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HYDROLOGICAL MODELING USING SWAT - THE CASESTUDY OF PUNE DISTRICT, INDIA

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Abstract

When creating a watershed management pro- gramme for resource development and conservation in India,the availability of correct information about surface runoff plays a vital role. With the purpose of studying the effects of land-use decisions and climate change on runoff, water quality, agriculture chemical output, and sediment and nutrient transport, the SWAT conceptual hydrological model was created. It is semi-distributed, long-term, and physically-based. the research being done nowTo evaluate the hydrological data, SWAT has been used.The study's main goal is to create a runoff model employing a geospatial database for calculating runoff and studying the effects of changes in the percentage of land covered by various land-use classes on SWAT outputs at the subbasin level.

Index Terms—Runoff-modeling, Arc-SWAT, Arc-GIS, DEM, Hydrological model.

I. INTRODUCTION

Water is a precious resource that is vital for sustaining life on Earth. It is a dynamic substance that exists in different forms, including liquid, solid, and gas, and is constantly moving through the environment in a continuous cycle. Un- derstanding the behavior of water is crucial for a range of applications, including agriculture, hydrology, ecology, and climate science. By studying water, scientists can better predict and manage water resources, identify potential hazards such as floods and droughts, and develop sustainable solutions to water-related issues. Overall, understanding the behavior of water is critical for the well-being of both humans and the natural environment.

One of the most important functions of water is its role as a solvent. Water is an excellent solvent, meaning that it can dis- solve many different types of substances. This property allows water to transport nutrients and waste products throughout the body. For example, in the human body, water helps to transportnutrients to cells and remove waste products through urine and sweat.

In addition to its role as a solvent, water also plays animportant role in maintaining pH balance in the body. pHis a measure of the acidity or alkalinity of a substance, andit is essential for the proper functioning of many biological processes. Water helps to regulate pH levels in the body, ensuring that they remain within a healthy range.

A. Hydrological Modeling

Hydrological modeling is a field of study that involves the use of mathematical models to understand and predict the behavior of water in the environment. The models used in hydrological modeling are designed to simulate the movementof water through different components of the hydrological cycle, such as precipitation, evaporation, infiltration, runoff, and groundwater flow.

Hydrological models are used to study a wide range of water-related issues, including flood forecasting, drought prediction, water resource management, and climate change impacts on water resources. By simulating the behavior of water in different scenarios, hydrological models can help scientists and policymakers make informed decisions about how to manage and protect this vital resource.

Hydrological modeling is a highly interdisciplinary field that draws on knowledge from a wide range of disciplines, in- cluding hydrology, meteorology, geology, ecology, and math- ematics. The development of hydrological models requires a deep understanding of the physical processes that governthe behavior of water in the environment, as well as the mathematical tools required to simulate these processes.

B. GIS in Hydrological Modeling

GIS (Geographic Information System) is a powerful tool forhydrological modeling as it allows for the efficient analysis and visualization of spatial data related to water resources. Hydrological modeling refers to the process of simulating the behavior of water systems, such as river basins, watersheds, and aquifers.

GIS technology can be used to collect, store, manipulate, and analyze different types of hydrological data, such as topography, land use, soil type, rainfall, evapotranspiration, stream flow, and groundwater recharge. With GIS, this data can be combined and overlaid to create comprehensive hydro- logical models that can be used for a variety of purposes, such as flood mapping, water resource management, and environmental impact assessment.

C. *Soil and Water Assesment Tool (SWAT)*

The Soil and Water Assessment Tool (SWAT) is a hydrolog- ical model developed by the Agricultural Research Service of the United States Department of Agriculture (USDA-ARS) to simulate the impacts of land management practices on water, sediment, and agricultural chemical yields in watersheds. SWAT is a physically-based, semi-distributed model that is capable of simulating the hydrology, erosion, nutrient cycling, and water quality of large and complex watersheds.

The SWAT model divides a watershed into smaller sub- watersheds and further divides each sub-watershed into hydro- logic response units (HRUs) based on the land use, soil type, and slope. The model then simulates the various processes that occur within each HRU, such as rainfall, infiltration, evapotranspiration, soil erosion, nutrient cycling, and stream flow. SWAT uses various databases, such as weather data, soil characteristics, land use and management practices, and hydrologic parameters to simulate these processes.

The model has been widely used for various purposes, including assessing the impacts of land use change on water resources, evaluating the effectiveness of conservation prac- tices, and predicting the impacts of climate change on water resources. It has been applied to watersheds around the world, and there is a large user community that continues to develop and improve the model.

II. LITRATURE REVIEW

Hydrological modeling has become a critical tool for water resources management, particularly in regions facing water scarcity and increasing demand for water. Among the many hydrological models available, the Soil and Water Assessment Tool (SWAT) is widely used due to its capability to simulate the complex processes that occur in the water cycle. This literature review focuses on the use of SWAT in hydrological modeling for the case study of Pune district in India.

Pune district, located in the western part of India, is an important agricultural region that has been experiencing water scarcity due to increasing demand from urbanization and industrialization. The study by Gupta et al. (2019) aimed to use the SWAT model to simulate the hydrological processes in the Indrayani and Bhima river basins of Pune district. The authors used GIS data to set up the model and calibrated it using observed streamflow data. The results showed that the SWAT model could effectively simulate the streamflow in the two river basins, and the calibrated model could be used for future water resources management.

Another study by Kulkarni et al. (2021) focused on the application of SWAT for the hydrological modeling of the Mutha river basin in Pune district. The authors used the SWAT- CUP software for calibration and validation of the model and found that the model performed well in simulating the streamflow. The study also showed that the SWAT model could be used to assess the impact of land use changes on water resources in the region.

In a similar study, Anjum et al. (2020) used the SWAT model for hydrological modeling of the Bhima river basin in Pune district. The authors calibrated the model using observedstreamflow data and assessed the impact of climate change scenarios on water resources in the region. The study showed that the SWAT model could be used to assess the impact of cli-

mate change on water resources and could help in developing adaptation strategies for water resources management.

the literature review suggests that the SWAT model is an effective tool for hydrological modeling in Pune district, India. The studies reviewed show that the model can simulate streamflow accurately and can be used to assess the impactof land use changes and climate change on water resources in the region. The results of these studies can be used for developing water resources management strategies in the region, particularly in the face of increasing demand for water and water scarcity.

III. AREA OF STUDY

The Khadakwasla basin is a catchment area and reservoir located in the western Indian state of Maharashtra. It is situated on the Mutha River, about 21 kilometers southwest of the city of Pune.

The Khadakwasla reservoir is the primary source of water for the city of Pune, as well as the nearby Pimpri-Chinchwad industrial area. The reservoir has a total capacity of 1,950 million cubic meters and a surface area of approximately 20 square kilometers. The reservoir’s dam, which was completed in 1879, is an important historical landmark in the region.

The catchment area of the Khadakwasla basin spans over 2,500 square kilometers and includes the surrounding hills and forests. The catchment area receives rainfall during the monsoon season, which typically lasts from June to September.The rainfall in the catchment area replenishes the reservoir and is critical for maintaining the water supply for Pune and the surrounding areas.

The Khadakwasla basin is not only important for water supply but also for recreational purposes. The reservoir andthe surrounding hills attract many visitors, who enjoy boating, fishing, and hiking in the area.

Overall, the Khadakwasla basin is a significant resource for the region, providing water for millions of people and supporting a range of economic and recreational activities.

IV. DATA USED IN STUDY

In present Study SWAT has been used in the current work to simulate runoff of the Khadakwasla basin watershed. For the creation of runoff, raster datasets like a digital elevation model (DEM), land use, and vector data like rainfall and temperature are needed. For SWAT simulation, every input dataset needs to be projected to Universal Transverse Mercator (UTM).Land- use, Topography, DEM, and meteorological data are SWAT inputs.

A. *Digital Elevation Model (DEM)*

A digital elevation model (DEM) is a digital representation of the topography of a landscape. It is created using remote sensing data, such as satellite imagery, and ground-based measurements to generate a 3D model of the Earth's surface. DEMs are used for a wide range of applications, including flood modelling, land use planning, and environmental man- agement. In the context of the Soil and Water Assessment Tool

Fig. 1. Area of study

(SWAT), DEMs are used to generate hydrological models that simulate the movement of water through a watershed.

SWAT is a hydrological model that is used to predict the impact of land use and management practices on water qualityand quantity in a watershed. It is widely used for watershed management and conservation planning, and can help to identify best management practices (BMPs) that reduce soilerosion, improve water quality, and enhance water availability. To use SWAT, a DEM is required as input data. The DEM provides information on the elevation and slope of the terrain, which is used to calculate the flow of water through thewatershed. The SWAT model divides the watershed into sub-basins, which are further divided into hydrological responseunits (HRUs). Each HRU represents a unique combination of land use, soil type, and slope, and is used to simulate the movement of water and nutrients through the watershed.

The DEM is also used to derive other important parameters,such as the drainage network, flow accumulation, and flow direction. These parameters are used to calculate the volume and timing of water movement through the watershed, which is critical for predicting the impact of land use and management practices on water quality and quantity.

In addition to generating hydrological models, DEMs can also be used to create 3D visualizations of the landscape, which can be used for land use planning, environmental management, and education. DEMs can also be combined with other datasets, such as soil maps and land use maps,to generate more detailed models of the watershed.

a digital elevation model is a critical component of the Soil and Water Assessment Tool (SWAT). It provides important information on the topography and hydrology of a watershed, which is used to simulate the movement of water and nutrients through the landscape. By using DEMs to generate hydrolog- ical models, we can better understand the impact of land use and management practices on water quality and quantity, and develop effective conservation strategies that protect our waterresources.

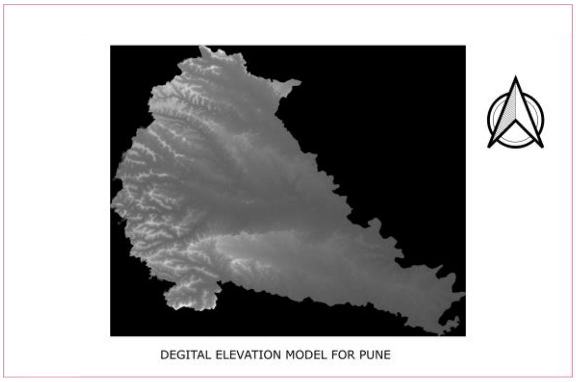

Fig. 2. Digital Elevation model of Pune Region

B. Topography

Topography plays a crucial role in watershed management. It refers to the shape and features of the land surface, including the elevation, slope, and aspect. Understanding the topography of a watershed is essential for designing effective conservationstrategies, predicting the movement of water and sediment, and mitigating the impacts of natural disasters, such as floods and landslides.

One of the key ways that topography influences watershed management is by determining the flow of water through the landscape. The topography of a watershed determines the location of streams and rivers, and the direction and velocity of water movement. This information is critical for identifyingareas of high erosion risk, predicting the impact of land use changes, and designing effective erosion control and sediment management measures.

Topography also affects the distribution of vegetation and soil types within a watershed. Different plant species thrivein different topographic conditions, such as on slopes or in valleys, and can impact the hydrology of a watershed by affecting the amount of water that infiltrates the soil orruns off the surface. Similarly, soil types vary depending on topography, with different soil types having different water holding capacities, nutrient contents, and erosion resistance.

Another way that topography influences watershed man- agement is by affecting the location and intensity of natural disasters. Areas with steep slopes and high elevations are more prone to landslides, while low-lying areas are more susceptibleto flooding. By understanding the topography of a watershed, we can identify areas of high risk and design effective disaster management strategies, such as the installation of retention ponds or the implementation of floodplain zoning. In addition to its practical applications, topography is also important for visualizing and communicating information about watersheds.Topographic maps provide a 3D representation of the land- scape, which can be used to identify areas of high erosion

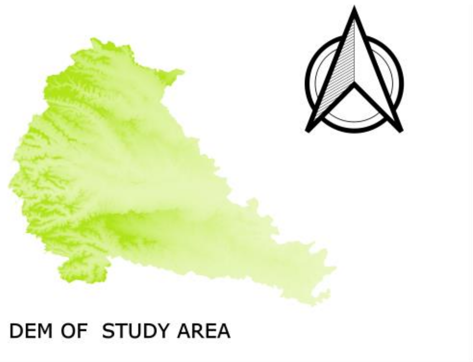

Fig. 3. Topography of area

risk, visualize the movement of water and sediment, and plan land use and conservation strategies.

topography plays a critical role in watershed management. By understanding the topographic characteristics of a water- shed, we can design effective conservation strategies, predict the movement of water and sediment, and mitigate the impacts of natural disasters. Topography also provides a powerful visu- alization tool for communicating information about watersheds and engaging stakeholders in conservation efforts.

C. Soil Map

A soil map is a representation of the distribution and characteristics of different types of soils within a geographical area. It is an important tool for land use planning, crop management, and environmental conservation. Soil maps are typically produced by soil surveyors who use a combination of field observations, laboratory analyses, and remote sensing data to classify soils into different categories based on their physical, chemical, and biological properties.

The classification of soils is based on several factors, including texture, structure, color, depth, drainage, organic matter content, and pH. These factors are used to group soils into categories such as sand, silt, clay, loam, and peat. Soil maps are typically drawn at different scales, ranging from global to local, depending on the intended use and level of detail required.

The primary purpose of a soil map is to provide information on the characteristics of different soils within a given area. This information can be used to make informed decisions regarding land use, crop selection, and environmental man- agement. For example, farmers can use soil maps to determine which crops are best suited for different areas of their farm based on the soil type and its nutrient content. Similarly, urban planners can use soil maps to identify areas that are proneto flooding or erosion and plan appropriate infrastructure and land use strategies.

Soil maps can also be used to identify areas of ecological importance, such as wetlands, forests, and grasslands. These areas may be important for biodiversity conservation, carbon sequestration, or other ecosystem services. By identifying areas with unique soil characteristics, soil maps can help inform conservation and restoration efforts.

In addition to their practical uses, soil maps can also be used for educational and research purposes. Soil maps provide a visual representation of the complex interactions between soil, vegetation, and climate, and can help researchers understand the ecological processes that shape our planet. Soil maps can also be used to track changes in soil properties over time, such as changes in soil organic matter content or pH, which can be used to monitor the effects of land use changes, climate change, or other environmental factors.

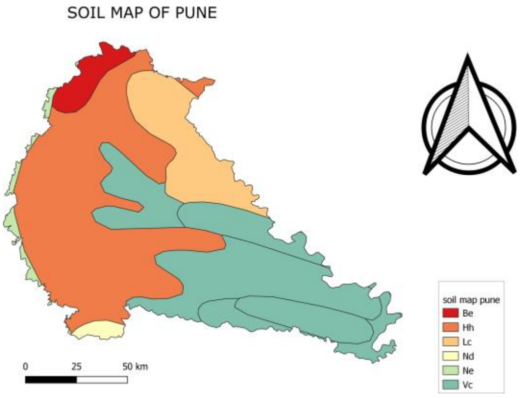

Fig. 4. Soil Map Of Study Area

D. *Watershed Delination*

Watershed delineation is the process of identifying the boundaries of a watershed or catchment area, which encom- passes all the land and water resources that drain into a common point or river system. The process of watershed delineation involves the use of topographic data, such as digital elevation models (DEMs), to identify the flow direction and accumulation of water across a landscape.

There are several methods for watershed delineation, in- cluding automated algorithms and manual delineation using geographic information systems (GIS) software. In general, the process involves identifying the highest point on the landscape and tracing the flow of water downhill from that point, creatinga network of streams and rivers that define the boundaries of the watershed.

The accuracy of watershed delineation depends on the resolution of the topographic data used, the accuracy of the flow direction algorithms, and the quality of the input data usedto calibrate the model. It is important to note that watershed delineation is not a precise science, and the results can vary depending on the method and assumptions used.

Once a watershed has been delineated, it can be used to inform a range of management activities, including water resource planning, soil conservation, and land use planning. Watershed delineation is a critical component of watershed management and plays an important role in ensuring the sustainable use and management of natural resources.

Table for soil Data

Sr No	Legend names	Detail Name
1	Be	Eutric Cambisols
2	Hh	Haplic Phaeozems
3	Lc	Chromic Luvisols
4	Nd	District nitosols
5	Ne-	Eutric Nitosols
6	Vc	Chromic Vertisols

Fig. 5. Soil Data Table

V. METHODOLOGY

A. *Swat Model*

The SWAT model includes the data of hydro logical modeling which is watershed delination , Digital elevationmodel,runoff data of the study area, temperature data.

SWAT subdivides the watershed in to the sub-basins con- nected to the stream network. the HYDRO LOGIC RES PONCE UNIT is made of soil and land use combination of above two.

SWAT uses a combination of hydrological and water quality models to simulate the effects of land use changes, such as deforestation or agricultural development, on the amount and quality of water flowing into a waterbody. The model takes into account a range of factors, including climate, topography, soil type, and vegetation cover, to predict how changes in landuse will affect the water cycle within a watershed.

The Swat model consist of the various process such for creation of HRU (Hydrological responce Unit), Watershed Delination , Digital elevation model. The all the data is createdby using the SWAT (Soil and Water Assesment Tool). This Tool is very useful, it helps to create the Watershed of any area. For the run of SWAT model the following flow chart is Provided which guide to step by step process to smoothly runa SWAT Model.

VI. DISCUSSION

in this resarch of the pune district , we have studied about the pune by using the QGIS (Quantum Geographi- cal Information System) QSWAT (Quantum Soil and wa- ter assesment Tool),In this research we have seen various degital elevation model of pune district.and also we have studied about the soil map of pune district. in the pune district their are 6 various type of soil is observed which are Be(Eutric Cambisoil),Hh(Haplic phaeozems),Lc(Chromic Lu- visoil),Nd(District Nitosoil),Ne-(eutric netosoil) Vc(chromic vertisoils). all above are the type of soil as provided by the gloal soil map.in which two soil type are mostly observed in the study area which are Hh(Haplic phaeozems) Vc(chromic vertisoils).

Fig. 6. SWAT PROCESS MODEL

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