EFFECT OF CROP MANAGEMENT PRACTICES ON WATER BALANCE COMPONENTS IN AN AGRICULTURAL CATCHMENT

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Introduction

Rice is a staple food for nearly half the global population and about 90% of global rice production and consumption happens in Asia (Mohanty, 2013). The projected increase in global population is expected to significantly impact the demand for rice production (Kubo and Purevdorj, 2004). Water management practices associated with rice cultivation can have significant impact on the water balance components in the region (Sudhir-Yadav et al., 2011).

A major portion of the rice production in the state of Kerala, India is concentrated in the Bharathapuzha river basin, a catchment that has been identified to be a significant hotspot for climate change (George and Athira, 2020). Drissia and Anjali (2022) found that the eastern part of the catchment is severely water stressed. They also identified a significant shift in the agricultural practice in the region, from water intensive paddy cultivation towards plantations. The variations in the water balance components and agricultural practices in the catchment have a feedback effect, which needs to be studied to maintain the water and food security in the region (Langarudi et al., 2019).

The Soil & Water Assessment Tool (SWAT) is a widely used physically based hydrological model that is capable of simulating how the water balance and water quality components in a catchment respond to the changes in climate variables and management practices on a continuous time step (Arnold et al., 1998). The model was initially developed to be used in ungauged catchments without calibration, but with the increase in its popularity, the model was improved with more parameters and management operations, so that it could be customised for different locations and use cases (Arnold and Fohrer, 2005). SWAT model provides considerable customisability to simulate various management practices in the catchment. A crop growth submodel with a large database of crops and plants is available in the model to simulate the changes in crop biomass and yield within the catchment. SWAT model provides the possibility to model various crop management strategies at high level of detail, including planting of crops, tillage, nutrient and pesticide applications, irrigation operations, harvesting etc. Thus, the model is capable of simulating the sensitivity of the catchment water balance components to different crop management strategies.

In this work, we have attempted to analyse the sensitivity of water balance components in the Bharathapuzha catchment to changes in crop management practices using the SWAT hydrological model.

Materials and methods

The 30 m SRTM DEM (Farr et al. 2007) was used to delineate the catchment, with outlet points specified at Kumbidi, Mankara, Pudur and Pulamanthole and an inlet point at Ambarampalayam. Sentinel-2 10m Land Use/Land Cover data (Karra et al. 2021), FAO Soil data and 3 slope classes are used to develop the HRUs in the SWAT model. Gridded Precipitation (Pai et al., 2014) and Temperature (Srivastava et al., 2009) data from India Meteorological Department (IMD) were used as the weather inputs to the SWAT Model.

To analyse the sensitivity of the Bharathapuzha catchment to variations in crop management practices, different scenarios of management operations were simulated in the model. The crop database in SWAT model includes rice crop. The area in the catchment where rice paddy is cultivated is marked as RICE in the land use map to simulate rice paddy cultivation in the catchment. With all the inputs to the model remaining the same, the management practices are modified in the model, and the water balance components are compared. Four scenarios are considered in the present study:

S1: No management scenario – In this scenario, no management practices are added in the model. The model uses default management parameters to simulate the crop management and growth.

S2: Pothole scenario – Potholes in the SWAT model are depressional storages, that are hydrologically similar to artificially impounded rice paddies. This scenario simulates the artificial impounding in the rice paddies using the pothole module, without specifying the source of irrigation or management operations for the crop

S3: Irrigation Source – The source of irrigation water to the crops are specified for each subbasin. There are 7 major reservoirs in the model setup for the catchment, and the subbasins in the command area of the reservoirs are specified to have the reservoir as their irrigation source, to simulate canal operations. The rice paddies in the remaining subbasins consider the reach as their source of irrigation water

S4: Irrigation Scheduling – This is the full management scenario, where proper schedule for various crop management operations like planting, tillage, fertiliser and pesticide application, auto irrigation, impounding depth, harvesting, crop rotation etc are added in the model.

Results and Discussions

The SWAT model setups for the four scenarios were run for the same period, 1989 to 2017 and the catchment water balance components simulated in the different scenarios are analysed to understand how different levels of crop management affects the catchment water balance. The basin averaged surface runoff (SurQ), groundwater flow (GwQ), evapotranspiration (ET), deep percolation (Pecol) and water yield (Yield) are extracted from the four SWAT models and compared (Fig 1). It is seen that over the catchment, the surface flow and evapotranspiration is least in the scenario with no management, and highest in the scenario where full management is added. The water yield in the catchment, which is the total sum of water entering the principal channel is highest in the no management scenario, and least in the full management scenario. Significant reduction is observed in the water yield when water is allowed to impound in S2. When ponding of water is allowed using potholes in S2, the evapotranspiration from the catchment is seen to increase. Further increase in the evapotranspiration is seen when irrigation scheduling is specified in S4, indicating more water is diverted to paddy in the scenario. Specifying the source of water for irrigation in S3 does not result in a major change in any of the water balance components. Adding irrigation scheduling leads to significant reduction in the water entering the stream, resulting in a considerable reduction in the water yield in S4.

The SWAT model setup for the Bharathapuzha, with 4 outlets, 1 inlet and 7 reservoirs lead to 103 subbasins, out of which 89 subbasins contain rice land use. When considering the overall water balance of the catchment, subbasins where rice paddies are not present are also included. The water balance of the subbasins with RICE land use were analysed separately to focus on the effect of paddy management, to exclude the influence of subbasins without rice. A two sample Kolmogorov–Smirnov (KS) test was conducted at 5% significance level, to identify if there is any significant difference in the distribution of the subbasin water balance components across different scenarios considered in the study (Table 1). It is seen that the Surface runoff, evapotranspiration and water yield has significant difference between the S1 and S4 scenarios. The water balance components in the no management scenario S1 are seen to be significantly different from the water balance components of the inundated scenario, S2, validating the observation by Sudhir-Yadav et al., (2011), that paddy management has significant impact on water balance.

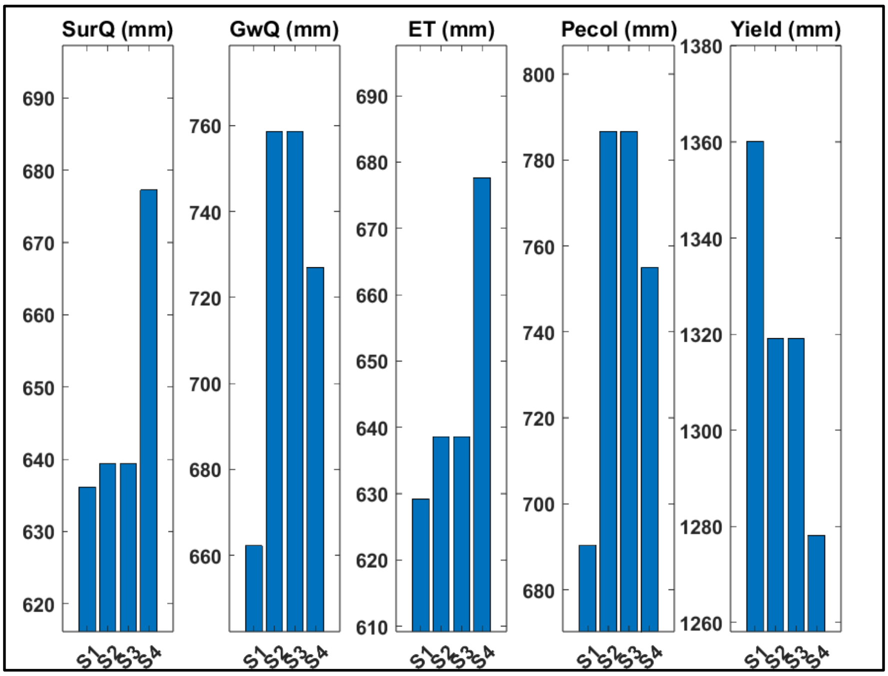

Figure 1: Variation in catchment water balance components across the different SWAT model setups for the Bharathapuzha catchment.

Table 1: p-value for a two sample KS test conducted for subbasin water balance components across scenarios. A p-value less than 0.05 indicate that the null hypothesis of the test, that the two data comes from populations with the same distribution is rejected.

KS Test	S1-S2	S2-S3	S3-S4	S1-S4
SurQ	0.00	1.00	1.00	0.00
GwQ	0.00	1.00	0.28	0.07
ET	0.00	1.00	0.00	0.00
Pecol	0.00	1.00	0.28	0.07
Yield	0.00	1.00	0.14	0.00

Thus, significant variations are observed in the water balance with variations in water management operations in the catchment. No direct pattern is observable in the variation, as complex processes are involved in catchment scale water cycle. Predicting the response of the catchment to crop and water management activities is therefore not straightforward. Modelling exercises like the present work is important in understanding how irrigation and crop management activities can affect the hydrological cycle in the catchment. The present work can be extended out by focusing on the S4 scenario. The number of crop rotations per year, the time of planting, the depth of inundation, the frequency of irrigation, frequency of pesticide application, etc can be modified in the model, to study how each component affects the water balance.

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