TB-208L

Discussion on the Suitability of SWAT Model Applied to Hydrological Simulation of Paddy Field in Taiwan

Jyun-Yi Huang[1] and Li-Chi Chiang[1]*

[1]National Taiwan University, Department of Bioenvironmental Systems Engineering No.1, Sec.4, Roosevelt Rd., Taipei 10617, Taiwan
*Corresponding author: lchiang@ntu.edu.tw

In Taiwan, rice is highly demanded as an important role in agriculture. Thus, irrigation water consumption of paddy fields accounts for the majority of agricultural water usage. With the increasingly extreme drought and flood events in recent years, the unstable supply of irrigation water in the rice-growing period shows that the distribution and utilization of irrigation water are very critical. Taoyuan City is the second largest rice production area in North Taiwan, among which the Nankan River Basin is one of the important rice irrigation areas with dense irrigation channel networks for providing stable water sources in this area. Since the establishment of Irrigation Agency of the Council of Agriculture, Executive Yuan, the Taoyuan Management Office and Shihmen Management Office have implemented planned irrigation and water supply for the irrigation areas in Taoyuan. Each workstation of the management offices is in charge of collecting basic statistical information of paddy fields for each irrigation group, from which annual irrigation plan will be drawn to calculate the quantity of water for irrigation and supply. After years of implementation, the results showed that the systematic irrigation water and supply strategy can satisfy the demand of water requirement of different rice crops during each growth stages, achieving the best outcome of agricultural operation for paddy fields. Many domestic studies in Taiwan have used the data on the quantity of irrigation water provided by the management offices to evaluate the benefits of the established management measures for irrigation/drainage of agricultural operation in paddy fields of Nankang River basin. The management offices could then use these study results as reference to continuously improve the management strategy in practice. Although the research on evaluations of agricultural management of paddy field in Taiwan has been significantly advanced, there are only few studies on the suitability of hydrological model simulation for paddy fields. In this study, the Soil and Water Assessment Tool (SWAT) model, a hydrological model, was used to assess the mechanism of paddy simulation and the water balance of paddy fields in the Nankan River Basin, and further examine the feasibility and effectiveness of agricultural management practices and evaluate the suitability of the model when applied to two stages of hydrological stimulation of paddy fields in Taiwan.

The Nankan River Basin includes the main stream of the Nankan River and the upstream basins of the Jiadong and Dakwai River, and the paddy fields planted with two-period rice cultivation from 2009 to 2013 were simulated in this study. The SWAT 2012 model used in this study simulates paddy fields as potholes. In order to match the actual irrigated paddy field area, we set up a designed classification system to reclassify the 2nd land surveying data and used the degree of coverage as the basis for evaluating the effectiveness of land use integration. We collected the statistics provided by the Taoyuan and Shihmen Management Offices to establish the irrigation water quantity during different farming periods of each group as the planned irrigation water depth. Moreover, multiple irrigation and drainage scenarios with different pothole situations were included in the simulations. The hydrological algorithm of SWAT model was primarily the water yield of pothole in terms of water balance point, as the theoretical water yield of pothole could be calculated from the theoretical hydrological formula of the model, and the simulation results of the model were compared to determine if the water balance was reached. Then, the accuracy of the model reflecting the trend of hydrological change in paddy fields could be examined.

The results showed that the area of paddy fields simulated by the model could cover approximately 70% of the actual irrigated area through the land use classification and integration, with good correlation (R^2 = 0.82). In terms of statistical error, it showed that the root mean square error (RMSE) of paddy field area after classification and integration was 25.46 ha, which was significantly lower than before (44.91 ha). By comparing the model simulations with and without pothole setting, the statistics values of NSE, PBIAS and R^2 of the streamflow simulation (without potholes) were -0.02, 50.8%, and 0.80, respectively, while the NSE, PBIAS and R2 with potholes were -0.31 ~ -0.14, 64% ~ 67%, and 0.31 ~ 0.59, respectively. By storage/drainage, the model could simulate the change of water quantity in potholes and streams, and also display the actual irrigation and drainage scenarios in the paddy fields of the study area. However, these results obviously overestimated the peak value on drainage day. It is suggested that the model should be improved in the future. When analyzing the simulation of pothole's water balance, the results of comparing theoretical water yield with the simulated water yield via the model were consistent with the non-pothole circumstance, which confirmed that the water balance theory was valid. However, in the pothole scenario, it was observed that the simulation results of the pothole model did not completely capture the data of water quantity generated by the surface runoff in the pothole for replenishing the river, which led to an underestimation of the theoretical calculation of water yield. In this study, we found that the difference between the analysis results had a similar trend with the amount of rainfall, indicating a necessity to modify the relationship between rainfall and runoff in the pothole model. The results of simulating paddy fields with pothole in the SWAT model showed that the model could clearly illustrate the unique hydrological features of paddy fields, despite the lack of accurate parameter settings and detailed hydrological algorithm for paddy fields. Therefore, when using the SWAT model for paddy irrigation simulation, we should refer to the irrigation and drainage strategy of the actual irrigated area, optimize the parameters of agricultural operations, and plan the input period of paddy fields in terms of agricultural management, as a more reasonable simulation of the hydrology of paddy fields in study. In addition, it is suggested to include data on rainfall, establish the relationship of rainfall and runoff, and examine the correlation between water yield and river discharge, so as to improve the suitability of the model of hydrological simulation of paddy field.

Keywords: SWAT model; Nankan river basin; Paddy field; irrigation