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Doctoral Thesis

THE IMPACT ASSESSMENT OF WATER RESOURCE MANAGEMENT ON FARMS IN THE PING WATERSHED, NORTHERN THAILAND

In partial fulfillment of the requirements for the Degree of Doctor of Philosophy

By

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The impact assessment of water resource management on farms in the Ping watershed, Northern Thailand

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STATEMENT

This Dissertation Thesis has been written only by using the literature listed at the bibliography. The reported results, unless explicitly stated otherwise, are original.

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Signature

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ABSTRACT

The irrational use of water in agriculture is often responsible for several problems concerning the depletion of water resources. Water resources sustainability has crucial for the existence of farming system which is dependent on the cropping pattern practices. Moreover, the water resources sustainability also the management needs to be consistent of Integrated Water Resources Management (IWRM). IWRM is a process that promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare. The paper has been researched and formulated in favour of creating scientific base for the further Water Policy Amendments and practical steps towards provision enough water for farmers in Northern Thailand regions. However, it also concerns the studies of existing water resource management and determines factors affecting decision making about water use and management within different farming systems. In these cases, a multi-criteria decision making model has been determined that aims at allocating efficient water and land resources to farms in the Ping watershed area by optimizing a set of important socio-economic objectives which depend on sustainable agricultural (rural) development. The solution was found by the using two analytical steps as follows: single objective optimization by linear programming (LP) and compromise the outcome from LP through the multi-criteria objectives by goal programming.

These resources include: land, labour, capital, fertilizer, pesticides and irrigation water. In irrigated areas with storage dam, existing cropping pattern included the in-season rice, the off season-rice, vegetables (chili, pak choi, cauliflower, long bean, and cabbage), soybean and sweet corn. Under the model cropping pattern conditions was produced the off-season rice, pak choi, cauliflower), soy bean, sweet corn, and cabbage which get the benefit increased four times.

However, in the case of the irrigated areas with dike dam the model showed that the suitable cropping pattern was different from the existing ones. Thus, the model cropping pattern as the suitable cropping pattern recommended the in-season rice, long bean, coriander, celery, and sugar cane. If the farmers plant follow the multi objectives model the benefit increased two times.

In the case of the rainfed areas, the model cropping pattern recommended to grow the in-season rice, long bean, marigold, maize, sweet corn, tobacco, galangal, lemon grass, banana and longan which the advised of cropping pattern from in the multi objectives model should plant long bean, marigold, sweet corn, tobacco, galangal, and banana which get the benefit increased four times.

Keywords: water resource management, multi-criteria decision making, cropping pattern, farming system

ABSTRAKT

Nesprávné využívání vody v zemědělství způsobuje mnoho problémů týkajících se čerpání vodních zdrojů. Udržitelnost vodních zdrojů má zásadní význam pro existenci zemědělských systémů založených na obdělávání půdy. Udržitelnost vodních zdrojů a jejich využívání musí být pojato jako integrované. IRWM - Integrované Řízení Vodních Zdrojů je proces, který podporuje koordinovaný rozvoj a hospodaření s vodou, půdou a souvisejícími přírodními zdroji s cílem maximalizovat hospodářský a sociální blahobyt. Výzkum provedený v této práci má za cíl vytvoření vědeckých základů pro Změny Vodní Politiky a formuluje praktické kroky směřující k zajištění dostatku vody pro zemědělce v severních oblastí Thajska. Dále se výzkum zabývá studiem stávajícího hospodaření s vodními zdroji a určuje faktory ovlivňující rozhodování o využití vody v rámci různých systémů hospodaření. Pro tyto případy byl vytvořen vícekriteriální rozhodovací model, který je zaměřen na efektivní alokaci vodních a půdních zdrojů farmám v oblasti povodí řeky Ping pomocí optimalizace řady důležitých sociálně-ekonomických cílů, které závisí na udržitelném rozvoji venkova. Řešení bylo nalezeno pomocí dvou analytických kroků následovně: pomocí linearního programování a poté byl nalezen kompromis pomocí cílového programovaní

Tyto zdroje zahrnují: půdu, práci, kapitál, hnojiva, pesticidy a vodu k zavlažování. V zavlažovaných oblastech s přehradami byla pěstována sezónní a mimosezónní rýže, zelenina (chilli, pak choi, květák, fazolové lusky a zelí), sója a cukrová kukuřice. Podle modelového vzoru je v osevním postupu zařazena mimosezónní rýže, pak choi, květák, sójové boby, cukrová kukuřice a zelí, čímž se čtyřnásobně zvýšuje zisk.

V případě zavlažované plochy vodou z přehrady model ukázal, že stávající osevní postup není správný. Doporučený osevní postup je následující: sezónní rýže, fazolové lusky, koriandr, celer a cukrová třtina. Zemědělcům, kteří využili multi objectives model (doporučený osevní postup), se dvojnásobně zvýšil zisk.

V případě oblastí závislých na srážkách model osevního popstupu doporučuje pěstovat sezónní rýži, fazolové lusky, měsíček lékařský, kukuřici na zrno, cukrovou kukuřici, tabák, galangal, citrónovou trávu, banán a longan, zatímco multi objectives model doporučuje pěstovat fazolové lusky, měsíček lékařský, cukrovou kukuřici, tabák, galangal a banán, Tento model zvýší zisk dokonce čtyřnásobně.

Klíčová slova: řízení vodních zdrojů, multikriteriální rozhodování, osevní postup, zemědělský systém

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1. Introduction

Thailand is inhabited by 65.47 million people in 2010 (NSO, 2011). The majority people live in rural according to Thai Statistical Office in 2011 is 73%, (presents with percentage of rural area) whereas in urban areas is 33.3% in 2008 (ADB, 2009). The economic structure of Thailand is composed of two major sector, i.e. agriculture sector (mostly in rural areas) and industrial sector (mostly in Bangkok, its vicinity, and industrial areas). Gross Domestic Product (GDP) 2010 of Thailand is 7.8% which agricultural sector is -2.2% but non agricultural sector is 8.8%. Compare with 2002 the total contribution of agricultural sector to GDP in 2010 has decreased 1.5% and non agricultural sector has increased 2.9% (NESDB, 2011). In the same period the major economic activity, predominantly contribute to GDP, industrial (54.38%) comprises of manufacturing (34.15%), with food, beverages, tobacco, textiles, construction materials, and machinery being the major products. The agricultural sector contributed 11.46% to the GDP based on largest contributors are paddy, rubber, maize, tapioca roots and sugar cane (NSO, 2011).

Thailand’s in past three decades of sustained and rapid economic development have stimulated a quantum expansion in the demand for water services for power, irrigation and domestic and industrial usage. The government has devoted significant resources to meet this demand, and an approach towards water resources management has emerged, with emphasis on the expansion of access to services-electricity, irrigation and water supply for domestic purpose. (Le Huu Ti and Facon T., 2001). Population pressure and economic growth lead to increase demands for water in all sectors (Kitchaichareon J., 2003). As for Thailand, demand for water is about 53 billion cubic meters annually. Out of the volume, almost 90 percent is allocated for agriculture, 6 percent for domestic, and the rest for industrial use (Sacha S. et al, 2000). Demand for water in the country is estimated about 70 billion cubic meters annually in the next 10 years (BOI, 2007).

At national level, the recent public concerns lie with a series of floods and droughts, costly irrigation investment, and competition and conflict over water resources. Since 1980, as more non-agricultural activities development in both upper and lower watershed areas, Northern Thailand witnessed the emergence of water conflict and shortage. Formally, irrigation management in all regions has been centralized for more than fifty years. In Northern Thailand, the state and Royal Irrigation Department (RID) has completed more than ten large and medium scale irrigation projects since 1950. These sought to increase commercial production in five major provinces, including the Ping Watershed areas (Tan-Kim-Yong U., 2001).

Water resource management includes both water governance and routine activities of water delivery services and uses for agriculture and non-agricultural production, and watershed conditions and hydrological services. For agricultural production and rice-growing countries, water resource management is mainly focus on key major water sectors in irrigation, watershed conservation, fishery, and pollution control (Tan-Kim-Yong U., 2001). Communal household water supply systems were often established with assistance from government organizations, while the management is under the control of the villages. The use and allocation of water is based on explicit rules and regulations, which ascertain the exclusive use of the source for household water and control the use in times of scarcity (Elstner P. et al, 2006). Natural water sources are mostly used by local communities. Water usage in this sector can be divided into two groups: 1) direct use of water for agriculture, animals and everyday life, usually according to locally developed systems of water management such as the community water management systems known as muang fai in Northern Thailand, and 2) indirect use such as a habitat for important resources such as fisheries. At the moment, there is no law that recognizes community rights to use water from natural sources (Chantawong M. et al, 2002).

Integrated Water Resources Management (IWRM) is a process which promotes the co-ordinate development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems (GWP, 2000). The definition of IWRM is through the trend which IWRM to a large extent covers the main problems related to water, development and sustainability. However, the principle of subsidiary needs to be lifted here to ensure that decisions are made by responsible and equally capable water user (SIWI, 2004). IWRM is one of the perfect tools that should be applied in order to minimize the problems related to water resources. The IWRM approach of which is adopted in Thailand should be further applied in the 25 river basins in the country. Moreover, the Royal Thai Government's policies on water resource management and the solutions for development or rehabilitation will be verified and presented into three main categories based on area functions which are the upper (forest area), middle (agricultural area and community), and lower (downstream included coastal area) River Basin (edms, 2007).

In the Ping watershed in northern Thailand, the catchment areas are 33,898 km^2, average runoff 7,965 (million m^3), storage capacity 14,107 (million m^3), irrigation area 310,868 ha. Water requirement includes domestic consumption 75.26 (million m^3), ecological balance 457.27 (million m^3), irrigation/agriculture 2,428.2 (million m^3) and hydropower 3,623 (million m^3) (Sacha S. et al, 2000). Water scarcity in agricultural sector is pushing farmers to adapt as best they can to a declining and fluctuating water supply. Several water management strategies at farm level are applied to prevent water shortage in their farms such as investment in pumping device and water storage and investment in water distribution technology at farm level. However, farmers are still blamed that they use water inefficiently because they do not have to pay for irrigation water and, thus, have little incentive to conserve water or to use it efficiently on high-value crops. As a result, irrigation efficiency is under 30% (TDRI, 1990).

The present thesis focus on the impact assessment of water resource management on farms in the ping watershed, Northern Thailand which has been researched and formulated in favour of creating scientific base for the further Water Policy Amendments and practical steps towards provision enough water for farmers in Northern Thailand regions. Their literature analysis has mainly focused on references of East-Asian authors who interest in management and safeguarding of water in this area which they want to enhance the policy in essential to sustain life, development, and environment. From the analysis of main references three hypotheses have been formulated as especially focusing on first hypothesis is water resource management plays an important role in sustainable agricultural development and its positive impact can especially be insured through suitable crop structure. The second hypothesis is the farmers’ water associations in upstream and downstream areas have important potential to improve water resource management which affects the efficiency of water use. The last hypothesis is a more efficient use of water resource based on a quantitative approach to farmers’ economy improves the farmers’ socio-economic situation.

The Thesis´ main objective states that and methodology encompasses as main methods by the multi-objective model will be used to determine factors affecting decision making about water use and management. These techniques are used widely to solve multi-objective and multi-resource decision making problems where conflicts exist among different objectives. As to the Thesis´ results the most important ones are expected to show a clear explanation about differentiation of water resource managements, the economic efficiency of water use, and factors affecting decision making about water use and management in Ping watershed, Northern Thailand.

In the final chapter the conclusions evaluate appropriateness of hypotheses and confirm them. Other conclusions have also been formulated on the basis of the reference analysis and the own research. The recommendations give suggestions on decision maker involved in agricultural systems under the sustainable condition and economic situation.

2. Literature Review and Theory

2.1 Physical environmental setting in Northern Thailand

Thailand has been divided into 25 river basins. The average annual rainfall countrywide is about 1,700 mm. The total volume of water from rainfall in all the river basins in Thailand is estimated at 800,000 million m^3, 75 percent of which or about 600,000 million m^3 is lost through evaporation, and infiltration; the remaining 25 percent or 200,000 million m^3 constitutes the runoff (Table 1) that flows in rivers and streams. (Sacha S. et al, 2000). As result of water scarcity, competition for water thus exists between regions, between different sectors, and between upstream and downstream users in catchments and river basins. The vision statement for Thailand is shown below (Figure 1).

Table 1 Thailand's surface water resources

Region	**Catchment area (km^2)**	**Average annual rainfall (mm/year)**	**Amount of rainfall (million m^3)**	**Amount of runoff (million m^3)**
Northern	169,640	1,280	217,140	65,140
Central	30,130	1,270	38,270	7,650
North-eastern	168,840	1,460	246,500	36,680
Eastern	34,280	2,140	73,360	22,000
Western	39,840	1,520	60,560	18,170
Southern	70,140	2,340	164,130	49,240
Total	512,870	-	799,960	198,880

Source: Le Huu Ti and Thierry Facon, 2001

"By the year 2025, Thailand will have sufficient water of good quality for all users through efficient management and an organizational and legal system that will ensure equitable and sustainable use of water resources, with due consideration for the quality of life and the participation of all stakeholders." (Le Huu Ti and Facon T. 2001).

Conceptual framework used to guide the meeting is shown in the diagram below.

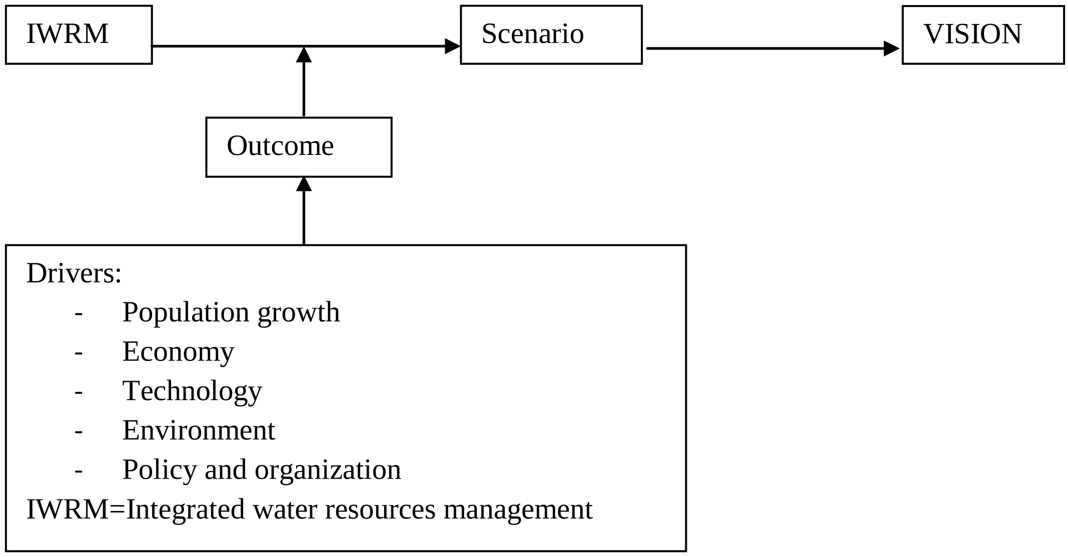

Figure 1 Conceptual framework

Source: Le Huu Ti and Thierry Facon, 2001

For more than fifty years of water vision for agriculture and rural development, many irrigated agricultural development projects have been implemented in parallel with the development of irrigation. However, irrigation intensity is still low. Compared with the 132 million rai of total farmland, only 30 million rai are under irrigation (Le Huu Ti and Facon T., 2001). Historically, most of large-scale water resources development projects in the country were constructed from the 1950s to the 1970s and the areas served under the projects were only on fifth of the total cultivated area. A large number of farms still do not enjoy the benefits of irrigation water. The government therefore started a small-scale development program in the 1980s with the aims of improving the living conditions of the people in poor rural areas and of reducing income disparity, and water resources development was part of the program. In conclusion, water resources development for agriculture and rural development should be considered of strategic importance, first for economic growth, by efficiently using the existing irrigated area and developing new areas wherever possible, and second for rural development in rainfed agricultural areas, by promoting more small-scale projects and appropriate technology such as rainwater harvesting.

At national level, the recent public concerns lie with a series of floods and droughts, costly irrigation investment, and competition and conflict over water resources. Since

1980, as more non-agricultural activities development in both upper and lower watershed areas, Northern Thailand witnessed the emergence of water conflict and shortage. Formally, irrigation management in all regions has been centralized for more than fifty years. In Northern Thailand, the state and Royal Irrigation Department (RID) has completed more than ten large and medium scale irrigation projects since 1950. These sought to increase commercial production in five major provinces, including the Ping Watershed areas (Tan-Kim-Yong U., 2001). In the Ping watershed in northern Thailand (Table 2), the catchment areas are 33,898 km^2, average runoff 7,965 (million m^3), storage capacity 14,107 (million m^3), irrigation area 310,868 ha. Water requirement includes domestic consumption 75.26 (million m^3), ecological balance 457.27 (million m^3), and irrigation/agriculture 2,428.2 (million m^3) (Sacha S. et al, 2000).

Table 2 Description of water provision and water demand in the north of Thailand

Name of river basin		**Ping**	**Wang**	**Yom**	**Nan**
Catchment area		33,898	10,791	23,616	34,330
Average runoff (10^6 m^3)		7,965	1,104	3,117	9,158
Storage capacity (10^6 m^3)		14,107	197	98	9,619
Irrigation area (*rai*)		1,942,927	472,350	994,205	1,780,637
Water requirement (10^6 m^3/year)	Domestic consumption	75.26	20.21	53.87	66.29
	Tourism industry	1.00	1.00	0.08	0.32
	Ecological balance	457.27	48.00	315.36	315.36
	Irrigation/Agriculture	2,428.20	487.42	859.13	2,870.80
	Hydropower	3,623.00	45.00	-	2,583.00

Source: Le Huu Ti and Thierry Facon, 2001

Note: 1 hectare = 6.25 rai

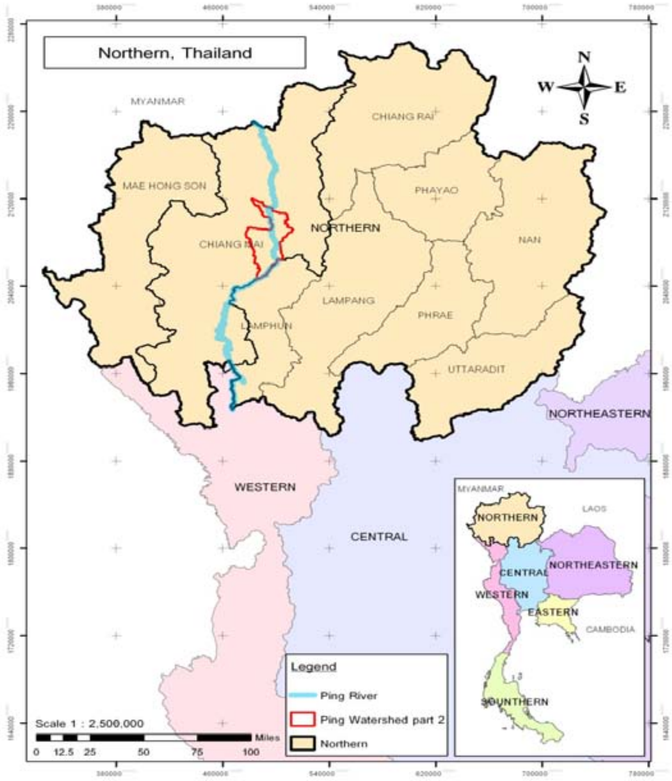

Figure 2 Ping Watershed Part2 in Northern Thailand

Source: Regional Irrigation Office 1

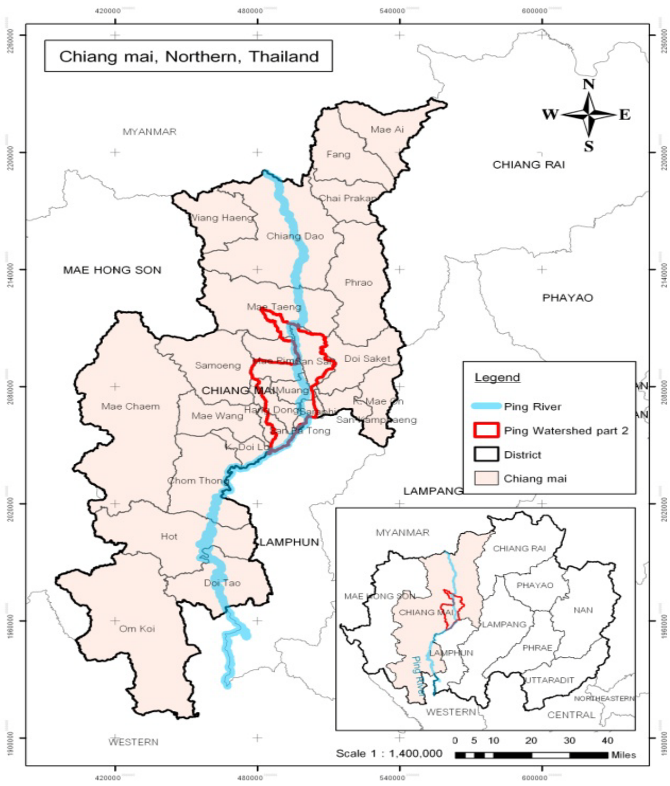

Figure 3 Ping Watershed Part2 in Chiang Mai Province, Northern Thailand

Source: Regional Irrigation Office 1

2.2 Water Management Principles

A meeting in Dublin in 1992 (The International Conference on Water and Environment (ICWE), Dublin, Ireland, January, 1992) gave rise to four principles that have been the basis for much of the subsequent water sector reform (Cap-Net, 2005). At ICWE over 500 participants representing 100 countries and 80 international and non-governmental organizations, the following principles were recommended to guide global water management and development efforts (Mei Xei, 2006).

Principle 1. "Ecological". Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.

The notion that fresh water is a finite resource arises as the hydrological cycle on average yields a fixed quantity of water per time period. This overall quantity cannot yet be altered significantly by human actions, though it can be, and frequently is, depleted by man-made pollution. The freshwater resource is a natural asset that needs to be maintained to ensure that the desired services it provides are sustained. This principle recognizes that water is required for many different purpose, functions and services; management therefore, has to be holistic (integrated) and involve consideration of the demands placed on the resource and the threats to it.

The integrated approach to management of water resources necessitates co-ordination of the range of human activities which create the demands for water, determine land uses and generate waterborne waste products. The principle also recognizes the catchment area or river basin as the logical unit for water resources management.

Principle 2. "Institutional". Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels.

Water is a subject in which everyone is a stakeholder. Real participation only takes place when stakeholders are part of the decision-making process. The type of participation will depend upon the spatial scale relevant to particular water management and investment decisions. It will be affected too by the nature of the political environment in which such decisions take place. A participatory approach is the best means for achieving long-lasting consensus and common agreement. Participation is about taking responsibility, recognizing the effect of sectoral actions on other water users and aquatic ecosystems and accepting the need for change to improve the efficiency of water use and allow the sustainable development of the resource. Participation does not always achieve consensus, arbitration processes or other conflict resolution mechanisms also need to be put in place.

Governments have to help create the opportunity and capacity to participate, particularly among women and other marginalized social groups. It has to be recognized that simply creating participatory opportunities will do nothing for currently disadvantaged groups unless their capacity to participate is enhanced. Decentralising decision making to the lowest appropriate level is one strategy for increasing participation.

Principle 3. "Gender". Women play a central part in the provision, management and safeguarding of water.

The pivotal role of women as provides and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources. It is widely acknowledge that women play a key role in the collection and safeguarding of water for domestic and - in many cases - agricultural use, but that they have a much less influential role than men in management, problem analysis and the decision-making processes related to water resources.

IWRM requires gender awareness. In developing the full and effective participation of women at all levels of decision-making, consideration has to be given to the way different societies assign particular social, economic and cultural roles to men and women. There is an important synergy between gender equity and sustainable water management. Involving men and women in influential roles at all levels of water management can speed up the achievement of sustainability; and managing water in an integrated and sustainable way contributes significantly to gender equity by improving the access of women and men to water and water-related services to meet their essential needs.

Principle 4. "Economic". Water has an economic value in all its competing uses and should be recognized as an economic good as well as a social good.

Within this principle, it is vital to recognize first the basic of all human beings to have access to clean water and sanitation at an affordable price. Managing water as an economic good is an important way of achieving social objectives such as efficient and equitable use, and of encouraging conservation and protection of water resources. Water has a value as an economic good as well as a social good. Many past failures in water resources management are attributable to the fact that the full value of water has not been recognized.

Value and charges are two different things and we have to distinguish clearly between them. The value of water in alternative uses is important for the rational allocation of water as a scare resource, whether by regulatory or economic means. Charging (or not charging) for water is applying an economic instrument to support disadvantaged groups, affect behavior towards conservation and efficient water usage, provide incentives for demand management, ensure cost recovery and signal consumers' willingness to pay for additional investments in water services. Treating water as an economic good is an important means for decision making on the allocation of water between different water use sectors and between different uses within a sector.

2.3 Impacts and benefits of water resource

Impacts: Most uses of water bring benefits to society but most also have negative impacts which may be made worse by poor management practices, lack of regulation or lack of motivation due to the water governance regimes in place (Cap-Net, 2005).

Table 3 Impacts of the water use sectors on water resources

	Positive impacts	Negative impacts
Environment	• Purification • Storage • Hydrological cycle	
Agriculture	• Return flows • Increased infiltration • Decreased erosion • Groundwater recharge • Nutrient recycling	• Depletion • Pollution • Salinisation • Water logging • Erosion
Water supply & sanitation	• Nutrient recycling	• High level of water security required • Surface and groundwater pollution

Source: Cap-Net, 2005

Benefits

Environment benefits

The ecosystem approach provides a new framework for IWRM that focuses more attention on a system approach to water management: protecting upper catchments (e.g. reforestation, good land husbandry, soil erosion control), pollution control (e.g. point source reduction, non-point source incentives, groundwater protection) and environmental flows. It provides an alternative to a sub-sector competition perspective that can join stakeholders in developing a shared view and joint action (Cap-Net, 2005).

Agriculture benefits

As the single largest user of water and the major non-point source polluter of surface and groundwater resources, agriculture has a poor image. Taken alongside the low value added I agricultural production, this frequently means that, especially under conditions of water scarcity, water is diverted from agriculture to other water uses. However, indiscriminate reduction in water allocation for agriculture may have far-reaching economic and social consequences. With IWRM, planners are encouraged to look beyond the sector economics and take account of the implications of water management decisions on employment, the environment and social equity. By bringing all sectors and all stakeholders into the decision-making process, IWRM is able to reflect the combined "value" of water to society as a whole in difficult decisions on water allocations. This may mean that the contribution of food production to health, poverty reduction and gender equity, for example. Could over-ride strict economic comparisons of rates of return on each cubic metre of water. Equally, IWRM can bring into the equation the reuse potential of agricultural return flows for other sectors and the scope for agricultural reuse of municipal and industrial wastewaters (Cap-Net, 2005).

Water supply and sanitation benefits

Above all, property applied IWRM would lead to the water security of the world's poor and unserved being assured. The implementation of IWRM based policies should mean increased security of domestic water supplies, as well as reduced costs of treatment as pollution is tackled more effectively. Recognizing the rights of people, and particularly women and the poor, to a fair share of water resources for both domestic and household-based productive uses, leads inevitably to the need to ensure proper representation of these groups on the bodies that make water resource allocation decisions The focus on integrated management and efficient use should be a stimulus to the sector to push for recycling, reuse and waste reduction. High pollution charges backed by rigid enforcement have led to impressive improvements in industrial water-use efficiencies in the industrialized countries, with benefits for domestic water supplies and the environment (Cap-Net, 2005).

2.4 Integrated Water Resource Management (IWRM)

2.4.1 Definition of Integrated Water Resource Management (IWRM)

There is growing awareness that comprehensive water resources management is needed, because (B.Gumbo and P. van der Zaag, 2001):

- fresh water resources are limited;
- those limited fresh water resources are becoming more and more polluted, rendering them unfit for human consumption and also unfit to sustain the ecosystem;
- those limited fresh water resources have to be divided amongst the competing needs and demands in a society;
- many citizens do not as yet have access to sufficient and safe fresh water resources;
- techniques used to control water (such as dams and dikes) may often have undesirable consequences on the environment;
- there is an intimate relationship between groundwater and surface water, between coastal water and fresh water, etc. Regulating one system and not the others may not achieve the desired results.

Hence, engineering, economic, social, ecological and legal aspects need to be considered, as well as quantitative and qualitative aspects, and supply and demand. Moreover, also the “management cycle” needs to be consistent.

Integrated water resource management (IWRM) is a process that promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare without compromising the sustainability of ecosystems and the environment (GWP, 2010).

The word integration thus often has very different connotations and interpretations depending on the author(s) concerned. Depending upon the author(s), integrated water resource management means integration of (Biswas K. A., 2004):

- objectives that are not mutually exclusive (economic efficiency, regional income redistribution, environmental quality, and social welfare);
- water supply and water demand;
- surface water and groundwater;
- water quantity and water quality;
- water and land related issues;

- different types of water uses: domestic, industrial, agricultural, navigational, recreational, environmental, and hydropower generation;
- rivers, aquifers, estuaries, and coastal waters;
- water, environment, and ecosystems;
- water supply and wastewater collection, treatment, and disposal;
- macro, meso and micro water projects and programs;
- urban and rural water issues;
- water-related institutions at national, regional, municipal, and local levels;
- public and private sectors;
- government and NGOs;
- timing of water release from the reservoirs to meet domestic, industrial, agricultural, navigational, environmental, and hydropower generation needs;
- all legal and regulatory frameworks relating to water, not only directly from the water sector, but also from other sectors that have implications on the water sector;
- all economic instruments that can be used for water management;
- upstream and downstream issues and interests;
- interests of all different stakeholders;
- national, regional, and international issues;
- water projects, programs and policies;
- policies of all different sectors that have implications for water, both in terms of quantity and quality, and also direct and indirect (sectors include agriculture, industry, energy, transportation, health. Environment, education, gender, etc.);
- intra-state, interstate, and international rivers;
- bottom-up and top-down approaches;
- centralization and decentralization;
- national, state, and municipal water policies;
- national and international water policies;
- timing of water release for municipal, hydropower, agricultural, navigational, recreational, and environmental water uses;
- climatic, physical, biological, human, and environmental impacts;
- all social groups, rich and poor;

- beneficiaries of the projects and those who pay the costs;
- present and future generations;
- all gender-related issues;
- present and future technologies; and
- water development and regional development.

The above list, which is by no means comprehensive, identifies 35 sets of issues that different authors consider to be the issues that should be integrated under the aegis of integrated water resources management. Even at a conceptual level, all these 35 sets of issues that the proponents would like to be integrated, simply cannot be achieved.

The definition emphasizes that Integrated Water Resources Management (IWRM) is a process. Thus, IWRM is not a goal in itself. It is a means to an end, or rather it is the process of balancing and making trade-offs between different goals in an informed way. The most basic social, economic and environmental goals are implicit in the definition (Jonch-Clausen T. and Fugl J., 2001):

- economic efficiency in water use: because of the increasing scarcity of water and financial resources, the finite and vulnerable nature of water as a resource and the increasing demands upon it, water must be used with the maximum possible economic efficiency in order to ensure social welfare and contribute to the elimination of poverty;

- social equity: the basic right for all people to have access to water of adequate quantity and quality for the sustenance of human well-being must be universally recognized;

- environmental and ecological sustainability: the present use of the resource should be managed in a way that sustains the vital life-support systems, thereby not compromising use by future generations of the same resource.

The specific details of these goals will have to be balanced through political negotiations in the IWRM process. Finally, the definition emphasizes that IWRM is about co-ordination. It is the “integrating handle” that can lead us from fragmented subsectoral to holistic cross-sectoral water management.

The Integrated Water Resources Management (IWRM) is one of the perfect tools that should be applied in order to minimize the problems related to water resources (edms, 2007). The application of IWRM involves a seven-step cycle that is illustrated (Figure 4) which the following seven stages can be identified (NeWAter, 2005):

1) Establish status. The starting point of the IWRM process is the critical water resources issue seen in the national context. Progress towards a management framework is charted within issues can be addressed and agreed, and overall goals achieved.

2) Build commitment to reform. Political will is a prerequisite and building or consolidating a multistakeholder dialogue comes high on the list of priority actions. Dialogue needs to be based on knowledge about the subject matter and raising awareness is one of the tools to establish this knowledge and participation of the broader population.

3) Analyse gaps. Given the present policy and legislation, the institutional situation, the capabilities and the overall goals, gaps in the IWRM framework can be analysed in the light of the management functions required by critical issues.

4) Prepare strategy and action plan. The strategy and action plan will map the road towards completion of the framework for water resources management and development and related infrastructural measures. A portfolio of actions will be among the outputs, which will be set in the perspective of other national and international planning processes.

5) Build commitment to action. Adoption of the action plan at the highest political levels is the key to any progress and full stakeholder acceptance is essential for implementation. Committing finance is another prerequisite for the transfer of planned actions into implementation on the ground.

6) Implement framework. Realizing plans poses huge challenges. The enabling environment, the institutional roles and the management instruments have to be implemented. Changes have to be made in present structures and the building of capacity and capability, taking into account infrastructure development, need to take place.

7) Monitor and evaluate progress. Progress monitoring and evaluation of process inputs and outcomes serve to adjust the course of action and motivate those driving the processes. Choosing proper descriptive indicators is essential to the monitoring value.

By 2008 UN-Water reported that a total of at least 58 countries around the world had adopted IWRM and were in the process of implementation. However, it is widely recognized that implementing IWRM is invariably a long-term process involving many challenged. In practice, this means giving water an appropriate place on the national agenda; crating greater “water awareness” among decision makers responsible for economic policy and policy in water related sectors; and encouraging people to think “outside the box” of traditional sectoral definitions (Mysiak J. et al, 2010).

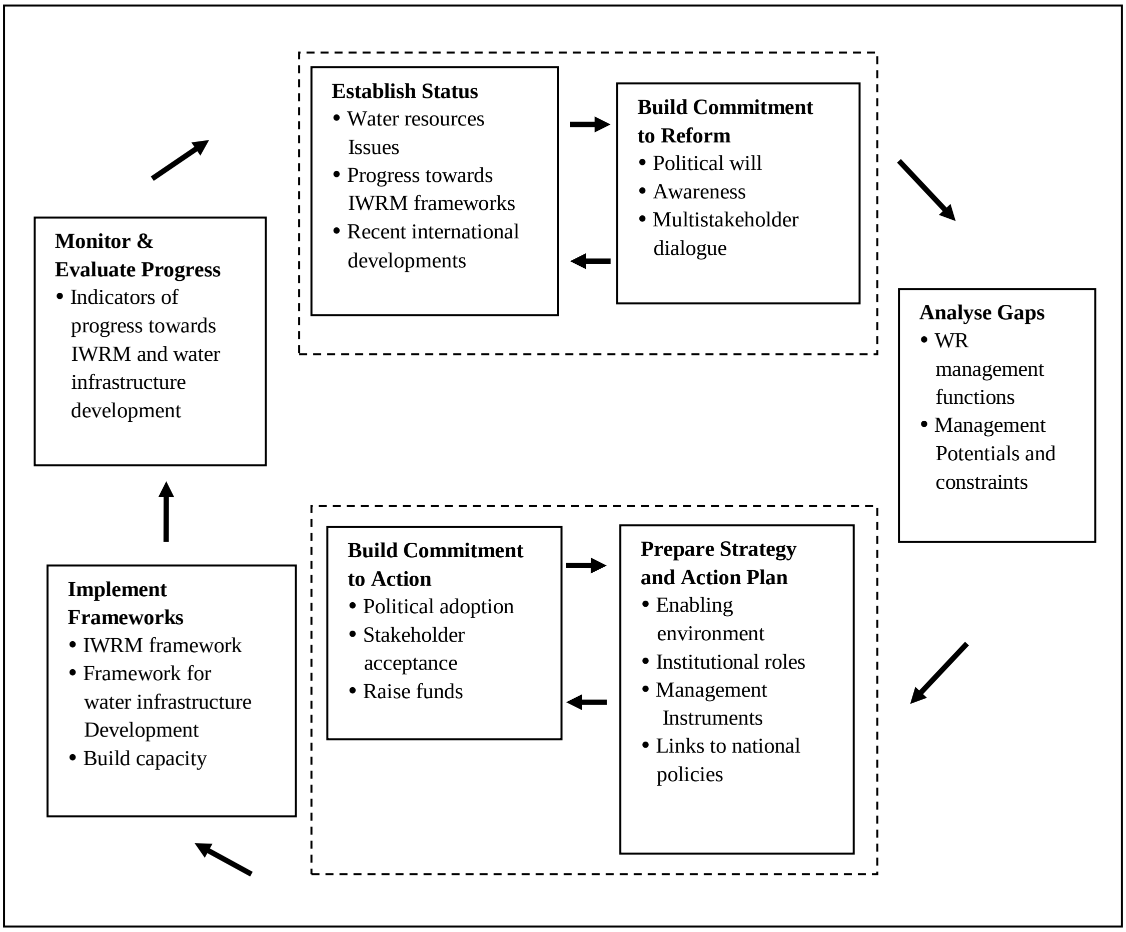

Figure 4 The Integrated Water Resources Management Cycle

Source: NeWater, 2005

2.4.2 IWRM tools

The Global Water Partnership has created an IWRM toolbox designed to support the development and application of IWRM approaches. Consequently, GWP's toolbox aims to provide IWRM practitioners with a wide range of tolls and instruments that they can select and apply according to their needs. The tools fail into three main categories: (a) Enabling Environment, (b) Institutional Roles, and (c) Management Instruments (Mei Xei, 2006).

(a). Enabling Environment. This category consists of three sub-categories. ***Policies*** to set goals for water use, protection and conservation. Policy development is important for setting national objectives for managing water resources and delivering water services. Policies should embody the IWRM concepts of integration, decentralization, participation, and sustainability, taking a holistic view of water's value and considering potential users of water, land uses and water quality. ***Legislative framework to translate*** water policy into law. This covers ownership of water, permit and rights to use water, and the legal status of water user groups. ***Financing/incentives to allocate*** financial resources to meet water needs. Financing and incentive structures are needed to fund capital-intensive water projects, support water service delivery, and provide other public goods such as flood control and drought preparedness. They can be resources from the public sector, private finance, and joint public-private partnership.

(b). Institutional Roles. This category consists of two sub-categories: ***Creating an organizational framework.*** Tools focus on developing the institutions needed to manage water resources within an IWRM framework, shifting from top-down, centralized management to decentralized and participatory management. Such institutions include river and lake basin organizations, regulatory bodies, enforcement agencies, coordinating apex bodies of user associations, and public and private service providers. These organizations need to be given clear rights and responsibilities, and allow integration between them. The accountability of these water management organizations must be ensured, with attention given to gender issues. ***Building Institutional Capacity.*** Developing human resources is an integral part of developing effective water institutions at all levels, as regulatory bodies, civil society organizations, service providers, and central and local government officials will all need to be educated in IWRM principles and trained in the skills and tools of effective water management. Capacity-building should focus particularly on strengthening the ability of women and other disenfranchised groups to participate in water management.

(c). Management Instrument. Once the proper enabling environment and institutions are in place, these instruments address management problems. This category consists of eight sub-categories:

Water Resources Assessment to understand resources and needs, involving data collection and analysis in order to inform decision-making with a comprehensive view of water resources and water users.

Plan for IWRM to combine development options, to assess impact of resource use and human interaction. They can be national, regional, sectoral and basin plans.

Efficiency in Water Use to manage demand and supply, to improve supply efficiency, increase water reuse. Subsidies and regulation to encourage technology improvements, price signals, improved metering, and public awareness campaigns to change user behavior are all instruments that can be used to improve efficiencies.

Social inclusion to promote general public awareness, stakeholder participation, and transparency of institutions, in order to better enable the public to take a participatory role in IWRM.

Conflict Resolution to manage disputes and ensuring sharing of water benefits.

Regulatory and economic instruments to allocate water, set water use limits, use prices for efficiency and equity. Regulatory tools include emission standard, technology standard, and price controls, while economic tools include pollution charges, targeted subsidies, and markets for water use rights or pollution permits.

Information Management and Exchange to share knowledge for better water management.

2.4.3 IWRM is adopted in Thailand

The IWRM approach of which is adopted in Thailand had the plan aims to (edms, 2007):

a) Prepare an inventory of all water bodies to support the National Water Information Center

b) Modernize river basin development plan and water allocation plan

c) Prepare river basin management plan covering decision support system, flood forecasting and warning system, etc.

d) Implement aquifer storage recovery system in critical areas

e) Implement conjunctive use of surface and groundwater resources in potential areas

2.5 National water policy in Thailand

The national water vision in 2000, policy and other corresponding details were endorsed by the cabinet. The national water policy can be cited as follows (WWAP, 2006):

1) Accelerate the promulgation of the Draft Water Act to be the framework for national water management by reviewing the draft and implementing all necessary steps to have the act effective, including reviewing existing laws and regulations.

2) Create water management organizations both at national and river basin levels with supportive laws. The national organization is responsible for formulating national policies, monitoring and coordinating activities to fulfill the set policies. The river basin organizations are responsible for preparing water management plans through a participatory approach.

3) Emphasize suitable and equitable water allocation for all water use sectors, and fulfill basic water requirements in agriculture and domestic uses. This will be accomplished by establishing efficient and sustainable individual river basin water use priorities under clear water allocation criteria, incorporating beneficiaries' cost sharing based on ability to pay and level services.

4) Formulate clear directions for raw water provision and development compatible with the basins' potentials and demands, and demands, and ensuring suitable quality while conserving the natural resources and maintaining the environment.

5) Provide and develop raw water resources for farmers extensively and equitably in response to water demand for sustainable agricultural and domestic uses, similar to deliveries of other government basic infrastructure services.

6) Include water related topics at all levels of educational curriculum so as to create awareness for water value, understanding the importance of efficient water utilization, necessity and responsibility in maintaining natural and man made water sources.

7) Promote and support participation, including clear identification of its procedures, clear guidelines on right and responsibility of the public, non-government and government organizations in efficient water management. The water management includes water utilization, water source conservation, monitoring and preservation of water quality.

8) Accelerate preparation of plans for flood and drought protections, including warning, damage control and rehabilitation efficiently and equitably with proper utilization of land and other natural resources.

9) Provide sufficient and sustainable financial support for action programs in line with the national policy, including water related research public relations, information collection and technology transfer to public.

At present, the national water policy is under the process of reviewing and assessing.

Public policy on water rights is a case study on the upper ping river basin. This research is an alternative policy for government to manage water resource problems focus on conflicting of water accessibility. Bottom-up approach is the government's major policy to desire, satisfy stakeholders and participative management should be applied. Quantitative analysis reveals the main factor of this achievement which is to determine the top priority for water consumption and agriculture. Qualitative analysis can determine the strategies of the policy implementation which overspread thoroughly to organization development, qualitative service, efficient operation and successful mission. The above strategies involve strength of public, equity also rules and priority determination of water rights. This research is in accordance with The National Research Council of Thailand (NRCT) and Royal Irrigation Department (RID)'s strategies in promoting health quality, extending the water management to be effective, equitable and enduring also an integration of improving and participative developing process and all level management (Prommolmard S., 2008).

The Ninth National Plan (2002-2006)

In the Ninth National Plan, priority on water resources management is given to the following issues (edms, 2007):

- Shifting from the supply-side approach to the demand-side strategy. In Thailand, the supply-side approach has dominated the development and management of water resources for more than three decades. With new water-related problems arising, serious consideration should be given to the demand-side approach. Instead of focusing on investment for additional water supplies, the demand management option will concentrate on the organisational and institutional aspects in order to reduce costs while promoting sustainability and environmental conservation.

- A comprehensive overall basin water management strategy will be substituted to the project-by-project approach. This strategy will be formulated by integrating institutional, policy, legal and technical measures, and will seek to provide guidance for the systematic development, management and protection of a basin's water resources in order to meet the increasing demands of socio-economic and population growth in the basin area.
- Water should be recognised as a tradable commodity, since it has an economic value in all its competing uses. Therefore, incentives, regulations, permit restrictions, and penalties that will help guide and convince the people to use water efficiently and equitably will be established. Meanwhile, innovations in water-saving technology will also be encouraged.
- Economic instruments should be considered for the alleviation of protracted water crises. The regulations supporting these economic instruments should be clear and acceptable to all groups of water users. Effective and realistic cost-recovery mechanisms should be adopted and implemented. This would require considerable public awareness and education. Whether full cost recovery or recovery of operational cost is pursued should depend on water usage and local conditions.
- The government will try to set up the institutional framework of water administration with users' participation by transforming its strategy and operating style in order to give the opportunity to stakeholders, especially local people, to participate in water resources management, such as announcing to the public all the projects that affect people living in a given area and allowing representatives from the operating area to participate in the decisions that affect them.
- The private sector should be encouraged to play a more important role in water resources management, especially concerning wastewater in urban areas.

The Tenth National Plan (2007-2011)

In the Tenth National Plan, priority on environment and natural resources management is restore a sound environment with more balance between economic development and environmental sustainability. It is given to the following issues (UNPAF, 2006):

- Community organizations and civil society are more effectively engaged in natural resources and environmental management and actively involved in policy and decision making process.
- Effective and efficient implementation of major Multilateral Environmental Agreements (MEAs) and strengthened sustainable use of natural resources and management of biodiversity, renewable energy, water, urban and industrial pollution, and disaster risk reduction.
- Community learning and advocacy of pro-poor policies on sustainable use and management of natural resources and environment taking place on a continuous basis.

The beginning of national water policy (1961-1981) focused to invest the large and medium scale irrigation project to increasing irrigation area. The middle of national water policy (1982-2001) invested in the small scale irrigation project to rural area and the present water policy (2002-2011) had a new conceptual approach towards integrated water resource management in Thailand.

Features of the Thai agriculture

In Thailand agriculture's relative decline has been pronounced for several decades. Since the late 1980s, however, the data suggest a dramatic acceleration in the rate of decline, accompanied by an absolute reduction in agricultural employment. About five years ago a group of leading Thai economists wrote that "the current prognosis is for the labor force in agriculture to decline absolutely sometime in the 1990s". By the time this statement was published, the absolute size of the Thai agricultural labor force was already shrinking, and had been so since 1989. The fact of this decline in a rapidly growing economy should not be surprising, but the speed at which the labor force growth trended negative, and the magnitude of its subsequent decline, are remarkable. While some part of this trend may reflect improved data collection methods, the substantive economic causes are intuitively easy to grasp: tremendous aggregate investment growth, bidding up wages in all sectors and stimulating accelerated mechanization as a substitute for labor in agriculture (Coxhead I., Plangpraghan J., 1998).

The perception of water as an open access resources is widespread among policy makers, the existence of diverse forms of control, ownership and use rights of water resources being widely ignored. It is believed that water is overused as a consequence of the inability of local communities to establish viable regulations that would guarantee a more sustainable use of water resources. This perception is often used as an argument for enhanced state control of the management of water resources. Many NGOs, on the other hand, claim that local communities share common values about water rights and management, that communal management guarantees equal access to water resources and that all community members act according to locally established rules of water management. Communities-based institutions have a potential for enhancing sustainable water management in northern Thai watershed if the social cohesion within local communities remains intact and elected local authorities can be held accountable for their actions. In cases, however, where local elites or outside investors have undermined the capacity of those institutions, external interventions are justified. In the past, many of these interventions have faced difficulties in enhancing more equitable access to water and increasing efficiency of water management due to lack of coordination, transparency, and participation of local stakeholder (Neef A. et al., 2004).

The diversification in terms of land use pattern and the composition of gross value of agricultural production is lower in the former than in the latter region. Considerable differences are observed among different production environments within each region. The extent of diversification is higher in irrigated and rain-fed areas in contrast to the flood-prone areas in the central plain. Whereas in the northeast, the rain-fed village has experienced higher level of diversification than the irrigated and drought-prone areas. The lack of access to land and irrigation facilities are major constraints for the northeast both for the cultivation of modern rice and higher cropping intensity. The immediate impact of irrigation is, therefore, increased rice intensification. In the poorer region, the concern for food security explains the dominance of rice, and even diversification is attempted to maintain income stability and to meet subsistence needs. The differences in the nature of farming (commercial versus subsistence) are reflected in the constraints to diversification as perceived by farmers. The main constraints perceived by the northeast farmers are the lack of access to production factors whereas in central farmers face marketing problem. The differences in the ability to diversify in the two regions are reflected in the growing inequality between regions while inequality has declined in the more prosperous regions (Ahmad A., Isvilanonda S., 2003).

The poverty reduction in Thailand occurs among both farm and non-farm households and this qualitative outcome is not dependent on the particular poverty line used in the analysis. The reduction in farm and non-farm poverty incidence occurs despite some increase in inequality within Thailand. Liberalization raises real skilled wages relative to real unskilled wages and this effect increases inequality. Both Thailand's own liberalization and that of the rest of the world reduce poverty among farm and non-farm households, but the largest benefits from across-the-board liberalization, measured in terms of effects on poverty, arise from Thailand's own liberalization. If the trade liberalization is confined to just agricultural products, the results are somewhat different. A similar increase in inequality occurs, but unilateral agricultural liberalization in Thailand raised poverty incidence among farm households while reducing it slightly among non-farm households. This negative effect on rural households arises from a reduction in real unskilled wages. When the rest of the world also liberalizes agricultural trade, this increase in farm level poverty in Thailand disappears. Thailand's farm poor thus have an interest in agricultural liberalization, provided the rest of the world also liberalizes, but not otherwise (Warr P., 2009).

A major structural rigidity is found in the imbalance between the rapid structural change of national income and the slow structural change of employment. The increasing income inequality between the 50 percent of the population who depend on agriculture and the 50 percent who do not, heightens the importance of rural natural resources during the transitional stage. Educational reforms, land titling, access to capital markets, improved agricultural productivity, and increased nonagricultural employment are the key policy reforms necessary for restoring the balance between a still-growing resource-dependent population, rising income expectations, and a limited and partially-degraded natural resource base (Theodore P., Dhira P., 1991).

Agricultural land resources

Land is a limiting resource in Thailand as in many of the third world countries. With time, the situation will worsen due to soil degradation which reduces the performance of the soil. Exponential growth of urban centers consumes large areas of prime land as the centers originally developed on lands that had potential to feed the community. Those countries which have opted to adopt large-scale irrigation programs to compliment their food producing capacity are generally at risk due to salinization and or alkalization which slowly but surely accompanies irrigation in arid and semiarid environments (P. Moncharoen, T. Vearasilp and H. Eswaran, 2001). It has been argued that, in principle, the land reform program must be designed to change a deficient agrarian structure with the main purpose of raising productivity and improving the distribution of land and income. From the start in 1975, land reform in Thailand had predominantly dealt with improving land rights of farmers occupying reserved forestland. This is necessary to improve access to lands as well as to strengthen land ownership security of those farmers. This has to continue as is currently being pursed. However, other issues, especially tenancy in private lands, and landlessness especially among farm workers, should get a higher priority than before. Over the long period of land reform, these problems have not been solved and appear to remain the same or even get worse. As is generally found, poverty and food insecurity is particularly prevalent among the landless rural people. Improving access to land by means of land reform will certainly help alleviate rural poverty and increase food production (Neef A., Onchan T., and R. Schwarzmeier, 2003).

According to an official publication of the Thai Ministry of Agriculture and Co-operatives, the rapid increase in agricultural production and arable land has resulted in soil loss of approximately 120 tons of soil per hectare annually from most severely affected cultivated, deforested upland areas. This erosion has caused heavy siltation in water reservoirs and sedimentation along rivers. Significant quantities of soil and plant nutrients are leached by water run-off, estimated in a total nutrient loss of 27.4 million tons per year. The Land Development Department estimates that 19.4 million hectares of soil are prone to salinization, while saline soils already cover some 0.56 million hectares, and acid sulfate soils 0.14 million hectares. The report does not even include the further problem of water shortage or the pollution of waterways form overuse of agrochemicals and contamination of irrigation water by shrimp farming (Buch-Hansen M. et al., 2006).

The paper describes a GIS-based system, Econsuit that supports dynamic assessment of economic land suitability for major economic crops in Northern Thailand. Prior to economic land evaluation, a physical land suitability index in computed using a fuzzy set approach in GIS. The procedure bypasses crop modeling and permits suitability to be defined in a continuous scale with a graphic interface enabling a user to dynamically assign diagnostic factors and weights for physical land evaluation. Economic land evaluation is accomplished by assigning field survey data to land mapping units using spatial interpolation. Expected yields in the Econsuit were obtained by multiplying the optimum yield with proportional yield factors. The optimum yield is not a biological maximum but rather a realistically maximum attainable yield recorded in field survey results in the study areas assuming normal management conditions and no removable limitations. The physical suitability index which directly affected crop yields was used as a proportional yield factor. Estimated yield for a given LUT for each LMU was then calculated. Expected total revenues were estimated by multiplying expected yields by a given output price (C. Samranpong et al., 2009).

Agriculture policies in Thailand

In Thailand, rice cultivation is not just food production but a part of the Thai culture. Rice farming is passed on from one generation to the next. Farmers rely on their rice production for household consumption and sell any excess. Even if there were technically viable substitutes available for rice, Thai farmers do not have sufficient knowledge or training to allow them to quickly adjust the composition of crops planted in response to relative price changes. Also, few purchased inputs are used in the Thai rice production. Thus, from Thai farmers' perspective, there are virtually no substitutes for rice and few variable inputs other than family labor (Sachchamarga K. and Williams W. G., 2004).

The overall objectives of Thailand rice policy have long been to raise rice production to meet increasing domestic consumption and to maintain an exportable supply. Production policy and marketing as well as trade policies are interwoven in their impacts on the price which return affect production and export (Wiboonponge A. and Chaovannapoonphol Y., 2001).

Rice policies and strategies to develop the rice sector in Thailand are developed by the Ministry of Agriculture and Cooperative together with the Ministry of Commerce. Before presenting the strategies for the Cabinet where they get approved, the National

Rice Policy Committee has to take the policies and strategies under consideration (Forssell S., 2008).

The rice price policy were a major agricultural commodities on which the government had price policies for a long time especially when their prices slumped. Historically the rice price policy had two major goals. The first was to support rice farmers through price support, enabling farmers to sell their rice at a higher price than that determined by the free market. The second objective was food security for poor consumers especially in the urban areas; the measure allowed the rice reserve to be sold to consumers at a price lower than the market price-especially during 1973-1974 because of the hike in the price during that period. These two measures, which had a high public profile, were very politically important, but had rather low economic impacts. However, there were other intervening measures at the export level, which affected the domestic price during 1960-1985. These measures were:

1. Collecting a rice premium from rice exporters by the Department of Foreign Trade and the Ministry of Commerce,
2. Collecting an export duty by the Department of Customs,
3. Compelling rice exporters to sell their rice reserves at a price lower than the market price, and
4. Limiting export quantity by restricting export permits to exporters. (Gypmantasiri P. et al, 1997)

Between 2007 and 2011, six strategies for sustainable development are to be implemented. The strategies concern different aspects of the domestic rice sector and include production and rice farmers' development as well as product development and marketing. Marketing overseas are also included together with strategies for value creation and logistics development. The most controversial of the strategies in the one concerning rice price stabilization (Forssell S., 2008).

2.5.1 Water policy transitions in Northern Thailand

Since 1961, Thailand's water development for irrigation was implemented under the strategy and direction of comprehensive National Economic and Social Development

Plans (NESDP). At the beginning, the emphasized target was construction of large and medium scale irrigation projects to increase new irrigable areas as much as possible to guarantee or reduce the risk of a lack of water in the agriculture sector. The progress and trends of water resources development during different NESDP is presented (Table 4). As a result of development in earlier phases, Thailand was able to expand irrigable areas to large portion of its total agricultural land (Bastakoti C. R. and Shivakoti P. G., 2008).

The larger water infrastructure projects of the 1960s to 1980s were announced as part of the five-year government development plans. The First National Economic and Social Development Plan (1961-66) identified the export potential of the central plains of Chao Phraya Basin. Increasing need for electricity, agriculture and manufacturing led to the construction of a dam at the lower end of the Upper Ping named after His Majesty the King Bhumipol Adulyadej, a critical supporter of investments in water infrastructure projects in Thailand. In the Upper Ping basin, the Mae Taeng Project was constructed to solve the problem of "water shortages" for agriculture. In the Third Plan (1972-76), major large-scale dams in the Upper Ping basin-the Mae Ngad and Mae Kuang Dam project-began construction. In the Fourth Plan (1977-81) the Royal Irrigation Department (RID) accelerated the replacement with permanent concrete structures on traditional irrigation and established the Northern Industrial Estate in Lamphun Province (Lebel L. et al, 2008).

Table 4 Progress and trends of irrigation development in Thailand during different National Economic and Social Development Plan (NESDP) periods

NESDP periods	**Irrigation Area (million rai)**	**% Irrigation area over total Area**	**% increase in capacity over previous plan**
First Plan (1961-1966)	9.72	3.03	NA
Second Plan (1967-1971)	10.96	3.42	4.19
Third Plan (1972-1976)	14.38	4.48	61.46
Fourth Plan (1977-1981)	15.84	4.94	4.58
Fifth Plan (1982-1986)	18.71	5.83	12.6
Sixth Plan (1987-1991)	20.71	6.46	5.34
Seventh Plan (1992-1996)	21.68	6.76	4.84
Eighth Plan (1997-2001)	22.39	6.98	2.06
Ninth Plan (2002-2006)	28.49	8.88	13.26
Tenth Plan (2007-2011)*	30.71	9.58	7.25

Source: Office of Budget Programming and Project Planning

Note: 1 hectare = 6.25 rai

During the 1980s more focus was given on distributing development to rural areas and hence small-scale projects were implemented. In the 1990s, the development stated to take the basin approach under which potential water deficit areas were located and new development projects were identified especially in the Cha Phraya and East Coast Basins. During the past 10 years, there was a major shift in the approach to water resources development and the focus was on the construction of small-scale projects instead of large and medium-scale projects. These measures represented a new conceptual approach towards integrated water resources management in Thailand (Bastakoti C. R. and Shivakoti P. G., 2008).

The major purpose of these irrigation systems has been to provide dependable water during the rainy season because of the unpredictability of rain in the area (Seetisam M. and Gypmantasiri P., 1990). Muang fai system are managed to cope with dry spells during the wet season, variable timing in onset of the monsoon, and in suitable locations, sharing dry season base flows. Overall this made them amenable, at least in initial phases, to the intensification in cropping which followed with commercial development of first rice and then other crops (Lebel L. et al, 2008). For the upland and highland areas, with a few exceptions, crop production depends entirely on the rainfall (Seetisam M. and Gypmantasiri P., 1990). Upland irrigation systems are usually technically and institutionally simpler than lowland ones because greater slopes make the gravity-based water system easier to manage (Lebel L. et al, 2008).

Today muang fai institutions are diverse: some function like a modern association, some are informal groups undersigned by provincial government, some draw on the power of democratically elected local government. Now about 70 percent of the irrigated agricultural land is managed and maintained by government agencies while the rest is run by a variety of communal systems. Much of the new infrastructure was introduced by the central bureaucracy through the RID with minimal notification or consultation with farmers or local irrigations systems, some of which may be downstream and affected by these interventions (Lebel L. et al, 2008).

The reduction in local autonomy in managing water resources that emerged in the wet-to-dry transition is a point of ongoing contention. The infrastructure built gave greater management control of water to the RID. First, it controls and monitors the flow and distribution of water through a sluice gate along the canal. Second, it imposed rules and regulations that farmers must follow. Third, it limits areas of agriculture as well as the cropping system through water distribution calendars, especially in the dry season. Farmers are called for a meeting by the RID before the dry season starts in order to inform them about the water budget and areas that could be covered. RID officials, it was explained to us several times, discuss a water budget that is about 80 percent of the actual amount available because they know plantings will exceed agreed plans. The policy transition from a management regime focused on supporting wet season rice based on diversion of monsoon-induced floods to a multiseason and mixed-crop calendar required and was supported by large expansion in irrigation infrastructure built and managed by the state. Individual farmers, local muang fai groups and a highly institutionalized RID organization have been the key actors in this transition (Lebel L. et al, 2008).

Farming systems in Northern Thailand

The typical cropping system in the Northern which mountains upland area where the cropping patterns are upland rice, field crops (cropping systems such as soybean-mungbean, corn-mungbean, mungbean-cotton, corn-sorghum etc.) and fruits such as lychee, longan, mango etc. The fruit tree-based cropping systems are mostly intercropped with field crops, vegetable crops and flowers. With only 10 percent of the lowland under irrigation, the cropping system are wet season rice followed by dry season rice or soybean, mungbean, peanut, tobacco, sweet corn, baby corn, onion, garlic, tomato, water melon etc. The typical cropping systems in this region, therefore, are rice-based cropping systems and fruit tree-based cropping systems (FAO, 2001).

Chiang Mai is considered one of the country's major sources of agricultural products, and its agricultural area is the second largest in the northern region of the country. Many kinds of plants can be grown in the province, with rice, soybeans, tobacco, longan, lychee, oranges, garlic, onions, and shallots among its major agricultural crops; temperate-climate vegetables and flowers are also grown. The agricultural products of the province are for domestic consumption as well as for export (Pattanapant A. and Shivakoti P.G., 2009). The most extensively planted short field crop is maize, most of which is sold for use in producing animal feed. There are also substantial areas planted to various legumes, especially soybean, mungbean and groundnut. Various upland areas planted to legumes have been displaced by maize during recent year (Ministry of Natural Resources and Environment, 2005).

In the irrigated areas at Chiang Mai, rice is the main crop in the rainy season. Most of the rice grown in this season is glutinous (Seetisam M. and Gypmantasiri P., 1990; Gypmantasiri P. et.al., 2003; Limnirankul B., 2007). Given an average rainy season, yields of 2.69-3.21 t/ha can be expected. These are substantially higher than the national average. The average dry-season rice yields are much higher, averaging 3.90 t/ha in Chiang Mai. Both regions have only about 30 percent of rice land under irrigation. The remaining 70 percent of rice is rainfed and allows single cropping only. In the single-cropping systems, the land remains fallow for about 7 months each year after the rice harvest. The rice growth in the Upper North is mainly used for subsistence, based on a glutinous rice type, RD6, used in home consumption. Other crops grown in this area include longan, an important economic fruit crop, established in permanent fruit orchards on sloping areas and in lowland areas around homesteads. (Limnirankul B., 2007).

Four types of farming systems dominate the farm landscape of Mae Taeng district. These are diverse irrigated rice farming system in the lowland, the dry season rotational cropping after rice on rice land, and in the flood recession field, fruit tree as permanent orchards on the upper terrace slopes, such as longan, and the livestock integrated system. The lowlands are under the Mae Taeng Irrigation Project, and are provided with water almost throughout the year. The farmers begin their rice planting land preparation when they have completed their cropping cycles in the land. The area is serviced by a tube well powered by a diesel pump, and water pumped from the Ping River. This water is available throughout the dry season. Several cropping sequences of non-rice crops, mainly sweet corn, glutinous corn, and hybrid maize seed are planted on contract. Chili and egg plant are relay-cropped into sweet corn, making the land the most intensively cropped area from October to July (Limnirankul B., 2007).

The application of chemicals in conventional agriculture to increase productivity can result in environmental degradation, bring about economic problems and cause harmful effects on farmers, labors and consumers. Responding to these problems, a number of non-governmental organizations and government agencies have been promoting organic agriculture in the province of Chiang Mai in order to assure food safety and at the same time alleviate the poverty of farmers. The present study discusses the organic agriculture movement in Chiang Mai and compares organic agriculture with conventional agriculture in terms of yields, socio-economic considerations and human health aspects. Organic agriculture has the potential to help small farmers achieve sustainable development. However, most conventional farmers are still resistant to switching to organic farming, as they have negative perceptions of organic systems, which include fears of low yield and quality, high production costs and delayed income. Farmers who are land tenants and in debt believed that their families' fundamental needs could not be met through the practice of organic agriculture. In order to counter such views, the government should implement policies that would intensify the promotion of organic agriculture among farmers (Pattanapant A. and Shivakoti P. G., 2009).

2.5.2 Water resources and use in Northern Thailand

Four categories of water use from the Global Water Partnership (SDC, 2005):

- **Water for people** refers to the drinking water sector and to sanitation services.
- **Water for food** refers to the farming sector including livestock and fisheries and rainfed or irrigated cultivation of food, feed or fiber crops.
- **Water for Nature** refers to the source of water as well as to the availability of water for nature and for the preservation of ecosystems.
- **Water for Other Uses** refers mainly to the use of water for industry, energy and transportation.

Water resources

Water resources are vital assets in the development of Thailand. Water is essential for human consumption, sanitation, the production of food and fiber, as well as far the production of many industrial goods. But rainfed agriculture alone cannot provide sufficient products for the growing population and development of the country; therefore, irrigation is assuming an increasingly important role in the agricultural sector. The most striking characteristic of the water resource is its uneven and inequitable spatial and temporal distribution. Some areas have too little water, others have too much, suffering from floods which can cause substantial loss of life and damage to property. One of the main objectives of water resources development is to even out this inequity (Kuneepong P., 2001).

Surface water

The total volume of water from the rainfall in Thailand is estimated at 800,000 million m^3 of which 600,000 million m^3 is lost and the remaining 200,000 million m^3 is left as water resource to be developed. The most important and the largest river basin in Thailand is the Chao Phraya Basin. It originates in the mountain ranges in the North and covers nearly all the areas in the northern and central regions. The major tributaries are the Ping, Wang, Yom and Nan rivers. Their confluence occurs at Nakhon Sawan some 200 kilometers north of Bangkok, forming tire Chao Phraya. The Pa Sak joins the Chao Phraya River about 55 kilometers. The average annual runoff at the river mouth is 30,300 million cubic meters, or 170 millimeters in terms of depth. (The volume of water is sometimes expressed as depth of water over the basil, area it covers). The majority of agricultural products are produced in this basin (Kuneepong P., 2001).

Ground water

Long-term population growth and economic development is placing ever-increasing demands on all natural resources in Thailand. The stress on water in the main development regions is especially heavy, and groundwater has become an important resource for industrial use and urban water-supply. Moreover, as a consequence of recent droughts, it has become more widely exploited for irrigated agriculture to insure dry-season cropping. In the Chao Phraya Basin the typical dry-season shortfall in supply from surface water is some 2,440 million m^3, and to offset this groundwater is being heavily developed by more than 10,000 wells capable of producing more than 1,120 million m^3. Thus, Thailand needed a soundly-based and effectively-implemented management system to ensure sustainable and efficient use of its valuable groundwater resources. In general terms it can be said that all of the major alluvial aquifers possess very large reserves of freshwater in storage, but their rates of active replenishment (while very significant) are still subject to a large degree of uncertainty (Foster S., 2008).

Water resources for agriculture

The state's irrigation system includes dams, dikes and canals. Despite being a man-made water system, much of the irrigation system still depends on natural waterways for conveying water to users. The Royal Irrigation Department (RID), the Department for Energy Promotion and Development, and the Electricity Generating Authority of Thailand are major agencies that are responsible for construction and maintenance of the irrigation system (Chantawong M. et al, 2002). RID has attempted to emphasize farmers' participation in on-farm water management with the aim to promote the most effective use of irrigation water as well as to prevent conflicts among farmers during any water use crisis. It also emphasizes on creating water management organization both at national and river basin levels with supportive legislation (Bastakoti C.R. and Shivakoti P.G., 2008).

Natural water sources are mostly used by local communities. Water usage in this sector can be divided into two groups: 1) direct use of water for agriculture, animals and everyday life, usually according to locally developed systems of water management (such as the community water management systems knows as muang fai in Northern Thailand), and 2) indirect use such as a habitat for important resources such as fisheries (Chantawong M. et al, 2002). The farmer-managed systems in the country have been facilitated and supported only after the well recognition of people's participation and governance on irrigation systems operation and maintenance by the government. Government owns the large and medium scale irrigation systems, but management responsibilities are divided into both government and farmers at two different levels. The farmers are responsible to manage on-farm irrigation canals, while government organizations managed the main systems such as reservoir and head works maintenance, discharge and allocation of water into different irrigation systems (Bastakoti C. R. and Shivakoti P. G., 2008).

The Ping River and its tributaries are the major water resources for agricultural intensification in Northern Thailand where has a long tradition of community irrigation projects. Local irrigation systems called muang fai are gravitational systems where the river's water is blocked by an artificial weir (fai) and thus directed into a system of canals and sub-canals. Muang fai research has been conducted on the description of their structural arrangement and management (Wytinck M.S., 1997; Surareks V., 2006; Ounivichit T., 2007; Ounivichit T. et al, 2008).

The main canal is the muang and the sub-canals are called muang soi. Each soi has a series of gated which are opened to flood individual farm plots. These plots are sub-divided with mounds outlining each section. Bamboo tubes are placed under the mounds to regulate the flow of water between sections. One muang fai system may irrigate from fifty to five thousand rai (one rai is equal to approximately 0.16 hectares or 0.395 acres), depending on local needs and conditions. Smaller systems tend to dominate the more marginal and outlying areas and the larger systems are found in the centre of the basin. The size of the area to be served determines the size and permanence of the weir structure. Smaller weirs tend to be temporary structures which require yearly maintenance or rebuilding. Larger weirs are generally built strong enough to withstand normal wet season inundation but can be damaged by floods (Wytinck M.S., 1997).

The irrigation systems-traditional and communal, known locally as muang fai, or the government system (under the responsibility of the Royal Irrigation Department)-are diversion systems (Ounivichit T. and Satoh M., 2002; Limnirankul B., 2007). In small scale muang fai system by locally, irrigation water users know each other and directly participate in the irrigation management. Their leaders personally know every water user, and are thoroughly familiar with the field conditions and other information pertaining to irrigation. On the other hand, in large scale muang fai system by government, it is not possible for all water users in the system to know each other. Their leaders also cannot afford the time and resources to get to know every water user because the number of irrigation water users is so large, with some residing in different communities, or to become familiar with the field conditions of the large number of farms scattered over a wide region (Ounivichit T., 2007; Ounivichit T. et al, 2008). Both systems are designed to provide supplementary water for rainy season rice, particularly during land preparation and transplantation, and to overcome dry spells in late June to mid July. The amount of irrigation land for dry season cropping will depend on the amount of rainfall during the rainy season along the upper watershed or beyond the headwork of the diversion weirs. In addition to access to systems based on diversion weirs for dry-season irrigation, farmers also invest in tube wells using diesel pumps to draw water for irrigation. Electric pumps along the main river have also been installed by the Department of Energy Promotion, to provide irrigation water for small areas (Limnirankul B., 2007).

Muang fai members were involved in all irrigation management process. Despite their lower technology when compared with that of the national irrigation systems, they could sustainably serve all their members who were willing to accept higher costs than beneficiaries of the national irrigation systems. All decisions on what and how to do things together were clearly laid out through exchange of local information and were strictly followed. The management structure of the small scale system was straightforward, using farm intake sizes as the priority criteria for all joint management matters. That of the larger scale system was in-laid with extended mechanisms for joint planning and operation, accountability check and balance, and social sanction instruments through association with local administrators. The commonality of the small and large scale systems is the observance of the quality of their members and their management agreements, and the emphasis on efforts to make all the irrigation management processes transparent to all members. Their management terminologies were simple and well-understood by members (Ounivichit T., 2007).

2.6 Principles of water as an economic good

Water has a value as an economic good (GWP, 2000); Many past failures in water resources management are attributable to the fact that water has been-and is still-viewed as a free good, or at least that the full value of water has not been recognized. In a situation of competition for scarce water resources such a notion may lead to water being allocated to low-value uses and provides no incentives to treat water as a limited asset. In order to extract the maximum benefits from the available water resources there is a need to change perceptions about water values and to recognize the opportunity costs involved in current allocative patterns.

Value and charges are two different things (GWP, 2000); Concern has been voiced over the social consequences of "the economic good" concept. How would this affect poor people's access to water? To avoid confusion over this concept there is a need to distinguish clearly between valuing and charging for water. The value of water in alternative uses is important for the rational allocation of water as a scarce resource (using the "opportunity cost" concept), whether by regulatory or economic means. Charging for water is applying an economic instrument to affect behavior towards conservation and efficient water usage, to provide incentives for demand management, ensure cost recovery and to signal consumers' willingness to pay for additional investments in water services.

Useful water value concepts (GWP, 2000); The following concepts of water value have been found useful within IWRM. The full value of water consists of its use value-or economic value-and the intrinsic value. The economic value which depends on the user and the way it is used, include: value of (direct) users of water, net benefits from water that is lost through evapotranspiration or other sinks (e.g. return flows), and the contribution of water towards the attainment of social objectives. The intrinsic value included non-use values such as bequest or existence values (Figure 5).

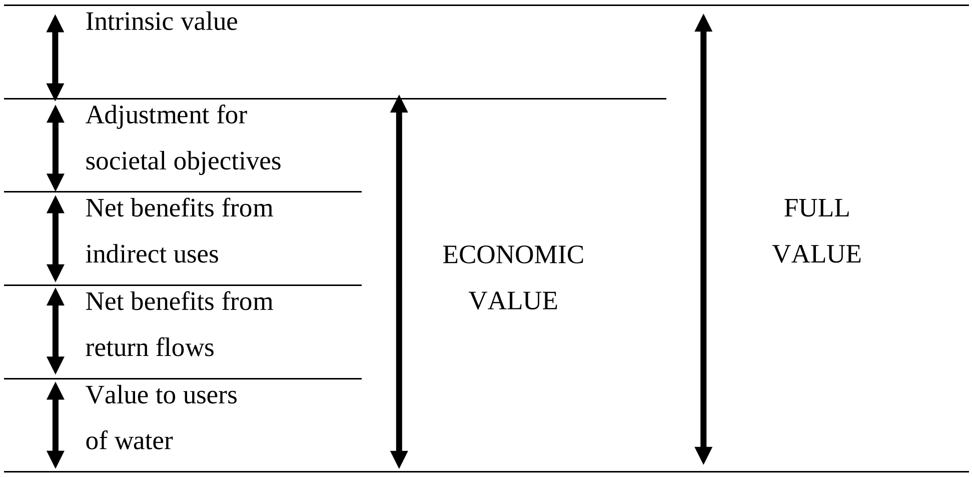

Figure 5 General principles for valuing water

Source: GWP, 2000

Useful water cost concepts (GWP, 2000); The full cost of providing water includes the full economic cost and the environmental externalities associated with public health and ecosystem maintenance. The full economic cost consists of: the full supply cost due to resource management, operating and maintenance expenditures and capital charges, the opportunity costs from alternative water uses, and the economic externalities arising from changes in economic activities of indirectly affected sectors (Figure 6).

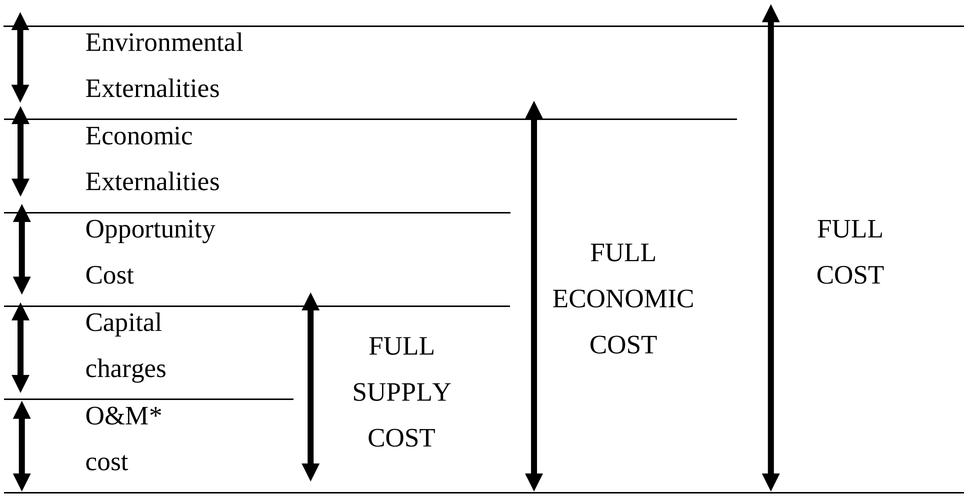

Figure 6 General principles for costing water

Source: GWP, 2000

Note: *O&M=Operation and Maintenance

2.7 Cost-benefit analysis

Cost-benefit analysis is carried out in order to compare the economic efficiency implication of alternative actions. The benefits from an action are contrasted with the associated costs (including the opportunity costs) within a common analytical framework. The benefits and costs are usually measured physically in widely differing units; comparison is enabled through use of the common numeraire of money. The benefits and costs of each option are determined relative to the common scenario that would prevail if no action were taken. The net benefit of each option is given by the difference between the costs and benefits. The most economically efficient option is that with the highest present value of net benefit, i.e. net present value (NPV); economic efficiency requires selection of the option with maximum NPV. Options are economically viable only where the NPV that they generate is positive. Cost-benefit analysis provides a rational and systematic framework for assessing alternative management and policy options. It entails identification and economic valuation of all positive and negative effects of alternative options. This involves the translation of all benefits and costs into monetary terms, including where possible, non-marketed environmental, social and other impacts. It is based on the underlying assumption that individual preferences should determine the allocation of resources among competing uses in society (Turner K. et al., 2004).

The Benefit Cost Ration (BCR) is the ratio of the present value of benefits to the present value of costs. The BCR can be expressed as follows:

$$BCR = \frac{PV_{Benefits}}{PV_{Costs}}$$

Where:

$$PV_{Benefits} = \sum_{n=0}^{N} \frac{B_n}{(1+r)^n}$$

$$PV_{Costs} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n}$$

The definition of the characteristic of PV is:

B_n = benefits in year n expressed in constant dollars

C_n = costs in year n expressed in constant dollars

r = real discount rate

n = evaluation period in years

2.8 Economically efficient allocation: the theory

The focus on economic efficiency as the primary objective in the development and allocation of water resources is because of its importance as a social objective; efficiency values having viable meaning in resolving conflicts and assessing the opportunity costs of pursuing alternative uses. Although economically efficient allocation of irrigation water is rarely attained in practice, analysis of economic efficiency provides a useful point of reference for understanding causes of inefficient allocation and mechanisms for improving the overall economic performance of irrigated production. (Turner K. et al., 2004).

Economically efficient allocation of water is desirable to the extent that it maximizes the welfare that society obtains from available water resources. Welfare in this context refers to the economic well-being of society and is determined by the aggregate well-being of its individual citizens. Economically efficient allocation maximizes the value of water across all sectors of the economy. This is achieved through the allocation of water to uses that are of high value to society and away from uses with low value. Efficient allocation occurs in a competitive, freely functioning market when supply is in equilibrium with demand. Under these conditions, the marginal cost of the supply of water is equal to the marginal benefit of the use of water (i.e. the benefit of goods and services provided by an additional unit of water). The marginal benefit and marginal cost are the same across all uses and equate with the market price. However, where there are distortionary constraints, such as subsidies or taxes, the maximization procedure will result in a second-best efficient allocation.

A feature of economically efficient allocation is that no reallocation can make anyone better off without making at least on person worse off, a condition that is described as “Pareto optimal”. The relative efficiency of alternative allocations can be analyzed with respect to this, i.e. in terms of whether they provide a “Pareto improvement”. A change in allocation is considered desirable if at least one person gains in welfare and no one loses. However, this criterion proves too stringent in practice as few changes can be made in the real world that do not reduce the well-being of others. For this reason, an adaption is usually employed; this is described as a “potential Pareto improvement” or the Kaldor-Hicks criterion. A change in allocation is considered desirable if those individuals who gain from the change can hypothetically compensate those who lose and still be better off than they were previously. It is anticipated that compensation does not take place, owing to difficulties of identifying and compensating all necessary individuals. The criterion of potential Pareto improvement forms the basis of cost-benefit analysis, which is used to analyze the relative economic efficiency of alternative coursed of action (e.g. water allocation, and new irrigation schemes).

Although economic efficiency is an important factor, there are additional economic issues that decision–makers need to consider. Two of these issues are the distribution of costs and benefits across society and their distribution across generations. In terms of the former, neither the equity implications of an allocation nor the equity of the prevailing distribution of wealth are considered in analysis of economic efficiency. Focusing first on the equity implications of an allocation, costs and benefits are usually specified using values that are representative of the whole of society. However, the costs and benefits may not be borne equally by society; they may be concentrated in specific geographical areas. These differences may also correlate with differences in income borne by sections of society: environmental costs are often borne disproportionately by low-income sections of society. Such disparities can be incorporated into analysis through studies of costs and benefits for separate sections of society, though this adds to the information requirements and the demands of the analysis.

The prevailing distribution of wealth is usually assumed to be a given in analysis of economic efficiency. Equal weight is given implicitly to costs and benefits experienced by all members of society. However, circumstances arise where it is socially desirable to alter the distribution of wealth in the pursuit of greater equity. This can be incorporated into the analysis through the use of distributional weight. Weights are assigned to costs and benefits according to the section of society that they accrue to and the desired redistribution of wealth. For example, high weights can be applied to benefits that accrue to poor sections of society and low weights to benefits for the rich. Application of this procedure is challenging because of the difficulties of identifying the distribution of costs and benefits within society and of specifying appropriate weights, which is subjective. In the past, it has usually been considered more appropriate for decision-makers to consider prevailing inequalities separately from analysis of economic efficiency.

Present Values and Discounting

In most projects, the costs and benefits are going to be spread out over time. Since people are not indifferent with respect to the timing of costs and benefits, it is necessary to calculate the present value of all costs and benefits. It is therefore important that the valuation of costs and benefits takes into account the time at which they occur, since people generally prefer to receive benefits as early as possible and pay for costs as late as possible.

Discounting is performed for two reasons:

1) Immediate income or benefits are preferable to future income or benefits (social time preference).

2) Capital investment has an opportunity cost: it could earn a rate of return in other sectors of the economy if it were not used for the current project (opportunity cost of capital).

The standard approach to valuing costs and benefits that occur at different times is based on the fact that a dollar today is worth more than a dollar tomorrow. The approach reduces a time stream of costs or benefits to an equivalent amount in the price year’s dollars. This amount is known as the present value (PV) of the future costs and benefits.

The PV is calculated using the method of compound interest and the rate that converts future values into PV. The PV of costs and benefits can be expressed as follows (CASA, 2010):

$$PV_{Costs} = \sum_{n=0}^{N} \frac{C_n}{(1+r)^n}$$

$$PV_{Benefits} = \sum_{n=0}^{N} \frac{B_n}{(1+r)^n}$$

Where:

C_n = costs in year n expressed in constant dollars

B_n = benefits in year n expressed in constant dollars

r = real discount rate

n = evaluation period in years

Net Present Value (NPV)

NPV is perhaps the most straight forward CBA measure. It is the sum of the discounted project benefits less discounted project costs. It can be expressed as the following formula (CASA, 2010):

$$NPV = \sum_{n=0}^{N} \frac{B_n - C_n}{(1+r)^n}$$

Where:

B_n = benefits in year n expressed in constant dollars

C_n = costs in year n expressed in constant dollars

r = real discount rate

n = evaluation period in years

Using NPV as a decision rule, a project is potentially worthwhile (or viable) if the NPV is greater than zero; i.e. the total discounted value of benefits is greater than the total discounted costs (Table 5).

Table 5 Decision Rules with NPV

If	**Meaning**	**Action**
NPV>0	The project would be worthwhile	The project should be accepted
NPV<0	The project would not be worthwhile	The project should be rejected
NPV=0	The project neither adds or subtracts value	The project could be accepted since the required rate of return is being obtained

Source: Civil Aviation Safety Authority (CASA), 2010

Opportunity costs

The doctrine of opportunity cost is extremely important in economic analysis. We know that the cost in the value of inputs in the process of production. An input has got value because it is scare or limited. If we use the input to produce one good, it is not available to produce something else. The cost of producing one thing is measured in terms of what was given up in terms of next best alternative that is sacrificed. When we spend a certain amount of money on a particular thing, the money itself is not the cost but merely a measure of the value of other opportunities foregone. If several opportunities are given up for producing a particular commodity, it is the value of the next best forgone opportunity that constitutes cost. Thus it is called opportunity cost. The opportunity cost is the cost of next best alternative forgone. It is also called alternative cost (Jain T.R. and Trehan M., 2009).

2.9 Gross Profit Analysis

Profit variance analysis, often called gross profit analysis, deals with how to analyze the profit variance that constitutes the departure between actual profit and the previous year's income or the budgeted figure. The primary goal of profit variance analysis is to improve performance and profitability (Shim K.J. et al., 2009).

Profit, whether it is gross profit in absorption costing or contribution margin in direct costing, is affected by at least three basic items: sales price, sales volume, and costs. In addition, in a multiproduct firm, if not all products are equally profitable, profit is affected by the mix of products sold.

The differences between budgeted and actual profits are due to one or more of the following:

1) Changes in unit sales price and cost, called sales price and cost price variances, respectively. The difference between the sales price variance and cost price variance is often called a contribution-margin-per-unit variance or a gross-profit-per-unit variance, depending upon what type of costing system is being referred to, that is, absorption costing or direct costing. Contribution margin is, however, a better measure of product profitability because it deducts from sales revenue only the variable costs that are controllable in terms of fixing responsibility. Gross profit does not reflect cost-volume-profit relationships, nor does it consider directly traceable marketing costs.

2) Changes in the volume of products sold summarized as the sales volume variance and the cost volume variance. The difference between the two is called the total volume variance.

3) Changes in the volume of the more profitable or less profitable items referred to as the sales mix variance.

Detailed analysis is critical to management when multiproduct exist. The volume variance may be used to measure a change in volume, while holding the mix constant, and the mix may be employed to evaluate the effect of a change in sales mix, while holding the quantity constant. This type of variance analysis is useful when the products are substituted for each other, or when products that are not necessarily substitutes for each other are marketed through the same channel.

Types of Standards in Profit Variance Analysis

To determine the various causes for a favorable variance (an increase) or an unfavorable variance (a decrease) in profit, we need some kind of yardsticks to compare against the actual results. The yardsticks may be based on the prices and costs of the previous year, or any year selected as the base periods. Some companies are summarizing profit analysis data in their annual report by showing departures from the previous year's reported income. However, one can establish a more effective control and budgetary mix can be determined using such sophisticated techniques as linear and goal programming.

Single Product Firms

Profit variance analysis is simplest in a single product firm, as there is only one sales price, one set of costs (or cost price), and a unitary sales volume. An unfavorable profit variance can be broken down into four components: a sales price variance, a cost price variance, a sales volume variance, and a cost volume variance.

Sales Price Variance. The sales price variance measures the impact on the firm's contribution margin (or gross profit) of changes in the unit selling price. It is computed as:

Sales price variance = (actual price – budget price) x actual sales

If the actual price is lower than the budgeted price, for example, this variance is unfavorable; it tends to reduce profit.

Cost Price Variance. The cost price variance is simply the summary of price variance for materials, labor, and overhead. (This is the sum of material price, labor rate, and factory overhead spending variances). It is computed as:

Cost price variance = (actual cost – budget cost) x actual sales

If the actual unit cost is lower than budgeted cost, for example, this variance is favorable; it tends to increase profit. We simplify the computation of price variance by taking the sales price variance less the cost price variance and call it the gross-profit-per-unit variance or contribution-margin-per-unit variance.

Sales Volume Variance. The sales volume variance indicates the impact on the firm's profit of changes in the unit sales volume. This is the amount by which sales would have varied from the budget if nothing but sales volume had changed. It is computed as:

Sales volume variance = (actual sales – budget sales) x budget price

If actual sales volume is greater than budgeted sales volume, this is favorable; it tends to increase profit.

Cost Volume Variance. The cost volume variance has the same interpretation. It is:

(actual sales – budget sales) x budget cost per unit

The difference between the sales volume variance and the cost volume variance is called the total volume variance.

Multiproduct Firms

When a firm produces more than one product, there is a fourth component of the profit variance. This is the sales mix variance, the effect on profit of selling a different proportionate mix of products than the one that has been budgeted. This variance arises when different products have different contribution margins. In a multiproduct firm, actual sales volume can differ from that budgeted in two ways. The total number of units sold could differ from the target aggregate sales. In addition, the mix of the products actually sold may not be proportionate to the target mix. Each of these two different types of changes I volume is reflected in a separate variance.

The total volume variance is divided into two: the sales mix variance and the sales quantity variance. These two variances should be used to evaluate the marketing department. The sales mix variance shows how well the department has done in terms of selling the more profitable products, while the sales quantity variance measures how well the firm has done in terms of its overall sales volume. They are computed as:

Sales Mix Variance. (actual sales at budget mix – actual sales at actual mix) x budget CM (or gross profit/unit)

Sales Quantity Variance. (actual sales at budget mix – budget sales at budget mix) x budget CM (or gross profit/unit)

Sales Volume Variance. (actual sales at actual mix – budget sales at budget mix) x budget CM (or gross profit/unit)

2.10 The Production Function

The theory of production centers around the concept of a production function. A production function relates the maximum quantity of output that can be produced from given amounts of various inputs for a given technology. It can be expressed in the form of a mathematical model, schedule, or graph. A change in technology, such as the introduction of more automated equipment or the substitution of skilled for unskilled workers, results in a new production function. The production of most output (goods and services) requires the use of large numbers of inputs. The production of gasoline, for example, requires the use of many different labor skills (roughnecks, chemical engineers, refinery maintenance workers), raw materials (crude oil, chemical additives, heat), and types of equipment (boilers, distillation columns, cracking chambers). Also, production processes often result in joint outputs. For example, petroleum refining results in jet fuel, propane, butane, gasoline, kerosene, lubricant oil, tar, and asphalt.

Letting L and K represent the quantities of two inputs (labor L and capital K) used in producing a quantity Q of output, a production function can be represented in the form of a mathematical model, such as

$$Q = \alpha L^{\beta 1} K^{\beta 2}$$

Where α, β_1 , and β_2 are constants. This particular multiplicative exponential model is known as the Cobb-Douglas production function and is examined in more detail later in the chapter. Production function also can be expressed in the term of a schedule, as illustrated in the following ore-mining example (Mcguigan R. J. et al., 2008).

2.11 Goal Programming is adopted in water policy

2.11.1 Goal Programming is adopted in water pricing policy

The analysis of water pricing policy impacts clearly demonstrate that farmers display different behavior patterns related to this natural resource. Also, patterns of consumption vary along the demand curves as a result of increases in the water price. Inelastic price segments of the water demand curves coincide with prices at which the farmers are insensitive to resource price increases, maintaining their usual crop mixes without any substantial change. On the other hand, the elastic segments correspond to those water tariffs that encourage farmers to replace their current crops with others that have lower water requirements (Shajari S. et al, 2008). The study compares the effects of water pricing (volumetric and flat tariffs) and consumption quotas, in farmer's income, water agency revenues, agricultural employment and water demand for irrigation. (Saraiva P.J. and Pinheiro C.A., 2007) The research introduces a methodology for deriving water-demand functions in contexts in which farmers' behavior is not explained by the maximization of gross margin but by a utility function with several conflicting criteria. This methodology utilizes a weighted-goal programming approach to estimate a surrogate utility function for the farmer's decision process; this in turn is used to estimate the value of water demand in irrigated crop production using utility-derived demand functions. The empirical results of this study stress that water pricing as a single instrument for controlling water use is not a satisfactory tool for significantly reducing water consumption in agriculture. The reason for this is that consumption is not reduced significantly until prices reach such a level that farm income and agricultural employment are negatively affected (Gomez-Limon A.J., Berbel J., 2000).

The influence of the elasticity of water demand in reducing water consumption obtained through resource pricing is remarkable. It can be seen that in the elastic segments of the curves the increase in the price of water produces great savings in consumption due to changes in crop mixes, while in the elastic segments, tariff rises do not result in significant water savings, since farmers are not induced to change their crop plans (S. Shajari et al, 2008). A multiple criteria decision-making (MCDM) model to simulate the establishment of water markets is developed. The environment is an irrigated area governed by a non-profit agency, which is responsible for water production, allocation, and pricing. There is a traditional situation of historical rights, average-cost pricing for water allocation, large quantities of water used, and inefficiency. A market-oriented policy could be implemented by accounting for ecological and political objectives such as saving groundwater and safeguarding historical rights while promoting economic efficiency (Enrique B. et al, 2002).

Assessment of future impact can be done by different methods especially programming models. This study is to analyse future impact of different strategies and policies in water resource management and irrigation systems on the living standard of farm families, Northern Thailand. To be realistic strategies are based on problems facing the farmers and farmers' requirements. Two strategies are, namely, increasing irrigation water availability, and improving technical efficiency of irrigation management systems. A family model is applied and includes farm, household and external relations and maximizes family income in the objective function. A static linear programming model interpreted in a comparative static analysis is used to investigate various options to improve the use of irrigation water and their impact on farm-family income. Results of the future impact analysis provide recommendation for the irrigation authorities to improve their service and ultimately the living standard of the farm family. The result indicates that increasing irrigation water availability based on farmers' investment will be a constraint in future strategies. If the investment allows introducing some dry season crops, the farmers' investment in increasing irrigation water availability will turn out to be profitable for the farm families in all groups. Increasing technical efficiency by improving water distribution systems has a predominant impact on farming development and the regional supply of agricultural goods (Acharee S. and Werner D., 1999).

In these cases specific policy measures should be taken to protect water resources from harmful agricultural activities, mitigating at the same time their potential impact on farmers' welfare. A multicriteria decision-making model is formulated that aims at allocating efficiently water and land resources in a rural area of Greece, by optimizing a set of important socio-economic and environment objectives (Dionysis, 2009). Irrigated agriculture is directly influenced by various EU policies, especially the CAP and more recently the Water Framework Directive (WFD). The demand for water by agriculture is largely determined by CAP policy. On the other hand, the objective of the WFD is to regulate the supply (cost, quality, quantity) of water to agriculture. This work examines the relationships between these two policy instruments and applies a scenario analysis to a case study in central Spain using a multi-criteria model of farmer behavior (Gomez-Limon A.J. et al, 2002). The research stresses their importance for the implementation of the water demand policies. This approach enables a different analysis for each type of farmers in order to respond to the variety of utility functions (Jose A.G. et al, 2003). Policy scenarios are simulated by means of farmers. Multi-Attribute Utility Theory (MAUT) has been chosen as the methodological framework for model-building at farm level. Modeling representative farms in this way enables differential impacts of scenarios considered to be simulated and, through a process of aggregation, global results at basin level to be obtained. Results obtained from the simulation models are not only related to farmers' decision variables (crop mixes). A set of relevant economic, social and environmental attributes related to public criteria can also be obtained as a way of measuring the efficiency of the suggested policy scenarios (Laura R., Jose A.G., 2006).

Multi-Attribute Utility Theory is implemented in order to simulate agricultural decision making at various water pricing scenario. Water demand functions are then elicited, by means of the best crop and water allocation (farmers' decisions) in each scenario. The European Water Framework Directive recommends that any issue concerning water resource management (including water pricing policies) should be developed at the river basin level. Finally, the use of crop-water consumption as decision variable in the multicriteria decision making model has a significant effect on the elasticity of demand (lower elasticity), mainly at higher water charges. The reason is that farmers' ability to use deficient water quantities in order to reduce water consumption becomes a real alternative at the point, where, changing cropping patterns will entail the choice of low-profit non-irrigated crops. Therefore, at these pricing scenarios, deficient irrigation seems to be the best solutions as it subtracts less from farmers' gross margin than any potential change in the crop mix (Latinopoulos D., 2008). Multiple criteria analysis (MCA) is a framework for ranking or scoring the overall performance of decision options against multiple objectives. The approach has widespread and growing application in the field of water resource management. It finds that MCA is being heavily used for water policy evaluation, strategic planning and infrastructure selection. Water management is typically a multi-objective problem which makes MCA a well suited decision support tool. The outcomes are often intangible and are measured in a variety of units. MCA has been sound to assist with conflict resolution, stakeholder participation and community engagement. It has also been shown to improve the auditability, transparency and analytic rigour of water management decisions (Stefan H., Kerry C., 2007; Stefan H., Andrew H., 2008).

2.11.2 Goal Programming is adopted in cropping pattern planning

The research presents a regional scale problem about water resource management and consequently cropping pattern planning. Cropping pattern planning involves a complex set of interrelated environment and socio-economic criteria, which are inherently conflicting and inconsistent. In order to consider and include the water resource sustainability in the cropping pattern planning, that concerned with a special type of multi-objective programming problem where objective functions are of linear fractional structure (Abbas, Seyed A. and Manouchehr, 2010). In Egypt case study was to find the optimal cropping pattern, which maximizes the net income return per water cubic meter. The aim is to achieve the efficient utilization of the scare water resources. Two scenarios for the cropping pattern have been investigated. The first scenario is associated with the continuation of the local prices of crops; while the second one is associated with the dynamic global conditions, like applying the regulations of free trade agreements, which is expected to make the prices of the Egyptian crops approach their corresponding international prices. Comparing the result of the two scenarios, reveals that the second scenario yields better returns for the Egyptian agricultural sector; this indicates that pricing the Egyptian crops with international prices is indeed in favor of the agriculture sector in Egypt (Ahmed et al, 2006).

This paper designed and developed a multi-objective programming (MOP) model to illustrate the dynamic relationship among technologies, productive activities, constraints and farmers' objectives in the peri-urban vegetable production system and use the model as an economic tool in analyzing probable consequence of a given action or innovation on the farm. The best compromise solution was generated using four analytical steps, as follows: single objective optimization (to determine the ideal and anti-ideal values of the objective functions); constrained optimization (to generate the set of Pareto non-dominated solutions); cluster analysis (to trim down efficient set into smaller homogeneous groups); and compromise programming (to determine where the best compromise solution lies). This study then evaluated the income and risk impacts of technological innovation, specifically that of the technologies espoused by the AVRDC-Manila Peri-urban project for tomato and pak choi production during the hot-wet season (Sergio R. et al, 2006). In modeling farm systems it is widely accepted that risk plays a central role. Furthermore, farmers' risk aversion determines their decisions in both the short and the long run. The methodology based on multiple criteria mathematical programming to obtain relative and absolute risk aversion coefficients and apply this methodology to an irrigated area of Northern Spain (Jose A.G. et al, 2003). The Multicriteria Mathematical Programming model is used to simulate different scenarios and policies by the local stakeholders, due to changes on different social, economic and environmental parameters. In this way the decision makers can achieve alternative farm plans and agricultural land uses as well as to estimate economic, social and environmental impacts of different policies (Manos B. et al, 2010).

In dry land agricultural systems, single-, double-, and triple-cropped lands play different roles on ecological function, economic function and social function. In Sichuan province of China, the land area for various cropping patterns for three land types is in large proportion of Sichuan's cultivated land. In kind of situation, this paper presents how multi-objective programming can be efficiently used for modeling and solving crop planning problems for optimal production of several seasonal crops in a planning year based on the scientific principle of circular economy and the character of Sichuan province dry land agriculture. The objective is either the maximization of net revenue from cultivated land or the minimization of cost of cultivation (Wei. W. et al, 2009). The main aims of the research were to make up farm plans with multi goals regarding sustainability; to determine sustainable cropping patterns which comply with sustainable land use economically and ecologically with least sacrifice possible, suggesting agricultural and environmental policies concerning realization of economic and ecological sustainability of agricultural lands. This research was carried out in the district of Menemen, Izmir, Turkey. Farm plans that were obtained by goal programming models and linear programming in the aspect of sustainability of agricultural lands have given the same results. In the models that minimize fertilizer and pesticide use which effects sustainable use of agricultural lands in a negative way less income was brought by under the existing circumstances. According to the results it might be claimed that when the optimal farm plans are realized the sustainability of the land will be enabled. In the models that do not break sustainable land use but minimize the cost for fertilizers and pesticides; to increase the income and to put unused land in use again new alternative crops should be added to the existing one. Farmers' enthusiasm and belief in this issue are important. It was observed that most farmers were carrying out some rehabilitation activities for their lands and reducing use of fertilizers and pesticide (Ela A. et al, 2005).

Another type of Goal programming is Fuzzy Goal Programming which can solve the problem of cropping plan in agricultural system. This paper presents how fuzzy goal programming can be efficiently use for modeling and solving land-use planning problems in agricultural systems for optimal production of several seasonal crops in a planning year. In the model formulation of the problem, utilization of total cultivable land, supply of productive resources, aspiration levels of various productions of crops as well as the total expected profit from the farm are fuzzily described. In the decision-making situation, minimization of the under-deviational variables of the membership goals with highest membership value (unity) as their achievement levels defined for the membership functions of the fuzzy goals of the problem on the basis of the priorities of importance of achieving the aspired levels of the fuzzy goals to the extent possible is considered (Animesh B., Bijay B.P., 2005). A large-scale, multi-objective single-time-period model for planning the development of reclaimed lands is proposed. The period considered is a typical year at the most developed stage of the agricultural complex. Given specific development goals and a set of resource constraints, the model determines the optimal land allocation for the integrated agricultural development of a region, including agricultural and livestock production as well as agri-industries

(Hisham El-S., 1988). The optimal allocation of water to agriculture, the relative true economic value of water as well as the cropping patterns for the Shirvan Barzo (SB) dam area in North Khorasan Province of Iran. The analysis is based on linear programming (LP) and on multi goal linear programming (MGLP) models for determining solutions that can maximize net return to farmers. In the study, the priority of goals is developmental, social, economical, and environmental respectively. The results indicated that optimizing the cropping patterns along with proper the allocation of irrigation water has yet substantial potential to increase the net return from agriculture. It has already decreased the applied water as much as 19 percent (Keramatzadeh A. et al, 2011).

2.11.3 Goal Programming is adopted in water resource management

The cases study support to use goal programming to solve the problem of water resource management. The lexicographic goal programming (LPG) model is designed to illustrate how LPG can be used as an aid to solving fishery management and related activities with multiple objectives. The technique allows us to find the optimal solution, based on the priorities of the goals in a decision-making environment. In this study, the authorities have used LPG to examine a set of goals and objectives as they relate to the socioeconomic significance of fishery management in Maryland's Coastal Bays (Dinesh K., Julius A., 2006). The main objective of this paper is to create, apply and evaluate a model that aims at the simultaneous maximization of farmer's welfare and the minimization of the consequent environmental burden. More specifically, lexicographic goal programming technique is employed. This technique is implemented on a representative farm around Mashhad in Iran to seek for a solution-in terms of area and water allocation (under different crops)-resulting in figures that will come as close as possible to the decision maker's economic, social and environmental goals. According to results of lexicographic goal programming and comparison the values in different scenarios, it is observable that the best solution that lead to a win-win situation is to consider the compromise scenario. If the decision maker wishes an integrated agricultural management, then the compromising solution seems to be a quite acceptable one. In this situation, both environmental and farmer's welfare concerns has been considered so that maximum value of gross margin (GM) is achieved and amount of irrigation water and fertilizer consumption decreased with respect to current situation (Hooman M. et al, 2009).

Most water resources planning and management problems are so complex as to preclude the possibility that any individual or group of decision makers and analysts can assess the implications of the decisions to be made especially with multiple objectives. This is why models and multiobjective decision making methodologies are needed (Uri, 1983). A decision support model to help public water agencies allocate surface water among farmers and authorize the use of groundwater for irrigation (especially in Mediterranean dry regions) is developed. This is a stochastic goal programming approach with two goals, the first concerning farm management while the other concerns environmental impact. Targets for both goals are established by the agency. This model yields three reduction factors to decide the different reductions in available surface water, standard groundwater and complementary groundwater that the agency should grant/authorize for irrigation, this depending on if it is a dry or wet year. In drought periods, the model recommends using more groundwater than in wet periods (Mila B., Ignacio G., 2009).

Integrated water management models are required to evaluate alternative water allocation combinations among different uses. In this paper one multi-objective programming model of the Alqueva region was proposed and the Feasible Goals Method/Interactive Decision Maps (FGM/IDM) technique was used to compute and explore alternative water allocation on base of this model. Different allocation combinations were successively explored considering initially two and going up to the four criteria competing goals of agricultural income, final water levels in the dam, agricultural pollution and household and industrial consumption (Rui F. et al, 2009). In this study, multiobjective programming was developed for a realistic application in Kinmen Island, Taiwan, against the scarce water resource. Three alternatives, including a desalination facility, additional activated carbon equipment for the current wastewater treatment plant (WTP), and constructed wetlands were designed to improve water quality and to ensure sufficient water supply. The genetic algorithm technology is employed to search for the best solutions from the three alternatives. In addition, the fuzzy goal of cost and water quantity represented is utilized to determine the optimal control policy by the degree of satisfaction. In the optimal management of this case study, the desalination facility receives 17.8% of the treatment water and 20.7 and 61.5% of the treatment water allocated to the current WTP and constructed wetland, respectively (Chi-Feng C. et al, 2008).

This paper develops a framework for environmental economic decision making that includes the environment and economic sustainability criteria, and local peoples' preferences in the context of a lowland irrigated agriculture system using multi-criteria decision-making techniques. Several criteria, such as land capability/suitability, energy input/output ration, water demand and environmental costs, are considered as environmental sustainability criteria. Economic sustainability is measured from farmers', governments and societal viewpoints using extended cost-benefit analysis. The Geographic Information System (GIS) technique has been used to evaluate spatial sustainability criteria. The involvement of local people at various levels of the decision-making process is emphasized and their opinions are sought in the decision-making process using a two-stage field survey (Tiwari D.N. et al, 1999).

In some case, they developed the analyst of water management by a multi-criteria decision-making (MCDM). This is why the MCDM is the option to solve the problem. Many optimization models exist for water management systems but there is a knowledge gap in linking bio-economic objectives with the optimum use of all water resources under conflicting demands. The efficient operation and management of a network of nodes comprising storages, canals, river reaches and irrigation districts under environmental flow constraints is challenging. Minimization of risks associated with agricultural production requires accounting for uncertainty involved with climate, environmental policy and markets. Markets and economic criteria determine what crops farmers would like to grow with subsequent effect on water resources and the environment. Due to conflicts between multiple goal requirements and the competing water demands of different sectors, a MCDM framework was developed to analyze production targets under physical, biological, economic and environmental constraints. This approach is described by analyzing the conflicts that may arise between profitability, variable costs of production and pumping of groundwater for a hypothetical irrigation area (E. Xevi, S. Khan, 2005).The consequence of policy change were evaluated in case study (Baixo Alentejo, Portugal), using a Multi-Criteria Decision Making (MCDM) model that simulates farmers' preferred behavior. The study compares the effects of water pricing (volumetric and flat tariffs) and consumption quotas, in farmer's income, water agency revenues, agricultural employment and water demand for irrigation. Model results indicate that the adjustments in farmer's responses are dependent on the policy strategy enforced and on the policy level (Saraiva P.J., Pinheiro C.A., 2007).

The three Multiple Criteria Decision Making (MCDM) techniques: goal programming (GP), multi-objective programming (MOP) and compromise programming (CP) are discussed in terms of their usefulness for practical farm planning. Application of these methods is illustrated by using the example of a University farm in the UK. The model is of a modest size consisting of 8 constraints and 9 activities and incorporates different objectives. These objectives include: maximization of total gross margin; maximization of permanent labor utilization; minimization of hiring of labor; minimization of annual total variable costs; and, maximization of business trading surplus. Comparing three MCDM techniques considered, GP, MOP and CP, their advantages and drawbacks can be assessed. GP does not introduce computational difficulties as any conventional LP software can be used to solve this model. But in terms of information obtained from the model, GP is inferior to the other two techniques as it gives only one solution. There is also a problem of selecting weights attached to deviational variables. In addition, GP requires more precise information from the decision-maker, like target values, weight, etc. which are difficult to obtain. MOP has a more complicated procedure of obtaining solutions, but appropriate software package now exist for generating the efficient solutions-farm plans, from which the decision-maker can pick and implement the most suitable one. Then the problem arises as to how to select one solution from the set containing a multitude of efficient solutions (Bozena P., Rehman T., 1993).

The research suggests four problem areas in the measurement and modeling of farmers' goals for incorporation in to the multiple goal models (MGMs). First, the selection and specification of goals relevant to particular farmer decisions must be done by the analyst. Second, the goals must be defined by the analyst at a level of abstraction that permits the target levels and weights to be specified. Third, the metric properties of many of the goal measures developed do not correspond to the data requirements of the MGMs. Fourth, the assumed relationships among goals should be explicit and empirically verified (Patrick F.G., Blake F.B., 1980). The experiences described above indicate that multi-objective planning and management of water resources system is no less nor more successful in aiding real life decision making than attempts to use other operational research methodologies. It does, however, add ad important dimension to the decision making process. Success depends on several factors: the skill of the analyst in capturing the essence of the decision problem, his ability to develop and solve an appropriate model, and, most important, to communicate the process and results of his work to those charged with making the actual decision (Uri, 1983).

Decision makers may have several water management measures in response to the issue of water deficiency in Chekka Bay area and Amman Zarqa Basin, but they need simple methods and criteria for ranking the alternatives with respect to their economical efficiency. The Cost –Effectiveness Analysis method is used for supporting decisions to optimally combine water management measures at the river basin. Hydrologic and socio-economic data are used for assessing the future water balance and determine the sustainable management objectives. Both supply- and demand-side measures are investigated and compared. The analysis is based on two basic metrics to assess cost-effectiveness ratios: the average annualized and the marginal (or incremental) unit cost (Stephanie A. et al, 2009).

3. Objectives and Hypothesis

3.1 Objectives

3.1.1 Main Objective

The dissertation main objective is "**the impact assessment of water resource management on farms in the Ping watershed, Northern Thailand**" which has been researched and formulated in favor of creating scientific base for the further Water Policy Amendments and practical steps towards provision enough water for farmers in Northern Thailand regions.

3.1.2 Specific Objectives

i. To understand and explain existing water resource management within different farming systems in the Ping Watershed area through the crop structure.

ii. To determine factors affecting efficiency and management in different water resource management systems.

iii. To identify the development potentials of water resources under sustainable conditions in different water resource management systems with regards to farmers' socio-economic situation.

3.1.3 Expected Results

i. This study is expected to show a clear explanation about differentiation of water resource managements in Northern Thailand, e.g., non-irrigated, irrigated.

ii. This study is expected to show the economic efficiency of water use in different water resource management, e.g., non-irrigated, irrigated.

iii. This study is expected to show factors affecting decision making about water use and management, e.g., non-irrigated and also irrigated areas.

3.2 Hypothesis

Hypothesis I: Water resource management plays an important role in sustainable agricultural development and its positive impact can especially be insured through suitable crop structure.

Hypothesis II: The farmers' water associations in upstream and downstream areas have important potential to improve water resource management which affects the efficiency of water use.

Hypothesis III: A more efficient use of water resource based on a quantitative approach to farmers' economy improves the farmers' socio-economic situation.

4. Methodology

4.1 Data collection

4.1.1 Study area

The study areas are located in the Ping Watershed in Northern Thailand. Chiang Mai Province was selected as a study area because agro-ecological condition where is dominated by a series of mountain ranges running North-South and separated by basins. From this point of view, it represents the north of Thailand. However, water resource and project diversity. There are different types of water resource development projects for irrigation along the watershed in Chiang Mai Province. The projects can be classified into small, medium, and big scale irrigation projects. They are developed and managed by different groups, organizations and agencies.

Physical environmental setting of Ping watershed, Northern Thailand

Physical: The Upper Ping river basin (17˚ 14’ 30’’-19˚ 47’ 52’’ N, 98˚ 4’ 30’’-99˚ 22’ 30’’ E), has a catchment area of approximately 25,370 km^2 in the provinces of Lamphun and Chiangmai (Punpim P.M., Nutchanart S., 2009). Upper Ping river basin borders Myanmar to the north, Tak province to the south, Chiangrai and Lampang province to the east and Maehongson province to the west. The Ping River originates in Chiang Dao district of Chiangmai and flows downstream in the south to become the inflow for the Bhumipol dam-a large dam with an active storage capacity of 9.7 billion m^3. The river drains mountainous areas with steep hills up to elevations of 1,500 to 2,000 m, and valleys at elevations of 330 to 500 m. The Upper Ping River basin covers a catchment area of approximately 25,370 km^2 in the provinces of Chiangmai and Lamphun, Northern Thailand. The terrain of the basin is undulating and rolling to steep in upland areas flat along river floodplains. More than 70% of the basin cover is forest (Sriwongsitanon N., 2010).

Terrain: The landscape of the Upper Ping river basin is characterized by mountainous area and valleys of different sizes. The elevation ranges from 191 masl in Chiangmai valley to 2,569 masl on Inthanon, the highest peak in Thailand. Using categories commonly used by agencies in Thailand, the lowlands (<600 masl) and midlands (600-1,000 masl) equally occupy about 38 percent of the total area while the highlands

(>1,000 masl) form the rest of the area. Part of the lowlands is nearly flat with land slope of <2%, which allows surface irrigation to be conveniently implemented. Large portions of the highlands are associated with steep land with an average slope of more than 35%. The steep land is much more difficult for cultivation and its soil surface is vulnerable to soil erosion and degration (Thomas E.D., 2008).

Climate: Spatial distributions of climate data were achieved by spatial interpolation using daily rainfall and temperature records of about 250 weather stations in and around Upper Ping river basin and the digital elevation model. Rainfall starts in April in the highlands and Upper parts of Upper Ping river basin. The amount of rain is adequate for upland crops cultivation in the early part of May on the highlands and late May in the midlands and lowlands. Farmers have to wait until late July or early August for rainfall amounts to accumulate enough for paddy cultivation. In some highland areas, second cropping without irrigation may be possible where rainfall is prolonged until early November and soil is deep enough to store good amounts of residual soil moisture. Distribution of annual rainfall indicates that higher amounts of rainfall are generally found in the highlands and midlands and ranging from 800 to 1.200 mm in the lowlands (Thomas E.D., 2008). The weather of the basin is mainly influenced by the southwest and northeast monsoons and atmospheric depressions from the South China Sea from July to September, resulting in abundant rainfall from May to October. The average annual rainfall and runoff of the basin are 1,174 mm and 6,815 million m^3, respectively (Sriwongsitanon N., 2010).

4.1.2 Collective action

Collective action divided into 2 levels that are primary data and secondary data.

Primary data separated in 2 steps.

First step: The primary data was based on a micro survey and obtained from a farm-family-household survey carried out in the region during the period 2010/2011. A face to face interview was carried out with the respondents, where they were chosen through a stratified random sampling in each different farming system. These were chosen a simple random sampling by 75 samples in each different farming system. These were collected using a structured questionnaire, discussions as well as by direct observation.

The present study focuses on farm family household in Chiang Mai Province, Northern Thailand, with the ambition to understand the socio-economic in different farming system.

The classification and definition of the three groups and irrigation systems is as follows:

Group 1 the water using is rainfed area in Maetaeng District.

Group 2 the water using is irrigated area with dike dam in Sarapee District.

Group 3 the water using is irrigated area with storage dam in Sansai District.

In each group in the Ping watershed area was selected 75 samples thus total 225 samples in the study area (Figure 7). In rainfed area compose of Banchang, Banmaetaeng, and Khilek in Maetaeng district and in irrigated area with dike dam include in Tawangtan, Nongfang, and Yangnueng in Sarapee district. In rest group, in irrigated area with storage dam consist in Nongjom, Sansainoi, and Sansailuang in Sansai district (Table 6).

Second step: The primary data was collected by participation of persons each different farming system in village level. Interviewed persons included village headmen, water use association committees, irrigation officers and agricultural extension officers. Information was obtained from provincial officials including agriculturists, agricultural extension officers and rural development extension officers.

The structured questionnaire divides into 7 parts.

Part 1 General information of farmer

Part 2 Crop planning in 2010/2011

Part 3A Costs and income of annual crops

Part 3B Costs and income of perennial plant

Part 4 Livestock in household

Part 5 Non-agricultural income and expenditure of household

Part 6 Finance

Part 7 Water resource management in farm

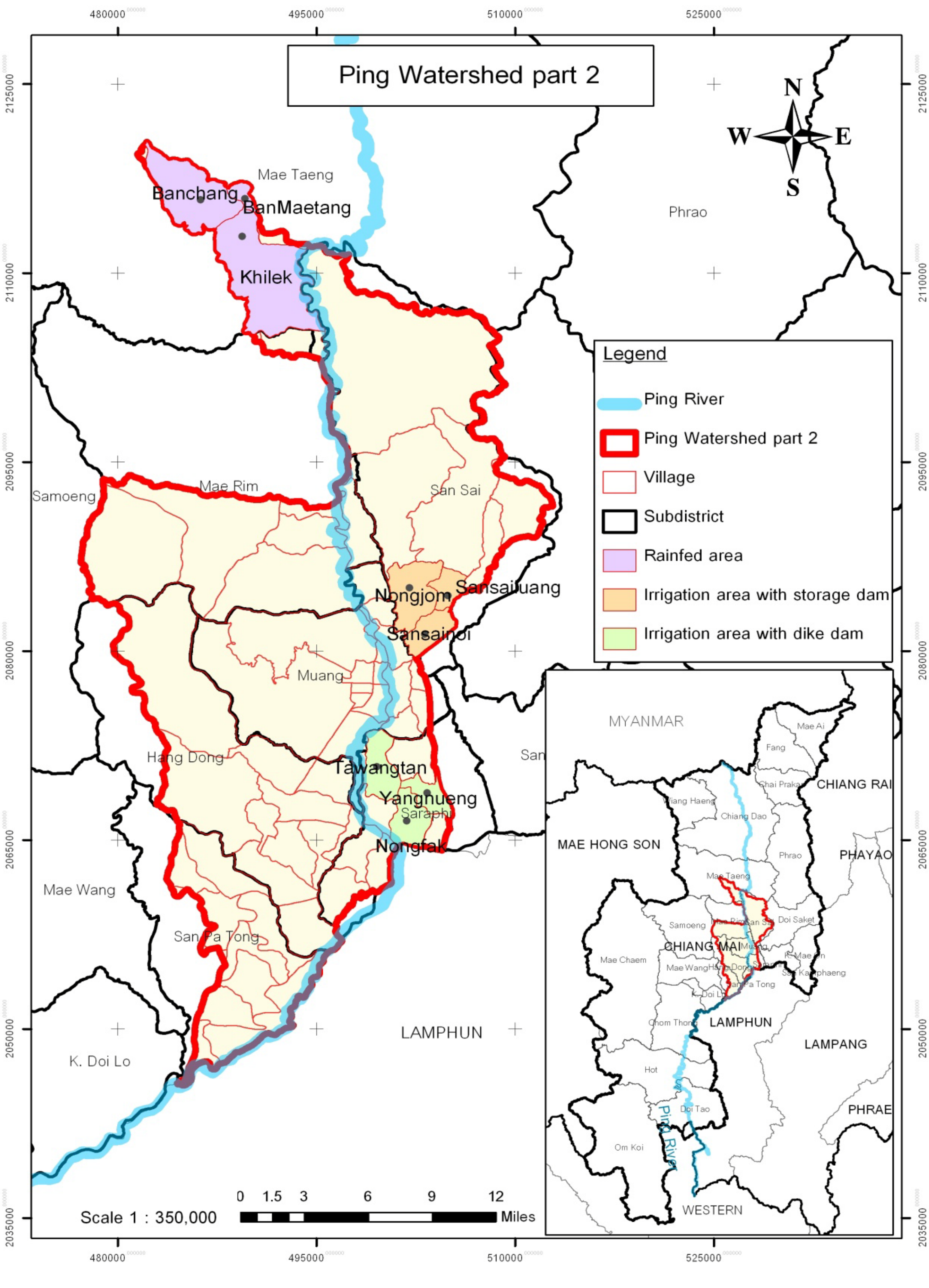

Figure 7 The study area in Ping Watershed Part 2

Source: Regional Irrigation Office 1

Table 6 Study Area in Chiang Mai Province

	Irrigation area (hectare)	**Village**	**District**	**Population**	**House-holds**	**Farmer house-hold**	**House-hold Samples**
Rainfed area	-	Banchang	Maetaeng	4,077[a]	786[a]	144[b]	25
	-	BanMaetaeng		4,274	1,588	486	25
	-	Khilek		9,009	3,878	518	25
Irrigated area with dike dam	1,296[b]	Tawangtan	Sarapee	9,292	2,126	788	25
		Nongfang		5,280	1,824	1,530	25
		Yangnueng		12,344	3,086	1,029	25
Irrigated area with storage dam	11,200[b]	Nongjom	Sansai	15,603	7,241	650	25
		Sansainoi		16,453	6,947	495	25
		Sansailuang		6,609	2,522	582	25
Total Samples							225

Source: data in 2010 from http://agtech.doae.go.th

Note: Irrigation area 1 ha = 6.25 rai

[a] = source www.thaitambon.com,

[b]= source data in 2009 from http://maetaeng.chiangmai.doae.go.th

Secondary data

The secondary data consisting of mainly socio-economic condition, physical environment, marketing information and other issues related to water resource management was collected. Another data was reviewed and analyzed from relevant government offices at central and local levels, relevant private and public organization

4.2 Descriptive analysis

The socio-economic analysis was based on statistic methods such as methods of exploratory data analysis, descriptive statistics. The calculations of descriptive parameters as well as some statistical analyses were used EXCEL. Methodology according to the theory in order to assess water management in Ping watershed:

Increasing of income: indicated by farm income and labour employment

Optimization of agriculture resource: indicated by price and yield risk

Considering of production constraints or parameters: capital, labour, water, land (scarcity of resources)

4.3 Quantitative analysis

Analysis of benefit was used to assess the economic efficiency of water used in different water resource management systems. The multi-objective model was used to determine factors affecting decision making about water use and management. These techniques are used widely to solve multi-objective and multi-resource decision making problems where conflicts exist among different objectives (Xevi E., Khan S., 2005). The multi-objective has been used extend the field of applications, as well as to have enlarged our knowledge of a real decision making process and decision-maker' objectives, especially in the field of agricultural enterprises (Berbel J., Rodriguez-Ocana A., 1998, Xevi E., Khan S., 2005).

The solution by using two analytical steps:

First step: data analysis by single objective optimization in linear programming (LP) for each objective includes in farm income, labor employment, price risk, and yield risk.

Second step: getting the outcomes from linear programming – 1. through the multi-objectives model 2. by Goal programming through minimization of objectives.

4.4 Linear Programming Model

Model specification

Variables

Each farmer has a set of variables X_i (crops). These are the decision variables that can assume any value belonging to the feasible set. The economic values of the crops resulted from the agricultural indicators form the survey data.

Objectives

Four objectives have been specified for the case illustrated here:

i) maximization of farm income

ii) maximization of hired labor employment

iii) minimization of price risk

iv) minimization of yield risk

Formulation of single objective

Objective 1: Maximization of farm income (FI)

The farm income under different crops is obtained by subtracting total variable costs (hired labor cost, fertilizer, pesticides, irrigation and other costs) from gross revenue (Francisco R.S. and Ali M., 2006).

$$MaxFI = \sum (R_i - C_i) X_i, \quad i = 1, 2, \dots, n \qquad (1)$$

Where: FI..…farm income of crop

R_i …. benefit from crop i;

C_i …. total variable costs incurred in the production of crop i;

X_i…...the area allocated to production of crop i;

i …. the crop index.

Objective 2: Maximization of hired labor employment

The intensity of production as well as the absence of mechanical means to perform most of the operations involved in vegetable production results in a large share of hired labor cost to total variable cost (Francisco R. S. and Ali M., 2006).

$$MaxHL_i = \sum HL_i = \sum (TL_i - FL_i) X_i \qquad (2)$$

Where: HL_i …. hired labour requirement of crop i;

TL_i …. total labour requirement of crop i;

FL_i …. family labour available for crop i;

X_i…....the area allocated to production of crop i;

i ….. the crop index.

Objective 3 and 4: Minimization of price risk and yield risk

An economically feasible production plan must pose minimum risk to farmers. The minimum risk comes from variable weather condition, insect pests and diseases, and changes in prices and other market conditions that cause high variability in farm income realized by farmers in production (Francisco R. S. and Ali M., 2006), total income variance of income derived in the production of crop i with net return, R_i, can be formulated as a quadratic formula given by

$$V(I) = \sum\sum \sigma_{ij} X_i X_j, \quad i,j = 1, 2, \ldots, n \tag{3}$$

Where: V(I)…total income variance

σ_{ij} ... Variance-covariance matrix of net income derived from the production of crop *i*;

X_i... the column vector of the area allocated to production of crop *i*;

X_j.. the row vector of the the area allocated to production of crop *j;*

i ... the crop index in the column vector;

j ... the crop index in the row vector.

Minimization of total income variance can then be expressed as:

$$MinV(I) = Min\sum\sum \sigma_{ij} X_i X_j \quad i,j=1,2, \ldots,n \tag{4}$$

Two sources of the minimum risk include: price induced by the minimum risk and yield induced by the minimum risk on the income. The price induced by the minimum risk is associated with the availability of the product in the market that is observed from year to year. The yield induced by the minimum risk is associated with the stability of yield of the crops from year to year.

The set of objective functions is constrained by availability of resources of vegetable farmers. These resources include: land, capital, labour, fertilizers, pesticides and irrigation water.

Constraints: will impose on the model include as follows:

1) Land: sum of all crop areas is equal to the total available area. The total land used for different crops at any time cannot exceed the total available land. The land allocated to a crop remains unchanged from the time of sowing to time of harvesting (Singh R. et al, 1987).

2) Labour: amount of family working labour is used as the upper limit of family labour constraints. The family working labour is assumed to be equal in each month. Hired labour is assumed to be unlimitedly available.

3) Capital: sum of all crops requiring capital is equal to the total available capital, earned incomes through sales of crops and available one unit of loan in each season.

4) Irrigation water: total water use in the irrigation areas should not exceed the total allocation in a given month. (E. Xevi and S. Khan, 2005).

$$TWREQ = \sum_c (X_c WREQ_{cm}), \quad m=1,\ldots,12 \qquad (5)$$

Where: TWREQ …. total water requirements of all crops per month;

WREQ ….. each crop of water requirements per month;

X_c…… the area allocated to production of crop *c*;

c ….. the crop index;

m...... months of the year.

However, the crop water requirements per month *WREQ (c, m)* may be estimated as a function of the crop coefficient, crop growth duration, evapo-transpiration and rainfall using climatic data or based on water balance techniques.

$$\sum_c (X_{(c)} WREQ_{(c,m)}) \le Allocation(m), \quad m=1,\ldots,12 \qquad (6)$$

The water requirements in this paper are assumed as the excess from evapo-transpiration over rainfall. Requirements for leaching of salts or pre-irrigation are not considered. The fraction of growth period in a given month for a given crop (*d_ratio (c, m)*) is given by:

d_ratio (c,m) = G_duration (c, m)/days(m)

Where: *G_duration(c,m)* …. growth duration of crop *c* in one month *m*;

days (m) …. number of days in one month *m*.

The crop water requirements are evaluated as follows:

$WREQ(c,m) = k_a(c,m) d\_ratio \times ET(m) - d\_ratio(c,m) Rain(m)$

Where: $k_a(c,m)$ …. crop coefficient of crop *c* in month *m* and *ET (m); Rain (m)* …. evapo-transpiration and rainfall in one month m.

where Allocation(m) = monthly water allocation for irrigation areas(ML)

5) Commodity balance: crop products can be sold in the market or consumed by the family.

Activities included in the model are as follows:

1) Farm activities: farming activities for each farming system are more or less the same. The crop activities consist of rice, other annual crops and vegetables (Sattarasart A., 1999).

2) Labour activities: family labour can be used within the farm to fulfil own requirements and for off-farm activities, too. The family labour for household activities is also required. Hired labour is allowed in order to increase labour supply (Kitchaichareon J., 2003).

3) Credit activities: two forms of credit are available in the model, formal and informal credit. The short term (one year) formal credit is allowed for the household. The informal credit comes from traders or other informal institutes and the long term (ten year) formal credit is allowed for the household from formal credit.

4) Water activities: water required for crop production is obtained from the available surface water resource which is available in each month (Singh R. et al., 1987).

5) Market: yield of all crops can be sold in the market at which the farmers can get market price in the period 2010/2011. The model put an average price of cultivation of these crops.

The basic models are constructed to represent the three water resources management groups in the study area. The data are based on a field survey carried out in 2010/11. The coefficients consider the input-output relations observed in each group. The general structure of the basic model is presented (Figure 8). Detail of the full model structure, which includes activities, constraints. (Mcgregor M.J. and Dent J.B., 1993).

Activities	Crop production	Land rent	Hired Labor	Loan	Saving consumption rice	Selling Yield	Crop balance	Right Hand Side (RHS)
Objective	a_{ij}							
Resource Constraints								
Land	1	-1						<=bi
Land rent		1						<=bi
Family labor	a_{ij}		-1					<=bi
Investment	a_{ij}		a_{ij}	-1				<=bi
Loan				1				<=bi
Water using	a_{ij}							<=bi
Yield balance	$-a_{ij}$				1	1		=0
Crop balance		$-a_{ij}$		$-a_{ij}$		a_{ij}	-1	=0

Figure 8 General structure of the basic farm household-family of linear programming model

4.5 Goal Programming Model

A multi-criteria Mathematical Programming model (MMP) has been developed to support the spatial development planning process. The model achieves the optimum farm plan in the area combining different criteria to a utility function under a set of constraints concerning different categories of land, labor, available capital, etc.

This methodology has been successfully implemented on real agricultural systems for water pricing (Shajari S. et al, 2008; Saravia P.J. et al, 2007; Gomez-Limon et al, 2000; Ballestero E. et al, 2002); for water agricultural policy (Latinopoulos D., 2009; Gomez-Limon et al, 2002, 2003, 2006; Latinopoulos D., 2008) for cropping pattern planning (Fasakhodi A.A. et al, Ahmed et al, 2006; Francisco R.S. et al, 2006; Manos B. et al, 2010; Wei et al, 2009) for water resource management (Sharma K.D. et al, 2006; Mansoori H. et al, 2009; Uri 1983, Bravo M. et al, 2009)

Description of goal programming model in different farming system

4.5.1 The structure of goal programming model

The multi objective model has to use the linear programming for analysis data and then get each objective to set on the multi objective model by weighted goal programming. The irrigated area with storage dam model decides the equal important of environmental and socio-economic which have 5 objectives and the weighted is equal below the formulation.

$$Minimize \sum_{g=1}^{5} \left(w_g d_g^- - \ w_g d_g^+ \right)$$

Subject to

$$c_{gj} X_j + d_g^- - d_g^+ = e_g$$

$$a_{ij} X_j \leq b_i$$

$$X_j, d_g^-, d_g^+ \geq 0$$

Where

g = objectives include in 1, 2, 3, 4, 5 objectives

d_g^- = deviation of objective g which the lower goal in the model

d_g^+ = deviation of objective g which the upper goal in the model

w_g = weighted of objective g

X_j = crop production in j

a_{ij} = coefficient of constraint j and activity j

b_i = constraint at j

c_{gj} = factor at objective g

e_g = the goal at objective g

Detail of the full model structure, which includes activities, constraints and 4 categories of goals (Figure 9)

Activities	Crop production	Land rent	Hired Labor	Loan	Saving consumption rice	Selling Yield	Crop balance	Social Max Hired Labor	Economic Risk Price	Economic Risk Yield	ENV Water	Economic Max Income	Social Max hired labor	Economic Risk Price	Economic Risk Yield	ENV Water	Economic Max Income	Right Hand Side (RHS)
Objectives												a_{ij}	a_{ij}	a_{ij}	a_{ij}	a_{ij}		
Resource Constraints																		
Land	1	-1																<=bi
Land rent		1																<=bi
Family labor	a_{ij}		-1															<=bi
Investment	a_{ij}		a_{ij}	-1														<=bi
Loan				1														<=bi
Water using	a_{ij}																	<=bi
Yield balance	$-a_{ij}$				1	1												=0
Crop balance		$-a_{ij}$		$-a_{ij}$		a_{ij}	-1											=0
Social Max Hired Labor	a_{ij}							1					-1					=bi
Economic Risk Price	a_{ij}								1					-1				=bi
Economic Risk Yield	a_{ij}									1					-1			=bi
ENV Water	a_{ij}										1					-1		=bi
Economic Max Income	a_{ij}											1					-1	=bi

Figure 9 General structure of the basic farm household-family of goal programming model

4.5.2 Irrigated area with storage dam model

The irrigated area with storage dam model includes in activity and constraint which activities show in 45 columns and constraint show in 44 rows.

Activities

X_1 - X_9 means crops production activity consist of the in-season rice, the off-season rice, chili, pak choi, cauliflower, long bean, soy bean, sweet corn, and cabbage (unit: rai)

X_{10} means land rent activity (unit: rai)

X_{11} – X_{21} means hired labor activity in 11 months of the year except May (unit: man-day)

X_{22} – X_{24} means loan activity consist of Bank for Agriculture and Agricultural Co-Operatives (BAAC), Co-operatives, and Village Fund (unit: baht)

X_{25} – X_{34} means yield activity include in saving consumption the in-season rice for household and other crops for selling in the market (unit:kilogram)

X_{35} means net income balance (unit: baht)

X_{36} means negative deviation of hired labor

X_{37} means negative deviation of risk price

X_{38} means negative deviation of risk yield

X_{39} means negative deviation of water using

X_{40} means negative deviation of income

X_{41} means positive deviation of hired labor

X_{42} means positive deviation of risk price

X_{43} means positive deviation of risk yield

X_{44} means positive deviation of water using

X_{45} means positive deviation of income

Constraints

R_1 means constraints of land use for cultivation include in own land and free land (unit: rai)

R_2 means constraints of rent land (unit: rai)

$R_3 – R_{13}$ means constraints of family labors work in 11 months except May for agricultural activities which the household can use all activities less than family labors man-day (unit: man-day)

R_{14} means constraints of investment crops from own cash and loan all year (unit: baht)

R_{15} means constraints of loan from Bank for Agriculture and Agricultural Co-Operatives (BAAC) (unit: baht)

R_{16} means constraints of loan from Co-Operatives (unit: baht)

R_{17} means constraints of loan from Village Fund (unit: baht)

$R_{18} – R_{28}$ means constraints of water using in 11 months for crops production except May (unit:m^3)

R_{29} means constraints of the in-season rice (unit: kilogram)

R_{30} means constraints of the saving consumption in-season rice which it have to enough for all year of household (unit: kilogram)

$R_{31} – R_{38}$ means constraints of yields consist of the off-season rice, chili, pak choi, cauliflower, long bean, soy bean, sweet corn, cabbage (unit: kilogram)

R_{39} means balance income (unit: baht)

R_{40} means first objective of social is max hired labor

R_{41} means second objective of economic is price risk

R_{42} means third objective of economic is yield risk

R_{43} means fourth objective of environment that is water using

R_{44} means fifth objective of economic that is income

4.5.3 Irrigated area with dike dam model

The irrigated area with dike dam model includes in activity and constraint which activities show in 55 columns and constraint show in 51 rows.

Activities

$X_1 – X_{13}$ means crops production activity consist of the in-season rice, the off-season rice, chili, pak choi, long bean, morning glory, coriander, celery, green shallot, spinanch, lettuce, sugar cane, and longan (unit: rai)

X_{14} means land rent activity (unit: rai)

$X_{15} – X_{26}$ means hired labor activity in 12 months of the year (unit: man-day)

$X_{27} – X_{30}$ means loan activity consist of Bank for Agriculture and Agricultural Co-Operatives (BAAC), Co-operatives, Village Fund, and Government

Savings Bank (GSB) (unit: baht)

$X_{31} – X_{44}$ means yield activity include in saving consumption the in-season rice for household and other crops for selling in the market (unit:kilogram)

X_{45} means net income balance (unit: baht)

X_{46} means negative deviation of hired labor

X_{47} means negative deviation of risk price

X_{48} means negative deviation of risk yield

X_{49} means negative deviation of water using

X_{50} means negative deviation of income

X_{51} means positive deviation of hired labor

X_{52} means positive deviation of risk price

X_{53} means positive deviation of risk yield

X_{54} means positive deviation of water using

X_{55} means positive deviation of income

Constraints

R_1 means constraints of land use for cultivation include in own land and free land (unit: rai)

R_2 means constraints of rent land (unit: rai)

$R_3 – R_{14}$ means constraints of family labors work in 12 months for agricultural activities which the household can use all activities less than family labors man-day (unit: man-day)

R_{15} means constraints of investment crops from own cash and loan all year (unit: baht)

R_{16} means constraints of loan from Bank for Agriculture and Agricultural Co-Operatives (BAAC) (unit: baht)

R_{17} means constraints of loan from Co-Operatives (unit: baht)

R_{18} means constraints of loan from Village Fund (unit: baht)

R_{19} means constraints of loan from Government Savings Bank (GSB) (unit: baht)

$R_{20} – R_{31}$ means constraints of water using in 12 months for crops production (unit:m^3)

R_{32} means constraints of the in-season rice (unit: kilogram)

R_{33} means constraints of the saving consumption in-season rice which it have to enough for all year of household (unit: kilogram)

$R_{34} – R_{45}$ means constraints of yields consist of the off-season rice, chili, pak choi, long bean, morning glory, coriander, celery, green shallot, spinach, lettuce, sugar cane, and longan (unit: kilogram)

R_{46} means balance income (unit: baht)

R_{47} means first objective of social is max hired labor

R_{48} means second objective of economic is price risk

R_{49} means third objective of economic is yield risk

R_{50} means fourth objective of environment that is water using

R_{51} means fifth objective of economic that is income

4.5.4 Rainfed area model

The rainfed area model includes in activity and constraint which activities show in 49 columns and constraint show in 48 rows.

Activities

$X_1 – X_{10}$ means crops production activity consist of the in-season rice, long bean, marigold, maize, sweet corn, tobacco, galangal, lemon grass, banana, and longan (unit: rai)

X_{11} means land rent activity (unit: rai)

$X_{12} – X_{23}$ means hired labor activity in 12 months of the year (unit: man-day)

$X_{24} – X_{27}$ means loan activity consist of Village Fund, Bank for Agriculture and Agricultural Co-Operatives (BAAC), Co-operatives, and Finance (unit: baht)

$X_{28} – X_{38}$ means yield activity include in saving consumption the in-season rice for household and other crops for selling in the market (unit:kilogram)

X_{39} means net income balance (unit: baht)

X_{40} means negative deviation of hired labor

X_{41} means negative deviation of risk price

X_{42} means negative deviation of risk yield

X_{43} means negative deviation of water using

X_{44} means negative deviation of income

X_{45} means positive deviation of hired labor

X_{46} means positive deviation of risk price

X_{47} means positive deviation of risk yield

X_{48} means positive deviation of water using

X_{49} means positive deviation of income

Constraints

R_1 means constraints of land use for cultivation include in own land and free land (unit: rai)

R_2 means constraints of rent land (unit: rai)

$R_3 – R_{14}$ means constraints of family labors work in 12 months for agricultural activities which the household can use all activities less than family labors man-day (unit: man-day)

R_{15} means constraints of investment crops from own cash and loan all year (unit: baht)

R_{16} means constraints of loan from Village Fund (unit: baht)

R_{17} means constraints of loan from Bank for Agriculture and Agricultural Co-Operatives (BAAC) (unit: baht)

R_{18} means constraints of loan from Co-Operatives (unit: baht)

R_{19} means constraints of loan from Finance (unit: baht)

$R_{20} – R_{31}$ means constraints of water using in 12 months for crops production (unit:m^3)

R_{32} means constraints of the in-season rice (unit: kilogram)

R_{33} means constraints of the saving consumption in-season rice which it have to enough for all year of household (unit: kilogram)

$R_{34} – R_{42}$ means constraints of yields consist of long bean, marigold, maize, sweet corn, tobacco, galangal, lemon grass, banana, and longan (unit: kilogram)

R_{43} means balance income (unit: baht)

R_{44} means first objective of social is max hired labor

R_{45} means second objective of economic is price risk

R_{46} means third objective of economic is yield risk

R_{47} means fourth objective of environment that is water using

R_{48} means fifth objective of economic that is income

5. Results and Discussions

5.1 Attribute of water resource on farming system in Ping watershed area

5.1.1 Water resource in storage dam is Mae Kuang Dam, Sansai district, Chiangmai province

Mae Kuang Udomtara Reservoir is located in Doi Saket district, Chiangmai province at 18˚ 56’ 54’’ North and longitude 99˚ 7’ 77’’ East. The altitude is 350 m above sea level. The reservoir has 569 km^2 catchment area, 11.8 km^2 surface of water area and 40-45 m in depth. The capacity of reservoir is 263 million m^3. It was constructed in 1991. There are 2 ways for water inflows, which are Huay Mae Kuang and Huay Mae Lai. Mae Kuang Udomtara reservoir is very important because it is main public water supply for Chiangmai Province. There are 2 main canals for water outflow. One canal release water to Doi Saket and San Kampaeng districts of chiangmai province, and Ban Thia and Muang districts of Lamphun province in total are 88,690 rais (Figure 10). The last canal release water to agriculture land in Sansai district of chiangmai province in 11,560 rais (Vijaranakorn T., 2003).

	
The main canal with water gate from Mae Kuang Dam	The main canal from Mae Kuang Dam

	
The concrete main canal	The small concrete canal to farm

Figure 10 Water resource in storage dam is Mae Kuang Dam

5.1.2 Water resource in dike dam is Tawangtan Muang Fai, Sarapee district, Chiangmai province

Tawangtan Muang Fai at M.1 Tawangtan subdistrict, Sarapee district, Chiangmai province, is the local comunitiy munag fai by farmers. The construction is the barrier of Ping river and control water resource to their farm by ground canal (Figure 11). The water user group have 5,000 household member and irrigated area approximately 8,600 rai cover in 3 subdistricts include in Tawangtan, Donkaew and Nongfag. The water allocation of Tawangtan Muang Fai relay of water through farm. In this case for the farmers get the less water resource of cultivation thus they have to allocate the water resource during the main canal but the farmers in the branch canal do not to share the water resource. Because of in the branch canal have a few water users. Tawantang Muang Fai is the barrier Ping river for controlling the water resource through the 4 main canals such as Muang Bok Kok, Munag Sang Aon, Muang Dong and Muang Ku Dang in Chiangmai province (Yotapakdee T., 2004).

	
Tawangtan dike dam	Tawangtan dike dam
	
Canal digging	The earth canal to farm

Figure 11 Water resource in dike dam is Tawangtan Muang Fai

5.1.3 Water resource in rainfed area at Maetaeng district, Chiang Mai province

Water resource management in rainfed area, there is a correlation between poverty and water stress. An insight into the inventories of natural resources in rainfed regions shows a grim picture of water scarcity, fragile environments, drought and land degradation due to soil erosion by wind and water, low rainwater use efficiency (35-45%), high population pressure, poverty, and low investments in water use efficiency measures, poor infrastructure and inappropriate policies (Figure 12). Drought and land degradation are interlinked in a cause and effect relationship, and the two combined are the main causes of poverty in farm household (Wani P.S. et al., 2009).

	
Sub Watershed of the Upper Ping River	Canal from Sub Watershed of the Upper Ping River to farm
	
Shallow well on farm	Small reservoir of private management on farm

Figure 12 Water resource in rainfed area is Maetaeng district

5.2 Management in different farming system in Ping Watershed Part 2

5.2.1 Management in irrigated area with storage dam, Sansai district

Water resource management in irrigated area with storage dam includes modern structures and concrete canals. The infrastructure were installed the sluice gates which operated by machinery or manually in Royal Irrigation Department (RID) which it allow RID's system to distribute water within system with greater control (Figure 13).

Irrigation governance includes a set of simple rules explaining shared water rights and responsibilities in communication and management among local groups and with RID. An agreement for a board and flexible water allocation is made to divide water between the systems. With flexibility established allocation among different system naturally required close communication and negotiation after the first allocation. Shared information is also considered as important to all leaders who should report to all leaders, or call the meeting for adjustment of shares, or new development within each system (Tan Kim Yong U., 2001).

The water resource management in irrigated areas with storage dams required the farmers´ cooperation with Royal Irrigation Department (RID). The farmers established a water users´ group at the management of authorities of RID. The water users´ group got the policy and action plan from RID to practice on farms. The water users group was supposed to take responsibilities at field level which under the RID policy. Therefore, the decision-making responsibility depends on the annual action plan from RID.

	
Pumping water from main canal to farm	Branch canal to farm
	
Branch canal	Small concrete canal to farm

Figure 13 Management in storage dam

5.2.2 Management in irrigated area with dike dam, Sarapee district

The water resource management on irrigated areas provided with water gates, the farmers created a water users´ group within the same main canal. The structure of water management in irrigated area with dike dam is based on a set rotation schedule when water becomes restricted. The tail end of canal will get the water first then it moves along to the head end canal which in the case of water resource on farm is enough whole years. They have to share the water use on farms on each canal branch by the schedule worked out by the water users´ group, for example 3 days on one canal branch and 3 days on other canal branch, etc. Before the rainy season the water users´ group repaired its canals by cleaning and cutting weeds, dredging canals for easy water access to their farms. Because of most canals made of earth the weed makes serious barrier for water flowing to farms. The farmers have water resource management on their farms without management interventions for the part of Royal Irrigation Department (RID). The agreement for repairing, providing that the farmers have a few areas, they should supply less labor than the members have the large areas (Figure 14).

All water users' group participated and discussed about the system development. They made agreements and collective activities schedule under the leadership who is elected by the member. The members must follow it. The rules have created in case of the lack of water. If some members violate the agreement, the leadership will charge the forfeit indicated the agreement.

The triangular social relation between the farmers, the delegate and the manager supported the equilibrium of the management structure. The manager worked with the village irrigation delegates in exchanging and cross checking regional hydraulic, biological and human information to lay the groundwork for creating a joint irrigation management plan (Ounvichit T., 2008)

	
The branch canal to farm	The small canal on farm
	
Small reservoir and poultries on farm	Small reservoir on farm

Figure 14 Management in irrigated area with dike dam

5.2.3 Management in rainfed area, Sansai district

The importance of rainfed agriculture varies regionally, but most of food for poor communities in developing countries is produced in rainfed agriculture which some 58 percent of farm land is rainfed area in South Asia (FAO, 2002). Investments in rainfed agriculture have large payoffs in yield improvement and poverty alleviation through income generation and environment sustainability (Pradhan S., 2007).

Almost of farmers cultivated the annual crops which they used the less water demanding crops. The farmers prevented the scared water by small reservoir, shallow groundwater and water tank in their farm for saving water for dry season. On the other hand, the water security on farm is the useful to decide the cultivation in next year.

There is the water resource management in rainfed area at 3 types. The first private management, farmers do not want to share water with other farmers. They can invest on their farm by themselves such as water tank, small reservoir etc. but the the size of water saving depends on their capital (Figure 15).

The second relative management, farmers in one zone is the relatives who have the farm nearby together which they can get the trust and confident together in their farms zone. It is easy to allocate, manage and develop by talking for solving the problem or invest the water security on their farm. The size of water saving have the bigger than private management because the farmers amass money for building the security water system on center for sharing to their farm.

The last community management, farmers in one zone is the neighbor farms who have the farm nearby together. They have the assist from the government because the community management is the big project for saving water for everybody in community. Thus the head of community must to write the project to government and they can get the budget by annual action plan in their community for invest the security water such as the big water reservoir, water supply from the ground water well.

Investments in rainfed agriculture can improve environmental sustainability. Poor management of rainwater in rainfed systems generates excessive runoff, causing soil erosion and poor yields due to a shortage of soil moisture. Investments to maximize rainfall infiltration and the water-holding capacity of soils minimize land degradation while increasing the water available in the soil for crop growth (Pradhan S., 2007).

	
Pumping water from canal to farm	Shallow well on farm

	
Private reservoir on farm	Reservoir of relative management
	
Reservoir of neighbor management	Reservoir of public in subdistrict

Figure 15 Management in rainfed area

5.3 Socio-economic analysis of farm-household system

The family resources

The analysis of family resources provides a basic for an understanding of water resource and management within the past development of farming system and the current situation. Moreover, the structure of the family influences the decision making process of water resource and management. Family resources can be used in the farm and off farm activities to generate income. Family resources almost compose of land, labor, capital, knowledge and water. Water resource can be used in the farm as well as household.

Family Members

The both of average household size between household in rainfed area and irrigated area with storage dam were 4 persons per family and the average of family labor was 2 persons per family. In contrast the average household size in irrigated area with dike dam was 3.39 persons per household and the average of family labor was 2.24 persons per household.

The ratio of men household heads were among 63-82.67 percent and the rest of women household heads who mainly took over the responsibility of the household after the death of their husbands. The average age of household head were surrounding 52-55 years old and most of the household heads had finished the primary school level between 81.33 to 90.67 percent. The rest of household head had finished the high school, bachelor's degree and at least 2.67-5.33 percent had not finished education (Table 7).

Table 7 Family size and household head information

Household head information	**Rainfed area**		**Irrigated area with dike dam**		**Irrigated area with storage dam**	
Household		**Percentage**		**Percentage**		**Percentage**
Mean age (year)	52		54.11		55	
Education level						
No education	4	(5.33)	-	-	2	(2.67)
Primary school	61	(81.33)	68	(90.67)	67	(89.33)
High school	9	(12)	5	(6.67)	5	(6.67)
Bachelor's degree	1	(1.33)	2	(2.67)	1	(1.33)
Number male	47	(63)	54	(72)	62	(82.67)
Number female	28	(37)	21	(28)	13	(17.33)
Family information						
Mean number of family member	4		3.39		4	
Mean number of family labor	2		2.24		2	

Source: by survey

Land Resources

Land Availability and Farm Size

In irrigated area with dike dam and rainfed area were not significant difference of land size at 5.69-6 rai but in the irrigation system was 8 rai. The land tenure in rainfed area was 6 rai of own land and rent land. In irrigated area with dike dam was 4.15 rai of own land, the rent land was 7.28 rai and the land without charge was 3.3 rai. In irrigated area with storage dam was 5 rai of own land, rent land at 10 rai and land without charge at 6 rai (Table 8). Not only own land is used in the farm activities, but also rented land and land used at no charge. The rent is usually paid by cash. The land without charge is normally got from the parents or cousin. A reason for renting land is the lack of land resources but they will rent it for producing and to earn some income. The price of renting land depends on the location and water sources.

Table 8 Land size and land tenure

Land information	Rainfed area	Irrigated area with dike dam	Irrigated area with storage dam
Land size (rai) Average total land	6	5.69	8
Land tenure (rai)			
Own land	6	4.15	5
Rent land	6	7.28	10
Land without charge	9	3.3	6

Source: by survey

Note: 1 ha = 6.25 rai

Crop production

Crop production plays the most important role in the study area, than livestock production. The important crops in the study area rice, vegetables, marigold, maize, sweet corn, tobacco, galangal, lemon grass, chili as annual crops and banana, sugar cane, longan as perennial crops. The analysis of crop production includes cropping pattern, cropping systems as well as benefit analysis. The differences in cropping patterns depend not only on the water source but also on the soil characteristics and topography (upland and lowland areas).

Cropping patterns

At the cropping patterns in 2010/2011 (Table 9) in rainfed area at Mae taeng district, the farmers' cultivated annual crops include in rice, long bean, marigold, maize in rainy season and sweet corn, tobacco in dry season. The cultivation all year are galangal, lemon grass, banana and longan. In this area, there is the constraint in water using on farms because most of crops have to plant in rain season starts in June to October , but in dry season in November to May, the farmers selected the crops for using the water less than rain season crops.

The principal crops in irrigated areas by dike dam in Sarapee district are the in-season rice in rain season and follow by the off-season rice, vegetables and sugar cane. The rain season starts June until September and the dry season among October to May year after year. The vegetables can plant all year which include in 8 types pak choi, morning glory, celery, green shallot, lettuce, long bean, spinach and chili because they use the short time of crops which is crucial for efficient land use planning. Significant areas are planted with perennials (longan)

The main crops in irrigated areas by storage dam in Sansai district are the in-season rice in rain season and follow by the off-season rice, pak choi, long bean, cauliflower, soybean, cabbage, sweet corn and chili. The structure of cultivation is quite the same with the irrigated area by dike dam in Sarapee district.

Table 9 Cropping pattern in 2010/2011 in Ping watershed, Chiangmai Thailand

	Jun	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Rainfed area												
Rice		←	—	—	—	→						
Long bean	←	—	→									
Marigold	←	—	—	→								
Maize	←	—	—	—	—	—	→					
Sweet corn, Tobacco							←	—	—	→		
Galangal, Lemon grass,	←	—	—	—	—	—	—	—	—	—	—	→
Banana	←	—	—	—	—	—	—	—	—	—	—	→
longan	←	—	—	—	—	—	—	—	—	—	—	→
Irrigated area with dike dam												
Rice		←	—	—	—	→	←	—	—	→		
Pak choi, Morning glory, Celery, Green shallot, Coriander Lettuce	←	→		←	→		←	→		←	→	
Long bean, Spinach	←	—	→		←	—	→		←	—	→	
Chili	←	—	—	—	—	—	—	—	—	→		
Sugar cane	←	—	—	—	—	—	—	—	—	→		
longan	←	—	—	—	—	—	—	—	—	—	—	→
Irrigated area with storage dam												
Rice		←	—	—	—	→	←	—	—	—	→	
Pak choi	←	→		←	→		←	→		←	→	
Long bean	←	—	→		←	—	→		←	—	→	
Cauliflower, Soy bean, Cabbage							←	→				
Sweet corn							←	—	—	—	→	
Chili	←	—	—	—	—	—	—	—	—	→		

Source: by survey

Animals kept in households

Most of the farmers in Ping watershed area about animal kept in household (Table 10) have chickens in household which in the irrigated area with dike dam have chickens farm. So the farmers have chickens average of selling approximately 228 no. On the other hand, in rainfed area and irrigated area with storage dam have average during 17-26 no. Ducks did not appear in rainfed area but most of ducks in irrigated area with storage dam is approximately 45 no. per household and the objective for selling. In irrigated area with dike dam, ducks average 8 no. per household and selling half of duck no. per year. Pigs and cattle have the objective for selling of household. In Ping watershed, the farmers call pigs and cattle is a piggy bank. Most of pigs are 1-2 no. per household with crop by crop in during 4-9 no. per crop. Most of cattle are 22 no. per household in irrigated area with storage dam but average no. of cattle 4-6 no. per household.

Table 10 Number of animals kept per family and its benefit analysis in Ping watershed, Northern Thailand

	Rainfed area	**Irrigated area with dike dam**	**Irrigated area with storage dam**
Chickens			
No. of household	8	30	20
Average no. of chickens per household	49	234.77	46.90
Average of selling	26.67	228.33	17.20
Average of consumption	9.75	6.89	1.75
Ducks			
No. of household	-	2	11
Average no. of ducks per household	-	8	45.45
Average of selling	-	4	43
Average of consumption	-	-	1
Pigs			
No. of household	2	2	1
Average no. of pigs per household	9	5	4
Average of selling	7	5	4
Average of consumption	-	-	-

Cattle			
No. of household	2	4	22
Average no. of cattle per household	4.5	6.25	4.68
Average of selling	1	5.25	3.41
Average of consumption	-	-	-

Source: by survey

Non-agricultural income and expenditure of household

The farmers in irrigated area can earn income from agriculture among 107,393 baht/household/year is irrigated area with storage dam and 112,399 baht/household/year is irrigated area with dike dam. Farmers in rainfed area can earn income lower than irrigated area that is 88,868 baht/household/year (Table 11). The non-agriculture comes from employee, commerce, money from son or daughter and other respectively.

The expenditure between rainfed area (57,526 baht/household/year) and irrigated area with storage dam (63,862.91 baht/household/year). In irrigated area with dike dam have the highest of expenditure is 81,281.87 baht/household/year.

Table 11 Non-agricultural income and expenditure of household

	Rainfed area	**Irrigated area with dike dam**	**Irrigated area with storage dam**
Non-agriculture income (baht)	88,868.75	112,399.34	107,393
Commerce (percentage)	(17.33)	(21.33)	(21.33)
Employee (percentage)	(61.33)	(61.33)	(37.33)
Handicraft (percentage)	-	-	(1.33)
From son or daughter (percentage)	(10.67)	(16)	(10.67)
Other (percentage)	(10.67)	(1.33)	(29.33)
Expenditure (baht)	57,526	81,281.87	63,862.91

Source: by survey

Note: 1 USD = 30.78 baht

Finance

The main loan comes from Bank for Agriculture and Agricultural Cooperatives (BAAC), Cooperatives, Village fund respectively. Most of loan is short time around 1 year which farmers have to borrow from finance institution for agriculture activity such as plowing, planting, buying fertilizer or pesticide, harvesting etc. The interest rate is similar in the Ping watershed at Northern Thailand. Farmers in irrigated area loaned from BAAC among 144,761-175,545 baht per year, on the other hand the farmers in rainfed area loaned less than farmers in irrigated area that loaned BAAC 90,000 baht per year (Table 12).

Table 12 Finance

Finance	Rainfed area (baht)	Interest rate (percent)	Irrigated area with dike dam (baht)	Interest rate (percent)	Irrigated area with storage dam (baht)	Interest rate (percent)
BAAC	90,000	7	144,761.9	7	175,545.45	7
Cooperatives	60,000	8	115,000	8	75,500	8
Village fund	22,000	6	15,625	6	17,500	6
GSB	-	-	82,500	9	-	-
Finance	18,000	7	-	-	-	-

Source: by survey

Note: 1 USD = 30.78 baht

5.4 The suitable cropping pattern by multi objective

5.4.1 The result of multi objective in irrigated area with storage dam, Sansai district

Cultivation activity

The suitable cropping pattern by model should plant the off-season rice (December-April) 4 rai and pak choi 3.77 rai can plant all year because it has a short time around 2 months for cultivation. Sweet corn should plant 1.44 rai in December-April and cauliflower 2.89 rai, soy bean 4 rai, cabbage 3.9 rai in December-January. The model suggest to farmers to rent land at 1.85 rai. The maximization of benefit on farm under constraints and activities is 592,964.55baht (Table 13).

Hired labor activity

The suitable cultivation suggests the hired labor for plowing and planting in August in irrigated area with storage dam. The family labor is not enough for cultivation activity that the household should hire labor for helping them in August should hire labor 862.94 man-day (Table 13).

Investment activity

The farmers at irrigation system in Sansai district have the own investment amount of 127,569.62 baht/year which it is not enough for cultivation all year by the suitable model. Thus, they have to borrow money from Co-operatives around 26.40 baht (Table 13).

5.4.2 The result of multi objective in irrigated area with dike dam, Sarapee district

Cultivation activity

The suitable cropping pattern should plant the in-season rice 1.58 rai in July-November. Coriander 2.16 rai and celery 1.14 rai can plant all year because it has a short time around 2 months for cultivation. Long bean 0.01 rai can plant 3 crops per year include in first crop in June-August, second crop in October-December, and the third crop in February-April. The model advised to have sugar cane 2.7 rai, so the maximization of benefit on farm under constraints and activities is 274,655.20 baht (Table 14).

Hired labor activity

The family labors are enough for plowing, planting and harvesting in irrigated area with dike dam all year. Therefore, they do not want to hire labor on farms by the model suggestion (Table 14).

Investment activity

The farmers in irrigated area with dike dam at Sarapee district have the own investment amount of 127,569.62 baht/year which it is enough for cultivation all year by the suitable model. Thus, they have not to borrow money from finance institution (Table 14).

5.4.3 The result of multi objective in rainfed area, Maetaeng district

Cultivation activity

The annual crops are a suitable cultivation activity which should plant long bean 9.86 rai in June-August and marigold 1.37 rai in June-September. The model advised to plant sweet corn 1.07 rai and tobacco 0.01 rai in the same period (December-March). Galangal 1.2 rai and banana 0.01 rai both of them can plant all year so farmers can follow the cropping pattern model, they can earn the maximization of benefit on farm under constraints and activities is 555,759.64 baht (Table 15).

Hired labor activity

The suitable cultivation suggest to farmers in rainfed area should use only family labor on farm which it is enough for the new cultivation activity (Table 15).

Investment activity

The farmers in rainfed area at Maetaeng district have the own investment amount of 131,471.3 baht/year which it is not enough for cultivation all year by the suitable model. Thus, they have to borrow money from Village Fund 234.15 baht (Table 15).

Table 13 Results of multi objective in irrigated area with storage dam

List	Constraint	Value	Slack[a]
1) Land (rai)			
The off-season rice		4	
Pak choi		3.77	
Cauliflower		3.89	
Soy bean		4	
Sweet corn		1.44	
Cabbage		3.9	
Total land		21	
Own land	11	11	
Rent land	10	10	
2) Hired labor (baht)			
June		-	
July		-	
August		862.95	
September		-	
October		-	
November		-	
December		-	
January		-	
February		-	
March		-	
April		-	
May		-	
3) Investment (baht)			
Own investment	129,416.64	129,416.64	
BAAC	174,545.45	-	
Co-operatives	75,500	26.40	
Village Fund	17,500	-	
4) Benefit (baht)	**121,684.22**	**592,964.55**	

Source: by analysis

Note: 1 ha = 6.25 rai

1 USD = 30.78 baht

[a] = slack is the unused amount of a resource at any level of operation. It is associated with less than or equal to constraints.

Table 14 Results of multi objective in irrigated area with dike dam

List	**Constraint**	**Value**	**Slack**[a]
1) Land (rai)			
The in-season rice		1.58	
Long bean		0.01	
Coriander		2.16	
Celery		1.14	
Sugar cane		2.7	
Total land		7.59	
Own land	7.45	7.45	
Rent land	7.28	0.14	7.14
2) Hired labor (man-day)			
June		-	
July		-	
August		-	
September		-	
October		-	
November		-	
December		-	
January		-	
February		-	
March		-	
April		-	
May		-	
3) Investment (baht)			
Own investment	127,569.62	127,569.62	
BAAC	144,761.9	-	
Co-operatives	115,000	-	
Village Fund	15,625	-	
GSB	82,500	-	
4) Benefit (baht)	**117,433.35**	**274,655.20**	

Source: by analysis

Note: 1 ha = 6.25 rai

1 USD = 30.78 baht

[a] = slack is the unused amount of a resource at any level of operation. It is associated with less than or equal to constraints.

Table 15 Results of multi objective in rainfed area

List	Constraint	Value	Slack[a]
1) Land (rai)			
Long bean		9.86	
Marigold		1.37	
Sweet corn		1.07	
Tobacco		0.01	
Galangal		1.20	
Banana		0.01	
Total land		13.52	
Own land	15	13.52	1.48
Rent land	6	-	
2) Hired labor (man-day)			
June		-	
July		-	
August		-	
September		-	
October		-	
November		-	
December		-	
January		-	
February		-	
March		-	
April		-	
May		-	
3) Investment (baht)			
Own investment	131,471.27	131,471.27	
Village Fund	22,000	234.15	
BAAC	90,000	-	
Co-operatives	60,000	-	
Finance	18,000	-	
4) Benefit (baht)	**113,162.6**	**555,759.64**	

Source: by analysis

Note: 1 ha = 6.25 rai

1 USD = 30.78 baht

[a] = slack is the unused amount of a resource at any level of operation. It is associated with less than or equal to constraints.

5.5 Comparing the result of cropping pattern between the existing crops and the proposed (suitable) crop

5.5.1 Comparing the result of cropping pattern between the existing crops and the proposed (suitable) crop by model in irrigated area with storage dam, Sansai district

In the existing crops, farmers had cultivated a lot of plant compose of the in-season rice, the off-season rice, chili, pak choi, cauliflower, long bean, soy bean, sweet corn and cabbage which the advice of cropping pattern from the multi objectives model to should plant in the off-season rice (4 rai), pak choi (3.77 rai), cauliflower (3.89 rai), soy bean (4 rai), sweet corn (1.44 rai), and cabbage (3.9 rai) which get the benefit 592,964.55 baht (Table 16).

Table 16 Comparing the result of cropping pattern between the existing crops and the proposed (suitable) crop by model in irrigated area with storage dam, Sansai district

Crops	**Existing crops (rai)**	**Model cropping pattern (rai)**
The in-season rice	8.15	-
The off-season rice	8.60	4
Chili	2.25	-
Pak choi	2.5	3.77
Cauliflower	4.67	3.89
Long bean	4	-
Soy bean	3	4
Sweet corn	1	1.44
Cabbage	2.5	3.9
Benefit (baht)	121,684.22	592,964.55

Source: by analysis

Note: 1 ha = 6.25 rai

Note: 1 USD = 30.78 baht

5.5.2 Comparing the result of cropping pattern between the existing crops and the proposed (suitable) crop by model in irrigated area with dike dam, Sarapee district

In the existing crops, farmers had cultivated a lot of plant compose of the in-season rice, the off-season rice, chili, pak choi, long bean, morning glory, coriander, celery, green shallot, spinach, lettuce, sugar cane and longan. In the multi objectives model should plant the same area of the in-season rice (1.58 rai), long bean (0.01 rai), coriander (2.16 rai), celery (1.14 rai), and sugar cane (2.7 rai). If the farmers plant follow the multi objectives model the benefit increased 274,655.2 baht (Table 17).

Table 17 Comparing the result of cropping pattern between the existing crops and the proposed (suitable) crop by model in irrigated area with dike dam, Sarapee district

Crops	**Existing crops (rai)**	**Model cropping pattern (rai)**
The in-season rice	8.03	1.58
The off-season rice	5.95	-
Chili	0.625	-
Pak choi	0.96	-
Long bean	0.69	0.01
Morning glory	2.67	-
Coriander	2.10	2.16
Celery	2.50	1.14
Green shallot	0.50	-
Spinach	0.42	-
Lettuce	0.50	-
Sugar cane	3.59	2.7
Longan	3.60	-
Benefit (baht)	117,433.35	274,655.20

Source: by analysis

Note: 1 ha = 6.25 rai

Note: 1 USD = 30.78 baht

5.5.3 Comparing the result of cropping pattern between the existing crops and the suitable crop by model in rainfed area, Maetaeng district

In the existing crops, farmers had cultivated a lot of plant compose of rice, long bean, marigold, maize, sweet corn, tobacco, galangal, lemon grass, banana and longan which the advised of cropping pattern from in the multi objectives model should plant long bean (9.86 rai), marigold (1.37 rai), sweet corn (1.07 rai), tobacco (0.01 rai), galangal (1.2 rai), and banana (0.01 rai) which get the benefit 555,759.64 baht (Table 18).

Table 18 Comparing the result of cropping pattern between the existing crops and the proposed (suitable) crop by model in rainfed area, Maetaeng district

Crops	**Existing crops (rai)**	**Model cropping pattern (rai)**
The in-season rice	5.7	-
Long bean	1.75	9.86
Marigold	1.75	1.37
Maize	4.2	-
Sweet corn	4	1.07
Tobacco	6.78	0.01
Galangal	5	1.20
Lemon grass	1	-
Banana	5.8	0.01
Longan	6.06	-
Benefit (baht)	113,162.6	555,759.64

Source: by analysis

Note: 1 ha = 6.25 rai

Note: 1 USD = 30.78 baht

5.6 Summary of model cropping pattern under the socio-economic and environment conditions for sustainable development.

5.6.1 Benefit from model

The model cropping pattern recommended the crops on farms that the irrigated area with storage dam should plant the off-season rice, pak choi, cauliflower, soy bean, sweet corn, and cabbage. The farmers get the benefit 592,964.55 baht. In the irrigated area with dike dam should plant the in-season rice, long bean, coriander, celery and sugar cane which farmers get the benefit 274,655.20 baht. In rainfed area should plant long bean, marigold, sweet corn, tobacco, galangal and banana which farmers get the benefit 555,759.64 baht (Figure 16).

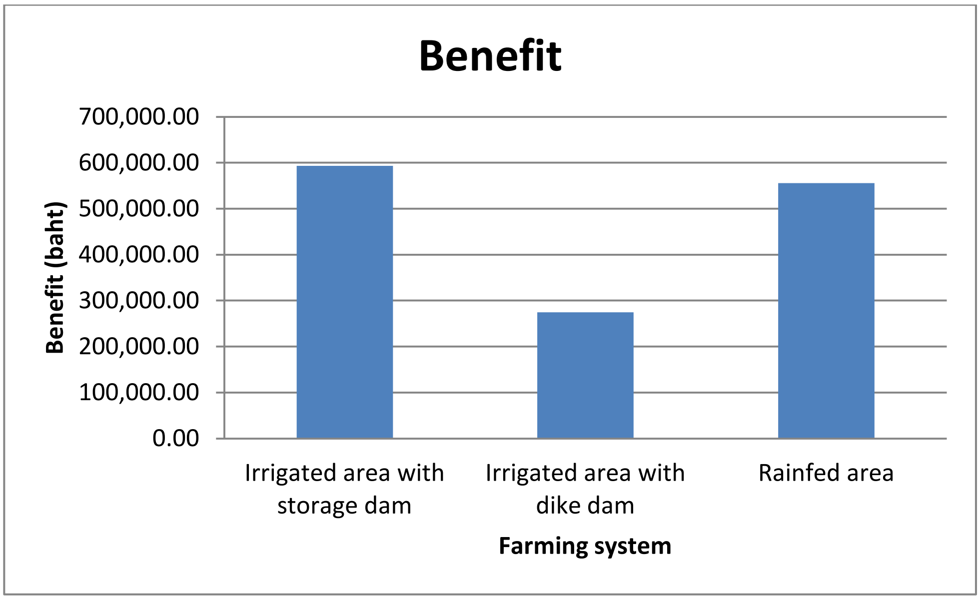

Figure 16 Benefit in different farming system

Note: 1 USD = 30.78 baht

5.6.2 Land use of crop production

Land use of crop production in irrigated area with storage dam should use the own land at 11 rai and renting land at 10 rai. In irrigated area with dike dam should use the own land 7.45 rai and renting land at 0.14 rai. In rainfed area should use the only own land 13.52 rai (Figure 17).

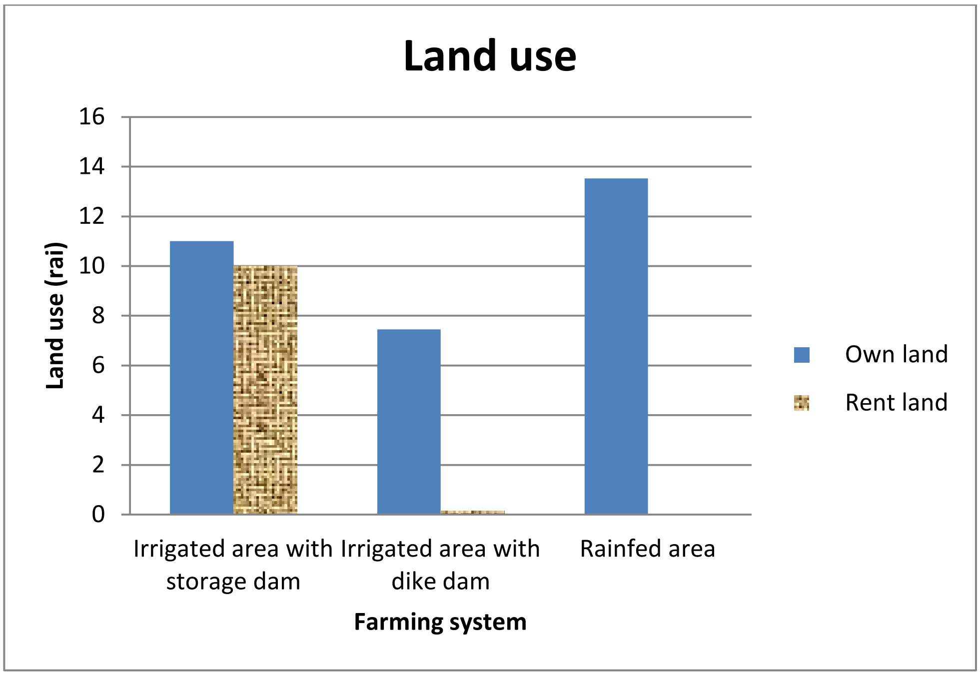

Figure 17 Land use in different farming system

Source: by analysis

Note: 1 ha = 6.25 rai

5.6.3 Investments in crop production

The investments of crop production in irrigated system is nearly cost that by storage dam use 129,443.04 baht on farms and by dike dam use 127,569.62 baht. The rainfed area use 131,705.42 baht on farms that is higher than both of irrigated system (Figure 18).

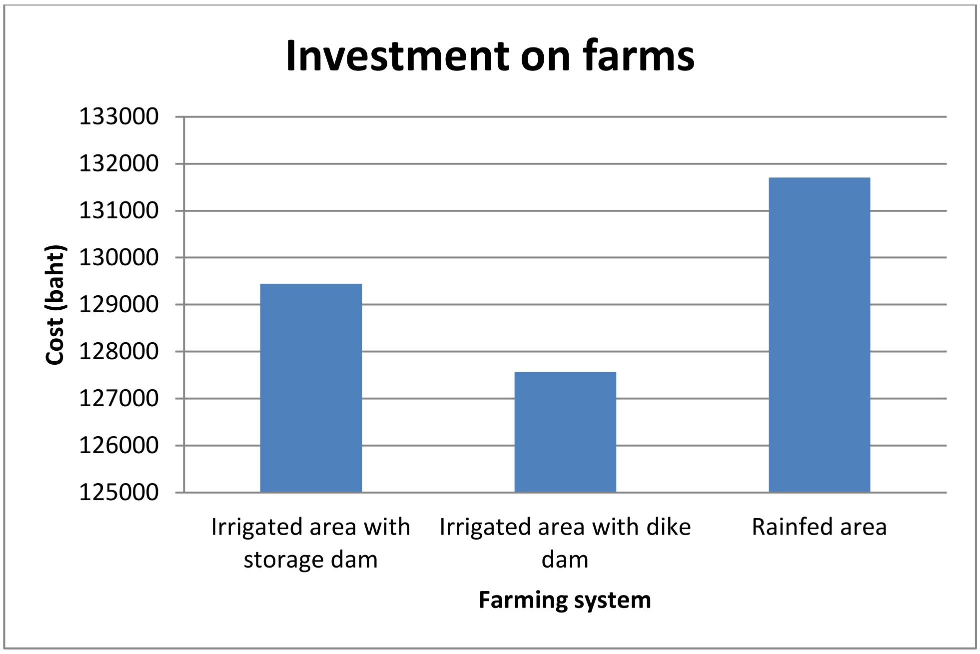

Figure 18 Investments on farms in different farming system

Source: by analysis

Note: 1 USD = 30.78 baht

5.6.4 Water use

The water use in both of irrigation system is nearly which by storage dam use 1,198,902.27 m^3 and by dike dam use 1,374,641 m^3 on farms. On the other hand, in rainfed area use 680,063.89 m^3 for crops production on farms (Figure 19).

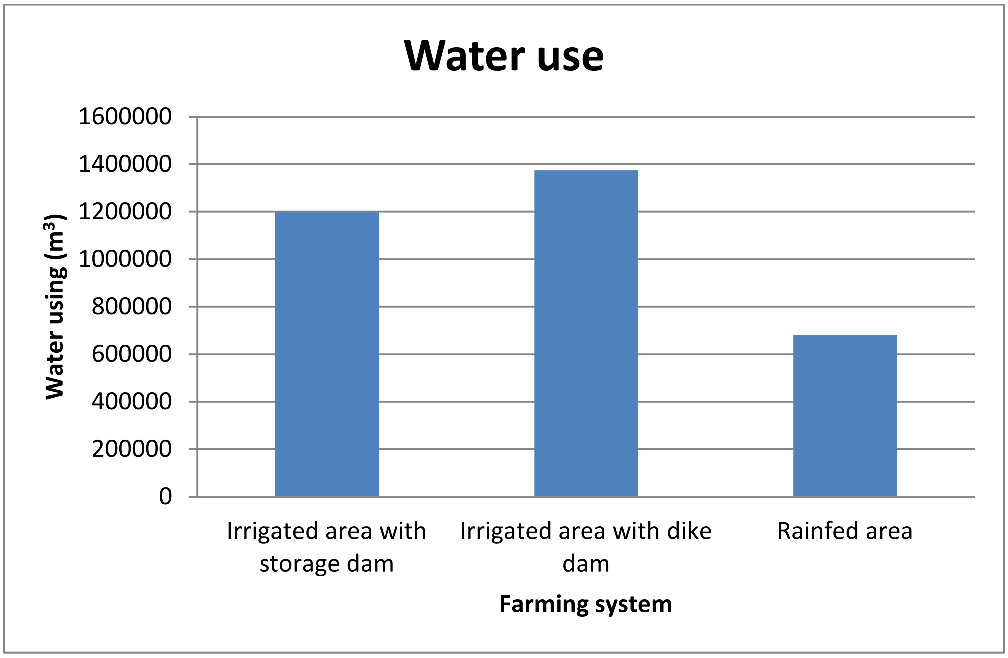

Figure 19 Water use in different farming system

5.7 Shadow price of production

The shadow price is an economic term that indicates the change in the optimal value of the objective function when the right hand side of some constraint changes by a unit amount (Winston L.W. et al, 2009). The shadow price is valid up to the allowable increase or decrease in the constraint. The shadow price after the constraint is changed by the entire allowable amount is unknown, but is always less favorable than the reported value due to diminishing returns. To determine if a constraint is binding, compare the Final Value with the Constraint R.H. Side. If a constraint in non-binding, its shadow price is zero.

The result of multi objectives model revealed the entire factor of crops production was used in the model and appeared the shadow price in yield of the in-season rice and sugar cane in irrigated area with dike dam. If farmers will increase the in-season rice land use 1 rai, the deviation will decrease 0.01 per the increased land use 1 rai on farms (Table 19).

Table 19 Table of shadow price of multi objectives in irrigated area with dike dam

Constraints	**Shadow price**
Yield	
The in-season rice	0.01
The in-season rice for consumption	-
The off-season rice	-
Chili	-
Pak choi	-
Long bean	-
Morning glory	-
Coriander	-
Celery	-
Green shallot	-
Spinach	-
Lettuce	-
Sugar cane	0.01
Longan	-

Source: by analysis

5.8 Sensitivity analysis

The data analysis illustrated the cultivation in different farming system in Ping Watershed. In the sensitivity analysis, if some factor changes, it will affect of suitable cropping pattern.

The sensitivity analysis has 2 contributions below:

5.9.1 Changing longan price are increased price by10%, 20%, 30%

5.9.2 Changing the water resource decreased water resource by 10%, 20%, 30%

5.8.1 The sensitivity analysis of longan price

In the assumption, if the longan will have the rise price, the farmers will decrease the lowland from paddy rice to increase longan because it uses activities on farms less than paddy rice. Thus farmers will earn from non-agriculture sector. The sensitivity analysis was conducted by use of the longan price at rainfed area and irrigated areas (dike dam) because the most of annual crops had the price support from the government. The price of longan did not have the price support thus if it changes the cultivation of longan will change, too, following the rising price.

The sensitivity analysis in irrigated area with dike dam has increase crops from the model cropping pattern which are the off-season rice, pak choi, coriander, green shallot, spinach, lettuce, and longan. If the longan price rises up 30 percent the cropping pattern select longan in the model around 3.64 rai (Table 20).

The sensitivity analysis in rainfed area increase crops from the model cropping pattern which are the in-seson rice, maize and longan. If the longan price rise up 10 percent the cropping pattern select longan in the model around 1.33 rai but the model did not select longan in the cropping pattern at the increase 20 and 30 percent (Table 21).

Table 20 Sensitivity analysis of price for comparing the proposed (suitable) cropping pattern in irrigated area with dike dam

Crops	Model cropping pattern (rai)	Increase 10 percent	Increase 20 percent	Increase 30 percent
The in-season rice	1.58	1.58	1.58	1.58
The off-season rice	-	4.32	2.52	-
Chili	-	-	-	-
Pak choi	-	2.46	2.46	2.46
Long bean	0.01	0.01	0.01	0.01
Morning glory	-	-	-	-
Coriander	2.16	5.74	-	-
Celery	1.14	-	-	-
Green shallot	-	3.93	-	-
Spinach	-	2.67	3.94	3.94
Lettuce	-	-	-	2.89
Sugar cane	2.7	2.7	-	-
Longan	-	-	-	3.64

Source: by analysis

Note: 1 ha = 6.25 rai

Table 21 Sensitivity analysis of price for comparing the proposed (suitable) cropping pattern in rainfed area

Crops	Model cropping pattern (rai)	Increase 10 percent	Increase 20 percent	Increase 30 percent
The in-season rice	-	-	-	1.97
Long bean	9.86	9.86	9.86	9.86
Marigold	1.37	1.21	3.07	-
Maize	-	-	-	3.98
Sweet corn	1.07	1.97	1.97	1.97
Tobacco	0.01	-	-	-
Galangal	1.20	2.73	-	2.1
Lemon grass	-	4.42	-	-
Banana	0.01	-	-	-
Longan	-	1.33	-	-

Source: by analysis

Note: 1 ha = 6.25 rai

5.8.2 The sensitivity analysis of water resource

The changing of decreased water resource affected the farm production because the cropping pattern in the model set maximize of water using on farms. The crops can get the optimal water using on farms but the water requirement of each crop showed water using in the suitable cropping pattern by model. Thus the rest of water using in model comes from the minus of the water requirement from the water using on farms. Since paddy rice is high water requirement on crops but other annual crops do not decrease the farm production because they use a few water requirements on crops so the changing water using affects in the rice production and benefit on farms.

The results in irrigated area with storage dam showed the changing crops when the water using decreased at 10 until 30 percent. The crops were the off-season rice (2.56 rai), pak choi (2.51 rai), and sweet corn (1.97 rai) at decreased water using 30 percent. The model selected the in-season rice (1.78 rai), chili (3.87 rai), soy bean (5.18 rai) and sweet corn (1.97 rai) at decreased water using 20 percent. The model selected the in-season rice (4.02 rai), chili (3.23 rai), sweet corn (1.97 rai) and cabbage (1.2 rai) at decreased water using 30 percent (Table 22).

Table 22 Sensitivity analysis of water resource in irrigated area with storage dam

Crops	**Model cropping pattern (rai)**	**Decrease 10 percent**	**Decrease 20 percent**	**Decrease 30 percent**
The in-season rice	-	-	1.78	4.02
The off-season rice	4	2.56	-	-
Chili	-	-	3.87	3.23
Pak choi	3.77	2.51	-	-
Cauliflower	3.89	-	-	-
Long bean	-	-	-	-
Soy bean	4	-	5.18	-
Sweet corn	1.44	1.97	1.97	1.97
Cabbage	3.9	-	-	1.2

Source: by analysis

Note: 1 ha = 6.25 rai

The results revealed that in irrigated area with dike dam were still the in-season rice (1.58 rai) but other crops were changed such as the off-season rice (4.31 rai), pakchoi (2.46 rai), green shallot (3.93 rai), spinach (2.67 rai) and sugar cane (2.7 rai) at the decreased water using 10 percent. The crops were still selected the same crops in the condition of decreased water using 10 percent but the model changed slightly only the area size (Table 23).

Table 23 Sensitivity analysis of water resource in irrigated area with dike dam

Crops	**Model cropping pattern (rai)**	**Decrease 10 percent**	**Decrease 20 percent**	**Decrease 30 percent**
The in-season rice	1.58	1.58	1.58	1.58
The off-season rice	-	4.31	-	-
Chili	-	-	-	-
Pak choi	-	2.46	2.46	2.46
Long bean	0.01	-	-	-
Morning glory	-	-	-	-
Coriander	2.16	-	-	-
Celery	1.14	-	5.07	1.74
Green shallot	-	3.93	4.93	4.93
Spinach	-	2.67	3.94	3.94
Lettuce	-	-	-	-
Sugar cane	2.7	2.7	-	1.91
Longan	-	-	-	-

Source: by analysis

Note: 1 ha = 6.25 rai

Results indicated that in rainfed area were similar between the decreased water using 10 percent and 30 percent which were the in-season rice, long bean, marigold, and sweet corn but they were different only in the area size. The sensitivity analysis of decreased water using 20 percent were marigold, maize, sweet cron, galangal, lemon grass and longan (Table 24).

Table 24 Sensitivity analysis of water resource in rainfed area

Crops	**Model cropping pattern (rai)**	**Decrease 10 percent**	**Decrease 20 percent**	**Decrease 30 percent**
The in-season rice	-	1.02	-	4.48
Long bean	9.86	9.86	-	2.54
Marigold	1.37	1.24	1.45	1.22
Maize	-	-	1.5	1.5
Sweet corn	1.07	1.97	1.97	1.97
Tobacco	0.01	-	-	-
Galangal	1.20	-	4.81	-
Lemon grass	-	-	1.37	-
Banana	0.01	-	-	-
Longan	-	-	1.68	5.6

Source: by analysis

Note: 1 ha = 6.25 rai

The second goal was: to determine factors affecting decision-making about water use and management in different water resource management systems.

Factors affecting decision-making on water use and management in different water resource management systems: price of crops, costs of crop production and water supply.

The first factor affecting the decision-making process on crop cultivation depends on the price of crop. If farmers foresee increased price of some crops they will cultivate it on larger areas than the year before. However, the price support from government is also important to influence the farmers´ decision.

The second factor is the cost of crop production of each crop. It is because the farmers decide to cultivate crops at lowest possible costs but under the condition they would get the highest farm incomes.

The last factor to be assumed by farmers is water supply. The farmers have to know the inflow potential for each year before the crop planting season. If they know they will have less water they decide to grow less water demanding crops (such as beans). As the consequence of the lack of water the farm economy is always disturbed and the farmers lose incomes.

The last goal was: assessment of the development potential of water resources under sustainable conditions in different water resource management systems with regards to farmers' socio-economic situation.

The results revealed the development potentials of water resource management under sustainable conditions in each farming system differs each other because the farmers are aware of water scarcity on farms for the next generations. The development potential depends on the conservation and protection of forest resources by the local community. On irrigated areas (storage dams and water gates) the farmers have got a secured development within the water users´ groups which makes them strong in brain storming for getting knowledge. It is especially important for developing their fields and creating a proper water resource management in irrigated areas. It is necessary for getting water security according to a farmers´ plan for solving the water scarcity within the local community on irrigated areas with water gates. On irrigated areas with storage dams the farmers usually work out their annual plans by themselves which gives them opportunity to discuss their problems in detail with RID officers.

5.9 Discussion

The impact assessment of water resource management in rainfed area has 3 types compose of private management, relative management and community management. In the private management, farmers can invest on their farm by themselves such as water tank, small reservoir etc. but the size of water saving depends on their capital. The research of Neef A. et al. (2005) supported that the private management has the same type in Northern Thailand which private ponds are used either by individual farmers or by close relatives in a shared arrangement. On the other hand, Asian Development Bank (2001) supports private sector participation because ADB is expected to improve performance and efficiency, particularly in service delivery. ADB will seek to provide innovative financial package to enable commercial lenders and promoters to manage the risks involved with investing in water-related projects.

The relative management, farmers in one zone is the relatives who have the farm nearby together which they can get the trust and confident together in their farms zone. It is easy to allocate, manage and develop by talking for solving the problem or invest the water security on their farm. The last community management, farmers in one zone is the neighbor farms who have the farm nearby together. They have the assist from the government because the community management is the big project for saving water for everybody in community. Dulyapach S. (1998) agreed in water management in Northern Thailand that the local community in rainfed will manage on sustainable farming and protecting of nature resources which it is not a legal local institution. However, this thing has proved itself as a valuable tool in creating local participation in sustainable uses and protect of their natural resources. The results of Polperm P. (1990) also supported that the opportunity or ability to get water in traditional irrigation system management has an influence on the equity because the farmers as a group help solving problem in critical water demand period by getting water into the fields and hence reduces the value of productivity.

In irrigated areas compose of 2 types are with dike dam and with storage dam which in irrigated areas with dike dam the farmers created a water users´ group on the same main canal (ground canal); this is made by themselve without control for the part of the RID. They have to share the water use according to the schedule with other canal branches. On the other hand, in irrigated areas with storage dams the farmers have to cooperate with RID, they have a concrete canal bringing water to their farms. The farmers created the water users group which was managed by RID officers. The farmers through their water groups get a policy orientation and action plan from the RID to implement on their farms. The result of Sattasart A. (1999) of confirmed that the management system of the irrigation water and the irrigation scheme has influenced the efficiency of using irrigation water. The farmers prefer the water distribution system managed by farmers' groups. The farmers' needs require increasing the water storage capacity or improving the water distribution system. The use of irrigation together with other resources and inputs has a positive impact on the living standard of the family.

There are price, costs and water supply capacity. If the farmers see a price increase or a price support of some crops by the government they will cultivate its more area than the year before. The farmers also prefer to grow low cost crops but suppose to get high on-farm incomes. They require knowing a future water potential inflow before the crop planting season. If they have prospects to get less water they are going to grow less water demanding crops. The FAO (2001) supported that the effect of factor price, water resource and investment on farms which the crop pattern changes are the outcome of the interactive effect of many factors which can be broadly categorized into the following five groups a) Resource related factors covering irrigation, rainfall and soil fertility. b) Technology related factors covering not only seed, fertilizer, and water technologies but also those related to marketing, storage and processing. c) Household related factors covering food and fodder self sufficiency requirement as well as investment capacity. d) Price related factors covering output and input prices as well as trade policies and other economic policies that affect these prices either directly or indirectly. The last factor, institutional and infrastructure related factors covering farm size and tenancy arrangements, research, extension and marketing systems and government regulatory policies.

Given the variety and scale of competing uses for water–domestic, industrial, agricultural and environmental–moving water to where it is needed is inescapably a mix of economics, engineering and socio–political concerns. Moreover, the management of water resources is often linked to other environmental and resources issues, such as climate change. It may be possible to mitigate climate change through conservation of existing forests, reforestation of degraded forests or afforestation (FAO, 2009). The study of ADB (2001) explained the development potential of water resource management under sustainable conditions in each farming system in Ping watershed area is different because the farmers are aware of water scarcity on farms for the next generations. The development potential consists in conservation of forest resources by the local community especially in rainfed areas. The farmers have the sustained development in the water users´ group to be strong in brain storming for getting knowledge and develop their fields. Therefore, the farmers adapted the idea of cultivation and conservation together on their fields under sustainable to next generations. The study aware in the integrated water resource management because it is a process to improve to planning, conservation, development, and management of water, forest, land and aquatic resources in a river basin context, to maximize economic benefits and social welfare in an equitable manner without compromising the sustainability of vital environment systems.

6. Conclusions and Recommendations

6.1 Conclusions

The study areas are located in the Ping Watershed in Northern Thailand. Chiang Mai Province was selected as a study area because agro-ecological condition where is dominated by a series of mountain ranges running North-South and separated by basins. The present study focuses on farm family household, with the ambition to understand the socio-economic in different farming system. It was chosen a stratified random sampling in each different farming system where they were chosen through a simple random sampling by 75 samples in each different farming system thus total 225 samples in the study area. In rainfed area compose of Banchang, Banmaetaeng, and Khilek in Maetaeng district and in irrigated area with dike dam include in Tawangtan, Nongfang, and Yangnueng in Sarapee district. In rest group, in irrigated area with storage dam consist in Nongjom, Sansainoi, and Sansailuang in Sansai district.

The study aimed to explain existing water resource management and determine factors affecting efficiency in different water resource management systems in the Ping Watershed area. The solution by using two analytical steps: first step: data analysis by single objective optimization in linear programming (LP) for each objective includes in farm income, labor employment, price risk, and yield risk. Second step: getting the outcomes from linear programming through the multi-objectives model by Goal programming through minimization of objectives.

Water resource management within different farming systems in Ping watershed area, in rainfed areas the farmers store the scarce water in small reservoirs and water tanks on their farms for saving it for the dry season because the water on-farm security is an indispensable prerequisite in decide-making upon the next year crop. In irrigated areas with dike dam the farmers created a water users´ group on the same main canal (ground canal); this is made by themselves without control for the part of the RID. They have to share the water use according to the schedule with other canal branches. In irrigated areas with storage dams the farmers have to cooperate with RID, they have a concrete canal bringing water to their farms. The farmers created the water users group which was managed by RID officers. The farmers through their water groups get a policy orientation and action plan from the RID to implement on their farms.

The factor affecting decision-making on water use and management in different water resource management systems are price, costs of crop production and water supply. If the farmers see a price increase or a price support of some crops by the government they will cultivate its more area than the year before. The farmers also prefer to grow low cost crops but suppose to get high on-farm incomes. They require to know a future water potential inflow before the crop planting season. If they have prospects to get less water they are going to grow less water demanding crops.

The development potential of water resource management under sustainable conditions in each farming system is different because the farmers are aware of water scarcity on farms for the next generations. The development potential consists in conservation of forest resources by the local community especially in rainfed areas. The farmers have the sustained development in the water users´ group to be strong in brain storming for getting knowledge and develop their fields.

The main findings of this study can be conclusions as follow:
Due to the above facts the Hypothesis I (Water resource management in Ping watershed area plays an important role in sustainable agricultural development) can be confirmed that the water supply influence the yield, income and water availability.

The water resource management is very important which the labor resource use in farming activities in the irrigated area was higher than farmers in rainfed area. In rainfed area result showed the farmers store the scarce water in small reservoirs and water tanks on their farms for saving it for the dry season because the water on-farm security is an indispensable prerequisite in decide-making upon the next year crop. At the several saving water type can use longer available to next generation which farmers aware the water scarcity thus they want to conserve forestry. They changed in environmental concern and conservation behavior in rainfed area such as farmers do not swidden agriculture. The results confirmed in the irrigated area also because farmers can manage crop if they know the runoff information from RID all year. However, the participation among farmers and RID’s officer changed their behavior and awareness of water using.

The arguments as discussed in this paragraph lead to the confirmation of Hypothesis II (The upstream-downstream structure in water resource management affects the efficiency of water use). The upstream downstream relations are a traditional assist with water resource management in Ping watershed area. The upstream water allocation must be harmonized with the downstream water availability.

The upstream is rainfed area can access water resource with rainfall before the downstream so they have to manage crop in efficiency and the rest water through Ping river for downstream. Thus, Farmers collected rainfall water for dry season by investment capacity for storage. However, in irrigated area can use water from irrigation project by canal and main Ping river which they have enough water supply on farm. Farmers depend on the water supply from organized by themselves or institutions focused on reliability and a higher water supply in the dry season. Therefore, it is assist relations water using on farms between the upstream and downstream structure.

The arguments as discussed in this paragraph lead to the confirmation of Hypothesis III (A more efficient use of water resource will improve the farmers' socio-economic situation). According to the results confirmed that the three farming systems increased the high income and efficiency of land use because farmers introduced water saving on farms. They can manage to cultivate the next year crop.

An investment in water resource development for sustainable agricultural will increase household income and the efficiency of land use because the farmers have water saving on farms which they can manage to cultivate the next year crop. The analysis of benefit of crop production in the 3 type of different farming system which the highest return on irrigated area with storage dam is the off-season rice, pak choi, cauliflower, soybean, sweet corn and cabbage. The middle return on rainfed area is the in-season rice, longbean, coriander, celery and sugar cane. The lowest return on irrigated area with dike dam is longbean, marigold, sweet corn, tobacco, galangal and banana. The analysis of resource use efficient shows the potential of improve the farmers' socio-economic situation in Ping watershed area.

6.2 Recommendations

On the base of the above conclusions, the following can be recommended:

1. There is a high water demand in upstream and downstream rural areas in order to assure the development of agricultural systems under the sustainable condition. Further research on socio-economic with water resource is recommended to acutely insure awareness on environment conservation.

2. Economic situation of land users will evolve into the future. The factor effects in land use are the increasing growth and impact of territory expansion from urban areas in Ping watershed. Thus, farmers have the intensive multi cropping in land use for getting more agricultural income. On the other hand, the multi cropping farming depends on access water resource on farm. Future research by adding land use and soil fertilizer is recommended to aware the in the future with environmental consideration.

3. It can be recommended to use the cropping patterns proposed by multi-function model on farms in Ping watershed. The model is consistent with each farming system where there are differences in risk and uncertainty. Because the risk and uncertainty come from weather condition, nature resources and flexible of market these factors must be considered as variables which cannot be controlled by farmers themselves. The above model processes these factors and produces management advice which is, according to our survey, acceptable by the farmers for their better operational and economic (including water consumption) parameters.

4. The multi objective model in this research used the cross-section data in 2010/11. The future research of model is recommended with some dynamic data that is the long term for insuring the sustainability in socio-economic and environmental.

5. The collected data by questionnaire and survey is recommended to improve of collecting questioner according to the river basin of upstream and downstream.

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8. Annex

1. Collected data on Watershed farmers by questionnaire;

No. questionnaire................

Questionnaire of Doctoral Student
The impact assessment of water resource management on farms in the Ping Watershed,
Northern Thailand

By MSc. Teeka Yotapakdee,
Ph.D student of Economic Development Department
Institute of Tropics and Subtropics
Czech University of Life Sciences Prague

Part 1 General information of farmer

Name……………………………………………………… Sex....................................
Status……………………………………………………… (head of household, wife, son, daughter, other..............)
Age...............year Education....................................
Major career.. Minor career..
Member of household.................
Labor of household.......................

Part 2 Crop planting in 2010/2011

Planting area……………….rai Owner…………….rai Rent…………….rai Free…………….rai

Amount of Plot………………………..plot

plot	Area (rai)	plant	Land tenure[1]	Certificate of ownership	Water using[2]	Planting in month	Harves-ting in month	Yield				Price (baht/kg.)
								total	consump tion	keep breeding	sell	

[1] Land tenure 1=owner 2=rent 3=free

[2] Water using 1=irrigation 2=reservoir owner 3=reservoir public 4=ground water

Part 3 A Costs and income of annual crops

plant					
Area (rai)					
Seed themselves (kg.)					
Seed purchased (kg.)					
Seed price (baht/kg.)					
Cost of plowing (baht)					
Family labor plowing (manday)					
Hired labor plowing (manday)					
Hired labor wage (baht/manday)					
Family labor planting (manday)					
Hired labor planting (manday)					
Hired labor wage (baht/manday)					
Family labor caring plant (manday)					
Hired labor caring plant (manday)					

Hired labor wage (baht/manday)					
Cost of pesticide grass (baht)					
Cost of pesticide (baht)					
Chemical fertilizer ………………….. Price (baht/kg.) Quantity (kg.)					
Chemical fertilizer ………………….. Price (baht/kg.) Quantity (kg.)					
Chemical fertilizer ………………….. Price (baht/kg.) Quantity (kg.)					
Family labor harvesting (manday)					
Hired labor harvesting (manday)					
Hired labor wage (baht/manday)					
Total yield (kg.)					

Keep the seed for breeding (kg.)					
Consumption in household (kg.)					
Selling (kg.)					
Price (baht/kg.)					
Selling market					

Part 3 B Costs and income of perennial plant

Perennial plant……………………age……………………No.plot…………………area……………

List		First year for planting	Growth in year 2-4	Starting of yield in year 5-7	Constant yield in year 8-10	Constant to peak yield since year 11
Scion	Owner (unit)					
	Purchased scion (baht/unit)					
Plowing	Family labor (manday)					
	Hired labor (manday)					
	Hired labor wage (baht/manday)					
Planting	Family labor (manday)					
	Hired labor (manday)					
	Hired labor wage (baht/manday)					
Caring	Family labor (manday)					
	Hired labor (manday)					
	Hired labor wage (baht/manday)					
Composed fertilizer	Owner (kg.)					
	Purchased (kg.)					
	Price (baht/kg.)					
Chemical fertilizer ……………..	Quantity (kg.)					
	Price (baht/kg.)					
Chemical fertilizer ……………..	Quantity (kg.)					
	Price (baht/kg.)					

Chemical fertilizer ……………	Quantity (kg.)					
	Price (baht/kg.)					
Plant hormone	Quantity (kg.)					
	Price (baht/kg.)					
Plant hormone	Quantity (kg.)					
	Price (baht/kg.)					
Pesticide	Quantity (kg.)					
	Price (baht/kg.)					
Pesticide	Quantity (kg.)					
	Price (baht/kg.)					
Harvesting	Family labor (manday)					
	Hired labor (manday)					
	Hired labor wage (baht/manday)					
Other expenditure (baht)						

Part 4 Livestock in household

Type	Quantity per year(unit)	Cost per year(baht)	Quantity of selling per year (unit)	Income per year (baht)	Consumption in household (unit)
Chicken					
Pig					
Cow					

Part 5 Non-agricultural income and expenditure of household

Income/expenditure	Total (baht/year)
Income	
-trading	
-wage earner	
-handicraft	
-salary from daughter/son	
-other	
Expenditure of living	

Part 6 Finance

Loan source	Loans (baht)	Guarantee of loans	Objective of Loans	Interest rate	Term of credit repayment (year)
BAAC Bank					
Agricultural Cooperative Association					

Part 7 Water resource management in farm

7.1 Irrigation project name……………………………..……………..amount of water using…………………year

Possible for using water in this project ( ) all year, ( ) in period time…………………………………………

Expenditure of water using

i) for leader, water using fee …………………………………..baht/rai/year

ii) for irrigation project, water using fee …………………………………..baht/rai/year

iii) for other, water using fee …………………………………..baht/rai/year

The problem of using water in irrigation project……………………………………………………………………………

7.2 Organization of water resource management

Name…………………………………………...how to management in organization…………………………………………….

Are you member in organization? .... Do you have the water using schedule? ....

How many time of using water in farm? ....

Do you have the problem in organization? ………………………………………………………………………………….

If yes, it is ………………………………………………………………………………………………..

How to solve the problem? ………………………………………………………………………………………………

7.3 Does the farmer have the water resource development in farm?

Since 10 year ago such as reservoir by yourself, tank, ground water using etc.

If yes, it is …………..………………………………….. Cost or developing water resource………………… baht

How to use the water resource in farm?

………………………………………………………………………………..

………………………………………………………………………………………………

……………………………………………………….

2. Results of data processing;

2.1 Results of irrigated area with storage dam model

2.1.1 Answers Report in irrigated area with storage dam model

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		100.00	100.00

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		0	-1.28248E-15
$H$1		0	4.01808E-15
$I$1		6.2224E-16	0
$J$1		-2.89643E-15	3.7709E-15
$K$1		-9.4006E-15	3.89833E-15
$L$1		0.001425555	0.001425555
$M$1		7.06908E-15	4.09392E-15
$N$1		7.77269E-14	1.44383E-15
$O$1		3.04214E-15	3.90022E-15
$P$1		0	0
$Q$1		0	0
$R$1		0	0
$S$1		862.9464904	862.9464904
$T$1		0	0
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		26.39916667	26.39916667
$AD$1		0	0
$AE$1		1.69024E-11	0
$AF$1		0	0
$AG$1		-4.41035E-12	0
$AH$1		0	1.52196E-11
$AI$1		0	0
$AJ$1		0	0
$AK$1		1.140444	1.140444
$AL$1		0	0
$AM$1		0	0
$AN$1		0	0
$AO$1		0	0
$AP$1		202122.1862	202122.1862
$AQ$1		6.308960125	6.308960125
$AR$1		0	0
$AS$1		1198902.272	1198902.272
$AT$1		592964.5545	592964.5545
$AU$1		0	0
$AV$1		0	0
$AW$1		0	0
$AX$1		0	0
$AY$1		0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	0.00	$C$7<=$F$7	Not Binding	10.99857445
$C$8	rent land	-	$C$8<=$F$8	Not Binding	10
$C$9	family labor June	0.01	$C$9<=$F$9	Not Binding	39.98865258
$C$10	family labor July	0.04	$C$10<=$F$10	Not Binding	39.95596461
$C$11	family labor August	- 862.90	$C$11<=$F$11	Not Binding	902.904907
$C$12	family labor September	0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.98865258
$C$14	family labor November	0.04	$C$14<=$F$14	Not Binding	39.95596461
$C$15	family labor December	0.04	$C$15<=$F$15	Not Binding	39.95841656
$C$16	family labor January	0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.01	$C$17<=$F$17	Not Binding	39.98865258
$C$18	family labor March	0.04	$C$18<=$F$18	Not Binding	39.95596461
$C$19	family labor April	0.04	$C$19<=$F$19	Not Binding	39.95841656
$C$20	investment crop1	129,416.64	$C$20<=$F$20	Binding	0
$C$21	BAAC	-	$C$21<=$F$21	Not Binding	174545.45
$C$22	Coperative	26.40	$C$22<=$F$22	Not Binding	75473.60083
$C$23	Villange Fund	-	$C$23<=$F$23	Not Binding	17500
$C$24	June	0.20	$C$24<=$F$24	Not Binding	34369.72286
$C$25	July	0.18	$C$25<=$F$25	Not Binding	51818.21998
$C$26	August	0.17	$C$26<=$F$26	Not Binding	251842.8685
$C$27	September	0.00	$C$27<=$F$27	Not Binding	394489.44
$C$28	October	0.18	$C$28<=$F$28	Not Binding	186494.2228
$C$29	November	0.15	$C$29<=$F$29	Not Binding	96651.20642
$C$30	December	0.14	$C$30<=$F$30	Not Binding	34987.53646
$C$31	January	0.00	$C$31<=$F$31	Not Binding	23047.2
$C$32	Febuary	0.18	$C$32<=$F$32	Not Binding	12398.22499
$C$33	March	0.25	$C$33<=$F$33	Not Binding	31751.75081
$C$34	April	0.28	$C$34<=$F$34	Not Binding	46357.63942
$C$35	yield rice rain	0.00	$C$35=$F$35	Not Binding	0
$C$36	yield rice consumption	-	$C$36<=$F$36	Not Binding	80.99
$C$37	rice dry	- 0.00	$C$37=$F$37	Not Binding	0
$C$38	chilli	0.00	$C$38=$F$38	Not Binding	0
$C$39	pak choi	- 0.00	$C$39=$F$39	Not Binding	0
$C$40	cauliflower	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	long bean	0.00	$C$41=$F$41	Not Binding	0
$C$42	soy bean	- 0.00	$C$42=$F$42	Not Binding	0
$C$43	sweet corn	- 0.00	$C$43=$F$43	Binding	0
$C$44	cabbage	- 0.00	$C$44=$F$44	Not Binding	0
$C$45	balance income	- 0.00	$C$45=$F$45	Not Binding	0
$C$46	Socail Max Hired Labor	202,122.40	$C$46=$F$46	Not Binding	0
$C$47	Economic Risk Price	6.34	$C$47=$F$47	Not Binding	0
$C$48	Econnomic Risk Yield	1.14	$C$48=$F$48	Not Binding	0
$C$49	Env Water	1,198,904.00	$C$49=$F$49	Not Binding	0
$C$50	Economic Max Income	592,992.00	$C$50=$F$50	Not Binding	0

2.1.2 Sensitivity Report in irrigated area with storage dam model

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$G$1		-1.28248E-15	0	0	1E+30	2.871950936
$H$1		4.01808E-15	0	0	1E+30	3.286004916
$I$1		0	3.507478115	0	1E+30	3.507478115
$J$1		3.7709E-15	0	0	1.90265E+15	4.528913337
$K$1		3.89833E-15	0	0	1E+30	3.557189601
$L$1		0.001425555	0	0	1.313645619	70144.87108
$M$1		4.09392E-15	0	0	1E+30	0.550089103
$N$1		1.44383E-15	0	0	9.0106E+14	5.334178206
$O$1		3.90022E-15	0	0	1E+30	2.096571287
$P$1		0	0	0	1E+30	0
$Q$1		0	0	0	1E+30	0
$R$1		0	0	0	1E+30	0
$S$1		862.9464904	0	0	0	0
$T$1		0	0	0	1E+30	0
$U$1		0	0	0	1E+30	0
$V$1		0	0	0	1E+30	0
$W$1		0	0	0	1E+30	0
$X$1		0	0	0	1E+30	0
$Y$1		0	0	0	1E+30	0
$Z$1		0	0	0	1E+30	0
$AA$1		0	0	0	1E+30	0
$AB$1		0	0	0	1E+30	0
$AC$1		26.39916667	0	0	0	0
$AD$1		0	0	0	1E+30	0
$AE$1		0	0.003120431	0	1E+30	0.003120431
$AF$1		0	0.003120431	0	1E+30	0.003120431
$AG$1		0	0.003148721	0	1E+30	0.003148721
$AH$1		1.52196E-11	0	0	0	0
$AI$1		0	0.00258795	0	1E+30	0.00258795
$AJ$1		0	0.002456758	0	1E+30	0.002456758
$AK$1		1.140444	0	0	0	0
$AL$1		0	0.001642057	0	1E+30	0.001642057
$AM$1		0	0.002667089	0	1E+30	0.002667089
$AN$1		0	0.002620714	0	1E+30	0.002620714
$AO$1		0	0	0	1E+30	0
$AP$1		202122.1862	0	0	0	0
$AQ$1		6.308960125	0	0	0	0
$AR$1		0	0.004058339	0	1E+30	0.004058339
$AS$1		1198902.272	0	0	0	0
$AT$1		592964.5545	0	0.000168636	0	0
$AU$1		0	0.00049475	0.00049475	1E+30	0.00049475
$AV$1		0	15.7614374	15.7614374	1E+30	15.7614374
$AW$1		0	87.68108885	87.68514719	1E+30	87.68108885
$AX$1		0	8.34095E-05	8.34095E-05	1E+30	8.34095E-05
$AY$1		0	0.000168636	0	1E+30	0.000168636

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$C$7	land	0.00	-	11	1E+30	10.99857445
$C$8	rent land	-	-	10	1E+30	10
$C$9	family labor June	0.01	-	40	1E+30	39.98865258
$C$10	family labor July	0.04	-	40	1E+30	39.95596461
$C$11	family labor August	- 862.90	-	40	1E+30	902.904907
$C$12	family labor September	0.00	-	40	1E+30	40
$C$13	family labor October	0.01	-	40	1E+30	39.98865258
$C$14	family labor November	0.04	-	40	1E+30	39.95596461
$C$15	family labor December	0.04	-	40	1E+30	39.95841656
$C$16	family labor January	0.00	-	40	1E+30	40
$C$17	family labor Febuary	0.01	-	40	1E+30	39.98865258
$C$18	family labor March	0.04	-	40	1E+30	39.95596461
$C$19	family labor April	0.04	-	40	1E+30	39.95841656
$C$20	investment crop1	129,416.64	-	129416.64	2.06319E+16	129441.9736
$C$21	BAAC	-	-	174545.45	1E+30	174545.45
$C$22	Coperative	26.40	-	75500	1E+30	75473.60083
$C$23	Villange Fund	-	-	17500	1E+30	17500
$C$24	June	0.20	-	34369.92	1E+30	34369.72286
$C$25	July	0.18	-	51818.4	1E+30	51818.21998
$C$26	August	0.17	-	251843.04	1E+30	251842.8685
$C$27	September	0.00	-	394489.44	1E+30	394489.44
$C$28	October	0.18	-	186494.4	1E+30	186494.2228
$C$29	November	0.15	-	96651.36	1E+30	96651.20642
$C$30	December	0.14	-	34987.68	1E+30	34987.53646
$C$31	January	0.00	-	23047.2	1E+30	23047.2
$C$32	Febuary	0.18	-	12398.4	1E+30	12398.22499
$C$33	March	0.25	-	31752	1E+30	31751.75081
$C$34	April	0.28	-	46357.92	1E+30	46357.63942
$C$35	yield rice rain	0.00	- 0.00	0	0	1.140444
$C$36	yield rice consumption	-	-	80.99	1E+30	80.99
$C$37	rice dry	- 0.00	- 0.00	0	0	1.140444
$C$38	chilli	0.00	-	0	5149.178073	0
$C$39	pak choi	- 0.00	- 0.00	0	0	1.140444
$C$40	cauliflower	- 0.00	- 0.00	0	0	1.140444
$C$41	long bean	0.00	-	0	3260.459556	1.140444
$C$42	soy bean	- 0.00	- 0.00	0	0	1.140444
$C$43	sweet corn	- 0.00	- 0.00	0	0	1.140444
$C$44	cabbage	- 0.00	- 0.00	0	0	1.140444
$C$45	balance income	- 0.00	-	0	28.5111	81511.4889
$C$46	Socail Max Hired Labor	202,122.40	-	202122.4	1E+30	202122.1862
$C$47	Economic Risk Price	6.34	-	6.344599	2.3221E+14	6.308960125
$C$48	Econnomic Risk Yield	1.14	- 0.00	1.140444	201.886724	1.140444
$C$49	Env Water	1,198,904.00	-	1198904	1E+30	1198902.272
$C$50	Economic Max Income	592,992.00	0.00	592992	1E+30	592964.5545

2.1.3 Limits Report in irrigated area with storage dam model

Cell	Target Name	Value
$C$6		100.00

Cell	Adjustable Name	Value	Lower Limit	Target Result	Upper Limit	Target Result
$G$1		-1.28248E-15	-1.97215E-31	99.99537169	-1.97215E-31	99.99537169
$H$1		4.01808E-15	0	99.99537169	0	99.99537169
$I$1		0	7.4545E-15	99.99537169	7.4545E-15	99.99537169
$J$1		3.7709E-15	0	99.99537169	0	99.99537169
$K$1		3.89833E-15	0	99.99537169	0	99.99537169
$L$1		0.001425555	0.001425555	99.99537169	0.001425555	99.99537169
$M$1		4.09392E-15	0	99.99537169	0	99.99537169
$N$1		1.44383E-15	1.97215E-31	99.99537169	1.97215E-31	99.99537169
$O$1		3.90022E-15	0	99.99537169	0	99.99537169
$P$1		0	-6.23643E-14	99.99537169	-6.23643E-14	99.99537169
$Q$1		0	0	99.99537169	2.91038E-13	99.99537169
$R$1		0	0	99.99537169	2.91038E-13	99.99537169
$S$1		862.9464904	0	99.99537169	862.9464904	99.99537169
$T$1		0	0	99.99537169	2.91038E-13	99.99537169
$U$1		0	0	99.99537169	2.91038E-13	99.99537169
$V$1		0	0	99.99537169	2.91038E-13	99.99537169
$W$1		0	0	99.99537169	2.91038E-13	99.99537169
$X$1		0	0	99.99537169	2.91038E-13	99.99537169
$Y$1		0	0	99.99537169	2.91038E-13	99.99537169
$Z$1		0	0	99.99537169	2.91038E-13	99.99537169
$AA$1		0	0	99.99537169	2.91038E-13	99.99537169
$AB$1		0	-5.82844E-11	99.99537169	-5.82844E-11	99.99537169
$AC$1		26.39916667	26.39916667	99.99537169	26.39916667	99.99537169
$AD$1		0	-5.88343E-11	99.99537169	-5.88343E-11	99.99537169
$AE$1		0	7.00723E-12	99.99537169	7.00723E-12	99.99537169
$AF$1		0	7.00723E-12	99.99537169	7.00723E-12	99.99537169
$AG$1		0	4.19327E-12	99.99537169	4.19327E-12	99.99537169
$AH$1		1.52196E-11	0	99.99537169	0	99.99537169
$AI$1		0	5.66949E-12	99.99537169	5.66949E-12	99.99537169
$AJ$1		0	4.70674E-12	99.99537169	4.70674E-12	99.99537169
$AK$1		1.140444	1.140444	99.99537169	1.140444	99.99537169
$AL$1		0	1.37146E-12	99.99537169	1.37146E-12	99.99537169
$AM$1		0	2.88767E-12	99.99537169	2.88767E-12	99.99537169
$AN$1		0	3.12018E-12	99.99537169	3.12018E-12	99.99537169
$AO$1		0	-6.23643E-11	99.99537169	-6.23643E-11	99.99537169
$AP$1		202122.1862	202122.1862	99.99537169	202122.1862	99.99537169
$AQ$1		6.308960125	6.308960125	99.99537169	6.308960125	99.99537169
$AR$1		0	5.81735E-12	99.99537169	5.81735E-12	99.99537169
$AS$1		1198902.272	1198902.272	99.99537169	1198902.272	99.99537169
$AT$1		592964.5545	592964.5545	99.99537169	592964.5545	99.99537169
$AU$1		0	2.91038E-11	99.99537169	2.91038E-11	99.99537169
$AV$1		0	5.84421E-13	99.99537169	5.84421E-13	99.99537169
$AW$1		0	-5.81735E-12	99.99537169	-5.81735E-12	99.99537169
$AX$1		0	0	99.99537169	0	99.99537169
$AY$1		0	6.98492E-10	99.99537169	6.98492E-10	99.99537169

2.2 Results of irrigated area with dike dam model

2.2.1 Answers Report in irrigated area with storage dam model

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		99.92	99.92

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		1.57772E-30	1.57772E-30
$H$1		0	0
$I$1		0	0
$J$1		1.19744E-15	0
$K$1		0.011929962	0.011929962
$L$1		0	0
$M$1		0	2.16084E-15
$N$1		1.90774E-17	1.13691E-16
$O$1		0	0
$P$1		0	0
$Q$1		0	0
$R$1		1.80398E-19	2.69532E-19
$S$1		0	0
$T$1		0.1474783	0.1474783
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		0	0
$AD$1		0	0
$AE$1		0	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	0
$AL$1		0	0
$AM$1		1.41034E-12	-1.16103E-12
$AN$1		0	0
$AO$1		0	1.12331E-13
$AP$1		8.51	8.51
$AQ$1		0	0
$AR$1		5.46115E-12	0
$AS$1		0	0
$AT$1		0	0
$AU$1		0	0
$AV$1		3.23117E-27	3.23117E-27
$AW$1		0	0
$AX$1		-8.91054E-12	-1.35145E-12
$AY$1		0	0
$AZ$1		347573.3105	347573.3105
$BA$1		47.13325375	47.13325375
$BB$1		0	0
$BC$1		1374641.509	1374641.509
$BD$1		274655.2003	274655.2003

$BE$1	0	0
$BF$1	0	0
$BG$1	0	0
$BH$1	0	0
$BI$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	- 0.14	$C$7<=$F$7	Not Binding	7.585548338
$C$8	rent land	0.15	$C$8<=$F$8	Not Binding	7.1325217
$C$9	family labor June	0.09	$C$9<=$F$9	Not Binding	39.9050375
$C$10	family labor July	0.37	$C$10<=$F$10	Not Binding	39.63148346
$C$11	family labor August	0.35	$C$11<=$F$11	Not Binding	39.652003
$C$12	family labor September	0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.09	$C$13<=$F$13	Not Binding	39.9050375
$C$14	family labor November	0.37	$C$14<=$F$14	Not Binding	39.63148346
$C$15	family labor December	0.35	$C$15<=$F$15	Not Binding	39.652003
$C$16	family labor January	0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.09	$C$17<=$F$17	Not Binding	39.9050375
$C$18	family labor March	0.37	$C$18<=$F$18	Not Binding	39.63148346
$C$19	family labor April	0.35	$C$19<=$F$19	Not Binding	39.652003
$C$20	family labor May	-	$C$20<=$F$20	Not Binding	40
$C$21	investment crop1	27.41	$C$21<=$F$21	Not Binding	127542.2129
$C$22	BAAC	-	$C$22<=$F$22	Not Binding	144761.9
$C$23	Coperative	-	$C$23<=$F$23	Not Binding	115000
$C$24	Villange Fund	-	$C$24<=$F$24	Not Binding	15625
$C$25	SCB	-	$C$25<=$F$25	Not Binding	82500
$C$26	June	1.65	$C$26<=$F$26	Not Binding	40468.11023
$C$27	July	1.51	$C$27<=$F$27	Not Binding	77594.33347
$C$28	August	1.44	$C$28<=$F$28	Not Binding	296981.2848
$C$29	September	0.00	$C$29<=$F$29	Not Binding	442657.44
$C$30	October	1.48	$C$30<=$F$30	Not Binding	238626.6773
$C$31	November	1.29	$C$31<=$F$31	Not Binding	121537.5947
$C$32	December	1.20	$C$32<=$F$32	Not Binding	39561.35874
$C$33	January	0.00	$C$33<=$F$33	Not Binding	22533.12
$C$34	Febuary	1.46	$C$34<=$F$34	Not Binding	14133.57541
$C$35	March	2.09	$C$35<=$F$35	Not Binding	39396.31464
$C$36	April	2.35	$C$36<=$F$36	Not Binding	6363.603954
$C$37	May	-	$C$37<=$F$37	Not Binding	34788.096
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	170.13
$C$40	rice dry	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	chilli	-	$C$41=$F$41	Not Binding	0
$C$42	pak choi	0.00	$C$42=$F$42	Not Binding	0
$C$43	long bean	0.00	$C$43=$F$43	Not Binding	0
$C$44	morning glory	-	$C$44=$F$44	Not Binding	0
$C$45	coriander	- 0.00	$C$45=$F$45	Not Binding	0
$C$46	celery	- 0.00	$C$46=$F$46	Not Binding	0
$C$47	green shallot	-	$C$47=$F$47	Not Binding	0
$C$48	spinanch	-	$C$48=$F$48	Not Binding	0
$C$49	lettuce	0.00	$C$49=$F$49	Not Binding	0
$C$50	sugar cane	- 0.00	$C$50=$F$50	Not Binding	0
$C$51	longan	- 0.00	$C$51=$F$51	Not Binding	0
$C$52	balance income	- 0.00	$C$52=$F$52	Not Binding	0
$C$53	Socail Max Hired Labor	347,575.10	$C$53=$F$53	Not Binding	0
$C$54	Economic Risk Price	47.34	$C$54=$F$54	Not Binding	0

$C$55	Econnomic Risk Yield	8.51	$C$55=$F$55	Not Binding	0
$C$56	Env Water	1,374,655.97	$C$56=$F$56	Not Binding	0
$C$57	Economic Max Income	274,861.70	$C$57=$F$57	Not Binding	0

2.2.2 Sensitivity Report in irrigated area with storage dam model

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$G$1		1.57772E-30	0	0	1E+30	5.055844492
$I$1		0	14.17552634	0	1E+30	14.17552634
$J$1		0	4.314109244	0	1E+30	4.314109244
$K$1		0.011929962	0	0	1.166609718	8375.958701
$L$1		0	7.316599482	0	1E+30	7.316599482
$M$1		2.16084E-15	0	0	1E+30	1.457538465
$N$1		1.13691E-16	0	0	1E+30	1.839674246
$O$1		0	5.440636079	0	1E+30	5.440636079
$P$1		0	7.052851945	0	1E+30	7.052851945
$Q$1		0	4.762279022	0	1E+30	4.762279022
$R$1		2.69532E-19	0	0	1E+30	24.55424619
$S$1		0	6.140638153	0	1E+30	6.140638153
$T$1		0.1474783	0	0	0	0.119338478
$U$1		0	0	0	1E+30	0
$V$1		0	0	0	1E+30	0
$W$1		0	0	0	1E+30	0
$X$1		0	0	0	1E+30	0
$Y$1		0	0	0	1E+30	0
$Z$1		0	0	0	1E+30	0
$AA$1		0	0	0	1E+30	0
$AB$1		0	0	0	1E+30	0
$AC$1		0	0	0	1E+30	0
$AD$1		0	0	0	1E+30	0
$AE$1		0	0	0	1E+30	0
$AF$1		0	0	0	1E+30	0
$AG$1		0	0	0	1E+30	0
$AH$1		0	0	0	1E+30	0
$AI$1		0	0	0	1E+30	0
$AJ$1		0	0	0	1E+30	0
$AK$1		0	0.006803537	0	1E+30	0.006803537
$AL$1		0	0.006803537	0	1E+30	0.006803537
$AM$1		-1.16103E-12	0	0	0.809916384	0.007180984
$AN$1		0	0	0	1E+30	0.007195699
$AO$1		1.12331E-13	0	0	1E+30	0.005261109
$AP$1		8.51	0	0	0	2.492135374
$AQ$1		0	0	0	1E+30	0.006306272
$AR$1		0	0.001635442	0	1E+30	0.001635442
$AS$1		0	0.002705403	0	1E+30	0.002705403
$AT$1		0	0	0	1E+30	0.005939559
$AU$1		0	0	0	1E+30	0.005193558
$AV$1		3.23117E-27	0	0	1E+30	0.006614276
$AW$1		0	0.006927422	0	1E+30	0.006927422
$AX$1		-1.35145E-12	0	0	0.202479096	0
$AY$1		0	0	0	1E+30	0
$AZ$1		347573.3105	0	0	0.262485222	0
$BA$1		47.13325375	0	0	0.078351573	0.313664506
$BB$1		0	0.008828269	0	1E+30	0.008828269
$BC$1		1374641.509	0	0	0.095305661	0
$BD$1		274655.2003	0	0.000363819	0	0
$BE$1		0	0.000287708	0.000287708	1E+30	0.000287708
$BF$1		0	2.112378538	2.112378538	1E+30	2.112378538
$BG$1		0	11.74205305	11.75088132	1E+30	11.74205305
$BH$1		0	7.27455E-05	7.27455E-05	1E+30	7.27455E-05
$BI$1		0	0.000363819	0	1E+30	0.000363819

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$C$7	land	- 0.14	-	7.45	1E+30	7.585548338
$C$8	rent land	0.15	-	7.28	1E+30	7.1325217
$C$9	family labor June	0.09	-	40	1E+30	39.9050375
$C$10	family labor July	0.37	-	40	1E+30	39.63148346
$C$11	family labor August	0.35	-	40	1E+30	39.652003
$C$12	family labor September	0.00	-	40	1E+30	40
$C$13	family labor October	0.09	-	40	1E+30	39.9050375
$C$14	family labor November	0.37	-	40	1E+30	39.63148346
$C$15	family labor December	0.35	-	40	1E+30	39.652003
$C$16	family labor January	0.00	-	40	1E+30	40
$C$17	family labor Febuary	0.09	-	40	1E+30	39.9050375
$C$18	family labor March	0.37	-	40	1E+30	39.63148346
$C$19	family labor April	0.35	-	40	1E+30	39.652003
$C$20	family labor May	-	-	40	1E+30	40
$C$21	investment crop1	27.41	-	127569.62	1E+30	127542.2129
$C$22	BAAC	-	-	144761.9	1E+30	144761.9
$C$23	Coperative	-	-	115000	1E+30	115000
$C$24	Villange Fund	-	-	15625	1E+30	15625
$C$25	SCB	-	-	82500	1E+30	82500
$C$26	June	1.65	-	40469.76	1E+30	40468.11023
$C$27	July	1.51	-	77595.84	1E+30	77594.33347
$C$28	August	1.44	-	296982.72	1E+30	296981.2848
$C$29	September	0.00	-	442657.44	1E+30	442657.44
$C$30	October	1.48	-	238628.16	1E+30	238626.6773
$C$31	November	1.29	-	121538.88	1E+30	121537.5947
$C$32	December	1.20	-	39562.56	1E+30	39561.35874
$C$33	January	0.00	-	22533.12	1E+30	22533.12
$C$34	Febuary	1.46	-	14135.04	1E+30	14133.57541
$C$35	March	2.09	-	39398.4	1E+30	39396.31464
$C$36	April	2.35	-	6365.952	1E+30	6363.603954
$C$37	May	-	-	34788.096	1E+30	34788.096
$C$38	yield rice rain	- 0.00	- 0.01	0	0	0
$C$39	yield rice consumption	-	-	170.13	1E+30	170.13
$C$40	rice dry	- 0.00	-	0	928.7137628	0
$C$41	chilli	-	-	0	713.25217	0
$C$42	pak choi	0.00	-	0	568.3284223	0
$C$43	long bean	0.00	-	0	411.5707848	0
$C$44	morning glory	-	-	0	725.5871516	0
$C$45	coriander	- 0.00	- 0.00	0	0	0
$C$46	celery	- 0.00	- 0.00	0	0	0
$C$47	green shallot	-	-	0	570.601736	0
$C$48	spinanch	-	-	0	528.3349407	0
$C$49	lettuce	0.00	-	0	713.25217	0
$C$50	sugar cane	- 0.00	- 0.01	0	0	0
$C$51	longan	- 0.00	-	0	571.0585829	0
$C$52	balance income	- 0.00	-	0	147.4783	7132.5217
$C$53	Socail Max Hired Labor	347,575.10	-	347575.1	1E+30	347573.3105
$C$54	Economic Risk Price	47.34	-	47.34	1.60209E+18	47.13325375
$C$55	Econnomic Risk Yield	8.51	- 0.01	8.51	411.5707848	0
$C$56	Env Water	1,374,655.97	-	1374655.968	1E+30	1374641.509
$C$57	Economic Max Income	274,861.70	0.00	274861.7	1E+30	274655.2003

2.2.3 Sensitivity Report in irrigated area with storage dam model

Cell	Target Name	Value
$C$6		99.92

Cell	Adjustable Name	Value	Lower Limit	Target Result	Upper Limit	Target Result
$G$1		1.57772E-30	1.57772E-30	99.92487143	1.57772E-30	99.92487143
$H$1		0	0	99.92487143	0	99.92487143
$I$1		0	0	99.92487143	0	99.92487143
$J$1		0	0	99.92487143	0	99.92487143
$K$1		0.011929962	0.011929962	99.92487143	0.011929962	99.92487143
$L$1		0	0	99.92487143	0	99.92487143
$M$1		2.16084E-15	1.2938E-15	99.92487143	1.2938E-15	99.92487143
$N$1		1.13691E-16	1.13691E-16	99.92487143	1.13691E-16	99.92487143
$O$1		0	0	99.92487143	0	99.92487143
$P$1		0	0	99.92487143	0	99.92487143
$Q$1		0	0	99.92487143	0	99.92487143
$R$1		2.69532E-19	2.69532E-19	99.92487143	2.69532E-19	99.92487143
$S$1		0	0	99.92487143	0	99.92487143
$T$1		0.1474783	0.1474783	99.92487143	0.1474783	99.92487143
$U$1		0	0	99.92487143	850.2814196	99.92487143
$V$1		0	0	99.92487143	850.2814196	99.92487143
$W$1		0	0	99.92487143	850.2814196	99.92487143
$X$1		0	0	99.92487143	850.2814196	99.92487143
$Y$1		0	0	99.92487143	850.2814196	99.92487143
$Z$1		0	0	99.92487143	850.2814196	99.92487143
$AA$1		0	0	99.92487143	850.2814196	99.92487143
$AB$1		0	0	99.92487143	850.2814196	99.92487143
$AC$1		0	0	99.92487143	850.2814196	99.92487143
$AD$1		0	0	99.92487143	850.2814196	99.92487143
$AE$1		0	0	99.92487143	850.2814196	99.92487143
$AF$1		0	0	99.92487143	850.2814196	99.92487143
$AG$1		0	-3.6895E-12	99.92487143	-3.68683E-12	99.92487143
$AH$1		0	-3.65534E-12	99.92487143	-3.65269E-12	99.92487143
$AI$1		0	-3.7243E-12	99.92487143	-3.72161E-12	99.92487143
$AJ$1		0	-3.6218E-12	99.92487143	-3.61918E-12	99.92487143
$AK$1		0	0	99.92487143	0	99.92487143
$AL$1		0	0	99.92487143	0	99.92487143
$AM$1		-1.16103E-12	0	99.92487143	0	99.92487143
$AN$1		0	0	99.92487143	0	99.92487143
$AO$1		1.12331E-13	0	99.92487143	0	99.92487143
$AP$1		8.51	8.51	99.92487143	8.51	99.92487143
$AQ$1		0	0	99.92487143	0	99.92487143
$AR$1		0	1.89432E-13	99.92487143	1.89432E-13	99.92487143
$AS$1		0	7.73101E-14	99.92487143	7.73101E-14	99.92487143
$AT$1		0	0	99.92487143	0	99.92487143
$AU$1		0	0	99.92487143	0	99.92487143
$AV$1		3.23117E-27	3.23117E-27	99.92487143	3.23117E-27	99.92487143
$AW$1		0	9.55356E-16	99.92487143	9.55356E-16	99.92487143
$AX$1		-1.35145E-12	0	99.92487143	0	99.92487143
$AY$1		0	-3.94776E-12	99.92487143	-3.94776E-12	99.92487143
$AZ$1		347573.3105	347573.3105	99.92487143	347573.3105	99.92487143
$BA$1		47.13325375	47.13325375	99.92487143	47.13325375	99.92487143
$BB$1		0	-7.72715E-13	99.92487143	-7.72715E-13	99.92487143
$BC$1		1374641.509	1374641.509	99.92487143	1374641.509	99.92487143
$BD$1		274655.2003	274655.2003	99.92487143	274655.2003	99.92487143
$BE$1		0	0	99.92487143	0	99.92487143

$BF$1	0	-6.39488E-14	99.92487143	-6.39488E-14	99.92487143
$BG$1	0	7.72715E-13	99.92487143	7.72715E-13	99.92487143
$BH$1	0	-6.98492E-10	99.92487143	-6.98492E-10	99.92487143
$BI$1	0	-5.82077E-11	99.92487143	-5.82077E-11	99.92487143

2.3 Results of rainfed area model

2.3.1 Answers Report in rainfed area model

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6	goal	99.94	99.94

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		0	0
$H$1		9.86076E-32	9.86076E-32
$I$1		0	1.3652E-16
$J$1		-2.24031E-19	0
$K$1		0	1.06512E-15
$L$1		0.008864279	0.008864279
$M$1		-1.1513E-20	1.20341E-21
$N$1		0	0
$O$1		0.008071579	0.008071579
$P$1		0	0
$Q$1		0	0
$R$1		0	0
$S$1		0	0
$T$1		0	0
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		877.5458129	0
$AA$1		0	0
$AB$1		0	877.5458129
$AC$1		0	0
$AD$1		234.1447176	234.1447176
$AE$1		0	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		2.85816E-12	0
$AL$1		0	-8.88178E-16
$AM$1		5.40859E-13	0
$AN$1		2.121576418	2.121576418
$AO$1		0	0
$AP$1		0	0
$AQ$1		7.765423582	7.765423582
$AR$1		2.71635E-11	0
$AS$1		0	0
$AT$1		317363.1596	317363.1596
$AU$1		0	0
$AV$1		0	0
$AW$1		680063.887	680063.887
$AX$1		555759.6434	555759.6434
$AY$1		0	0
$AZ$1		0	0
$BA$1		0	0
$BB$1		0	0

$BC$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land crop1	0.02	$C$7<=$F$7	Not Binding	14.98306414
$C$8	rent land1	-	$C$8<=$F$8	Not Binding	6
$C$9	family labor June	0.02	$C$9<=$F$9	Not Binding	39.98111251
$C$10	family labor July	0.01	$C$10<=$F$10	Not Binding	39.99437411
$C$11	family labor August	0.01	$C$11<=$F$11	Not Binding	39.99437411
$C$12	family labor September	0.12	$C$12<=$F$12	Not Binding	39.87973348
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.99437411
$C$14	family labor November	0.01	$C$14<=$F$14	Not Binding	39.99437411
$C$15	family labor December	0.06	$C$15<=$F$15	Not Binding	39.93852916
$C$16	family labor January	0.03	$C$16<=$F$16	Not Binding	39.97097241
$C$17	family labor Febuary	0.03	$C$17<=$F$17	Not Binding	39.96786992
$C$18	family labor March	0.03	$C$18<=$F$18	Not Binding	39.96786992
$C$19	family labor April	- 877.52	$C$19<=$F$19	Not Binding	917.5158102
$C$20	family labor May	0.00	$C$20<=$F$20	Not Binding	39.99806282
$C$21	investment crop1	131,471.27	$C$21<=$F$21	Not Binding	0.001144364
$C$22	Villange fund	234.14	$C$22<=$F$22	Not Binding	21765.85528
$C$23	BAAC	-	$C$23<=$F$23	Not Binding	90000
$C$24	Coperative	-	$C$24<=$F$24	Not Binding	60000
$C$25	Finance	-	$C$25<=$F$25	Not Binding	18000
$C$26	water June	4.60	$C$26<=$F$26	Not Binding	11179.88005
$C$27	water July	3.46	$C$27<=$F$27	Not Binding	57013.62585
$C$28	water August	2.97	$C$28<=$F$28	Not Binding	155672.5546
$C$29	water September	2.98	$C$29<=$F$29	Not Binding	209785.7222
$C$30	water October	3.00	$C$30<=$F$30	Not Binding	124876.104
$C$31	water November	3.10	$C$31<=$F$31	Not Binding	44225.06028
$C$32	water December	3.80	$C$32<=$F$32	Not Binding	25432.36299
$C$33	water January	3.43	$C$33<=$F$33	Not Binding	16528.348
$C$34	water Febuary	3.88	$C$34<=$F$34	Not Binding	9291.031486
$C$35	water March	5.15	$C$35<=$F$35	Not Binding	11760.79922
$C$36	water April	5.07	$C$36<=$F$36	Not Binding	5709.425301
$C$37	water May	4.67	$C$37<=$F$37	Not Binding	8593.85303
$C$38	yield rice rain	-	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	375.64
$C$40	yield long bean	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	yield marigold	- 0.00	$C$41=$F$41	Not Binding	0
$C$42	yield maize	- 0.00	$C$42=$F$42	Not Binding	0
$C$43	yield sweet corn	- 0.00	$C$43=$F$43	Not Binding	0
$C$44	yield tobacco	0.00	$C$44=$F$44	Not Binding	0
$C$45	yield galangal	- 0.00	$C$45=$F$45	Not Binding	0
$C$46	yield lemon grass	-	$C$46=$F$46	Not Binding	0
$C$47	yield banana	- 0.00	$C$47=$F$47	Not Binding	0
$C$48	yield longan	-	$C$48=$F$48	Not Binding	0
$C$49	commodity balance	- 0.00	$C$49=$F$49	Not Binding	0
$C$50	Socail Max Hired Labor	317,365.70	$C$50=$F$50	Not Binding	0
$C$51	Economic Risk Price	0.88	$C$51=$F$51	Not Binding	0
$C$52	Economic Risk Yield	9.89	$C$52=$F$52	Not Binding	0
$C$53	Env Water	680,110.00	$C$53=$F$53	Not Binding	0
$C$54	Economic Max Income	556,068.10	$C$54=$F$54	Not Binding	0

2.3.2 Sensitivity Report in rainfed area model

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$G$1		0	1.666003503	0	1E+30	1.666003503
$H$1		9.86076E-32	0	0	1E+30	0.05203923
$I$1		1.3652E-16	0	0	1E+30	0.797437885
$J$1		0	4.529814608	0	1E+30	4.529814608
$K$1		1.06512E-15	0	0	1E+30	0.307795848
$L$1		0.008864279	0	0	3.762491034	0.623486409
$M$1		1.20341E-21	0	0	1E+30	0.742187966
$N$1		0	1.137694988	0	1E+30	1.137694988
$O$1		0.008071579	0	0	0.018701304	18.0062908
$P$1		0	0	0	1E+30	0.282352395
$Q$1		0	0	0	1E+30	0
$R$1		0	0	0	1E+30	0
$S$1		0	0	0	1E+30	0
$T$1		0	0	0	1E+30	0
$U$1		0	0	0	1E+30	0
$V$1		0	0	0	1E+30	0
$W$1		0	0	0	1E+30	0
$X$1		0	0	0	1E+30	0
$Y$1		0	0	0	1E+30	0
$Z$1		0	0	0	1E+30	0
$AA$1		0	0	0	1E+30	0
$AB$1		877.5458129	0	0	0	0.002144631
$AC$1		0	0	0	1E+30	0
$AD$1		234.1447176	0	0	0	0
$AE$1		0	0	0	1E+30	0
$AF$1		0	0	0	1E+30	0
$AG$1		0	0	0	1E+30	0
$AH$1		0	0	0	0	0.001906444
$AI$1		0	0	0	1E+30	0
$AJ$1		0	1.95848E-05	0	1E+30	1.95848E-05
$AK$1		0	0.000273798	0	1E+30	0.000273798
$AL$1		-8.88178E-16	0	0	1E+30	0.000990201
$AM$1		0	0.000180389	0	1E+30	0.000180389
$AN$1		2.121576418	0	0	0	0.002605024
$AO$1		0	0.000185547	0	1E+30	0.000185547
$AP$1		0	0	0	1E+30	0.001137695
$AQ$1		7.765423582	0	0	0	0.018716196
$AR$1		0	0.000364834	0	1E+30	0.000364834
$AS$1		0	0	0	1E+30	0
$AT$1		317363.1596	0	0	0	0.000204173
$AU$1		0	0.048707621	0	1E+30	0.048707621
$AV$1		0	0.001270315	0	1E+30	0.001270315
$AW$1		680063.887	0	0	0	0
$AX$1		555759.6434	0	0.000179834	0	0
$AY$1		0	0.000315094	0.000315094	1E+30	0.000315094
$AZ$1		0	113.4586704	113.507378	1E+30	113.4586704
$BA$1		0	10.11302118	10.11429149	1E+30	10.11302118
$BB$1		0	0.000147035	0.000147035	1E+30	0.000147035
$BC$1		0	0.000179834	0	1E+30	0.000179834

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$C$7	land crop1	0.02	-	15	1E+30	14.98306414
$C$8	rent land1	-	-	6	1E+30	6
$C$9	family labor June	0.02	-	40	1E+30	39.98111251
$C$10	family labor July	0.01	-	40	1E+30	39.99437411
$C$11	family labor August	0.01	-	40	1E+30	39.99437411
$C$12	family labor September	0.12	-	40	1E+30	39.87973348
$C$13	family labor October	0.01	-	40	1E+30	39.99437411
$C$14	family labor November	0.01	-	40	1E+30	39.99437411
$C$15	family labor December	0.06	-	40	1E+30	39.93852916
$C$16	family labor January	0.03	-	40	1E+30	39.97097241
$C$17	family labor Febuary	0.03	-	40	1E+30	39.96786992
$C$18	family labor March	0.03	-	40	1E+30	39.96786992
$C$19	family labor April	- 877.52	-	40	1E+30	917.5158102
$C$20	family labor May	0.00	-	40	1E+30	39.99806282
$C$21	investment crop1	131,471.27	-	131471.27	1.32139E+19	131631.8731
$C$22	Villange fund	234.14	-	22000	1E+30	21765.85528
$C$23	BAAC	-	-	90000	1E+30	90000
$C$24	Coperative	-	-	60000	1E+30	60000
$C$25	Finance	-	-	18000	1E+30	18000
$C$26	water June	4.60	-	11184.48	1E+30	11179.88005
$C$27	water July	3.46	-	57017.088	1E+30	57013.62585
$C$28	water August	2.97	-	155675.52	1E+30	155672.5546
$C$29	water September	2.98	-	209788.704	1E+30	209785.7222
$C$30	water October	3.00	-	124879.104	1E+30	124876.104
$C$31	water November	3.10	-	44228.16	1E+30	44225.06028
$C$32	water December	3.80	-	25436.16	1E+30	25432.36299
$C$33	water January	3.43	-	16531.776	1E+30	16528.348
$C$34	water Febuary	3.88	-	9294.912	1E+30	9291.031486
$C$35	water March	5.15	-	11765.952	1E+30	11760.79922
$C$36	water April	5.07	-	5714.496	1E+30	5709.425301
$C$37	water May	4.67	-	8598.528	1E+30	8593.85303
$C$38	yield rice rain	-	-	0	1971.949282	0
$C$39	yield rice consumption	-	-	375.64	1E+30	375.64
$C$40	yield long bean	- 0.00	- 0.00	0	0	7.707478222
$C$41	yield marigold	- 0.00	- 0.00	0	0	7.680496921
$C$42	yield maize	- 0.00	-	0	7142.974182	0
$C$43	yield sweet corn	- 0.00	- 0.00	0	0	7.730162046
$C$44	yield tobacco	0.00	-	0	246.5990445	2.121576418
$C$45	yield galangal	- 0.00	- 0.00	0	0	7.682406455
$C$46	yield lemon grass	-	-	0	7690.602199	0
$C$47	yield banana	- 0.00	-	0	3604.969781	7.765423582
$C$48	yield longan	-	- 0.00	0	0	7.949924366
$C$49	commodity balance	- 0.00	-	0	248.1934006	23071.8066
$C$50	Socail Max Hired Labor	317,365.70	-	317365.7	1E+30	317363.1596
$C$51	Economic Risk Price	0.88	- 0.05	0.881	2.983910671	0.815228486
$C$52	Economic Risk Yield	9.89	- 0.00	9.887	122.5479484	7.63327469
$C$53	Env Water	680,110.00	-	680110	1E+30	680063.887
$C$54	Economic Max Income	556,068.10	0.00	556068.1	1E+30	555759.6434

2.3.3 Limits Report in rainfed area model

Cell	Target Name	Value
$C$6	goal	99.94

Cell	Adjustable Name	Value	Lower Limit	Target Result	Upper Limit	Target Result
$G$1		0	0	99.94452898	0	99.94452898
$H$1		9.86076E-32	9.86076E-32	99.94452898	9.86076E-32	99.94452898
$I$1		1.3652E-16	6.59149E-15	99.94452898	6.59149E-15	99.94452898
$J$1		0	-1.94153E-19	99.94452898	-1.94153E-19	99.94452898
$K$1		1.06512E-15	1.97215E-31	99.94452898	1.97215E-31	99.94452898
$L$1		0.008864279	#N/A	#N/A	#N/A	#N/A
$M$1		1.20341E-21	4.33792E-15	99.94452898	7.88861E-31	99.94452898
$N$1		0	0	99.94452898	0	99.94452898
$O$1		0.008071579	#N/A	#N/A	#N/A	#N/A
$P$1		0	1.62581E-14	99.94452898	1.62581E-14	99.94452898
$Q$1		0	-2.51987E-13	99.94452898	-2.51987E-13	99.94452898
$R$1		0	0	99.94452898	7.62909E-06	99.94452898
$S$1		0	0	99.94452898	7.62909E-06	99.94452898
$T$1		0	0	99.94452898	7.62909E-06	99.94452898
$U$1		0	0	99.94452898	7.62909E-06	99.94452898
$V$1		0	0	99.94452898	7.62909E-06	99.94452898
$W$1		0	0	99.94452898	7.62909E-06	99.94452898
$X$1		0	0	99.94452898	7.62909E-06	99.94452898
$Y$1		0	0	99.94452898	7.62909E-06	99.94452898
$Z$1		0	0	99.94452898	7.62909E-06	99.94452898
$AA$1		0	0	99.94452898	7.62909E-06	99.94452898
$AB$1		877.5458129	0	99.94452898	877.5458205	99.94452898
$AC$1		0	0	99.94452898	7.62909E-06	99.94452898
$AD$1		234.1447176	234.1447176	99.94452898	234.1447176	99.94452898
$AE$1		0	-2.35502E-10	99.94452898	-2.35502E-10	99.94452898
$AF$1		0	-2.33321E-10	99.94452898	-2.33321E-10	99.94452898
$AG$1		0	-2.35502E-10	99.94452898	-2.35502E-10	99.94452898
$AH$1		0	0	99.94452898	0	99.94452898
$AI$1		0	0	99.94452898	0	99.94452898
$AJ$1		0	0	99.94452898	0	99.94452898
$AK$1		0	3.97616E-13	99.94452898	3.97616E-13	99.94452898
$AL$1		-8.88178E-16	0	99.94452898	0	99.94452898
$AM$1		0	1.8174E-12	99.94452898	1.8174E-12	99.94452898
$AN$1		2.121576418	2.121576418	99.94452898	2.121576418	99.94452898
$AO$1		0	4.81365E-18	99.94452898	4.81365E-18	99.94452898
$AP$1		0	0	99.94452898	0	99.94452898
$AQ$1		7.765423582	7.765423582	99.94452898	7.765423582	99.94452898
$AR$1		0	0	99.94452898	0	99.94452898
$AS$1		0	-2.51987E-10	99.94452898	-2.51987E-10	99.94452898
$AT$1		317363.1596	317363.1596	99.94452898	317363.1596	99.94452898
$AU$1		0	6.58473E-13	99.94452898	6.58473E-13	99.94452898
$AV$1		0	-3.42837E-12	99.94452898	-3.42837E-12	99.94452898
$AW$1		680063.887	680063.887	99.94452898	680063.887	99.94452898
$AX$1		555759.6434	555759.6434	99.94452898	555759.6434	99.94452898
$AY$1		0	1.74623E-10	99.94452898	1.74623E-10	99.94452898
$AZ$1		0	-6.58473E-13	99.94452898	-6.58473E-13	99.94452898
$BA$1		0	3.42837E-12	99.94452898	3.42837E-12	99.94452898
$BB$1		0	3.49246E-10	99.94452898	3.49246E-10	99.94452898
$BC$1		0	-1.16415E-10	99.94452898	-1.16415E-10	99.94452898

3. Results of sensitivity analyses;

3.1 Sensitivity Report in irrigated area with dike dam model by increasing longan price

3.1.1 Results of sensitivity analysis by increasing 10 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		99.92	99.92

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		1.57772E-30	1.57772E-30
$H$1		0	4.31892E-15
$I$1		0	0
$J$1		0	2.46148E-31
$K$1		0.011929962	0.011929962
$L$1		0	0
$M$1		2.16084E-15	5.74261E-17
$N$1		1.13691E-16	0
$O$1		0	3.93058E-16
$P$1		0	2.66721E-15
$Q$1		0	0
$R$1		2.69532E-19	2.69532E-19
$S$1		0	0
$T$1		0.1474783	0.1474783
$U$1		0	850.2814196
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		0	0
$AD$1		0	0
$AE$1		0	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	0
$AL$1		0	0
$AM$1		-1.16103E-12	0
$AN$1		0	0
$AO$1		1.12331E-13	0
$AP$1		8.51	8.51
$AQ$1		0	-4.70621E-13
$AR$1		0	0
$AS$1		0	1.15799E-13

$AT$1	0	0
$AU$1	0	0
$AV$1	3.23117E-27	1.00611E-12
$AW$1	0	0
$AX$1	-1.35145E-12	-3.96456E-12
$AY$1	0	0
$AZ$1	347573.3105	347573.3105
$BA$1	47.13325375	47.13325375
$BB$1	0	0
$BC$1	1374641.509	1374641.509
$BD$1	274655.2003	274655.2003
$BE$1	0	0
$BF$1	0	0
$BG$1	0	0
$BH$1	0	0
$BI$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	- 0.14	$C$7<=$F$7	Not Binding	7.585548338
$C$8	rent land	0.15	$C$8<=$F$8	Not Binding	7.1325217
$C$9	family labor June	- 850.19	$C$9<=$F$9	Not Binding	890.1864571
$C$10	family labor July	0.37	$C$10<=$F$10	Not Binding	39.63148346
$C$11	family labor August	0.35	$C$11<=$F$11	Not Binding	39.652003
$C$12	family labor September	0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.09	$C$13<=$F$13	Not Binding	39.9050375
$C$14	family labor November	0.37	$C$14<=$F$14	Not Binding	39.63148346
$C$15	family labor December	0.35	$C$15<=$F$15	Not Binding	39.652003
$C$16	family labor January	0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.09	$C$17<=$F$17	Not Binding	39.9050375
$C$18	family labor March	0.37	$C$18<=$F$18	Not Binding	39.63148346
$C$19	family labor April	0.35	$C$19<=$F$19	Not Binding	39.652003
$C$20	family labor May	-	$C$20<=$F$20	Not Binding	40
$C$21	investment crop1	127,569.62	$C$21<=$F$21	Binding	0
$C$22	BAAC	-	$C$22<=$F$22	Not Binding	144761.9
$C$23	Coperative	-	$C$23<=$F$23	Not Binding	115000
$C$24	Villange Fund	-	$C$24<=$F$24	Not Binding	15625
$C$25	SCB	-	$C$25<=$F$25	Not Binding	82500
$C$26	June	1.65	$C$26<=$F$26	Not Binding	40468.11023
$C$27	July	1.51	$C$27<=$F$27	Not Binding	77594.33347
$C$28	August	1.44	$C$28<=$F$28	Not Binding	296981.2848
$C$29	September	0.00	$C$29<=$F$29	Not Binding	442657.44
$C$30	October	1.48	$C$30<=$F$30	Not Binding	238626.6773
$C$31	November	1.29	$C$31<=$F$31	Not Binding	121537.5947
$C$32	December	1.20	$C$32<=$F$32	Not Binding	39561.35874
$C$33	January	0.00	$C$33<=$F$33	Not Binding	22533.12
$C$34	Febuary	1.46	$C$34<=$F$34	Not Binding	14133.57541
$C$35	March	2.09	$C$35<=$F$35	Not Binding	39396.31464
$C$36	April	2.35	$C$36<=$F$36	Not Binding	6363.603954
$C$37	May	-	$C$37<=$F$37	Not Binding	34788.096
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0

$C$39	yield rice consumption		-	$C$39<=$F$39	Not Binding	170.13
$C$40	rice dry	-	0.00	$C$40=$F$40	Not Binding	0
$C$41	chilli		-	$C$41=$F$41	Not Binding	0
$C$42	pak choi	-	0.00	$C$42=$F$42	Not Binding	0
$C$43	long bean		0.00	$C$43=$F$43	Not Binding	0
$C$44	morning glory	-	0.00	$C$44=$F$44	Binding	0
$C$45	coriander	-	0.00	$C$45=$F$45	Not Binding	0
$C$46	celery		0.00	$C$46=$F$46	Not Binding	0
$C$47	green shallot	-	0.00	$C$47=$F$47	Not Binding	0
$C$48	spinanch	-	0.00	$C$48=$F$48	Not Binding	0
$C$49	lettuce		0.00	$C$49=$F$49	Not Binding	0
$C$50	sugar cane	-	0.00	$C$50=$F$50	Not Binding	0
$C$51	longan	-	0.00	$C$51=$F$51	Not Binding	0
$C$52	balance income	-	0.00	$C$52=$F$52	Not Binding	0
$C$53	Socail Max Hired Labor		347,575.10	$C$53=$F$53	Not Binding	0
$C$54	Economic Risk Price		47.34	$C$54=$F$54	Not Binding	0
$C$55	Econnomic Risk Yield		8.51	$C$55=$F$55	Not Binding	0
$C$56	Env Water		1,374,655.97	$C$56=$F$56	Not Binding	0
$C$57	Economic Max Income		274,861.70	$C$57=$F$57	Not Binding	0

3.1.2 Results of sensitivity analysis by increasing 20 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		99.92	99.92

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		1.57772E-30	1.57772E-30
$H$1		4.31892E-15	2.52211E-15
$I$1		0	0
$J$1		2.46148E-31	2.46148E-31
$K$1		0.011929962	0.011929962
$L$1		0	0
$M$1		5.74261E-17	-3.63099E-15
$N$1		0	0
$O$1		3.93058E-16	0
$P$1		2.66721E-15	3.9443E-31
$Q$1		0	0
$R$1		2.69532E-19	0
$S$1		0	0
$T$1		0.1474783	0.1474783
$U$1		850.2814196	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		0	0
$AD$1		0	0
$AE$1		0	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	0
$AL$1		0	0
$AM$1		0	0
$AN$1		0	9.12759E-15
$AO$1		0	0
$AP$1		8.51	8.51
$AQ$1		-4.70621E-13	0
$AR$1		0	0
$AS$1		1.15799E-13	1.62928E-13
$AT$1		0	0
$AU$1		0	0
$AV$1		1.00611E-12	2.28318E-13
$AW$1		0	-1.31538E-11
$AX$1		-3.96456E-12	4.05437E-13

$AY$1	0	0
$AZ$1	347573.3105	347573.3105
$BA$1	47.13325375	47.13325375
$BB$1	0	0
$BC$1	1374641.509	1374641.509
$BD$1	274655.2003	274655.2003
$BE$1	0	0
$BF$1	0	0
$BG$1	0	0
$BH$1	0	0
$BI$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	- 0.14	$C$7<=$F$7	Not Binding	7.585548338
$C$8	rent land	0.15	$C$8<=$F$8	Not Binding	7.1325217
$C$9	family labor June	0.09	$C$9<=$F$9	Not Binding	39.9050375
$C$10	family labor July	0.37	$C$10<=$F$10	Not Binding	39.63148346
$C$11	family labor August	0.35	$C$11<=$F$11	Not Binding	39.652003
$C$12	family labor September	- 0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.09	$C$13<=$F$13	Not Binding	39.9050375
$C$14	family labor November	0.37	$C$14<=$F$14	Not Binding	39.63148346
$C$15	family labor December	0.35	$C$15<=$F$15	Not Binding	39.652003
$C$16	family labor January	- 0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.09	$C$17<=$F$17	Not Binding	39.9050375
$C$18	family labor March	0.37	$C$18<=$F$18	Not Binding	39.63148346
$C$19	family labor April	0.35	$C$19<=$F$19	Not Binding	39.652003
$C$20	family labor May	-	$C$20<=$F$20	Not Binding	40
$C$21	investment crop1	27.41	$C$21<=$F$21	Not Binding	127542.2129
$C$22	BAAC	-	$C$22<=$F$22	Not Binding	144761.9
$C$23	Coperative	-	$C$23<=$F$23	Not Binding	115000
$C$24	Villange Fund	-	$C$24<=$F$24	Not Binding	15625
$C$25	SCB	-	$C$25<=$F$25	Not Binding	82500
$C$26	June	1.65	$C$26<=$F$26	Not Binding	40468.11023
$C$27	July	1.51	$C$27<=$F$27	Not Binding	77594.33347
$C$28	August	1.44	$C$28<=$F$28	Not Binding	296981.2848
$C$29	September	- 0.00	$C$29<=$F$29	Not Binding	442657.44
$C$30	October	1.48	$C$30<=$F$30	Not Binding	238626.6773
$C$31	November	1.29	$C$31<=$F$31	Not Binding	121537.5947
$C$32	December	1.20	$C$32<=$F$32	Not Binding	39561.35874
$C$33	January	0.00	$C$33<=$F$33	Not Binding	22533.12
$C$34	Febuary	1.46	$C$34<=$F$34	Not Binding	14133.57541
$C$35	March	2.09	$C$35<=$F$35	Not Binding	39396.31464
$C$36	April	2.35	$C$36<=$F$36	Not Binding	6363.603954
$C$37	May	-	$C$37<=$F$37	Not Binding	34788.096
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	170.13
$C$40	rice dry	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	chilli	0.00	$C$41=$F$41	Not Binding	0
$C$42	pak choi	- 0.00	$C$42=$F$42	Not Binding	0
$C$43	long bean	0.00	$C$43=$F$43	Not Binding	0

$C$44	morning glory	-	$C$44=$F$44	Not Binding	0
$C$45	coriander	0.00	$C$45=$F$45	Not Binding	0
$C$46	celery	0.00	$C$46=$F$46	Not Binding	0
$C$47	green shallot	-	$C$47=$F$47	Not Binding	0
$C$48	spinanch	- 0.00	$C$48=$F$48	Not Binding	0
$C$49	lettuce	0.00	$C$49=$F$49	Not Binding	0
$C$50	sugar cane	- 0.00	$C$50=$F$50	Not Binding	0
$C$51	longan	0.00	$C$51=$F$51	Not Binding	0
$C$52	balance income	- 0.00	$C$52=$F$52	Not Binding	0
$C$53	Socail Max Hired Labor	347,575.10	$C$53=$F$53	Not Binding	0
$C$54	Economic Risk Price	47.34	$C$54=$F$54	Not Binding	0
$C$55	Econnomic Risk Yield	8.51	$C$55=$F$55	Not Binding	0
$C$56	Env Water	1,374,655.97	$C$56=$F$56	Not Binding	0
$C$57	Economic Max Income	274,861.70	$C$57=$F$57	Not Binding	0

3.1.3 Results of sensitivity analysis by increasing 30 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		99.92	99.92

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		1.57772E-30	1.57772E-30
$H$1		2.52211E-15	0
$I$1		0	0
$J$1		2.46148E-31	2.46148E-31
$K$1		0.011929962	0.011929962
$L$1		0	0
$M$1		-3.63099E-15	0
$N$1		0	-9.22656E-19
$O$1		0	0
$P$1		3.9443E-31	3.9443E-31
$Q$1		0	2.88979E-17
$R$1		0	-4.33681E-19
$S$1		0	3.63638E-18
$T$1		0.1474783	0.1474783
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		0	0
$AD$1		0	0
$AE$1		0	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	0
$AL$1		0	0
$AM$1		0	0
$AN$1		9.12759E-15	0
$AO$1		0	0
$AP$1		8.51	8.51
$AQ$1		0	0
$AR$1		0	2.35201E-12
$AS$1		1.62928E-13	0
$AT$1		0	0
$AU$1		0	0
$AV$1		2.28318E-13	0
$AW$1		-1.31538E-11	0
$AX$1		4.05437E-13	0

$AY$1	0	0
$AZ$1	347573.3105	347573.3105
$BA$1	47.13325375	47.13325375
$BB$1	0	0
$BC$1	1374641.509	1374641.509
$BD$1	274655.2003	274655.2003
$BE$1	0	0
$BF$1	0	0
$BG$1	0	0
$BH$1	0	0
$BI$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	- 0.14	$C$7<=$F$7	Not Binding	7.585548338
$C$8	rent land	0.15	$C$8<=$F$8	Not Binding	7.1325217
$C$9	family labor June	0.09	$C$9<=$F$9	Not Binding	39.9050375
$C$10	family labor July	0.37	$C$10<=$F$10	Not Binding	39.63148346
$C$11	family labor August	0.35	$C$11<=$F$11	Not Binding	39.652003
$C$12	family labor September	0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.09	$C$13<=$F$13	Not Binding	39.9050375
$C$14	family labor November	0.37	$C$14<=$F$14	Not Binding	39.63148346
$C$15	family labor December	0.35	$C$15<=$F$15	Not Binding	39.652003
$C$16	family labor January	0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.09	$C$17<=$F$17	Not Binding	39.9050375
$C$18	family labor March	0.37	$C$18<=$F$18	Not Binding	39.63148346
$C$19	family labor April	0.35	$C$19<=$F$19	Not Binding	39.652003
$C$20	family labor May	0.00	$C$20<=$F$20	Not Binding	40
$C$21	investment crop1	27.41	$C$21<=$F$21	Not Binding	127542.2129
$C$22	BAAC	-	$C$22<=$F$22	Not Binding	144761.9
$C$23	Coperative	-	$C$23<=$F$23	Not Binding	115000
$C$24	Villange Fund	-	$C$24<=$F$24	Not Binding	15625
$C$25	SCB	-	$C$25<=$F$25	Not Binding	82500
$C$26	June	1.65	$C$26<=$F$26	Not Binding	40468.11023
$C$27	July	1.51	$C$27<=$F$27	Not Binding	77594.33347
$C$28	August	1.44	$C$28<=$F$28	Not Binding	296981.2848
$C$29	September	0.00	$C$29<=$F$29	Not Binding	442657.44
$C$30	October	1.48	$C$30<=$F$30	Not Binding	238626.6773
$C$31	November	1.29	$C$31<=$F$31	Not Binding	121537.5947
$C$32	December	1.20	$C$32<=$F$32	Not Binding	39561.35874
$C$33	January	0.00	$C$33<=$F$33	Not Binding	22533.12
$C$34	Febuary	1.46	$C$34<=$F$34	Not Binding	14133.57541
$C$35	March	2.09	$C$35<=$F$35	Not Binding	39396.31464
$C$36	April	2.35	$C$36<=$F$36	Not Binding	6363.603954
$C$37	May	0.00	$C$37<=$F$37	Not Binding	34788.096
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	170.13
$C$40	rice dry	-	$C$40=$F$40	Not Binding	0
$C$41	chilli	-	$C$41=$F$41	Not Binding	0
$C$42	pak choi	- 0.00	$C$42=$F$42	Not Binding	0
$C$43	long bean	-	$C$43=$F$43	Not Binding	0

$C$44	morning glory		-	$C$44=$F$44	Not Binding	0
$C$45	coriander		0.00	$C$45=$F$45	Not Binding	0
$C$46	celery		0.00	$C$46=$F$46	Not Binding	0
$C$47	green shallot		-	$C$47=$F$47	Not Binding	0
$C$48	spinanch	-	0.00	$C$48=$F$48	Not Binding	0
$C$49	lettuce	-	0.00	$C$49=$F$49	Not Binding	0
$C$50	sugar cane		0.00	$C$50=$F$50	Not Binding	0
$C$51	longan	-	0.00	$C$51=$F$51	Not Binding	0
$C$52	balance income	-	0.00	$C$52=$F$52	Not Binding	0
$C$53	Socail Max Hired Labor		347,575.10	$C$53=$F$53	Not Binding	0
$C$54	Economic Risk Price		47.34	$C$54=$F$54	Not Binding	0
$C$55	Econnomic Risk Yield		8.51	$C$55=$F$55	Not Binding	0
$C$56	Env Water		1,374,655.97	$C$56=$F$56	Not Binding	0
$C$57	Economic Max Income		274,861.70	$C$57=$F$57	Not Binding	0

3.2 Sensitivity Report in rainfed area model by increasing longan price

3.2.1 Results of sensitivity analysis by increasing 10 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6	goal	99.94	99.94

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		0	4.50901E-15
$H$1		9.86076E-32	9.86076E-32
$I$1		1.3652E-16	1.21899E-14
$J$1		0	-1.10494E-15
$K$1		1.06512E-15	1.97215E-31
$L$1		0.008864279	0.008864279
$M$1		1.20341E-21	2.73672E-16
$N$1		0	4.42841E-16
$O$1		0.008071579	0.008071579
$P$1		0	1.33762E-14
$Q$1		0	0
$R$1		0	0
$S$1		0	0
$T$1		0	0
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		877.5458129	0
$AC$1		0	877.5312227
$AD$1		234.1447176	0
$AE$1		0	231.9564494
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	0
$AL$1		-8.88178E-16	0
$AM$1		0	0
$AN$1		2.121576418	2.121576418
$AO$1		0	0
$AP$1		0	0
$AQ$1		7.765423582	7.765423582
$AR$1		0	0
$AS$1		0	0
$AT$1		317363.1596	317363.1596
$AU$1		0	0
$AV$1		0	0

$AW$1	680063.887	680063.887
$AX$1	555759.6434	555759.6434
$AY$1	0	0
$AZ$1	0	0
$BA$1	0	0
$BB$1	0	0
$BC$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land crop1	0.02	$C$7<=$F$7	Not Binding	14.98306414
$C$8	rent land1	-	$C$8<=$F$8	Not Binding	6
$C$9	family labor June	0.02	$C$9<=$F$9	Not Binding	39.98111251
$C$10	family labor July	0.01	$C$10<=$F$10	Not Binding	39.99437411
$C$11	family labor August	0.01	$C$11<=$F$11	Not Binding	39.99437411
$C$12	family labor September	0.12	$C$12<=$F$12	Not Binding	39.87973348
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.99437411
$C$14	family labor November	0.01	$C$14<=$F$14	Not Binding	39.99437411
$C$15	family labor December	0.06	$C$15<=$F$15	Not Binding	39.93852916
$C$16	family labor January	0.03	$C$16<=$F$16	Not Binding	39.97097241
$C$17	family labor Febuary	0.03	$C$17<=$F$17	Not Binding	39.96786992
$C$18	family labor March	0.03	$C$18<=$F$18	Not Binding	39.96786992
$C$19	family labor April	0.03	$C$19<=$F$19	Not Binding	39.96999734
$C$20	family labor May	- 877.53	$C$20<=$F$20	Not Binding	917.5292855
$C$21	investment crop1	131,471.27	$C$21<=$F$21	Not Binding	0.001403196
$C$22	Villange fund	-	$C$22<=$F$22	Not Binding	22000
$C$23	BAAC	231.96	$C$23<=$F$23	Not Binding	89768.04355
$C$24	Coperative	-	$C$24<=$F$24	Not Binding	60000
$C$25	Finance	-	$C$25<=$F$25	Not Binding	18000
$C$26	water June	4.60	$C$26<=$F$26	Not Binding	11179.88005
$C$27	water July	3.46	$C$27<=$F$27	Not Binding	57013.62585
$C$28	water August	2.97	$C$28<=$F$28	Not Binding	155672.5546
$C$29	water September	2.98	$C$29<=$F$29	Not Binding	209785.7222
$C$30	water October	3.00	$C$30<=$F$30	Not Binding	124876.104
$C$31	water November	3.10	$C$31<=$F$31	Not Binding	44225.06028
$C$32	water December	3.80	$C$32<=$F$32	Not Binding	25432.36299
$C$33	water January	3.43	$C$33<=$F$33	Not Binding	16528.348
$C$34	water Febuary	3.88	$C$34<=$F$34	Not Binding	9291.031486
$C$35	water March	5.15	$C$35<=$F$35	Not Binding	11760.79922
$C$36	water April	5.07	$C$36<=$F$36	Not Binding	5709.425301
$C$37	water May	4.67	$C$37<=$F$37	Not Binding	8593.85303
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	375.64
$C$40	yield long bean	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	yield marigold	- 0.00	$C$41=$F$41	Not Binding	0
$C$42	yield maize	0.00	$C$42=$F$42	Not Binding	0
$C$43	yield sweet corn	- 0.00	$C$43=$F$43	Not Binding	0
$C$44	yield tobacco	0.00	$C$44=$F$44	Not Binding	0
$C$45	yield galangal	- 0.00	$C$45=$F$45	Not Binding	0
$C$46	yield lemon grass	- 0.00	$C$46=$F$46	Not Binding	0
$C$47	yield banana	- 0.00	$C$47=$F$47	Not Binding	0

$C$48	yield longan	-	0.00	$C$48=$F$48	Not Binding	0
$C$49	commodity balance	-	0.00	$C$49=$F$49	Not Binding	0
$C$50	Socail Max Hired Labor		317,365.70	$C$50=$F$50	Not Binding	0
$C$51	Economic Risk Price		0.88	$C$51=$F$51	Not Binding	0
$C$52	Economic Risk Yield		9.89	$C$52=$F$52	Not Binding	0
$C$53	Env Water		680,110.00	$C$53=$F$53	Not Binding	0
$C$54	Economic Max Income		556,068.10	$C$54=$F$54	Not Binding	0

3.2.2 Results of sensitivity analysis by increasing 20 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6	goal	99.94	99.94

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		4.50901E-15	0
$H$1		9.86076E-32	9.86076E-32
$I$1		1.21899E-14	3.07477E-17
$J$1		-1.10494E-15	-2.08555E-20
$K$1		1.97215E-31	1.97215E-31
$L$1		0.008864279	0.008864279
$M$1		2.73672E-16	-4.01569E-19
$N$1		4.42841E-16	9.86076E-32
$O$1		0.008071579	0.008071579
$P$1		1.33762E-14	-1.68937E-19
$Q$1		0	0
$R$1		0	0
$S$1		0	0
$T$1		0	0
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		877.5312227	877.5458188
$AD$1		0	234.1447176
$AE$1		231.9564494	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	0
$AL$1		0	0
$AM$1		0	0
$AN$1		2.121576418	2.121576418
$AO$1		0	0
$AP$1		0	0
$AQ$1		7.765423582	7.765423582
$AR$1		0	0
$AS$1		0	0
$AT$1		317363.1596	317363.1596
$AU$1		0	0
$AV$1		0	0
$AW$1		680063.887	680063.887
$AX$1		555759.6434	555759.6434

$AY$1	0	0
$AZ$1	0	0
$BA$1	0	0
$BB$1	0	0
$BC$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land crop1	0.02	$C$7<=$F$7	Not Binding	14.98306414
$C$8	rent land1	-	$C$8<=$F$8	Not Binding	6
$C$9	family labor June	0.02	$C$9<=$F$9	Not Binding	39.98111251
$C$10	family labor July	0.01	$C$10<=$F$10	Not Binding	39.99437411
$C$11	family labor August	0.01	$C$11<=$F$11	Not Binding	39.99437411
$C$12	family labor September	0.12	$C$12<=$F$12	Not Binding	39.87973348
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.99437411
$C$14	family labor November	0.01	$C$14<=$F$14	Not Binding	39.99437411
$C$15	family labor December	0.06	$C$15<=$F$15	Not Binding	39.93852916
$C$16	family labor January	0.03	$C$16<=$F$16	Not Binding	39.97097241
$C$17	family labor Febuary	0.03	$C$17<=$F$17	Not Binding	39.96786992
$C$18	family labor March	0.03	$C$18<=$F$18	Not Binding	39.96786992
$C$19	family labor April	0.03	$C$19<=$F$19	Not Binding	39.96999734
$C$20	family labor May	- 877.54	$C$20<=$F$20	Not Binding	917.5438816
$C$21	investment crop1	131,471.27	$C$21<=$F$21	Not Binding	0.000261355
$C$22	Villange fund	234.14	$C$22<=$F$22	Not Binding	21765.85528
$C$23	BAAC	-	$C$23<=$F$23	Not Binding	90000
$C$24	Coperative	-	$C$24<=$F$24	Not Binding	60000
$C$25	Finance	-	$C$25<=$F$25	Not Binding	18000
$C$26	water June	4.60	$C$26<=$F$26	Not Binding	11179.88005
$C$27	water July	3.46	$C$27<=$F$27	Not Binding	57013.62585
$C$28	water August	2.97	$C$28<=$F$28	Not Binding	155672.5546
$C$29	water September	2.98	$C$29<=$F$29	Not Binding	209785.7222
$C$30	water October	3.00	$C$30<=$F$30	Not Binding	124876.104
$C$31	water November	3.10	$C$31<=$F$31	Not Binding	44225.06028
$C$32	water December	3.80	$C$32<=$F$32	Not Binding	25432.36299
$C$33	water January	3.43	$C$33<=$F$33	Not Binding	16528.348
$C$34	water Febuary	3.88	$C$34<=$F$34	Not Binding	9291.031486
$C$35	water March	5.15	$C$35<=$F$35	Not Binding	11760.79922
$C$36	water April	5.07	$C$36<=$F$36	Not Binding	5709.425301
$C$37	water May	4.67	$C$37<=$F$37	Not Binding	8593.85303
$C$38	yield rice rain	-	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	375.64
$C$40	yield long bean	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	yield marigold	- 0.00	$C$41=$F$41	Not Binding	0
$C$42	yield maize	0.00	$C$42=$F$42	Not Binding	0
$C$43	yield sweet corn	- 0.00	$C$43=$F$43	Not Binding	0
$C$44	yield tobacco	0.00	$C$44=$F$44	Not Binding	0
$C$45	yield galangal	0.00	$C$45=$F$45	Not Binding	0
$C$46	yield lemon grass	- 0.00	$C$46=$F$46	Not Binding	0
$C$47	yield banana	- 0.00	$C$47=$F$47	Not Binding	0
$C$48	yield longan	0.00	$C$48=$F$48	Not Binding	0
$C$49	commodity balance	- 0.00	$C$49=$F$49	Not Binding	0

$C$50	Socail Max Hired Labor	317,365.70	$C$50=$F$50	Not Binding	0
$C$51	Economic Risk Price	0.88	$C$51=$F$51	Not Binding	0
$C$52	Economic Risk Yield	9.89	$C$52=$F$52	Not Binding	0
$C$53	Env Water	680,110.00	$C$53=$F$53	Not Binding	0
$C$54	Economic Max Income	556,068.10	$C$54=$F$54	Not Binding	0

3.2.3 Results of sensitivity analysis by increasing 30 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6	goal	99.94	99.94

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		-1.65636E-15	1.97215E-31
$H$1		9.86076E-32	9.86076E-32
$I$1		2.81635E-19	0
$J$1		3.26427E-20	3.98335E-20
$K$1		1.97215E-31	1.97215E-31
$L$1		0.008864279	0.008864279
$M$1		0	2.1025E-19
$N$1		9.86076E-32	9.86076E-32
$O$1		0.008071579	0.008071579
$P$1		0	-7.09645E-15
$Q$1		0	0
$R$1		0	0
$S$1		0	0
$T$1		0	0
$U$1		0	877.5312321
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		0	0
$AD$1		0	0
$AE$1		0	231.9564494
$AF$1		229.808704	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	6.20939E-12
$AL$1		0	0
$AM$1		0	0
$AN$1		2.121576418	2.121576418
$AO$1		0	0
$AP$1		0	0
$AQ$1		7.765423582	7.765423582
$AR$1		9.91892E-12	0
$AS$1		0	0
$AT$1		317363.1596	317363.1596
$AU$1		0	0
$AV$1		0	0
$AW$1		680063.887	680063.887
$AX$1		555759.6434	555759.6434

$AY$1	0	0
$AZ$1	0	0
$BA$1	0	0
$BB$1	0	0
$BC$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land crop1	0.02	$C$7<=$F$7	Not Binding	14.98306414
$C$8	rent land1	-	$C$8<=$F$8	Not Binding	6
$C$9	family labor June	0.02	$C$9<=$F$9	Not Binding	39.98111251
$C$10	family labor July	0.01	$C$10<=$F$10	Not Binding	39.99437411
$C$11	family labor August	0.01	$C$11<=$F$11	Not Binding	39.99437411
$C$12	family labor September	- 877.41	$C$12<=$F$12	Not Binding	917.4109655
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.99437411
$C$14	family labor November	0.01	$C$14<=$F$14	Not Binding	39.99437411
$C$15	family labor December	0.06	$C$15<=$F$15	Not Binding	39.93852916
$C$16	family labor January	0.03	$C$16<=$F$16	Not Binding	39.97097241
$C$17	family labor Febuary	0.03	$C$17<=$F$17	Not Binding	39.96786992
$C$18	family labor March	0.03	$C$18<=$F$18	Not Binding	39.96786992
$C$19	family labor April	0.03	$C$19<=$F$19	Not Binding	39.96999734
$C$20	family labor May	0.00	$C$20<=$F$20	Not Binding	39.99806282
$C$21	investment crop1	131,471.27	$C$21<=$F$21	Binding	0
$C$22	Villange fund	-	$C$22<=$F$22	Not Binding	22000
$C$23	BAAC	231.96	$C$23<=$F$23	Not Binding	89768.04355
$C$24	Coperative	-	$C$24<=$F$24	Not Binding	60000
$C$25	Finance	-	$C$25<=$F$25	Not Binding	18000
$C$26	water June	4.60	$C$26<=$F$26	Not Binding	11179.88005
$C$27	water July	3.46	$C$27<=$F$27	Not Binding	57013.62585
$C$28	water August	2.97	$C$28<=$F$28	Not Binding	155672.5546
$C$29	water September	2.98	$C$29<=$F$29	Not Binding	209785.7222
$C$30	water October	3.00	$C$30<=$F$30	Not Binding	124876.104
$C$31	water November	3.10	$C$31<=$F$31	Not Binding	44225.06028
$C$32	water December	3.80	$C$32<=$F$32	Not Binding	25432.36299
$C$33	water January	3.43	$C$33<=$F$33	Not Binding	16528.348
$C$34	water Febuary	3.88	$C$34<=$F$34	Not Binding	9291.031486
$C$35	water March	5.15	$C$35<=$F$35	Not Binding	11760.79922
$C$36	water April	5.07	$C$36<=$F$36	Not Binding	5709.425301
$C$37	water May	4.67	$C$37<=$F$37	Not Binding	8593.85303
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	375.64
$C$40	yield long bean	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	yield marigold	0.00	$C$41=$F$41	Not Binding	0
$C$42	yield maize	- 0.00	$C$42=$F$42	Not Binding	0
$C$43	yield sweet corn	- 0.00	$C$43=$F$43	Not Binding	0
$C$44	yield tobacco	0.00	$C$44=$F$44	Binding	0
$C$45	yield galangal	- 0.00	$C$45=$F$45	Not Binding	0
$C$46	yield lemon grass	- 0.00	$C$46=$F$46	Not Binding	0
$C$47	yield banana	0.00	$C$47=$F$47	Not Binding	0
$C$48	yield longan	0.00	$C$48=$F$48	Not Binding	0
$C$49	commodity balance	- 0.00	$C$49=$F$49	Not Binding	0

$C$50	Socail Max Hired Labor	317,365.70	$C$50=$F$50	Not Binding	0
$C$51	Economic Risk Price	0.88	$C$51=$F$51	Not Binding	0
$C$52	Economic Risk Yield	9.89	$C$52=$F$52	Not Binding	0
$C$53	Env Water	680,110.00	$C$53=$F$53	Not Binding	0
$C$54	Economic Max Income	556,068.10	$C$54=$F$54	Not Binding	0

3.3 Sensitivity Report in irrigated area with storage dam model by decreasing water use on farms

3.3.1 Results of sensitivity analysis by decreasing 10 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		100.00	100.00

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		-1.28248E-15	0
$H$1		4.01808E-15	2.56932E-15
$I$1		0	-1.00047E-16
$J$1		3.7709E-15	2.51186E-16
$K$1		3.89833E-15	0
$L$1		0.001425555	0.001425555
$M$1		4.09392E-15	-7.17851E-16
$N$1		1.44383E-15	1.97215E-31
$O$1		3.90022E-15	0
$P$1		0	0
$Q$1		0	0
$R$1		0	0
$S$1		862.9464904	862.9464904
$T$1		0	0
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		26.39916667	26.39916667
$AD$1		0	0
$AE$1		0	6.67872E-12
$AF$1		0	0
$AG$1		0	0
$AH$1		1.52196E-11	0
$AI$1		0	0
$AJ$1		0	2.81428E-11
$AK$1		1.140444	1.140444
$AL$1		0	0
$AM$1		0	0
$AN$1		0	9.60006E-12
$AO$1		0	0
$AP$1		202122.1862	202122.1862
$AQ$1		6.308960125	6.308960125
$AR$1		0	0
$AS$1		1198902.272	1198902.272
$AT$1		592964.5545	592964.5545
$AU$1		0	0

$AV$1	0	0
$AW$1	0	0
$AX$1	0	0
$AY$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	0.00	$C$7<=$F$7	Not Binding	10.99857445
$C$8	rent land	-	$C$8<=$F$8	Not Binding	10
$C$9	family labor June	0.01	$C$9<=$F$9	Not Binding	39.98865258
$C$10	family labor July	0.04	$C$10<=$F$10	Not Binding	39.95596461
$C$11	family labor August	- 862.90	$C$11<=$F$11	Not Binding	902.904907
$C$12	family labor September	0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.98865258
$C$14	family labor November	0.04	$C$14<=$F$14	Not Binding	39.95596461
$C$15	family labor December	0.04	$C$15<=$F$15	Not Binding	39.95841656
$C$16	family labor January	0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.01	$C$17<=$F$17	Not Binding	39.98865258
$C$18	family labor March	0.04	$C$18<=$F$18	Not Binding	39.95596461
$C$19	family labor April	0.04	$C$19<=$F$19	Not Binding	39.95841656
$C$20	investment crop1	129,416.64	$C$20<=$F$20	Binding	0
$C$21	BAAC	-	$C$21<=$F$21	Not Binding	174545.45
$C$22	Coperative	26.40	$C$22<=$F$22	Not Binding	75473.60083
$C$23	Villange Fund	-	$C$23<=$F$23	Not Binding	17500
$C$24	June	0.20	$C$24<=$F$24	Not Binding	30932.73086
$C$25	July	0.18	$C$25<=$F$25	Not Binding	46636.37998
$C$26	August	0.17	$C$26<=$F$26	Not Binding	226658.5645
$C$27	September	0.00	$C$27<=$F$27	Not Binding	355040.496
$C$28	October	0.18	$C$28<=$F$28	Not Binding	167844.7828
$C$29	November	0.15	$C$29<=$F$29	Not Binding	86986.07042
$C$30	December	0.14	$C$30<=$F$30	Not Binding	31488.76846
$C$31	January	0.00	$C$31<=$F$31	Not Binding	20742.48
$C$32	Febuary	0.18	$C$32<=$F$32	Not Binding	11158.38499
$C$33	March	0.25	$C$33<=$F$33	Not Binding	28576.55081
$C$34	April	0.28	$C$34<=$F$34	Not Binding	41721.84742
$C$35	yield rice rain	0.00	$C$35=$F$35	Not Binding	0
$C$36	yield rice consumption	-	$C$36<=$F$36	Not Binding	80.99
$C$37	rice dry	- 0.00	$C$37=$F$37	Not Binding	0
$C$38	chilli	0.00	$C$38=$F$38	Not Binding	0
$C$39	pak choi	- 0.00	$C$39=$F$39	Not Binding	0
$C$40	cauliflower	0.00	$C$40=$F$40	Not Binding	0
$C$41	long bean	0.00	$C$41=$F$41	Not Binding	0
$C$42	soy bean	0.00	$C$42=$F$42	Not Binding	0
$C$43	sweet corn	- 0.00	$C$43=$F$43	Binding	0
$C$44	cabbage	0.00	$C$44=$F$44	Not Binding	0
$C$45	balance income	0.00	$C$45=$F$45	Not Binding	0
$C$46	Socail Max Hired Labor	202,122.40	$C$46=$F$46	Not Binding	0
$C$47	Economic Risk Price	6.34	$C$47=$F$47	Not Binding	0
$C$48	Econnomic Risk Yield	1.14	$C$48=$F$48	Not Binding	0
$C$49	Env Water	1,198,904.00	$C$49=$F$49	Not Binding	0

$C$50	Economic Max Income	592,992.00	$C$50=$F$50	Not Binding	0

3.3.2 Results of sensitivity analysis by decreasing 20 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		100.00	100.00

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		0	1.7807E-15
$H$1		2.56932E-15	0
$I$1		-1.00047E-16	3.87369E-16
$J$1		2.51186E-16	-1.32038E-19
$K$1		0	0
$L$1		0.001425555	0.001425555
$M$1		-7.17851E-16	5.18466E-15
$N$1		1.97215E-31	1.97215E-31
$O$1		0	0
$P$1		0	0
$Q$1		0	0
$R$1		0	0
$S$1		862.9464904	862.9464904
$T$1		0	0
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		26.39916667	26.39916667
$AD$1		0	0
$AE$1		6.67872E-12	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		2.81428E-11	-5.96406E-12
$AK$1		1.140444	1.140444
$AL$1		0	0
$AM$1		0	0
$AN$1		9.60006E-12	6.95627E-12
$AO$1		0	0
$AP$1		202122.1862	202122.1862
$AQ$1		6.308960125	6.308960125
$AR$1		0	0
$AS$1		1198902.272	1198902.272
$AT$1		592964.5545	592964.5545
$AU$1		0	0
$AV$1		0	0

$AW$1	0	0
$AX$1	0	0
$AY$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	0.00	$C$7<=$F$7	Not Binding	10.99857445
$C$8	rent land	-	$C$8<=$F$8	Not Binding	10
$C$9	family labor June	0.01	$C$9<=$F$9	Not Binding	39.98865258
$C$10	family labor July	0.04	$C$10<=$F$10	Not Binding	39.95596461
$C$11	family labor August	- 862.90	$C$11<=$F$11	Not Binding	902.904907
$C$12	family labor September	0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.98865258
$C$14	family labor November	0.04	$C$14<=$F$14	Not Binding	39.95596461
$C$15	family labor December	0.04	$C$15<=$F$15	Not Binding	39.95841656
$C$16	family labor January	0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.01	$C$17<=$F$17	Not Binding	39.98865258
$C$18	family labor March	0.04	$C$18<=$F$18	Not Binding	39.95596461
$C$19	family labor April	0.04	$C$19<=$F$19	Not Binding	39.95841656
$C$20	investment crop1	129,416.64	$C$20<=$F$20	Binding	0
$C$21	BAAC	-	$C$21<=$F$21	Not Binding	174545.45
$C$22	Coperative	26.40	$C$22<=$F$22	Not Binding	75473.60083
$C$23	Villange Fund	-	$C$23<=$F$23	Not Binding	17500
$C$24	June	0.20	$C$24<=$F$24	Not Binding	27495.73886
$C$25	July	0.18	$C$25<=$F$25	Not Binding	41454.53998
$C$26	August	0.17	$C$26<=$F$26	Not Binding	201474.2605
$C$27	September	0.00	$C$27<=$F$27	Not Binding	315591.552
$C$28	October	0.18	$C$28<=$F$28	Not Binding	149195.3428
$C$29	November	0.15	$C$29<=$F$29	Not Binding	77320.93442
$C$30	December	0.14	$C$30<=$F$30	Not Binding	27990.00046
$C$31	January	0.00	$C$31<=$F$31	Not Binding	18437.76
$C$32	Febuary	0.18	$C$32<=$F$32	Not Binding	9918.544991
$C$33	March	0.25	$C$33<=$F$33	Not Binding	25401.35081
$C$34	April	0.28	$C$34<=$F$34	Not Binding	37086.05542
$C$35	yield rice rain	- 0.00	$C$35=$F$35	Not Binding	0
$C$36	yield rice consumption	-	$C$36<=$F$36	Not Binding	80.99
$C$37	rice dry	-	$C$37=$F$37	Not Binding	0
$C$38	chilli	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	pak choi	0.00	$C$39=$F$39	Not Binding	0
$C$40	cauliflower	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	long bean	- 0.00	$C$41=$F$41	Not Binding	0
$C$42	soy bean	- 0.00	$C$42=$F$42	Not Binding	0
$C$43	sweet corn	- 0.00	$C$43=$F$43	Binding	0
$C$44	cabbage	0.00	$C$44=$F$44	Not Binding	0
$C$45	balance income	- 0.00	$C$45=$F$45	Not Binding	0
$C$46	Socail Max Hired Labor	202,122.40	$C$46=$F$46	Not Binding	0
$C$47	Economic Risk Price	6.34	$C$47=$F$47	Not Binding	0
$C$48	Econnomic Risk Yield	1.14	$C$48=$F$48	Not Binding	0
$C$49	Env Water	1,198,904.00	$C$49=$F$49	Not Binding	0
$C$50	Economic Max Income	592,992.00	$C$50=$F$50	Not Binding	0

3.3.3 Results of sensitivity analysis by decreasing 30 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		100.00	100.00

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		1.7807E-15	4.02242E-15
$H$1		0	-2.46651E-31
$I$1		3.87369E-16	3.2358E-14
$J$1		-1.32038E-19	0
$K$1		0	-7.59144E-16
$L$1		0.001425555	0.001425555
$M$1		5.18466E-15	0
$N$1		1.97215E-31	1.97215E-31
$O$1		0	1.20441E-15
$P$1		0	0
$Q$1		0	0
$R$1		0	0
$S$1		862.9464904	862.9464904
$T$1		0	0
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		26.39916667	26.39916667
$AD$1		0	0
$AE$1		0	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	1.67512E-11
$AJ$1		-5.96406E-12	0
$AK$1		1.140444	1.140444
$AL$1		0	4.8025E-13
$AM$1		0	0
$AN$1		6.95627E-12	0
$AO$1		0	0
$AP$1		202122.1862	202122.1862
$AQ$1		6.308960125	6.308960125
$AR$1		0	0
$AS$1		1198902.272	1198902.272
$AT$1		592964.5545	592964.5545
$AU$1		0	0
$AV$1		0	0
$AW$1		0	0
$AX$1		0	0

$AY$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	0.00	$C$7<=$F$7	Not Binding	10.99857445
$C$8	rent land	-	$C$8<=$F$8	Not Binding	10
$C$9	family labor June	0.01	$C$9<=$F$9	Not Binding	39.98865258
$C$10	family labor July	0.04	$C$10<=$F$10	Not Binding	39.95596461
$C$11	family labor August	- 862.90	$C$11<=$F$11	Not Binding	902.904907
$C$12	family labor September	0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.98865258
$C$14	family labor November	0.04	$C$14<=$F$14	Not Binding	39.95596461
$C$15	family labor December	0.04	$C$15<=$F$15	Not Binding	39.95841656
$C$16	family labor January	0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.01	$C$17<=$F$17	Not Binding	39.98865258
$C$18	family labor March	0.04	$C$18<=$F$18	Not Binding	39.95596461
$C$19	family labor April	0.04	$C$19<=$F$19	Not Binding	39.95841656
$C$20	investment crop1	129,416.64	$C$20<=$F$20	Binding	0
$C$21	BAAC	-	$C$21<=$F$21	Not Binding	174545.45
$C$22	Coperative	26.40	$C$22<=$F$22	Not Binding	75473.60083
$C$23	Villange Fund	-	$C$23<=$F$23	Not Binding	17500
$C$24	June	0.20	$C$24<=$F$24	Not Binding	24058.74686
$C$25	July	0.18	$C$25<=$F$25	Not Binding	36272.69998
$C$26	August	0.17	$C$26<=$F$26	Not Binding	176289.9565
$C$27	September	0.00	$C$27<=$F$27	Not Binding	276142.608
$C$28	October	0.18	$C$28<=$F$28	Not Binding	130545.9028
$C$29	November	0.15	$C$29<=$F$29	Not Binding	67655.79842
$C$30	December	0.14	$C$30<=$F$30	Not Binding	24491.23246
$C$31	January	0.00	$C$31<=$F$31	Not Binding	16133.04
$C$32	Febuary	0.18	$C$32<=$F$32	Not Binding	8678.704991
$C$33	March	0.25	$C$33<=$F$33	Not Binding	22226.15081
$C$34	April	0.28	$C$34<=$F$34	Not Binding	32450.26342
$C$35	yield rice rain	- 0.00	$C$35=$F$35	Not Binding	0
$C$36	yield rice consumption	-	$C$36<=$F$36	Not Binding	80.99
$C$37	rice dry	0.00	$C$37=$F$37	Not Binding	0
$C$38	chilli	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	pak choi	0.00	$C$39=$F$39	Not Binding	0
$C$40	cauliflower	0.00	$C$40=$F$40	Not Binding	0
$C$41	long bean	- 0.00	$C$41=$F$41	Not Binding	0
$C$42	soy bean	0.00	$C$42=$F$42	Not Binding	0
$C$43	sweet corn	- 0.00	$C$43=$F$43	Binding	0
$C$44	cabbage	- 0.00	$C$44=$F$44	Not Binding	0
$C$45	balance income	- 0.00	$C$45=$F$45	Not Binding	0
$C$46	Socail Max Hired Labor	202,122.40	$C$46=$F$46	Not Binding	0
$C$47	Economic Risk Price	6.34	$C$47=$F$47	Not Binding	0
$C$48	Econnomic Risk Yield	1.14	$C$48=$F$48	Not Binding	0
$C$49	Env Water	1,198,904.00	$C$49=$F$49	Not Binding	0
$C$50	Economic Max Income	592,992.00	$C$50=$F$50	Not Binding	0

3.4 Sensitivity Report in irrigated area with dike dam model by decreasing water use on farms

3.4.1 Results of sensitivity analysis by decreasing 10 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		99.92	99.92

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		1.57772E-30	1.57772E-30
$H$1		0	4.31892E-15
$I$1		0	0
$J$1		0	2.46148E-31
$K$1		0.011929962	0.011929962
$L$1		0	0
$M$1		2.16084E-15	5.74261E-17
$N$1		1.13691E-16	0
$O$1		0	3.93058E-16
$P$1		0	2.66721E-15
$Q$1		0	0
$R$1		2.69532E-19	2.69532E-19
$S$1		0	0
$T$1		0.1474783	0.1474783
$U$1		0	850.2814196
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		0	0
$AD$1		0	0
$AE$1		0	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	0
$AL$1		0	0
$AM$1		-1.16103E-12	0
$AN$1		0	0
$AO$1		1.12331E-13	0
$AP$1		8.51	8.51
$AQ$1		0	-4.70621E-13
$AR$1		0	0
$AS$1		0	7.68583E-14
$AT$1		0	0
$AU$1		0	0

$AV$1	3.23117E-27	1.00611E-12
$AW$1	0	0
$AX$1	-1.35145E-12	-3.96456E-12
$AY$1	0	0
$AZ$1	347573.3105	347573.3105
$BA$1	47.13325375	47.13325375
$BB$1	0	0
$BC$1	1374641.509	1374641.509
$BD$1	274655.2003	274655.2003
$BE$1	0	0
$BF$1	0	0
$BG$1	0	0
$BH$1	0	0
$BI$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	- 0.14	$C$7<=$F$7	Not Binding	7.585548338
$C$8	rent land	0.15	$C$8<=$F$8	Not Binding	7.1325217
$C$9	family labor June	- 850.19	$C$9<=$F$9	Not Binding	890.1864571
$C$10	family labor July	0.37	$C$10<=$F$10	Not Binding	39.63148346
$C$11	family labor August	0.35	$C$11<=$F$11	Not Binding	39.652003
$C$12	family labor September	0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.09	$C$13<=$F$13	Not Binding	39.9050375
$C$14	family labor November	0.37	$C$14<=$F$14	Not Binding	39.63148346
$C$15	family labor December	0.35	$C$15<=$F$15	Not Binding	39.652003
$C$16	family labor January	0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.09	$C$17<=$F$17	Not Binding	39.9050375
$C$18	family labor March	0.37	$C$18<=$F$18	Not Binding	39.63148346
$C$19	family labor April	0.35	$C$19<=$F$19	Not Binding	39.652003
$C$20	family labor May	-	$C$20<=$F$20	Not Binding	40
$C$21	investment crop1	127,569.62	$C$21<=$F$21	Binding	0
$C$22	BAAC	-	$C$22<=$F$22	Not Binding	144761.9
$C$23	Coperative	-	$C$23<=$F$23	Not Binding	115000
$C$24	Villange Fund	-	$C$24<=$F$24	Not Binding	15625
$C$25	SCB	-	$C$25<=$F$25	Not Binding	82500
$C$26	June	1.65	$C$26<=$F$26	Not Binding	36421.13423
$C$27	July	1.51	$C$27<=$F$27	Not Binding	69834.74947
$C$28	August	1.44	$C$28<=$F$28	Not Binding	267283.0128
$C$29	September	0.00	$C$29<=$F$29	Not Binding	398391.696
$C$30	October	1.48	$C$30<=$F$30	Not Binding	214763.8613
$C$31	November	1.29	$C$31<=$F$31	Not Binding	109383.7067
$C$32	December	1.20	$C$32<=$F$32	Not Binding	35605.10274
$C$33	January	0.00	$C$33<=$F$33	Not Binding	20279.808
$C$34	Febuary	1.46	$C$34<=$F$34	Not Binding	12720.07141
$C$35	March	2.09	$C$35<=$F$35	Not Binding	35456.47464
$C$36	April	2.35	$C$36<=$F$36	Not Binding	5727.008754
$C$37	May	-	$C$37<=$F$37	Not Binding	31309.2864
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	170.13
$C$40	rice dry	- 0.00	$C$40=$F$40	Not Binding	0

$C$41	chilli		-	$C$41=$F$41	Not Binding	0
$C$42	pak choi	-	0.00	$C$42=$F$42	Not Binding	0
$C$43	long bean	-	0.00	$C$43=$F$43	Not Binding	0
$C$44	morning glory	-	0.00	$C$44=$F$44	Binding	0
$C$45	coriander	-	0.00	$C$45=$F$45	Not Binding	0
$C$46	celery		0.00	$C$46=$F$46	Not Binding	0
$C$47	green shallot	-	0.00	$C$47=$F$47	Not Binding	0
$C$48	spinanch	-	0.00	$C$48=$F$48	Not Binding	0
$C$49	lettuce		0.00	$C$49=$F$49	Not Binding	0
$C$50	sugar cane	-	0.00	$C$50=$F$50	Not Binding	0
$C$51	longan	-	0.00	$C$51=$F$51	Not Binding	0
$C$52	balance income	-	0.00	$C$52=$F$52	Not Binding	0
$C$53	Socail Max Hired Labor		347,575.10	$C$53=$F$53	Not Binding	0
$C$54	Economic Risk Price		47.34	$C$54=$F$54	Not Binding	0
$C$55	Econnomic Risk Yield		8.51	$C$55=$F$55	Not Binding	0
$C$56	Env Water		1,374,655.97	$C$56=$F$56	Not Binding	0
$C$57	Economic Max Income		274,861.70	$C$57=$F$57	Not Binding	0

3.4.2 Results of sensitivity analysis by decreasing 20 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		99.92	99.92

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		1.57772E-30	1.57772E-30
$H$1		4.31892E-15	0
$I$1		0	0
$J$1		2.46148E-31	2.46148E-31
$K$1		0.011929962	0.011929962
$L$1		0	0
$M$1		5.74261E-17	6.5175E-15
$N$1		0	5.07902E-16
$O$1		3.93058E-16	4.93038E-32
$P$1		2.66721E-15	3.9443E-31
$Q$1		0	0
$R$1		2.69532E-19	-1.77009E-14
$S$1		0	0
$T$1		0.1474783	0.1474783
$U$1		850.2814196	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		0	0
$AD$1		0	0
$AE$1		0	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	0
$AL$1		0	0
$AM$1		0	1.9305E-11
$AN$1		0	0
$AO$1		0	0
$AP$1		8.51	8.51
$AQ$1		-4.70621E-13	0
$AR$1		0	0
$AS$1		7.68583E-14	0
$AT$1		0	0
$AU$1		0	0
$AV$1		1.00611E-12	2.75219E-13
$AW$1		0	0
$AX$1		-3.96456E-12	-2.04921E-13

$AY$1	0	0
$AZ$1	347573.3105	347573.3105
$BA$1	47.13325375	47.13325375
$BB$1	0	0
$BC$1	1374641.509	1374641.509
$BD$1	274655.2003	274655.2003
$BE$1	0	0
$BF$1	0	0
$BG$1	0	0
$BH$1	0	0
$BI$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	- 0.14	$C$7<=$F$7	Not Binding	7.585548338
$C$8	rent land	0.15	$C$8<=$F$8	Not Binding	7.1325217
$C$9	family labor June	0.09	$C$9<=$F$9	Not Binding	39.9050375
$C$10	family labor July	0.37	$C$10<=$F$10	Not Binding	39.63148346
$C$11	family labor August	0.35	$C$11<=$F$11	Not Binding	39.652003
$C$12	family labor September	- 0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.09	$C$13<=$F$13	Not Binding	39.9050375
$C$14	family labor November	0.37	$C$14<=$F$14	Not Binding	39.63148346
$C$15	family labor December	0.35	$C$15<=$F$15	Not Binding	39.652003
$C$16	family labor January	- 0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.09	$C$17<=$F$17	Not Binding	39.9050375
$C$18	family labor March	0.37	$C$18<=$F$18	Not Binding	39.63148346
$C$19	family labor April	0.35	$C$19<=$F$19	Not Binding	39.652003
$C$20	family labor May	-	$C$20<=$F$20	Not Binding	40
$C$21	investment crop1	27.41	$C$21<=$F$21	Not Binding	127542.2129
$C$22	BAAC	-	$C$22<=$F$22	Not Binding	144761.9
$C$23	Coperative	-	$C$23<=$F$23	Not Binding	115000
$C$24	Villange Fund	-	$C$24<=$F$24	Not Binding	15625
$C$25	SCB	-	$C$25<=$F$25	Not Binding	82500
$C$26	June	1.65	$C$26<=$F$26	Not Binding	32374.15823
$C$27	July	1.51	$C$27<=$F$27	Not Binding	62075.16547
$C$28	August	1.44	$C$28<=$F$28	Not Binding	237584.7408
$C$29	September	- 0.00	$C$29<=$F$29	Not Binding	354125.952
$C$30	October	1.48	$C$30<=$F$30	Not Binding	190901.0453
$C$31	November	1.29	$C$31<=$F$31	Not Binding	97229.81871
$C$32	December	1.20	$C$32<=$F$32	Not Binding	31648.84674
$C$33	January	- 0.00	$C$33<=$F$33	Not Binding	18026.496
$C$34	Febuary	1.46	$C$34<=$F$34	Not Binding	11306.56741
$C$35	March	2.09	$C$35<=$F$35	Not Binding	31516.63464
$C$36	April	2.35	$C$36<=$F$36	Not Binding	5090.413554
$C$37	May	-	$C$37<=$F$37	Not Binding	27830.4768
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	170.13
$C$40	rice dry	0.00	$C$40=$F$40	Not Binding	0
$C$41	chilli	-	$C$41=$F$41	Not Binding	0
$C$42	pak choi	- 0.00	$C$42=$F$42	Not Binding	0
$C$43	long bean	- 0.00	$C$43=$F$43	Not Binding	0

$C$44	morning glory		-	$C$44=$F$44	Not Binding	0
$C$45	coriander	-	0.00	$C$45=$F$45	Not Binding	0
$C$46	celery	-	0.00	$C$46=$F$46	Not Binding	0
$C$47	green shallot	-	0.00	$C$47=$F$47	Not Binding	0
$C$48	spinanch	-	0.00	$C$48=$F$48	Not Binding	0
$C$49	lettuce		0.00	$C$49=$F$49	Not Binding	0
$C$50	sugar cane		0.00	$C$50=$F$50	Not Binding	0
$C$51	longan	-	0.00	$C$51=$F$51	Not Binding	0
$C$52	balance income	-	0.00	$C$52=$F$52	Not Binding	0
$C$53	Socail Max Hired Labor		347,575.10	$C$53=$F$53	Not Binding	0
$C$54	Economic Risk Price		47.34	$C$54=$F$54	Not Binding	0
$C$55	Econnomic Risk Yield		8.51	$C$55=$F$55	Not Binding	0
$C$56	Env Water		1,374,655.97	$C$56=$F$56	Not Binding	0
$C$57	Economic Max Income		274,861.70	$C$57=$F$57	Not Binding	0

3.4.3 Results of sensitivity analysis by decreasing 30 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6		99.92	99.92

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		1.57772E-30	1.57772E-30
$H$1		0	0
$I$1		0	0
$J$1		2.46148E-31	2.46148E-31
$K$1		0.011929962	0.011929962
$L$1		0	0
$M$1		6.5175E-15	0
$N$1		5.07902E-16	1.74704E-17
$O$1		4.93038E-32	4.93038E-32
$P$1		3.9443E-31	3.9443E-31
$Q$1		0	0
$R$1		-1.77009E-14	1.91375E-19
$S$1		0	0
$T$1		0.1474783	0.1474783
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		0	0
$AD$1		0	0
$AE$1		0	0
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	0
$AL$1		0	0
$AM$1		1.9305E-11	-1.8121E-12
$AN$1		0	0
$AO$1		0	0
$AP$1		8.51	8.51
$AQ$1		0	0
$AR$1		0	3.63882E-12
$AS$1		0	0
$AT$1		0	0
$AU$1		0	0
$AV$1		2.75219E-13	1.72385E-13
$AW$1		0	0
$AX$1		-2.04921E-13	1.57495E-11

$AY$1	0	0
$AZ$1	347573.3105	347573.3105
$BA$1	47.13325375	47.13325375
$BB$1	0	0
$BC$1	1374641.509	1374641.509
$BD$1	274655.2003	274655.2003
$BE$1	0	0
$BF$1	0	0
$BG$1	0	0
$BH$1	0	0
$BI$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land	- 0.14	$C$7<=$F$7	Not Binding	7.585548338
$C$8	rent land	0.15	$C$8<=$F$8	Not Binding	7.1325217
$C$9	family labor June	0.09	$C$9<=$F$9	Not Binding	39.9050375
$C$10	family labor July	0.37	$C$10<=$F$10	Not Binding	39.63148346
$C$11	family labor August	0.35	$C$11<=$F$11	Not Binding	39.652003
$C$12	family labor September	0.00	$C$12<=$F$12	Not Binding	40
$C$13	family labor October	0.09	$C$13<=$F$13	Not Binding	39.9050375
$C$14	family labor November	0.37	$C$14<=$F$14	Not Binding	39.63148346
$C$15	family labor December	0.35	$C$15<=$F$15	Not Binding	39.652003
$C$16	family labor January	0.00	$C$16<=$F$16	Not Binding	40
$C$17	family labor Febuary	0.09	$C$17<=$F$17	Not Binding	39.9050375
$C$18	family labor March	0.37	$C$18<=$F$18	Not Binding	39.63148346
$C$19	family labor April	0.35	$C$19<=$F$19	Not Binding	39.652003
$C$20	family labor May	-	$C$20<=$F$20	Not Binding	40
$C$21	investment crop1	27.41	$C$21<=$F$21	Not Binding	127542.2129
$C$22	BAAC	-	$C$22<=$F$22	Not Binding	144761.9
$C$23	Coperative	-	$C$23<=$F$23	Not Binding	115000
$C$24	Villange Fund	-	$C$24<=$F$24	Not Binding	15625
$C$25	SCB	-	$C$25<=$F$25	Not Binding	82500
$C$26	June	1.65	$C$26<=$F$26	Not Binding	28327.18223
$C$27	July	1.51	$C$27<=$F$27	Not Binding	54315.58147
$C$28	August	1.44	$C$28<=$F$28	Not Binding	207886.4688
$C$29	September	0.00	$C$29<=$F$29	Not Binding	309860.208
$C$30	October	1.48	$C$30<=$F$30	Not Binding	167038.2293
$C$31	November	1.29	$C$31<=$F$31	Not Binding	85075.93071
$C$32	December	1.20	$C$32<=$F$32	Not Binding	27692.59074
$C$33	January	0.00	$C$33<=$F$33	Not Binding	15773.184
$C$34	Febuary	1.46	$C$34<=$F$34	Not Binding	9893.063413
$C$35	March	2.09	$C$35<=$F$35	Not Binding	27576.79464
$C$36	April	2.35	$C$36<=$F$36	Not Binding	4453.818354
$C$37	May	-	$C$37<=$F$37	Not Binding	24351.6672
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	170.13
$C$40	rice dry	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	chilli	-	$C$41=$F$41	Not Binding	0
$C$42	pak choi	- 0.00	$C$42=$F$42	Not Binding	0
$C$43	long bean	- 0.00	$C$43=$F$43	Not Binding	0

$C$44	morning glory		-	$C$44=$F$44	Not Binding	0
$C$45	coriander		0.00	$C$45=$F$45	Not Binding	0
$C$46	celery	-	0.00	$C$46=$F$46	Not Binding	0
$C$47	green shallot	-	0.00	$C$47=$F$47	Not Binding	0
$C$48	spinanch	-	0.00	$C$48=$F$48	Not Binding	0
$C$49	lettuce		0.00	$C$49=$F$49	Not Binding	0
$C$50	sugar cane	-	0.00	$C$50=$F$50	Not Binding	0
$C$51	longan		0.00	$C$51=$F$51	Not Binding	0
$C$52	balance income	-	0.00	$C$52=$F$52	Not Binding	0
$C$53	Socail Max Hired Labor		347,575.10	$C$53=$F$53	Not Binding	0
$C$54	Economic Risk Price		47.34	$C$54=$F$54	Not Binding	0
$C$55	Econnomic Risk Yield		8.51	$C$55=$F$55	Not Binding	0
$C$56	Env Water		1,374,655.97	$C$56=$F$56	Not Binding	0
$C$57	Economic Max Income		274,861.70	$C$57=$F$57	Not Binding	0

3.5 Sensitivity Report in rainfed area model by decreasing water use on farms

3.5.1 Results of sensitivity analysis by decreasing 10 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6	goal	99.94	99.94

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		0	1.0217E-15
$H$1		9.86076E-32	9.86076E-32
$I$1		1.3652E-16	1.24686E-14
$J$1		0	-1.1361E-20
$K$1		1.06512E-15	1.97215E-31
$L$1		0.008864279	0.008864279
$M$1		1.20341E-21	3.19873E-19
$N$1		0	0
$O$1		0.008071579	0.008071579
$P$1		0	-1.24432E-14
$Q$1		0	0
$R$1		0	0
$S$1		0	0
$T$1		0	0
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	0
$Z$1		0	0
$AA$1		0	0
$AB$1		877.5458129	0
$AC$1		0	877.5312227
$AD$1		234.1447176	0
$AE$1		0	231.9564494
$AF$1		0	0
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	0
$AK$1		0	0
$AL$1		-8.88178E-16	0
$AM$1		0	0
$AN$1		2.121576418	2.121576418
$AO$1		0	0
$AP$1		0	3.00433E-13
$AQ$1		7.765423582	7.765423582
$AR$1		0	0
$AS$1		0	0
$AT$1		317363.1596	317363.1596
$AU$1		0	0
$AV$1		0	0

$AW$1	680063.887	680063.887
$AX$1	555759.6434	555759.6434
$AY$1	0	0
$AZ$1	0	0
$BA$1	0	0
$BB$1	0	0
$BC$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land crop1	0.02	$C$7<=$F$7	Not Binding	14.98306414
$C$8	rent land1	-	$C$8<=$F$8	Not Binding	6
$C$9	family labor June	0.02	$C$9<=$F$9	Not Binding	39.98111251
$C$10	family labor July	0.01	$C$10<=$F$10	Not Binding	39.99437411
$C$11	family labor August	0.01	$C$11<=$F$11	Not Binding	39.99437411
$C$12	family labor September	0.12	$C$12<=$F$12	Not Binding	39.87973348
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.99437411
$C$14	family labor November	0.01	$C$14<=$F$14	Not Binding	39.99437411
$C$15	family labor December	0.06	$C$15<=$F$15	Not Binding	39.93852916
$C$16	family labor January	0.03	$C$16<=$F$16	Not Binding	39.97097241
$C$17	family labor Febuary	0.03	$C$17<=$F$17	Not Binding	39.96786992
$C$18	family labor March	0.03	$C$18<=$F$18	Not Binding	39.96786992
$C$19	family labor April	0.03	$C$19<=$F$19	Not Binding	39.96999734
$C$20	family labor May	- 877.53	$C$20<=$F$20	Not Binding	917.5292855
$C$21	investment crop1	131,471.27	$C$21<=$F$21	Not Binding	0.001403196
$C$22	Villange fund	-	$C$22<=$F$22	Not Binding	22000
$C$23	BAAC	231.96	$C$23<=$F$23	Not Binding	89768.04355
$C$24	Coperative	-	$C$24<=$F$24	Not Binding	60000
$C$25	Finance	-	$C$25<=$F$25	Not Binding	18000
$C$26	water June	4.60	$C$26<=$F$26	Not Binding	10061.43205
$C$27	water July	3.46	$C$27<=$F$27	Not Binding	51311.91705
$C$28	water August	2.97	$C$28<=$F$28	Not Binding	140105.0026
$C$29	water September	2.98	$C$29<=$F$29	Not Binding	188806.8518
$C$30	water October	3.00	$C$30<=$F$30	Not Binding	112388.1936
$C$31	water November	3.10	$C$31<=$F$31	Not Binding	39802.24428
$C$32	water December	3.80	$C$32<=$F$32	Not Binding	22888.74699
$C$33	water January	3.43	$C$33<=$F$33	Not Binding	14875.1704
$C$34	water Febuary	3.88	$C$34<=$F$34	Not Binding	8361.540286
$C$35	water March	5.15	$C$35<=$F$35	Not Binding	10584.20402
$C$36	water April	5.07	$C$36<=$F$36	Not Binding	5137.975701
$C$37	water May	4.67	$C$37<=$F$37	Not Binding	7734.00023
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	375.64
$C$40	yield long bean	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	yield marigold	- 0.00	$C$41=$F$41	Not Binding	0
$C$42	yield maize	0.00	$C$42=$F$42	Not Binding	0
$C$43	yield sweet corn	- 0.00	$C$43=$F$43	Not Binding	0
$C$44	yield tobacco	0.00	$C$44=$F$44	Not Binding	0
$C$45	yield galangal	- 0.00	$C$45=$F$45	Not Binding	0
$C$46	yield lemon grass	0.00	$C$46=$F$46	Not Binding	0
$C$47	yield banana	- 0.00	$C$47=$F$47	Not Binding	0

$C$48	yield longan		0.00	$C$48=$F$48	Not Binding	0
$C$49	commodity balance	-	0.00	$C$49=$F$49	Not Binding	0
$C$50	Socail Max Hired Labor		317,365.70	$C$50=$F$50	Not Binding	0
$C$51	Economic Risk Price		0.88	$C$51=$F$51	Not Binding	0
$C$52	Economic Risk Yield		9.89	$C$52=$F$52	Not Binding	0
$C$53	Env Water		680,110.00	$C$53=$F$53	Not Binding	0
$C$54	Economic Max Income		556,068.10	$C$54=$F$54	Not Binding	0

3.5.2 Results of sensitivity analysis by decreasing 20 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6	goal	99.94	99.94

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		1.0217E-15	0
$H$1		9.86076E-32	0
$I$1		1.24686E-14	1.45295E-14
$J$1		-1.1361E-20	1.50463E-36
$K$1		1.97215E-31	1.97215E-31
$L$1		0.008864279	0.008864279
$M$1		3.19873E-19	4.81482E-35
$N$1		0	1.37536E-15
$O$1		0.008071579	0.008071579
$P$1		-1.24432E-14	1.68102E-18
$Q$1		0	0
$R$1		0	0
$S$1		0	0
$T$1		0	0
$U$1		0	0
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		0	877.5169044
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		877.5312227	0
$AD$1		0	0
$AE$1		231.9564494	0
$AF$1		0	229.808704
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		0	6.00552E-11
$AK$1		0	0
$AL$1		0	0
$AM$1		0	0
$AN$1		2.121576418	2.121576418
$AO$1		0	0
$AP$1		3.00433E-13	0
$AQ$1		7.765423582	7.765423582
$AR$1		0	0
$AS$1		0	0
$AT$1		317363.1596	317363.1596
$AU$1		0	0
$AV$1		0	0
$AW$1		680063.887	680063.887
$AX$1		555759.6434	555759.6434

$AY$1	0	0
$AZ$1	0	0
$BA$1	0	0
$BB$1	0	0
$BC$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land crop1	0.02	$C$7<=$F$7	Not Binding	14.98306414
$C$8	rent land1	-	$C$8<=$F$8	Not Binding	6
$C$9	family labor June	0.02	$C$9<=$F$9	Not Binding	39.98111251
$C$10	family labor July	0.01	$C$10<=$F$10	Not Binding	39.99437411
$C$11	family labor August	0.01	$C$11<=$F$11	Not Binding	39.99437411
$C$12	family labor September	0.12	$C$12<=$F$12	Not Binding	39.87973348
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.99437411
$C$14	family labor November	0.01	$C$14<=$F$14	Not Binding	39.99437411
$C$15	family labor December	0.06	$C$15<=$F$15	Not Binding	39.93852916
$C$16	family labor January	- 877.49	$C$16<=$F$16	Not Binding	917.4878768
$C$17	family labor Febuary	0.03	$C$17<=$F$17	Not Binding	39.96786992
$C$18	family labor March	0.03	$C$18<=$F$18	Not Binding	39.96786992
$C$19	family labor April	0.03	$C$19<=$F$19	Not Binding	39.96999734
$C$20	family labor May	0.00	$C$20<=$F$20	Not Binding	39.99806282
$C$21	investment crop1	131,471.27	$C$21<=$F$21	Not Binding	0.00140068
$C$22	Villange fund	-	$C$22<=$F$22	Not Binding	22000
$C$23	BAAC	-	$C$23<=$F$23	Not Binding	90000
$C$24	Coperative	229.81	$C$24<=$F$24	Not Binding	59770.1913
$C$25	Finance	-	$C$25<=$F$25	Not Binding	18000
$C$26	water June	4.60	$C$26<=$F$26	Not Binding	8942.984053
$C$27	water July	3.46	$C$27<=$F$27	Not Binding	45610.20825
$C$28	water August	2.97	$C$28<=$F$28	Not Binding	124537.4506
$C$29	water September	2.98	$C$29<=$F$29	Not Binding	167827.9814
$C$30	water October	3.00	$C$30<=$F$30	Not Binding	99900.28322
$C$31	water November	3.10	$C$31<=$F$31	Not Binding	35379.42828
$C$32	water December	3.80	$C$32<=$F$32	Not Binding	20345.13099
$C$33	water January	3.43	$C$33<=$F$33	Not Binding	13221.9928
$C$34	water Febuary	3.88	$C$34<=$F$34	Not Binding	7432.049086
$C$35	water March	5.15	$C$35<=$F$35	Not Binding	9407.60882
$C$36	water April	5.07	$C$36<=$F$36	Not Binding	4566.526101
$C$37	water May	4.67	$C$37<=$F$37	Not Binding	6874.14743
$C$38	yield rice rain	-	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	375.64
$C$40	yield long bean	0.00	$C$40=$F$40	Not Binding	0
$C$41	yield marigold	- 0.00	$C$41=$F$41	Not Binding	0
$C$42	yield maize	- 0.00	$C$42=$F$42	Not Binding	0
$C$43	yield sweet corn	- 0.00	$C$43=$F$43	Not Binding	0
$C$44	yield tobacco	- 0.00	$C$44=$F$44	Not Binding	0
$C$45	yield galangal	- 0.00	$C$45=$F$45	Not Binding	0
$C$46	yield lemon grass	- 0.00	$C$46=$F$46	Not Binding	0
$C$47	yield banana	- 0.00	$C$47=$F$47	Not Binding	0
$C$48	yield longan	- 0.00	$C$48=$F$48	Not Binding	0
$C$49	commodity balance	0.00	$C$49=$F$49	Not Binding	0

$C$50	Socail Max Hired Labor	317,365.70	$C$50=$F$50	Not Binding	0
$C$51	Economic Risk Price	0.88	$C$51=$F$51	Not Binding	0
$C$52	Economic Risk Yield	9.89	$C$52=$F$52	Not Binding	0
$C$53	Env Water	680,110.00	$C$53=$F$53	Not Binding	0
$C$54	Economic Max Income	556,068.10	$C$54=$F$54	Not Binding	0

3.5.3 Results of sensitivity analysis by decreasing 30 percent

Target Cell (Min)

Cell	Name	Original Value	Final Value
$C$6	goal	99.94	99.94

Adjustable Cells

Cell	Name	Original Value	Final Value
$G$1		0	4.48983E-16
$H$1		0	2.54061E-16
$I$1		1.45295E-14	1.22045E-14
$J$1		1.50463E-36	1.50463E-36
$K$1		1.97215E-31	1.97215E-31
$L$1		0.008864279	0.008864279
$M$1		4.81482E-35	-1.36991E-15
$N$1		1.37536E-15	0
$O$1		0.008071579	0.008071579
$P$1		1.68102E-18	5.66256E-14
$Q$1		0	0
$R$1		0	0
$S$1		0	0
$T$1		0	0
$U$1		0	877.5169061
$V$1		0	0
$W$1		0	0
$X$1		0	0
$Y$1		877.5169044	0
$Z$1		0	0
$AA$1		0	0
$AB$1		0	0
$AC$1		0	0
$AD$1		0	0
$AE$1		0	0
$AF$1		229.808704	229.8087043
$AG$1		0	0
$AH$1		0	0
$AI$1		0	0
$AJ$1		6.00552E-11	0
$AK$1		0	0
$AL$1		0	0
$AM$1		0	0
$AN$1		2.121576418	2.121576418
$AO$1		0	0
$AP$1		0	1.46744E-11
$AQ$1		7.765423582	7.765423582
$AR$1		0	0
$AS$1		0	0
$AT$1		317363.1596	317363.1596
$AU$1		0	0
$AV$1		0	0
$AW$1		680063.887	680063.887
$AX$1		555759.6434	555759.6434

$AY$1	0	0
$AZ$1	0	0
$BA$1	0	0
$BB$1	0	0
$BC$1	0	0

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$C$7	land crop1	0.02	$C$7<=$F$7	Not Binding	14.98306414
$C$8	rent land1	-	$C$8<=$F$8	Not Binding	6
$C$9	family labor June	0.02	$C$9<=$F$9	Not Binding	39.98111251
$C$10	family labor July	0.01	$C$10<=$F$10	Not Binding	39.99437411
$C$11	family labor August	0.01	$C$11<=$F$11	Not Binding	39.99437411
$C$12	family labor September	- 877.40	$C$12<=$F$12	Not Binding	917.3966396
$C$13	family labor October	0.01	$C$13<=$F$13	Not Binding	39.99437411
$C$14	family labor November	0.01	$C$14<=$F$14	Not Binding	39.99437411
$C$15	family labor December	0.06	$C$15<=$F$15	Not Binding	39.93852916
$C$16	family labor January	0.03	$C$16<=$F$16	Not Binding	39.97097241
$C$17	family labor Febuary	0.03	$C$17<=$F$17	Not Binding	39.96786992
$C$18	family labor March	0.03	$C$18<=$F$18	Not Binding	39.96786992
$C$19	family labor April	0.03	$C$19<=$F$19	Not Binding	39.96999734
$C$20	family labor May	0.00	$C$20<=$F$20	Not Binding	39.99806282
$C$21	investment crop1	131,471.27	$C$21<=$F$21	Not Binding	0.001144079
$C$22	Villange fund	-	$C$22<=$F$22	Not Binding	22000
$C$23	BAAC	-	$C$23<=$F$23	Not Binding	90000
$C$24	Coperative	229.81	$C$24<=$F$24	Not Binding	59770.1913
$C$25	Finance	-	$C$25<=$F$25	Not Binding	18000
$C$26	water June	4.60	$C$26<=$F$26	Not Binding	7824.536053
$C$27	water July	3.46	$C$27<=$F$27	Not Binding	39908.49945
$C$28	water August	2.97	$C$28<=$F$28	Not Binding	108969.8986
$C$29	water September	2.98	$C$29<=$F$29	Not Binding	146849.111
$C$30	water October	3.00	$C$30<=$F$30	Not Binding	87412.37282
$C$31	water November	3.10	$C$31<=$F$31	Not Binding	30956.61228
$C$32	water December	3.80	$C$32<=$F$32	Not Binding	17801.51499
$C$33	water January	3.43	$C$33<=$F$33	Not Binding	11568.8152
$C$34	water Febuary	3.88	$C$34<=$F$34	Not Binding	6502.557886
$C$35	water March	5.15	$C$35<=$F$35	Not Binding	8231.01362
$C$36	water April	5.07	$C$36<=$F$36	Not Binding	3995.076501
$C$37	water May	4.67	$C$37<=$F$37	Not Binding	6014.29463
$C$38	yield rice rain	- 0.00	$C$38=$F$38	Not Binding	0
$C$39	yield rice consumption	-	$C$39<=$F$39	Not Binding	375.64
$C$40	yield long bean	- 0.00	$C$40=$F$40	Not Binding	0
$C$41	yield marigold	- 0.00	$C$41=$F$41	Not Binding	0
$C$42	yield maize	- 0.00	$C$42=$F$42	Not Binding	0
$C$43	yield sweet corn	- 0.00	$C$43=$F$43	Not Binding	0
$C$44	yield tobacco	- 0.00	$C$44=$F$44	Not Binding	0
$C$45	yield galangal	0.00	$C$45=$F$45	Not Binding	0
$C$46	yield lemon grass	0.00	$C$46=$F$46	Not Binding	0
$C$47	yield banana	- 0.00	$C$47=$F$47	Not Binding	0
$C$48	yield longan	- 0.00	$C$48=$F$48	Not Binding	0
$C$49	commodity balance	0.00	$C$49=$F$49	Not Binding	0

$C$50	Socail Max Hired Labor	317,365.70	$C$50=$F$50	Not Binding	0
$C$51	Economic Risk Price	0.88	$C$51=$F$51	Not Binding	0
$C$52	Economic Risk Yield	9.89	$C$52=$F$52	Not Binding	0
$C$53	Env Water	680,110.00	$C$53=$F$53	Not Binding	0
$C$54	Economic Max Income	556,068.10	$C$54=$F$54	Not Binding	0