AGRICULTURAL WATER DEMAND PREDICTION MODEL BY USING INPUT-OUTPUT TABLE WITH IMPACTS FROM DECLARED STRATEGY OF THAILAND

Pongsak SUTTINON, Nasu SEIGO
Kochi University of Technology

***ABSTRACT*:** Agricultural sector is one of the main water consumers in Thailand including irrigation and livestock. Irrigation water demand model was developed into 2 scale; Thailand and provincial scale. Main crops in study area are only major rice, second rice, and sugarcane because of constraint of soil types. Thailand crop area was analyzed from situations of world and domestic market including gross domestic product in agricultural sector, cost of production factor, and unit crop price. It is certain that Thailand irrigation area will be decreasing because of urbanization. In provincial scale, crop area depends on trend of Thailand and economic situation in each area including the constraints such as; soil condition, possible agricultural area, irrigation service area of governmental agencies, and risk of climate. In case of normal rainfall year, agricultural water demand in Lower Chao Phraya River Basin is 2,195 MCM in year 2025. Irrigation sector is the main user with 2,141 MCM or 97 % of total agricultural water demand.

KEYWORDS: agricultural water demand prediction model, Input-output table

1. INTRODUCTION

Thailand is basically agricultural country. Most people located in rural area mainly work in irrigation activities. From this reason, agricultural sector is one of the important economic activities in Thailand. Gross Domestic Product or GDP growth rate in agricultural is low comparing with non-agricultural sector because of master plan concentrated industrial and service development in the past. However, GDP growth rate in this sector is constant even in the economic crisis in year 1997. In that period, industrial sector faced the high impacts with critically decreased GDP growth rate. After the economic crisis, Thai government carefully concentrates in agricultural sector again as shown in some strategy of the 9th and 10th national economic and social development plan.

Agricultural sector is main part of export value in Thailand with approximately 20 % of total. In the world, Thailand is the main exporter of agricultural product as following; the 1st order in rice, cassava, and maize; the 4th order in sugarcane. Thailand declared national master plan name “Thailand is the kitchen of the world” in the 9th national economic and social development plan. From this policy, food and beverage products were concentrated with higher demand of raw material from agricultural sector.

In the viewpoint of water use, agricultural activities consume much water especially rice which is main crop of Thailand. Only 1 % of consumed water in this sector is a big amount of water in industrial and household sector. Policy makers should carefully consider this part with the other users. Water share from one sector to another is very sensitive. It may change the water shortage problem to bigger problem as society and political problem.

1.1 Objectives

The main objective of this chapter is to develop agricultural water demand model by using input-output model to calculate effects from changing economic structure with the effect of climate factors.

Study area

The study area is located in Lower Chao Phraya River Basin. There are 7 provinces in this area; Ayutthaya, Bangkok, Nakon Pathom, Nontaburi, Pathum Thani, Samut Prakan, and Samut Sakhon as AYT, BKK, NKP, NTB, PTT, SPK, and SSK.

2. METHODOLOGY

The model mechanism of agricultural water demand management model developed is shown in figure 1. The model was divided into two parts; irrigation and livestock water demand.

2.1 Irrigation water demand

Firstly, irrigation water demand model was developed in national scale to calculate main crop area affected form world market and domestic market in Thailand with Input-output table model. Secondly, main crop area in each province was calculated from economic structure with trend of Thailand under constraints of possible agricultural area, irrigation service area, and soil condition. Thirdly, water use unit in each crop was analyzed with climate effect under uncertainty of rainfall in the future. Finally, irrigation water demand was calculated from forecasted main crop area and water use unit per area by using the following equation:

$$WD_{crop} = (ET_{crop} - P_e) * A_{crop}$$

Where, WD_{crop} is irrigation water demand, ET_{crop} is the water requirement in each crop, P_e is effective rainfall, and A_{crop} is the crop area.

World situation of agricultural was considered because Thailand is the main exporter in the world. From this reason, the main effects of irrigated demand from Thailand were 2 factor; (1) world market, and (2) domestic market.

In term of product of main crops in the world, the growth rates of each product were gradually increasing. One of interesting points is that the yield of each crop. Trend of yield or product per area is increasing in case of the world because of high technology and knowledge used to harvest. At the same time, the yield of each crop in Thailand is lower than the average world value except second rice and cassava.

In case of major rice, yield in Thailand is only 60 % of average world yield. There are many reasons are following; type of rice, hydrological and climate factors, irrigation method, etc. However, this gap between Thai yield and the world yield shows possible yield to increase. If the yield in Thailand is higher, farmer can produce more products at the same area and water but gets more benefit. Form this point, high productivity is one of the interesting measures to increase the value of used water in irrigation sector.

The main crop concentrated in this model are major rice (regular rice was planted in rainy season and use mainly rainfall), second rice (rice was planted in other seasons and mainly located in irrigation service area or close to water source), maize, cassava, and sugarcane. Now the agricultural area in Thailand is gradually decreasing form the past 20 years because of urbanization.

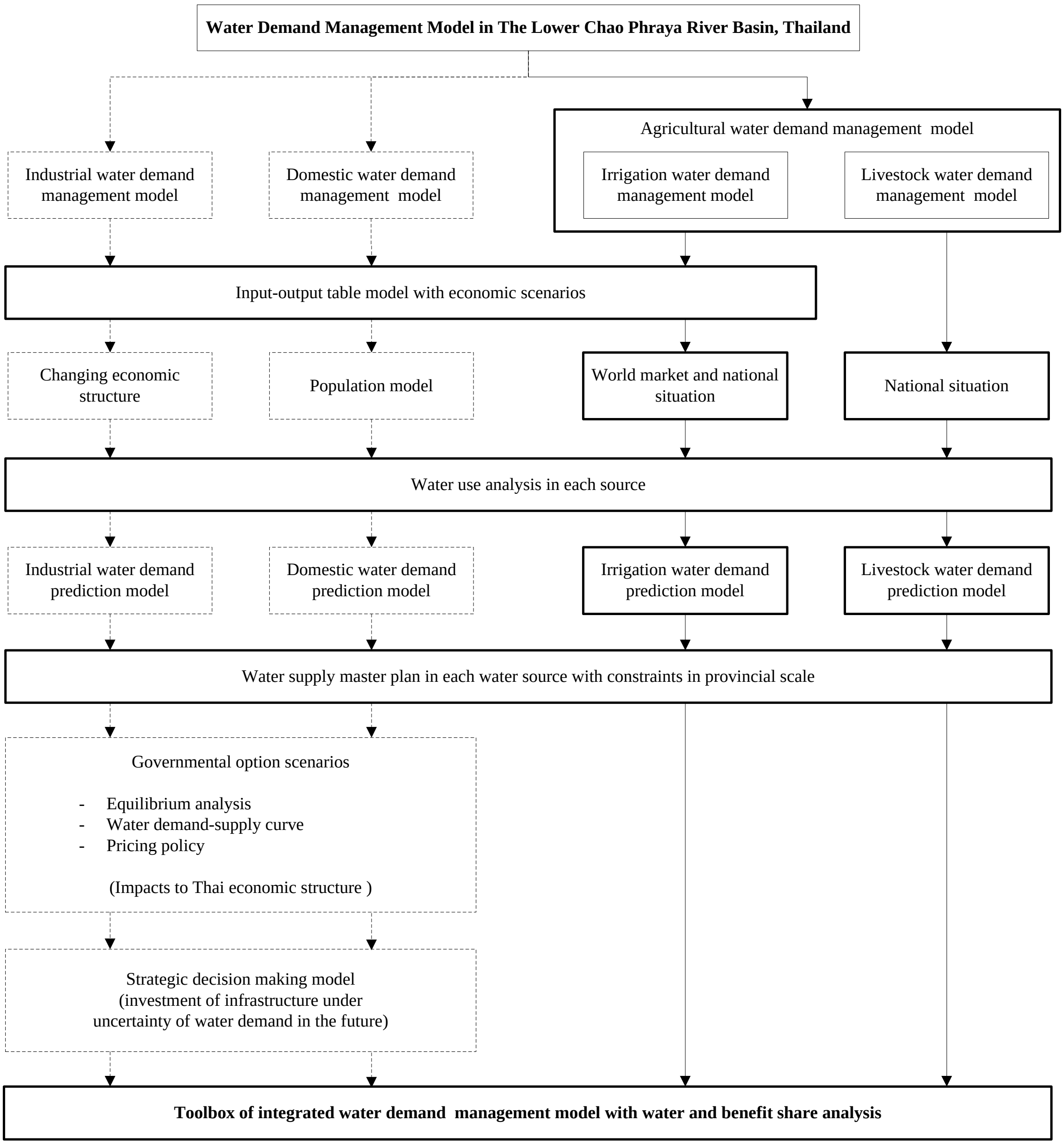


Figure 1. Model mechanism.

However, Royal Irrigation Department (RID) plan to construct more water infrastructure for irrigation service area. From this reason, the planted area of second rice is increasing.

In study area, rice is the main crop because of physical condition of soil. The main producer in this study area is Ayuttaya province on the upper part. It is interesting that rice farm in the lower part of study is much lower than the upper. The reason is that the main activities in lower part including Bangkok, nontaburi, Samut Prakan, and Samut Sakon are industrial and service area. The land cost in this area was rapidly increasing. The agricultural area was sold and change to industrial and inhabitant use.

Crop water demand is usually measured in terms of evapotranspiration. This rate depends on climate factors such as temperature, radiation, wind speed, precipitations, soil moisture, surface properties and etc. crop water requirement are estimated on reference crop evapotranspiration or ET_0. ET_0 is the maximum evapotranspiration rate that the atmosphere is capable of extracting from a well-watered field. Methods of estimating ET_0 depends on conditions and constraints in each area. The water requirement in each crop can be estimated as follows:

$$ET_{crop} = K_c * ET_0$$

Where, ET_{crop} is the water requirement in each crop, K_c is crop coefficient, ET_0 is the maximum evapotranspiration. Royal Irrigation Department (RID) collected related data and calculated the water requirement as shown in table 1 by using modified Penman-Monteith method recommended to be suitable with climate and hydrological factors of Thailand.

Water use unit per crop area is shown in term of (ET_{crop} - P_e). P_e or effective rainfall is excess rainfall or precipitation that is converted to runoff. However, effective rainfall in each crop depends on crop pattern. Major rice was planted from the starting of rainy season or July and harvested in the end of December but the second rice was planted from February to May. Farm crops can be plant in the whole year.

Finally water use unit per crop area was calculated by using data of water requirement in each crop and effective rainfall. However, irrigation sector is an activity that highly depended on rainfall factor. From this topic, uncertainty in rainfall in the future was considered as rainfall scenarios in table 2. This table was analyzed from rainfall data in the past and made the order from the lowest to the highest value to find the rainfall depth in each percentile. In this scenario, 20^{th} percentile was defined as low rainfall year. The 50^{th} percentile and 80^{th} percentile are normal and high rainfall year.

Table 1. Water requirement in each crop in study area.

Possible crop in study area	ET_{crop} , water requirement in each crop; mm.
Major rice	1155
Second rice	1155
Sugarcane	1632

(Source: RID)

Finally, irrigation water demand was calculated from summation of water in each crop as following.

$$WD_{irri} = \sum_{crop=1}^{n} (ET_{crop} - Pe_{crop}) * A_{crop}$$

Where, WD_{irri} is irrigation water demand, ET_{crop} is the water requirement in each crop, $P_{e,crop}$ is effective rainfall, A_{crop} is the crop area, Crop is possible crop in study area; major rice, second rice, and sugarcane.

Table 2. Rainfall data and rainfall scenario.

Raw data		New arranged data		Percentile	
Year	Rainfall, mm.	Year	Rainfall, mm.		
1994	1,716	2004	1,308	0.0	
1995	1,639	2003	1,384	15.7	
1996	1,681	1997	1,404	19.9	20^{th}
1997	1,404	1998	1,449	29.2	
1998	1,449	2002	1,548	49.7	50^{th}
1999	1,780	1995	1,639	68.5	
2000	1,791	2001	1,680	77.0	
2001	1,680	1996	1,681	77.2	80^{th}
2002	1,548	1994	1,716	84.5	
2003	1,384	1999	1,780	97.7	
2004	1,308	2000	1,791	100.0	

(Source: edited from Thai Meteorological Department)

2.2 Livestock water demand

Livestock sector is very low percentage if comparing with irrigation sector but the important point is environmental viewpoint. Wastewater from livestock in high density area such as Nakon Pathom is interesting topic for policy makers. The forecasting method in this sector is basically trend analysis form the data in the past. Water use unit per livestock was collect from Department of Livestock Developement. Finally, livestock water demand was calculated from forecasted number of each livestock and water use unit per head.

3. RESULTS

3.1 Irrigation water demand model

Thailand crop area model was developed in national scale with dimension of time series or matrix of 5 X 20 (5 major crop with 20 years) in forecasting step. The equation of model was shown as follow.

$$
\begin{aligned}
\mathrm{A\_TH(crop,t)} = {} & \mathrm{C1(crop) * GDP\_AGR\_WR(t)} \\
& + \mathrm{C2(crop) * GDP\_AGR\_TH(t)} \\
& + \mathrm{C3(crop) * CO\_Fe(t-1)} \\
& + \mathrm{C4(crop) * CO\_In(t-1)} \\
& + \mathrm{C5(crop) * PR\_WR(crop,t-1)} \\
& + \mathrm{C6(crop) * PR\_TH(crop,t-1)}
\end{aligned}
$$

Where, A_TH(crop,t) is Thailand crop area in each crop and forecasting year, C (prov) is constant in each crop, GDP_AGR_WR(t) is world gross domestic product in agricultural sector, GDP_AGR_TH(t) is Thailand gross domestic product in agricultural sector, CO_Fe(t-1) is cost of fertilizers in last year, CO_In(t-1) is cost of insecticides in last year, PR_WR(crop,t-1) is world unit price of each crop in last year, PR_TH(crop,t-1) is Thailand unit price of each crop in last year, crop consists of major rice, second rice, maize, cassava, and sugarcane.

Figure 2 shows planted area of main crop forecasted in Thailand scale. The results can be divided into two groups;

(1) Decreasing crop area: major rice, maize, and cassava

This situation is as same as the present trend. The irrigation area is decreasing because of urbanization in Thailand. The irrigation area was changed to industrial and inhabitant area especially in Bangkok and vicinities.

(2) Increasing crop area: second rice and sugarcane

This increasing crop area is second rice because the expansion of irrigation service area. Farmers can use same area to plant rice by twice a year with supported water from irrigation system. In case of sugarcane, there is more demand from international with higher price of sugarcane.

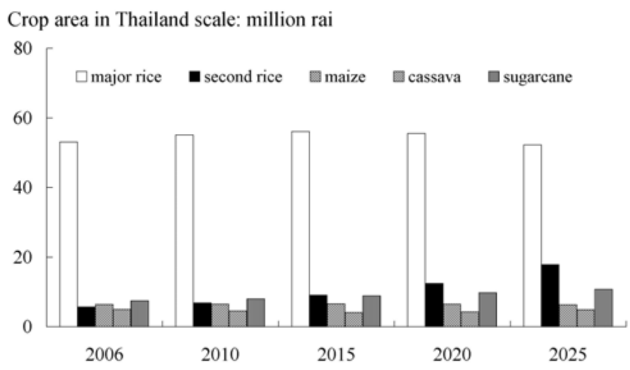


Figure 2. Planted area of main crop in national scale.

Provincial crop area model was developed with dimension of time series or matrix of 7 X 20 (7 provinces with 20 years) in forecasting step. The equation of model was shown as follow.

$$
\begin{aligned}
\mathrm{A\_PR(crop,prov,t)} = {} & \mathrm{C1(prov) * A\_TH(crop,t)} \\
& + \mathrm{C2(crop)*GDP\_AGR\_PR(prov,t)} \\
& \quad \mathrm{/GDP\_AGR\_TH(t)}
\end{aligned}
$$

Where, A_PR(crop,prov,t) is provincial crop area in each forecasting year, A_TH(crop,t) is Thailand crop area in each crop and forecasting year, C (prov) is constant in each crop, GDP_AGR_PR(t) is gross provincial product in agricultural sector, GDP_AGR_TH(t) is Thailand gross domestic product in agricultural sector, crop consists of major rice, second rice, and sugarcane, prov consists of 7 provinces in study area. The constraint consists of 1) Soil condition of each crop and province, 2) Possible agricultural area, 3) Inside and outside irrigation service area of RID.

The results can be divided into two groups;

(1) Case of inside irrigation service area

In this case, high percentage of crop area is major rice and second rice because of physical soil condition of clay. Only sugarcane was planted in Nakon Pathom. The ratio of major and second rice is equal because of completed irrigation service area in these 7 provinces. However, the irrigation area of major rice is decreasing because of urbanization but crop area of second rice is increasing to as same level as major rice because of completed irrigation service area as shown in figure 3.

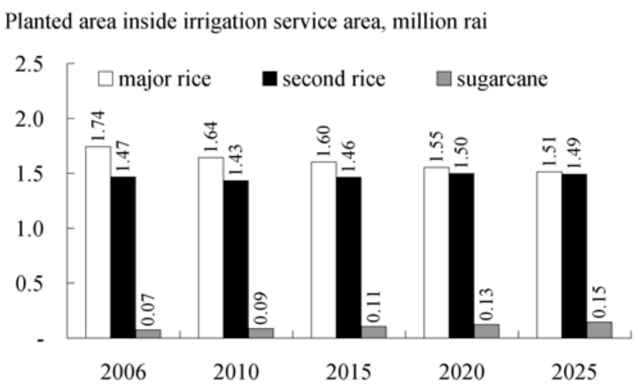


Figure 3. Planted area of main crop inside irrigation service area.

(2) Case of outside irrigation service area

The lower part of study area is mainly industrial and inhabitant area. Form this reason; there is no development of irrigation project. In the upper part of 7 provinces, there are many rice fields mainly in Ayuttaya province. Many irrigation projects are located in this area and most of them are already completed. Without new development plan, it can be said that there is no more irrigation service area in this area. Figure 4 shows constant of crop area outside irrigation service area.

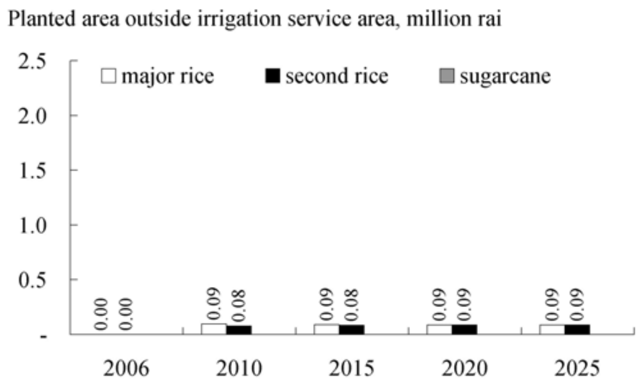


Figure 4. Planted area of main crop outside irrigation service area.

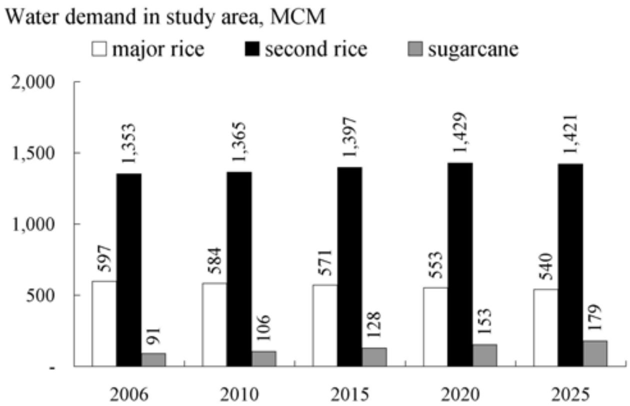
Figure 5 shows Irrigation water demand of main crop in case of normal rainfall year. Actually, water requirement of second rice is as same as major rice but major rice was planted in rainy season with high effective rainfall. Form this reason; water demand for major rice is less than case of second rice. The main water consumer in this area is second rice approximately 65 % of total.

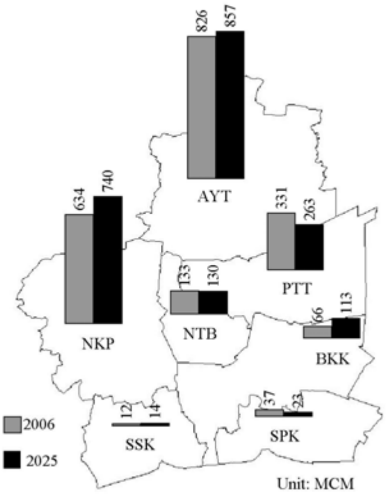
3.2 Livestock water demand model

Livestock water demand was calculated from forecasted number of each livestock by using trend analysis and fixed water use unit per head of each livestock in study area. The main water consumers are swine and chicken concentrated in Nakon Pathom approximately 75 % as shown in figure 6.

3.3 Agricultural water demand model

Agricultural water demand is summation of irrigation and livestock water demand. Figure 7 shows agricultural water demand in normal rainfall year.

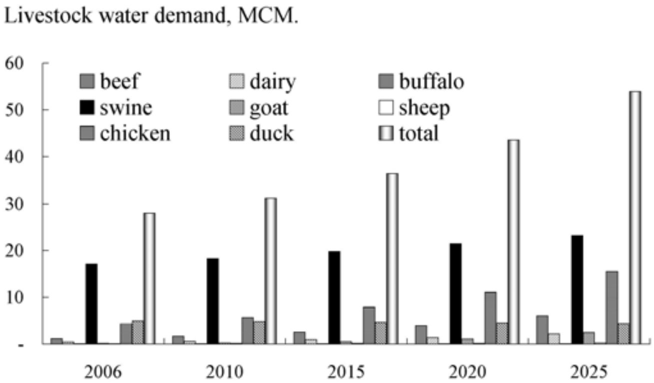


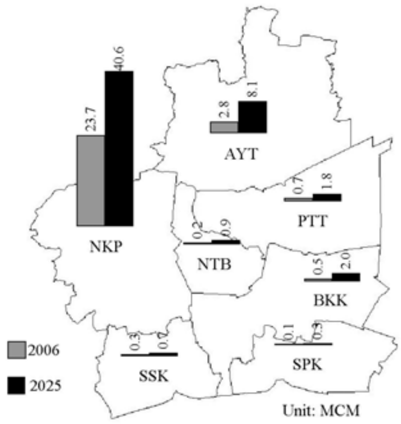


(a.) Total irrigation water demand

(b.) Provincial scale

Figure 5. Irrigation water demand of main crop in study area in case of normal rainfall year.

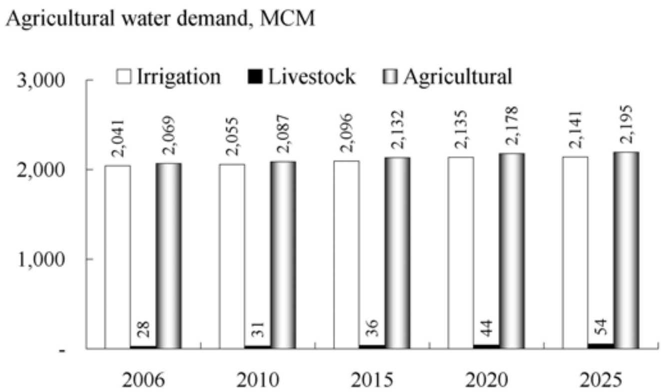


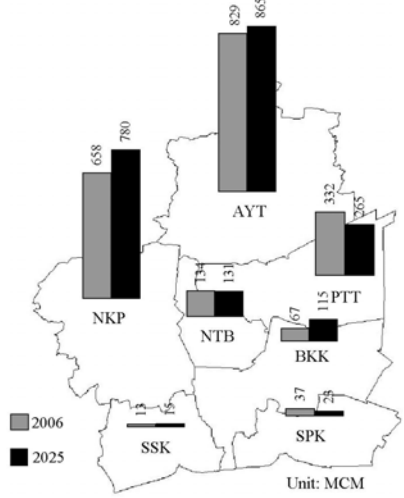


(a.) Total irrigation water demand

(b.) Provincial scale

Figure 6. Livestock water demand in study area.





(a.) Total agricultural water demand

(b.) Provincial scale

Figure 7. Agricultural water demand in study area in case of normal rainfall year.

In agricultural topic, irrigation water is the main water consumer approximately 97 % of total demand. The upper part of study area is high water user in agricultural sector because of irrigation society.

4. CONCLUSION

Proposed agricultural water demand model can forecasted water demand in irrigation and livestock sectors. Irrigation water demand model is function of crop area and water use unit per area in each crop. National crop area model was firstly analyzed with situations of world and Thailand market such as GDP in agricultural sector, cost of insecticides & fertilizers, and unit price of agricultural product. Provincial irrigation water demand was calculated by using function of Thailand crop area and ratio of GPP and GDP. Water use unit was calculated by evaportranspiration and effective rainfall with scenario of high, normal, and low rainfall year. Livestock water demand was predicted by using trend analysis. In this study area, irrigation is main sector that need high percentage of water.

5. RECOMMENDATION

The next interesting topic is how to manage the water share of each user and activity with the changing economics structure from declared policy?

The water rights and sharing in the dry season are always the critical period for water shortage problem. Water management system in Thailand is generally planned from the top-bottom or from central government to users. The problem of this method is that right of water in each user was designed and controlled by policy makers that don't use water in that area. One interesting measure used in Japan is bottom-top method or planning from local committee of each area. The committees consist of only water users in each sector such as factory, farmer, and the head of citizen located in that area. The officers form local-central government and specialists from academic fields play a role as only consultants. By this method, the right and sharing of water and benefit was designed by water users. The suitable solutions are generally buying / leasing / selling water right with satisfying received benefit.

REFERENCES

P. SUTTINON., 2008. *Water Demand Management Model in Lower Chao Phraya River Basin, Thailand*, PhD Dissertation, Kochi University of Technology, Kochi, Japan.

Royal Irrigation Department. (2003). *The Project of 9th Water Resources Master Plan and Irrigation Projects: Chao Phraya River Basin*.

Thai Meteorological Department. (2007). Climate data of Thailand, URL: http://www.tmd.go.th/ (last date accessed: 12 December 2007).