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Modelling of Flow In An Unsaturated Zone of Tank Clustered Catchment Using Geo-Spatial Technology

M. Kavisri*
** Department of Civil Engineering, Sathyabama University*
Chennai-600 119, TamilNadu, India
kavisrimanikannan1985@gmail.com

Abstract

Estimation of aquifer recharge is important for determining water resource availability. The objectives of this study is to estimate the water retention and hydraulic conductivity of unsaturated zone using HYDRUS 1D model. Hydrus-1D is used to determine the groundwater recharge in the Sindapalli sub basin. This sub basin consists of 15 tanks which form cascade of tanks. Map INFO and ARCGIS are used to delineate the study area map. The techniques such as Remote sensing and Geographic information systems (GIS) techniques have been generally used researchers for assessing the ground water recharge of a basin or terrain. In the present study HYDRUS 1D is used effectively to simulate the hydraulic heads and predict water levels based on calibration of past data. By using Hydrus-1D, field data is determined on Jan-2009 because in this period there is no evaporation after irrigation and water is flowing only towards downward direction. The mathematic and conceptual models are established. It is observed that this groundwater flow model can be used for similar studies.

Keyword- Aquifer, Digital Height Model, Geographical Information System

Introduction

Water is a scarce and precious national resource to be planned, developed and conserved as such and on an integrated and environmentally sound basis [5]. Water flow in the vadose zone especially aff ects the transfer rates between the land surface and the groundwater table, which are two key hydrologic boundaries [4]. As a storage medium, it is a zone in which water is immediately available to the biosphere. As a buffer zone between the land surface and aquifers below, the unsaturated zone is a controlling agent in the transmission of contaminants and aquifer-recharging water (John R Nimmo, 2005) [3]. The surface water storage bodies termed as tanks are commonly adopted in the Tamil Nadu state located in the south eastern state of particular India. Remote sensing techniques can produce high spatial coverage of important terms in the water balance for large areas, but at the cost of a rather sparse temporal resolution (Droogers et al., 2002) [2]. Information can be spatially represented through Geographic Information Systems, revealing spatial geometries that are often not apparent when information is provided in tabular form. Remote sensing measurements can be repetitive, allowing monitoring water management practices and evaluating impacts of interventions (W.G.M. Bastiaanssen et al., 1999) [1]. In the sub basin, tank irrigation is followed in the vicinity of tanks and well irrigation is practiced in other areas. Sindapalli sub basin consists of 15 tanks, mainly used for irrigation purposes. Few tanks connected by a common drainage and forms cascade of tanks. The cascade of tanks and individual tanks connected together through the main course, called Sindapalli Uppodai, thereby forming a clustered tank catchment as a whole. In addition to the above system few tanks are isolated tanks and have no direct connection with the other tanks or stream.

Study Area and Methodology

Sindapalli Uppodai sub basin of Vaippar river basin is located in Sivakasi taluk.Its running distance is nearly 26 km. The Location of the basin is Latitude of 9° 25’00”N to 9° 30’00” N and Longitude 77° 45’00”E to 77° 55’00”E. The temperature rise slowly to maximum in summer months up to may and after which it drops slowly.The mean maximum and minimum temperature is 33.95ºC and 23.78ºC respectively. The seventy years average annual rainfall is 799.8 mm from three distinct seasons that is South West monsoon, North East monsoon and transitional period. There are seven rain gauge station spread over the district and maintained by different organization. In this Sindapalli Uppodai is influenced by 3 rain gauge stations namely Vembakottai, Sathur and Sivakasi. The average annual rainfall values are 828.1, 665.3and 694.8 in mm respectively. Paddy is the main crop in both Kharif and Rabi seasons, whereas vegetables are grown in few patches in summer season. On an average, three irrigations are provided in each cropping season (Kharif and Rabi).

Data Requirement and Collection

Since the present study involves hydrological modelling of the tank clustered catchment**,** the data requirements were large. The map of tank clustered catchment system showing longitudinal section, details of irrigation structures, network of tank and topographic map of its command were collected from PWD, Virudhunagar. Soil map (scale 1:50,000) from PWD, Virudhunagar. The climatic data such as daily rainfall and pan evaporation of three meteorological stations were obtained from PWD, Virudhunagar. The leaf area index was measured by canopy analyser. Besides these, soil samples were collected from different locations (for different soil types) and physical properties of soils such as textural classification, hydraulic conductivity and soil moisture characteristic curves were determined experimentally. The monthly groundwater table depth was measured at 53 different locations in the command and processed to prepare the pre and post-monsoon groundwater table maps.

Pre-Processing

To develop a topographic map of the command, topographic data are digitized and interpolated using the topogrid interpolation technique available with GIS, Arc Info. A grid size of 200 x 200 m is used. The optical and CARTOSAT-1 data are used to develop the land use map of the study area shown in Figure 2.1. The command has six distinct land uses, namely, practiced in different parts of Sindapalli Uppodai sub basin depending upon the soil characteristics are pulses, rained crops, coconut, paddy, sugarcane, cotton, and groundnut. Figure 2.2 shows the conventional soil distribution map of the tank cluster catchment as obtained from PWD, Virudhunagar. Three major types of soil covering the whole study area, namely, silt loam, sandy loam, loamy sand are found. Sandy loam is the predominant soil of the command. Ground water level data were collected from 53 wells. The Location of well map shown in Figure 2.3 Historical water table measurements (from 2007 to 2009) show that the water table fluctuates from a minimum water table depth of 0.5 m to a maximum of 13 m with a mean depth of 5 m from ground surface.

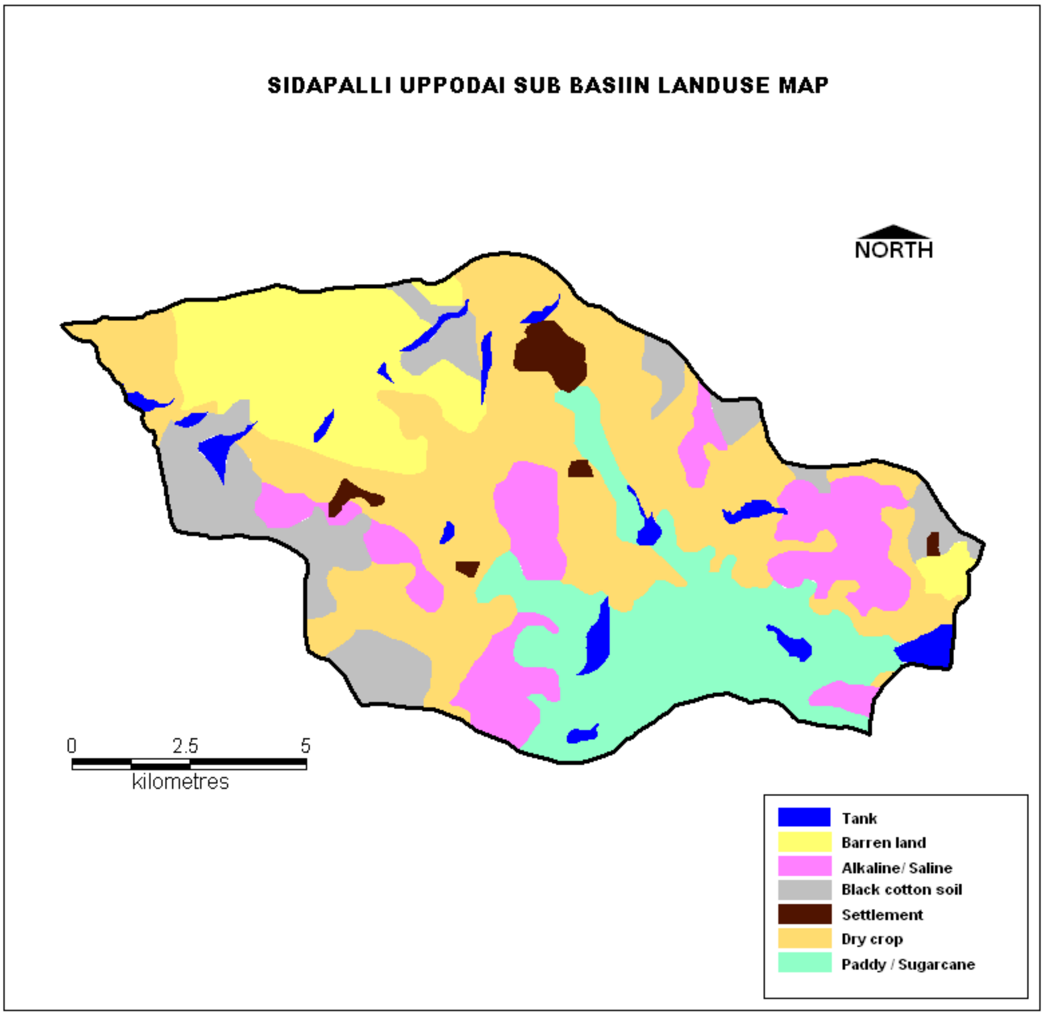

Figure 2.1: Land use/cover map

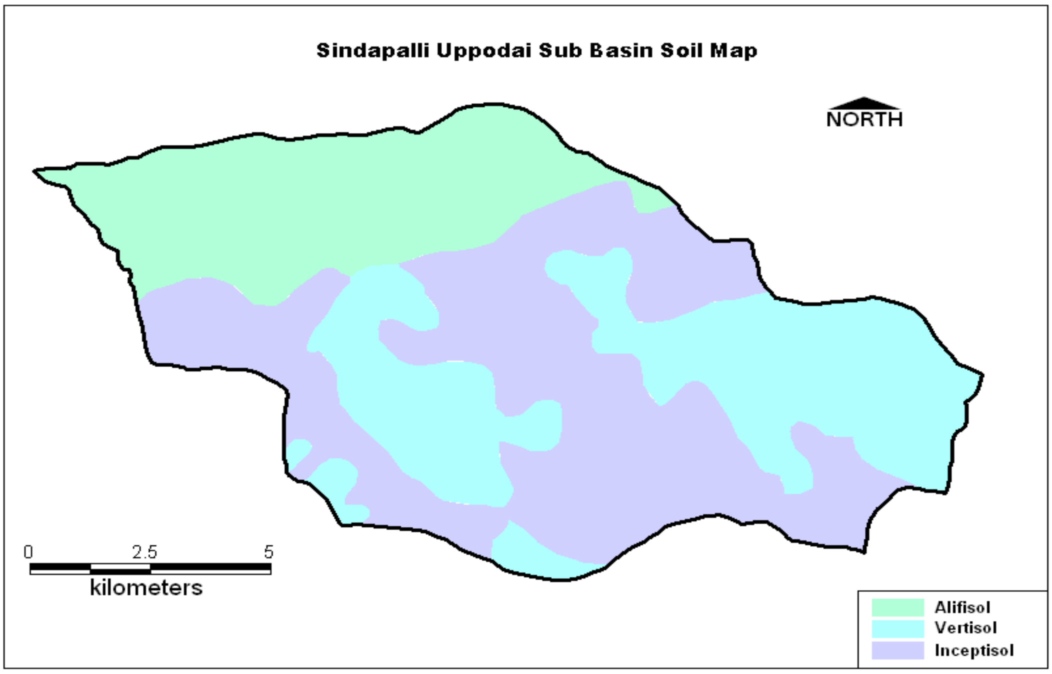

Figure 2.2: Soil distribution map

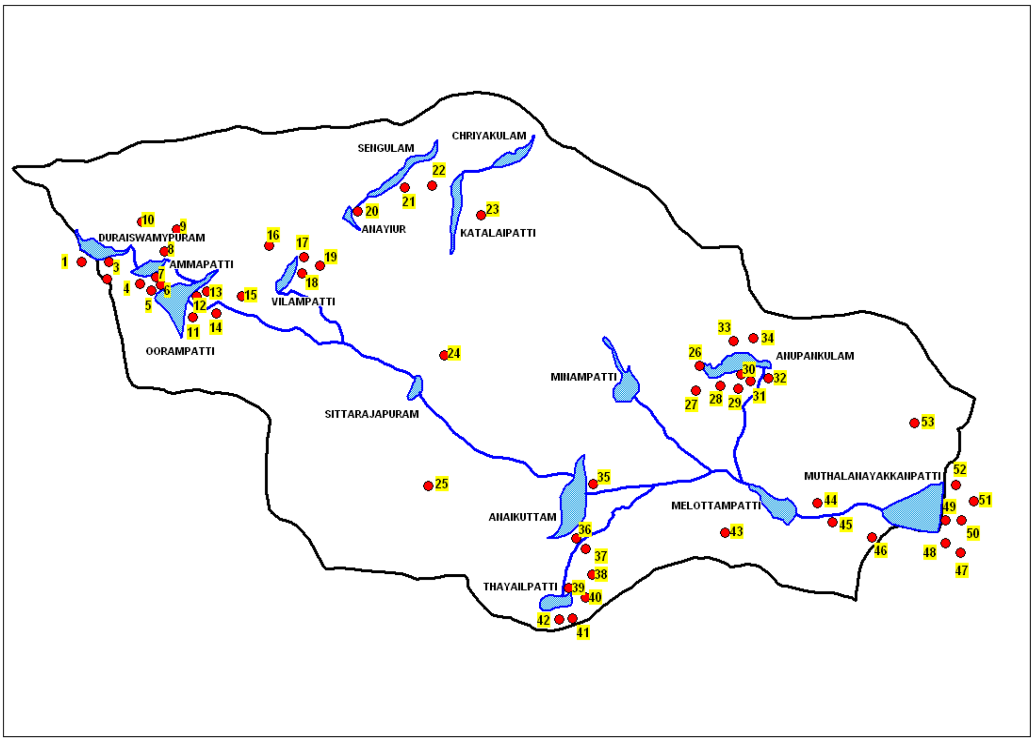

Figure 2.3: Ground Water Well Location Map

Methodology

Figure 2.4 shows the flowchart of modelling of flow in an unsaturated zone of tank cluster catchment framed by using soil hydraulic parameters.

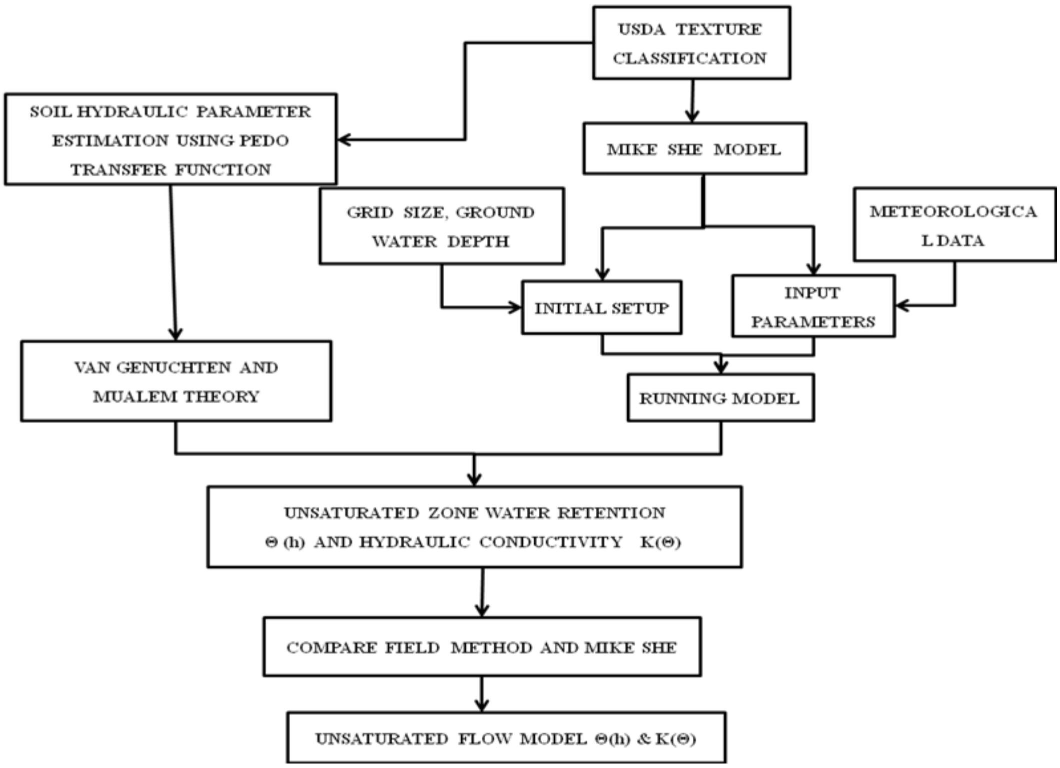

Figure 2.4: Modelling of Flow in an Unsaturated Zone of Tank Cluster Catchment Flow Chart

Soil Texture Analysis

Soil sample were collected at different location at different depth (0-30, 30-60 and 60-90 cm). Soil testing labs use wet methods for determining the relative amounts of the soil separates (sand, silt, and clay particles). Soil/water slurry is placed in a graduated cylinder. At different time intervals the density of water is measured to determine how much soil is remaining in suspension. Since sand particles will fall out of suspension first, followed later by silt particles, the relative amounts of samples textural class are calculated.

Hydrus 1d Model Initial Setup

The spatial grid size for the horizontal direction is and the vertical direction grid size varies with depth. The topmost layer, near the ground surface, thickness is smaller because the evaporation is restricted to that layer of the unsaturated zone. The remaining layer thicknesses are adjusted so that the simulation node corresponds to the experimental node for ease of comparison. Note that the layer thickness increases with the depth. No-flow conditions are specified on the lateral boundaries of the model domain for the unsaturated zone. The lower boundary is a constant water table elevation which plays an important role if shallow. Historical water table measurements (from 2007 to 2009) show that the water table fluctuates from a minimum water table depth of 0.5 m to a maximum of 13 m with a mean depth of 5 m from ground surface. The root water extraction below the water table is unlikely, and hence the constant head bottom boundary condition is a reasonable assumption.

Boundary Conditions

Table 3.1: Soil water conductive parameters through model identification

Depth cm	Lithology	θ_y	θ_s	α	n	K_s
upto40	Loam	0.086	0.322	0.0134	1.574	33.49
40-80	Clay Loam	0.089	0.361	0.0319	1.179	22.33
80-120	Loam	0.091	0.365	0.0329	1.150	34.66
120-260	Clay Loam	0.99	0.376	0.015	1.147	23.33
260-340	Clay	0.103	0.418	0.086	1.153	12.96

Top of the model is open boundary, which receives precipitation, irrigation and evaporation and crop root uptake. The data can be directly endowed with practical observed precipitation and evaporation data, and crop root update module in Hydrus-1D.Bottom is the known pressure boundary, and can be directly endowed with pressure, using observation data in Hydrus-1D software.

Results and Discussion

From the Figure 3.1, is comparing the calculated and observed value of pressure head. The hydraulic parameters are identified by using trial and error method. The value of n changing for various depth.It is very sensitivity to moisture alteration. By using Hydrus-1, field data is determined on Jan-2009 because in this period there is no evaporation after irrigation and water is flowing only towards downward direction. Some of the error observed while running the model. The observed value is greater than the standard value, the model will run again.

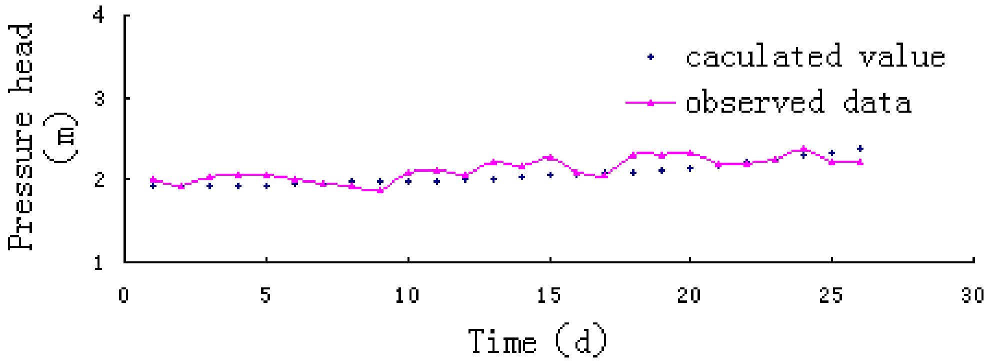

Figure 3.1: Comparing Calculated value and Observed Value

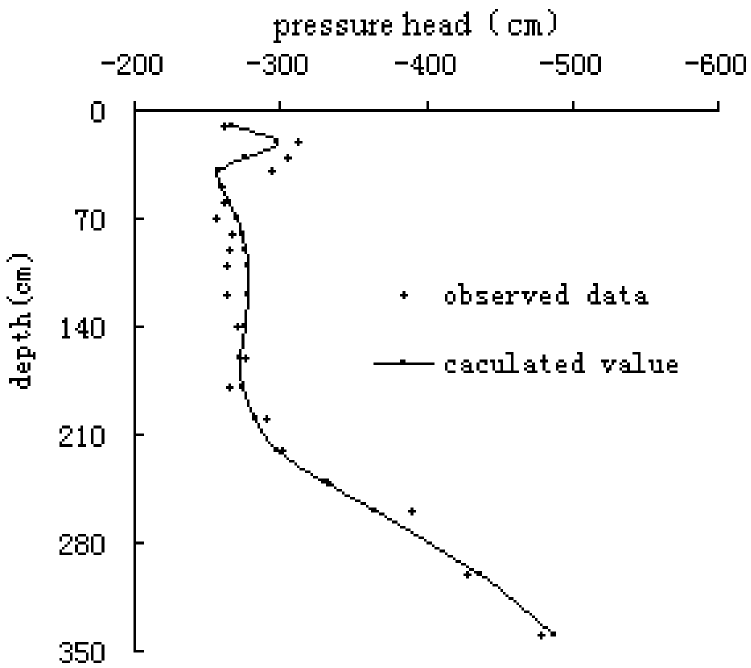

Figure 3.2: Comparing Calculated and Observed Value of Pressure Head

Conclusions

In the present study, the groundwater assessment unit is considered as watershed and groundwater recharge is estimated by considering the different recharge components separately for command and non-command areas. Groundwater modeling involves voluminous data and accuracy of results depends on the data available.GIS is a powerful tool successfully used to create data to estimate groundwater recharge. Map INFO and ARCGIS are used to delineate the study area map. In the present study HYDRUS 1D is used effectively to simulate the hydraulic heads and predict water levels based on calibration of past data. It is observed that this groundwater flow model can be used for similar studies. One can increase the existing study area or by varying the recharge to some extent and can observe the scenario of groundwater system.

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