EVALUATION OF SURFACE WATER SHORTAGE AND POTENTIAL USE OF GROUNDWATER FOR THE AGRICULTURAL WATER DEMAND IN THE UPPER CHAO PHRAYA RIVER BASIN IN THAILAND

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1. INTRODUCTION

Upper Chao Phraya river basin (UCP) experiences insufficiency of available surface water to meet the rice (popular cash crop in Thailand) water demand in the dry season (November to April). This is because of expansion of rice growing area that is driven by rice product price insurance policy over a last few years and only 12% (118 mm) of mean annual rainfall distributes in this period. To overcome the surface water shortage, groundwater is an available and popular option for alleviating the problem. In fact, it is a secondary water source for planting rice in the dry season. On the other hand, the basin has been facing with floods normally in the middle of September to the end of October. Both problems are increasing trends in terms of economic loss. To cope with the problems schemes such as shifting growing rice period and using other waster source (e.g., groundwater) might be alleviated loss from floods and surface water shortages.

Therefore, the starting growing rice in May (1.5 months earlier) in order to harvested in the end of August before flood comes during September to October and using groundwater were evaluated as a sustainable option to cope with floods and droughts in the study basin.

2. UPPER CHAO PHRAYA RIVER BASIN

Fig.1 shows the UCP that is located in the northern region of Thailand. The basin covers approximately 109,073 km^2 or about 22% of the country area. Making agriculture is main activity for majority of a total 7.4 million people live the basin. There is approximately 40,570 km^2 or about 35.6% of the catchment area classified as agricultural area.

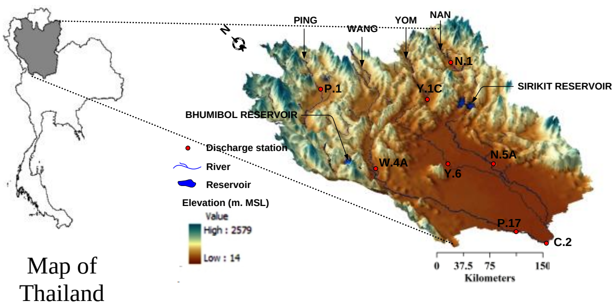

Fig.1 Upper Chao Phraya River basin and main gauging stations

In fact, there are two large reservoirs (Bhumibol and Sirikit reservoirs) located in the basin with a total storage capacity of about 23 km^3 but approximately 80% of the agricultural area is rainfed. Therefore, huge volume of water from the reservoirs has less benefit to the majority of gricultural area.

3. METHODOLOGY AND DATA

A regional version of water resources called H08 model was developed by Hanasaki et al. (2012). Three sub-models out of six sub-models of the H08 were applied to assess temporal and spatial distributions of surface water over the UCP (Pratoomchai et al., 2014). Soil Moisture Deficit method (SMD) (Rushton and Ward, 1979) and two dimensional groundwater flow model (Prickett and Lonnquist, 1971) were applied to estimate groundwater recharge and its storage, respectively. A Water Sufficiency Index (WSI) by Ekkawatpanit et al. (2009), which calculated a ratio of water consumption (rice water demand) to total available surface water (surface runoff), was used to assess surface water shortage. The Penman-Monteith method was applied to calculate crop evaprotranspiration (ET_O) and using to estimate rice water demand.

Kotsuki et al. (2010) developed a set of seven meteorological data (here after called K10 data), i.e., rainfall, surface air temperature, surface pressure, wind speed, specific humidity, shortwave and longwave downward radiations over the studied basin with a 5 min × 5 min spatial resolution. Spatial average values of aquifer and streambed properties in the UCP were adopted from Pratoomchai et al. (2014). Rice calendar, crop coefficient (K_C for rice), and conditions to maintain water depth in a paddy field are followed Office of Agricultural Economics and Royal Irrigation Department of Thailand. The data as above-mentioned were served as input data for assessing surface water, groundwater, and rice water demand, respectively, in the UCP.

4. RESULTS AND DISCUSSION

Simulated of the H08 model yielded key hydrological variables in spatial average over the UCP during 1986-2000. Approximately 987 mm was observed in spatial mean annual rainfall in the basin. There was 88% (868 mm) distributed in the wet season and 70% (612 mm) from the wet seasonal rainfall occurred in two months of September and October. Huge proportion by 810 mm loss through evaporation and only 18% of mean annual rainfall contributed to surface runoff.

For the subsurface water resulted from groundwater

Key words: Groundwater, Surface water shortage, Upper Chao Phraya River basin
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recharge and groundwater flow models, approximately 99 mm (equivalent to 10.6 km^3 in water volume) or 9.4% of mean annual rainfall recharged to groundwater storage annually. In fact, 71% of annual groundwater recharge took place from September to October, which was flooding period in the UCP. According to the 15 years simulation (1986-2000), we found the variation of groundwater storages varied from 71.8 to 78.6 km^3 depending on hydrological forcing events. For the sake of sustainable groundwater use, thus approximately 10.6 km^3, which was the same amount as mean annual groundwater recharge and claimed that amount as renewable groundwater storage annually. In our assessment, only renewable groundwater storage allowed for extracting to compensate the surface water shortage. This limitation was set in order to protect the depletion of groundwater. In brief, the basin has approximately 30.6 km^3 as annual total available water (surface runoff + renewable groundwater storage).

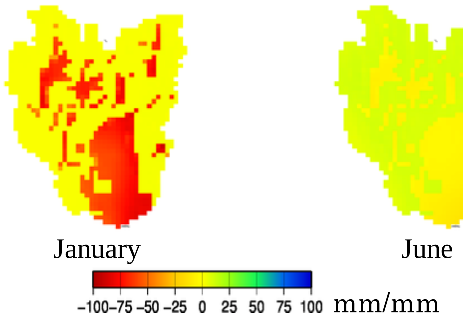

Fig.2 Water Sufficiency Index (WSI) map

Due to majority of water consumption accounted in agricultural sector and rice production was the major crop in the UCP, therefore only the rice water demand was assumed as the basin water demand. The annual rice water demand was approximately 650 mm or 175 (27%) mm and 475 mm (73%) for the wet and dry season, respectively. The high water demand for rice that was not supplied by surface water causes surface water shortages, as evaluated using the WSI. For example, in January and June (**Fig.2)** were surface shortage and no surface water shortage months, respectively.

Fig.3 shows a role of renewable groundwater storage to reduce the surface water shortage. Orange and light blue bar graphs were spatial average surface of water shortage and extracting groundwater, respectively, to fulfill the shortage in monthly basis. Accumulated of both the shortage and renewable groundwater storage also show in the same figure. This assessment was conducted under the CI (cropping intensity) = 1.4 or approximately 56,800 km^2 in annual rice growing area. There is clearly see that after the long run 15 years or 180 months, the accumulated renewable groundwater storage (light blue line) able to compensate the extracted volume (orange line). This suggests that all months in surface water shortage able to use groundwater without groundwater depletion problem.

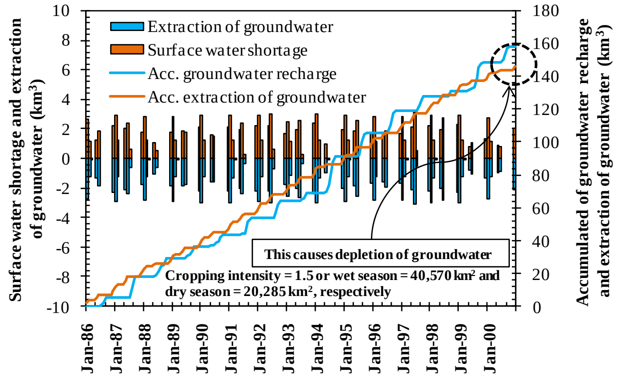

Fig.3 A role of renewable groundwater storage to alleviate surface water shortage

5. CONCLUSIONS

The integrated among three major components (i.e., surface water, groundwater, and water demand) show both the opportunity and limitation for developing groundwater to compensate the surface water shortage. In terms of quantity (total available water and water demand) and area (an area growing with rice), the assessment shows the basin has capacity for making rice production up to 1.4 CI. In addition, the basin often faces with floods and droughts. These problems are expected occurring in the future. Thus, the assumptions using in this integrated assessment has a high potential to be a sustainable way or scheme to alleviate the problems.

Our study not only evaluate water resources and its potential to use groundwater in the wet and dry seasons but illustrate the possible option to reduce a potential of rice damage from floods and droughts.

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