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Application of RETC Software Program in Estimation of Soil Hydraulic Parameters in Lokapavani Catchment

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Abstract : Interest in the unsaturated (vadose) zone has dramatically increased in the recent years because of growing evidence and public concern that the quality of subsurface envioronment is being adversely affected by industrial, municipal and agricultural activities. While a large number of laboratory and field methods have been developed over the years to measure the soil hydraulic functions, most methods are relatively costly and difficult to implement. Accurate in situ measurement of the unsaturated hydraulic conductivity has remained especially cumbersome and time consuming. Water retention curve q(h) and hydraulic conductivity function k(q) of the unsaturated soils are the key parameters in any quantitative description of water flow into and through the unsaturated zone. The RETC (RETention Curve) software uses the parametric models of van Genuchten and Brooks-Corey to represent the soil water retention curve and theoretical pore size distribution models of Mualem and Burdine to predict the unsaturated hydraulic conductivity function from observed water retention data. For this study, disturbed and undisturbed soil samples were collected at 17 locations in the Lokapavani catchment under K.R. Sagar command in Mandya district of Karnataka state. From disturbed soil samples, grain size distribution and soil moisture retention data were obtained and from undisturbed soil samples, saturated hydraulic conductivity was measured in the laboratory. Using these data as input to the RETC software, Brooks-Corey parameters (á, n) were determined to derive the retention characteristic and unsaturated hydraulic conductivity. The values of á and n parameters for Brooks-Corey model were found to vary from 0.01936 to 0.22560 and 0.24647 to 0.82137 respectively. These results (as necessary input for unsaturated zone modeling) will be helpful for prediction of soil moisture flow and groundwater recharge in Lokapavani catchment.

Key Words: Soil moisture, Hydraulic conductivity, Retention curve, Brooks-Corey model, RETC.

INTRODUCTION

The water movement in the unsaturated zone, together with its water holding capacity is very important for assessing the water demand of the vegetation, as well as for the recharge of the ground water storage. A fair description of the flow in the unsaturated zone is also crucial for predictions of the movement of pollutants into ground water aquifers.

For analytical studies on soil moisture regime, critical review and accurate assessment of the different controlling factors is necessary. The controlling factors of soil moisture may be classified under two main groups' viz climatic factors and soil factors. Climatic factors include rainfall intensity, storm duration, inter-storm period, temperature of soil surface, relative humidity, radiation, evaporation, evapotranspiration. The soil factors include soil matric potential and water content relationship of soil, saturated hydraulic conductivity and effective porosity. Besides these factors, the information about depth to water table is also required.

Saturated and unsaturated hydraulic conductivity is related to degree of resistance from soil particles when water flows through soil pores. Unsaturated hydraulic conductivity is affected markedly by the volumetric water content of soil. Direct measurement of unsaturated hydraulic conductivity is difficult and it can be indirectly evaluated through the soil moisture characteristic curve.

Computer models are now routinely used in research and management to predict the movement of water and chemicals into and through the unsaturated zone of soils. One alternative to direct measurement of the unsaturated hydraulic conductivity is to use theoretical methods which predict the conductivity from more easily measured soil water retention data. Methods of this type are generally based on the statistical pore size distribution models, a large number of which have appeared in the soil science literature during the past several decades [see Mualem (1986) for a review].

In this study, disturbed and undisturbed soil samples were collected at 17 locations in the Lokapavani catchment under K.R. Sagar command in Mandya district of Karnataka state. From disturbed soil samples, grain size distribution and soil moisture retention data were obtained and from undisturbed soil samples, saturated hydraulic conductivity was measured in the laboratory through ICW Lab Permeameter. Grain size analysis was carried out by mechanical sieve analysis and Master sizer E system. Soil moisture retention data was obtained from Pressure Plate apparatus in the laboratory which was used to derive Brooks-Corey parameters using the RETC software.

RETC SOFTWARE

RETC (RETention Curve) computer program is used for describing the hydraulic properties of unsaturated soils. The program may be used to fit several analytical models to observed water retention and/or unsaturated hydraulic conductivity or soil water diffusivity data. RETC can be applied to four broad classes of problems as mentioned below.

A. *The direct (or forward problem)*: RETC may be used to calculate the unsaturated hydraulic functions if the model parameter vector b = (q_r , q_s , á, n, m, I, K_s) is specified by the user.

B. *Predicting K(h) from observed q(h) data*: This option permits one to fit the unknown retention parameters (with or without restricted m, n values) to observed soil water retention data.

C. *Predicting q(h) from observed K(h) data*: In some instances, experimental conductivity data may be available but no observed retention data. RETC may then be used to fit the unknown hydraulic coefficients to observed conductivity data.

D. *Simultaneous fit of q(h) and K(h) data*: This option results in a simultaneous fit of the model parameters to observed water retention and hydraulic conductivity data.

In the present study, Class B (as mentioned above) has been used. The RETC program uses the approach of either Burdine (1953) or Mualem (1976) for prediction of unsaturated hydraulic conductivity. These soil water retention and hydraulic conductivity functions are given below.

Brooks-Corey Model

One of the most popular function for describing q(h) has been the equation of Brooks and Corey (1964), further referred to as the BC- equation, is given as

$$S_e = \frac{\theta-\theta_r}{\theta_s-\theta_r} = \begin{matrix} (\alpha h)^{-n} & (\alpha h > 1) \\ 1 & (\alpha h \leq 1) \end{matrix} \qquad (1)$$

Mualem's Model

The model of Mualem (1976) for predicting the unsaturated hydraulic conductivity, K can be written as

$$K(S_e) = K_s S_e^l \left[\frac{f(S_e)}{f(1)}\right]^2$$

with

$$f(S_e) = \int_0^{S_e} \frac{1}{h(x)} dx \qquad (2)$$

Burdine's Model

The model of Burdine (1953) can be written in a general form as follows

$$K(S_e) = K_s S_e^l \frac{g(S_e)}{g(1)} \quad (3)$$

in which

$$g(s_e) = \int_0^{S_e} \frac{1}{[h(x)]^2} dx$$

STUDY AREA

The study area is in the Pandavapura taluk of Mandya district in Karnataka state, as shown in Figure 1 (Singh et al., 2001). It lies between the latitudes $12^0 28'$ N to $12^0 32'$N and longitudes 76^0 40' E to $76^0 45'$E. The study area falls in Krishna Raja Sagar command, which consists of two contour canals, Vishveshwaraiah Canal (V.C.) and Chikkadeveraya Sagar Canal (C.D.S.). Total command area in the study area is 68 sq.km, in which 20.7 sq.km. comes under CDS canal command and 47.3 sq.km. under VC canal command. The lengths of the CDS and VC canals are 31 km and 42.2 km respectively. The discharge of the CDS canal at Darassaguppe village is 747.06 cusecs and that of VC is 2253 cusecs near Harohalli village. In the west and north, VC canal limits the boundary of the study area and in the east, the extent of the study area ends with the 24-VC distributary. In the south, Bangalore-Mysore highway limits the boundary of the study area. The main crops grown in the area are sugarcane and paddy. Crops are sown in rotation basis.

METHODOLOGY

Location of soil sampling sites is indicated in Figure 2. Total seventeen sites (P1 to P16, NP1) were selected in such a way that different types of soils found in the area are covered and the sites are easily approachable and well distributed all over the study area. Saturated hydraulic conductivity was measured by ICW Lab Permeameter from undisturbed soil samples. The disturbed soil samples were used to measure grain size distribution and soil moisture retention characteristics in the laboratory.

Measurement of Particle Size Distribution

To determine grain size distribution, oven dried soil sample weighing 500 gm is washed through the sieve number 200 (i.e.75 micron). The portion of soil particles retained on sieve (coarse grain, +75 micron) is subjected to mechanical sieve analysis and the particle passing through the sieve (fine grain, -75 micron) is subjected to Master Sizer analysis. In sieve analysis, the portion retained on each sieve is collected and weighted. The percentage of soil sample retained on each sieve on the basis of total weight of soil sample and the percentage of weight passing through each sieve is calculated (Bowles, 1986). The fraction of the soil, which is finer than 75 micron size, is used for Master Sizer E system analysis.

The results of coarse grain analysis and fine grain analysis were blended. The textural analysis was carried out based on the percentage of sand, silt and clay for each soil sample.

Measurement of Saturated Hydraulic Conductivity

The saturated hydraulic conductivity of undisturbed soil samples was determined using ICW Lab Permeameter in the laboratory with constant head and falling head methods depending upon the type of soil. Both methods use basic Darcy's law.

Measurement of Soil Moisture Characteristics

Soil Moisture Characteristics, also called the retention curves, are the plots of moisture content versus suction head. It shows the amount of moisture, a given soil holds, at various tensions. The moisture characteristic curve of a soil sample can generally be determined by equilibrating a soil

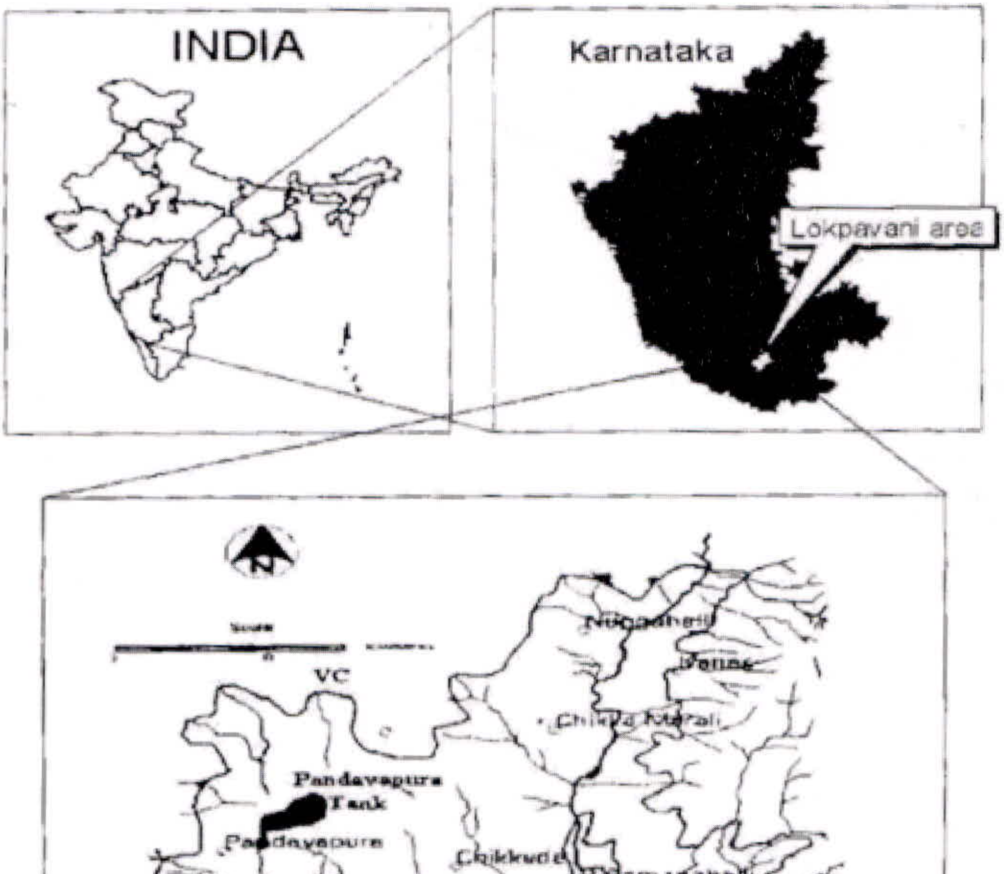

Fig. 1. Location Map of Study Area

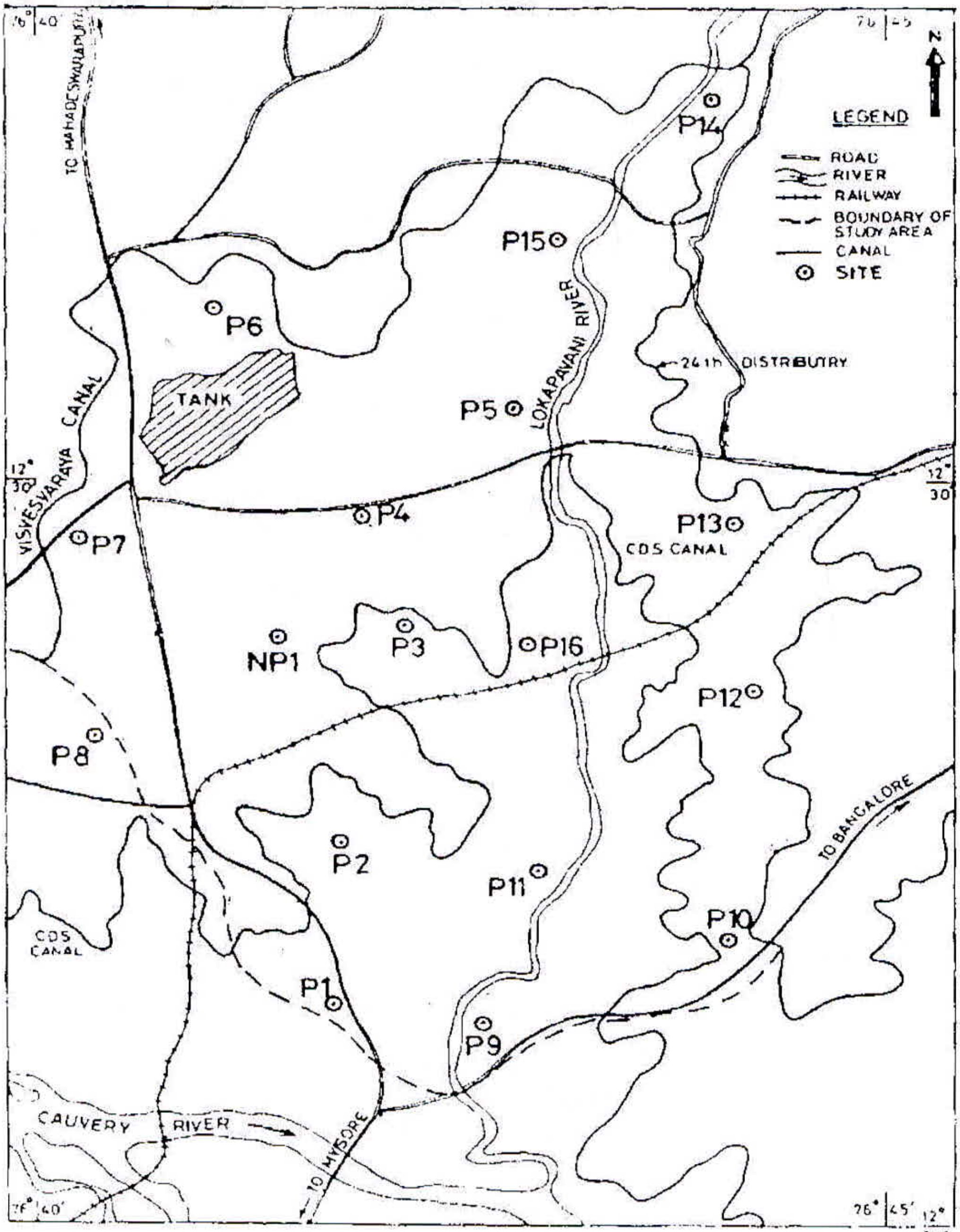

Fig. 2. Location of Soil Sampling Sites

sample at a succession of known tension value and each time determining the amount of moisture. The graph is plotted between the tension and corresponding soil moisture value to obtain the soil moisture characteristic curve. Different soil type gives different characteristic curves.

Pressure plate apparatus is a standard method for obtaining the soil moisture characteristic curves. Soil samples were prepared after drying, light hammering and passing through 2.00 mm sieve. The soil passing through 2.00 mm sieve were used for determining the soil moisture characteristic by applying 0.10, 0.33, 1.00, 3.00, 5.00, 10.00, 15.00 bars pressure respectively. A soil water matrix potential of about -1/3 bars has been found to correspond to the field capacity, where as a soil water matrix potential of about -15 bars has been found to correspond to wilting point (Henry, 1984). The water present in the soil between field capacity and wilting point is known as available water. It is generally considered to be matrix potential in the range of -0.3 to -15.0 bars.

USE OF RETC SOFTWARE

Using the observed soil moisture retention data and saturated hydraulic conductivity, the parameters of Brooks and Corey (á and n) were derived by RETC software program for all the 17 locations of the study area.

RESULTS AND DISCUSSION

The disturbed soil samples collected from 17 locations in the study area were analyzed in the laboratory for grain size distribution, soil moisture retention characteristics and saturated hydraulic conductivity. Table 1 shows saturated hydraulic conductivity and textural classification of soil samples at different locations in the study area.

Table 2 shows the soil moisture retention data obtained through pressure plate apparatus in the laboratory. Using the soil moisture retention data and saturated hydraulic conductivity for each soil sample (17 nos.), the parameters of Brooks-Corey model were obtained by

From Table 3, it is observed that the values of á and n (Brooks-Corey parameters) were found to vary from 0.01936 to 0.2256 and 0.24647 to 0.82137 respectively. The coefficient of determination R^2 varies from 0.9418 to 0.9994 for BC model. Figure 3 shows the relation between r and h using RETC software at location P3. Figure 4 shows the relation between K and r using RETC software at location P3.

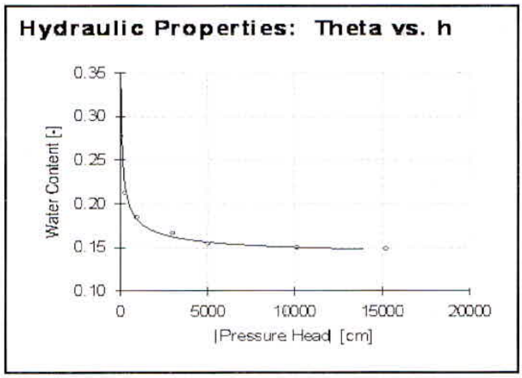

Fig. 3. Relation between r and h at Site P 3 using RETC Software

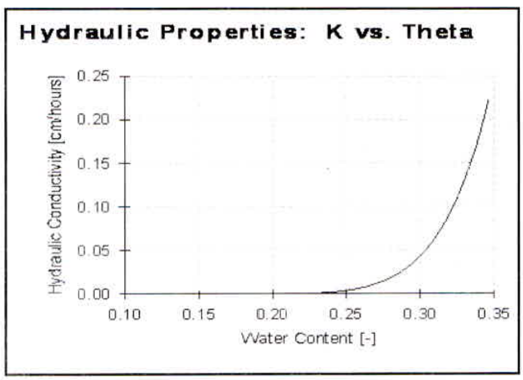

Fig. 4. Relation between K and r at Site P3 using RETC Software

Table 1. Textural Classification and Hydraulic Conductivity of Soil

S.N.	Site	Depth (cm)	K_s (m/day)	Gravel %	Sand %	Silt %	Clay %	Soil Texture	Mean Size (mm)	Effective Size (mm)
1.	P 1	30	0.40	11.5	58.4	27.8	2.3	Sandy loam	0.495	0.006
2.	P 2	35	0.40	29.1	45.0	22.6	3.3	Loamy sand	0.785	0.004
3.	P 3	40	0.05	8.3	34.7	49.3	7.7	Sandy loam	0.049	0.002
4.	P 4	35	0.40	0.2	47.7	46.0	6.1	Sandy loam	0.070	0.003
5.	P 5	40	0.40	5.8	65.3	26.4	2.5	Sandy loam	0.354	0.004
6.	P 6	30	0.03	4.0	64.9	27.4	3.7	Sandy loam	0.201	0.004
7.	P 7	70	0.02	9.0	78.1	11.4	1.5	Sand	0.428	0.020
8.	P 8	15	0.49	5.2	83.3	9.9	1.6	Sand	0.578	0.031
9.	P 9	50	1.01	22.0	54.9	20.0	3.1	Loamy sand	0.882	0.005
10.	P10	35	0.02	0.7	52.9	36.9	9.5	Sandy loam	0.114	0.002
11.	P 11	40	0.40	7.8	65.0	24.1	3.1	Sandy loam	0.342	0.006
12.	P 12	25	0.01	0.5	55.8	36.1	7.6	Sandy loam	0.143	0.003
13.	P 13	30	0.03	38.9	38.9	18.7	3.5	Loamy sand	0.884	0.005
14.	P 14	40	0.40	1.5	52.3	38.7	7.5	Sandy loam	0.116	0.002
15.	P 15	30	0.40	13.3	55.9	25.5	5.3	Sandy loam	0.334	0.004
16.	P 16	60	0.11	0.4	48.9	39.7	11.0	Loam	0.063	0.002
17.	NP 1	50	0.05	2.9	64.7	29.6	2.8	Sandy loam	0.178	0.005

Table 2. Soil Moisture Retention Data

S.N.	Site	Pressure (1st row in bar, 2nd row in centimeter)							Available moisture content %
		0.1	0.33	1	3	5	10	15	
		101.9	336.5	1019.8	3059.4	5099	10198	15297	
1	P1	14.99	10.69	8.29	7.10	6.61	6.00	5.50	5.19
2	P2	23.08	18.20	14.87	13.42	12.50	11.65	11.00	7.20
3	P3	27.67	21.10	18.32	16.55	15.34	14.90	14.75	6.35
4	P4	30.00	19.04	15.61	13.17	12.40	11.77	11.00	8.04
5	P5	21.44	15.20	12.65	10.50	9.81	9.20	9.00	6.20
6	P6	22.47	12.89	10.18	9.10	8.20	7.85	7.70	5.19
7	P7	15.98	11.16	9.19	7.16	7.18	6.64	6.60	4.52
8	P8	13.81	11.05	9.39	7.80	6.20	5.79	5.60	5.45
9	P9	19.68	11.29	8.25	6.47	5.65	5.51	5.30	5.99
10	P10	22.20	15.37	13.60	11.28	9.81	9.24	9.10	6.27
11	P11	24.99	19.88	16.94	13.81	12.25	11.83	11.30	8.58
12	P12	21.21	14.06	12.35	9.64	9.30	8.54	8.03	6.03
13	P13	17.77	10.83	9.21	6.80	6.45	6.31	6.00	4.83
14	P14	26.87	20.02	18.63	14.93	13.89	13.27	12.80	7.22
15	P15	22.17	14.38	11.80	10.50	9.40	8.70	8.21	6.17
16	P16	24.53	17.03	14.41	11.29	10.75	10.45	9.90	7.13
17	NP1	29.30	19.93	15.46	12.07	11.15	10.08	9.85	10.08

Table 3. Brooks-Corey Parameters for Lokapavani Catchment

S.N.	Location	θ_r	θ_s	α	n	R^2
1	P1	0.04485	0.20197	0.02566	0.42584	0.9980
2	P2	0.08694	0.28914	0.02632	0.34672	0.9970
3	P3	0.13498	0.34622	0.22560	0.48579	0.9970
4	P4	0.10732	0.43200	0.22380	0.64169	0.9960
5	P5	0.07711	0.28204	0.02322	0.47102	0.9980
6	P6	0.07697	0.33403	0.01936	0.82137	0.9968
7	P7	0.05703	0.2103	0.02155	0.5101	0.9963
8	P8	0.05600	0.18082	0.02188	0.46593	0.9418
9	P9	0.04792	0.28911	0.02033	0.66604	0.9988
10	P10	0.07362	0.30155	0.02799	0.42322	0.9880
11	P11	0.05380	0.30698	0.02760	0.24647	0.9958
12	P12	0.07178	0.28599	0.02348	0.49955	0.9898
13	P13	0.05521	0.24900	0.02089	0.61774	0.9915
14	P14	0.09672	0.32922	0.02502	0.33736	0.9838
15	P15	0.07894	0.32308	0.02497	0.58519	0.9927
16	P16	0.08572	0.32476	0.02271	0.48745	0.9952
17	NP1	0.07523	0.39628	0.02315	0.45467	0.9994

CONCLUSION

Using the RETC software, parameters of Brooks-Corey model (á and n) were determined for different locations in Lokapavani catchment in order to derive the soil moisture retention data and unsaturated hydraulic conductivity. The values of á and n (Brooks-Corey parameters) were found to vary from 0.01936 to 0.2256; 0.24647 to 0.82137 respectively. These results (as necessary input for unsaturated zone modeling) will be helpful for prediction of soil moisture flow and groundwater recharge in the Lokapavani catchment.

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The following symbols are used in this paper.

- q = Soil moisture content
- á = Empirical parameter in BC model (L^{-1})
- n = Pore size distribution parameter in BC model
- q_r = Residual water content
- q_s = Saturated water content
- h = Suction head (L)
- I = Pore-connectivity parameter
- K = Unsaturated hydraulic conductivity (LT^{-1})
- Ks = Saturated hydraulic conductivity at saturation (LT^{-1});
- S_e = Effective degree of saturation