Determination of Runoff and Infiltration of Various Soil Using Basic Hydrology System

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Abstract—**Hydrology is a crucial field that helps us understand and manage water resources. By studying hydrology, we can learn how rainfall and runoff work together, how water flows through a "watershed, and how to predict and manage runoff. The Investigation of runoff and infiltration of various soil using "basic hydrology system" also known as "Rainfall simulator Apparatus". The Experiment was conduct using Basic hydrology system, Coarse sand, red soil, Rice plant and their performance was evaluated based on Runoff and Infiltration. The result shown that infiltration rate is affected by the type of soil that used. The infiltration rate is faster in a coarse sand, become slowly in a red soil. Therefore, the infiltration capacity was affected by the void ratio of the soil and moisture content of the soil.**

Index Terms—**Runoff, Infiltration, Rainfall Simulation, Soil Porosity, Moisture Content, Coarse Sand, Red Soil**

I. INTRODUCTION

Hydrology is a crucial field that helps us understand and manage water resources. By studying hydrology, we can learn how rainfall and runoff interact, how water flows through a watershed, and how to predict and manage runoff.

The word hydrology comes from "hydro," meaning water, and "logy," meaning science. Hydrology is concerned with the circulation of water and its constituents through runoff, streamflow, and the transport of substances dissolved or suspended in flowing water. It primarily focuses on water on or near the land surface; ocean waters fall under the domain of oceanography and marine sciences.

Hydrology is closely related to other natural sciences. Understanding precipitation and evaporation requires knowledge of climatology and meteorology. Similarly, infiltration is linked to soil science, groundwater flow to geology, surface runoff to geomorphology, and streamflow to fluid mechanics. Additionally, studying the transport of dissolved or suspended substances involves concepts from chemistry and physics.

Engineering hydrology focuses on aspects of hydrology that are essential for designing and operating engineering projects related to water control and usage.

II. LITERATURE REVIEW

Abdul Wahid et. al. (2022) [1] compared infiltration rates across three land-use types: secondary forest, agroforestry, and moorland. A survey method was employed, with field data collected at three locations. Infiltration rate measurements were conducted using a double-ring infiltrometer, with five repetitions at each sampling site. The results showed that moorland had the lowest infiltration rate (4.72 cm/h), while agroforestry had the highest (12.87 cm/h). These findings indicate that land use significantly affects soil physical properties and compaction, highlighting the need for sustainable soil and water conservation strategies.

Axel Bronstert et. al. (2022) [4] discussed the challenges of accurately modelling surface runoff in distributed hydrological models. Surface runoff contributes significantly to total runoff, particularly during periods of high rainfall intensity or low soil infiltrability. However, modelling surface runoff remains challenging due to variable rainfall intensity, soil surface infiltrability, preferential flow paths, and spatial variability. This study presents observational data and modelling approaches to address these challenges and improve the accuracy of surface runoff and soil moisture simulations. The results stem from infiltration and infiltration-excess experiments

conducted at three spatial scales. The study introduces a model based on a double-porosity soil, enabling the combined simulation of high infiltration rates and dampened soil moisture distribution after infiltration ceases, as observed in field conditions. Additionally, an approach to modelling the effects of soil surface conditions on actual infiltration capacity is presented. These advancements enhance the plausibility and explanatory power of the model concerning surface runoff generation and soil moisture dynamics.

F. D. Zorrilla et. al. (2021) [6] examined the impact of high rainfall intensity on erosion rates in Indonesia. Land cover conditions play a crucial role in determining water degradation within the hydrological cycle. The shape and type of plant canopy significantly affect soil structure and water absorption. This study aimed to assess the role of plant canopy in influencing rainwater interception and its contribution to the hydrological cycle. Tree species were selected based on their dominance at the study site using the transect method. The dominant trees identified were Sea Sengon (Paraserianthes falcataria), Teak (Tectona grandis), Suren (Toona sinensis), and Durian (Durio zibethinus). The results showed that high rainfall intensity over long periods influenced the amount of rainwater passing through the canopy. The Durian tree had the highest canopy density (0.301), while the Sea Sengon had the lowest (0.240). The Suren tree had a lower canopy escape value compared to the other species, likely due to its round and oval canopy shape. A higher canopy density reduces canopy escape, supporting the hydrological cycle.

Nidhi Kumari et. al. (2020) [9] conducted laboratory experiments to generate rainfall-runoff data using a rainfall simulator (Advanced Hydrological System, AHS). The AHS is embedded with Arm Soft Educational Software S12MKII-306 for hydrological analysis. A hydrograph, which graphically represents the relationship between flow and time resulting from rainfall over a catchment, was generated. The sand tank was set to different slope levels, ranging from a minimum of 1.5% to a maximum of 3.5%, before conducting tests.

Pushpalatha Raji et al. (2020) [10] analysed rainfall-runoff characteristics in a 1.23 ha study area where significant runoff occurred during the rainy season.

Runoff from seven storms was measured using a rectangular notch, and a relationship between discharge and corresponding head at the downstream end was established, yielding an R² value of 0.98. The runoff coefficient for the study area was 0.12. Unit hydrographs were derived from various storm hydrographs, with storms P1 and P7 used to develop a representative unit hydrograph. A rainfall-runoff relationship was established as $Y = 0.2X - 0.85$, with an R² value of 0.98. Additionally, rainfall mass curve analysis provided a relationship between maximum intensity and duration as $Y = 9X - 0.69$, with an R² value of 0.95. The study concluded that rainwater recharge structures constructed based on these analyses significantly enhanced the local water table. The derived rainfall-runoff relationship and representative unit hydrograph could be useful for designing future rainwater harvesting and recharge structures in the study area.

A. Mansida et. al. (2020) [3] examined the relationship between surface runoff and infiltration in a watershed, emphasizing how increased surface runoff leads to flooding and reduced infiltration, thereby decreasing groundwater supply and affecting river flow. The study tested the impact of vegetation on runoff and infiltration using a rainfall simulator with intensities of 12 mm/h and 15 mm/h on two vegetation types—mango and bamboo—in the Moros watershed. The results indicated that changes in land cover increased surface runoff and reduced infiltration. Consequently, land use should be carefully managed to preserve forest functions as natural water retention areas. Unregulated land conversion could lead to unexpected flooding and ecosystem disruption.

Muhammad Adnan et. al. (2019) [8] tested different soil bed formations using advanced hydrology apparatus under severe rainfall conditions. The primary objective was to observe water retention and volume discharge concerning soil combinations and changes in slope levels. Additionally, an advanced decision-making technique incorporating artificial neural networks (ANNs) was employed to predict and analyse the interrelationships among various parameters.

The study found that ST-1 (100% clay) performed well in retaining a large quantity of water (7.28

L/min), making it suitable for irrigation. In contrast, ST-2 (100% sand) demonstrated better performance for structural applications, as sand drains water quickly and retains significantly less water (0.16 L/min). Slope changes also influenced water retention; at a 3% slope level with 100% clay, water resistance was higher compared to sand. Soil type ST-3 exhibited effective water retention even at a 3% slope. These findings can assist engineers and designers in optimizing soil bed formations for construction and irrigation purposes.

G.S. Dwarakish et. al. (2015) [5] provides a detailed review of studies conducted to analyse the hydrological impacts of land use change and evaluate different scenario modelling approaches. Additionally, the paper includes a brief description of basic hydrologic models used to simulate streamflow. This review highlights the importance of model comparison and performance evaluation in modelling studies.

The results indicate that: Modelling the potential impacts of land use and climate change is essential for effective water resource management. analysing variations in hydrological response across catchments with different land use characteristics, climatic conditions, and climate scenarios is crucial. Integrating different models with hydrologic models can be an effective method for forecasting future trends in hydrological response.

Ankit Chakravarti et. al. (2014) [2] conducted a laboratory experiment to generate rainfall-runoff data using a rainfall simulator. To validate the observed data, a model was established to estimate runoff using the Artificial Neural Network (ANN) technique.

Methods: A total of 12 laboratory experiments were conducted using a rainfall simulator to generate runoff hydrographs under various slope and rainfall intensity conditions over the catchment. For validation, the observed runoff hydrograph data were simulated using an ANN model. The ANN model was developed using 1,076 collected data points to compute runoff discharge. To train the ANN model, the dataset was divided into three parts: 70% for training, 15% for testing, and 15% for validation.

The ANN model provided better estimations compared to the observed values, demonstrating its usefulness for water resource planning and management. To assess model performance, the Nash-Sutcliffe Efficiency (NSE) criterion was used, yielding an NSE value greater than 95%.

Jun Huang et. al. (2012) [7] conducted a study using simulated rainfall events to examine the effects of various factors—vegetation cover, rainfall intensity, and slope angle—on soil moisture increase after rainfall and the infiltration recharge coefficient. The study considered soils hosting three different plants: purple medic (PM), spring wheat (SW), and ryegrass (RS), along with bare soil (BL). These soil surfaces were tested at four different slopes (8.8%, 17.6%, 26.8%, and 36.4%) and subjected to five different rainfall intensities (0.5, 0.75, 1.0,1.5and 2.0 mm min^{-1}).

The results were as follows Vegetation cover: Increased wetting front depth (35 cm vs. 25 cm), doubled soil moisture increase (36.7 mm vs. 18.3 mm), and increased the recharge coefficient by 1.5 times. Rainfall intensity: Water storage initially increased, then decreased; no significant difference in soil water content increase. Slope: Water storage initially increased but then decreased sharply; significant differences were observed between gradual and steep slopes. Recharge coefficient: Increased with vegetation cover but decreased with rainfall intensity, slope, and initial soil water content.

III. METHODOLOGY

List of steps used to carry out the investigation are as follow:
1) To collect various material i.e. Coarse sand, red soil and Seeds of Rice
2) Experiment on soil and sand by using Basic hydrology system.
3) To determine Rainfall Runoff.
4) To determine the infiltration rate.

IV. RESULT & DISCUSSION

From the experiment, we can see that the types of soil influence the infiltration rates. The infiltration of water into different types of soils depends on various factors

such as soil texture, porosity, permeability, and compaction.

Coarse sand has larger particle sizes compared to fine sand, which makes it more permeable and allows water to flow through it more easily. This means that the infiltration rate of water in coarse sand will generally be higher than that of fine sand and runoff will be comparatively low. However, if the coarse sand is highly compacted, its porosity and permeability will decrease, which will limit water infiltration.

Red soil is a type of clayey soil that is common in arid and semi-arid regions. It is characterized by its high plasticity, low permeability, and high expansiveness. Due to its low permeability, water infiltration into clayey soil is generally slow. However, once the soil is saturated with water, it can hold water for long periods of time, making it a good source of moisture for plants. our study showed that runoff was comparatively less than infiltration rate.

In summary, the infiltration rate of water into different types of soils varies depending on soil texture, porosity, permeability, and compaction. Coarse sand generally has higher infiltration rates than red soil has lower infiltration rates due to its low permeability.

V. CONCLUSION

1. The infiltration rate is affected by the type of soil that used. The infiltration rate is faster in a coarse sand, become slowly in a red soil and very slowly in a fine sand. Therefore, infiltration capacity was affected by the porosity of the soil and moisture content of the soil.
2. The maximum amount of rainfall runoff occurs in fine sand, while the least amount of runoff occurs in coarse sand depending on slope and flow rate conditions because fine sand contains less voids and can hold less water than coarse sand thus more surface runoff.
3. The slope is used to simulate the natural topography or terrain of an area. The slope represents the angle or gradient at which water flows down the surface, replicate the runoff process in real landscapes.
4. Hydrographs are useful in rainfall-runoff and infiltration analysis because they provide a graphical representation of the flow rate or discharge of water over time in a specific location, typically in response to a rainfall event.

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