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Infiltration Modelling in A Micro-Watershed of Dal Catchment

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Abstract: - Infiltration process is one of the most natural phenomena which plays significant role in engineering problems. Prediction of soil infiltration is a major problem due to its variability and proper selection of the technique used to determine the parameters of the models which depend on the local soil characteristics. The present study was carried out in a micro-watershed of Dal catchment, Srinagar, J&K state, India. The GIS (Geographic Information System) software was used to delineate the boundary of watershed and based on land use several observation points were selected to predict the infiltration rate under different land covers i.e. agriculture field, built-up land, orchard field and to compare validity of different infiltration equations viz. Horton, Philip and Kostiakov. The data on the infiltration of soil from the study area was generated through field measurements using double ring infiltrometer for post monsoon season with existing land covers and least square method of curve fitting were employed for determination of model parameters. In addition to this pedotransfer functions(PTF's) were employed to evaluate the parameters of Philip's infiltration model and compared with those of graphical method. Before conducting the field infiltration tests, the data regarding different soil properties like bulk density, moisture content, soil texture, hydraulic conductivity and organic matter were determined which effects the soil infiltration process and required for estimation of PTF's for the Philip's model. Statistical analysis was carried out between observed and evaluated infiltration rates in order to check the performance of these models.

Key Words: — Micro-Watershed, Dal Catchment, Soil Infiltration.

I. INTRODUCTION

Infiltration is the downward entry of water from surface sources like rainfall or irrigation into the soil. It replenishes the deficiency of soil moisture. The surplus water moves downward into the soil by the gravitational force and builds up the groundwater storage. The process of infiltration in the hydrologic cycle is initiated when precipitation in any form gets absorbed into the soil. The rate at which it progress is called as infiltration rate and measured in mm/hr or cm/hr. Infiltration is followed by percolation for more depth hence cannot be separated from each other, as below the earth surface infiltration rate is measured by the rate of percolation (Ogbe et al., 2011).

Water around the world is distributed in three sections as atmosphere, biosphere and lithosphere. The most important part of fresh water which is easily available is called underground water. It plays very significant role in water resource management which is formed through infiltration process. Water infiltration into soils is a process of major importance to agriculturalists and hydrologists. Accurate estimation of infiltration is a key input in watershed management. It plays very important role in planning and design of various water resources projects including design of hydraulic structures. In addition, soil infiltration characteristics are helpful for runoff estimation and irrigation management. For this reason, a careful study will require to explain infiltration phenomena.

The present study is based on estimation of infiltration characteristics in a micro- watershed of Dal catchment in Kashmir region (J&K). The boundary of the study area was delineated using GIS software. The land-use map of the study area was generated and sites were selected on the basis of different land-use categories. From the selected sites the soil samples were collected for determination of various soil properties which effect the infiltration process and the double ring infiltrometer was used to collect the field infiltration data. To determine appropriate model for measuring infiltration rate three infiltration models (Horton, Kostiakov and Philip) have been used in the study area. In addition to this Philip's model parameter were evaluated using pedotransfer function (F. Haghighi 2010) and compared with those of Philip's graphical method.

II. REVIEW OF LITERATURE

The study of soil-water movement during the infiltration process has attracted many researchers from the diverse disciplines including soil science, hydrology, agriculture, civil engineering and the environmental sciences for couple of years together and resulted in enormous literature on both logical and experimental infiltration investigations.

The review of the findings from various studies related to various aspects of infiltration process in chronological order is presented in this chapter.

Naeth et.al.(1991) applied the Kostiakov's equation to determine its suitability to characterize infiltration on mixed prairie and fescue grassland ecosystems in Alberta, Canada.

Three study sites representing major rangeland ecosystems of southern and central Alberta were selected. Each selected site had long term grazing treatments, ungrazed controls, grass-dominated vegetation that had never been cultivated, and slopes of less than 2%. Infiltration data was collected in late July 1985 and 1986 using double ring infiltrometer and Kostiakov's infiltration model was then applied on the field data. The results indicated that the Kostiakov's equation fit the infiltration data very well. It was found that changes in antecedent soil water and different grazing regimes altered the equation parameters.

Cerda (1997) In Mediterranean Scrubland in Spain to explore the spatial and seasonal changes of infiltration rates. The measurements were taken with cylinder infiltrometer and simulated rainfall on limestone. Data were collected for autumn, winter, spring and summer season in 1990. A sprinkler type rainfall simulator producing an intensity of 55 mm/hr over1 m2area at least for 1 hour was used for simulation of rainfall. The discharge produced from seven experimental plots was measured at 1minute interval. Infiltrometer measurement and simulate drain fall experiments were conducted for each plot in each season. The soil samples were obtained before the experiments at the depths of 0-20 cm, 40-60 cm and from surface for finding the soil moisture content. The study concluded that, measurements with the help of ponding and simulated rainfall found suitable for studying infiltration process. The infiltration rates were found to be very high in a summer while, the surface runoff was observed to be very low.

Robert and Janice.(1999) carried out an experiment on infiltration through disturbed urban soils along with compost. This project studied a common but less understood problem related to land development and soil structure modifications. This resulted into reduction of infiltration at the same time increase in runoff. The scheme was separated into two tasks: i) testing impacted soils infiltration rates, and ii) improving soil with compost to increase infiltration and inhibit runoff. This project assessed an extensive problem, reduced infiltration because of disturbed soils, and provide probable alternative of soil amendment using compost.

Mailhol.(2003) did an experiment to endorse a Horton's predictive form of infiltration for furrow irrigation simulation. A modeling approach was suggested for forecasting the developing process of infiltration under furrow method of irrigation. The Horton's equation permits the usage of predictive approach for the progressing infiltration process using solution of the Water Balance Equation (WBE). In this study the soil parameters, which represents hydraulic properties of soil like saturated hydraulic conductivity (Ks); capillary length (λc) and difference of saturated water content and initial water content ($\Delta\theta$) are studied of all furrow samples before irrigation. The predictive form of Horton infiltration was found to be applicable for furrow irrigation with existing irrigation practices and cropping pattern.

John and Shanley.(2003) assessment of infiltration rate of major soils in Ireland was studied with the purposes to assess the infiltration capacity, spatial and temporal variability of some major soils. Double ring infiltrometer were used for determination of soil infiltration in the study area. The infiltration measurements were carried out in two series. Series 1 was carried out in summer 1988 while series 2 observations were carried out in 1996. The soil parameters i) Texture of soil; ii) moisture content; and iii) bulk density were also studied. The observations for infiltration rate were made in inner cylinder at 1, 5, 10, 15, 30, 45 and 60 minutes' intervals. The duration of test ranged from 4.5 to 7.5 and 6.5 to 8.5 hours for winter and summer respectively. The study showed a pronounced seasonal effect of initial water content of soil on infiltration capacities. In summer, the infiltration capacity was observed 3.5 times greater than that of winter.

Mohan and Sangeeta. (2005) carried out experimentation on estimation of recharge applying infiltration models in a basin at Neyveli (Tamil Nadu). The paper shown that, infiltration models like Green and Ampt., modified Kostiakov and Horton fit the observed field data. The method of least square was used for evaluation of the model parameters, which were used to estimate instantaneous infiltration rates. In this study the comparison of results was done with standard SWAT (Soil and Water Assessment Tool) model which was developed by the USDA (United States Department of Agriculture), and agricultural research service (ARS). The Horton's model showed very good correlation with SWAT model. The Horton model was found to be the best infiltration model for the estimation of recharge in the Neyveli area. Igbadun and Idris. (2007) the performance assessment of infiltration models in a hydrological soil was investigated. The study has been carried out with the objectives: a) to evaluate performance of four infiltration models namely; Kostiakov, modified Kostiakov, Kostiakov- Lewis and Philips (1978) and b) to estimate the models parameters and to compare cumulative infiltration depth estimates by the models with measured values. The research was conducted in the Zango flood plains in Samaru, Zaria in Nigeria. Water infiltration is highly sensitive to soil and irrigation management. Infiltration characteristics are important variables in the design of irrigation system and key input in the development of soil water management and conservation practices. The appropriate infiltration model was selected based on soil physical properties in the area such as bulk density, hydraulic conductivity and soil textured class were studied. The soil samples were taken before the start of infiltration measurement. In the field infiltration

measurements were taken at two points in each strip and cumulative infiltration depth and the cumulative infiltration time were estimated. For determination of model parameters, the average of cumulative infiltration depth and time from two observation points was taken. The estimated model parameters were used to determine cumulative infiltration for each strip. The difference between the field measured and model simulated cumulative infiltration depths were analyzed using the absolute mean difference and coefficient of determination (R2) statistical indices. The study concluded that, Kostiakov and modified Kostiakov's models provide the best fit than other four models. Haghighi et al. (2010) evaluated infiltration models and hydraulic parameters to determine final infiltration rate of soil. The final rate of infiltration was compared with that of hydraulic conductivity. The study was carried out on watershed of Taleghan in Iran at eight points. The soil at two sites was homogeneous, having similar surface conditions with textural deviation from loamy-clay to clay-loam with silt. The soil properties like saturated hydraulic conductivity, total porosity, electrical conductivity, initial moisture content, organic matter and particle size distribution were calculated by taking 48 sampling at depths of 0-15 and then 15- 30cm.Infiltration was measured with double ring infiltrometer. In this study infiltration models like Kostiakov-Lewis, Philips and Horton were evaluated to fit the field infiltration data. The MATLAB software was used to estimate final rate of infiltration and the factor of sorptivity. For performance evaluation was done by root mean squared error (RMSE), the values of R were high in the study area. The results of the study showed that Horton's model estimated infiltration rates were having closer values to that of field measured. Ogbe et al. (2011) on comparison of four infiltration models in sandy soil of Lafia, Nigeria; infiltration measurements were carried by double ring infiltrometer at 9 points on three Strips (100m × 30m). The Soil samples were collected from area adjacent to the marked points from two dissimilar depths, 0 – 15 and 15 – 30 cm. The moisture content was determined by gravimetric method and soil texture by mechanized analysis. In the study models parameters were estimated and the cumulative infiltration depths estimated by the models and field measured were compared. The four models used were Kostiakov, modified Kostiakov, Philips and Horton. The infiltration model parameters were determined to develop a prediction curve.

The comparison of field measured cumulative infiltration and predicted infiltration by different models was carried out by plotting plots. The slope of the best fit line and coefficient of determination (R2) for each model were determined to assess the discrepancies between the model predicted and field measured values. The investigations concluded that Horton's model gave best fit compared to other models.

Selim.(2011) presented the effect of land use on soil infiltration rate in a heavy clay soil in Egypt using double ring infiltrometer. The investigation was carried out on three sites which were located in the canal command of El-Salam, Egypt. The first location was cultivation land, second un-cultivated land and the third location was under fish farming. The bulk density and water content of soil were determined using samples from 20cm of the top soil layer. The infiltration curves for the different sites as well as cumulative infiltration curves obtained by Selim (2011). The gravimetric water content method was used for determination of volumetric water content. For determination of particle size sieve analysis as the hydrometer method was applied. The authors concluded that, the rate of infiltration mainly depends on the initial moisture content in case of deep clayey soil.

Hasan et.al.(2015) developed an infiltration characteristic model by using the modified Kostiakov's model for the Agricultural Engineering demonstration field of Bangladesh Agricultural Research Institute(BARI). The infiltrometer were installed in the study area. The infiltration data was collected and the parameters of the equation $y = at\alpha + b$ for accumulated infiltration were estimated. Modified Kostiakov's model was then applied using the calculated value of parameters. The calibrated model simulations showed good agreement to observed values of accumulated infiltration. It was thus concluded that model will be very helpful for making a good irrigation scheduling and best water management.

Ruth et.al.(2015) evaluated the capability of Philip's infiltration model in simulating water infiltration on the soils of Aba, Abia state. Nigeria. The rate of soil water infiltration was determined by double ring infiltrometer in 5 different locations all located in the selected study area. The lowest and highest cumulative infiltration was determined. Philip's infiltration model was then applied on the field data in order to determine the soils infiltration parameters and also to estimate the model equations for the soils. The estimated parameters were substituted into the model equation in order to simulate specific infiltration equations for each location.

Simulated infiltration rate equations were obtained for five different locations. The filed data showed close relationship with the simulated data, this implied that the model could be used to simulate water infiltration.

III. Result And Discussion

The results of the soil analysis are shown in Table 5&6. The soil analysis results show that soil texture varied from sandy-clay to loamy sand, soil water content, bulk density, hydraulic conductivity, organic matter varies from 19.07 to 29.68 %, 1.215 g/cm3 to 1.568 g/cm3, 0.10 to 4.17inch/hr, 4.58 to

6.72% respectively. Infiltration tests were carried out in micro-watershed of Dal catchment at different selected locations, analysis was carried out and individual infiltration rate curves were developed. The average infiltration rate for different land use varies from 117.86 to 240.84 mm/hr. From the results it was found that the values of parameters of infiltration model varies from soil to soil and soil type. On comparison of observed and estimated infiltration rate graphically and statistically it is found that the computed average values of coefficient of correlation (C.C) values (0.99, 0.95 and 0.98), geometric mean error ratio (1.01, 0.94 and 0.99), NSE (Nash-Sutcliffe efficiency) were (0.99, 0.96 and 0.97) and those of RMSE (Root Mean Square Error) were 19.47, 31.42 and 44.68 mm/hr for Horton's, Philip's and Kostiakov's model respectively. In addition to this, Philip's model parameters based on pedotransfer function were evaluated and compared with those of field data. The average values of statistical parameters i.e. coefficient of correlation, geometric mean error ratio, root mean square error and Nash-Sutcliffe efficiency for Philip's model were (0.96, 0.95 25.55 mm/hr and 0.97) respectively.

IV. Conclusion

Based on the present study, the following specific conclusion can be inferred:

- The constant infiltration rate in the micro-watershed varies from 49mm/hrto 122.01mm/hr for built-up land cover and agriculture field respectively.
- The average infiltration rate was observed as a minimum of 117.84mm/hr for built-up land and maximum of 240.86mm/hr for agriculture field.
- The soil properties like moisture content, hydraulic conductivity, bulk density, porosity and organic content effects the rate of infiltration in the present micro-watershed. It was found that the points at which moisture content was higher, the infiltration rate was slow and it took less time to achieve basic infiltration rate. It also has been observed that organic matter has a significant influence rate on study area.
- The computed average values for statistical parameters like coefficient of correlation (0.99,0.95 and 0.98), geometric mean error ratio (1.01,0.94 and 0.99), Nash-Sutcliffe efficiency (0.99,0.96 and 0.97) and those of root mean square error (19.47,31.42 and 44.68 mm/hr) for Horton's, Philip's and Kostiakov's model respectively indicates that Horton's model can be selected as an appropriate one to predict soil infiltration rate in the study area.
- On the basis of pedotransfer function the average values of statistical parameter like coefficient of correlation, geometric mean error ratio, Nash-Sutcliffe efficiency and root mean square error are (0.96,0.95,0.97 and 25.55) respectively for Philip's two term model. It shows very close value to observed data as compared to graphical method of Philip's model and should be preferred for parameters estimation of Philip's model in the selected area.
- Based on overall results, it can be concluded that the Horton's model is best fit model to predict the infiltration rate for the given study area.

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