ALTERNATIVE MODELS TO FINANCE IRRIGATION SERVICES AND THEIR IMPACTS ALONG THE RICE CHAIN VALUE: A CASE STUDY IN CENTRAL THAILAND

by

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ABSTRACT

This study focused on the assessment of value of irrigation water used in paddy field and cost of irrigation water services in Sam Chuk O&M project, Suphan Buri province, Central part of Thailand. Specifically, the study involves primary and secondary data collection from the study site related to production cost of rice farmers, yield of rice production, climates, soil type, crop calendar, and the rice marketing channel system of Suphan Buri province. The amount of irrigation water applied in paddy field was used CROPWAT 8.0 model in estimation then used this amount to calculate the value of irrigation water using the Residual Imputation Method (RIM). Results show that the average value of irrigation water had contributed into 2 cases. For case without government subsidy, the value of irrigation water is 0.017 US$/m^3 and 0.019 US$/m^3 for dry and wet season, respectively. For case with government subsidy, the value of irrigation water is 0.033 US$/m^3 and 0.045 US$/m^3 for dry and wet season, respectively. In addition, the cost of irrigation project was based on Sam Chuk O&M project investment. Results show that the average cost of irrigation water service per area is 140.95 US$/ha/year or in form the mass unit of paddy production is 13.063 US$/ton and 13.477 US$/ton for dry and wet season, respectively. Moreover, the added value of paddy production is considered at the primary milling process that consisted brown rice bran, husk, white rice bran and broken white rice. In addition, milling process of white rice 1 ton had used the material production or paddy 2 tons. Therefore, the added value of by-product from milling process is 138.433 US$/ton. Moreover, the total paddy production for each season is around 50% that is 940,000 tons and 950,000 tons for dry and wet season, respectively. Therefore, 90% of white rice production in Suphan Buri province is selling to export market and another 10% is selling to domestic market. In conclude the new finance irrigation service to cover irrigation water service and maintenance costs is provided by 4 scenarios from the output that mention above. This is only scenario of sharing cost of irrigation water service. In addition, there are needs supporting from the related institutional offices.

Keywords: Irrigation water value, Cost of irrigation water services, Rice supply chain, Finance irrigation services, Irrigation cost recovery

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
BAAC	Bank for Agriculture and Agricultural Co-operatives
BOT	Bank of Thailand
CAP	Country Assistance Plan
CRF	Cost Recovery Factor
DIT	Department of Internal Trade
DOAE	Department of Agricultural Extension
DWAF	Department of Water Affairs and Forestry - South Africa
FAO	Food and Agriculture Organization
GMP	Good Manufacturing Practices
HACCP	Hazard Analysis and Critical Control Points
IBRD	International Bank for Reconstruction and Development
MOF	Marketing Organization for Farmers
O&M	Operation and Maintenance
OAE	Office of Agricultural Economics
OECD	Organization for Economic Co-operation and Development
PWO	Public Warehouse Organization
RID	Royal Irrigation Department
RIM	Residual Imputation Method
SCP	Sam Chuk Operation and Maintenance Project
TDRI	Thailand Development Research Institute
TRF	Thailand Research Fund
USDA	United States Department of Agriculture
WB	World Bank
WUAs	Water User Associations

rai	1ha = 6.25 rai
Baht	1US$ = 31.387 (average 2010)

CHAPTER 1

INTRODUCTION

1.1 Background

Agricultural water supply in many parts of the world is entering an era of physical scarcity (Tiwari, 2005). The growing demand for water in household, commercial and industrial sectors as a result of population and industrial growth combined with frequent occurrence of droughts have raised increasing concerns about the conventional wisdom of perceiving irrigation water as a free gift of nature. The growing scarcity of water calls for a new approach that recognizes water as a scarce economic resource and consider pricing irrigation water. (Serageldin, 1995; Petit, 1994; Feder et al., 1994; WB, 1993; Sampath, 1992).

Besides, lacking of cost recovery mechanisms in many government-managed irrigation systems has resulted in poor operation and maintenance (Sampath, 1992; Howe et al., 1993).

These problems of low efficiency, poor management and non-financial sustainability have been addressed by a wide range of actions, including rehabilitation, modernization, improvement of technical management, and participatory management, etc.

The limited benefits obtained so far have generated calls for a larger use of the economic principles for the management of water, particularly in the wake of the Hague and Dublin meeting (Rogers et al., 1997; UNESCO, 2002). The pricing of water and creating water markets are among the measures that have received most attention from academics and development banks. They gave rise to abundant literature but relatively few practical applications.

The pricing of irrigation water can be considered as a pre-requisite for sustainable use of water resource. The underlying principle of natural resource pricing in relation to sustainability concerns is that natural resource prices should reflect i) the cost of extraction, ii) any environmental costs involved, and iii) the benefits forgone in the future from using a unit resource today (Pearce and Warford, 1993). The economic sustainability criteria or the socially optimal rule for water use can then be measured by comparing farmer's willingness to pay and the opportunity costs or the scarcity rent of water.

In Thailand, agriculture accounts for 70% of water withdrawals (Anukularmphai, 2002) and despite increasing shortages, is seen to be marred by very low levels of efficiency, since irrigation is applied to crops with high water requirements and relatively low efficiency and value.

Besides, most of the irrigation schemes would not be financially sustainable without strong support from government budgets via the Royal Irrigation Department (RID). Moreover, these schemes are facing high expenditures for recurring rehabilitation in addition to large initial investments.

In Thailand, the water used for agricultural production is supplied without charge. In an international context where cost recovery and "getting the prices right" are becoming accepted principles, reforms could be engaged in that direction (Molle, 2007). Pricing water is not a new idea in Thailand. The proposals for water pricing in Thailand can founds as early as 1903, when H. van der Heide (1903), a Dutch engineer suggested that a "water tax" could be proportional to the quantity of water used, and should be applied mostly for season crops and garden cultivation.

The logic of water pricing in that time may have been borrowed from practices in Java, India or other Asian countries under colonial rule. Likewise, in the post-World War II period when the International Bank for Reconstruction and Development funded the development of infrastructures in the Chao Phraya delta, the consultant in charge of the study saw no difference between irrigation supply and railways or electricity and stated that it would 'not be a misuse of language or an exaggeration to describe the position [of Thailand] as extraordinary. The Irrigation Department is thus unique among the commercial departments of the Government in Thailand in deriving no revenue from its services and unique or nearly so in this respect, throughout the world' (IBRD, 1950). Although, at the time, the Thai government had shown willingness to establish fees once the scheme would be completed and proper supply ensured to users (IBRD, 1950), the idea seems to have then vanished and only recently come to the fore. In the aftermath of the 1997 financial crisis, reform of the agriculture and water sectors was encouraged by both the World Bank and the Asian Development Bank (ADB), and the latter supported the definition of an ambitious plan aimed at introducing river basin management, service agreements between RID and users, cost recovery dubbed as 'cost-sharing', and legal dispositions around a Water Law. This policy remained a dead letter for a set of reasons that cannot be easily untangled, but which includes resistance from line agencies, weak political support and the over-optimistic and often unrealistic nature of many of the proposals. Despite the setting of a policy matrix that defined commitment to successive milestones to be achieved, the process lost momentum before being eventually discontinued by the Thaksin administration (Molle, 2007).

During the 1950s, Thailand's three major exports were agricultural products: rice, teak, and rubber. In 2011, agriculture was an important sector of the Thai economy that represented 12.2% of its GDP (World Fact Book of USA, 2012).

Today, rice is still one of the most important crops. Irrigated rice represents 40% of the total rice production (OAE, 2011), and irrigation is mainly used for the production of rice especially in central region of Thailand (RID). As such, irrigation is important for the agricultural sector and for the Thai economy.

Rice requires important quantities of water for its production, for example, 40-60% of total water used for producing irrigated rice is lost in evapotranspiration. That water has an increasing economic value (due to its increasing scarcity) and due to the cost of supplying that irrigation water. At the moment these costs are paid mostly from the Government's budget. As a result, the question become rising "why irrigation water is subsidized?" which is not equitable when considering other user sectors of society.

However, if farmers are not paying the right price for water does not mean they are the only stakeholder's beneficiating from these subsidies, Given their low level of organization and the difficulties in general for the agricultural sector to keep their productivity rent for themselves, one can argue that the water subsidies are also used by other stakeholders of the value chain (millers, traders, etc.). This raises a second question whether farmers should be the only one to pay for water, and what mechanisms could be thought out so that different stakeholders beneficiating from low prices of water contributes more. These reasons will become investigation on the conditions and applicability of an equitable and sustainable financing model for irrigation water services in Thailand.

1.2 Problem Statement

RID has implemented many irrigation projects to solve the potential water shortages during the dry season for agricultural production. Non-agricultural (e.g. industrial, domestic) water users are increasingly using irrigation water from irrigation projects as well (Sribenjachote, 2001).

RID has plans to develop water resources to increase the supply of water (that will require important investments, e.g. dam constructions or irrigation system).

Another way to solve the water shortage would be to reduce water demand by charging water usages. It is also likely to increase water use efficiency of rice producers. The Royal Irrigation Act in 1942, amended in 1975, requires the charge of irrigation water from the users. However, the RID do not charge water to agricultural water users. As a result, they do not know the value of water.

Although rice farmers do not pay any fees for irrigation water they use, their use of water produce an important economic value. The economic value of irrigation water represented by the free provision of a key input, benefits the farmers, as primary producers, then other operators in the supply processing and marketing chain. Between 1953 and 1985, Thailand implemented the so-called “rice premium”, as a tax on rice, which contributed up to about 30% of all State revenues in the 50s-60s used to cover costs in the past and investment on irrigation . In turn, such tax was used for a massive public investment in irrigation infrastructure and the full subsidization of water supply costs. With the end of such a mechanism, and in a context of liberalization, decentralization, private-public partnerships, and modernization of the irrigation sector, the question raised as to how irrigation supply costs could be covered in the future, taking account of the economic value generated along the rice chain. The need for this study arises from existing fact; the new national water law advocates that water is to be used to achieve efficiency and long-term environmentally sustainable social and economic benefits for the society from its use (Principle 7 of water law) (DWAF, 1996). With the exception of providing water for basic human needs and agriculture consumes, water is no longer a free good and every user is expected to pay for water so that the rule of efficiency can be applied. The agriculture irrigation water users sector is no exception to this rule and estimation of water productivity and value in the sector is therefore required. Also, owning to the current conditions of an equitable and sustainable of irrigation water services, water pricing may be a key incentive to improve irrigation water use efficiency and to encourage smallholder farmers to conserve and reallocate water to high value uses such as from subsistence oriented kind of farming to high value cropping systems). Therefore, it appears necessary that this study is undertaken, in order to assist those authorities responsible for designing water pricing policy in the agriculture irrigation water users sector, creating water markets, charging for irrigation water supply (O&M at least).

1.3 Research questions

As presented in previous section, overarching question: what is the economic value of water as a resource used for rice production? Then 2 sub questions rise:

1) What is the value of irrigation water of rice farmer?

2) What is the cost of irrigation water supply?

3) What is the added economic value along the rice supply chain?

4) Drawing from previous, is it possible to define possible new financing and arrangements in the maintenance of irrigation systems costs.

1.4 Objective of the study

The main objective of the study was investigated ways of covering the costs incurred by irrigation water supply in Thailand. The main assumption is that fist water as an input to rice production has a high economic value from user view point. A second assumption is that, value added along the supply chain is cost indirectly derived from water use, so it could be mobilized. As a consequence, the following sub objectives are considered, as operational tasks to perform:

1. Assess use value of water in rice production.

2. Assess the costs incurred by irrigation supply at irrigation system level.

3. Assess value added along supply chain.

4. Investigate possible cost recovery mechanisms.

1.5 Scope of the Study

- The data collection was carried out of irrigated paddy cultivation of Sam Chuk operation and maintenance project, Suphan Buri province, Central of Thailand.

- The scope of the study was focused only white rice that include processing of production such as paddy growing, harvesting and marketing of rice.

- The data was analyzed and assessed by filed data collection, interview questionnaire and information relating.

- The actual irrigation schedules and field management were analyzed and assessed by CROPWAT 8.0 model.

- The rice price was analyzed and assessed by field surveys, farmer's interview farm level and market price which supported data by the Thai Rice Mill Association, the Thai Rice Exporters Association for exported and another departments.

1.6 Limitation of the Study

The study requires many data information that are needed for calculation and analysis. All of the data are required secondary data. The data of actual rice field management, actual irrigation management and actual rice yield were collected by questionnaires. Therefore, only the data of year 2009 or 2010 if available that were collected because farmers could not remember so far and the accuracy of these data depends on the knowledge and responsibility of farmers who were interviewed. Therefore, the estimation irrigation water requirement apply in paddy field used CROPWAT 8.0, the input data is assumed the field application efficiency (E_a) equal to 70% because we have not much time to measure in the field. Moreover, the field canal efficiency (E_b) and conveyance efficiency (E_c) based on the criteria for efficiency of irrigation that suggested by Doorenbos and Pruitt (1997). The calculation value of irrigation water using RIM was consisted data collection by interviewing only 20 farmers because there was not time too much to collect. The main reason of that is the effect from 2011 flood crisis.

CHAPTER 2

LITERATURE REVIEW

2.1 Concepts of Estimated the Irrigation Water used in Rice Farmer

2.1.1 Crop and Irrigation System

Managing irrigation requires an evaluation of crop water requirements at each stage of plant growth, and the operation and maintenance of the irrigation system (Hoffman and other, 1990). The most important management objective was established when and how much water should be supplied based on crops water requirements.

Crop water requirement is the amount of water required to compensate the evapotranspiration loss from the cropped field (Allen et al., 1998). Although the values for crop evapotranspiration and crop water requirement are exactly same, the crop evapotranspiration represents the amount of water lost while crop water requirement represents the amount of water that needs to be supplied to avoid water stress.

Many theoretical and empirical methods exist to estimate crop's evapotranspiration (ET). For example, some empirical methods estimate ET based on one or more of the basic parameters controlling ET. Data required for these methods include solar radiation expressed in evaporation equivalent, long term mean maximum and min temperatures mean daily based temperature.

Pan ET method measured losses from surface of the pan (Hoffman, 1990). Penman-Monteith used aerodynamic and radiation data to predict of evapotranspiration (Doorenbos and Pruitt (1997), Hoffman and others (1990), James (1988)). Monteith method had the ability to accommodate the dynamic process of ET, which is produced by available energy and bounded by the quantity of energy exchange between their surface and overlaying atmosphere. This method had the most sufficient result and accurate.

Compared and evaluated with 20 different methods, and compared with 11 locations by lysimeter data with Varity of climatic condition. The result is shown that the Penman method was the best performance and accurate for both humid and arid condition for calculation of evapotranspiration. The FAO was used this method for different researches for finding crop water requirement. Nowadays, computer technology many models have been developed that calculates ET based on set of climatic data. The water requirements are calculated based on ET, and that the recognized way to obtain it is the penman monteith equation.

2.1.2 Reference Crop Evapotranspiration (ET_o)

"The evapotranspiration rate from a reference surface, not short of water, is called the reference crop evapotranspiration or reference evapotranspiration and is denoted as ET_o. The reference surface is hypothetical grass reference crop with specific characteristics" (Allen et al., 1998).

For Allen et al. (1998), the only factors affecting ET_o are climatic parameters that can be computed from weather data. The FAO Penman-Monteith equation (PM) is the most widely used method for determining ET_o. PM equation is based on the relevant climatic data such as net radiation absorbed by leaves, temperature, vapor pressure deficit, and wind speed.

2.1.3 Crop Evapotranspiration (ET_c)

"The crop evapotranspiration under standard conditions, denoted as ET_c, is the evapotranspiration from disease-free, well-fertilized crops, grown in large fields, under optimum soil water conditions, and achieving full production under the given climatic conditions" (Allen et al., 1998).

Crop evapotranspiration (ET_c) can be calculated from meteorological data and an empirical relationship between ET_c and ET_o. That is estimated by multiplying the reference evapotranspiration ET_o by a crop coefficient (k_c) (Dodds et al., 2005)

$$ET_c = k_c \times ET_o \tag{2.1}$$

Water requirements of rice and other economic crops of Thailand have been studied thoroughly (table 1).

Keawlumyai, and et al., (2008) studied and researched on crop water requirement of paddy Suphanburi 1 variety (white paddy); he used the direct seeding method that was conducted in lysimeter tanks in Suphan Buri province, Samchook operation and maintenance project, Regional Irrigation Office 12. The germinated seed were sown and rice was harvested after 115 days. 76mm of water was supplied to the field 14 days after seeding, when the stems of paddy were high enough. The study showed the crop water requirement (ET_c) for rice was 642.60 mm when excluding percolation and land preparation needs.

However, for the irrigation water supplied to the field must be more than the crop water requirement because of field efficiency loss (auxiliary water) such as leaching, temperature modification, and crop quality (USDA, Part 623 Ch2. Irrigation Water Requirement). Also, the amount of irrigation water supply must include water used in land preparation. In general, these is estimated around 150 – 250 mm (FAO, 2004)

Table 1 The crop water requirement of rice and the economic crops of Thailand

Title	Life plants (day)	The number of days the plant needs water (day)	The crop water requirement (m^3/ha)			
			North	Central	Northeast	South
Rice (paddy)	100	86	6,881	7,213	7,325	6,881
Soybean	100	86	3,656	3,875	3,950	3,656
Maize	100	86	2,688	3,643	3,713	3,438
Sugarcane	300	270	9,588	10,163	10,350	9,588

Source: Royal Irrigation Department, 1998

2.1.4 On-Farm Irrigation Water Requirement

The methodology for determination of crop ET and crop water requirements was summarize all parameters below.

- Crop evapotranspiration (ET_c)—Determine a weighted crop ET including all crops grown. This should be based on various climatic areas in the project if the differences are sufficient. Often small valleys adjoining larger valleys have different microclimates.

- Effective precipitation (P_e)—Determine weighted effective precipitation for each climatic area.

- Ground water contribution—Determine weighted contribution to plant growth by the water table.

- Net Irrigation Water Requirement (IR)—Determine weighted net irrigation water requirements for all crops grown. Water needed and used for climate and salinity control (auxiliary water) must be included. The formula below is used to calculate the net irrigation water requirement.

- Application efficiencies—Estimate typical overall on-farm efficiencies based on method and system of water application and management. Other factors include typical soil intake characteristics and available water capacity (AWC), typical field size, shape and slopes, net applications, and climatic factors. Water losses to deep percolation and runoff must be estimated. In some project areas, all or part of this water can be available to down slope water users. Seasonal irrigation efficiencies must be established and used rather than single event application efficiencies. It may be advantageous to use realistic estimated monthly irrigation efficiency values rather than one value for the entire season.

- Gross irrigation requirement—Determine weighted gross irrigation water requirements for all crops grown in the project area, by irrigation method and system. Net application per irrigation is a major factor in application efficiencies especially for surface irrigation. The formula to determine gross irrigation requirement is shown below.

Net Irrigation Water Requirement:

$$\text{Net IR} = ET_c - P_e - \text{Ground water contribution} + \text{Auxiliary water need} \qquad (2.2)$$

Gross Irrigation Water Requirement:

$$\text{Gross Irrigation Requirement} = \text{Net IR} / \text{Irrigation Efficiency } (E_i) \qquad (2.3)$$

Therefore, both of net irrigation water requirement and gross irrigation requirement can shows in unit depth of water (e.g. mm/season) or volumetric unit (m^3/season). For determine irrigation efficiency of irrigation project, there was many materials of irrigation that referred to efficient of irrigation, presented by FAO. The irrigation efficiency classified in 3 parts;

- Water Conveyance Efficiency, E_c of irrigation canal system in irrigation project.
- Field Canal Efficiency, E_b that is responsibility of farmer groups.
- Water Application Efficiency, Ea that is responsibility of each farmer.

The criteria of efficiency in each part of irrigation system are shown in table 2. E_a, E_b, and E_c have the rank between 50-80%, 70-90%, and 65-90%, respectively. Therefore, the irrigation efficiency of irrigation project calculates from equitation 2.4.

$$E_i = E_a \times E_b \times E_c \qquad (2.4)$$

Thus, irrigation efficiency ranges between 23-65% or the average of irrigation efficiency is 44%. In summary, there are many losses in irrigation system that starts from farm, canal, and irrigated system. The average maximum losses are 56%. However, in general the irrigation projects do not have detailed performance measures such as E_a, E_b, and E_c.

In Thailand at the field scale, Kerdpituk (1984) recommended and introduced the used of equation 2.5 to calculate the irrigation efficiency of a paddy field

$$E_a\text{ (paddy)} = \frac{ETc + \textit{percolation loss} + \textit{water used in land preparation} - P_{eff}}{\textit{Gross irrigation water supply}} \times 100 \qquad (2.5)$$

<u>Remark</u>; the effective rainfall (P_{eff}) is the factor that has effect with irrigation efficiency. Therefore, the estimated effective rainfall should be careful and used the method that appropriate with country.

Table 2 Criteria for efficiency of irrigation

Criteria	Efficiency (%)	Average Efficiency (%)
Field Application Efficiency, Ea	50-80	65
Surface	50-80	65
Drip	less than 80	less than 40
Sprinkler	60-80	70
Paddy field	65-75	70
Field Canal Efficiency, Eb	70-90	80
Conveyance Efficiency, Ec	65-90	77.5
Irrigation Efficiency, Ei	23-65	44

Source; Doorenbos and Pruitt (1977) and llaco/Empire M&T (1979)

At the end, in this study was used filed application efficiency of paddy field equal to 70% for estimated the irrigation water requirement in CROPWAT 8.0 model.

2.1.5 Rice Irrigation Water Requirements

Water plays a prominent role in rice production. While many other cropping systems use water mainly for productive purpose (transpiration), the rice cropping system uses water in a wide variety of ways, both beneficial and non-beneficial. Rice systems need water for three main purposes: i) evapotranspiration; ii) seepage and percolation; and iii) specific water management practices such as land preparation and drainage prior to tillering. Table 3 shows the total water requirements of irrigated rice, but the actual water demand of farmers is often much higher because conventional application techniques are often less than 50 percent efficient (FAO, 2004).

Table 3 Irrigation water requirements of irrigated rice (FAO, 2004)

Purpose of water use	Consumptive use (mm/season)		Remarks
	Low	High	
Land preparation	150	250	Refilling soil moisture, ploughing and pudding
Evapotranspiration	500	1,200	
Seepage and percolation	200	700	Maintaining water pounding
Mid-season drainage	50	100	Refilling water basin after drainage
Total	**900**	**2,250**	

For Thailand, recorded to the result on study irrigation water requirement for rice cultivation case study of Rungsit Tai operation and maintenance project, Phatumthani, used RS & GIS estimation (Phuraya, 2007) and compared with field measurement as show in table 4

Table 4 Water requirement of irrigation rice in selected irrigation schemes of Thailand

Irrigation Scheme/ (Estimated method)	Location	Gross irrigation water supply (m^3/ha)		Source
		Dry	Wet	
Rungsit Tai/ (RS&GIS)	Phatumthani	8,815	4,309	Phuraya, 2007
Rungsit Tai/ (Field measurement)	Phatumthani	12,070	8,261	

2.1.6 Applied CROPWAT 8.0 Model to Calculate Irrigation Water Requirement

CROPWAT 8.0 model has been applied to calculate net irrigation water requirement for rice cultivation at field level (FAO). Moreover, this model can calculate the net and gross irrigation scheme. Thus, it can use applied to estimate the irrigation water distribution of the irrigation project.

CROPWAT is mainly based on the FAO guidelines to estimate crop water requirement (Allen et al., 1998), and to calculate irrigation requirements (e.g. Smith, 1992; Zhiming et al., 2007: Yarahmadi, 2003) CROPWAT takes into account the precipitation and the potential evaporation in calculating net irrigation water requirement.

2.2 Estimation of Water Value

After water is traded, the value of irrigation water for agriculture can be estimated by the area under the water demand curve. In practice, this can be operated in various ways. The techniques depended on available data and other constraints because water valuation can be quite complex and expensive to collect data.

The value of irrigation water can be deriving from a number of perspective: (1) how much yield or gross margin (GM) a unit of irrigation might give; (2) how much money are farmer ready to pay to get that input; (3) how much does it cost to supply a unit of water; and (4) how these estimated values (such as GM per m^3 and willingness to pay) can be compared with what farmers actually pay? (Yokwe, 2005). In addition, this study will use residual imputation technique in evaluation value of irrigation water.

RIM is used because we only consider the value of water used by farmers (not other components of the value of water); If we consider that value only, then water is considered an input to a production process that is not paid for. Several methods exist to consider the value of water then: RIM, but also farm models that simulate water demand. We chose RIM, for its simplicity and robustness; besides since farmers in the region are making mainly one crop (rice), the advantages of the farm model over the plot calculations are limited;

The residual valuation method or residual imputation method is often used for measuring the value of an unpaid input to produce output (Young, 1996). Data on production costs other than water and revenues can be used indirectly to estimate the marginal value of water based on the principles of cost minimization or profit maximization (Hassan and Lange, 2004). This method is most suitable when the residual claimant (water in our case) contributes the largest fraction of the value of output. The technique is based in two principal postulates or axioms (Young and Gray 1985):

1) The prices of all resources are equated to their marginal returns. The producers are assumed to profit maximizerss, i.e. they add productive inputs up to the point where the value of marginal products is equal to the costs of the additional inputs. If there are other inputs which are unpriced, not competitively priced or not employed to the point where their price equals their value of marginal product, then the residual imputation method will generate inaccurate estimates of water values (Saliba and Bush 1987).

2) The total value of product can be divided into shares, in such a way that each resource is paid according to its marginal productivity and the total product is completely exhausted (Baumol, 1977).

Applicability of this method to use in the case study

RIM can be applied to evaluate value of irrigation water for rice production, where data on dry season crop and wet season crop are known (Young, 1996). Assuming the rice production process in which paddy (Y) is produced using the following factors of production: machinery (M), labor (L), and other natural resources [e.g. land (R), fertilizer (F), pesticide (P), Seed (S), and water (W)]. The production function was specified as:

$$Y=f(M,L,R,F,P,S,W) \tag{2.7}$$

If factors and products are traded in efficient markets, the total value produced (price x quantity) can be divided into shares in such a way that each resource is paid according to its marginal productivity (equation 2.8):

$$TVP_Y = (VMP_M \times Q_M) + (VMP_L \times Q_L) + (VMP_R \times Q_R) + (VMP_F \times Q_F) + (VMP_P \times Q_P) + (VMP_S \times Q_S) + (VMP_W \times Q_W) \tag{2.8}$$

where TVP represents total value of product, Y; VMP represents value marginal product of resource i; and Q is the quantity of resource i.

The first postulate, which asserts that P_i = VMP_i, we can substitute the P_i into (2.8). When rearranged, the equation becomes (equation 2.9):

$$P_W \times Q_W = TVP_Y - [(P_M \times Q_M) + (P_L \times Q_L) + (P_R \times Q_R) + (P_F \times Q_F) + (P_P \times Q_P) + (P_S \times Q_S)] \tag{2.9}$$

On the assumption that all variables in (2.9) are known except P_W, that expression can be solved for that unknown to impute the value (shadow price) of the residual claimant, (water) P^*_W, as follows:

$$P_W = \{TVP_Y - [(P_M \times Q_M) + (P_L \times Q_L) + (P_R \times Q_R) + (P_F \times Q_F) + (P_P \times Q_P) + (P_S \times Q_S)]\}/Q_W \tag{2.10}$$

There are some literature result of water value used residual imputation that studied in Pakistan, Tanzania, and South Africa as shown in table 5.

Table 5 Water Value used RIM in $USD/m^3

Crops	Country/ Province	Conditions dry season/ wet season	Estimated value of water	Source
Wheat	Pakistan	Wet season	0.012	Ashfaq et al., 2005
Rice	Pakistan	Wet season	0.067	Ashfaq et al., 2005
Sugarcane	Pakistan	Wet season	0.003	Ashfaq et al., 2005
Cotton	Pakistan	Wet season	0.016	Ashfaq et al., 2005
Potato	Pakistan	Dry season	0.070	Ashfaq et al., 2005
Onion	Pakistan	Dry season	0.139	Ashfaq et al., 2005
Sunflower	Pakistan	Dry season	0.006	Ashfaq et al., 2005
Rice	Tanzania	n.a.	0.030	Kadigi et al., 2004
Vegetable	South Africa	n.a.	0.188	Speelman et al., 2008
Rice/paddy	Tanzania	n.a.	0.23	Musamba et al., 2011
Non paddy	Tanzania	n.a.	0.073	Musamba et al., 2011
Rice	Thailand	Wet season / North region	0.04	Prombut, 2007
Rice	Thailand	Wet season / Northeast region	0.027	Prombut, 2007
Rice	Thailand	Dry season / North region	0.004	Prombut, 2007
Rice	Thailand	Dry season / Northeast region	0.001	Prombut, 2007
Upland crops	Thailand	Dry season / North region	0.0003	Prombut, 2007
Upland crops	Thailand	Dry season / Northeast region	0.022	Prombut, 2007
Vegetable	Thailand	Dry season / North region	0.0045	Prombut, 2007

Studies in Thailand were also made, but the result was different. They differ in the way of the data collection and study location. Prombut, (2007) studied the economic value of irrigation water by the residual imputation method in north and northeast region of Thailand. In north region, the selection study area was Mea Koung project and in northeast region was Huay Saneng project. Both studies were based secondary data such as statistic data of price of paddy, cultivated area, total production, and the total amount of irrigation water supply of irrigation project, the average cost of farmers classify by regions and the amount of water storage, etc. Calculations were made with averaged data (over 30 years, and over all types of farmers), and results should be interpreted with care.

Another study using the marginal product value of irrigation water in Thailand showed that it varies across irrigation project and systems (Wuttisorn, 2001). For example, the marginal product value of irrigation water on Mae Taeng irrigation project which is located in northern part of Thailand that was estimate 1 baht/m^3 during the period of 1980 to 1991. In addition, Also Wuttisorn, (2001) referred to Kaosa-ard (2001) estimated the marginal value product of irrigation water in selected irrigation project that shown in Table 6.

Interesting in the marginal value product of irrigation water that is marginal value product in the greater Chao Phraya irrigation scheme (gravity only irrigation system) is 0.18 baht/m^3. This is the lowest value among the selected irrigation areas. There are many factors of difference in marginal value product of irrigation water, for example, the different prices of the different commodities for which water is used, the available technology (e.g. infrastructure constraints, irrigation system), and the last physical conditions in specific locations such as soil characteristics, and climate, etc. (Wuttisorn, 2001). Moreover, if considering in the water allocation system point which normally focuses on releasing water from upper Chao Phraya irrigation area, and diverting water from the nearby Mae Klong river basin it should reconsider because of the relatively low benefit of using water in the lower basin. The relatively low marginal value product in the lower Chao Phraya area to an extent contradicts the common view of the lower Chao

Phraya area, which is recognized as the rice bowl of the country, creating a great deal of economic value to the country (Wuttisorn, 2001).

Table 6 Marginal value product of irrigation water in selected irrigation projects in Thailand

Irrigation project	*Water value (US$/m^3) (period 1987-2000)	Seasonal
The Chao Phraya Basin		
1. Pitsanulok irrigation project	0.084	Dry
2. Pumping irrigation project, lower north region (operated by the Department of Energy Development and Promotion)	0.183	Dry
3. Pumping irrigation project, Tak province (operated by RID)	0.051	Dry
4. Groundwater irrigation project, Sukhothai province	0.151	Dry
5. Greater Chao Phraya irrigation project (gravity system)	0.006	Dry
6. Pumping irrigation project, Greater Chao Phraya irrigation scheme (operated by RID)	0.057	Dry
The Mae Klong River Basin		
1. Mae Klong irrigation project	0.055	Dry

Remark: * is average 1US$ = 28.900 THB during period 1987-2000

Source; Kaosa-ard, (2001)

2.3 Concept of Cost of Irrigation Services

Perret et al. (2008) referred to Brisoe (1997) and Rogers et al. (1998) to outline the theoretical underpinnings of the idea of 'water as an economic good'. They suggested a conceptual framework for both direct costs (supply financial costs) and indirect costs (opportunity costs, cost of externalities).

The full economic cost of irrigation water can be divided into (Perret et al., 2008):

- Operation and maintenance (O&M) costs; these are associated with the daily running of the supply system (e.g. electricity for pumping, labor, repair materials, input costs for managing and operating storage and distribution); they often include administrative and other direct costs (e.g. internalized environmental and resource costs); in practice, there is usually little dispute as to what are considered O&M costs and how they can be measured;

- Capital costs; these costs should include capital consumption (depreciation charges) and interest costs associated with infrastructure, reservoirs and distribution systems; cost-benefit analysis (CBA) approaches to full financial costs stress a forward-looking accounting stance and look for the costs associated with replacement of the capital stock with increasing marginal costs supplies;

- Opportunity cost, which addresses the fact that by consuming water, the user is depriving another user of the water; if that other user has a higher value for the water, then there are some opportunity costs experienced by society due to this misallocation of the resource;

- Economic externalities, which include the positive or negative impacts of irrigation use upon other activities (e.g. pollution, salinization, upstream diversion, downstream recharge).

The first two costs form is the direct full financial costs. Tardieu and Prefol (2002) suggest that these two costs should at least be covered for financial sustainability. They form the so-called ‘sustainability costs’, which recovery ensures the scheme’s operation, at least in the short- and medium term, and is acceptable by users (if charged).

Improving cost recovery clearly involves more than just charging higher fees or spending more on fee collection. However, which water costs are to be recovered and what mechanisms can be used to recover them have to be specified. The full costs of providing irrigation water can be divided into three categories: direct project costs, environmental costs, and marginal user costs.

2.3.1 Cost Recovery and Water Pricing for Irrigation and Drainage Projects

Water pricing and cost recovery of irrigation investments and O&M costs have been contentious issues for many decades (Easter and Liu, 2005). Charges for irrigation water are usually low, and often only a small percentage of farmers are actually paying these charges. In some projects, fee collection rates are near zero, even when water charges are well below the cost of project operation and maintenance (O&M). This creates serious problems both for irrigation agencies and, in the long run, for farmers. If the fees collected do not cover the costs of an irrigation project, its sustainability, without continued government subsidies, may be at risk.

There are many different reasons for low water fee collection rates (Easter and Liu, 2005) including the following:

- No link between fees collected and funds allocated to an irrigation project
- Lack of farmer participation in project planning and management
  Poor communication and lack of transparency between farmers and irrigation management
- Poor water delivery service (timing, duration, or quantity inadequate) and no penalties for managers and irrigation project personnel who provide poor service
- No user penalties for nonpayment of water charges
- Low priority given to fee collection, efficient water use, and system O&M
- Small size and very low incomes of irrigated farms
- Corruption of irrigation officials

The list illustrates that the cost-recovery problem is, at least partly, an assurance problem: assurance regarding what water users will do, as well as assurance concerning what water managers and their staff will actually do as opposed to what they say they will do.

The main reasons for low cost-recovery rates are likely to vary among countries and even among projects within one country. The good news is that steps can be, and have been, taken to correct some of these problems. For example, more and more countries have started to encourage water user participation by establishing water user associations (WUAs). In many cases, system management turned over to farmers. Both Turkey and Sri Lanka have used management turnover as a means of improving performance. For Turkey, it helped increase cost recovery to 76 percent in 1998 (Table 7). Sri Lanka did not experience any significant improvement in productivity with turnover, however, except where it was combined with project rehabilitation (Samad and Vermillion 1998). In addition, there is no direct cost-recovery system in Sri Lanka. Instead, the government feels that it gets indirect cost recovery by transferring management to farmer organizations that have full responsibility for O&M below the head of the distributional canals.

Farmers at a water users' conference elected a WUA executive committee. Villages helped mobilize community human resources for both the WUA conference and the executive committee election, which helped improve farmer participation and WUA operations. The WSC charter also requires farmer representatives from the WUAs to be on the WSC board of directors, so that farmers are directly involved in WSC management and decision-making. Irrigation project authorities and local water bureaus constantly held training programs for farmers, which helped enhance the WUAs' operational capacities after transfer of the local irrigation systems. As a result, farmers are actively trying to improve their system through strong user participation, although in some areas village leaders have tended to dominate associations.

2.3.1.1 Principles of Cost Recovery and Applicability of this method to use in the case study

After determining which costs to include when pricing irrigation water, the next concern is what percentage of total costs should be allocated to farmers. In many cases, who should bear the costs of providing irrigation water is not clear. Whether the farmers should pay the full costs depends on factors including project objectives and the number of beneficiary groups besides irrigated farmers. Irrigation projects serve multiple beneficiaries in two major ways. One case is multipurpose projects; the other is projects involving indirect beneficiaries of the increased agricultural production.

In projects with large indirect benefits, some of the costs may be allocated to the indirect beneficiaries. For example, in countries where the government pursues a low food price policy, food processors and consumers both may benefit more from irrigation improvement projects than farmers. In such cases, subsidizing the project through tax revenue from the benefiting consumers and processors might be an alternative to help fund the project.

2.3.1.2 Cost Recovery Approach

Capital costs of irrigation indicate the total cost incurred in the development of a project. The cost recovery amount is usually calculated multiplying the cost recovery factor by the annual cost of the project distributed over the project life period. The Cost Recovery Factor (CRF) is expressed as eq. 2.11:

$$\mathrm{CRF} = \left[\frac{i \times (1+i)^n}{(1+i)^n - 1}\right] \tag{2.11}$$

where,

i is discount rate and n is life period of the project. CRF converts a present payment into a stream of equal annual payments over a specified time, at a specified discount rate.

2.4 Role of Economic Incentive in Improving Water Use in Irrigated Agriculture

The increasing demand for water, growing scarcity and rising cost of augmentation have led to the realization that water has to be allocated and used efficiently (Grimble, 1999). In the past, economic measures such as water charge and taxes have mainly been introduced with the aim of generating revenue to partially cover the cost of supplies (OECD, 1999).

The use of incentive-based measures for improving efficiency in the resource use is very rare in practice. It is precisely secure property rights, which provide incentives for efficient resource allocation. This applies specifically to smallholder irrigation farmers who require predictable outcomes of decisions before expending farming activities or intensifying their production methods, etc. In this context, there is a need for conceptualizing on the role economic incentive measures and resource use efficiency, producer's cost and economic variables. The rest of the section provides a brief description of the role of economic incentive measures in motivating improved water use in irrigation at various levels of policy intervention.

2.4.1 Water Charging and Cost recovery

Water prices denote any charge or levy that farmers have to pay in order to obtain access to water in their fields (OECD, 1999) and is based on the user pays principle that those who benefit from the use of scarce resource should pay (Dommem, 1993). The adoption of the user pays principle provides a basis for pricing and allocation scarce among different uses, which could help improve water use efficiency and reduce conflicts in sharing scarce water (Tewari, 1998). Water charging and cost recovery refers also to that issue but also to others, as there are a number of approaches to pricing or taxation. However, in practice, there are several issues involved in the pricing of irrigation water for achieving different aspects of water use efficiency.

In some developing countries, irrigation water is also charged on the basis of output per area, i.e. irrigators pay a certain water fee for each unit of output they produce (Johansson, 2000). The basic concept is that farmers should pay the charge according to the crop productivity or value of output they derived per unit of water used e.g. gross margin gained per m^3. For example, in Pakistan, Philippines, Mexico, and India the output pricing system is based on type of crops grown, which somewhat reflects the charging system according to the amount for water used (Yoduleman, 1989; Tewari, 1998; Johannson, 2000).

Another basic concept is that of farmers willingness-to-pay (WTP) based on pricing: how much users are ready to pay? And cost based approach to pricing: how much does it cost to supply water to the user? As indicated earlier, in smallholder irrigation sector in South Africa, when existing, charging systems are more often based on accost recovery principle, at least for O&M (Perret et ak.2003).

2.4.2 Subsidies

Subsidy on irrigation water is considered as the difference between what farmers actually pay per unit of irrigation water and the marginal cost of supply or full cost price of water. Perret, et al. (2003) studied in South Africa smallholder irrigation water that has been highly subsidized in the past, and even at least the capital costs are still being subsidized. As farmers receive irrigation water at a relatively lower price, it provides no economic incentives to them for using water more efficiently (Backeberg, 1996). Elimination of existing subsidy in the smallholder irrigation sector and re-investment of the resulting fiscal saving in efficient water use technologies could thus improve WUE and result in large monetary benefits. In the South Africa context, as presented in the preceding section, Department of water and Forestry of South Africa (DWAF) charging policy entails the idea that the operational subsidies (O&M costs) will be phased out over 5 years after the WAUs is established and contract is set up by DWAF. This means that ultimately after 5 years farmers should pay for additional costs under the current water consumption (Perret, et al., 2003)

Table 7 Selected Countries or Regions Reporting Low Cost-recovery Rates or Low Collection Rates (K. William Easter and Yang Liu, 2005)

Country/reqion	***Collection rate***	***Percentage of cost recovered***	***Comment***
Argentina 1997 (Sevendsen et al. 1997)	70 percent	12 percent of O&M	Water charges are very low and based on area: fixed area fee of $70/ha/year. Fee collections are managed jointly by the government and the water user associations.
Bangladesh 1998 (Government of People's Republic of Bangladesh 2000)	3 to 10 percent	Low	In 1997-98, water charges were levied in only 6 of the 15 major irrigation schemes.
Botswana 1994-95 (Thema 1997)	n.a.	44 percent of the O&M in 1995; cost-recovery rates have been between 35 and 45 percent since1988. Government pays capital cost	Increasing block pricing system. By the end of 1996-97, revenue was scheduled to recover O&M costs, but by 1995 charges were too low to cover these costs.
Jaiba Project, Brazil 1995 (Azevedo 1997)	66 percent	52 percent of total costs	The two-part water charging system is well designed, but collection rates are too low
Columbia 1996 (Svensen et al. 1997)	76 percent	52 percent of O&M	Responsibility for fee collection has been shifted to water user associations. The transfer was too quick, with too time and effort invested in clarifying water rights and responsibilities.
Maharashtra, India 1984 (Easter 1997)	58 to 67 percent	n.a.	There is no link between fees and funds allocated for O&M. There are penalties for default payments, but neither user participation nor incentives for service providers to collect fees

Table 7 Cont’n

Country/reqion	***Collection rate***	***Percentage of cost recovered***	***Comment***
Italy 1997 (Destro 1997)	n.a.	60 percent of total costs	Water charges are too low and based on area.
Jordan 1999 (Rupert and Urban 1999)	n.a.	50 percent of O&M	Water fees are too low, services are not related to water charges, meters are broken, and the volume of water used is deduced from an assumed discharge rate instead of using the meters.
Macedonia 2000 (Hatzius 2000)	42 percent	n.a.	There are no incentives for service providers to collect fees, and user penalties are not effectively enforced for nonpayment.
Nepal 1984 (Easter 1993)	20 percent	n.a.	There is no link between fees and O&M. Fee collection is not give high priority. There are no incentives to collect fees and no enforcement of penalties for nonpayment.
Pakistan 2001 (Ahmad 2002)	30 to 35 percent	n.a.	Revenue from water charges is pooled with other taxes and goes to provincial treasury. There is no clear link between fee payment and service provided.
Philippine 1995 (Svendsen et al. 1997)	58 percent	58 percent of O&M	Area-crop-based water charges, US$77/year/ha on average in 1997.
Sri Lanka 1984 (Easter 1993)	8 percent	n.a.	Communication between farmers and irrigation officials is poor. There is no clear responsibility for O&M.
Tunisia 1991 (Hamdane 2002)	n.a.	National average is 70 percent of O&M costs; ranging from 44 percent in the Central region to 76 percent in the Northern region	Water charges are too low and the public agency managing irrigation is not financially autonomous.

Removal of the existing subsidy for eliminating the existing inefficiency in smallholder sector, and making a shift from 'negative' to 'positive' subsidies, for improving efficiency in water use however, involves several issues such as:

- first, the investment subsidy is considered as the most politically acceptable means for pleasing the farmers in the rural areas, thought major beneficiaries of such subsidy schemes such as for irrigation water have been the agribusiness people in the part rather than the small farmers (DWAF, 1999b);

- second, subsidies aimed at providing economic incentives to farmers, if not designed well and not specifically targeted to specific group, that promote WUE, the it may result in misallocation of resources and also, lower efficiency in water use (Tewari, 2003);

- third, subsidy needs to be implemented only for the transitional period required for making a shift towards the adoption of water productivity. Otherwise, it could also result in over-dependency of farmer on such grants and credits, and would be difficult to modify the farmer's behavior; and

- finally, using subsidy as an economic incentive measure should thus be carefully implemented with evaluation of the impacts of existing subsidy and potential impacts of elimination of such subsidy on the poor households and rural employment opportunities.

Different types of subsidies such as grants (as in Zanyokwe scheme) or payments to WUAs (as in Thabina scheme), provision of extension service. Etc. could be implemented depending upon their effectiveness and suitability to a particular region or scheme such as:

- Subsidies that constitute payment for part of the investment cost (e.g. O&M costs) on water conservation practices to be paid to the farmers on basis of per unit water saved or designated types of water saving technologies;

- Conservation subsidies for crop diversification to be paid on the basis of water saved per unit crop area, or loss in productivity or incremental cost of production (e.g., for making a shift from low yield cropping systems to high yield cropping system);

- Research grants for undertaking the research on efficient water application technologies, and management practices.

2.5 ADB's Role in the reform of water management in Thailand

Thailand was one of the Asian Development Bank (ADB) and attended as a member in 1966. Since joining ADB, Thailand has received approximately $6.14 billion consisting 89 loans. The greatest share of the loans have gone to the energy sector, followed by transport and communications, finance, and water supply, sanitation, and waste management calculated to 33.34%,21.04%,17.01%, and 9.69%, respectively. The remaining loans have gone to support projects in health, education, agriculture and natural resources, and industry and trade accounted to 18.92% (The Asian Development Bank, 2011).

After financial crisis in Thailand, the government has received $300 million from ADB for financial sector restructuring and $500 million for social sector restructuring. Moreover, ADB had funding with foreign financial institutions to provide $1 billion for the Export-Import Bank of Thailand which lend to the private sector. In addition, the government was totally handed with 600 million U.S. dollars loan in 1999 from ADB and the Overseas Economic cooperation Fund (OECF) to reform agricultural sector.

The ADB loan conditions are specified under the Country Assistance Plan (CAP) that can be divided to many divisions such as financial sector restructuring and capital market development, education system privatization, public health system privatization, and agricultural sector restructuring (The Asian Development Bank, 2000).

ADB's policies on the restructuring of agriculture were covered the management of water resources, land, upstream areas, credit system, marketing system and research. In addition, the government’s role adjustment is one of the conditions that lead to productivity increasing, export capability rising and the growth of the agricultural sector in Thailand.

The reform of water management structure is one requirement of ABD loan’s condition. ABD also requires the formulation of National Water Resources Policy, a Water Law enactment, an application of cost recovery’s policy in irrigation and a rising of the National Water Resources Committee’s authority in water resources management. Privatization of an irrigation system is covered in the condition that should perform by having a private company supervision of the irrigated operation system. Irrigated sharing in the cost occurring from water management is the issue that incites irrigated water users to perform (Chantawong, 2002).

However, irrigation cost sharing is not successful measurement because there are many factors that against the enforcement such as political sensitive, farmer’s income, and water charge systems. Thus, the studies of irrigation water pricing were established that lead to feasibility studies in irrigated water charging. The studies were done by many organizations both locally and internationally such as the Royal Irrigation Department (RID), the Thailand Development Research Institute (TDRI), the Thailand Research Fund (TRF), and World Bank (WB).

Additionally, there was a study of irrigation management modernization in Chao Phraya river basin by cooperated between the RID and the WB. The study was focused in the management of irrigation system, structure and organizational role. Moreover, the result was showed that the government bear O&M cost both of middle and large projects approximately 200-250 baht per rai per year accounted 5% of farmer’s net income per year. Thus, famers should pay for O&M cost of irrigation following the Participatory Irrigation Management scheme (Punya Consultant and et.al, 2000).

2.6 Thailand’s Rice Policy

Given the importance of rice in Thailand, the successive governments have intervened in the rice market and the rice trading. They followed two main purposes: first, the control of domestic price for consumers (particularly in urban areas), and second, the guarantee of a minimum price or revenue to farmers (Laiprakorbsub, 2012).

In recent years, two major of rice price policies were developed by the Ministry of Agriculture and Cooperatives together with the Ministry of Commerce (Forssell, 2009).

The first policy is a mortgage scheme that was introduced in 2001 under the Thaksin Shinawatra government (World Bank, 2008). The government pledges farmer’s rice before the harvesting seasons. If the market prices increase, farmers can bring the money to redeem their rice (Prasertsri, 2008). On the other hand, unredeemed products are sold by the government.

Figure 2.1 demonstrates the process of mortgage policy. There are many steps under this project. First of all, farmers need to register their rice plantations with the Department of Agricultural Extension (DOAE). Thus, they will receive the certificate which included the completed checking by their community and the sign of the farmer and assigned staffs. In addition, millers are required to be registered as well. The Public Warehouse Organization (PWO) and Marketing Organization for Farmers (MOF) have an authority for recruitment of rice mill participants. The rice mills have served as the point of paddy deposit and they are responsible to issuing a certificate that assured the pledge. Additionally, participated millers must strictly comply following the requirements that assigned by the government and provide determined equipment such as dehumidified dryer and truck- weighing machine. Planting and harvesting are done by the production plan that will be the duration of the project.

Paddy selling can be classified into two cases. Firstly, farmers can sell their product immediately when the market price is higher than the government-mortgage price. Lastly, farmers can pledge their product at registered rice mills when the market price is lower than the mortgage price. As a result, the rice mills have issued a certificate for them. Then, farmers have submitted their certificate to the Bank for Agriculture and Agricultural Co-operatives (BAAC) for the mortgage and received the money following the mortgage regulations. For example, the government set up the limited amount of pledge that was not more than 500,000 baht per person. However, farmers are able to redeem the pledge within four months if the market price increased. The payment that farmers have to pay for redeem consists of loan and interest. In term of the rice mills after issuing the certificate, they have hulled the rice based on the government regulations and delivered the milled rice to the central warehouse. As a result, government agencies have paid the cost for transportation among the mills and central warehouse (Department of Internal Trade, 2001).

The second policy is price insurance scheme. This policy was operated between early 2010 and 2011 by the Abhisit administration. The principle of this scheme is to pay the difference in price between market price and guaranteed price, when the former is lower than the latter. Farmers receive compensation equal to price difference multiplied by the amount of sold product.

Figure 2.2 illustrates the procedure of price guarantee policy starting with the rice plantation until the compensation payment. Additionally, there were five related actors that consist of the DOAE, farmers, community, millers and BAAC which has different operating. The procedure can be divided into ten steps. First of all, farmers must plant the rice during assigned period. For example, the farmer who plants the rice during the 1st May – 31th October 2010 can attend the project in 2011. Second step was planted area and type of product registration. Farmers must register their planted area and type of rice that they produced with the DOAE. However, there were several conditions which affected farmers who participated in this project. The amount of the production is confined that was not more than 25 ton per household. Documents that used in the registration were ID card and a copy of household registration. Then, the DOAE will issue the certificate for farmers. After certificate receiving, the audit committee of the district community has an authority to continually inspect the production area. Hence, the inspector will verify farmer’s production. Next, farmers have to submit all documents to the BAAC for income insurance contract. In term of harvesting, it is operated following the production plan. Farmers can sell their products to millers that the prices were acceptance. After that, the millers paid the money to farmers. If the reference market price that announced by the government in every Monday is lower than the guarantee price, they can request for the compensation. On the other hand, the compensation is calculated by the quantities of rice that were not more than 25 ton (Thai Rice Exporter Association, 2012).

After the survey was conducted, the new government changed back the policy to a mortgage scheme with a price of 15,000 baht per ton for 100% white paddy and 20,000 baht per ton for Hom Mali paddy.

To conclude, both policies aim to support short-term goal that is the farmer's income guarantee whereas they do not focus on longer term goals such as enhancing the farmer's ability. Finally, both policies lead to market distortions.

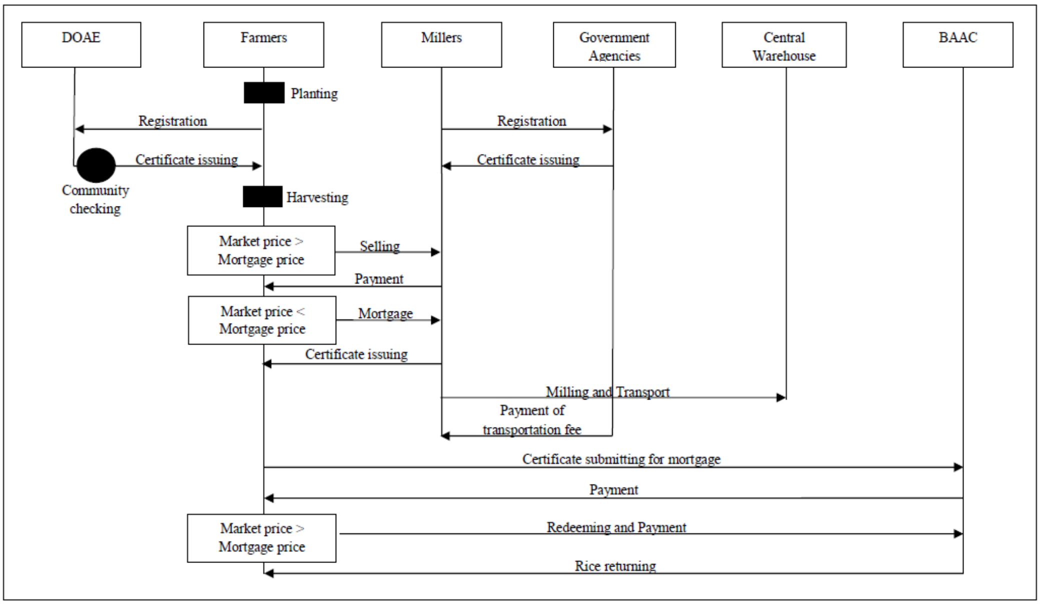


Figure 2.1 The process of mortgage policy

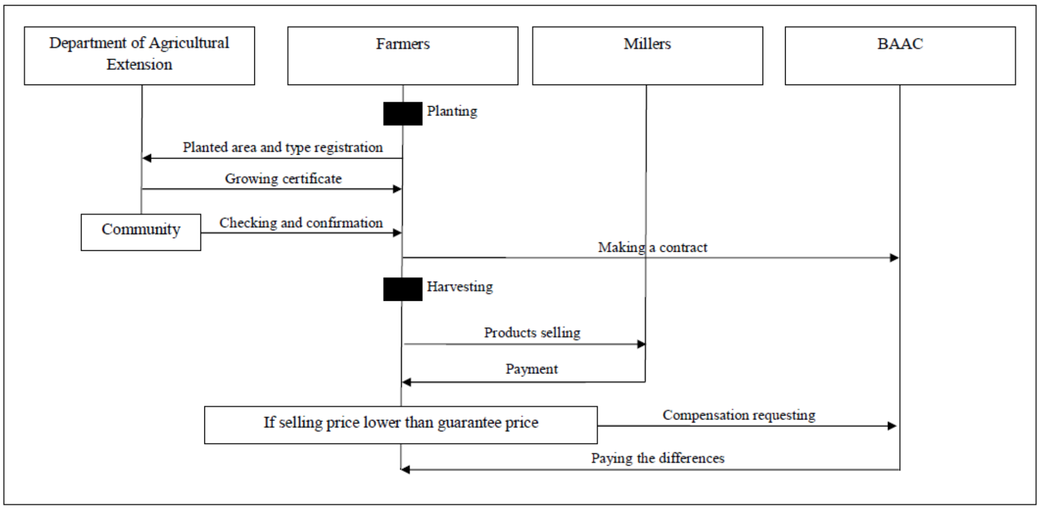


Figure 2.2 The procedure of price guarantee policy

2.7 Rice Marketing System

Department of Internal Tread (DIT) and Thammasat University Research and Consultancy Institute, (2008) described the rice supply chain in Thailand are consist many component from the upstream to downstream as well as the links and supported which levels have different roles. However, it can connect together between the supply chains. The study of supply chain can analyze and evaluate the opportunity in value added of rice production and processing and also meeting the needs of consumers. The classifications of manufacturing and marketing have 3 levels that is 1) Upstream level 2) Middle stream level 3) Downstream level as shows in figure 2.3. Rice is the main agricultural production of Thailand market and World market. There are many processing of rice production that starts manufacturing from the upstream (Farmer) up to the distribution of production at the downstream.

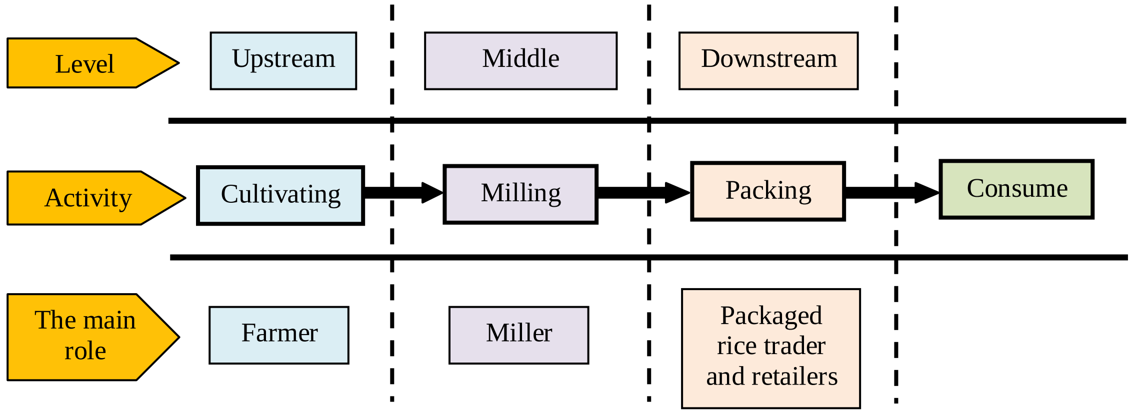


Figure 2.3 Rice supply chain in Thailand

Source; DIT and Thammasat University Research and Consultancy Institute, 2008

The market price of rice marketing has increase along the supply chain because there are many factors in rice processing such as logistic system, industrial system that are related value added of rice production as shows in figure 2.4.

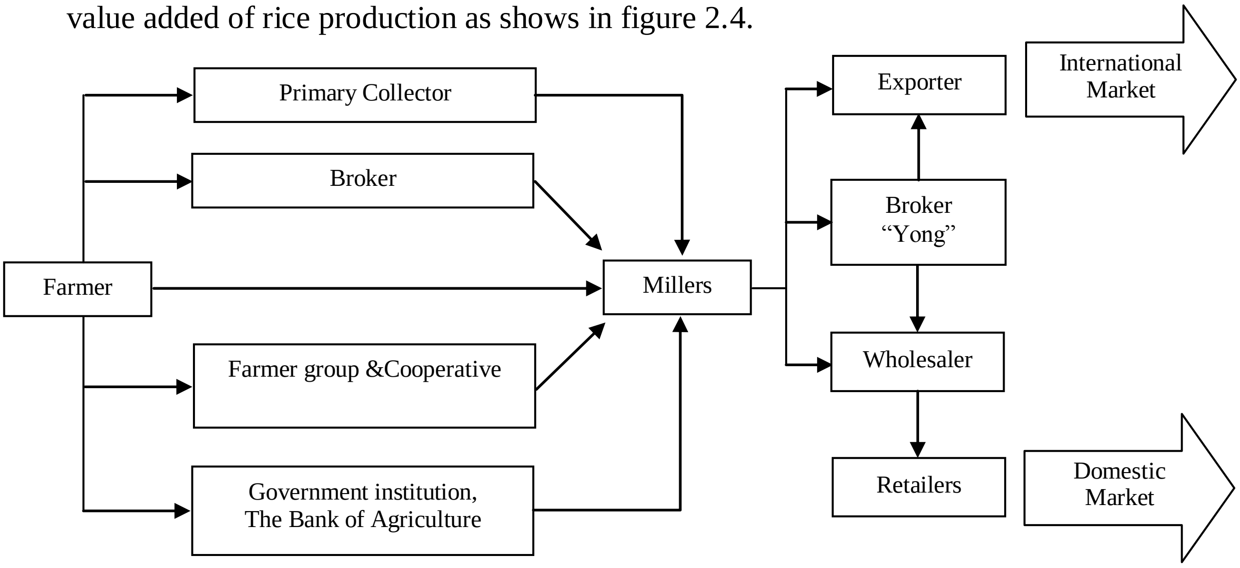


Figure 2.4 The structure of logistic system of rice market in Thailand

Source; Public Warehouse Organization Ministry of Commerce Thailand

Forssell (2009) reported that the marketing of rice in Thailand has complicated structures because there are many intermediaries and different systems that depend on types of rice. Not only government but also private operators perform in the system that can be divided into two groups. The first one is marketing system for paddy. This system also separated into two levels that are local and central. There are five intermediaries at the local level following farmers, local traders, brokers, farmer's organizations and government agencies. Some farmers have directly sold their paddy to millers. In contrast, local buyers have assembled the paddy from farmers or local markets when they have not owned their vehicles and then the collectors have transported it to the mills. At this level, the local traders are usually a village shop owner. Sometimes, they provide credit in cash or production inputs for farmers (Wiboonpongse and Chaovanapoonphol, 2001).

Brokers and commission agents act in rice marketing that connect between rice exporters or wholesalers and millers while their percentage at the local level is rather small. Almost millers use brokers in order to find the rice in the specific varieties and required qualities and quantities that they want. However, only a small number of millers sell the rice directly to exporters and wholesalers (Forssell, 2009).

Farmer's organization is the fouth connector of paddy's marketing system at the local level. It can be divided into two types. The first one called Farmers Group which refers as a group of legal unit that composed at least 30 farmers. The group aims to increase their bargaining power by together acting. The acting could be performed in marketing activities, hiring and acquiring facilities. The group may operate and provide transports, equipments and storages. They may also fulfill financial transactions. . In addition, they sell their paddy directly to traders or millers. The second type of farmer's organization is an agricultural cooperative which has collected the paddy from members and sold it to the market. There are small numbers of agricultural cooperative that are specialized in milling and rice marketing (Wiboonpongse and Chaovanapoonphol, 2001).

The local level in the rice marketing system is operated by the Thai government. The government has agents that buy the rice directly from the farmers. The price is depended on the governmental policy. For example, governmental agents bought the rice from farmers at a guarantee minimum price which was the policy under the Abhisit administration. Nowadays, the number of rice buying by the government has risen due to the mortgage program (Wiboonpongse and Chaovanapoonphol, 2001).

At the central level, the central paddy markets located in the main production areas are established by two main actors that are government agencies and private sector. The governmental market centers are organized by two ministries that are the Department of Agricultural Extension (DOAE) and the Bank for Agriculture and Agricultural Corporative (BAAC). The main function of its market is assigned as government procurement centers. Moreover, basic facilities and services are provided such as drying lawns, warehouses, weighing equipment. Wiboonponge and Chavanapoonpohl (2011) reported that there are 176 sub-district paddy centers organized by the DOAE, the Ministry of Agriculture and Agricultural Cooperative. These governmental procurement centers accommodate rice under price policy measures. Furthermore, there are three regional market centers located in the North, Northeast and Central that set up by the BAAC. In term of privately owned central markets, the Ministry of Commerce supports the markets. The objective of this market set up as a meeting place for assemblers, traders and millers, who want to interface, negotiate and make transactions. Different services and facilities are provided depending on the size of the market place. Normally, it provides drying lawns, gauges to control moisture, storerooms, labors and loans. The market places generate profits from its services and facilities.

The second marketing system of rice is milled rice system. Millers are the main actor in both local and central level because all the paddy rice has passed through them. There are many sizes of the miller. Small millers have facilitated for farmers and villages in order to mill the rice for their household consumption. In contrast, medium and large millers mill for local, regional and export markets occasionally. In the past years, the number of mills has been steadily decreasing. The reason of that declining was the increasing of many difficulties that led to business survival. There were many factors considered in the competition. One of them was technology usage. Upgraded technology for both production and packing were applied by the larger millers while the smaller and medium sized ones employed inefficient technology. As a result, they cannot survive in the business. During the past decade, many standards were implemented by the larger millers such as Good Manufacturing Practices (GMP), International Organization for Standardization (ISO) and Hazard Analysis and Critical Control Points (HACCP) (Vanichanont, 2004). According to the financial system in Thailand, the financial institute can provide loans with low interest that is an opportunity for new entrancing and existing mills in order to expand and develop their business (Dawe et al., 2008). After milling process, rice can take different channel before it reaches to final destination. Commission agents are accounted as the largest share of milled rice buying. They help to find the required qualities and quantities of rice that wholesalers and exporters determine. In Thailand, rice industry is a very strong sector consisting of more than 100 rice exporting companies (Vanichanont, 2004). According to the mortgage program, the government has purchased the rice approximately 6.78 million ton in 2011/2012 scheme (Prachachat, 2012). An abundant share of rice from millers is bought by government agencies. Then, they sell the rice to wholesalers who resell it again to retailers and consumers. Only large millers have sold some rice directly to exporters or foreign importers. However, millers sometimes have directly sold the rice to wholesalers, retailers or consumer that calculated only small share in this way (Wiboonpongse and Chaovanapoonphol, 2001).

According to the above explanation, the rice marketing system might not seem so complicated. Nevertheless, there are different actors that related in the system and the different type of rice is the factor that determined the marketing system characteristic. Figure 2.5 illustrates the marketing system for rice in general (Wiboonpongse and Chaovanapoonphol, 2001).

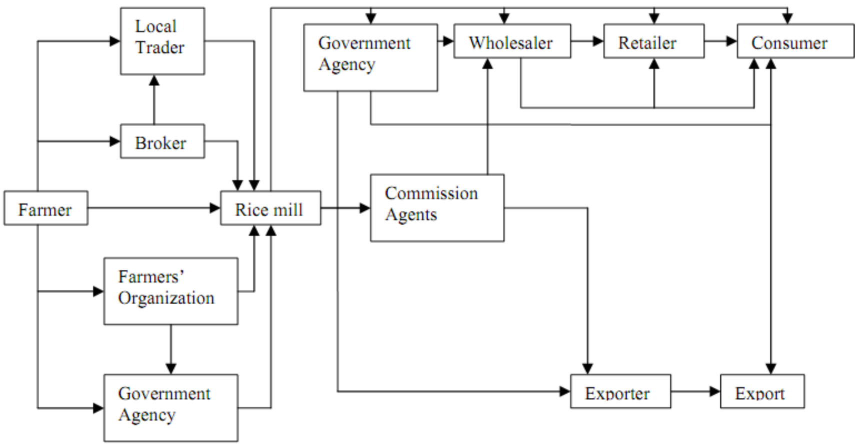


Figure 2.5 Marketing Systems for Rice

Source: Wiboonpongse and Chaovanapoonphol (2001), p. 198

2.8 Value added analysis along the rice supply chain in Thailand

2.8.1 Rice supply chain

Rice is a major agricultural production of Thailand. We can decompose the supply/value chain into three levels.

The **upstream level** corresponds to the farm level production of rice. Nowadays, farmers' cultivation practices have changed from the past: many operations formerly done by farmers themselves are now contracted out or mechanized. However, farmers still sale paddy by themselves. Moreover, exporters and wholesalers are also increasingly contracting out farmers: they provide the necessary factor of production such as seed, machinery, etc., and in turn they purchase the farmers paddy production at a price agreed at the start of the contract. In summary, the changing practice style of farmers has 2 characteristics: 1) changing from crop cultivation to farm management, And 2) from self-decision making to contract farming.

After harvesting, farmers will sell paddy to the buyer who is actor in the middle level step. The linking between the upstream and middle stream have linked by intermediary actors such as, collector, and government agencies.

The **middle stream level** is mainly concerned with the milling of paddy. The main actor in this process is the miller who buys paddy from upstream level actors. Therefore, millers are transforming the paddy into white rice salable and by-product of rice processing, such as rice husk, rice bran, broken rice, etc. to the downstream level actors

Milling is mainly done by Thai investors, but the number of foreigners also investing with Thai people increased. The statistic from Department of Business Development reported foreign investors in milling process that is China, Australia, Canada, Japan, America, Singapore, and Taiwan, etc.

After being milled, white rice is sold to downstream actors. The transport between the middle stream and downstream have links to intermediary related such as broker, wholesaler, retailer, and exporter.

Finally, the **downstream level's** main activity is to distribute white rice to consumers by packaging the rice in many forms and sizes.

The white rice in domestic market can be distributed into two main ways: 1) Traditional Trade, 2) Modern Trade. The most popular way is Traditional Trade (70% of the market). Moreover, rice business can divide into 2 options that are packaged rice and rice retailer (see figure 2.6). Normally, the most consumers select buying shred rice that is the selling way of Tradition Trade.

Currently, for the selling of packaged rice in Thailand have competitive pricing in modern trade than the traditional trade that shown in the proportion of 90:10. The leaders of packaged rice have 3 lists of brand such as Kaset brand, Mah Boonkrong brand, and Hong Thong brand there are the proportion of market is 11% for each brand. Moreover, there are other brands 67% such as Cha Lad Chim brand, Benjarong brand, and Royal Umbrella brand (Prachachat Business News, February 15, 2008). The investment cost of Thai packaged rice traders is rice sacks cost, packaging cost, human labor cost, interest, transportation cost, managing cost, and marketing cost.

(a) (b)

Figure 2.6 (a) Packaged rice in superstore and (b) Rice Retailer in local area

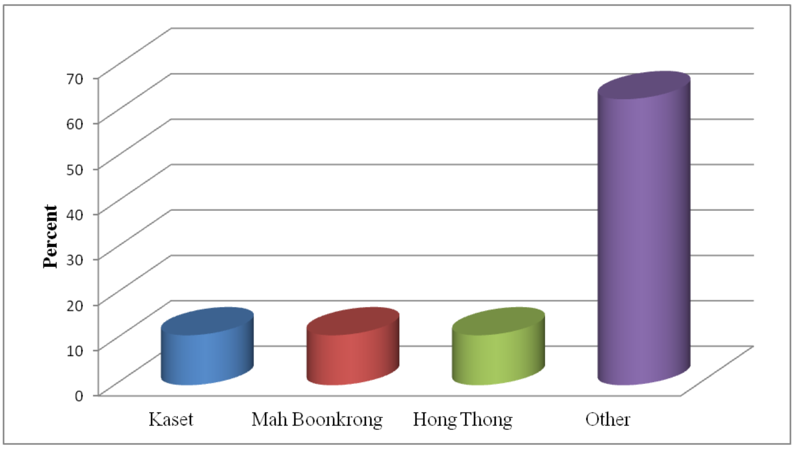


Figure 2.7 The proportion marketing of packaged rice in Thailand

Source; Prachachat Business News, February 15, 2008

In conclusion, rice supply chain of Thailand is including of upstream level, middle level, and downstream level. There are businesses related or intermediate to links in each level such as Fertilizer and chemical business, Machinery and agricultural equipment, seed, and investment source. Moreover, the rice processing producers used rice as production to produce in next step. Furthermore, the support units that provides indirect support.

2.8.2 Related industries

From the analysis rice supply chain in Thailand mentioned above there are many related industries in each level of supply chain that shown in figure 2.8 as detail follow below.

2.8.2.1 Seed Industries

Seed is the one factor that is important process in the upstream level. The selected of seed have effect with quality and quantity of paddy production that mean selected the high quality of seed it can increase the yield of paddy and reduce the investment cost such as fertilizer, chemical. The source of seed of farmer is follow below.

1) From the previous season that mean before selling paddy, farmers divided the seed of paddy for using in next season. Therefore, it is the source of seed that has lowest cost and very famous. However, there is a problem that is mutation when used that seed grown in very period. Also, the performance of seed has decrease and will affect the yield of paddy.

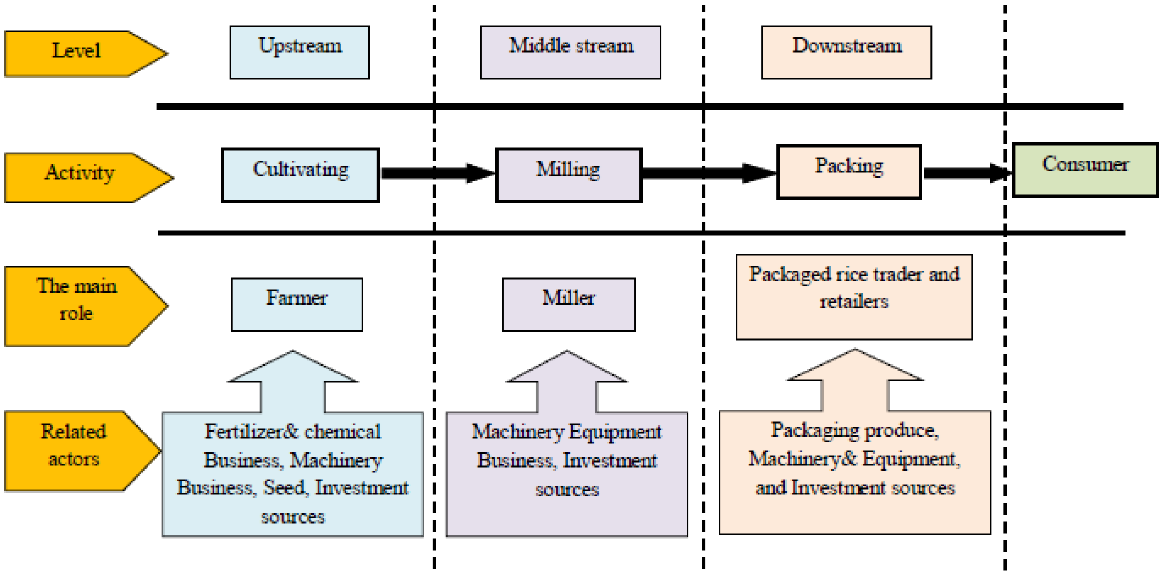


Figure 2.8 Rice production structure and related actors

Source; DIT and Thammasat University Research and Consultancy Institute, 2008

2) Buy from other source such as Research and Development of rice verities Office, paddy traders, and Contract Framing.

- Research and Development of rice verities Office is the distribute source and seed selling of government but farmers have problem from seed lacking

- Paddy Traders; nowadays, paddy traders have change function to the supporter of production factors that supported farmers such as seed, fertilizer and chemical, transportation, and investment. Thus, paddy traders buy the seed from Research and Development of rice verities Office and cultivation propagating to get the seed and selling to farmers.

- Contract Farming; farmers who make a contract with the employer. Sometime the employer will give the seed in cultivation.

2.8.2.2 Fertilizer Industries

Fertilizer is another one of the factor that affect with quality and quantity of paddy production. Farmer can buy in many sources such as the local fertilizer and chemical traders, paddy traders, and Bank of Agricultural, etc.

Conditions in the fertilizer market, Thailand is very readiness source of raw materials to be used to produce like commercial. There is need to imported and high demand. Since 1997, the demand of fertilizer around 3.35 million ton and increased in 2007 around 4.42 million ton that have marketing value around 35,000 million Baht. The condition of competition in domestic is semi competitive and semi-monopolistic. It cans classification of fertilizer market into 2 classes as describe below.

1) Private market; in the private market can classified the fertilizer traders into 3 groups that is fertilizer importer, fertilizer importer and mixed for selling, and agricultural cooperative.

2) Government market; it operate by government agency such as Agricultural Marketing Organization, and Bank of Agricultural and Cooperation. There is more in Bank of Agricultural and Cooperation because it is the main buyer from fertilizer importer groups, and fertilizer importer and mixed for selling groups. After that, the Bank of Agricultural and Cooperation give a loan with farmers who need investment in buying fertilizer.

Furthermore, fertilizer is the main factor that directly affect with production cost and profit of farmers. Thailand Rice Department has the policy that increase the revenue of farmers by reducing the production cost which used the bio-fertilizer. Moreover, Thailand Rice Department have plan to increase the Bio-Fertilizer plants around 402 plants are available and the Organic-Fertilizer and Chemical Fertilizer plants around 1,000 plants will reopen and can produce the fertilizer to community again (Bangkok Business News, April 29, 2008)

2.8.2.3 Machinery Industries

Equipment and machinery is another factor of production that affect with production cost of farmers. It means using of machinery in planted that have reducing the production cost such labor cost. Currently, the numbers of farmers are reducing and increase of labor wage. Also, the machinery becomes to the important factor especially the commercial cultivation or the large cultivated area.
Machinery Industries are the heavy industry that had the marketing value around 10,000 million Baht and also imported (T. Isawaree, 2006). The machinery is related in paddy cultivation that is land preparation equipment, sowing equipment, harvesting and threshing machinery. From the machinery described that shows the development of machinery and also it cans replace the labor in paddy cultivation. However, the price or cost of machinery is very expensive. Therefore, some farmer uses their machinery in employed.

Moreover, the machinery and equipment is the supported industry of production in middle stream and downstream level especially mill that is middle stream level and high demand for machinery. Furthermore, the quality of white rice depends on machinery.

2.8.2.4 Investment Sources

Investment factor is a factor that is important with operation business of upstream level up to downstream level. Financial resources accessing is a major drawback of farmers. The importance investment sources of farmers are Bank of Agricultural and Cooperation, paddy traders, Agricultural Cooperative, mill, and including Contract Farming employer. For mill in year 2008, some mill had to close the factory because increasing of production cost that is the cost of raw materials (paddy). Therefore, they need to increased investment and difficult of financial resources accessing and lending. As a result, some mill factory had close operation.

2.8.2.5 Rice Processed Industries

Rice processed industry is the industry in the downstream that is the most industry of value added in rice production. It can produce in many forms of products such as products for consumption. From the study of value creation in Mood Consumption of Faculty of Agricultural Industry, Kasetsart University (2007) reported the value added of rice by bring the rice to the second product stage. It will increase the value of product and becomes to the new product in the market. That study was survey rice production which is commercial produce. The basic of value added of rice production is shown in figure 2.9.

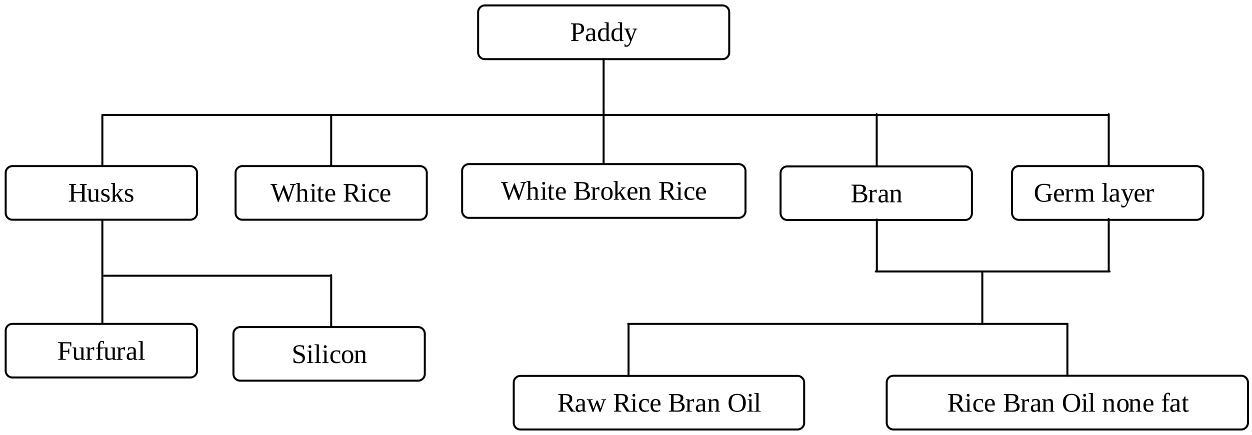


Figure 2.9 The primary of rice processed

Source; Faculty of Agricultural Industry, Kasetsart University, Thailand (2007)

Figure 2.8 are shown the primary of rice processed that is explaining the component of paddy. There are consisting 5 components; 1) Husks, 2) White Rice, 3) White Broken Rice, 4) Bran, and 5) Germ layer. After milling, these components of paddy can produce many productions such as bran. For example, when the extraction process the product is the raw rice bran oil and the extraction process of raw rice bran oil will get the oil acid, oil for frying, etc. The rice production can classify 2 main groups that are 1) Foods, and 2) Non-Foods.

Rice production for consumption is the value added of rice industry that need supported from a variety of different unit of rice industry. Also, it can be successful and increase the supply chain process such as rice, rice flour, and glutinous rice flour. These can be the raw production of food such as noodle industry, and dessert production, etc. There are classification of rice production in 3 types 1) Major Food Group, 2) Snack Group, and 3) Drink group.

Nowadays, rice industry has many products. For example, the producer of Hong Thong brand that produce the packaged rice. Moreover, they are mill, wholesaler in domestic market, and exporter. The new innovation of them, they produce and upgrade the quality of rice or called Premium Rice such as Premium rice with iron and calcium (A. Lamonpech, 2008). Figure 2.10 is shown the type of rice processed, and figure 2.11 is shown the proportion of utilization of rice in Thailand.

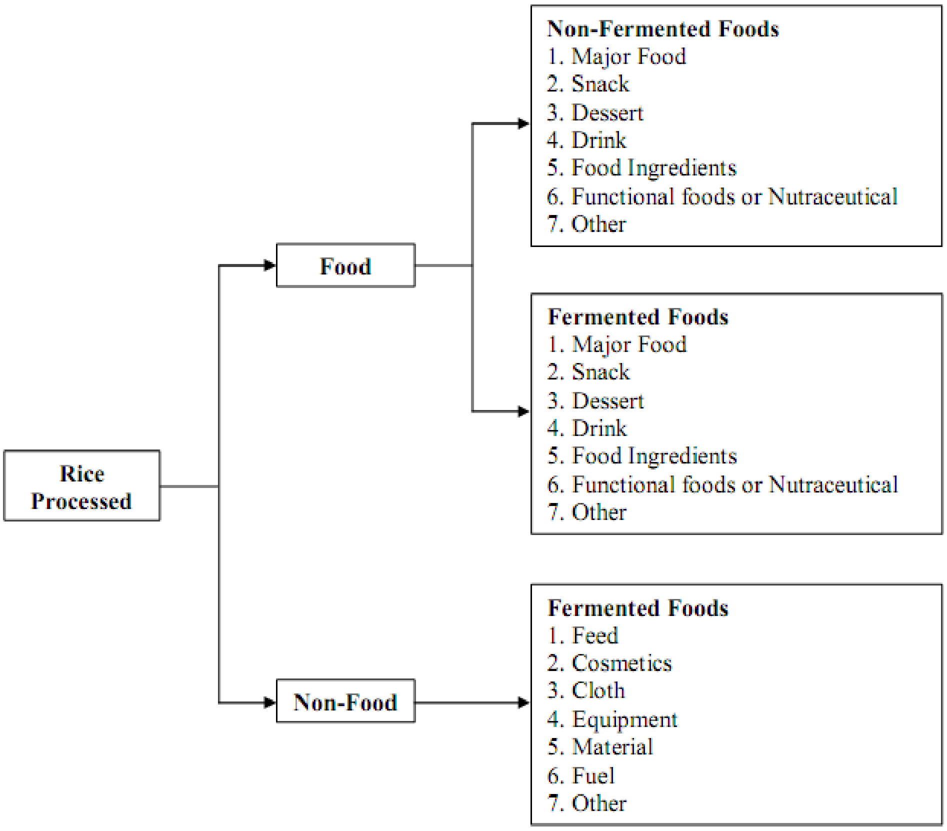


Figure 2.10 Type of rice processed

Source; Faculty of Agricultural Industry, Kasetsart University, Thailand (2007)

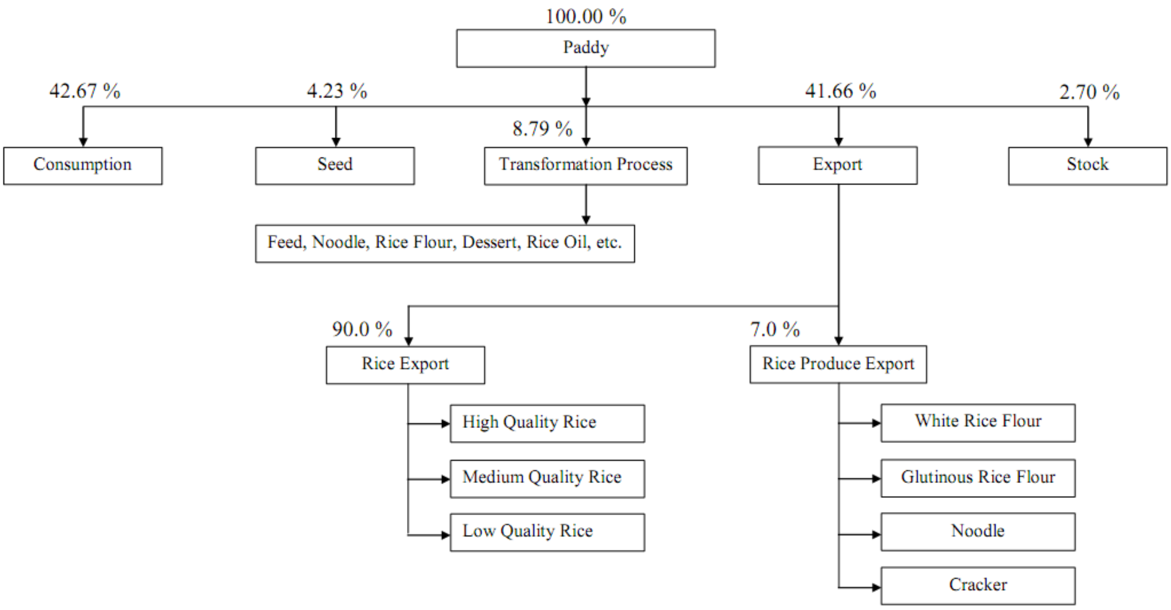


Figure 2.11 The Utilization of Rice Production in Thailand

Source: Ministry of Agriculture, 2009

CHAPTER 3

METHODOLOGY

3.1 Methodology Approach

The study was concentrated in the analysis of costs and benefits of the Sam Chuk irrigation scheme located in Suphan Buri province, Thailand. Moreover, the study was conducted four main types which were, (a) estimate the value of water for irrigated rice farmers, (b) perform added-value analysis and input-output analysis along the supply chain, (c) assess the costs incurred by RID to supply irrigation, and (d) investigate possible new financing and institutional arrangements to cover for irrigation supply and maintenance costs. The major steps have following:

- Organize a farm survey of 20 farms within the irrigation scheme to collect information about the inputs used to produce rice such as, machinery (M), labor (L), seed (S), fertilizer (F), pesticide (P) and water (W). Moreover, assessing actual yields of rice field and the price of rice production at farm level; This information was used to estimate the value of irrigation water to rice farmer using the residual imputation method;

- Assess the operation and maintenance costs of the Sam Chuk irrigation schemeas well as investments made since its construction;

- Information collecting on the price of rice along the supply and marketing chain and perform added-value analysis and input-output analysis performing along the chain;

- Work on possible new financing and institutional arrangements to cover the irrigation supply and maintenance costs;

The research methodology framework is given as following figure in section 3.2.

3.2 Research Methodology Framework

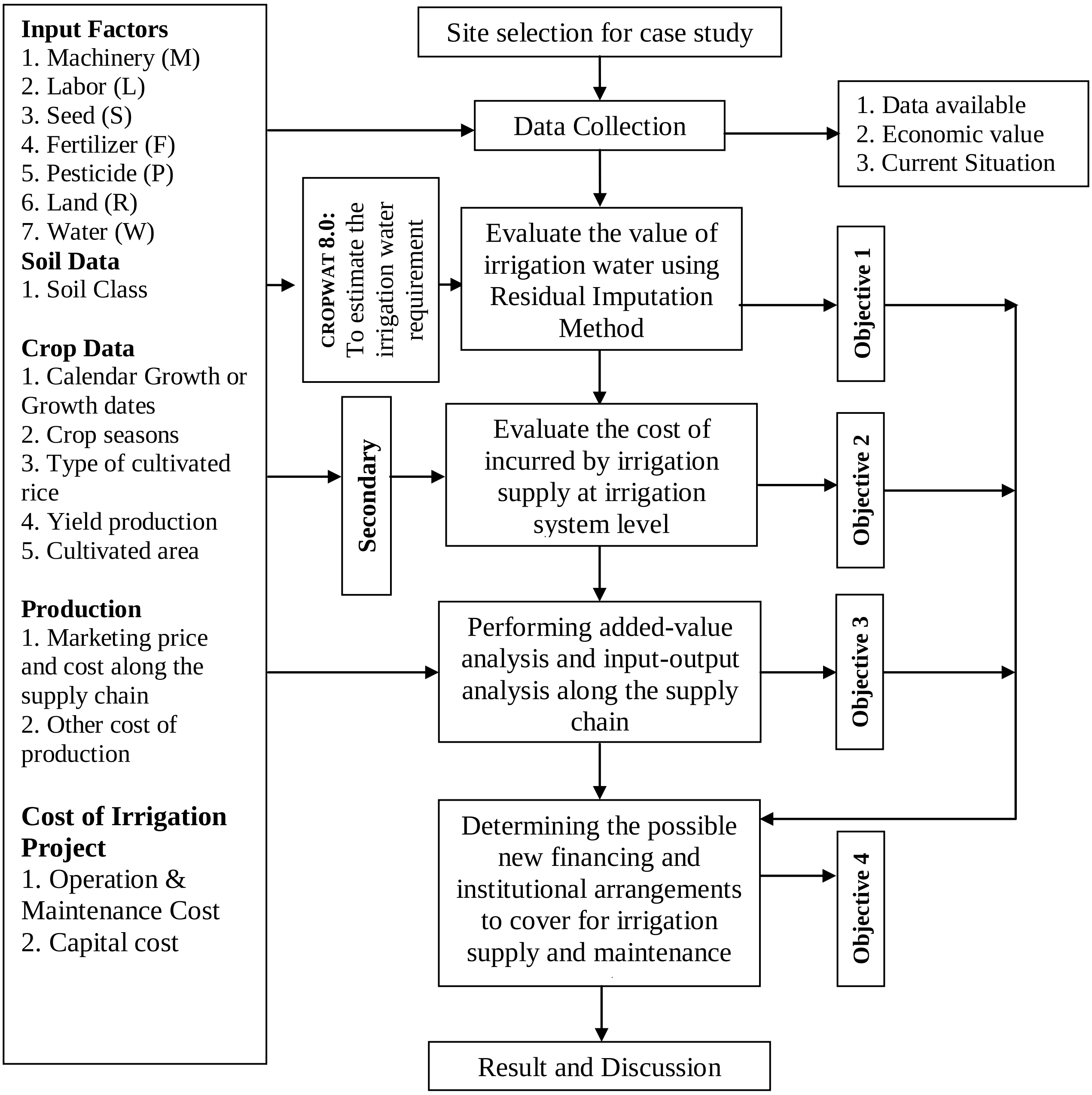


Figure 3.1 Frameworks for Methodology

Table 8 Summary of methods, indicators, data requirements and data sources based on the objectives of the study

No.	Objective	Indicators	Method or Approach	Data requirement	Data Sources
1	Investigating the economic value of water for rice farmers	• Yield, • water use, labor, fertilizer use, pesticides use, draft power use, machinery, direct energy use, production costs, net farming income, (indicators expressed as per ha)	• Data collection and analysis • Using CROPWAT 8.0 calculate the amount of irrigation water supply in paddy field • Residual Imputation Method	• total land use for producing rice, area effectively cropped over one year, information on soil, climate, basin hydrology • input-output data for the production of irrigated rice for farmers contrasted by their farm size; • cropping calendar, rice crop • Water availability indicator at local level	Survey of 20 farmers to assess their practices at field level (record of inputs/outputs for the cropping season 2009/2010 Secondary data about the irrigation scheme and some market prices
2	Assessing the costs incurred by irrigation supply at irrigation system level.	• water delivery schedule • quantity of water, water account, budget of Irrigation Project	• Data collection and analysis • Financing Method	O & M cost of irrigation project	Secondary data from Sam Chuk O&M project that consist about cost of construction, O&M cost, etc.
3	Value chain along rice marketing channel.	marketing process; price and cost of product	• Secondary Data Analysis	price market at any levels	Interviews with the president of Suphan Buri Rice Millers Association Secondary data from Suphan Buri milled rice association
4	Investigating possible new financing arrangements to cover for irrigation supply and maintenance costs.	Scenario	Analysis result	Outputs of previous sub-objectives	

3.3 Selection and Description of the Study Area

3.3.1 Selection of the study area

The study area located under the Sam Chuk operation and maintenance project (SCP) which is an irrigation project located in Sam Chuk district, Suphan Buri province, in the central plain of Thailand. SCP is the part of Tha Chin (Figure 3.2)

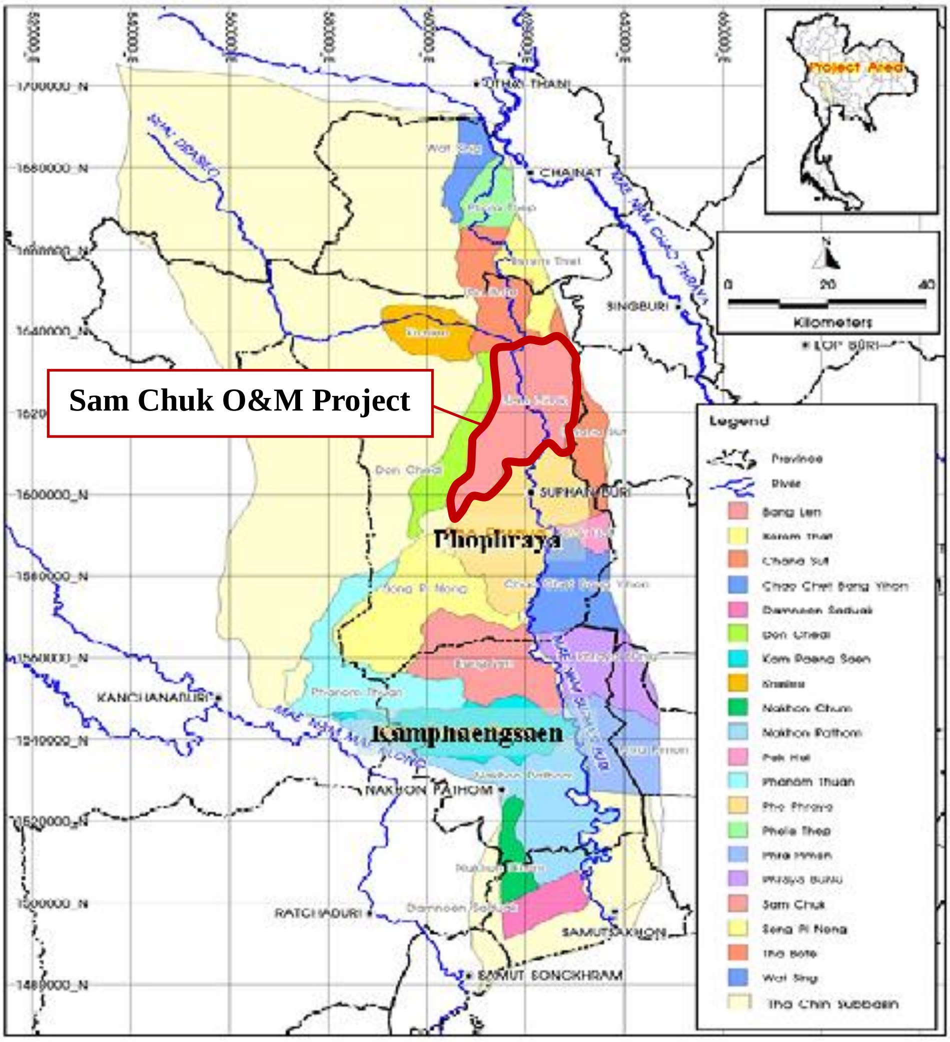
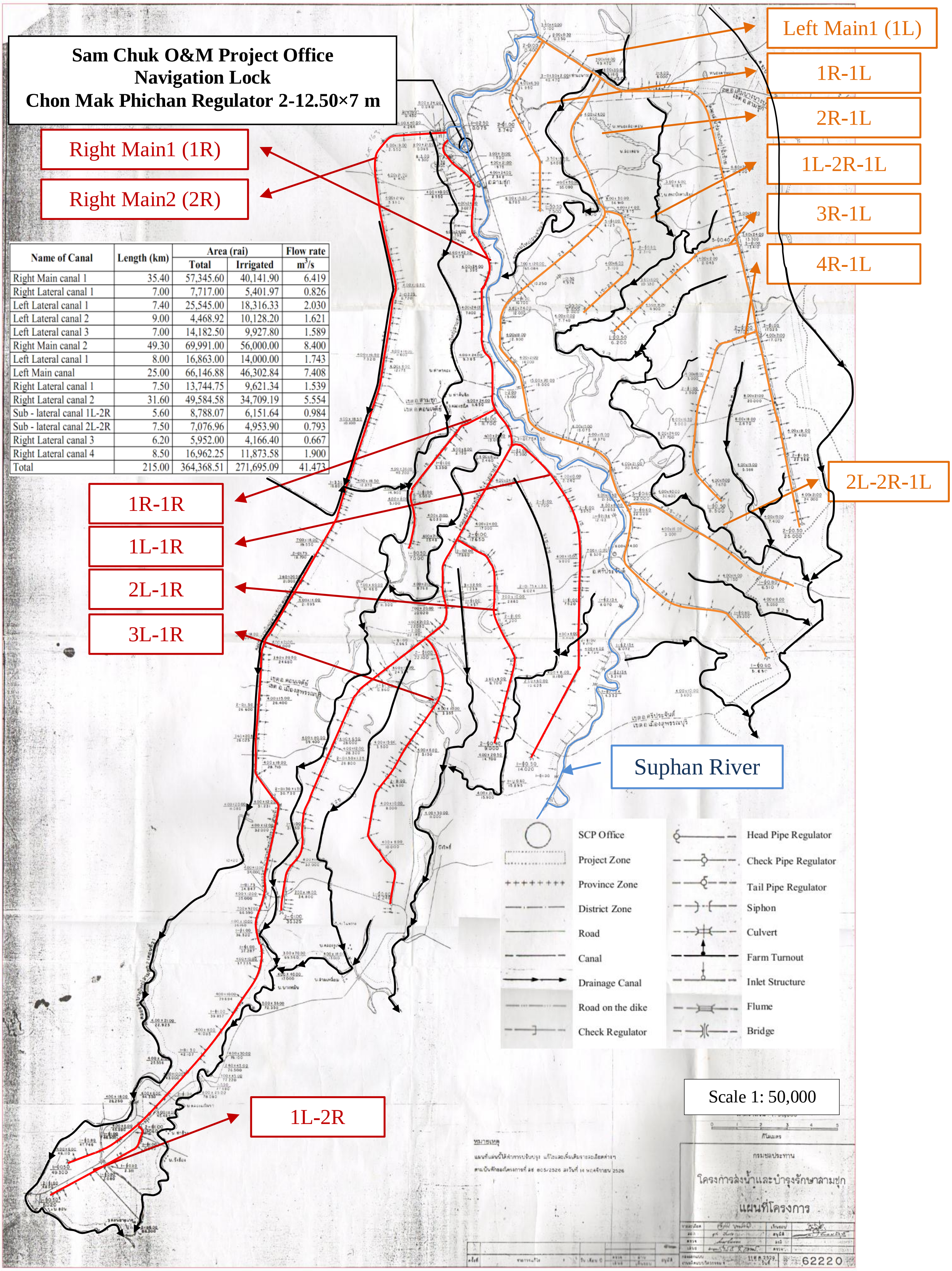


Figure 3.2 Operation and maintenance project in Tha Chin Basin

3.3.2 Study area description

History of project

Tha Chin River is the distributary of the Chao Phraya River. It splits from the Chao Phraya river at Chainat province in the central plain of Thailand. The Tha Chin River drains a total area of 13,681 square kilometers. Furthermore, Tha Chin Basin is a part of the Chao Phraya Watershed and it can be divided in to three sections which are 1) Makarm Teo project or Pollathep project, 2) Sam Chuk project, and 3) Pho Phraya project.



Name of Canal	Length (km)	Area (rai)		Flow rate
		Total	Irrigated	m^3/s
Right Main canal 1	35.40	57,345.60	40,141.90	6.419
Right Lateral canal 1	7.00	7,717.00	5,401.97	0.826
Left Lateral canal 1	7.40	25,545.00	18,316.33	2.030
Left Lateral canal 2	9.00	4,468.92	10,128.20	1.621
Left Lateral canal 3	7.00	14,182.50	9,927.80	1.589
Right Main canal 2	49.30	69,991.00	56,000.00	8.400
Left Lateral canal 1	8.00	16,863.00	14,000.00	1.743
Left Main canal	25.00	66,146.88	46,302.84	7.408
Right Lateral canal 1	7.50	13,744.75	9,621.34	1.539
Right Lateral canal 2	31.60	49,584.58	34,709.19	5.554
Sub - lateral canal 1L-2R	5.60	8,788.07	6,151.64	0.984
Sub - lateral canal 2L-2R	7.50	7,076.96	4,953.90	0.793
Right Lateral canal 3	6.20	5,952.00	4,166.40	0.667
Right Lateral canal 4	8.50	16,962.25	11,873.58	1.900
Total	215.00	364,368.51	271,695.09	41.473

Figure 3.3 Map of Sam Chuk O&M Project

Source; Ground Survey Division, RID (1983)

Location

The water distribution system of the Sam Chuk O&M Project start from the upper Chao Phaya Dam at the Polathep regulator throught the Tha Bote regulator to the Sam Chuk regulator or Chon La Mak Pijarn regulator at the 79+100 km.

SCP is a sub project of the Suphan River Irrigation Project. This project was presented by Sir Thomas Ward in 1935. The project includes the Chon Mak Phichan Regulator, a gate which was completed constructed in 1937. The SCP was constructed over a period of 20 years. Since 1955, the water delivery system included 270 km long main channel and other structures. The project office is located at 14.771N, 100.088E.

The project was constructed to serve various objectives: irrigation and drainage, flood control and water storage (using the water gate), land setting and transportation. The project supply irrigation by continuous flow and rotation methods;

Main Headwork Structure; _Chonla Mak Phichan Regulator_

- Maximum water level is +9.150 m. (MSL)
- Water storage level is +9.150 m. (MSL)
- The number and size of gate is 2 gates (2 × W12.50 × H7.00 m) (Figure 3.4)
- Designed maximum flow rate is 318 m^3/s

Figure 3.4 Chonla Mak Phichan Regulator (Coordinates 14.770N, 100.090E)

Navigation lock

Navigation lock is the regulator that built up for the boat transport action. The size of navigation lock is W 35.00 m. L 50.00 m, In addition, the office of SCP is located near the Navigation lock (Figure 3.5).

	
Navigation Lock (Coordination 14.771N 100.088E)	The office of SCP (Coordination 14.771N 100.088E)

Figure 3.5 The building structure at head office of SCP

Headgate of Main Canal

There are consist the three main conveyances for three main canals that using for irrigation water supplying and controlling in irrigation canals such as headgate of right main canal 1, headgate of right main canal 2, and headgate of left main canal.

1) Headgate of Right Main Canal 1(1R) is the gate that built by reinforcement-concrete which sizes 1-2.50×2.10 m. The maximum of water flow is 16 m^3/s as shown Figure 3.6

Figure 3.6 Headgate of Right Main Canal 1 (1R)

2) Headgate of Right Main Canal 2 (2R) is the flume that built by reinforcement-concrete which the large sizes is 2.40×2.10 m and the small size is 1.60×1.10 m. In addition, both of flumes have 36.85 m of length. The maximum of water flow or capacity is 10.238 m^3/s.

Figure 3.7 Headgate of Right Main Canal 2 (2R)

3) Headgate of Left Main Canal 1 (1L) is the siphon that built by reinforcement-concrete and the sizes is 3-1.50×2.10 m and the length is 80.00 m. The maximum of water flow is 16.66 m^3/s. For, flume, the sizes is 1-3.10×1.30 m and the maximum water flow is 6.88 m^3/s.

Figure 3.8 Headgate of Left Main Canal 1 (1L)

The project supplies irrigation water to 6 Suphan Buri province's districts which are Doembang Nangbuat, Sam Chuk, Sri Prachan, Don Chedi, Au Thong, and Muang Suphan Buri and 1 district in Ang Thong province that is Sam Gho.

The SCP project area is 366,413 rai (58,626 ha). In fact, only 313,569 rai (50,171 ha) that receive water through the 3 primary canals. The total length of primary canals is 109.7 km.

Furthermore, there are 11 secondary canals of a total which accounted 114.24 km of length. Moreover, on-farm system has 1,111 ditchs, which the total length is around 1,077 km. In addition, there are 487 drainage ditchs which the total length is around 313 km (Table 9, Figure 3.3)

3.3.3 Economic and agriculture conditions

The economic activity in this project was agriculture. Around 80% of the irrigated area was paddy field and another 20% was vegetable, fruit, and shrimp and fish ponds (Sam Chuk O&M project, 2010). The rice varieties mainly used were RD 29, RD 31 and local varieties. There was approximately 90% of RD varieties and 10% of local varieties (e.g. Suphan Buri and Phitsanulok varieties). The average yield of paddy was 800-900 kg/rai or 5,000-5,625 kg/ha (SCP, 2010) which is higher than the national average. Therefore, rice farmers were making a decent living out of their agricultural activities, especially when compared with other agricultural areas of the country.

Major crop (1st crop) – was started growing in May and harvesting in August – September, and will harvested in December.

Second crop (2nd crop) – the farmers almost used the same seeding and there were harvested in February – April. In this project, there was a complete irrigation system.

3.3.4 Administration

The management of water in SCP is under the responsibility of the regional director of the Regional Irrigation Office 12 of the Royal Irrigation Department. SCP is structured into 8 branchs as show in Figure 3.9.

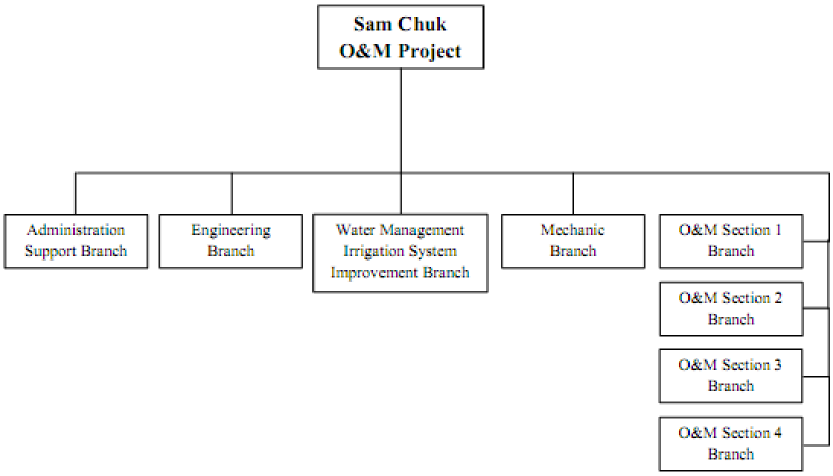


Figure 3.9 Organizational structure of SCP

Administration Support Branch

The responsibility of Administration Support Branch is controling of administration, finance accounting, and procurement and supply of project.

Engineering Branch

The responsibility of Engineering Branch is budget planning of repaired, improvements and maintenance project, and inspection of the building as well as monitoring and reporting.

Table 9 The detail of overall construction in Sam Chuk O&M Project (SCP, 2010)

Irrigation Systems	Details	1ha = 6.25 rai	
1. Irrigated Area	Left side	144,637	rai
	Right side	168,932	rai
	Total	313,569	rai
2. Length of main canal	Left side	25.00	km
	Right side	84.70	km
	Total	109.70	km
3. the number and length of lateral canal and sub-lateral canal	Left side = 6 canals	66.90	km
	Right side = 5 canals	47.34	km
	Total = 11 canals	114.24	km
4. Main structure of SCP			
Head Regulator	1	place	
Check Regulator or Cross Regulator	7	places	
Tail Regulator	3	places	
Head Pipe Regulator	11	places	
Check Pipe Regulator	26	places	
Tail Pipe Regulator	13	places	
Navigation Lock	1	places	
Flume	7	places	
Siphon	3	places	
Culvert	24	places	
Check Drop	1	places	
Farm intake or Farm turnout	574	places	
Off-take or Regulator	44	places	
Constant Head Orifice	106	places	
Pipe intake	3	places	
Timber Bridge	16	places	
Reinforcement Concrete Support Bridge (Base is timber structure)	4	places	
Reinforcement Concrete Bridge	151	places	
On-Farm System			
Ditch	1,111 canals	1,077.60	km
Drain ditch	487 canals	316.36	km
Ditch structure	2,114	places	
Drain ditch structure	361	places	
5. Other			
Farm Road	391 ways	284.883	km
Drain System			
1. Main drain canal	Left side	19.384	km
	Right side	65.497	km
	Total	84.88	km
2. Lateral and sub lateral drain canal	Left side = 6 canals	77.592	km
	Right side = 6 canals	63.225	km
	Total = 12 canals	140.82	km
3. The number of structure in drain system	72	places	
4. Flood dike protection structure and length	2 places	24.4	km

Water Management Irrigation System Improvement Branch

The responsibility of the Water Management Irrigation System Improvement Branch is water allocation planning, water distribution, water using for increasing of irrigation efficiency and also include cropping patterns planning as well as crop production surveying.

Mechanic Branch

The responsibility of Mechanic Branch is maintenance of vehicle, machinery, communication tool, water pumping for cultivation as well as hoist of regulator. Moreover, maintain and repair hoist of regulator.

Operation and Maintenance Branch 1

The office of O&M Branch is located in headworks of SCP. Moreover, O&M branch was resporned in the right side of Suphan Buri River. The area under responsibility of O&M 1 Branch is 119,539 rai (19,126 ha), and 93,000 rai (14,880). For the total area, it can divided into 10 zones including sercurity and maintenance the headworks project.

Operation and Maintenance Branch 2

There is located at moo 3 Sam Chuk sub-district, Sam Chuk district, Suphan Buri province. The total areas under responsibility is 83,300 rai (13,328 ha). In these area, 77,632 rai (12,421 ha) are accounted for irrigated area calculated 93 percent of the total areas which divided into 7 zones.

Operation and Maintenance Branch 3

The locate of O&M Branch 3 were covered the total areas around 92,450 rai (14,792 ha). There is irrigated areas around 84 percent of total area.

Operation and Maintenance Branch 4

The O&M Branch 4 has responsibility the total area that is 75,184 rai (12,029 ha). It is irrigated areas around 66,720 rai (10,675 ha) or 89 percent of total areas. These can divide into 6 zones.

Figure 3.10 is shown the classification of irrigated area under reponsibility of each O&M Barnch in SCP. In additon, Figure 3.11 – 3.15 also shown the irrigation schematic diagrams of SCP and each O&M Branch. The schematic diagrams is shown the detail of canals system and regurators such as cross regulator in the canals.

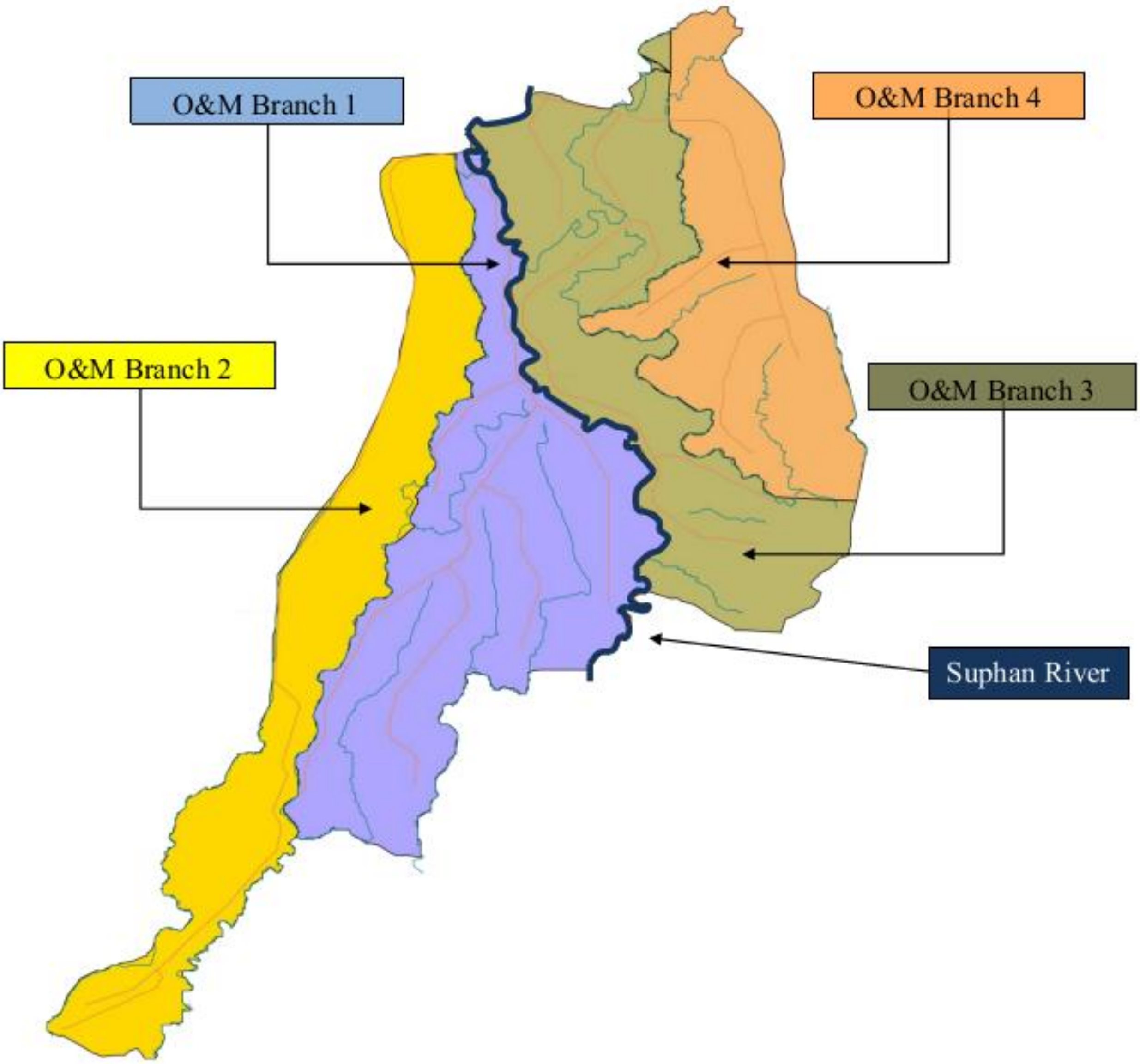


Figure 3.10 Irrigation areas under responsibility of each O&M Branch

Source; SCP, 2010

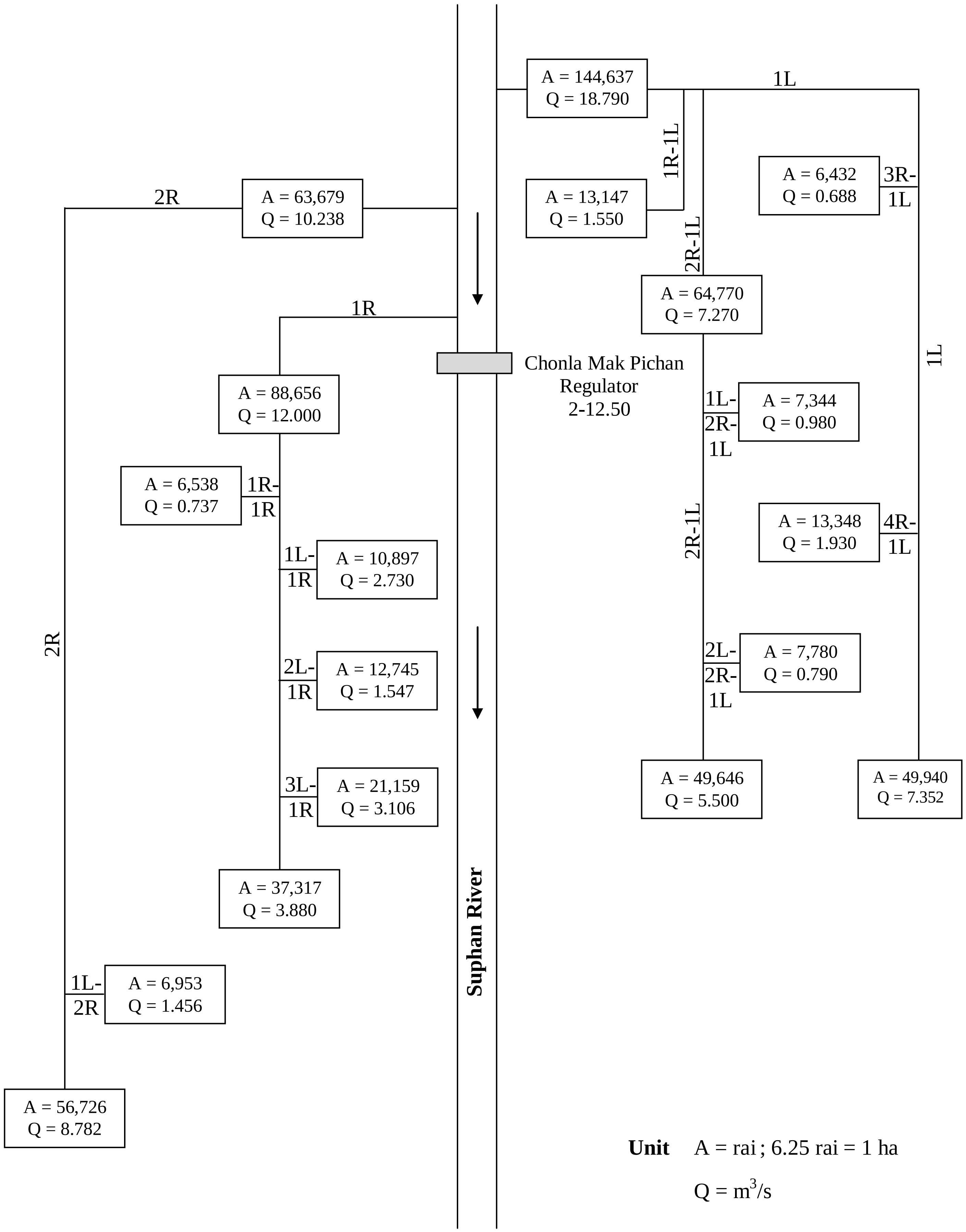


Figure 3.11 Irrigation Schematic Diagrams of SCP

Source; RID and JICA, 1995

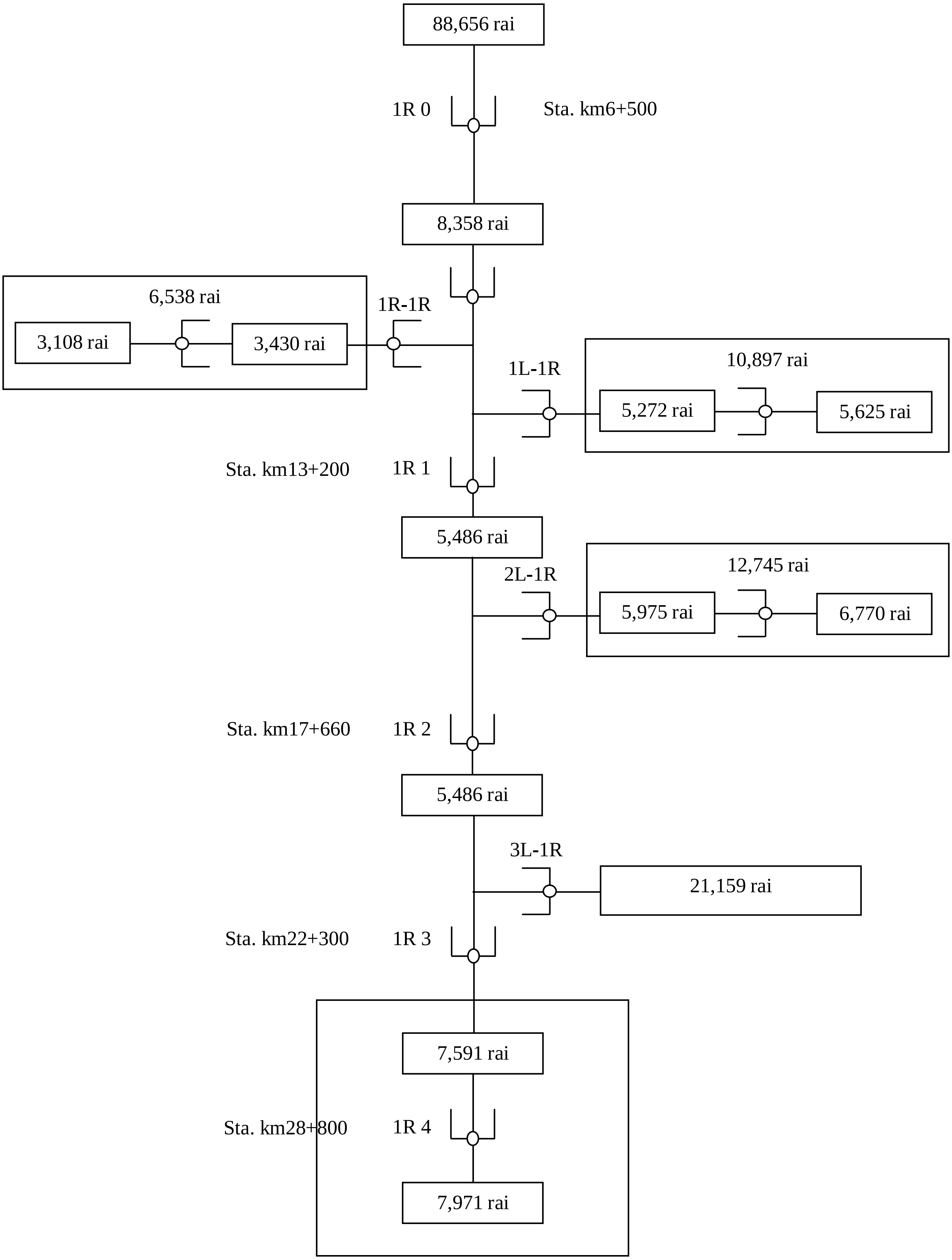


Figure 3.12 Irrigation Schematic Diagrams in Operation and Maintenance Branch 1
Irrigated Areas = 88,656 rai

Source; RID and JICA, 1995

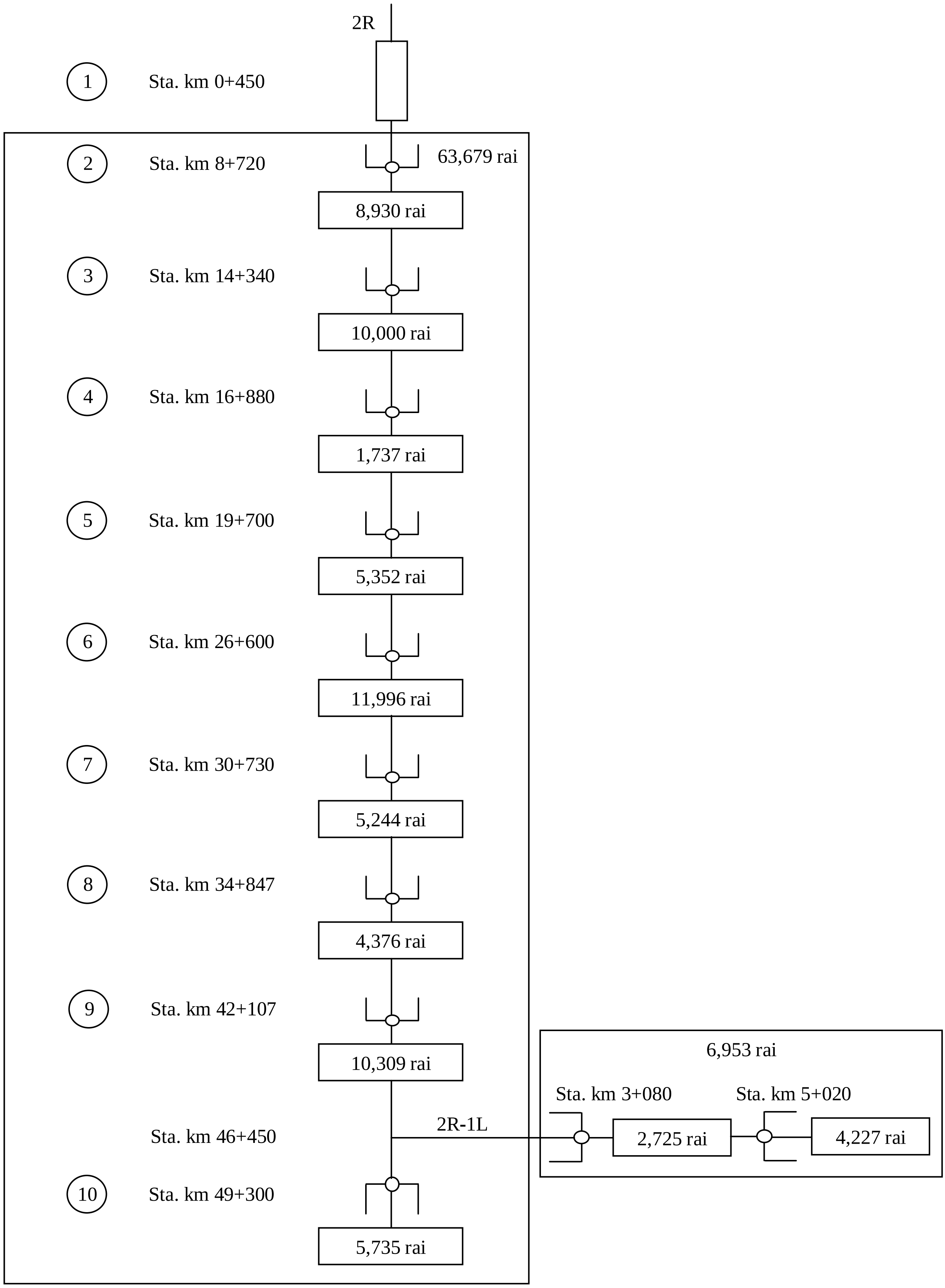


Figure 3.13 Irrigation Schematic Diagrams in Operation and Maintenance Branch 2 (2R)
Irrigated Areas = 70,632 rai

Source; RID and JICA, 1995

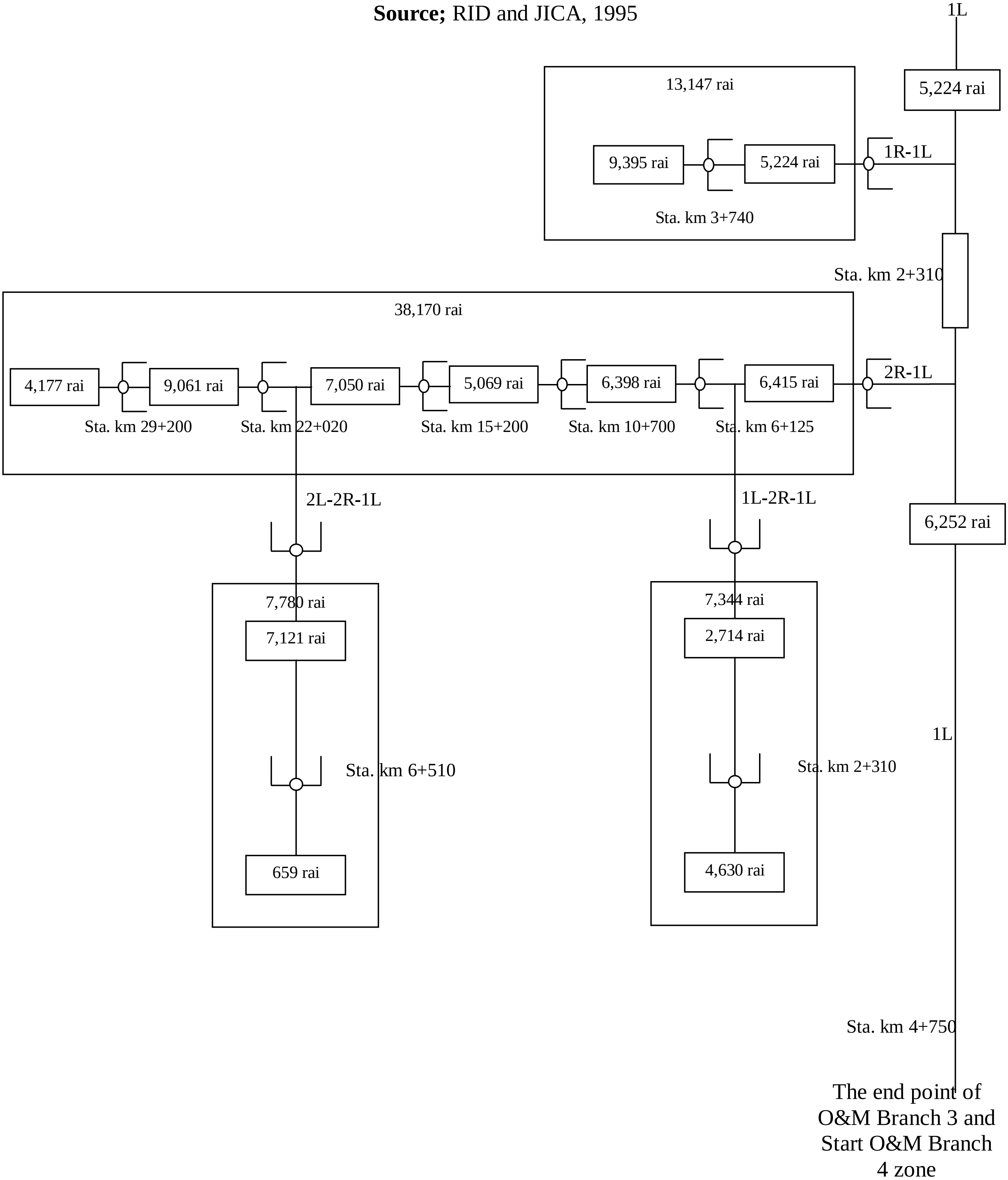


Figure 3.14 Irrigation Schematic Diagrams in Operation and Maintenance Branch 3 (1L)
Irrigated Areas = 77,917 rai

Source; RID and JICA, 1995

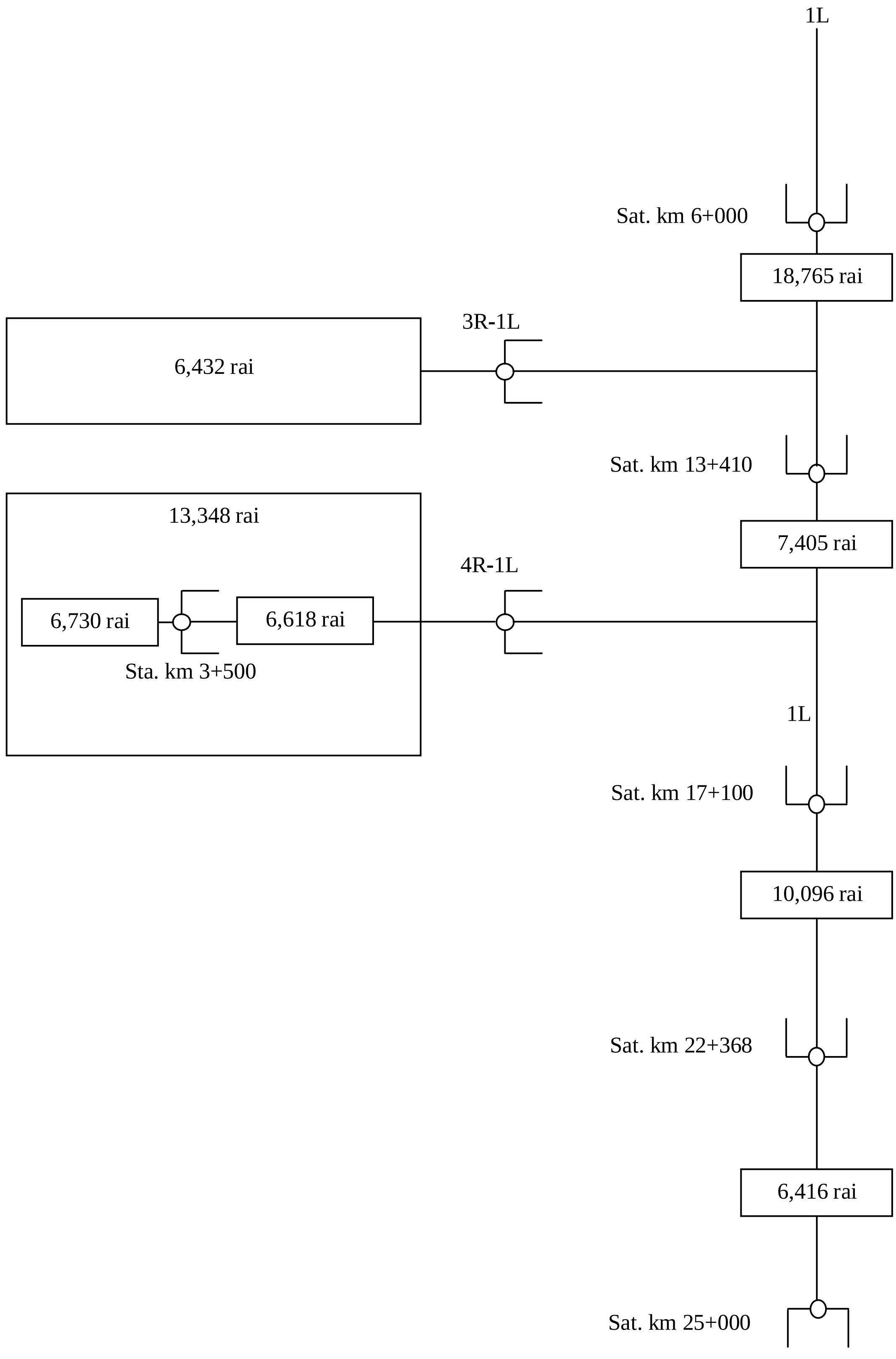


Figure 3.15 Irrigation Schematic Diagrams in Operation and Maintenance Branch 4 (1L) Irrigated Areas = 66,720 rai

Source; RID and JICA, 1995

3.4 Required data for CROPWAT 8.0 model in order to calculate the amount of irrigation water used

In this study, the contents consist the total amount of irrigation water used in paddy field in study area under Sam Chuk O&M Project, Suphan Buri province, central region of Thailand based on the CROPWAT 8.0 model. This model used to estimate the net and gross of irrigation water supply in paddy field.

The CROPWAT model can be used as a tool to estimate irrigation water requirement, the table 8 shows their data requirement.

Limitation of effective rainfall method used in CROPWAT, effective rainfall is defined as that portion rain fall which is useful directly for crop production at the site where it falls. Effective rainfall is influenced by the intensity of the rainfall, evapotranspiration and percolation losses and crop and irrigation management practices (Dastan, 1974). There are four common empirical methods to calculate effective rainfall (green water use) using CROPWAT. Methods which are used to calculate green water use as follows:

1. Fixed percentage of rainfall,
2. Dependable rainfall,
3. Empirical formula,
4. USDA Soil Conservation Service method.

In this study, dependable rainfall method is used to estimate the effective rainfall because Thailand is located in the humid tropics. It is almost the same in sub-humid climate. Therefore, the monthly effective rainfall calculated according to dependable rainfall formula as follows:

$$\mathrm{P_{eff}} = 0.6 \times \mathrm{P_{tot}} - 10 \text{ for } \mathrm{P_{tot}} < 70\ mm\ and$$

$$\mathrm{P_{eff}} = 0.8 \times \mathrm{P_{tot}} - 24 \text{ for } \mathrm{P_{tot}} > 70\ mm$$

where;

P_{eff} is Effective rainfall and P_{tot} is total monthly rainfall in mm. According to TMD report (2006) referred to Martin Smith presented this method that is the good linear regression and appropriate with sub-humid climate.

This study had setting program by follow;

- Total date of land preparation equal to 20 days included 5 days for pudding and used FAO formulas.
- Effective Rainfall used dependable rainfall method.
- Rice scheduling; the scheduling criteria for divided to irrigation time and irrigation application. For irrigation time setting had selected the fixed water depth that is irrigation at 10 mm water depth. For irrigation application setting used refill to fixed water depth at 150 mm and using irrigation efficiency of field application was 70% for paddy field.

Table 10 Data requirement to estimate actual evapotranspiration (ETa) and irrigation water supply in paddy field

Parameter	Data Type	Specified Data	Sources	Unit
Meteorological data	Air Temperature	Monthly means of minimum and maximum temperature	TMD, RID	°C
	Relative humidity	Percent relative humidity (Mean monthly)		%
	Sunshine duration	Monthly means sunshine duration hours		Hours
	Wind speed	Wind speed at 2 m height		m/s
	Rainfall	Mean monthly rainfall		mm
Soil data	Soil type, soil texture	-	FAO	-
	Infiltration data	Maximum infiltration rate	FAO	mm/day
Field application efficiency, Ea	Criteria of irrigation efficiency	**Ea of paddy field = 70%**	Doorenbos and Pruitt (1977)	%
Crop data	Crop coefficient (Kc)	-	RID, FAO	
	Crop development stage		RID, FAO, Rice Department	
	Planted date	Field data	Rice Department, Interviews with farmer	

3.4.1 Field Application Efficiency Input Data

From the table 2 in chapter 2, the data input in CROPWAT 8.0 that used in the estimation of irrigation efficiency in paddy field or field application efficiency (Ea). There are Ea equal to 70% as paddy field criteria.

The result from CROPWAT 8.0 is the gross irrigation water requirement that will be used to calculate the value of irrigation water used by rice famers at the field level.

3.5 Calculate the value of irrigation water used in paddy field

The value of irrigation water is computed by using the Residual Imputation Method (described in details by Young, 1996, pp. 34-38); we subtracted total cost from total revenue and then dividing the residual value or the gross margin by the quantity of irrigation water used.

$$P_W = [TVP_Y - (P_M \times Q_M + P_L \times Q_L + P_R \times Q_R + P_F \times Q_F + P_P \times Q_P + P_S \times Q_S)]/Q_W$$

Data requirements

a) Irrigation requirements of paddy field in rain reason and dry season in 2009/2010 were calculated using the CROPWAT 8.0 model.
b) Price of rice at farm gate (Baht/Ton) in irrigated area during the dry and the wet season were obtained from interview miller and president of Suphan Buri Milled rice Association during period 2010.
c) Yields of paddy (kg/rai or kg/ha) in irrigated area during dry and wet seasons.
d) Harvested area (rai or ha) of irrigated area.
e) Production cost (Baht/rai or Baht/ha) in irrigated area was included expenditure of seed (S), labor (L), machinery (M), land rental (R), fertilizer (F), pesticide and weed control (P).

3.6 Value added of rice production along the market chain in Suphan Buri province

Base on interview with the miller and president of Suphan Buri Mill Rice Association, especially white rice 5% in the main stage such as farmer, miller, and wholesaler. In addition, secondary data relate with the rice marketing system, and reference market price.

3.7 Cost of operation and maintenance of Sam Chuk operation and maintenance project

The initial value of the irrigation project was calculated based upon CPI. The CPI input data based on Bank of Thailand discussion paper, the input inflation rate is shown in figure 3.16 (Sitthichaiwiset et al., 2012). The variable of inflation rate was used to calculate the initial value of construction as using the following equation;

Variable inflation rate $= (1+inf_1) \times (+inf_2) \times (1+inf_3) \times \ldots. \times (1+inf_n)$

where: inf_n is inflation rate of period n

The average inflation rate for all periods can be calculated as

$$(1+inf_a)^n = (1+inf_1) \times (+inf_2) \times (1+inf_3) \times \ldots. \times (1+inf_n)$$

or

$$inf_a = [(1+inf_1) \times (+inf_2) \times (1+inf_3) \times \ldots. \times (1+inf_n)]^{1/n} - 1$$

where: inf_a is average inflation rate

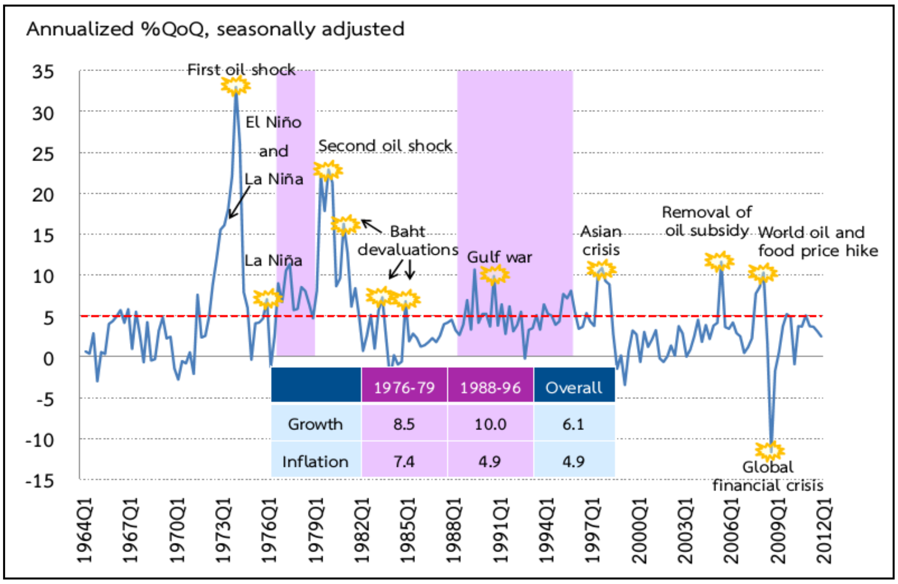


Figure 3.16 Thailand inflation rate compared with World situation considered at 1[st] quarter

Source; Sitthichaiwiset et al., (2012)

There are 3 steps of evaluation the cost of irrigation project. Fist, cost of construction was calculated from 1937 to 1993 by using the variable inflation rate which base on consumer production inflation rate. Second step is that the irrigation project cost estimation is current value in 2012 calculation by using the result from the first step and actual data collected from Sam Chuk O&M project. This calculation based on the average of the CPI rate and used the present value method. In addition, the renovation cost in 2012 was average from cost of construction during 1937 – 1993 then using the present value method define the current renovation cost in 2012. However, the other cost such as improvement of irrigation system cost, salary, O&M cost, and project management costs in 2012 are not available. Thus, the represent cost was average each cost from the previous data during 2008 – 2011. The last step is the annual cost of irrigation water calculation that is estimated from using the current construction cost and total O&M cost calculated by cost recovery factor method by assuming project work life equal to 50 years, the salvage value equal to 1% of current construction cost, and discount rate equal to 12%.

The cost recovery factor as shown below;

$$CRF = \left[\frac{(1+i)^n}{(1-i)^n - 1}\right]$$

where, *i* is discount rate and *n* is life period of the project

Table 11 The data of O&M cost of Sam Chuk O&M project

Year	Renovation	Improvement of irrigation system	Salary	O&M	PM	Total	Irrigated area
	Baht	Baht	Baht	Baht	Baht	Baht	rai
2008	N/A	29,435,300	25,357,940	43,684,300	623,400	99,100,940	313,569
2009	N/A	0	25,177,470	67,114,600	1,226,300	93,518,370	313,569
2010	N/A	60,165,000	24,929,260	80,017,900	1,623,520	166,735,680	313,569
2011	N/A	45,953,100	26,552,660	83,551,400	486,400	156,543,560	313,569
2012	***11,930,623**	**33,888,350	**25,504,333	**68,592,050	**989,905	140,905,261	313,569

Source; Sam chuk Operation and Maintenance project (2011) and own calculation
* The renovation cost from first step, ** the average during 2008 - 2011

3.8 Simulation the financing scenario

Setting the scenario which was defined the possible new financing and institutional arrangements by combination the result of objective 1, 2, and 3 together.

3.9 Data Collection

3.9.1 Climatic data

The climate of this study is classified as Tropical Savannah. The climate is generally not an obstacle of the crop cultivation, especially rice. There were three seasons in a year; the rainy season started from June to October, the dry season started from February to May, and the cold season started from October to February. We used the Suphan Buri meteorological station (14° 28’ 28’’E 100° 8’ 20’’N) calculations of ETo for the study (TMD, 2010). Basing on the data from RID, the main meteorological characteristics of the irrigation system was summarized as follow table 12

3.9.2 Soil data

Normally, soil characteristic in Sam Chuk Irrigation Project was black clay soil and loamy clay soil which sustain for rice and upland crops cultivation.

Table 12 The climatic data of Suphan Buri province, Thailand (TMD, average over 30 years)

Month	Min	Max	Humidity	Wind	Sunshine	Solar Radiation	ET_o
	°C	°C	%	km/day	hours	$MJ/m^2/day$	mm/day
January	19.2	31.7	67	147	7.6	17.6	4.0
February	21.7	33.9	68	164	7.0	18.2	4.5
March	23.5	35.7	67	207	7.3	20.0	5.4
April	25.1	36.9	66	207	7.2	20.6	5.8
May	25.3	35.4	71	199	6.1	18.9	5.2
June	25.0	34.2	72	225	5.1	17.2	4.9
July	24.6	33.6	74	216	5.0	17.0	4.7
August	24.6	33.3	75	207	5.0	17.1	4.6
September	24.6	32.3	79	147	4.9	16.5	4.0
October	24.4	31.5	80	147	6.2	17.3	4.0
November	22.4	30.6	75	199	7.1	17.2	4.1
December	19.4	30.6	70	181	7.5	16.9	3.9
Average	**23.3**	**33.3**	**72**	**187**	**6.3**	**17.9**	**4.6**

The rainfall was concentrated from May to October with about 86.60% annual rainfall. The average monthly rainfall based on the record from Suphan Buri meteorological station as follow table 13.

Table 13 The average monthly rainfall data of Sam Chuk station 30 years period, Suphan Buri

Month	[1/] Monthly Rainfall (mm)	[2/] Effective Rainfall (mm)
January	6.5	0.0
February	7.3	0.0
March	18.3	1.0
April	59.1	25.5
May	120.6	72.5
June	100.2	56.2
July	106.0	60.8
August	127.2	77.8
September	253.9	179.1
October	209.3	143.4
November	42.2	15.3
December	9.3	0.0
Total	**1,059.9**	**631.5**

Source; [1/]Thai Metrological Department, 2011 and
[2/]Using dependable rainfall method

3.9.3 Secondary data collecting

In this section, it presented the secondary data that collected from Sam Chuk Operation and Maintenance Irrigation Project, Department of Internal Trade, Thai Rice Mills Association, Thai Rice Exporter, and document report. There were data related as follow below,

- The rice cultivated area in irrigation project.
- Investment cost, O&M cost, project management cost, and officer salaries was recorded from RID and Sam Chuk operation and maintenance project.

- The rice marketing channels in Suphan Buri province and marketing cost of millers, exporters, and wholesalers or retailers in domestic market was shown in table 14 – 16.
- The price of paddy product, white rice product and FOB. price

Table 14 Marketing cost of millers

Marketing cost of millers (Baht/ton of white rice)	
Cost of milling rice	350
Packing and packaging cost	230
Weight loss fee	100
Management cost	50
Transportation cost	400
Tax fee (Baht/ton)	60
Total (Baht/ton)	**1,190**

Source; Interview the president of Suphan Buri Mill Rice Association, 2011

Table 15 Marketing cost of exporters

Marketing cost of exporter (Baht/ton of white rice)	
Quality improvement	380
Packing and packaging	260
Overhead cost	12
Management cost	200
Transportation by Container	239
Total (Baht/ton)	**1,091**

Source; applied from Rodmua (2009); average 2007 – 2009

Table 16 Marketing cost of wholesalers or retailers in domestic market

Marketing cost of wholesalers or retailers (Baht/ton of white rice)	
Quality improvement	380
Packing and packaging	260
Overhead cost	12
Management cost	200
Stock warehouse expenditure (40 Baht/ton/month)	480
Transportation by Container	50
Total (Baht/ton)	**1,382**

Source; applied from Rodmua (2009); average 2007 – 2009

The price of white rice 5% in Domestic market of Thailand during 2008 – 2011 is shown in table 17. This price is reference by Department Internal Trade (DIT) of Thailand that domestic consumers buy from local market or supermarkets (5 kg/ pack) such as Tesco Lotus supermarket, Big C supermarket. There are different from the miller gate price because there are logistic cost and marketing cost of rice Business Company. However, DIT has managing the price of rice because rice production is controlling production of Thailand national. Table 18 is shown the FOB prices of white rice 5% of exporter that is approximately 18 Baht/kg (average 2008 – 2010).

Table 17 Price of White Rice 5% in Domestic market during 2008-2011(DIT, Thailand)

Month	White Rice 5% (Baht / 15 kg)			
	2008	2009	2010	2011
January	230	385	395	395
February	230	385	395	383.75
March	321	410	395	380
April	441.25	425	395	380
May	485	402.5	395	380
June	455	395	395	380
July	445	395	395	380
August	440	395	395	380
September	440	395	395	380
October	408.13	395	395	380
November	385	395	395	380
December	385	395	395	380
Average per 15 kg	389	398	395	382
Average per kg	26	27	26	25
Average per kg during 2008 - 2011	26			

Table 18 F.O.B prices of White rice 5% during 2008-2010 (Department of Foreign Trade, Thailand)

Month	Baht/ton (1$US = 31.387)			$US/ton		
	White Rice 5%			White Rice 5%		
	2008	2009	2010	2008	2009	2010
January	12,210	18,236	17,891	389	581	570
February	14,250	18,644	17,012	454	594	542
March	17,388	19,083	15,631	554	608	498
April	26,145	17,514	14,407	833	558	459
May	30,540	16,510	14,030	973	526	447
June	26,804	17,294	13,967	854	551	445
July	25,549	17,451	13,748	814	556	438
August	23,980	16,792	14,250	764	535	454
September	23,509	16,572	15,223	749	528	485
October	20,935	15,662	15,474	667	499	493
November	18,079	16,541	16,447	576	527	524
December	17,765	18,456	17,169	566	588	547
Average per ton	21,429	17,396	15,437	683	554	492
Average per ton during 2008 - 2010	18,088			576		

3.9.3.1 Rice cultivated area in Sam Chuk Operation and Maintenance Project

The data had record from Sam Chuk operation and maintenance project between 1984 and 2010 that shows as table B-1 in the Appendix B. The cultivated area is consist paddy,

3.9.3.2 Detail of Construction Building and Canals system

SCP is the old project and large project. There are many constructions along the irrigation canals such as farm intake (or farm turnout), cross regulator, etc. The detail of construction building and canals systems have conclude is shown in table B-2 and B-3 in the Appendix B, respectively.

CHAPTER 4

RESULTS AND DISCUSION

4.1 Farmers characteristic

Questionnaire survey was done in irrigated areas which under Sam Chuk operation and maintenance project to find more details about field and irrigation management, farm price, farm and hired labor use, fertilizer costs, weed and pesticide control costs, machinery usages and costs, and yields in the study area in 2009/2010, the 20 farmers are interviewed for my servey.

The questionnaire is shown in Appendix A.

Rice farmers planted rice only 2 times a year that was dry season 2009/2010 and wet season 2010. The crop patterns of dry and wet season are shown in table 19 and 20, respectively.

Table 19 Rice cultivation patterns during dry season in the year 2009/2010 (Field survey, 2011)

Plot No.	Variety	Duration of the cycle	Cultivated Practice	Planted Date	Harvested Date	Planted area (ha)
1	RD 29	110 - 120	wet direct seed	15 Nov - 21 Nov	14 Mar - 20 Mar	1.76
2	RD 31	110 - 120	wet direct seed	22 Nov - 28 Nov	21 Mar - 27 Mar	1.92
3	RD 29	110 - 120	wet direct seed	29 Nov - 05 Dec	28 Mar - 03 Apr	1.92
4	RD 31	110 - 120	wet direct seed	15 Nov - 21 Nov	14 Mar - 20 Mar	2.4
5	RD 31	110 - 120	wet direct seed	15 Nov - 21 Nov	14 Mar - 20 Mar	2.4
6	RD 31	110 - 120	wet direct seed	29 Nov - 05 Dec	28 Mar - 03 Apr	4
7	RD 31	110 - 120	wet direct seed	06 Dec - 12 Dec	04 Apr - 10 Apr	4.8
8	RD 31	110 - 120	wet direct seed	22 Nov - 28 Nov	21 Mar - 27 Mar	6.4
9	RD 31	110 - 120	wet direct seed	06 Dec - 12 Dec	04 Apr - 10 Apr	7.2
10	RD 31	110 - 120	wet direct seed	15 Nov - 21 Nov	14 Mar - 20 Mar	8
11	RD 31	110 - 120	wet direct seed	06 Dec - 12 Dec	04 Apr - 10 Apr	8.8
12	RD 31	110 - 120	wet direct seed	22 Nov - 28 Nov	21 Mar - 27 Mar	9.6
13	RD 31	110 - 120	wet direct seed	15 Nov - 21 Nov	14 Mar - 20 Mar	10.4
14	RD 31	110 - 120	wet direct seed	22 Nov - 28 Nov	21 Mar - 27 Mar	11.2
15	RD 29	110 - 120	wet direct seed	29 Nov - 05 Dec	28 Mar - 03 Apr	12
16	RD 31	110 - 120	wet direct seed	22 Nov - 28 Nov	21 Mar- 27 Mar	12.8
17	RD 29	110 - 120	wet direct seed	29 Nov - 05 Dec	28 Mar - 03 Apr	12.8
18	RD 31	110 - 120	wet direct seed	06 Dec - 12 Dec	04 Apr - 10 Apr	13.6
19	RD 31	110 - 120	wet direct seed	29 Nov - 05 Dec	28 Mar - 03 Apr	14.4
20	RD 29	110 - 120	wet direct seed	29 Nov - 05 Dec	28 Mar - 03 Apr	15.2
					Total	161.6

Table 20 Rice cultivation patterns during wet season in 2010 (Field survey, 2011)

Plot No.	Variety	Duration of the cycle	Cultivated Practice	Planted Date	Harvested Date	Planted area (ha)
1	RD 29	110 - 120	direct seeding	23 May - 29 May	19 Sep - 25 Sep	1.76
2	RD 31	110 - 120	direct seeding	30 May - 05 Jun	26 Sep - 02 Oct	1.92
3	RD 29	110 - 120	direct seeding	06 Jun - 22 Jun	03 Oct - 09 Oct	1.92
4	RD 31	110 - 120	direct seeding	23 May - 29 May	19 Sep - 25 Sep	2.4
5	RD 31	110 - 120	direct seeding	23 May - 29 May	19 Sep - 25 Sep	2.4
6	RD 31	110 - 120	direct seeding	06 Jun - 12 Jun	03 Oct - 09 Oct	4
7	RD 31	110 - 120	direct seeding	13 Jun - 29 Jun	10 Oct - 16 Oct	4.8
8	RD 31	110 - 120	direct seeding	30 May - 05 Jun	26 Sep - 02 Oct	6.4
9	RD 31	110 - 120	direct seeding	13 Jun - 29 Jun	10 Oct - 16 Oct	7.2
10	RD 31	110 - 120	direct seeding	23 May - 29 May	19 Sep - 25 Sep	8
11	RD 31	110 - 120	direct seeding	13 Jun - 29 Jun	10 Oct - 16 Oct	8.8
12	RD 31	110 - 120	direct seeding	30 May - 05 Jun	26 Sep - 02 Oct	9.6
13	RD 31	110 - 120	direct seeding	23 May - 29 May	19 Sep - 25 Sep	10.4
14	RD 31	110 - 120	direct seeding	30 May - 05 Jun	26 Sep - 02 Oct	11.2
15	RD 29	110 - 120	direct seeding	06 Jun - 12 Jun	03 Oct - 09 Oct	12
16	RD 31	110 - 120	direct seeding	30 May - 05 Jun	26 Sep - 02 Oct	12.8
17	RD 29	110 - 120	direct seeding	13 Jun - 19 Jun	10 Oct - 16 Oct	12.8
18	RD 31	110 - 120	direct seeding	13 Jun - 19 Jun	10 Oct - 16 Oct	13.6
19	RD 31	110 - 120	direct seeding	06 Jun - 12 Jun	03 Oct - 09 Oct	14.4
20	RD 29	110 - 120	direct seeding	06 Jun - 12 Jun	03 Oct - 09 Oct	15.2
					Total	161.6

4.1.1 Gender structure, age and education levels of rice farmers

The study included 20 rice growers in Sam Chuk district. All of them cultivated in irrigated area of Sam Chuk operation and maintenance project. Rice farmers accounted 75% (15 persons) of male and 25% (5 persons) of female (Figure 4.1).

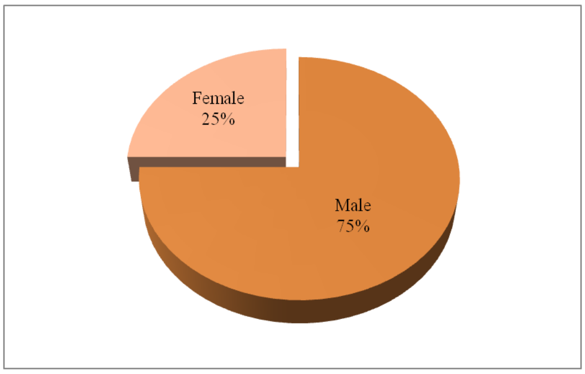


Figure 4.1 Gender of rice farmers

Source: Field survey, 2011

The average age of rice farmers was 48.1 years old which maximum age was 59 years old while minimum age was 38.5 years old as shown in table 15. In term of male, 47.6 years old was the average age. The maximum and minimum age was 60 and 35 years old, respectively. The average age of female was 48.6 years old which maximum and minimum age was 58 and 42 years old, respectively.

Table 21 Age structure of respondents

Gender	Average age	Maximum	Minimum
Male	47.6	60	35
Female	48.6	58	42
Total	**48.1**	**59**	**38.5**

Source: Field survey, 2011

Additionally, 50% of the samples (10 persons) completed elementary school, 25% of the samples (5 persons) completed secondary school or vocational certificate and another 5% of the samples (5 persons) were uneducated (Figure 4.2).

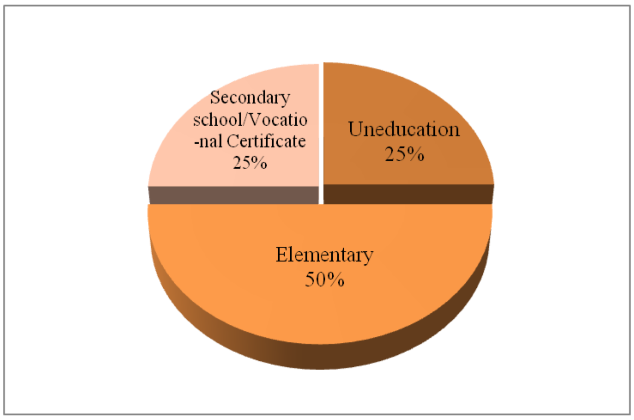


Figure 4.2 Education levels of rice farmers
Source: Field survey, 2011

4.1.2 Rice Cultivated Sizes and Experience

From survey, farm sizes are divided into three sizes that are small size (≤ 6.25 ha), middle size (6.26 – 10.75 ha) and large size (10.76 – 15.25 ha). It was found that 35% (7 persons) of sample had small size farm, 30% (6 persons) of sample had middle size farm, and another 35% (7 persons) of sample had large size farm (Figure 4.3).

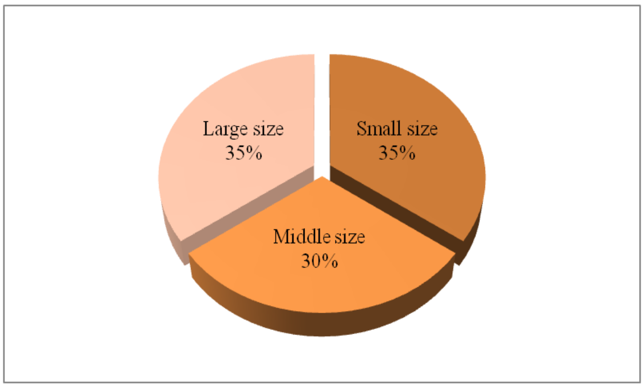


Figure 4.3 Rice cultivated sizes
Source: Field survey, 2011

The average experience of rice farmers was 24.6 years. The maximum experience of rice farmer was 36.5 years while minimum experience was 15 years. Moreover, the average experience years of male were 22.13 years. Maximum experience and minimum experience was 38 and 10 years old, respectively. For female farmers, maximum and minimum of experience were 35 and 20 years. The average of experience was 27.0 years (Table 22).

Table 22 Average experience of respondents

Gender	Average Experience	Maximum	Minimum
Male	22.13	38	10
Female	27.0	35	20
Total	**24.6**	**36.5**	**15**

Source: Field survey, 2011

4.2 Calculation of Irrigation Water Requirement

Based on the data of crop pattern obtained from farm interviews, the average of monthly maximum and minimum air temperature, average monthly maximum and minimum relative humidity, wind speed and actual daily duration of sunshine during three past decades at SCP, we developed a CROPWAT 8.0 model to calculate the gross irrigation water requirement (Table 23). The amount of irrigation water supplied to the paddy field includes water using in land preparation and the water consumed by the crop (evapotranspiration).

Compared result with result on study irrigation water requirement for rice cultivation case study of Rungsit Tai operation and maintenance project, Phatumthani, Thaialnd (Phuraya, 2007) and FAO, 2004 was shown in table 24. However, the result depended on the surveyed date detailing which planting data, rainfall data, and climatic data. Therefore, the amount of irrigation water requirement was different from the previous study in Thailand. However, the rank of result was under FAO result.

Table 23 The amount of irrigation water requirement supply in paddy field in Sam Chuk operation and maintenance project using CROPWAT 8.0 model estimate, field application efficiency of paddy field (Ea) = 70%

	Unit	Dry season 2009/2010				Wet season 2010			
		Average	S.D.	Min	Max	Average	S.D.	Min	Max
Net IR	mm/season	1,164	4.42	1,157	1,169	708	33.61	652	734
Gross IR =Net IR/0.7	mm/season	1,663	6.31	1,653	1,669	1,012	48.03	932	1,048

Source; Concluded from data analysis

Table 24 Compared result of the amount of irrigation water requirement supply in paddy field (mm/season)

Case	Method	Dry season	Wet season	Project/Province
This study	CROPWAT 8.0 model	1,663	1,012	Sam Chuk, Suphan Buri
Phuraya,2007	RS&GIS model	881	431	Rangsit Tai, Patumthani
Phuraya,2007	Actual Measurement	1,207	826	Rangsit Tai, Patumthani
FAO, 2004	-	900 (low) – 2,250 (high)		General area

4.3 Production Cost of Rice Farmers

In these surveys, it had high yield in both seasons (dry and wet). The average yield was 5.40 Ton/ha for dry season in 2009/2010 and 5.23 Ton/ha for wet season 2010. From interview, farmers had not pesticide disease (brown plant hopper) and not flooding occurred. However, the yield production depends on pesticide disease and flood disaster. Since 2008, there was pesticide disease diffusion throughout Thailand. As a result, the yield of production decreased approximately 60% – 80% of the average production in 2009/2010. It was mean rice farmers lost their yield. In 2008/2009, pesticide disease (especially brown plant hopper) in central region of Thailand had effect paddy field around 380,800 ha. There was most effect in irrigated area accounted 14 – 18 provinces of central region (Soithong, Rice Department, 2010) as shown in figure 4.4. The production cost of rice farmers are composed with seed expenditure, labor expenditure (included opportunity cost), land rental (included opportunity cost), expenditure of machinery, fertilizer, pesticide and weed control chemical in dry season 2009/2010 and wet season 2010 that shown in table 25 and 26, respectively.

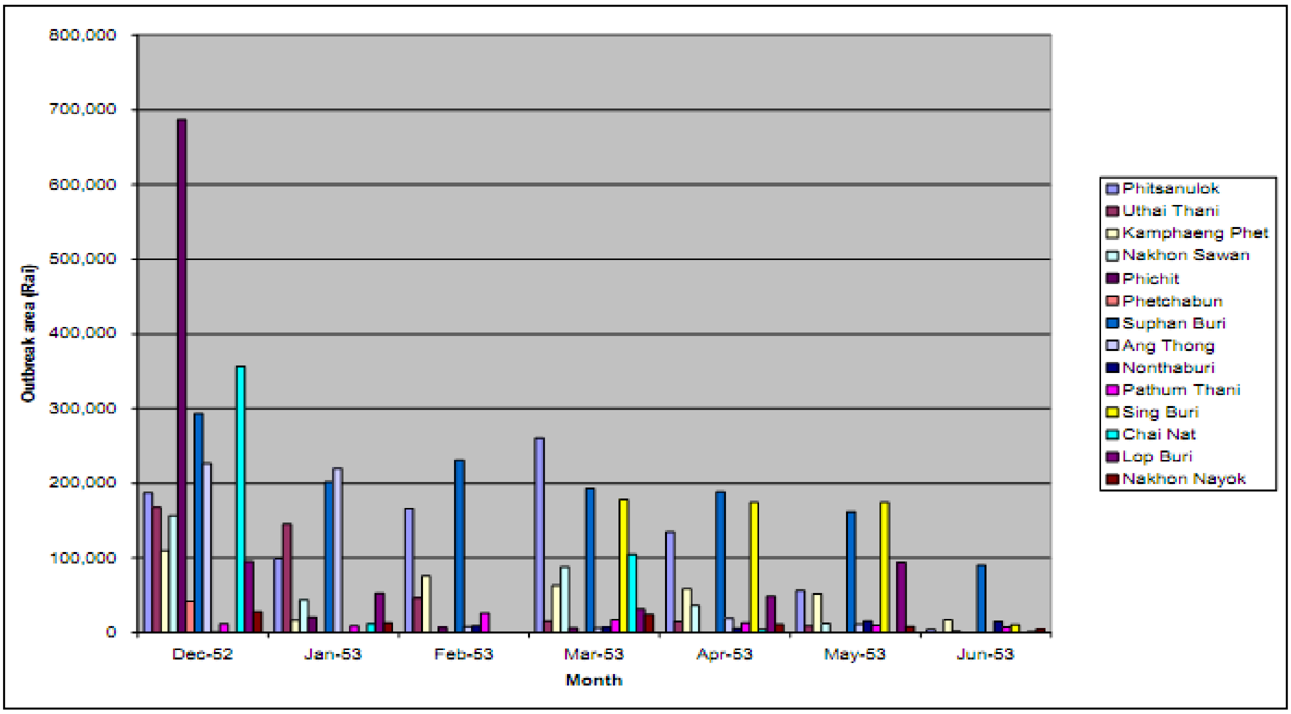


Figure 4.4 The outbreak area of brown plant hopper in central region of Thailand, during to December 2008 – June 2009
Source; Soithong, 2010

Table 25 The plot production cost of rice farmer and yield in dry season crops 2009/2010

Plot No.	Plot area rai	Plot area ha	Yield Ton/ha	Seed Baht/ton	Labor Baht/ton	Harvesting Baht/ton	Land rental Baht/ton	Machinery Baht/ton	Fertilizers Baht/ton	Pesticide Baht/ton	Weed control Baht/ton	Total cost Baht/ton
1	11	1.76	5.30	649	1,379	613	1,179	611	755	508	575	6,269
2	12	1.92	5.21	660	1,392	556	1,200	518	919	566	576	6,387
3	12	1.92	5.10	614	1,335	588	1,225	524	875	578	553	6,293
4	15	2.40	5.20	602	1,250	617	1,202	615	819	542	517	6,165
5	15	2.40	5.25	655	1,238	617	1,190	588	811	537	512	6,150
6	25	4.00	5.25	655	1,238	610	1,190	580	827	550	512	6,164
7	30	4.80	5.50	569	1,329	543	1,136	484	895	518	549	6,024
8	40	6.40	5.30	591	1,321	568	1,179	541	879	583	545	6,207
9	45	7.20	5.40	637	1,413	526	1,157	501	861	528	572	6,196
10	50	8.00	5.40	580	1,274	641	1,157	571	833	602	583	6,242
11	55	8.80	5.50	569	1,398	521	1,136	508	918	609	573	6,232
12	60	9.60	5.50	625	1,329	543	1,136	507	895	584	549	6,169
13	65	10.40	5.60	559	1,171	602	1,116	573	902	573	545	6,042
14	70	11.20	5.60	559	1,305	543	1,116	517	879	573	539	6,032
15	75	12.00	5.60	614	1,229	641	1,116	639	739	573	545	6,096
16	80	12.80	5.40	637	1,296	568	1,157	541	863	572	535	6,170
17	80	12.80	5.40	580	1,204	617	1,157	615	789	594	498	6,055
18	85	13.60	5.60	559	1,305	538	1,116	524	879	588	539	6,047
19	90	14.40	5.40	637	1,204	610	1,157	580	804	535	498	6,025
20	95	15.20	5.50	569	1,171	625	1,136	623	864	513	555	6,055
Average			5.40	606	1,289	584	1,158	558	850	561	544	6,151
SD.			0.15	36.58	74.62	39.55	32.55	47.23	51.38	30.37	25.60	102.75
Min			5.10	559	1,171	521	1,116	484	739	508	498	6,024
Max			5.60	660	1,413	641	1,225	639	919	609	583	6,387

Table 26 The plot production cost of rice farmer and yield in wet season crops 2010

Plot No.	Plot area rai	Plot area ha	Yield Ton/ha	Seed Baht/ton	Labor Baht/ton	Harvesting Baht/ton	Land rental Baht/ton	Machinery Baht/ton	Fertilizers Baht/ton	Pesticide Baht/ton	Weed control Baht/ton	Total cost Baht/ton
1	11	1.76	5.14	670	1,423	601	1,217	541	779	524	594	6,349
2	12	1.92	5.05	681	1,436	565	1,238	475	949	584	594	6,523
3	12	1.92	4.94	633	1,378	599	1,265	480	902	597	571	6,424
4	15	2.40	5.04	621	1,290	628	1,240	566	845	560	534	6,284
5	15	2.40	5.09	676	1,278	628	1,229	540	837	554	529	6,271
6	25	4.00	5.09	676	1,278	620	1,229	533	853	568	529	6,286
7	30	4.80	5.33	587	1,372	553	1,173	443	923	535	567	6,152
8	40	6.40	5.14	609	1,363	578	1,217	497	907	602	563	6,336
9	45	7.20	5.23	657	1,458	536	1,194	460	889	545	591	6,330
10	50	8.00	5.23	598	1,315	652	1,194	523	860	621	602	6,366
11	55	8.80	5.33	587	1,443	530	1,173	467	948	629	591	6,367
12	60	9.60	5.33	645	1,372	553	1,173	465	923	602	567	6,299
13	65	10.40	5.43	577	1,209	613	1,152	527	811	533	509	5,929
14	70	11.20	5.43	577	1,347	553	1,152	475	907	592	557	6,159
15	75	12.00	5.43	634	1,268	652	1,152	588	763	509	507	6,072
16	80	12.80	5.23	657	1,338	578	1,194	497	891	591	552	6,298
17	80	12.80	5.23	598	1,242	628	1,194	566	814	613	514	6,170
18	85	13.60	5.43	577	1,347	547	1,152	482	907	606	557	6,175
19	90	14.40	5.23	657	1,242	620	1,194	533	829	552	514	6,143
20	95	15.20	5.33	587	1,208	636	1,173	573	788	529	572	6,067
Average			5.23	625	1,330	594	1,195	511	866	572	556	6,250
SD.			0.15	37.75	77.01	39.70	33.59	42.82	56.34	35.94	31.08	140.08
Min			4.94	577	1,208	530	1,152	443	763	509	507	5,929
Max			5.43	681	1,458	652	1,265	588	949	629	602	6,523

4.4 Estimating the Value of Irrigation Water

Irrigation water values are calculated per m^3. The results of the RIM calculations of irrigation water value per m^3 and per ha are presented table 21 and 22 for dry season and wet season, respectively. This study was considerd in case of high yield and the value of irrigation water depended on selling price of paddy during 2010. The result classified in two cases that were without subsidies and with subsidies from government. The irrigation water value in case of without subsidies is 0.54 Baht/m^3 for dry season and 0.60 Baht/m^3 for wet season. In case of with subsidies, the irrigation water value was higher than result of without subsidy scheme. The average value was 1.04 Baht/m^3 for dry season and 1.40 Baht/m^3 for wet season.

The example of calculation for plot farm 1 for dry season (table 27) as below:

<u>Case: Without subsidy</u>

Value of Irrigation water = {(Gross income (Baht/ton) – Production cost (Baht/ton)) x Yield (ton/ha)}/ Volume of irrigation water (m^3/ha)
= {(7,800 – 6,269) x 5.30} / 16,674

= 0.49 Baht/m^3

<u>Case: With subsidy</u>

Value of Irrigation water = {(Gross income (Baht/ton) – Production cost (Baht/ton)) x Yield (ton/ha)}/ Volume of irrigation water (m^3/ha)
= {(9,353 – 6,269) x 5.30} / 16,674

= 0.98 Baht/m^3

The similar calculation was applied for the wet season on the table 28.

Table 27 is shown the calculation value of irrigation water in dry season crops 2009/2010

Plot	Plot area	Yield	Production cost		Gross income				Gross irrigation supply Ea 70%		***WP	Water value					
					*without subsidy		**with subsidy					without subsidy			with subsidy		
No.	ha	Ton/ha	Baht/ton	Baht/ha	Baht/ton	Baht/ha	Baht/ton	Baht/ha	mm/season	m^3/ha	kg/m^3	Baht/m^3	Baht/kg	Baht/ha	Baht/m^3	Baht/kg	Baht/ha
1	1.76	5.30	6,269	33,225	7,800	41,340	9,353	49,571	1,667	16,674	0.32	0.49	1.53	8,115	0.98	3.08	16,346
2	1.92	5.21	6,387	33,274	7,800	40,638	9,353	48,729	1,653	16,534	0.32	0.45	1.41	7,364	0.93	2.97	15,455
3	1.92	5.10	6,293	32,094	7,800	39,780	9,353	47,700	1,663	16,634	0.31	0.46	1.51	7,686	0.94	3.06	15,607
4	2.40	5.20	6,165	32,059	7,800	40,560	9,353	48,636	1,667	16,674	0.31	0.51	1.63	8,501	0.99	3.19	16,576
5	2.40	5.25	6,150	32,286	7,800	40,950	9,353	49,103	1,667	16,674	0.31	0.52	1.65	8,664	1.01	3.20	16,817
6	4.00	5.25	6,164	32,359	7,800	40,950	9,353	49,103	1,663	16,634	0.32	0.52	1.64	8,591	1.01	3.19	16,744
7	4.80	5.50	6,024	33,133	7,800	42,900	9,353	51,442	1,669	16,694	0.33	0.59	1.78	9,767	1.10	3.33	18,308
8	6.40	5.30	6,207	32,898	7,800	41,340	9,353	49,571	1,653	16,534	0.32	0.51	1.59	8,442	1.01	3.15	16,673
9	7.20	5.40	6,196	33,458	7,800	42,120	9,353	50,506	1,669	16,694	0.32	0.52	1.60	8,662	1.02	3.16	17,048
10	8.00	5.40	6,242	33,706	7,800	42,120	9,353	50,506	1,667	16,674	0.32	0.50	1.56	8,414	1.01	3.11	16,800
11	8.80	5.50	6,232	34,276	7,800	42,900	9,353	51,442	1,669	16,694	0.33	0.52	1.57	8,624	1.03	3.12	17,166
12	9.60	5.50	6,169	33,927	7,800	42,900	9,353	51,442	1,653	16,534	0.33	0.54	1.63	8,973	1.06	3.18	17,514
13	10.40	5.60	6,042	33,835	7,800	43,680	9,353	52,377	1,667	16,674	0.34	0.59	1.76	9,845	1.11	3.31	18,542
14	11.20	5.60	6,032	33,781	7,800	43,680	9,353	52,377	1,653	16,534	0.34	0.60	1.77	9,899	1.12	3.32	18,596
15	12.00	5.60	6,096	34,138	7,800	43,680	9,353	52,377	1,663	16,634	0.34	0.57	1.70	9,542	1.10	3.26	18,239
16	12.80	5.40	6,170	33,319	7,800	42,120	9,353	50,506	1,653	16,534	0.33	0.53	1.63	8,801	1.04	3.18	17,187
17	12.80	5.40	6,055	32,696	7,800	42,120	9,353	50,506	1,669	16,694	0.32	0.56	1.75	9,424	1.07	3.30	17,810
18	13.60	5.60	6,047	33,864	7,800	43,680	9,353	52,377	1,669	16,694	0.34	0.59	1.75	9,816	1.11	3.31	18,512
19	14.40	5.40	6,025	32,537	7,800	42,120	9,353	50,506	1,663	16,634	0.32	0.58	1.77	9,583	1.08	3.33	17,969
20	15.20	5.50	6,055	33,304	7,800	42,900	9,353	51,442	1,663	16,634	0.33	0.58	1.74	9,596	1.09	3.30	18,138
									Average	**16,634**	**0.32**	**0.54**	**1.65**	**8,915**	**1.04**	**3.20**	**17,302**
									S.D.	**63.13**	**0.01**	**0.04**	**0.10**	**742**	**0.06**	**0.10**	**947**
									Min	**16,534**	**0.31**	**0.45**	**1.41**	**7,364**	**0.93**	**2.97**	**15,455**
									Max	**16,694**	**0.34**	**0.60**	**1.78**	**9,899**	**1.12**	**3.33**	**18,596**

Remarks

1 Average farmer's selling prices at 25% of paddy moistures = 7,800 Baht/ton for dry season 2009/2010
2 Average purchase price of white paddy at 15% of paddy moisture =8,675 Baht/ton (crops year 2010) source; Suphan Buri Mill rice Association
3 Government guarantee price of white paddy at 15% of paddy moisture = 10,000 Baht/ton
4 Average government subsidies = 1,553 Baht/ton = 10,000 Baht/ton (Guarantee prices) - 8,447 Baht/ton (Average reference prices)
* Farmer's income without subsidy price = Farmer's selling prices = 7,800 Baht/ton
** Farmer's income with subsidy price = 9,353 Baht/ton = Farmer's selling prices (7,800 Baht/ton) + government subsidies (1,553 Baht/ton)
*** WP_i = Irrigation Water Productivity

Table 28 is shown the calculation value of irrigation water in wet season crops 2010

Plot	Plot area	Yield	Total cost		Farmer income				Gross irrigation supply Ea 70%		***WP	Water value					
					*without subsidy		**with subsidy					without subsidy			with subsidy		
No.	ha	Ton/ha	Baht/ton	Baht/ha	Baht/ton	Baht/ha	Baht/ton	Baht/ha	mm/season	m^3/ha	kg/m^3	Baht/m^3	Baht/kg	Baht/ha	Baht/m^3	Baht/kg	Baht/ha
1	1.76	5.14	6,349	32,607	7,400	38,004	8,953	45,980	1,036	10,357	0.50	0.52	1.05	5,398	1.29	2.60	13,373
2	1.92	5.05	6,523	32,931	7,400	37,359	8,953	45,199	1,049	10,486	0.48	0.42	0.88	4,428	1.17	2.43	12,268
3	1.92	4.94	6,424	31,749	7,400	36,570	8,953	44,245	1,033	10,326	0.48	0.47	0.98	4,821	1.21	2.53	12,496
4	2.4	5.04	6,284	31,666	7,400	37,287	8,953	45,112	1,036	10,357	0.49	0.54	1.12	5,621	1.30	2.67	13,447
5	2.4	5.09	6,271	31,901	7,400	37,646	8,953	45,546	1,036	10,357	0.49	0.55	1.13	5,745	1.32	2.68	13,646
6	4	5.09	6,286	31,978	7,400	37,646	8,953	45,546	1,033	10,326	0.49	0.55	1.11	5,668	1.31	2.67	13,568
7	4.8	5.33	6,152	32,790	7,400	39,438	8,953	47,715	932	9,318	0.57	0.71	1.25	6,649	1.60	2.80	14,925
8	6.4	5.14	6,336	32,540	7,400	38,004	8,953	45,980	1,049	10,486	0.49	0.52	1.06	5,464	1.28	2.62	13,440
9	7.2	5.23	6,330	33,120	7,400	38,721	8,953	46,847	932	9,318	0.56	0.60	1.07	5,601	1.47	2.62	13,728
10	8	5.23	6,366	33,309	7,400	38,721	8,953	46,847	1,036	10,357	0.51	0.52	1.03	5,412	1.31	2.59	13,539
11	8.8	5.33	6,367	33,934	7,400	39,438	8,953	47,715	932	9,318	0.57	0.59	1.03	5,504	1.48	2.59	13,781
12	9.6	5.33	6,299	33,573	7,400	39,438	8,953	47,715	1,049	10,486	0.51	0.56	1.10	5,866	1.35	2.65	14,142
13	10.4	5.43	5,929	32,174	7,400	40,155	8,953	48,583	1,036	10,357	0.52	0.77	1.47	7,981	1.58	3.02	16,409
14	11.2	5.43	6,159	33,419	7,400	40,155	8,953	48,583	1,049	10,486	0.52	0.64	1.24	6,736	1.45	2.79	15,164
15	12	5.43	6,072	32,948	7,400	40,155	8,953	48,583	1,033	10,326	0.53	0.70	1.33	7,208	1.51	2.88	15,635
16	12.8	5.23	6,298	32,954	7,400	38,721	8,953	46,847	1,049	10,486	0.50	0.55	1.10	5,767	1.32	2.66	13,893
17	12.8	5.23	6,170	32,287	7,400	38,721	8,953	46,847	932	9,318	0.56	0.69	1.23	6,434	1.56	2.78	14,560
18	13.6	5.43	6,175	33,505	7,400	40,155	8,953	48,583	932	9,318	0.58	0.71	1.23	6,650	1.62	2.78	15,077
19	14.4	5.23	6,143	32,146	7,400	38,721	8,953	46,847	1,033	10,326	0.51	0.64	1.26	6,575	1.42	2.81	14,702
20	15.2	5.33	6,067	32,332	7,400	39,438	8,953	47,715	1,033	10,326	0.52	0.69	1.33	7,106	1.49	2.89	15,383
									Average	**10,122**	**0.52**	**0.60**	**1.15**	**6,032**	**1.40**	**2.70**	**14,159**
									S.D.	**480.28**	**0.03**	**0.09**	**0.14**	**863**	**0.13**	**0.14**	**1,052**
									Min	**9,318**	**0.48**	**0.42**	**0.88**	**4,428**	**1.17**	**2.43**	**12,268**
									Max	**10,486**	**0.58**	**0.77**	**1.47**	**7,981**	**1.62**	**3.02**	**16,409**

Remarks

1 Average farmer's selling prices at 25% of paddy moistures = 7,400 Baht/ton for wet season 2010
2 Average purchase price of white paddy at 15% of paddy moisture =8,675 Baht/ton (crops year 2010) source; Suphan Buri Mill rice Association
3 Government guarantee price of white paddy at 15% of paddy moisture = 10,000 Baht/ton
4 Average government subsidies = 1,553 Baht/ton = 10,000 Baht/ton (Guarantee prices) - 8,447 Baht/ton (Average reference prices)
* Farmer's income without subsidy price = Farmer's selling prices = 7,400 Baht/ton
** Farmer's income with subsidy price = 8,953 Baht/ton = Farmer's selling prices (7,400 Baht/ton) + government subsidies (1,553 Baht/ton)
*** WP_i = Irrigation Water Productivity

There were some studies that concerned about irrigation water value. Table 29 is shown comparing the results of water value in this study with water value from other literatures.

Table 29 Compared water value $US/m^3 (1US$ = 31.387 Baht during 2010)

Crops	Country/ Province	Conditions dry season/ wet season	Estimated value of water	Source
Rice	Thailand	Dry season / Central region	[a]0.017	This study
Rice	Thailand	Dry season / Central region	[b]0.033	This study
Rice	Thailand	Wet season/ Central region	[a]0.019	This study
Rice	Thailand	Wet season/ Central region	[b]0.045	This study
Rice	Pakistan	Wet season	0.067	Ashfaq et al., 2005
Rice	Tanzania	n.a.	0.030	Kadigi et al., 2004
Rice	Tanzania	n.a.	0.23	Musamba et al., 2011
Rice	Malaysia	n.a.	0.130	Jaafar et al., 2000
Rice	Angola	n.a.	0.008	Agudelo et al., 2001
Rice	Malawi	n.a.	0.048	Agudelo et al., 2001
Rice	Mozambique	n.a.	0.013	Agudelo et al., 2001
Rice	Zambia	n.a.	0.004	Agudelo et al., 2001
Rice	Zimbabwe	n.a.	0.074	Agudelo et al., 2001

Remark: a means water value excluded government subsidies
b means water value included government subsidies

The differences of water values were heavily dependent on variables as the crop selling price and government's subsidies price, the water productivity, market price of fertilizer and pesticide chemical, market price of seed, machinery expenditure, land rental, and labor wage. As can be seen from the table, value of irrigation water for rice in this study was nearly the same with the study for rice in Mozambique (0.013 $US/m^3) and Tanzania (0.03$US/m^3) for value in dry season ([a]0.017 – [b]0.033 $US/m^3) and for wet season ([a]0.019 – [b]0.045 $US/m^3) was almost same Malawi (0.048 $US/m^3). The result of this study was differed because of difference in location of study area, time period, yield, price of production during that time, and price policy, etc. All of these reasons were affected to the estimation of water values. As a result, if rice farmers have many benefits from selling production (high net income), the economic water values have too high also. Moreover, if irrigation water supplies service is high efficiency (including water conveyance efficiency, field canal efficiency and field water application efficiency). It means farmer can be used high efficient (have not loss from irrigation system) that affect water values (high values). However, this result was reflected water values at field scale. Therefore, it should be considering in whole scale (irrigation system; Conveyance, main canals, secondary canal, and paddy field).

4.5 Cost of Irrigation System

The investment of SCP O&M project was calculated from data available from SCP. The method of estimation investment cost of irrigation project based on variable inflation rate during construction period 1937 – 1993. The investments of irrigation system were consisted water distribution systems and drainage system such as water structures controlling, irrigation canals and drainage canals. Also, cost of operation and maintenance cost had included in the cost of irrigation project. The present value of irrigation system cost is shown in table 30.

Table 30 The investment of Sam Chuk O&M project and O&M cost in 2012

Initial construction cost convert to 1993 during 1937 - 1993	Initial renovation cost in 1993 = average construction cost convert to 1993 during 1937 - 1993	[1]Construction cost in 2012 used $CPI_{average}$ 5.1%	[2]Average O&M cost in 2012
Baht	**Baht**	**Baht**	**Baht**
265,412,747	4,656,364	670,684,793	140,741,037

Source; own calculation based on data of Sam Chuk O&M project.
[1]Present value of construction cost = Initial cost in 1993 × $(1+inf_{average})^n$; n = 2012 – 1993 = 13, and average inflation rate = 5.1%.
[2]average O&M cost of Sam Chuk O&M project during 2008-2011 that included salary budget, improvement budget, O&M budget, project management budget, and renovation cost (Initial renovation cost).

Determining the annual cost of irrigation water per unit area was determined by using cost recovery factor method for over 50 years in the future. For finance, the discount rate was used in this calculated that is 12%. As the result, the annual of capital cost (construction cost) was 1,616 Baht/ha/year (259 Baht/rai/year) and the annual of O&M cost was 2,808 Baht/ha/year (449 Baht/rai/year). Thus, the total cost of irrigation water is combination between annual capital cost and annual O&M cost which was 4,424 Baht/ha/year (1 year is dry season and wet season). Conclusion of calculation is shown in table 31.

Table 31 The annual cost of irrigation water at discount rate = 12%

List of cost	Work life	Initial cost	salvage value	CRF	Area serve	Annual cost
	years (n)	**Baht**	**Baht**		**ha/year**	**Baht/ha/year**
Capital cost (Construction cost)	50	680,045,524	6,800,455	0.12	50,171	1,616
O&M cost	Every year	140,905,261	-	-	50,171	2,808
					Total	**4,424**

Source; own calculation based on cost recovery factor.
[1] Salvage value = 1% of initial cost,
[2] Area serve = Irrigated area under the irrigation project= 50,171 ha

The calculation of irrigation water cost per cubic meter and per ton of paddy was combined the result of the first objective that shown in previous section. The assumption of calculation was the amount of irrigation water used to apply in paddy field divided the efficiency of irrigation system (E_s). Thus, the irrigation system efficiency were consisted the efficiency of canal (E_b) and conveyance (E_c) that based on Doorenbos and Pruitt (1977). In addition, E_b and E_c were equal to 0.8 and 0.775, respectively. As a result, the irrigation system efficiency equal to E_b multiplies with E_c that is 0.62. Therefore, The irrigation project have to provide the water which more than actual farmer's consumed because there were some losses in the system before farmers take water to their field. This was caused of the cost of irrigation water per cubic meter that were low. It is shown the low efficiency of irrigation system. However, the irrigation water losses may be maintains and increases the groundwater table level.

Table 32 is shown the cost of irrigation project investment. The result will be used to analyze in the fourth objective with combination the result of the first object.

Table 32 Cost of irrigation project investment (Capital cost + O&M cost)

Season	Irrigation water used in paddy field	Irrigation system efficiency	[1]Irrigation system supplied	Yield	Cost of irrigation investment		
	m^3/ha	$E_s = E_b \times E_c$	m^3/ha	Ton/ha	Baht/ha	Baht/Ton	Baht/m^3
Dry	16,634	0.62	26,830	5.40	2,212	410	0.08
Wet	10,122	0.62	16,325	5.23	2,212	423	0.13
Total per year	26,756	-	43,155	10.63	4,424	832	0.21
Average per season	13,378	-	21,578	5.32	2,212	416	0.11

Source; own calculation

[1] is Irrigation water used in paddy field / E_s ; $E_s = E_b \times E_c$,
where; E_b = 80% and E_c = 77.5%

Table 33 is shown the O&M cost of irrigation project that was also used to analyze in the fourth objective with combination the result of the first object.

Table 33 Cost of operation and maintenance (O&M cost)

Season	Irrigation water used in paddy field	Irrigation system efficiency	[1]Irrigation system supplied	Yield	O&M cost		
	m^3/ha	$E_s = E_b \times E_c$	m^3/ha	Ton/ha	Baht/ha	Baht/Ton	Baht/m^3
Dry	16,630	0.62	26,823	5.40	1,404	260	0.05
Wet	10,120	0.62	16,323	5.23	1,404	268	0.09
Total per year	26,750	-	43,145	10.63	2,808	528	0.14
Average per season	13,375	-	21,573	5.32	1,404	264	0.07

Source; own calculation

[1] is Irrigation water used in paddy field / E_s; $E_s = E_b \times E_c$,
where; E_b = 80% and E_c = 77.5%

The comparing cost and value of irrigation water per cubic meter in SCP is shown in table 34. Therefore, considering of investment of irrigation project has effective because it was created the value approximate 5 times of investment cost for without subsidies case and 11 times for with subsidy case. This is shown the investment on SCP's irrigation system that was feasible to invest in economics perspective view.

Table 34 Comparing the cost of irrigation water and values of irrigation water

Season	Cost of Irrigation Water			Value of Irrigation Water	
	Capital cost	O&M cost	Total cost	Without subsidy	With subsidy
	US$/$m^3$	US$/$m^3$	US$/$m^3$	US$/$m^3$	US$/$m^3$
Dry	0.001	0.002	0.003	0.017	0.033
Wet	0.002	0.003	0.004	0.019	0.045
Average per season	0.001	0.002	0.003	0.018	0.039
Total per year	0.003	0.004	0.007	0.036	0.078

Source; own calculation

1US$ = 31.387 THB during 2010

Considering in farmer's net income per cost of irrigation investment, farmers had ability to pay the irrigation water charging because the farmer's net income was more than the cost of irrigation investment which approximately 3.37 times for without subsidy case and 7.10 times for with subsidy case as shown in table 35. However, farmer's paying ability concerning with farmer's net income per cost of farmer's production was lower than the proportion of farmer's paying ability of farmer's net income and cost of irrigation investment. This was a reason of transmission the irrigation water costing to other stakeholders in rice marketing channels such as rice millers, domestic consumers and rice exporter.

Table 35 The proportion of farmer's net income and cost of irrigation investment or Return on Equity, RoE

Season	**Yield**	**Cost of irrigation investment**		**Farmer's net income**			
				Without subsidy		**With subsidy**	
	Ton/ha	**Baht/ha**	**Baht/Ton**	**Baht/ha**	**Baht/Ton**	**Baht/ha**	**Baht/Ton**
Dry	5.40	2,212	410	8,915	1,649	17,302	3,202
Wet	5.23	2,212	423	6,032	1,150	14,159	2,703
Average per season	5.32	2,212	416	7,474	1,400	15,731	2,953
Total per year	10.63	4,424	832	14,947	2,799	31,461	5,905
Farmer's net income / Cost of irrigation investment				3.38	3.36	7.11	7.09
				3.37		7.10	

Source; own calculation

Table 36 The proportion of farmer's net income and cost of farmer's production or Return on Investment of farmer's view point, RoI

Season	**Yield**	**Cost of farmer's production**		**Farmer's net income**			
				Without subsidy		**With subsidy**	
	Ton/ha	**Baht/ha**	**Baht/Ton**	**Baht/ha**	**Baht/Ton**	**Baht/ha**	**Baht/Ton**
Dry	5.40	33,218	6,151	8,915	1,649	17,302	3,202
Wet	5.23	32,707	6,250	6,032	1,150	14,159	2,703
Average per season	5.32	32,963	6,200	7,474	1,400	15,731	2,953
Total per year	10.63	65,925	12,401	14,947	2,799	31,461	5,905
Farmer's net income / Cost of farmer's production				0.23	0.23	0.48	0.48
				0.23		0.48	

Source; own calculation

Focusing on the proportion of farmer's net income and cost of operation and maintenance (see table 37), farmer's net income per operation and maintenance cost was higher than the proportion of farmer's net income per irrigation investment (capital cost + O&M cost) which accounted approximately 58 percent. Therefore, it was descripted that the farmer's net income after paid the irrigated operation and maintenance cost was higher than the farmer's net income after paid the irrigation investment. However, it should has the farmer's willingness study in order to find their paying willingness.

Table 37 The proportion of farmer's net income and cost of operation and maintenance

Season	**Yield**	**Cost of Operation and Maintenance**		**Farmer's net income**			
				Without subsidy		**With subsidy**	
	Ton/ha	**Baht/ha**	**Baht/Ton**	**Baht/ha**	**Baht/Ton**	**Baht/ha**	**Baht/Ton**
Dry	5.40	1,404	260	8,915	1,649	17,302	3,202
Wet	5.23	1,404	268	6,032	1,150	14,159	2,703
Average per season	5.32	1,404	264	7,474	1,400	15,731	2,953
Total per year	10.63	2,808	528	14,947	2,799	31,461	5,905
Farmer's net income / Cost of O&M				5.32	5.30	11.20	11.18
				5.31		11.19	

Source; own calculation

4.6 Rice Marketing Channel in Suphan Buri province

The rice marketing channel in the study at the upstream level which collected from the president of Suphan Buri Rice Millers Association is shown in figure 4.5. Farmers were directly distributed or sold the paddy to miller accounted 20% of total paddy production. Another 80% is sold to local center market. That means that the local center market was a linking connection between upstream level (farmers) and middle stream level (miller). After miller gate, normally almost 100% of milled rice production in Suphan Buri province was white rice 5%. Miller sold white rice 5% to the exporter, local wholesalers and owned export calculated 80%, 10%, and 10%, respectively. Moreover, miller sold brown rice bran, husk, rice bran, and white broken rice A1 super to local buyers that was a raw material of fuel (for husk), frying oil (for rice bran). The proportion of value added of 1,000 kg of paddy is shown in figure 4.6.

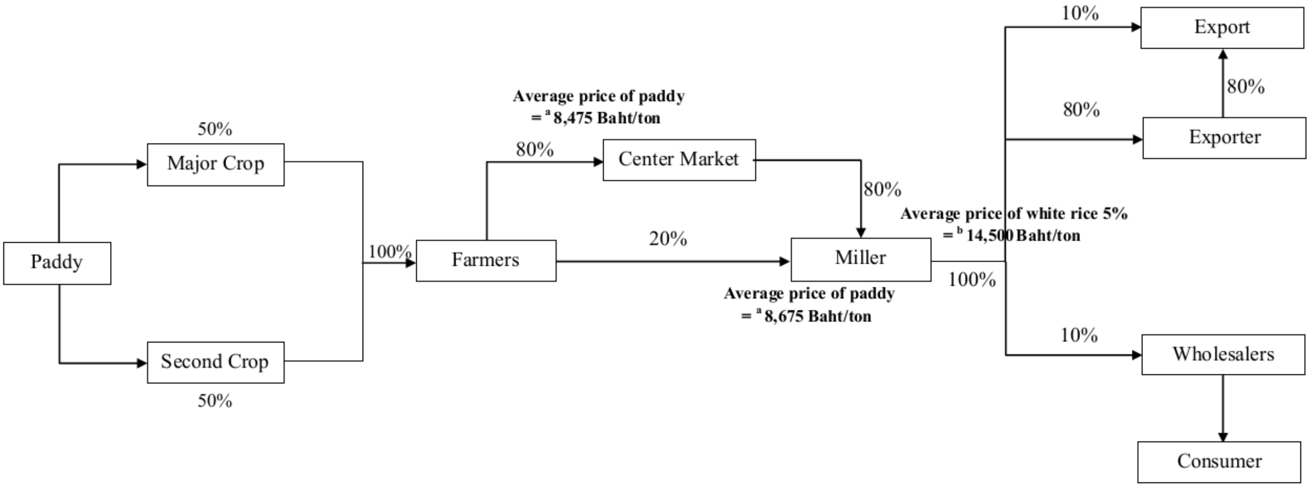
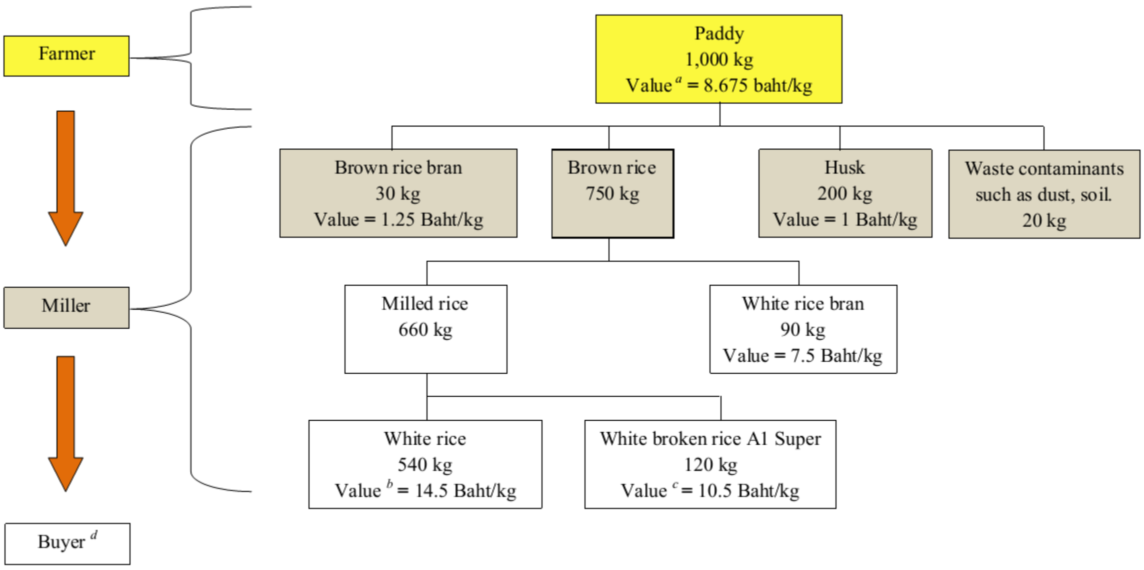


Figure 4.5 The marketing channel of paddy production in Suphan Buri 2009/2010
Source; Concluded from field survey data



Remark: *a* is the average price of dry paddy at 14 – 15% of moisture in 2010
b is the average price of white rice 5% in 2010;
c is the average price of white broken rice 5% grade ***A1 super***
d is the buyer that included broker, rice business company in domestic and international market (export).

Figure 4.6 The portion of value added of paddy production and the component of paddy milled in Suphan Buri

Source; Concluded from field survey data

From the figure 4.6, it was shown the value added of paddy 1,000 kg of rice miller stage. Therefore, millers were used 2,000 kg of paddy to produce 1,080 kg of white rice. The marketing cost of millers was approximately 1,190 Baht/ton of white rice. Thus, the profit of miller can calculate as follow:

= 2 × [(200 kg×1 Baht/kg) + (30 kg×1.25 Baht/kg) + (540 kg×14.5 Baht/kg) + (120 kg×10.5 Baht/kg) + (90 kg×7.5 Baht/kg)] – (2 ×7,600 Baht) – 1,190 Baht/ton

= 3,615 Baht/ton of white rice

In addition, the cost of exporters was 1,191 Baht/ton. Moreover, the FOB price of white rice was 18,088 Baht/ton of white rice 5%. Therefore, the calculation of exporter's profit is shown below:

= FOB prices (Baht/ton) – selling price of millers (Baht/ton) – processing cost of exporters (Baht/ton)

= 18,088 – 14,500 – 1,091

= 2,497 Baht/ton

Moreover, the marketing cost of wholesalers or retailers in domestic markets was approximately 1,382 Baht/ton. Thus, the calculation of wholesalers or retailers profit was shown below:

= Consumer selling price or Domestic prices (Baht/ton) – selling price of millers (Baht/ton) – marketing cost of wholesalers or retailers (Baht/ton)

= 26,000 – 14,500 – 1,382

= 10,118 Baht/ton

4.7 The possible new financing irrigation service to cover for irrigation supply and maintenance costs.

From the result of first objective, second objective and third objective, the possible new financing by shearing the irrigation supply and maintenance cost to stakeholders in rice marketing chain was analyzed. The irrigation water charging rate should be used in term of mass product (ton) because it was easy when setting the scenario of water charging with stakeholder in rice marketing system.

Current situation Farmers have not do anything and do not want to pay for water charging because they have concerned about the amount of water which insufficient in dry season. In addition, the unstable price and low price of paddy in the market are the main reason that farmers does not want to pay. Furthermore, the miller and rice business company are unwilling to pay water charging. Moreover, the most important serious is the political sensitive because the sense of feeling has directly affected with the vote base in political competition.

Scenario 1 Farmers have to pay for irrigation water covering the O&M cost. The units of irrigation water charging should be in term of mass product. The irrigation water charging rate to cover O&M cost was 260 Baht/ton for dry season and 268 Baht/ton for wet season. Therefore, the total of irrigation water charging during 1 year (dry and wet season) was 528 Baht/ton. As a result, the production cost of farmers will increase approximately 4.23 percent for dry season and 4.29 percent for wet season.

Scenario 2 Farmers have to pay for irrigation water to cover for Capital cost + O&M cost. This scenario was charge irrigation water cost based on capital cost and O&M cost of irrigation water with farmers. The main reason of charging with farmers was farmers still have subsidies money from the government already. Thus, they should have responded the cost of irrigation water. The rate of irrigation water charging was 410 Baht/ton for dry season and 423 Baht/ton for wet season. Therefore, the production cost of farmers has increased around 6.67 percent and 6.77 percent for dry and wet season, respectively.

Scenario 3 Farmer's guaranteed a minimum price covering the capital cost only and charged O&M cost with another stakeholder in rice marketing chain. In this stage we will classified into two case; 1) Domestic market, and 2) Export market.

1) Domestic market; there were the suppliers of white rice production to consumer that was the wholesalers and retailers in domestic market. The marketing costs of both actors were assuming the same that was approximately 1,382 Baht/ton (see table 34). In addition, the price of retailer selling to consumers was around 26 Baht/kg or 130 Baht/ 5 kg bag (DIT, 2012). The irrigation water charging was considered in farmers guaranteed a minimum price that was equal to 304 Baht/ton/year (150 Baht/ton for dry season and 154 Baht/ton for wet season) as shown in table 41. In addition, the O&M cost have transmitted to miller, wholesaler or retailer, and consumer also have to buy higher price than before charged around 1.056 Baht/kg (27.056 Baht/kg or 135 Baht/ 5kg bag)

2) Export market; the charging for O&M cost is shown in form of the price of miller selling to exporters. Therefore, the price at miller selling was increased around 1,056 Baht/ton. As a result, to cover the net income of exporter their have to increase the F.O.B. price from 18,088 Baht/ton to 19,144 Baht/ton. The foreigner consumers should be responsible water charging same as domestic consumers.

Scenario 4 Capital cost and O&M cost are charged to farmers and they re-charged it to next actors who were the millers. Thus, the selling price of paddy was increased from 7,800 Baht/ton to 8,210 Baht/ton for dry season and 7,400 Baht/ton to 7,823 Baht/ton for wet season. The average selling price of paddy per season was 8,017 Baht/ton. After that, millers re-charged it to buyers. The miller also increases the selling price of white rice as the same of full cost of irrigation project for remain their income. As a result, the wholesalers or were increased the retail price. Thus, the price at retail level was increased from 26,000 Baht/ton (130 Baht/ 5kg bag) to 26,834 Baht/ton (134 Baht/ 5kg bag) as same as the F.O.B price was increased equal to full cost of irrigation project (834 Baht/ton) that from 18,088 Baht/ton to 18,922 Baht/ton.

The summary of scenario of the financing model in water charging system on rice marketing channel system is shown in table 37. In addition, the net income of each actor has differed from each scenario. Therefore, the each scenario has differed in the return to cover irrigation project.

Table 38 Summary scenario of the financing model to cover cost of irrigation project

Scenarios	Farmer net income (Baht/ton)	Miller net income (Baht/ton)	Export net income (based on F.O.B. price) (Baht/ton)	Retail price to customer in Domestic (Baht/ 5kg bag)	F.O.B price (Baht/ton)
Current situation					
Dry	1,649	3,615	2,497	130.00	18,088
Wet	1,150	3,615	2,497	130.00	18,088
Scenario 1: Farmer have to cover for O&M cost only, Dry = 260 Baht/ton and Wet = 268 Baht/ton					
Dry	1,389	3,615	2,497	130.00	18,088
Wet	882	3,615	2,497	130.00	18,088
Scenario 2: Farmers have to pay for irrigation water to cover for Capital cost + O&M cost, Dry = 410 Baht/ton and Wet = 423 Baht/ton					
Dry	1,239	3,615	2,497	130.00	18,088
Wet	727	3,615	2,497	130.00	18,088
[/1]**Scenario 3:** Farmer's guaranteed a minimum price to cover capital cost only and charged O&M cost with another stakeholder in rice marketing chain					
Dry	1,499	3,615	2,497	135.28	19,144
Wet	995	3,615	2,497	135.28	19,144
[/2]**Scenario 4:** Final customer at retail level has to cover both of capital and O&M cost of irrigation project					
Dry	1,649	3,615	2,497	134.17	18,922
Wet	1,150	3,615	2,497	134.17	18,922

Source; own summary

[/1] the capital cost has covered by farmer and O&M cost has covered by millers but the selling price of white rice 5% has also increasing

[/2] the capital cost and O&M cost has covered by farmer and the selling price of paddy has also increasing

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Due to the scarcity in the agricultural water supply, many organizations attempt to propound policies that lead to efficient water using in order to cultivate agricultural crops. In Thailand, approximately 70% of water withdrawal is accounted in agriculture. Moreover, it appears that the water used for agricultural production does not have an efficient management which reaches to the increase of water shortage. Rice is an important crop that requires a lot of water for its production and it also faces inefficient water usage. In addition, Thai Government has subsidized the water as a free from any charge for rice production through irrigation system which farmers should have the water management in order to achieve the highly benefit. In fact, farmers were not done it. As a result, the irrigation water pricing becomes a considering issue that the ADB attempt to stimulate the policy enforcement in the country. Meanwhile, who should undertake the cost of irrigation water if the water pricing policy is operated. This study is aimed to study about the investigation on the conditions and applicability of an equitable and sustainable financing model for irrigation water services in Thailand using rice production that run to be a special case for this study.

The data are derived from 20 rice producers who located under Sam chuk Operation and Maintenance Project, Suphan Buri Province. Meanwhile the analysis method is used quantitative analysis by using CROPWAT 8.0 model, Residual Imputation Method and Microsoft excel program.

5.2 Conclusions

The results of study lead to the following conclusion:

1. The value of irrigation water used by paddy cultivation in Sam Chuk operation and maintenance project using residual imputation method was divided in to two case; Case 1 was without subsidy from government that average approximate 0.017 US$/m^3 for dry season and 0.019 US$/m^3 for wet season. Case 2 was with subsidy from government that average approximate 0.033 US$/m^3 for dry season and 0.045 US$/m^3 for wet season. The amount of irrigation water used to apply in paddy field was estimated from CROPWAT 8.0 model and applied to estimate the value of irrigation water.

2. The cost of irrigation project was based on irrigated areas was approximate 2,212 Baht/ha/season (67.576 US$/ha/season) or 4,424 Baht/ha/year (135.152 US$/ha/year) and transferred to unit cost of irrigation water per cubic meter that approximate 0.11 Baht/m^3/year or 0.007 US$/m^3/year (0.003 US$/m^3 for dry season and 0.004 US$/m^3 wet season). Moreover, in the unit cost of irrigation water per mass of paddy was approximate 410 Baht/ton of paddy (13.063 US$/ton of paddy) for dry season crops and 423 Baht/ton of paddy (13.477 US$/ton of paddy) for wet season crops. All of this result based on primary data and secondary data that was collected from Sam Chuk operation and maintenance project.

3. The added values of paddy production in Saphan Buri province was collected only the primary at milling process only. Therefore, the added values of paddy production was

consisted the by-production from milling such as brown rice bran, husk, and white rice bran white broken rice. As a result, 1 ton of white rice production was needed 2 tons of paddy in producing. Thus, the income of miller from by-product of milling was 4,345 Baht/ton (138 US$/ton). In addition, the 2 tons of paddy can made the added value in form of white rice and by-product of milling process around 20,005 Baht/ton of white rice. The total paddy production in 2010 was 940,000 tons for dry season crops and 950,000 tons from wet season. The average price of paddy that miller buy from farmers was 7,800 Baht/ton and 7,400 Baht/ton for dry and wet season at 24-25% of moisture, respectively. The rice marketing channel system of Suphan Buri province started from 100% of paddy production that miller buy 80% from center market and 20% from farmers. After milling process, the white rice production around 507,600 tons (dry season production) and 513,000 tons (wet season production) was sold to 10% of domestic market and 90% of export.

4. The investigating possible new financing and arrangements to cover for irrigation supply and maintenance costs was analyzed using the output of previous sub-objectives to set the scenario of irrigation water charging system. The scenario of irrigation water charging in this study had 4 scenarios. For each scenario have differed in the irrigation water charged price. First scenario was charged from farmer to cover O&M cost only. Second was charged to cover full cost of irrigation (capital cost and O&M cost) from farmer. Third was charged from farmers at minimum guaranteed price that was capital cost and O&M cost was charged from millers. However, the price of white rice production in each stage also increasing too. The last was charged full cost of irrigation water from farmers and the price of production in each stage also increasing under the real cost of each sector occurred. However, a water charge is corresponding to an increase in production costs which cannot easily be passed to the consumer because of the tight dependence of rice prices to the world market.

5.3 Recommendation

From the finding of this study some suggestions are proposed as follow:

1. This study only considers the values of irrigation water used by rice farmers, however, for other farmers cultivation crops should be considering as well as.

2. This study reflected only the cost of Sam Chuk O&M project. It should has the study in the other project in order to find the cost of all irrigation project in Thailand.

3. This study can apply for next study in the future that related about the possible ways of water charging along the rice supply chain for recovery cost of irrigation service in Thailand. Therefore, it can base on the result of this study.

4. Government should stimulate the enforcement of water charging in agricultural sector especially in rice cultivation. If the water charging is operated, government should have the policy which controls the price of paddy product and guarantee the water using is sufficient for farmer's cultivation in dry season. Moreover, it should have the preventive avoiding the flooding problem.

5. Water charging should be considered in many factors such as political sensitive, the stable in price of agricultural production, and flood & drought crisis.

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APPENDIX A

Mr. Peerasut Saringkarn **Questionnaire No._____**

A combined analysis of rice supply chain and water resource use in rice cropping system:

Case studies in selected regions of Thailand

Survey Questionnaire at Farm level

1. General information of farm owner

Name and family name of farmer...

Address...

....

Telephone.. E-mail address...

Name and family of farm manager (if any)...

Address...

....

Telephone.. E-mail address...

2. Farm location

Land area..(Rai)

Address...

....

3. The history of land used within the past three years: Indicate the type of crop/variety grown

1st Year.................................2nd Year...................................3rd Year.................................

4. Cultivation practice ☐ transplanting ☐ wet seeded ☐ dry seeded

5. Rice seed source

Varietal name	Area (rai)	Seed source	Distance from source (km)	Type of vehicle	Oil/fuel consumption (liters)	Seed used (kg)	Seed rate (kg/rai)	Price (Baht)

Please answer the following question based on the growing rice.

6. Jasmine rice production

Area cultivated......................................rai

Area harvesting....................................rai

Threshed jasmine rice production or yield...kg/rai

Price of threshed jasmine rice at the farm (price/kg)..Baht

Price of threshed jasmine rice (price/kg)...Baht

7. Field operation

7.1 Human Labor

No.	Type of operation	Area (rai)	Family labors			Hired labors			
			Family labors	Total (days)	Working Time	No. of labors	Total (days)	Working Time	Wage/day
1	Land operation								
2	Transplanting rice								
	2.1 land preparation								
	2.2 sowing								
	2.3 transplanting								
3	Sowing								
4	Fertilizer application								
	4.1 chemical								
	4.2 organic								
5	Pest and weed management								
	5.1 insecticide								
	5.2 pesticides								
	5.3 herbicides								
	5.4 fungicides								
	5.5 raticides								
	5.7 Other..................								
	5.8 Other..................								
	5.9 Other..................								
	5.10 Other................								
6	Water management								
7	Harvesting								
8	Threshing								

7.2 Tractor

Source of Tractor: ☐ Owner ☐ Rental

If using the rental Tractor: Cost of the rental...............................(Baht/rai) or (Baht/day)

No.	Type of operation	Name	Model	Working time (hrs/day)	Total time (days)	Oil/fuel consumption for working (liters)	Oil/fuel consumption for rallying (l/hrs)	House power (hp)
1.	Land operation							
	1.1 tillage							
	1.2 puddling							
	1.3 plough							
	1.4 other................							
	1.5 other................							
2	Transplanting rice Land operation							
	2.1 tillage							
	2.2 puddling							
	2.3 plough							
	2.4 other................							
	2.5 other................							

7.3 Machinery

No.	Type of operation	Name	Model	Working time (hrs/day)	Total time (days)	rental machinery: cost (Baht/day)	Oil/fuel consumption (liters)	House power (hp)
1	Land operation							
2	Transplanting rice							
	2.1 land preparation							
	2.2 sowing							
	2.3 transplanting							
3	Sowing							
4	Fertilizer application							
	4.1 chemical							
	4.2 organic							
5	Pest and weed management							
	5.1 insecticide							
	5.2 pesticides							
	5.3 herbicides							
	5.4 fungicides							
	5.5 raticides							
	5.7 Other................							
6	Water management							
7	Harvesting							
8	Threshing							

7.4 Water pump

Pump type..Diameter of pipe...

Fuel consumption...Horse Power (hp)..

Pump discharge..Head of water..

Pump operating time....................................

7.5 How do you think about adequacy of water?

☐ always enough and timely

☐ o.k.

☐ not always good but cannot complain

☐ not so good, not enough or not in time

☐ hardly ever o.k. (not enough and not in time)

7.6 Animal Draft and water use

<table>
<tr><th rowspan="2">No.</th><th rowspan="2">Type of operation</th><th rowspan="2">Area (rai)</th><th colspan="3">Animal Draft</th><th colspan="2">Water use</th></tr>
<tr><th>Type of animal</th><th>No. of Animals</th><th>Working time</th><th>mm/rai</th><th>sources</th></tr>
<tr><td>1</td><td>Land operation</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">2</td><td colspan="7">Transplanting rice</td></tr>
<tr><td>2.1 land preparation</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2.2 sowing</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2.3 transplanting</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Sowing</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="3">4</td><td colspan="7">Fertilizer application</td></tr>
<tr><td>4.1 chemical</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4.2 organic</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="7">5</td><td colspan="7">Pest and weed management</td></tr>
<tr><td>5.1 insecticide</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5.2 pesticides</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5.3 herbicides</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5.4 fungicides</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5.5 raticides</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5.7 Other..................</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Water management</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Harvesting</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>Threshing</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

8. Fertilizer application

Name of fertilizer	Formula of N-P-K	Application rate (kg/rai)	Active ingredients (%)	Total use (kg/ha)	Price (price/unit)

9. Do you understand about the effect of using fertilizer to soil quality?

☐ very bad ☐bad ☐average ☐good ☐excellent

10. Pest, weed and other chemical management

Name	Name of pesticide/ Weed control/chemical	Application rate (kg/rai)	Active ingredients (%)	Total use (kg/rai)	Price (price/unit)
1. Diseases					
1.1					
1.2					
1.3					
1.4					
1.5					

Pest, weed and other chemical management (Cont'd)

Name	Name of pesticide/ Weed control/chemical	Application rate (kg/rai)	Active ingredients (%)	Total use (kg/rai)	Price (price/unit)
1.6					
1.7					
1.8					
1.9					
1.10					
2. Insects					
2.1					
2.2					
2.3					
2.4					
2.5					
2.6					
2.7					
2.8					
3. Weeds					
3.1					
3.2					

3.3					
3.4					
3.5					
3.6					
3.7					
3.8					
3.9					
3.10					
4. Animals pests					
4.1					
4.2					
4.3					
4.4					
4.5					
4.6					
4.7					
4.8					
4.9					
4.10					

11. Sprayer or other implements use during the chemical application

Name	Specific model name	Power (hp)	Oil/Fuel consumption	Cost (Baht/day)

12. Did you use tractor, machinery, sprayer or other implements for other crops? If yes, please describe that how many percentage of using these implements for jasmine rice and other crops

Name of implements	Crops Name	Percentage (%)

13. Harvesting and threshing practices

Case 1: Harvest and thresh by labor

Performance	Notice
1. Blooming 80%	☐ Blooming consistently throughout rice field. ☐ Blooming inconsistently throughout rice field.
2. Water drainage	☐ Water draining seven days before harvest. ☐ Water draining longer than 10 days before harvest. ☐ No water draining.
3. Panicle performance	☐ Turn yellow completely. ☐ Three quarters of panicle turn yellow. ☐ Whole panicle remains green. ☐ Panicle over dried.
4. Harvest by ☐ labor ☐ machine	Field condition ☐ Dried ☐Wet
6. Rice pile up in stack.	Amount............................stacks
7. Threshing ☐ Labor ☐ Threshing machine ☐ Animal	☐ Same variety of rice was harvested from last crop. ☐ Different variety of rice was harvested from last crop. Explain cleaning practice. ☐ Others...
8. Total Produce	☐ Sale paddy in form of wet grain..................................ton. ☐ Safe for seeding / self consumption.............................ton.

Case 2: Harvest and thresh rice by machine

Performance	Notice
1. Blooming 80%	☐ Blooming consistently throughout rice field. ☐ Blooming inconsistently throughout rice field. ☐ ....
2. Water drainage	☐ Water draining seven days before harvest. ☐ Water draining longer than 10 days before harvest. ☐ No water draining.
3. Panicle performance	☐ Turn yellow completely. ☐ Three quarters of panicle turn yellow. ☐ Whole panicle remains green. ☐ Panicle over dried.
4. Harvesting date	Field condition ☐ Dried ☐Wet

5. Harvesting machine	☐ Last harvest was the same variety. ☐ Last harvest was different variety Indicate name.. (If known) Indicate cleaning method to eliminate remaining grain.. ☐ Others...
6. Total Produce	☐ Sale paddy in form of wet grain..................................ton. ☐ Safe for seeding / self consumption.............................ton.

14. Drying practice (If produce is sold in form of wet paddy, omit this clause).

Dry date: Starting date.. Finish date...

Performance	Criteria
1. Performance of drying court. ☐ Ground courty. ☐ Cement courty. ☐ Asphalt court.	☐ Thickness of paddy layer is less than 5 cm. ☐ Thickness of paddy layer is 5-10 cm. ☐ Thickness of paddy layer is greater 10cm.
2. The last drying on this courty was on ....(date).	☐ Other produce.. ☐ Rice (variety name)..................................... ☐ Other activity...
3. Material lay under produce during drying.	☐ None ☐ Canvas/plastic ☐ Net ☐ Others..
4. Cleaning drying court.	☐ None ☐ Sweeping ☐ Others (indicate)..
5. The sun shines condition (in general).	☐ Strong sunlight ☐ Medium sunlight ☐ Cloudy ☐ Rain ☐ Others..
6. Turn over paddy during drying.	Frequency of turning over paddy..................... time/day
7. Drying period.	Number drying day.......................days
8. Material used for covering paddy during drying period.	☐ none ☐ cover paddy with.......................................
9. Dryer.	☐ Last drying was.................(indicate variety) ☐ Cleaning to eliminate grain remaining in the machine.. Drying time: Starting at.........o'clock am or pm until.................o'clock am or pm. Drying duration..................hours.

15. Transportation

15.1 Transportation from farm to storehouse

Before transportation, what's kind of parcel/container that use for packing the threshed jasmine rice?
....

Capacity of parcel/container...kg

Distance..km

Type of vehicle..

Capacity of vehicle...ton

Oil/fuel consumption...liters/round

15.2 Transportation from storehouse to mill

Mill name..

Mill location..

Distance...km

Type of vehicle..

Capacity of vehicle...ton

Oil/fuel consumption...liters/roun

16. Irrigation information

16.1 Distribution water to Individual Field

☐ By pumping ☐ By gravity ☐ Other (specify).................................

16.2 Type of irrigation Practice

☐ Surface (furrow, border, basin) ☐ Sub surface (drip)

☐ Overhead (sprinkler irrigation) ☐ Other (specify)..

16.3 water supply

Crop	Dry season			Wet season		
	1st crop	2nd crop	3rd crop	1st crop	2nd crop	3rd crop
Crop name						
Area cultivated (rai)						
Irrigated area (rai)						
How many times do farmer get irrigation water during the crop cycle (dry season)?						
How much irrigation water delivery to the field (m^3/s or m^3) per one time?						
How many hours irrigation water delivery to the field per one time?						

17. Crop information

17.1 Crop calendar

Variety of rice	Dry season						Wet season					
	Month											
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.

17.2 Crop production

Crop	Dry season			Wet season		
	1st crop	2nd crop	3rd crop	1st crop	2nd crop	3rd crop
Area cultivated (rai)						
Area harvested (rai)						
Crop production or yield (kg/rai)						
Price of crop at farm (price/kg)						
Market price (price/kg)						

18. Income, Selling, and Farm Revenue

Description	Dry season			Wet season		
	1st crop	2nd crop	3rd crop	1st crop	2nd crop	3rd crop
Product sold (price)						
Self-consumption (kg)						
Selling value (price)						

APPENDIX B

Table B–1 The Cultivated area in rain season and dry season in year 1984 – 2010 of Sam Chuk operation and maintenance project

Year	Cultivated areas in dry season (ha)							Cultivated areas in wet season (ha)						
	Rice	Fruit	Sugarcane	Vegetable and upland	Shrimp - Fish	Other	Total	Rice	Fruit	Sugarcane	Vegetable and upland	Shrimp - Fish	Other	Total
1989	37,307	177	4,644	185	941	5,545	48,800	42,166	176	4,610	284	960	604	48,800
1990	37,344	179	3,084	265	283	7,645	48,800	42,193	742	4,943	37	249	636	48,800
1991	15,182	749	6,334	1,118	303	25,115	48,800	40,556	800	6,761	178	259	247	48,800
1992	24,522	1,342	6,756	1,033	339	14,808	48,800	39,764	904	6,794	-	330	1,008	48,800
1993	16,325	1,298	6,794	465	334	23,584	48,800	39,541	1,119	7,160	-	231	750	48,800
1994	11,843	1,339	8,295	216	248	26,837	48,800	37,952	1,342	7,661	-	255	1,591	48,800
1995	22,807	1,352	8,430	200	245	15,766	48,800	34,578	1,352	8,430	200	245	3,995	48,800
1996	35,887	1,461	8,790	76	235	2,350	48,800	31,993	1,486	8,790	253	235	6,042	48,800
1997	32,671	1,486	8,790	199	235	5,419	48,800	37,076	1,593	9,003	104	147	877	48,800
1998	33,719	1,663	9,004	293	250	3,871	48,800	37,296	1,938	7,124	167	300	1,975	48,800
1999	32,608	2,397	7,124	116	300	6,256	48,800	36,213	2,265	6,879	168	293	2,982	48,800
2000	39,012	2,021	3,641	-	252	3,874	48,800	41,618	2,021	3,481	-	252	1,268	48,800
2001	39,236	2,028	3,641	-	252	3,644	48,800	37,309	2,021	3,481	-	258	5,566	48,800
2002	41,496	2,021	3,641	160	252	1,231	48,800	39,666	1,885	3,481	190	252	3,325	48,800
2003	38,747	2,315	3,574	-	288	3,876	48,800	39,667	2,315	3,574	-	288	2,796	48,800
2004	38,940	3,324	2,468	160	356	3,552	48,800	40,564	2,611	3,166	160	288	2,010	48,800
2005	41,024	2,140	3,166	174	356	1,940	48,800	40,308	2,611	3,166	160	288	2,266	48,800
2006	40,456	2,611	3,166	-	288	3,650	50,171	43,880	2,611	3,166	-	288	65	50,171
2007	43,149	2,611	3,095	124	187	1,004	50,171	39,718	2,611	3,095	160	187	4,399	50,171
2008	37,418	2,611	3,095	-	187	6,859	50,171	38,286	2,611	3,095	-	187	5,832	50,171
2009	43,517	2,611	3,095	-	187	761	50,171	34,558	2,611	3,413	-	187	9,242	50,171
2010	37,908	2,611	3,095	-	187	6,370	50,171	40,481	2,200	3,413	-	188	3,730	50,171

Source; Sam Chuk operation and maintenance project, 2010

Table B–2 Detail of Construction Building in SCP (adapted from SCP, 1995)

Name	Sta. km	Size	Type	Finished	Cost of Construction (Baht)	Type of gate
Navigation Lock	79+700	35.00x50.00	RC	1937	386,305	Slide gate
Chon Lamak Pichan reg.	79+700	2- ⊔ 12.50	Concrete	1937	386,305	Slide gate
Samchuk reg.	0+0.75	1-□ 2.50x2.90	Concrete	1937	18,886	Slide gate
Cross reg. 1R	13+200	1-□ 2.00x2.40	Concrete	1938	6,800	Slide gate
Head reg. 1R-1R	11+760	1- O 1.00x9.00	Concrete	1938	1,910	Slide gate
Head reg. 2L-1R	17+600	2- O 1.00x14.00	Concrete	1938	2,971	Slide gate
Head reg. 2R-1L	3+200	2- □ 3.00	Concrete	1940	6,430	Slide gate
Head reg. 2R-1L	0+000	2- ⊔ 3.00	Concrete	1940	6,429	Slide gate
Head reg. 2L-2R-1L	22+000	3- Ø 6.00	Concrete	1940	1,158	Slide gate
Siphon	2+700	3- □ 1.50x2.10	Concrete	1941	98,993	Slide gate
Siphon	2+750	□1.50x2.10	Concrete	1941	98,993	Slide gate
Head reg. 3R-1L	13+400	5- Ø 0.40	Concrete	1941	2,841	Slide gate
Head reg. 4R-1L	17+000	2- Ø 0.10	Concrete	1941	2,833	Slide gate
Tail reg. 1R	35+400	2- O 1.00x7.00	Concrete	1942	10,000	Slide gate
Head reg. 1L-2R-1L	6+100	4- Ø 0.60	Concrete	1945	1,920	Slide gate
Flume	0+450	⊔2.40x2.10	Concrete	1946	132,388	Slide gate
Cross reg. 1R	22+300	1- ⊔ 2.00	Concrete	1954	99,999	Slide gate
Cross reg. 2R-1L	15+100	1- ⊔ 2.00	Concrete	1954	99,999	Slide gate
Flume	0+900	⊔3.70x34.00	Concrete	1955	720,000	-
Cross reg. 1L	13+410	5- Ø 0.50	Concrete	1957	64,600	Slide gate
Cross reg. 2R-1L	6+125	5- Ø 0.10	Concrete	1957	64,600	Slide gate
Cross reg. 1L	17+025	3- Ø 0.10	Concrete	1958	169,963	Slide gate
Cross reg. 2R-1L	10+700	5- Ø 0.10	Concrete	1959	64,600	Slide gate
Cross reg. 2R-1L	22+020	2- Ø 0.10	Concrete	1959	25,840	Slide gate
Cross reg. 1R	28+800	1-□ 1.25x1.25	Concrete	1969	87,000	Slide gate
Siphon	31+700	1- Ø 0.10	Concrete	1970	137,000	Slide gate
Siphon	44+170	2- Ø 0.10	Concrete	1970	274,000	Slide gate
Siphon	46+900	1- Ø 0.10	Concrete	1970	137,000	Slide gate
Cross reg. 2R	14+340	2-□ 2.25x2.00	Concrete	1971	424,000	Slide gate
Cross reg. 1L	22+368	2- Ø 0.10	Concrete	1971	75,000	Slide gate
Cross reg. 2R	19+700	2-□ 1.75x1.75	Concrete	1972	220,000	Slide gate

Table B–2 Cont'n

Name	Sta. km	Size	Type	Finished	Cost of Construction (Baht)	Type of gate
Head reg. 3L-1R	22+100	2- O 1.00x10.50	Concrete	1972	82,000	Slide gate
Cross reg. 2R	26+600	2- □ 1.50x1.50	Concrete	1973	200,000	Slide gate
Tail reg. 2R-1L	31+650	1- Ø 0.60	Concrete	1973	30,000	Slide gate
Cross reg. 2R	34+847	2- □ 1.75x1.75	Concrete	1975	154,000	Slide gate
Cross reg. 2R	42+107	1- □ 1.50x1.50	Concrete	1975	240,000	Slide gate
Head reg. 1L-1R	13+200	1- □ 1.75x1.50	Concrete	1976	300,000	Slide gate
Tail reg. 2R	49+300	1- Ø 0.50x0.50	Concrete	1976	21,000	Slide gate
Cross reg. 2R-1L	29+200	1- Ø 0.10	Concrete	1976	79,000	Slide gate
Aqueduct	0+900	⊔ 1.50x2.50	Concrete	1977	2,541,100	-
Aqueduct	16+680	⊔ 3.20x1.50	Concrete	1977	2,541,100	Slide gate
Cross reg. 2R	8+720	2- □ 2.25x2.00	Concrete	1977	700,000	Slide gate
Cross reg. 1R	17+660	2- □ 2.00x2.00	Concrete	1978	400,000	Slide gate
Siphon	22+965	1- Ø 1.00	Concrete	1978	220,000	-
Siphon	36+502	1- Ø 1.00	Concrete	1979	154,000	Slide gate
Siphon	37+287	1- Ø 1.00	Concrete	1979	154,000	Slide gate
Siphon	39+857	1- Ø 1.00	Concrete	1979	154,000	Slide gate
Head reg. 1R-1L	0+400	2- Ø 1.00x1.00	Concrete	1980	250,000	Slide gate
Cross reg. 2R	30+730	2- □ 1.75x1.50	Concrete	1982	498,540	Slide gate
Flume	2+700	⊔ 3.10x1.80	Concrete	1988	7,250,000	Slide gate
Flume	16+880	⊔ 3.20x1.60	Concrete	1988	7,250,000	Slide gate
Aqueduct	2+750	⊔ 3.10x1.80	Concrete	1988	10,614,800	Slide gate
Head reg. 3R-1L	n.a.	2-Ø 0.60	Concrete	1988	177,300	Slide gate
Head reg. 4R-1L	17+000	2-Ø 0.10	Concrete	1988	168,300	Slide gate
Tail reg. 1L	25+000	2-Ø 0.60	Concrete	1988	143,100	Slide gate
Cross reg. 1R	6+500	1- ⊔ 6.00	Concrete	1989	3,154,830	Radial gate
Flume 2R	0+450	⊔ 2.20x2.10	Concrete	1993	2,391,000	Slide gate
Cross reg. 1L	6+040	1- ⊔ 4.00	Concrete	1993	6,741,000	Slide gate

Table B–3 Detail of Canals System of SCP (adapted from SCP, 1995)

Name	Length			Cost	Year of Finished
	Start	End	Total (km)	Baht	Construction
1R-1R	0+000	7+000	7.000	23,130	1938
2L-1R	0+000	9+000	9.000	37,620	1938
3L-1R	0+000	12+246	12.246	51,180	1938
1R-1L	0+000	7+500	7.500	106,460	1940
1L-1R	0+000	14+020	14.020	151,420	1941
2R	0+000	49+300	49.300	532,450	1941
1L-2R	0+000	5+020	5.020	54,220	1941
2R-1L	0+000	31+650	31.650	460,910	1941
1L-2R-1L	0+000	5+600	5.600	60,480	1941
2L-2R-1L	0+000	7+500	7.500	16,520	1941
3R-1L	0+000	6+200	6.200	90,470	1942
4R-1L	0+000	8+500	8.500	81,470	1942
1R	0+000	35+400	35.400	3,822,280	1944
1L	0+000	25+000	25.000	1,521,100	1944
Krasiew drainage - Suphan river	0+000	1+400	1.400	61,160	1952
Main drainage SAMCHUK 1	23+600	88+880	65.280	2,851,880	1952
Drainage 1L - SAMCHUK 1	0+000	12+210	12.210	533,420	1952
Drainage 2L - SAMCHUK 1	0+000	17+240	17.240	753,160	1952
Drainage 5L - SAMCHUK 1	12+351	15+048	2.679	117,820	1952
Main drainage SAMCHUK 2	13+420	39+430	26.010	1,136,300	1952
Drainage 2L Songpeenong	0+000	8+830	8.830	385,760	1952
Drainage 1L-2L Songpeenong	0+000	19+388	19.388	847,000	1952
Drainage 1L-1L-2L Songpeenong	0+000	3+260	3.260	142,420	1952
Main drainage Suphan 2 (M. Thamanow)	46+200	65+584	19.384	846,830	1952
Drainage 1R Suphan 3	0+000	41+930	41.930	1,831,790	1952
Drainage 1R-1R Suphan 3	0+000	8+100	8.100	353,860	1952
Drainage 2R Suphan 3	0+000	7+750	7.750	338,570	1952
Drainage 3R Suphan 3	0+000	5+764	5.764	251,810	1952
Drainage 1L-1R Suphan 3	0+000	5+048	5.048	220,530	1952
Drainage 2L-1R Suphan 3	0+000	9+000	9.000	393,180	1952