4.8	4.8
Farm size	Total farm size (ha)	3.7	3.3
Non-farm income	Log annual non-farm income of household (thousand MMK)	1,348.4	847.5
Livestock unit	Total livestock unit of household	3.4	3.4
Market distance	Market distance (km)	13.9	11.1
Water source	No. of water source	1.4	0.6
Female participation in farm management	Female participation percentage in decision-making of farm management activities	39.4	33.8
Cash crop growing	1 = if farmer grow cash crop, 0 = otherwise		
Block position	Position of field in Block (Block 1 (upstream)=1, Block 2(middle)=2 and Block 3(downstream)=3)		
Participation in village development group	1 = if household participate in village development group, 0 = otherwise		

Table 4.24 Estimation results of endogenous switching regression: Irrigation impact on sample farmers' annual crop income

Explanatory variable	Irrigation selection	Crop income (Ln)	
		Beneficiary	Non-beneficiary
Education	0.004	0.025	-0.072*
Farming experience	-0.005	0.005	-0.004
Family size	-0.062	0.050	-0.137*
Farm size	0.012	0.127***	0.161***
Non-farm income	0.009	-0.013*	-0.015
Market distance	0.151***	-0.052***	-0.028
Cash crop growing	-1.505***	0.642***	1.402***
Livestock unit	-0.031	0.021**	-0.027
Female participation in decision-making of farm management	0.0005	-0.0007	0.0008
Block position	0.031	-0.292***	0.111
Participation in village development group	0.473	-0.181	-0.275
Water source	2.150***		
Constant	-3.045***	14.896***	14.264***
$Ln\delta_{beneficiary}$, $Ln\delta_{non-beneficiary}$		-0.326***	-0.027
$\rho_{beneficiary}$, $\rho_{non-beneficiary}$		-0.755***	-0.445*
Number of observations			285
Wald χ^2			106.431***
Log pseudo-likelihood			-402.520
Likelihood ratio test for independent equations χ^2			8.641***

Note: *, ** and *** present significance at 10%, 5% and 1% levels.

Source: Own calculation based on parameter estimates in Stata 12

4.4.1 Average expected annual crop income, treatment and heterogeneity effects of irrigation schemes

The impact of canal irrigation was measured by comparing the conditional and counterfactual conditions and presented in Table 4.25. Case (a) and (b) represented the expected annual crop income observed in the sample while case (c) and (d) represented the counterfactual annual crop income (Table 4.25). The average treatment effect on treated farmers (ATT) was measured by finding the difference between the actual average crop income of beneficiaries and the counterfactual income what they would have earned if they had not used canal irrigation. The average treatment effect on untreated farmers (ATU) is indicated by the difference between their actual average crop income of non-beneficiaries and the counterfactual income that they would have earned if they had used canal irrigation. The percentage change of average treatment effects on farmer was calculated in order to provide the realistic interpretations of the treatment effects.

The results of ATT and ATU from the endogenous switching regression estimation showed positive and statistically significant results, indicating that canal irrigation provided significant positive impact on the annual crop income of farmers. As in the results, the access of canal irrigation by beneficiaries caused an increase of about 34% of annual crop income along with the existing use of other water sources. On the other hand, if they did not access it, their crop income would decrease in the same percentage. Based on ATU, if non-beneficiaries accessed canal irrigation, their crop income would increase about 32% with the existing use of other water sources.

The base heterogeneity effect of beneficiaries (BH1) was negative and statistically significant. Under current condition non-beneficiaries produced cash crops with a high rate of return (such as onion) in winter using tube wells. The result of the base heterogeneity effects (BH1) suggested that the non-beneficiaries would have achieved higher annual crop income through accessing canal irrigation condition (Case d) than the observed crop income of beneficiaries (Case a).

Additionally, if the base heterogeneity effect of non-beneficiaries (BH2) was negative and statistically insignificant, showing that the beneficiaries would have achieved a lower crop income without receiving canal irrigation (Case c) than the observed crop income of non-beneficiaries (Case b). This is because beneficiaries mainly grew rice in the summer and monsoon which relied on canal irrigation under current condition.

The transition heterogeneity effects (TH) in sample farmers was positive and statistically insignificant, indicating the effects of irrigation scheme on annual crop income were higher for beneficiaries as compared to that of non-beneficiaries. The positive transition heterogeneity effects (TH) revealed that the impact of canal irrigation scheme on annual crop income was higher for the canal irrigation beneficiaries compared with that of non-beneficiaries. This was because irrigation scheme could increase crop production and reduce vulnerability caused by the seasonality of crop production and external shocks.

Table 4.25 Average treatment effects of irrigation on annual crop income

	Decision stage				Treatment effect	Effect in %[a]
	To use irrigation		Not to use irrigation			
	Mean	SD	Mean	SD		
Beneficiary	(a) 14.3	0.5	(c) 14.0	0.7	ATT:0.3***	34.3
Non-beneficiary	(d) 14.5	0.8	(b) 14.2	0.9	ATU:0.3***	31.8
Heterogeneity effects	BH1 = -0.1**		BH2 = -0.2		TH: 0.0	

Note: ** and *** present significance at 5% and 1% levels.

Source: Own calculation based on parameter estimates in Stata 12

[a] The percentage changes in average treatment effect was derived based on 100 (e^{TE} -1), where "e" is the exponential "e" (e = 2.718) and "TE" is the average treatment effects provided by the analysis of the log-transformed variable.

4.5 Water Management Activities of Beneficiaries

4.5.1 Water distribution ways

As demonstrated in Table 4.26, there were different methods of in-field level water distribution within the block command areas. The majority of the beneficiaries from Block 1 (61%) and Block 2 (51%) practiced alternative water distribution for ‘head-end’ and ‘tail-end’. Most beneficiaries (about 30 to 40%) from Block 2 and 3 used the ‘head-end first’ distribution method because of difficulties of access to water. Block 3 also used tail-end first (39%) method. In all blocks, either ‘head-end’ first or alternative distribution methods were commonly used.

Beneficiaries from Block 3 used more ‘tail-end first’ practice compared with beneficiaries from other blocks while beneficiaries from Block 1 used a more ‘first come-first serve’ practice and beneficiaries from Block 2 used a more ‘need-based’ practice.

4.5.2 Perception of beneficiaries on performance of water management committee

Farmers’ perceptions about the performance of water management committees provide better insights and information relevant to effective water management guidelines. The benefits resulting from effective water management are expected to be; improved performance in water distribution in terms of adequacy, reliability (effective coordination of committee members), timeliness (water availability in time) and fairness between head, middle and tail end area. Perceptions about irrigation water allocation were measured by considering four items: water adequacy, fairness of water distribution, water availability in time and the coordination of water management committee members (Table 4.27).

Regarding the allocation of irrigation water, a majority (93%) of beneficiaries in Block 1 achieved adequate irrigation water compared with about 70% and 73% of beneficiaries in Block 2 and 3 respectively. Among the three blocks, beneficiaries from Block 1 received the best amount of irrigation water for crops production as they accessed irrigation water from the main canal of the first lift in the irrigation scheme.

Overall, a majority (80 to 90%) of beneficiaries from all blocks described water allocation was fair. Although the majority (84%) of beneficiaries from Block 1 received irrigation water in time, only about 44% of beneficiaries from Block 3 received irrigation water in time. Regarding the coordination of the committee members, 87% of beneficiaries from Block 1 were (about 78% of them from Block 2 and 3) satisfied with coordination activities of the committee members, compared to only 78% from Block 2 and 3.

4.5.3 Water-related conflicts in the study area

Farmers have always struggled to get better access to water in order to sustain crop production. There has been a history of unethical behavior like fighting and stealing water when this is the only means get water. In the study area water-related conflicts mostly came from poor attitudes of irrigation beneficiaries and inadequate water distribution (Table 4.28). In the block area beneficiaries from Block 3 were involved more in water-related conflicts than beneficiaries from other blocks due to inadequate water. Twenty five percent of farmers from Block 3 were involved in water-related conflict due to differences with some other irrigation beneficiaries. In Block 2 ‘first come-first serve’ practice caused conflict for about 10% of beneficiaries.

Based on conflict sources mentioned, about 25% of beneficiaries each from Block 2 and 3 were involved in water-related conflict but even in Block 1 (19%) had conflicts (Table 4.29).

Table 4.26 Irrigation water distribution ways in the study area

Water distribution ways	Irrigation water distribution (frequency of farm household)			
	Block 1 (n=31)	Block 2 (n=113)	Block 3 (n=64)	Total (n=208)
Alternative	19 (61.3)	58 (51.3)	10 (15.6)	87 (41.8)
Head-end first	5 (16.1)	37 (32.7)	24 (37.5)	66 (31.7)
Tail-end first	1 (3.2)	4 (3.5)	25 (39.1)	30 (14.4)
First-come first-serve	4 (12.9)	6 (5.3)	4 (6.3)	14 (6.7)
Need based	2 (6.5)	8 (7.1)	1 (1.6)	11 (5.3)
χ^2	62.3^{***}			

Note: Value in parentheses presents percentage. *** presents significance at 1% level.

Table 4.27 Perception of irrigation beneficiaries on performance of water management committee

Activities of water management committee	Perception on water management committee (frequency of farm household)				χ^2
	Block 1 (n=31)	Block 2 (n=113)	Block 3 (n=64)	Total (n=208)	
Water adequacy	29 (93.0)	79 (69.9)	47 (73.4)	155 (74.5)	7.2^{**}
Fairness of water distribution	28 (90.3)	91 (80.5)	54 (84.4)	173 (83.2)	1.8^{ns}
Water availability in time	26 (83.9)	71 (62.8)	28 (43.8)	125 (60.1)	14.8^{***}
Coordination among committee member	27 (87.1)	88 (77.9)	50 (78.1)	165 (79.3)	1.3^{ns}

Note: Value in parentheses presents percentage.

** and *** present significance at 5% and 1% levels. ns = not significant.

Table 4.28 Conflict sources of irrigation beneficiaries in water management

Reasons of conflicts	Frequency of farm household			
	Block 1 (n=31)	Block 2 (n=113)	Block 3 (n=64)	Total (n=208)
Inadequate water	6 (19.4)	28 (24.8)	28 (43.8)	62 (29.8)
Out of sympathy	2 (6.5)	8 (7.1)	16 (25.0)	26 (12.5)
First-come first-serve	1 (3.2)	11 (9.7)	3 (4.7)	15 (7.2)
No answer	22 (71.0)	66 (58.4)	17 (26.6)	105 (50.5)
χ^2		31.3^{***}		

Note: Value in parentheses presents percentage. *** presents significance at 1% level.

Table 4.29 Involvement of irrigation beneficiaries in water-related conflict in 2016-2017 cropping season

Conflict involvement	Conflict involvement (frequency of farm household)			
	Block 1 (n=31)	Block 2 (n=113)	Block 3 (n=64)	Total (n=208)
Involved	6 (19.4)	29 (25.7)	16 (25.0)	51 (24.5)
Not involved	25 (80.6)	84 (74.3)	48 (75.0)	157 (75.5)
χ^2		0.5^{ns}		

Note: Value in parentheses presents percentage. ns = not significant.

4.5.4 Farmer participation in collective water management

Regarding farmer participation in water management, forms and levels of participation were measured for providing a participation index. Forms of beneficiary participation in activities such as providing labour, decision making, information dissemination and regulating the rotational irrigation schedule are shown in Table 4.30. In labour-based participation, beneficiaries (83 to 90%) from all blocks contributed mostly in repairing the distribution canals. Compared to the involvement of beneficiaries from Blocks 1 and 2, beneficiaries (69%) from Block 3 participated less in repairing infield distribution canals. However, beneficiaries (54-58%) from all blocks were less involved in repairing pumps compared to other activities. Compared to Blocks 1 and 2, the beneficiaries from Block 3 were less actively involved in labour-based activities except pump repair. The reason was probably as they get less irrigation water from the irrigation scheme.

During the water management meeting, water management committee members and beneficiaries always make decision on water allocation among blocks. The beneficiaries (86-97%) from Blocks 1 and 2 actively attended water management meeting. Higher proportion of beneficiaries (74%) from Block 1 actively participated in meeting but their action on the discussion was 54%. However, a majority (71 to 73%) of beneficiaries from Block 2 and 3 actively disseminated the water-related information. It was found that there was a relative decrease in actually carrying out the actions that had been discussed.

More than 50% of beneficiaries form Block 3 participated actively in the informing about unlawful use of canal water and damages and leakages of canals to the water management committee compared with beneficiaries from other blocks. These findings, therefore, indicated that there was more problematic water management in Block 3.

The levels of participation in collective water management activities were measured by using a 5-point Likert scale from zero to four (0 = not involved, 1 = low, 2 = average, 3= high and 4 = very high) for providing a composite index of participation (Table 4.31).

Table 4.30 Collective activities in water management of beneficiary households

Activities of water management	Activities involvement (frequency of farm household)				χ^2
	Block 1 (n=31)	Block 2 (n=113)	Block 3 (n=64)	Total (n=208)	
Labour-based					
Canal repair	28 (90.3)	98 (86.7)	53 (82.8)	179 (86.1)	1.1^{ns}
Infield distribution canal repair	25 (80.6)	100 (88.5)	44 (68.8)	169 (81.3)	10.5^{***}
Pump repair	17 (54.8)	61 (54.0)	37 (57.8)	115 (55.3)	0.3^{ns}
Decision making					
Attend water management meeting	30 (96.8)	97 (85.8)	48 (75.0)	175 (84.1)	7.9^{**}
Active participation in meeting	23 (74.2)	71 (62.8)	28 (43.8)	122 (58.7)	9.8^{***}
Take action on the discussion	17 (54.8)	60 (53.1)	24 (37.5)	101 (48.6)	4.6^{*}
Information dissemination					
Disseminate water related information	20 (64.5)	80 (70.8)	47 (73.4)	147 (70.7)	0.8^{ns}
Regulating rotational irrigation schedule					
Informing unlawful use of canal water	6 (19.4)	40 (35.4)	32 (50.0)	78 (37.5)	8.8^{***}
Informing damage and leakage of canal	7 (22.6)	36 (31.9)	35 (54.7)	78 (37.5)	12.6^{***}

Note: Value in parentheses presents percentage.

*, ** and *** present significance at 10%, 5% and 1% levels. ns = not significant.

In labour-based participation, beneficiaries participated in more than an average level in canal and infield distribution canal repair. Pump repair always had fewer participants compared to in other types of labour-based activities. In decision making activities, about 34% of beneficiaries participated at average level attending water management meetings but approximately 41 to 51% of beneficiaries did not get involved in active participation in the meeting or taking action on the discussion. Although most beneficiaries participated more than average level in activity of attend water management meeting, their level of participation gradually decreased in the activities of active participation in meeting and take action on the discussion.

For information dissemination, about 33% of beneficiaries participated at average level but about 29% of beneficiaries were not involved. Most beneficiaries (63%) were not involved in any activities of regulating rotational irrigation schedule.

Table 4.31 Level of collective participation in water management of beneficiary households

(n=208)

Activities of water management	Level of participation in water management				
	Not involved	Low	Average	High	Very high
Labour-based					
Canal repair	29 (13.9)	28 (13.5)	63 (30.3)	62 (29.8)	26 (12.5)
Infield distribution canal repair	39 (18.8)	26 (12.5)	55 (26.4)	52 (25.0)	36 (17.3)
Pump repair	93 (44.7)	33 (15.9)	46 (22.1)	28 (13.5)	8 (3.8)
Decision making					
Attend water management meeting	33 (15.9)	36 (17.3)	71 (34.1)	42 (20.2)	26 (12.5)
Active participation in meeting	86 (41.3)	24 (11.5)	56 (26.9)	31 (14.9)	11 (5.3)
Take action on the discussion	107 (51.4)	35 (16.8)	37 (17.8)	22 (10.6)	7 (3.4)
Information dissemination					
Disseminate water related information	61 (29.3)	33 (15.9)	68 (32.7)	34 (16.3)	12 (5.8)
Regulating rotational irrigation schedule					
Informing unlawful use of canal water	130 (62.5)	22 (10.6)	19 (9.1)	29 (13.9)	8 (3.8)
Informing damage and leakage of canal	130 (62.5)	26 (12.5)	24 (11.5)	19 (9.1)	9 (4.3)

Note: Value in the parentheses presents percentage.

4.5.5 Measuring collective participation of beneficiaries

The participation index (PI) was computed using Principal Component Analysis (PCA) for individual beneficiaries in collective water management activities (Table 4.32). From the results of PCA, 3 components that had eigen-values greater than 1 were retained. The higher explanatory power was found in the first principal component (PC-1) that explained 33.2% of the variation in participation of beneficiaries in collective activities while the other principal components, PC-2 and PC-3 explained 17.4% and 13.2% respectively. According to results, 63.7% of variation in the data can be explained by these three components (PCs). Among these three PCs, only the first component (PC-1) provided no negative coefficients. Therefore, PC-1 was retained to generate the participation index because it presented the aggregate variations as a result of the differing degrees of participation. The retained first component can be used alone without much loss in information because it accounts for a large percentage of variance in the variables (Manyoung et al., 2006).

Beneficiary farmers' participation in decision making activities (more or less 0.7) dominated on the first component (PC-1) as well as on the water-related information dissemination (Table 4.32). This result indicated that the involvement of participating farmers was relatively higher in decision making through participating in meetings. Such farmers were also involved in other activities such as labour-based activities as well as reporting damage and leakage of canals to maintain irrigation infrastructure and curb water loss. The performance of a particular activity which achieves success or failure, affected the performance of the other activities because most of the management activities in communal irrigation schemes were complementary in nature (Fujiie et al., 2005). Irrigation beneficiaries, therefore, must be encouraged to participate equally in all activities as an effective approach to ensure sustainable management of communal irrigation scheme.

Table 4.32 Collective participation index generation using Principal Component Analysis (PCA) in water management of beneficiaries

Items	Principal Component (PC)		
	1	2	3
Eigen values	2.9	1.6	1.2
% of Variance	33.2	17.4	13.2
Cumulative %	33.2	50.6	63.7
Variables	factor loadings		
Canal repair	0.5	-0.2	0.4
Infield distribution canal repair	0.3	-0.4	0.7
Pump repair	0.5	-0.1	-0.5
Attend water management meeting	0.7	-0.4	0.0
Active participation in meeting	0.8	-0.3	-0.2
Take action on the discussion	0.7	-0.2	-0.4
Disseminate water related information	0.6	0.4	0.3
Informing unlawful use of canal water	0.4	0.7	0.2
Informing damage and leakage of canal	0.5	0.7	-0.0

4.6 Descriptive Statistics of Variables Used in the Tobit Model for Water Management of Beneficiaries

The descriptive statistics in Table 4.33 indicate a large majority (84-87%) of beneficiaries (respondents) from 3 blocks were males (Appendix 7). It indicates a large involvement of males in farming. There was an indication of small difference in the average age of beneficiary respondents from three blocks (Appendix 7). As the results indicate, the average age of beneficiaries was approximately 50 years. The average schooling years of beneficiaries from three blocks was nearly similar and ranged from 4 to 5 years (Appendix 7). Since Blocks 2 and 3 were implemented after Block 1 there was a considerable difference in farmers' irrigated experience, as much as 7.5 years in some cases.

Table 4.33 also provided a profile of the beneficiary households in terms of farm household assets and social relations. Concerning land ownership, beneficiaries from Block 2 had the highest farm size (4.3 ha), followed by beneficiaries from Block 1 (3.5 ha) and Block 3 (2.8 ha) (Appendix 7). However the average farm labour of beneficiary households from the three blocks was almost the same (2.5 persons per households) (Appendix 7). Similarly, the number of water sources available for crops production among the blocks was not different (1.4 sources) (Appendix 8). Involvement of beneficiary households in social organizations (village development group, social-help group and cooperative association and, saving and loan association, etc.) was measured (Appendix 7). The result indicated that average numbers of social organization (0.8) involved by beneficiaries among three blocks were similar. Although the beneficiary households from all blocks cultivate crops in three seasons (summer, monsoon and winter), they mainly relied on canal water for crop production in summer. The result indicated quite a difference in summer crop income among the three blocks; beneficiaries from Block 1 earned 1009.8 thousand MMK, Block 2 earned 568.1 thousand MMK and Block 3 earned 308.4 thousand MMK. Since there was more favorable access to irrigation water in Block 1 in comparison with other the blocks, its beneficiaries earned much more income from summer crop cultivation than the beneficiaries from other blocks (Appendix 8).

Perception about irrigation water allocation was measured by using four indicators; water adequacy, fairness of water distribution, water availability in time and coordination among water management committee members (Table 4.33).

Regarding allocation of irrigation water, a majority of beneficiaries (93%) in Block 1 received adequate irrigation water while about 70% and 73% of beneficiaries from Block 2 and 3 respectively received adequate irrigation water. Among the three blocks, beneficiaries from Block 1 received their water for crop production from the main canal which was the first lift of the irrigation scheme. A majority of beneficiaries (80 to 90%) from all blocks described that water allocation was fair. This is despite only 44% of beneficiaries from Block 3 receiving irrigation water in time. Regarding coordination among the committee members, a majority of beneficiaries (78 to 87%) from all blocks described coordination activities of the committee members as being effective.

In the study area, water-related conflicts arise mostly due to poor attitudes of farmers acting in their unmediated self-interest often due to inadequate water supply. Since there was less favorable access to irrigation water in Blocks 2 and 3, those beneficiaries (25%) were much more involved in water-related conflict than the beneficiaries (19%) from Block 1 (Table 4.33). The beneficiaries (38 to 45%) from Block 1 and 2 regularly attended water management meetings but beneficiaries (83%) from Block 3 were much less regular (Table 4.33). This reveals that water availability is very crucial for users' participation in meetings.

4.7 Determinants of Participation in Collective Water Management Activities

The result of the Tobit model is shown in Table 4.34. The dependent variable for the model was participation index (PI), resulting from PCA on farmer participation in water management activities. The results showed that the participation in collective water management was influenced by the irrigation experience of respondents, number of water sources, summer crop income, social (organization) involvement of the household, water management meetings attendance as well as water-related conflict involvement of beneficiary households and the perceptions of beneficiaries on irrigation water management (water availability in time, fairness of water distribution and effectiveness of coordination among the committee members).

Table 4.33 Descriptive statistics of variables used in model for water management of Beneficiaries

Particulars	Unit	Irrigation command area		
		Block 1 (n=31)	Block 2 (n=113)	Block 3 (n=64)
Respondent characteristics				
Gender (Male)	%	87.1	84.1	87.5
Gender (Female)	%	12.9	15.9	12.5
Age	year	49.0 (9.5)	51.9 (8.9)	47.6 (9.4)
Education	year	5.4 (3.4)	4.3 (2.8)	3.9 (3.4)
Irrigated farming experience	year	7.5 (3.2)	5.6 (3.5)	2.9 (1.2)
Household characteristics				
Farm size	hectare	3.5 (1.9)	4.3 (2.9)	2.8 (2.5)
Family farm labour	number	2.7 (1.1)	2.6 (1.3)	2.4 (1.2)
Water source	number	1.4 (0.6)	1.4 (0.6)	1.4 (0.7)
Social organization involved	number	0.8 (0.9)	0.8 (0.8)	0.7 (0.7)
Summer crop income	thousand MMK	1009.8 (962.3)	568.1 (749.9)	308.4 (8297.7)
Perception on water management				
Water adequacy	%	93.0	69.9	73.4
Fairness of water distribution	%	90.3	80.5	84.4
Water availability in time	%	83.9	62.8	43.8
Coordination among water management committee members	%	87.1	77.9	78.1
Conflict involvement				
Involved	%	19.4	25.7	25.0
Not involved	%	80.6	74.3	75.0
Attendance in meeting				
Regular	%	45.2	38.1	17.2
Less-regular	%	54.8	61.9	82.8

Note. Value in parentheses presents standard deviation.

According to the results, irrigation experience and involvement in social organizations increased the probability of participation in water management. Furthermore, timely water availability, attendance at water management meetings and involvement in water-related conflicts increased the probability of participation in water management activities. Having other water sources would decrease the probability of participation in water management activities.

The coefficient for the irrigated farming experience of beneficiaries was statistically significant at the 5% level and positively related to the probability of participation. A one year increase in the irrigated farming experience would increase the probability of participation by 0.051%. It can be implied that the beneficiaries who have more experience in irrigated farming would participate more in water management activities.

The estimated coefficient for the number of water sources available was statistically significant at the 5% level and negatively related to the probability of participation. A one unit increase in water sources would reduce the probability of participation by 0.23%. When beneficiaries have other water sources, the probability of their participation in collective activities would decrease. The results showed that canal water has lower cost and required a small task force for irrigation compared to other water sources.

The coefficient for summer crop income was statistically significant at the 10% level and positively related to the probability of participation. A 1% increase in summer crop income realized will increase the probability of participation by 0.042%. Regarding economic incentives, beneficiaries who received more income from irrigated farming in summer were more willing to participate in collective water management activities than those that received less.

The coefficient of social organization involvement was statistically significant at the 10% level and positively related to the probability of participation in water management. If there is a one unit increase in social organization involvement, the probability of participation will increase by 0.13%. Results showed that beneficiary households that were more involved in social organizations would prefer to participate more in collective water management activities than those that were less involved.

Beneficiaries who frequently attended water management meetings and beneficiaries who received irrigation water in time for crop irrigation were more likely to participate in collective water management. Besides, effective coordination among water management committee resulted in lower participation in collective water managements.

The result indicated that fair distribution of water among head-end and tail-end beneficiaries would increase participation in collective activities. Moreover, beneficiary households that were involved more in water-related conflict were more willing to participate in collective water management activities than those that were less involved.

Table 4.34 Determinants of collective participation in water management

Variables	Coefficient	t-valve
Age (year)	0.005^{ns}	0.9
Gender ((male=1, female=0)	0.211^{ns}	0.9
Education (year)	0.017^{ns}	0.9
Irrigation experience (year)	0.051**	2.4
Farm size (hectare)	0.023^{ns}	1.1
Family farm labor (no.)	0.044^{ns}	1.2
Water source (no.)	-0.23**	-2.4
Summer crop income (Ln)	0.042*	1.9
Block position (Block 1=1, Block 2=2, Block 3=3)	0.074^{ns}	0.7
Field position (head-end=1, middle=2, tail-end=3)	0.083^{ns}	1.0
Social organization involvement (no.)	0.13*	1.7
Irrigation water adequacy (adequate=1, inadequate=0)	0.016^{ns}	0.1
Water availability in time (yes=1, no=0)	0.347**	2.4
Fairness of water distribution (fair=1, unfair=0)	0.525***	2.8
Coordination (effective=1, ineffective=0)	-0.408**	-2.3
Attending water management meeting (regular=1, less regular=0)	0.895***	7.4
Water-related conflict involvement (involve=1, not involve=0)	0.519***	3.9
Constant	-1.983***	-3.9
Sigma	0.8	
LR chi^2	114.1***	
Pseudo R^2	0.2	

Note: *, ** and *** present significance at 10%, 5% and 1% levels. ns = not significant.

CHAPTER V

CONCLUSION AND POLICY IMPLICATIONS

5.1 Conclusion

This study analyzed the impact of an irrigation scheme on crop income and the determinants of farmers' participation in collective water management activities under the Pyawt Ywar pump irrigation project area, Myinmu Township, Sagaing Region. In this study, 285 sampled farmers from Pyawt Ywar pump irrigation project area were divided into 208 beneficiaries who could access canal irrigation water and 77 non-beneficiaries who could not access canal irrigation water. Descriptive analysis was done to understand farm household characteristics and gender participation in decision making of farm management and income generating activities. Furthermore, this analysis was used to describe collective water management activities in the study area including water distribution ways, forms and levels of participation of beneficiary farmers. Full Information Maximum Likelihood Endogenous Switching Regression (FIML ESR) model was employed to estimate the impact of canal irrigation on crop income by controlling the problem of selection bias and endogeneity.

The socio-economic profile suggested there was no difference between two groups in terms of age, farming experience, family size, family farm labour and livestock unit asset. Most respondents had only received primary education and households were mostly male-dominated. Although most farmers were primary education level but graduated farmers were found more in beneficiaries. Average farm size was the same, but beneficiaries possessed a great amount of lowland because of access to the irrigation scheme and other water sources. Higher participation in social organization was found in beneficiaries.

In both beneficiary and non-beneficiary households, male family members participated more in the decision making for farm management activities because the gender of respondents was mostly male and they were nearly always employed in farming. This was also true of the decision making process for salaried occupations but for wage labour and self-employment both men and women were involved.

Several water sources were available for crop production; not only canal irrigation water but also tube well, lake and the Mu River enabling farmers to diversified crops. Most beneficiaries and non-beneficiaries grew crops in the monsoon and also winter crops. Due to canal access, beneficiaries utilized land more than non-beneficiaries resulting in increased crop intensify and agricultural production. There was high variation in cropping intensity amongst the beneficiaries.

The farm households in the study area relied largely on crop income which accounted for more than half of household income. Monsoon and winter crops were the major income sources for beneficiary and non-beneficiary households. In the summer, rice was the main crop income source for beneficiaries while horticultural crops production played a key crop income source for non-beneficiaries. Both beneficiaries and non-beneficiaries cultivated rice mainly in the monsoon but pigeon pea production was the main crop income source at that time. Although most of beneficiaries and non-beneficiaries grew chickpea in winter, onion was the main cash crop for them. Beneficiaries received a higher crop income from monsoon and summer season crops compared to non-beneficiaries due to accessing canal irrigation in those seasons. Non-beneficiaries who cultivated crops mainly on the upland relied mostly on crop income from winter crop production.

Irrigation beneficiaries cultivated crops mainly on the lowland therefore relying mostly on farm income from rice production. On the other hand, most cultivated crops in the non-beneficiary group were high market-demand crops which paid usually a higher income for them. Therefore, non-beneficiaries may receive more income than beneficiaries due to their cropping choices.

In the study area, non-farm income generating activities (including wage labour occupation, self-employment and salary occupation) were very crucial for farm household livelihoods. Irrigation beneficiaries had better income sources than non-beneficiaries. Non-farm earnings contributed to household income improvement. The average non-farm income of beneficiaries was significantly higher than that of non-beneficiaries. Probably beneficiaries may have opportunity to engage in relatively higher income generating business and due to the larger amount of their family member employed in those business.

In the study area, farm and non-farm incomes were vital for livelihood improvement of the sample farm households. Although beneficiaries received more earnings from non-farm activities whilst non-beneficiaries received more earnings form crop production, average household income was not different between two groups.

According to FML ESR results, variables relating to market distance, cash crop (onion) growing and water source availability had significant impact on the farmer's decision to use canal irrigation. Sample farm households having more water sources, have more opportunity to use scheme irrigation. Farm households which settle near the market are more likely to use scheme irrigation and farm households which grow cash crop (onion) are less likely to use it.

According to the outcome equation, farmers who possessed larger farms received higher crop income. Cultivation of cash crop affected income. Cash crop growers received higher annual crop income than non-growers. The distance of the nearest market from home affected crop income. Farm households which were closer to the market generated higher crop income. Farm further away probably suffered from difficulties with transportation costs in the study area.

Block position influenced negatively on the crop income of beneficiaries. Farmers from locally high-field elevations within the command area had lower crop incomes. It seems that unequal distribution of water among the blocks resulted in insufficient water and low crop yield. Livestock holdings also influenced crop income positively, probably due to the effect of both animal labour and the benefits of organic matter for crops. Animals can also be sold when there are financial constraints and the cash realized can then be used for farm improvements which may increase crop income. It was also found that the development of the rural livestock sector become increasingly important. Non-farm income influenced negatively on crop income, implying that earnings from non-farm activities would not be reinvested in a crop sector where there might be uncertainties.

According to counterfactual analysis, the ATT and ATU were positive and significant for both beneficiaries and non-beneficiaries, noting that access to canal irrigation has resulted in a positive impact on crop income of farmers with the existing use of other water sources. This was hypothesized to occur primarily due to crop intensification and crop diversification. Receiving canal irrigation water significantly increases crop income for all farmers in the irrigation command area, and the effects are more important for non-beneficiaries because they would have benefited more by receiving irrigation scheme water. Thus, the irrigation scheme has a positive impact on farm households in the irrigation command area.

Water management activities were collectively managed by the local beneficiaries in the form of water management committee in the study area. Irrigation water was distributed with 4 ways of distribution. Among distribution ways, alternative water distribution for head-end and tail-end was the most practicing way. The results indicated that both practices in water distribution and perception about the water management committee depended on block position and the most practiced method was alternative water distribution for head-end and tail-end. Inadequate water supply resulted in more water-related conflicts in Block 3.

The way beneficiary farmers participated in collective water management varied according to the position of block. Beneficiaries from upper block positions were highly involved in labour-based and decision making activities. However, beneficiaries from lower block positions involved themselves more in information dissemination and regulating the rotational irrigation schedule activities. This was due to inadequate and unequal water distribution.

Levels of participation varied according to the type of activity. Beneficiaries participated more in canal and infield distribution canal repair but in pump repair activity, the participation level decreased. Although most beneficiaries participated more than the average in attending water management meetings, their active level of participation gradually decreased with less active participation in meetings and follow-up. For the activity of information dissemination, beneficiaries participated more than the average level but their level of participation decreased over time in regulating the rotational irrigation schedule. These varying levels of participation might be due to field plot position along the distribution canal, block position and water availability.

Based on Tobit regression results, the study concludes that development of the canal irrigation scheme depended on beneficiary farmers' participation in collective water management. The interplay of socio-economics, institutional and resource-based attributes influenced the farmer's participation in collective water management. Experience with irrigation and the use of other water sources influenced farmer participation in collective water management as shown by the higher probability of participation amongst those with more experience. Canal irrigation beneficiary farmers who had access to more water sources participated less in collective water management compared to farmers having access to fewer, thus, illustrating a different factor's effect on participation.

Irrigated crop income in the summer gradually influenced farmer participation in the collective activities of water management. Farmers who had a higher economic incentive through greater investment in summer irrigation were more willing to participate in collective water management activities than those that earned less. It was also noted that beneficiary households that were more involved in social organizations were more amenable to participate in collective water management activities than those that were less socially engaged.

The study concluded that perceptions of beneficiary farmers on water management significantly affected the probability of participation in collective activities. Perceptions of providing irrigation water in time for crop irrigation and distributing water fairly among head-end and tail-end by beneficiaries would increase participation in collective activities. Perceptions of effective coordination among the water management committee members by beneficiaries resulted in lower participation in collective water managements. Beneficiaries who perceived that the water management committee was effective participated in less number of collective water management activities.

Beneficiaries who frequently attended water management meetings were more likely to participate in collective water managements. Attending the water management meeting was an important factor: good information led to greater understanding of water management plans and involvement with the follow-up activities. Moreover, beneficiary farmers who were more involved in water-related conflict were more willing to participate in collective water management activities than those that did not have conflicts.

5.2 Policy Implications

The Pyawt Ywar pump irrigation project provided water in monsoon and summer season and did not provide water in winter season. Irrigation would be also essential at the time of water shortage in winter and summer season. Therefore, irrigation department would also manage system to fulfill water requirement in crop seasons. It would be one simple mechanism of agricultural crop production improvement to the farmers.

Under the irrigation project, cash crop growing activity should be developed by providing technologies and input with reasonable price and quality. Cropping intensity was varying from 26% to 300% in the study area. To increase agricultural production, reaching to maximum cropping intensity of 300% should be enhanced. In addition, extension institutions need more focus on the development of livestock sector to increase farm income. Moreover, to promote gender role, female leadership programs concerning farm management and business management should be provided to farm households in the irrigation command area.

Non-farm income has the potential for rural livelihood improvement. Family labours of farm households in the study area were allocated in non-farm activities for generating income. Although earnings from non-farm activities should be invested in crop sector, it would not be reinvested indirectly in crop sector. It might be not enough for reinvestment in crop sector. Therefore the development of non-farm income generating activities should be paid attention.

Based on the result, the irrigation scheme have a positive impact on crop income of irrigation beneficiaries and non-beneficiaries alike, the system should be improved by upgrading and expanding the irrigation facilities. Other barriers such as unequal water distribution amongst blocks should be solved. In the study area, there was a constraint relating the distance to market for farm households. By solving the constraint of market distance, their rural income would become improvement. Therefore, market constraints need to be solved with improvements in road access, transportation facilities and marketing system.

The study clearly shows the necessity of improving the existing collective management practices of the irrigation scheme. Local irrigation users need to be engaged and educated in collective water management. If such programs are well designed and executed amongst the local irrigation beneficiaries, water related conflicts will be reduced. It can be seen that a key factor in both quality of the system and development in water distribution can be achieved by promoting community participation.

It is hope that there be increasing farmer participation in collective water management and in reducing water-related conflicts by increasing equity and adequacy in the water distribution systems and by improving both infrastructure and management. The irrigation department should promote policies that remove obstacles resulting in unequal water distribution, inadequate supply and any delays in water supply in the cropping season.

The water management committee should emphasize effective coordination and decision making activities with a transparent management system. Moreover, the committee should also put much more emphasis on decision making activities and taking actions according to discussion. Mutual understanding and mutual respect in the rural community are key factors because they enhance the culture of farmers' involvement in social organization and in water management.

Irrigation scheme can contribute positive impact on crop income. However, appropriate rehabilitation program for irrigation infrastructure is needed to fulfil targeted irrigation area of the scheme. Influencing factors on collective water management are crucial for sustainability of the scheme. Therefore training and motivation programs are needed for implementing irrigation management transfer and participatory irrigation management to reduce public expenditure burden and improve efficiency, equity and sustainability of the scheme. In summary, by improving irrigation schemes and their management Myanmar will be able to create a sustainable agriculture sector, increase rural development and provide a way out of poverty for her farmers.

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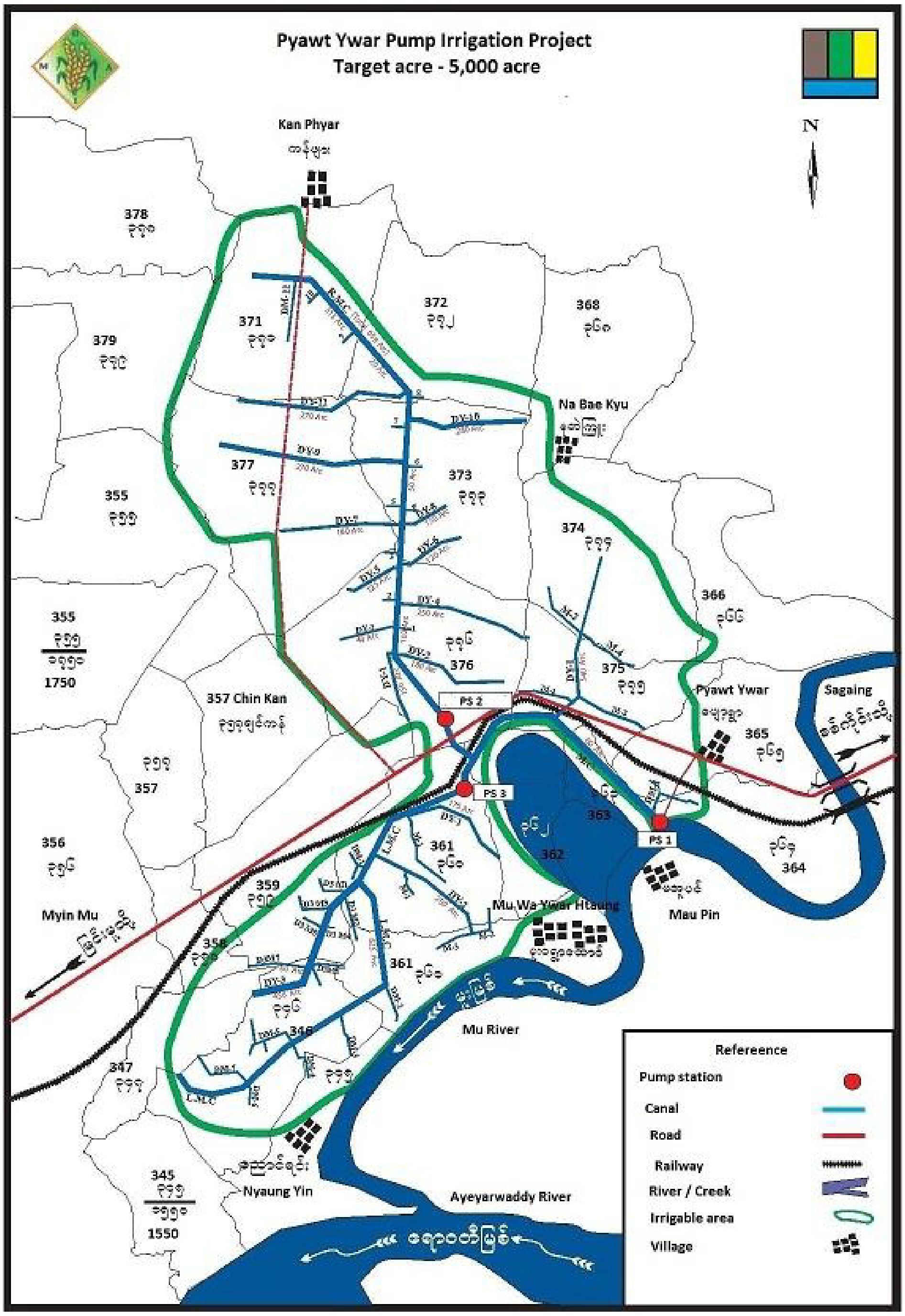
APPENDICES

Appendix 1. Price, sown area and yield of main crops grown in the study area (2016-2017)

Crops	Beneficiary			Non-beneficiary		
	Price (MMK/kg)	Sown area (ha)	Yield (kg/ha)	Price (MMK/kg)	Sown area (ha)	Yield (kg/ha)
Summer						
Rice (using lake water)	250.4	0.9	4364.2	245.4	0.7	4111.9
Rice (using canal water)	277.9	1.2	4408.4	-	-	-
Sesame	1105.3	0.9	318.5	1144.8	0.8	362.2
Green gram	1007.7	1.3	792.8	-	-	-
Monsoon						
Rice (Manawthuka)	296.8	1.4	3736.4	268.1	0.8	2469.3
Rice (Ayermin)	440.7	1.1	3353.0	478.5	1.4	3227.7
Groundnut	877.2	0.8	693.0	937.0	0.7	822.9
Sesame	1245.9	0.9	309.1	1259.5	0.7	373.3
Green gram	1105.3	0.9	1779.8	1070.3	0.8	1996.6
Pigeon pea	744.1	0.7	603.0	726.3	0.7	796.2
Sunflower	686.0	0.8	352.6	706.4	0.9	346.8
Winter						
Onion	444.0	0.7	517530.1	709.3	0.8	11765.4
Chickpea	1184.2	1.3	989.8	1123.9	1.1	601.6
Groundnut	942.6	0.8	614.5	953.5	1.2	380.4
Red phaseolus	553.1	0.9	997.6	482.6	0.7	1141.5
Green gram	1057.9	0.8	1101.8	917.4	0.6	1346.7

Source: Calculation based on own survey, 2017

Appendix 2. Study area in Myinmu Township



Appendix 3. Conversion factor for Tropical Livestock Unit (TLU)

Types of animal	Tropical Livestock Unit (TLU)
Bullock/Ox	1.10
Cow/ Dairy cow	1.00
Calf	0.20
Goat/Sheep	0.10

Source: Storck, et al., (1991)

Appendix 4. Level of collective participation in water management of Block 1 beneficiary households

(n=31)

Activities of water management	Level of participation in water management				
	Not involved	Low	Average	High	Very high
Labour-based					
Canal repair	3 (9.7)	2 (6.5)	9 (29.0)	8 (25.8)	9 (29.0)
Infield distribution canal repair	6 (19.4)	2 (6.5)	7 (22.6)	5 (16.1)	11 (35.5)
Pump repair	14 (45.2)	2 (6.5)	6 (19.4)	7 (22.6)	2 (6.5)
Decision making					
Attend water management meeting	1 (3.2)	7 (22.6)	9 (29.0)	9 (29.0)	5 (16.1)
Active participation in meeting	8 (25.8)	1 (3.2)	12 (38.7)	8 (25.8)	2 (6.5)
Take action on the discussion	14 (45.2)	6 (19.4)	9 (29.0)	1 (3.2)	1 (3.2)
Information dissemination					
Disseminate water related information	11 (35.5)	4 (12.9)	11 (35.5)	4 (12.9)	1 (3.2)
Regulating rotational irrigation schedule					
Informing unlawful use of canal water	25 (80.6)	3 (9.7)	1 (3.2)	2 (6.5)	0 (0.0)
Informing damage and leakage of canal	24 (77.4)	3 (9.7)	0 (0.0)	2 (6.5)	2 (6.5)

Note: Value in the parentheses presents percentage.

Appendix 5. Level of collective participation in water management of Block 2 beneficiary households

(n=113)

Activities of water management	Level of participation in water management				
	Not involved	Low	Average	High	Very high
Labour-based					
Canal repair	15 (13.3)	14 (12.4)	34 (30.1)	39 (34.5)	11 (9.7)
Infield distribution canal repair	13 (11.5)	14 (12.4)	35 (31.0)	32 (28.3)	19 (16.8)
Pump repair	52 (46.0)	16 (14.2)	26 (23.0)	16 (14.2)	3 (2.7)
Decision making					
Attend water management meeting	16 (14.2)	13 (11.5)	41 (36.3)	27 (23.9)	16 (14.2)
Active participation in meeting	42 (37.2)	11 (9.7)	36 (31.9)	18 (15.9)	6 (5.3)
Take action on the discussion	53 (46.9)	19 (16.8)	22 (19.5)	16 (14.2)	3 (2.7)
Information dissemination					
Disseminate water related information	33 (29.2)	17 (15.0)	38 (33.6)	20 (17.7)	5 (4.4)
Regulating rotational irrigation schedule					
Informing unlawful use of canal water	73 (64.6)	13 (11.5)	10 (8.8)	13 (11.5)	4 (3.5)
Informing damage and leakage of canal	77 (68.1)	14 (12.4)	12 (10.6)	7 (6.2)	3 (2.7)

Note: Value in the parentheses presents percentage.

Appendix 6. Level of collective participation in water management of Block 3 beneficiary households

(n=64)

Activities of water management	Level of participation in water management				
	Not involved	Low	Average	High	Very high
Labour-based					
Canal repair	11 (17.2)	12 (18.8)	20 (31.3)	15 (23.4)	6 (9.4)
Infield distribution canal repair	20 (31.3)	10 (15.6)	13 (20.3)	15 (23.4)	6 (9.4)
Pump repair	27 (42.2)	15 (23.4)	14 (21.9)	5 (7.8)	3 (4.7)
Decision making					
Attend water management meeting	16 (25.0)	16 (25.0)	21 (32.8)	6 (9.4)	5 (7.8)
Active participation in meeting	36 (56.3)	12 (18.8)	8 (12.5)	5 (7.8)	3 (4.7)
Take action on the discussion	40 (62.5)	10 (15.6)	6 (9.4)	5 (7.8)	3 (4.7)
Information dissemination					
Disseminate water related information	17 (26.6)	12 (18.8)	19 (29.7)	10 (15.6)	6 (9.4)
Regulating rotational irrigation schedule					
Informing unlawful use of canal water	32 (50.0)	6 (9.4)	8 (12.5)	14 (21.9)	4 (6.3)
Informing damage and leakage of canal	29 (45.3)	9 (14.1)	12 (18.8)	10 (15.6)	4 (6.3)

Note: Value in the parentheses presents percentage.

Appendix 7. Demographic and socio-economic characteristics of beneficiary households

Items	Farm household (n=208)			
	Block 1 (n=31)	Block 2 (n=113)	Block 3 (n=64)	F-test
Gender (no.)				
Female	4 (12.9)	18 (15.9)	8 (12.5)	
Male	27 (87.1)	95 (84.1)	56 (87.5)	
Age (year)				
Mean	49.0	51.9	47.6	4.7^{***}
Range	30-68	27-72	27-67	
SD	3.4	2.8	3.4	
Education level (year)				
Mean	5.4	4.3	3.9	2.4^{*}
Range	1-14	1-16	1-16	
SD	3.4	2.8	3.4	
Land ownership (ha)				
Mean	3.5	4.3	2.8	6.8^{***}
Range	0.6-7.5	0.4-4.6	0.2-15.2	
SD	1.9	2.9	2.4	
Family farm labour (no.)				
Mean	3.4	3.3	2.9	2.0^{*}
Range	1-6	1-10	1-6	
SD	1.4	1.7	1.5	
Involvement in social organization (no.)				
Mean	0.8	0.8	0.7	0.0^{ns}
Range	0-3	0-3	0-2	
SD	0.9	0.8	0.6	

Note: Value in the parentheses presents percentage.

* and *** present significance at 5% and 1% levels. ns= not significant.

Appendix 8. Irrigated farming related activities of beneficiary households

Items	Farm household (n=208)			
	Block 1 (n=31)	Block 2 (n=113)	Block 3 (n=64)	F-test
Attendance in water-related meeting (no.)				
Less regular	17 (54.8)	70 (61.9)	53 (82.8)	
Regular	14 (45.2)	43 (38.1)	11 (17.2)	
Irrigated farming experience (year)				
Mean	7.5	5.6	2.9	30.1^{***}
Range	2-12.0	1-15	1-7	
SD	3.2	3.5	1.2	
Water source availability for crop production (no.)				
Mean	1.4	1.4	1.4	0.4^{ns}
Range	1-3	1-3	1-3	
SD	0.6	0.6	0.7	
Summer crop income (thousand MMK)				
Mean	1,009.9	568.1	308.4	8.0^{***}
Range	187.8-4,735.6	30.1-3,822.0	11.3-3,870.0	
SD	962.4	749.9	810.8	

Note: Value in the parentheses presents percentage.

*** present significance at 1% level. ns = not significant.

Appendix 9. Water sources for crop production of sample farm households

Items	No. of water source		t-test
	Beneficiary (n=208)	Non-beneficiary (n=77)	
Mean	1.4	0.6	-9.2^{***}
Minimum	1.0	0.0	
Maximum	3.0	2.0	
SD	0.6	0.7	

Note: *** presents significance at 1% level.

Appendix 10. Distance from home to the nearest local market for sample farm households

Items	Market distance (km)		t-test
	Beneficiary (n=208)	Non-beneficiary (n=77)	
Mean	13.9	11.0	-4.6^{***}
Minimum	7.2	7.2	
Maximum	20.1	20.1	
SD	4.2	5.6	

Note: *** presents significance at 1% level.

Appendix 11. Female participation in farm management decision

Items	Female participation (%)		t-test
	Beneficiary (n=208)	Non-beneficiary (n=77)	
Mean	39.4	33.8	-1.0^{ns}
Minimum	0	0	
Maximum	100	100	
SD	41.4	39.9	

Note: ns = not significant.