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Development of a Distributed Water Stress Model for Karuvannur River Basin

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Abstract

Water stress is a situation where the availability of water is a major constraint on growing water demands. In this study the water stress status of Karuvannur River Basin (KRB) is assessed in a distributed scale. It is computed on the basis of a factor called stress ratio expressed as the ratio of water demand and water availability. Therefore, connecting the quantity of water demand with the amount available can shed light to the status of the water resource and the need for further corrective action. In this study, the water stress analysis is carried out both in basin and sub-basin scale. For that, the Karuvannur river basin is divided into 11 sub-basins and their water availability is assessed based on long term rainfall-runoff simulation using Soil Water Assessment Tool (SWAT). The water availability of the basin is computed by analyzing historical data. By conducting frequency analysis, the total available water is taken as the discharge that equalled or exceeded 95% of the time. The water demand is calculated considering the domestic requirement alone. It is seen that though total available water is more than enough to meet the domestic demand of water at basin scale, water scarcity in certain areas got exposed only when the analysis is done on a sub-basin level and to a monthly time scale. Since water is sufficiently available within this basin, by implementing conservation measures within the basin, such problems can be solved. These results may also assist in planning of future water resources development and reducing the water crisis that may prevail in Karuvannur river basin due to water scarcity.

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1. Introduction

Water resources are finite in space and time. Sustainable water management in a river basin requires knowledge of water availability & water requirements of the basin in the present & future for various purposes. Conventional spatially and temporally lumped estimates of water availability do not help much in the planning & development of water resources in the watershed. Spatial variation due to distributed land use, soil texture, topography, ground water level & hydro meteorological conditions should be accounted for in the water availability estimation. The water availability and demand assessment of a basin is the key aspect in water resources development and management programmes. In this study, ArcGIS interface of SWAT is used. The water availability and demand assessment of Karuvannur river basin is carried out to evaluate the annual and monthly level water stress in both basin and sub-basin level focusing on strategies for water conservation and management. The water resource status of Karuvannur river basin in the year 2020 is forecast based on the water stress ratio.

Water scarcity is the lack of sufficient available water resource to meet the demands of water usage within a region. The overall water stress of the basin can only be obtained in a lumped scale. To get a clear picture of the spatial and temporal variation of water stress in the river basin, the problem should be analysed in a distributed level, both in spatial and temporal scale.

Shimelis B. D. et al.[1] developed a simple model to assess space–time relationships of water resource availability and demand in watersheds. The spatial and temporal distribution of water resources and the corresponding demand were quantified. Results have shown significant variability of water availability and demand in the Mara River Basin (MRB). According to Shimelis B. D. et al. [2], MRB has been maintaining the livelihood of people and pristine biodiversity from the Mau Escarpment in Kenya through Mara-Serengeti protected areas to the flood plains in Tanzania. The MRB presents a delicate balance of water utilization by human settlement and pristine biodiversity. Previous studies reported increasing pressure from population growth, expansion of agriculture and pastoral land, deforestation, urbanization and land degradation in the basin.

Hoffman et al. [3] identified six major water demand sectors Human population, Livestock population, Wildlife population, Lodges and Tent camps, Large-scale Irrigation farming and Large-scale mining and estimated their respective monthly demand volume with a cautionary notice of data insufficiency.

Bingner [4] simulated runoff for ten years for a watershed in northern Mississippi. The SWAT model produced reasonable results in the simulation of runoff on a daily and annual basis from multiple sub basins, with the exception of a wooded sub basin. Results showed a good agreement between observed and simulated runoff and sediment yield during the study period.

In this paper a novel approach is used for the assessment of water availability and demand of Karuvannur river basin on a spatial and temporal scale by dividing it into 11 sub-basins. Out of several water balance models available, SWAT model is selected and applied for this study. For the entire basin and each of the sub basins, the flow duration curves are developed and Q_{95} is found out and the water availability is evaluated in basin and sub-basin level. Then the water demand for domestic purpose is found both in basin and sub-basin level. The final output is the water resource status of each sub basins which clearly shows the water stress areas in the Karuvannur watershed.

2. Study Area and Data Description

The Karuvannur watershed lies between $10^{\circ} 15'$ to $10^{\circ} 40'$ North latitude and $76^{\circ} 00'$ to $76^{\circ} 35'$ East longitude within Thrissur district and shares the Western boundary of Palakkad district of Kerala and thereby covers an area of 1054km^2 . Karuvannur Bridge located at $10^{\circ} 24' 13.84''$ N and $76^{\circ} 12' 58.09''$ E is taken as the outlet for the area considered.

The ArcSWAT graphical user interface is used to manipulate and execute the major functions of SWAT model from the ArcGIS tool. The inputs required for the model are prepared as required by the ArcGIS interface of SWAT.

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