E03

Hydrologic Characteristics and Modeling of the Tonle Sap Sub-basins

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1. Introduction

Tonle Sap is the largest lake in Cambodia and known as the most productive ecosystem in Southeast Asia. It provides fishes and water resources for irrigation in the surrounding cities of the lake. The rapid development inside and outside of the basin as well as climate change has threatened this ecosystem. Over the past few decades, the basin has been affected by anthropogenic activities such as water infrastructure development, deforestation, agricultural expansion, and urbanization. While various kinds of research focused on Tonle Sap Lake and the Mekong mainstream including the study of water quality, groundwater, and sediment transport, there is a very limited study on the Tonle Sap sub-basins. Most studies overlooked the importance of these sub-basins and their characteristics. The main objective of this study was to understand the hydrologic characteristic of the Tonle Sap sub-basins. Two different approaches included data analysis and hydrological modeling were adopted.

2. Study Area

Tonle Sap is located in the central plain of Cambodia. It consists of 11 major tributaries and the Tonle Sap Lake, covering a catchment area of 86,000 km^2 (figure 1). The major parts of the basin are lowland with elevation less than 100 meters. The climate is driven by the southwest monsoon and the northeast monsoon, giving wet season (May-October) and dry season (November-April), respectively. The mean annual rainfall varies from 1,000 to 1,700 mm increasing in an easterly direction. There are 12 hydrological stations and 60 rain gauges available in the study area.

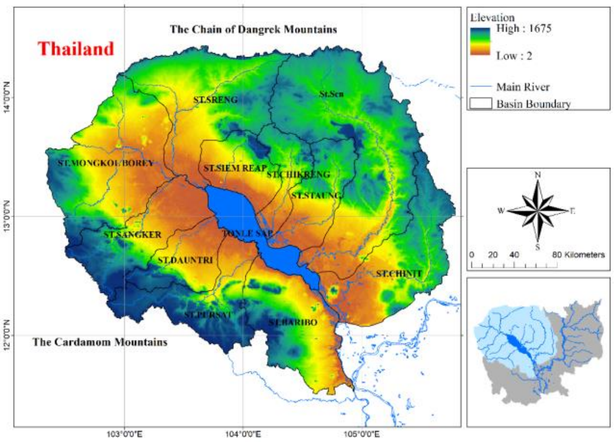

figure 1. Map of the Tonle Sap basin

3. Methodology

Data Analysis

Data has been collected and analyzed to understand the hydrologic characteristics of each sub-basin. Water balance analysis and flashiness index were adopted in the study. The term flashiness reflects the frequency and rapidity of short-term changes in streamflow. Changes in watershed size, topography, soil, land-use, and climatological condition may increase or decrease the flashiness of streamflow.

The Richards-Baker Flashiness Index (R-B Index) is a dimensionless index and its value is independent of the units chosen to represent flow[1].

$$R - B\ \ Index = \frac{\sum_{i=1}^{n} |q_i - q_{i-1}|}{\sum_{i=1}^{n} q_i} \qquad \text{eq. 1}$$

where q_i is the discharge at i time step

Rainfall-Runoff-Inundation (RRI) Model

Hydrologic model RRI was used to simulate the discharge and inundation for each basin from 2000 to 2010. RRI model is a two-dimensional model that can simulate rainfall-runoff and flood inundation at the same time[2].

In this study, the simulation was performed under two different settings. Default parameters with possible inundation were used in setting one. While river depth was deepened in setting two in order to eliminate the inundation effect. Input data included topographic data from HydroSHEDS, meteorological data from JRA-55, land-use from MODIS, and rainfall data from available rain gauges.

4. Results and Discussions

The study analyzed the mean annual runoff and the flashiness of each sub-basin. The results suggested that runoff was controlled by precipitation and proportion of forest land cover, while the flashiness of runoff was influenced by catchment size, proportion of mountainous area, slope steepness and inundation. Based on the mean annual runoff, the Tonle Sap sub-basins were classified into 2 groups. They were high runoff catchments (i.e., mean annual runoff over 400 mm) and lower runoff catchments. The results from the flashiness R-B index showed that two types of runoff pattern (i.e., damping pattern and flashy pattern) were seen in each group of the catchments. Therefore, there were 4 noticeable hydrological characteristics in the Tonle Sap sub-basins, namely high runoff with damping pattern (HRD), high runoff with flashy pattern (HRF), low runoff with damping pattern (LRD) and low runoff with flashy pattern (LRF) (figure 2).

RRI model simulated discharge and inundation simultaneously from 2000-2010 under 2 different settings. The simulation results of RRI model in setting one indicated good agreement between the observed and simulated discharge with Nash-Sutcliffe Efficiency (NSE) up to 0.59 at the Kampong Thmar Station. In setting one, inundation was seen from the simulation. Therefore, it can be said that inundation was one of the components which form the hydrologic characteristics of the Tonle Sap sub-basins. In this study, RRI model did not perform well in some sub-basins due to some uncertainties of input data such as the lack of observed evapotranspiration data, river cross-section, and exclusion of groundwater modeling. On the other hand, the simulated discharge tended to have high variation in low runoff catchments.

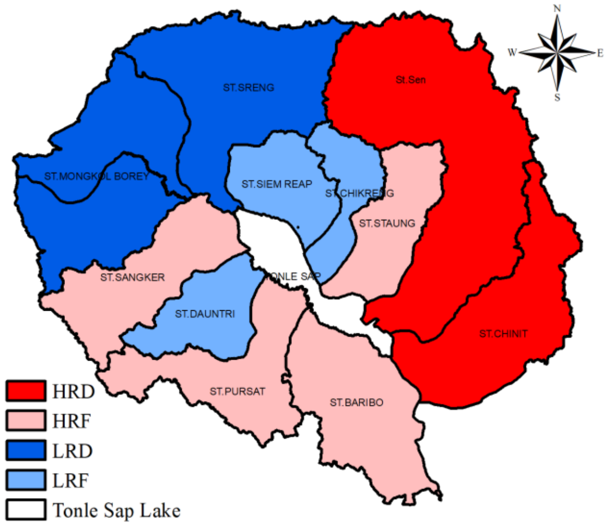

figure 2. Map of hydrologic characteristics in the Tonle Sap sub-basins

5. Conclusion

The Tonle Sap sub-basins were assessed to understand the hydrologic characteristics by performing data analysis and applying a coupling rainfall-runoff and inundation model. As a result, four hydrological characteristics were identified. Moreover, the model simulation showed good agreement between observed and simulated discharge. The results of the simulation could be improved if groundwater modeling is considered and more accurate data of river cross-sections are available.

References

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2) Sayama, T., Ozawa, G., Kawakami, T., Nabesaka, S., & Fukami, K. (2012). Rainfall–runoff–inundation analysis of the 2010 Pakistan flood in the Kabul River basin. *Hydrological Sciences Journal*, 57(2), 298-312.