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Pedo-transfer Functions for Predication of Soil Hydraulic properties in Kamblihal SWS Northern Dry Zone of Karnataka State

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ABSTRACT: Prediction of important soil quality indicators from easily measurable soil properties by developing pedotransfer functions for different types of soils is very much essential to take up corrective measures quickly to improve soil quality for sustainable higher productivity. A detailed study was conducted to evaluate land resources of Kamblihal sub-watershed located in semi- arid region of North eastern Dry Zone of Karnataka (Zone-2), India. Cadastral parcels of Kamblihal sub-watershed overlaid on IRS P6 LISS-IV merged Cartosat–1 satellite imagery, which was used as base map for interpreting soil units. Soil slope and parent material inputs were collected from Survey of India toposheets and Geological Survey of India lithological maps, respectively. Soil profiles and morphological studies were made to classify entire sub-watershed (covering 1023.74 ha) into seven soil series and these soil series, further classified into 9 soil phase/management units. The multilinear regression analysis indicated that the soil separates (sand, silt and clay) have significantly contributed in developing PTFs for FC and IR. The mean values of solum weighted average of sand, silt, clay, FC and IR was 42.26, 12.19, 44.01, 28 and 0.18 per cent, respectively. The soil attributes were subjected to logarithmic or square root transformation to mitigate high platykurtic keeping kurtosis value 3 as standard to be arrived. The PTFs for prediction of FC using soil separates (sand, silt and clay) as independent variable were significant at 5% for silt and 1% for clay with R^2=0.952. The PTFs for prediction of IR using soil separates (sand, silt and clay) as independent variable were significant 1% for clay with R^2=0.668.

Keywords: Field capacity, Infiltration rate, soil quality indicators and Pedo-transfer functions.

INTRODUCTION

The hydraulic qualities of the soil determine the type and quantity of water that is accessible for plant growth. Most crops begin to wilt when the water content drops below 15 bar (1500 kPa) (Rijsberman 2006; Schewe *et al*., 2013). The most crucial soil hydraulic parameters that determine the application and frequency of irrigation are soil moisture constants such as field capacity (FC), wilting point (WP), and infiltration rate (IR) (Santra *et al.*, 2018). Parameters governing the retention and movement of water and chemicals in soils are notorious for the difficulties and high labor costs involved in measuring them. Often, there is a need to estimating FC, WP and IR parameters from other, more readily available data such as soil texture, Soil depth, pH, EC, available N, P_2O_5 and K_2O (Patil and Chaturvedi 2012).

Knowledge of soil hydraulic properties on temporal and spatial scales is crucial for managing natural resources as well as planning land use, simulating crop and environmental conditions, and monitoring changes in soil properties brought on by dynamic land-use changes in the future. Given the trends in diminishing factor productivity, this fact acquires increased importance for agricultural land-use planning. However, it can be difficult, expensive, time consuming and labour intensive to directly assess some of the physical, chemical and hydrological characteristics of soils, both in the field and in the lab (McBratney *et al.*, 2018). Pedotransfer functions allow the use of few easily measured soil variables to estimate the correlated variables (Obiero *et al.*, 2013). Best selection of the number of explanatory variables is important in developing the powerful pedotransfer function. The size of the data set overlies the number of explanatory variables in evaluating the power of the pedotransfer functions (Mtama *et al*., 2018).

MATRIAL AND METHODS

Study area: Kamblihal sub watersheds (SWS) is located in the Northern dry zone of Karnataka State, India (Fig. 1) lies between latitudes and longitudes of 16^0 3' N – 76^0 16' E and 16^0 2' N – 76^0 18' E, covering an area of about 1023.74 ha. The mean monthly minimum and mean monthly maximum temperatures of 19.08°C and 31.97°C, respectively with a total annual rainfall of 520mm (Fig. 2). The Potential Evapotranspiration (PET) is 141 mm and varies from a low of 81 mm in December to 199 mm in the month of May. The PET is always higher than precipitation in all the months except during the end of June to end of September. Generally, Length of Growing Period (LGP) is from June 1st week to 4th week of October (120-150 days). The major area comes under rainfed cultivation with rainfed crops like sorghum, pigeon pea and pearl millet.

Experimental procedure: A detailed land resource inventory was carried out at a 1:8000 scale, using Indian Remote Sensing Satellite-P6 (IRS P6) Cartosat-1 merged LISSIV satellite imagery (2.5 m spatial resolution) as base map to interpret the soil physiographic unit map. The soil (soil profile depth, number of horizons, soil color, soil structure, texture, consistency, presence of carbonates, and soil pH) and site (slope, erosion, drainage, runoff, gravelliness, stoniness, presence of rocks on surface, lithology/parent material and current land use) characteristics were recorded for all soil profile sites on a standard pro forma (Pedon description form which consists of a list of soil and site parameters that need to be recorded during a field study (Soil Survey Staff, 2014). Further, soil series were divided into soil phases based on the surface characteristics with respect to soil texture, slope, erosion and gravelliness. The classification of soil series was made as per soil taxonomy (Soil survey staff, 2008). Seven soil series were identified and their area distribution and description were mapped (Table 1, Fig. 3). Soil samples were collected from representative pedons and analyzed for different physical and chemical properties following standard procedures (Black, 1965; Jackson, 1973).

Soil texture was evaluated using the feel method, and slope with the help of a dumpy level. Organic carbon (OC) was determined using the Walkley & Black (1934) wet oxidation method. Available N was determined by a modified alkaline potassium permanganate method as described by Subbiah and Asija. Available P_2O_5 was determined using Olsen's method. Available K_2O was estimated using a flame photometer after extraction with ammonium acetate. Soil reaction (pH) was determined in 1:2.5 soil water suspensions using a glass electrode (Piper, 1966). Electrical conductivity was measured in the soil water (1:2.5) suspension using a conductivity bridge (Jackson, 1973). The level of free calcium carbonate ions in soil samples was determined using a rapid titration method with standard HCl (Piper, 1966). Available sulphur in soil was extracted with $CaCl_2 .2H_2O$ (0.15 %), and the extract was reacted with barium chloride crystals. The intensity of the resulting turbidity was measured using a spectrophotometer at a wavelength of 420 nm (Jackson, 1973). Water retention at 1/3 bar (Field capacity (FC)) and 15 bar (permanent wilting point (PWP) by pressure plate apparatus method (Klute, 1986).

Statistical Analysis

Karl Pearson's correlation coefficient. Bivariate pearson's correlation coefficient (r) was performed for X and Y variables of soil parameters.

$$r = \frac{\Sigma\,(X - \bar{X})\,(Y - \bar{Y})}{\sqrt{\Sigma\,(X - \bar{X})^2}\,\sqrt{(Y - \bar{Y})^2}}$$

Where r = Pearson's correlation coefficient

$\bar{x}$ = Mean of x variable

$\bar{y}$ = Mean of y variable

Descriptive statistical analysis and correlation studies were carried out as per the methodology given by Rangaswamy (2006). The original data were converted to solum weighted average (SWA) to avoid the outliers from different horizons of each profile. Hence the resultant soil series wise data were used.

$$\text{Solum Weighted Average} = \frac{\Sigma[\text{Variable} * \text{Horizon depth (cm)}]}{\text{Total profile depth (cm)}}$$

Development of PTFs. Stepwise multiple regression technique was used for developing PTFs in a statistical software SPSS (version 16.0). First, the soil datasets were subjected to analysis of data consistency and adequacy. Thereafter, the variables used for PTFs, were selected considering the cause–effect relationship and correlation coefficients amongst them. The statistical analyses for mean, standard deviation, maximum and minimum values, indicating the central tendency and spread of the dataset, were carried out for the selected variables. 20% used for validation of dataset. Stepwise regression technique was used in SPSS to develop multiple regression models as PTFs. A criterion of 5 % and 1 % significance levels was used for acceptance and rejection respectively, of an independent variable.

METHODS TO FIT PTFS

Multivariate regression: The most common method used in estimation PTFs is to employ multiple linear regressions.

For example: aX Y bX cX .... = 1 + 2 + 3 + (1)

$$Y = a_0 + \sum_{k=1}^{K} a_k X_k$$

Where: Y denotes depended variable, Xi (i = .2,1 L, n) is independent variable, and a, b, … are unknown coefficients of the model.

Selection of best fit regression model as PTF. Based on the F values derived from ANOVA of regression table, coefficient of determination (R^2) and adjusted R^2, an effective and efficient regression model was selected as the best-fit regression model as PTF. The adjusted R^2 was calculated from the following expression;

$$R^2_{\text{adjusted}} = 1 - \frac{(1 - R^2)(N - 1)}{N - p - 1}$$

Where R^2 = sample R-square
p = Number of predictors
N = Total sample size

The effectiveness of a regression model is measured by the values of R^2 and adjusted R^2. A more effective regression model will have highest R^2 value with a greater number of predictor variables. However, the model may not be efficient. The efficiency of a regression model is assessed by the F value. An efficient model will have the most significant or highest F ratio with a smaller number of predictor variables. However, the model may not be effective. Hence a compromise is made to select a best-fit regression model looking at the largest increase in the value of adjusted R^2 while introducing a new predictor variable into the model (Patil *et al*., 2013).

RESULTS AND DISCUSSION

Statistical characteristics of the soil properties: Table 7 provides descriptive statistics of soil properties Kamblihal sub-watershed soils. Soil depth of all the seven-soil series Belihal (BHL), Chikyerdal (CHK), Garjapur (GRJ), Kallamalli (KML), KamarKhedTanda (KMT), MaskiTanda (MST) and Naglapur (NAG) varied from shallow to deep. The variability of soil depth (Fig. 4) may be due to variations in topography and slope gradient (Satish Kumar & Naidu 2012). Soils of Kamblihal SWS were having sansdy clay to clay textural class. The soils of BHL, CHK, KMT and MST series has sandy clay texture whereas, GRJ, KML and NAG series soil texture were clay. The clay, sand and silt contents vary between 38.63 % and 50.78 %, 34.16 % and 48.13 % and 9.39 % and 14.59 % respectively. The soil reaction (pH) ranges from neutral to strongly alkaline, with a mean of 8.30. EC of the soil also varies from 0.23 to 0.52 dSm^{-1}. The pH was low at surface and then showed increasing trend with depths due to their accumulation of bases in the solum as they were poorly leached from upper horizons (Rajesh *et al*., 2023). The lower value of EC in the surface horizons may be due to free drainage conditions which favored the removal of released bases by percolating water (Pillai and Natarajan 2004). OC ranges between 0.30 % and 0.54 %, with mean of 0.41 %. This could be attributed to low OC status of soil coupled with low nitrogen fertilization application leading to nitrogen deficiency Low organic matter content in these areas due to low rainfall and low vegetation cover facilitate faster degradation and removal of organic matter leading to nitrogen deficiency (Rajesh *et al*., 2019). The FC and PWP range from 19.12 % to 44.16 % (mean 28.00 %) and 9.00 % to 15.84 % (mean 11.90 %) respectively, Except pH, EC, sand and silt content, other parameters are positively skewed, and among the soil properties, soil pH, EC, OC, PWP and silt shows least variability with CV (Table 2&4).

Soil fertility data showed that (Table 8) the available nitrogen of the soils ranges from 202.43 to 270.11 kg/ha, with a mean of 229.23 kg/ha. Available phosphorus of the soil varies from 27.51 to 39.04 kg/ha, with a mean of 34.56 kg/ha. Available phosphorous content decreased with the depth in most of the pedons, this could be attributed to higher removal than replenishment in the sub soil and also high phosphorous fixation capacity as well as less mobility of available phosphorous (Mathews *et al.,* 2009). Available potassium of the soil ranges from 243.19 to 426.68 kg/ha, with a mean of 304.85 kg/ha. High content of available potassium found in surface horizon than the sub-surface horizons, may be due to more intense weathering, release of labile potassium from organic residues and application of low K fertilizers (Geetha *et al.* 2019). Exchangeable calcium and magnesium range from 8.98 ppm to 35.91 ppm (mean 22.31 ppm) and 5.24 ppm to 18.29 ppm (mean 12.54 ppm) respectively. The calcium and Magnesium were increased with increase in soil depth. Comparing these ions (Mg^{2+}, Na^{+} and Ca^{2+}) it was clear that Mg^{2+} was present in low amount than Ca^{2+}, because of its higher mobility. These results are in conformity with findings of Rajesh *et al.* (2021). Available sulphur of the soils ranges from 7.67 to 13.66 kg/ha, with a mean of 10.29 kg/ha. Calcium carbonate ranges from 7.75 % to 21.22 % (mean 14.26 %), except available phosphorus, exchangeable calcium and magnesium, other parameters are positively skewed (Table 3&5).

Correlation analysis: The results of correlation studies show that FC in kamblihal SWS soils is significantly strong positive correlated with clay ($p<0.01$) and negatively correlated with sand ($p<0.01$). Clay is significantly strong positive correlation with potassium ($p<0.01$) and moderate positive correlated with SOC ($P<0.05$). Sand is significantly strong negatively correlated with clay ($p<0.01$) and moderate negative correlated with sulphur ($p<0.05$) (Table 6).

PTFs: The PTFs were developed using the selected soil properties, *viz.* clay and silt as independent variables. The FC and PWP of soil were determined by the following equations

FC = -a + b (silt) + c (clay),

Where is an intercept, b & c are the regression coefficients. The PTFs of soil hydraulic properties (FC and PWP) were developed. The developed PTFs were cross-validated by ten-fold cross-validation techniques. Criteria of 1% and 5% level of significance were used for acceptance or rejection of a predictor variable in these models. The prediction of FC and PWP through the developed PTFs was satisfactory with high R^2 (0.952). 95 per cent of the variation was explained by the silt and clay for field capacity at 5% and 1% level significantly.

Clay with its large adsorption surface and reflects the negative charge of clay, greatly influence the soil water content due to adsorption of dipolar water molecules Tiwary *et al.* (2014) developed PTFs for soil moisture content in (black soil region, using silt and clay content of observations of 8 soil profiles (Table 9).

FC= -75.371+2.211silt*+1.736clay** R^2=0.952

Infiltration rate mainly depends on pore size and particle size. The PTFs for prediction of infiltration were developed from soil particles, *viz.* sand, silt and clay (Table 9). Infiltration rate varied from 0.09 to 0.35 cm/h, with mean and standard deviation of 0.18 and 0.108 mm/h respectively. Infiltration rate (mm/h) increased with decreasing clay content. The R^2 value (R^2 = 0.668). 67 per cent of the variation was explained by the clay for infiltration rate at 1% level significantly.

The model was run using sand, silt and clay as independent variable for determination of infiltration rate and showed that clay was negatively influences the infiltration rate at 1% level due to clay is having more adsorption surface due more number of micropores and porespace and avoid movement of water into the ground surface. Unlike soil moisture constants, only limited research has been carried out on soil infiltration rate which might be due to the complex process and high variance (Yi *et al.*, 2016).

Infiltration rate = 0.96 -0.018 (clay) ** R^2=0.668

Characterizing soil response to hydrology is a challenging task, particularly because of the difficulty in quantifying soil hydraulic properties and their spatial variability. For practical applications of PTFs, we need approaches that provide for hydraulic information in a cost-effective manner, minimizing requirements for direct measurement of soil hydraulic properties. The PTFs developed in this study are improvised hydrologic predictions of kamblihal SWS. Regular updating of PTFs with increased number of observations as well as increased number of independent variables like BD and aggregate stability will improve the results.

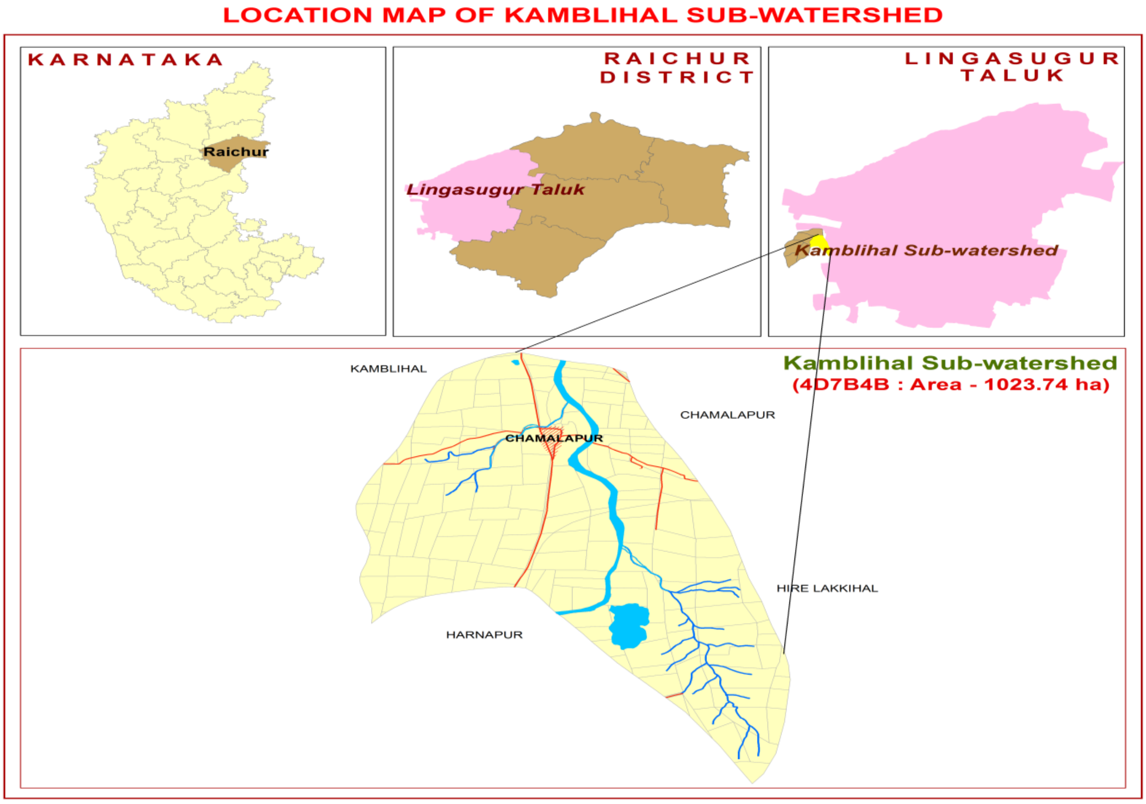

Fig. 1. Location of Kamblihal sub watershed is located in Lingasugur taluk, Raichur District.

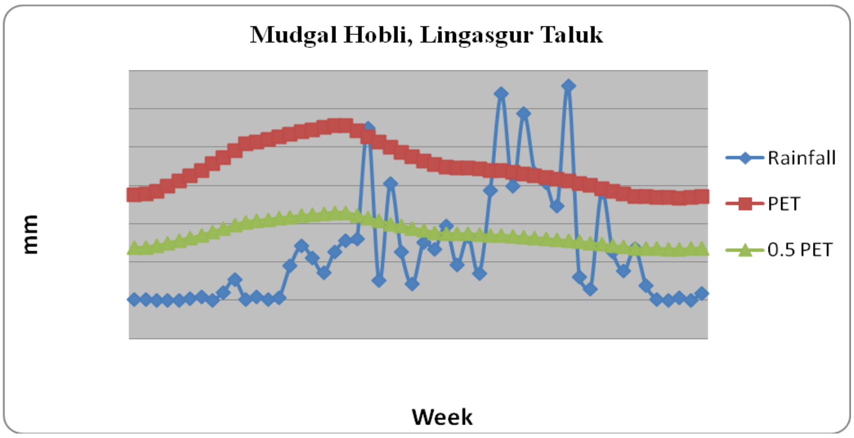

Fig. 2. Annual Rainfall: 520 mm. in the Mudgal Hobli, Lingasugur Taluk and Raichur District.

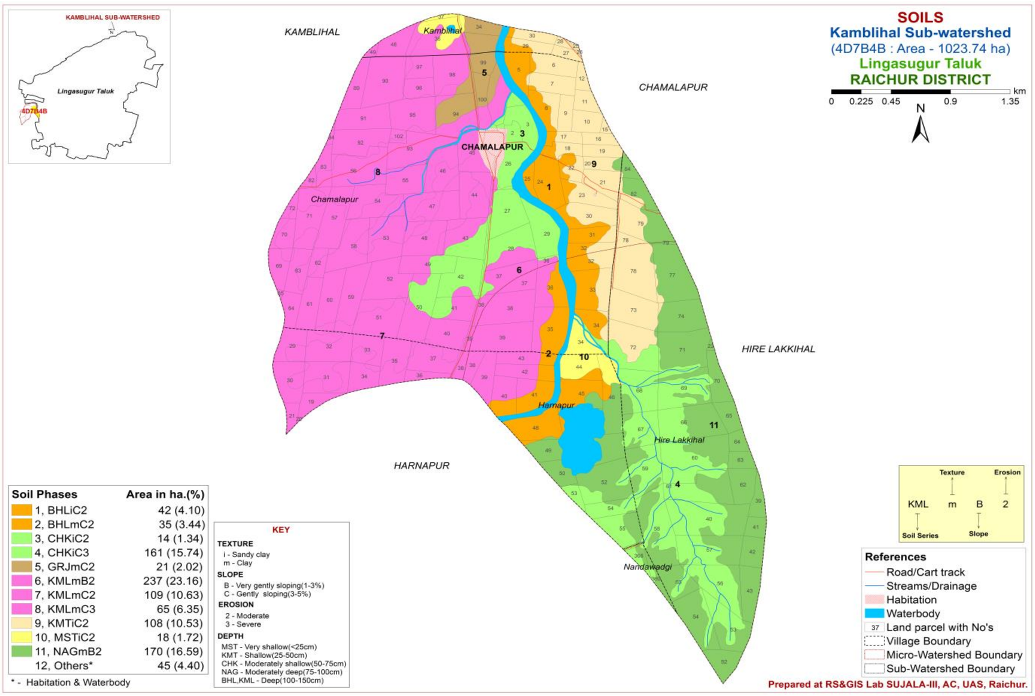

Fig. 3. Soil map of Kamblihal Sub-watershed.

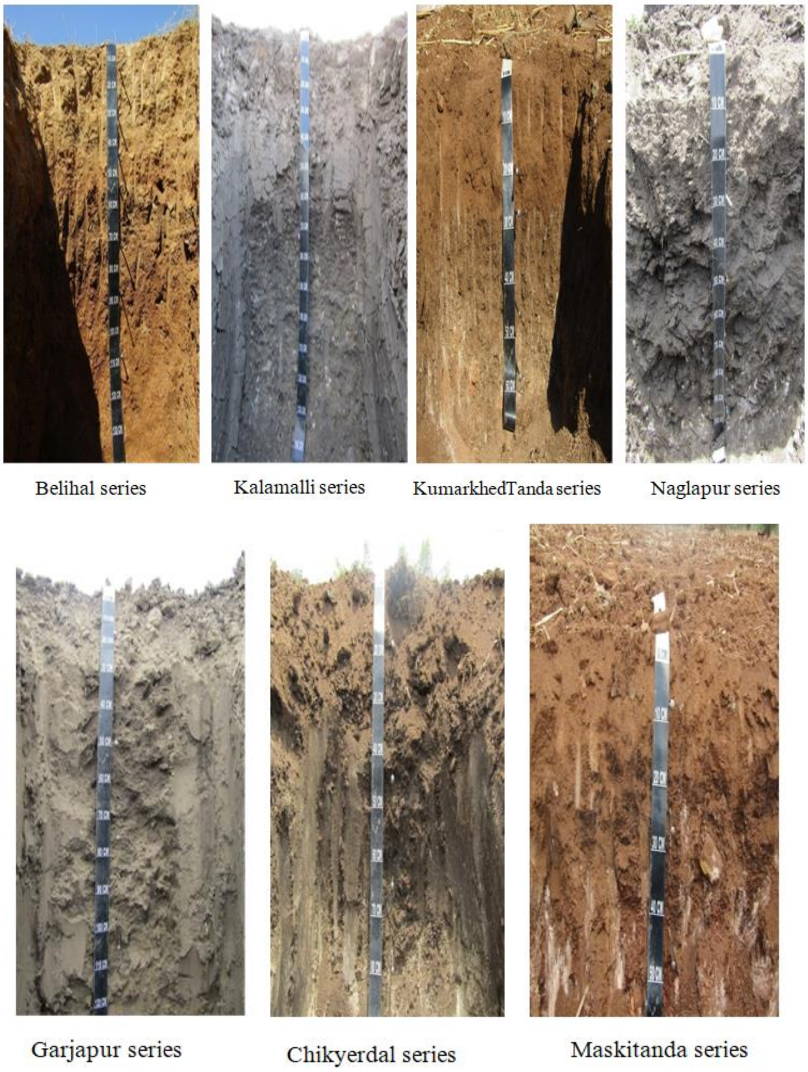

Fig. 4. Soil profile of identified soil series of Kamblihal SWS.

Table 1: Map unit description of Kamblihal sub-watershed.

Sr. No.	Soil Phase	Description	Area in ha. (%)
1.	BHLiC2	Belihal series, deep (100-150cm) having sandy clay textured soils occurring on gently sloping (3-5%) with moderate erosion.	42(4.10)
2.	CHKiC2	Chikyerdal series, moderately shallow (50-75cm) having sandy clay textured soils occurring on gently sloping (3-5%) with moderate erosion.	14(1.34)
3.	CHKiC3	Chikyerdal series, moderately shallow (50-75cm) having sandy clay textured soils occurring on gently sloping (3-5%) with severe erosion.	161(15.74)
4.	GRJmC2	Garjapur series, deep (100-150cm) having clay textured soils occuring on Gently sloping (3-5%) with moderate erosion.	21(2.02)
5.	KMLmB2	Kallamalli series, moderately Deep (100-150 cm) having clay textured soils occurring on very gently sloping (1-3%) with moderate erosion.	237(23.16)
6.	KMLmC3	Kallamalli series, moderately deep (100-150 cm) having clay textured soils occurring on gently sloping (3-5%) with Severe erosion.	65(6.35)
7.	KMTiC2	Kamar Khed Tanda series, shallow (25-50cm) sandy clay textured soils occurring on gently sloping (3-5%) with moderate erosion.	108(10.53)
8.	MSTiC2	Maski Tanda series, very shallow (<25 cm) having sandy clay textured soils occurring on gently sloping (3-5%) with moderate erosion.	18(1.72)
9.	NAGmB2	Naglapur series, moderately deep (75-100 cm) having Clay textured soils occurring on very gently sloping (1-3%) with moderate erosion.	170(16.59)
	Others*	Habitation and Waterbody.	45(4.40)

Table 2: Physico-chemical properties of soils of Kamblihal sub-watershed.

Sr. No.	Series	Name of the Soil Samples	Depth	Sand (%)	Silt (%)	Clay (%)	FC (%)	PWP (%)	pH	EC	OC (%)
1	**KMTiC2**	P1-1	0-20	51.58	10.95	37.47	15.56	8.78	8.33	0.35	0.42
2		P1-2	20-41	49.53	12.08	38.39	19.48	10.28	8.35	0.37	0.31
3		P1-3	41-68	47.57	13.08	39.35	21.75	12.49	8.47	0.40	0.29
4		P1-4	68-84	43.21	16.17	40.62	25.58	13.76	8.50	0.48	0.14
			SWA	**48.18**	**12.91**	**38.90**	**20.44**	**11.30**	**8.41**	**0.39**	**0.29**
5	**NAGmB2**	P2-1	0-18	37.46	10.29	52.25	38.56	10.78	8.30	0.28	0.62
6		P2-2	18-48	35.99	13.87	49.89	39.48	11.28	8.51	0.26	0.59
7		P2-3	48-66	34.86	15.98	48.78	40.75	12.49	8.64	0.59	0.48
8		P2-4	66-89	32.25	17.49	50.26	41.58	13.76	8.73	0.63	0.46
			SWA	**35.09**	**14.50**	**50.23**	**40.09**	**12.06**	**8.55**	**0.42**	**0.54**
9	**CHKiC3**	P3-1	0-19	49.82	10.23	39.95	17.59	9.63	8.48	0.21	0.52
10		P3-2	19-42	48.57	11.01	40.42	20.48	10.55	8.57	0.29	0.43
11		P3-3	42-63	45.57	12.08	42.35	23.67	13.76	8.61	0.35	0.39
12		P3-4	63-75	41.21	14.17	44.62	28.16	16.80	8.69	0.42	0.27
			SWA	**46.87**	**11.62**	**41.51**	**21.87**	**12.22**	**8.58**	**0.31**	**0.42**
13	**KMLmB2**	P4-1	0-14	53.58	9.63	36.79	14.27	7.85	7.92	0.27	0.54
14		P4-2	14-33	51.58	10.95	37.47	17.56	9.78	8.10	0.39	0.49
15		P4-3	33-62	49.53	12.08	38.39	19.48	11.28	8.29	0.41	0.43
16		P4-4	62-83	47.57	13.08	39.35	23.75	14.49	8.31	0.45	0.38
17		P4-5	83-103	43.21	16.17	40.62	26.58	16.76	8.46	0.48	0.31
			SWA	**48.83**	**12.54**	**38.63**	**20.67**	**12.26**	**8.24**	**0.41**	**0.42**

Table 3: Physico-chemical properties of soils of Kamblihal sub-watershed.

	Series	NAME OF THE SOIL SAMPLES	Depth	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (m.eq /100g)	Mg (m.eq/100)	S (ppm)	$CaCO_3$ (%)
1	**KMTiC2**	P1-1	0-20	225.79	39.65	336.97	5.18	2.59	12.48	12.45
2		P1-2	20-41	200.70	34.18	290.17	6.79	4.74	9.74	15.64
3		P1-3	41-68	194.73	32.65	286.85	10.84	6.47	7.00	17.58
4		P1-4	68-84	188.49	27.49	208.45	13.48	7.12	4.20	20.43
			SWA	**202.43**	**33.71**	**284.67**	**8.98**	**5.23**	**8.45**	**16.41**
5	**NAGmB2**	P2-1	0-18	310.55	44.16	469.95	16.23	10.27	13.56	9.54
6		P2-2	18-48	295.14	39.68	306.43	18.56	11.08	11.48	11.25
7		P2-3	48-66	240.98	38.27	301.39	22.14	12.45	9.22	13.22
8		P2-4	66-89	230.64	31.29	298.03	23.08	14.85	8.01	15.88
			SWA	**270.63**	**38.13**	**336.31**	**19.98**	**12.16**	**10.54**	**12.50**
9	**CHKiC3**	P3-1	0-19	259.13	35.46	310.76	7.45	4.68	11.54	8.16
10		P3-2	19-42	237.86	31.82	295.46	9.58	5.41	9.50	10.49
11		P3-3	42-63	205.64	28.56	255.80	11.43	7.39	6.47	12.74
12		P3-4	63-75	191.28	25.49	213.49	15.86	9.82	5.86	14.65
			SWA	**226.77**	**27.51**	**275.12**	**10.56**	**6.49**	**8.59**	**11.20**
13	**KMLmB2**	P4-1	0-14	297.46	40.19	296.31	9.46	5.76	9.64	15.49
14		P4-2	14-33	271.82	38.56	288.73	11.45	7.23	8.51	16.55
15		P4-3	33-62	249.63	35.72	258.49	12.76	8.71	7.29	17.81
16		P4-4	62-83	210.54	33.49	212.85	14.82	10.96	7.00	18.93
17		P4-5	83-103	190.75	29.81	182.46	15.69	11.85	6.74	20.43
			SWA	**240.82**	**35.25**	**245.14**	**13.06**	**9.10**	**7.67**	**18.00**

Table 4: Physico-chemical properties of soils of Kamblihal sub-watershed.

Sr. No.	Series	Name of the soil samples	Depth	Sand (%)	Silt (%)	Clay (%)	FC (%)	PWP (%)	pH	EC	OC (%)
1	**BHLiC2**	P1-1	0-20	49.58	10.95	39.47	16.37	9.18	7.23	0.17	0.49
2		P1-2	20-48	47.53	11.08	41.39	18.59	11.50	7.40	0.20	0.43
3		P1-3	48-73	44.21	12.18	43.01	21.75	13.47	7.89	0.23	0.39
4		P1-4	73-94	41.31	14.27	44.28	24.91	14.82	8.05	0.29	0.32
		P1-5	94-119	39.58	15.02	45.40	26.85	16.22	8.12	0.34	0.29
			SWA	**40.62**	**11.63**	**39.19**	**19.96**	**12.03**	**7.10**	**0.23**	**0.35**
5	**MSTiC2**	P2-1	0-9	48.26	9.23	42.51	12.48	7.12	8.15	0.28	0.54
6		P2-2	9-22	45.76	11.17	43.07	14.73	9.38	8.39	0.31	0.48
7		P2-3	22-42	42.38	13.47	44.15	16.55	11.28	8.57	0.44	0.42
			SWA	**44.69**	**11.85**	**43.46**	**15.11**	**9.80**	**8.42**	**0.37**	**0.46**
9	**GRJmC2**	P3-1	0-18	39.46	10.54	48.46	41.29	13.28	8.23	0.21	0.55
10		P3-2	18-28	37.62	11.25	49.15	42.45	14.16	8.31	0.37	0.49
11		P3-3	28-72	35.59	12.86	50.76	43.08	15.49	8.44	0.39	0.41
12		P3-4	72-102	33.47	13.56	51.18	45.73	16.78	8.56	0.48	0.37
		P3-5	102-130	32.38	13.09	52.45	46.61	17.65	8.67	0.51	0.35
			SWA	**35.10**	**12.63**	**50.78**	**44.16**	**15.84**	**8.48**	**0.41**	**0.41**
13	**CHKiC2**	P4-1	0-20	49.28	8.45	42.27	17.86	6.48	8.09	0.19	0.45
14		P4-2	20-42	46.71	9.56	43.73	19.25	8.96	8.43	0.25	0.36
15		P4-3	42-60	44.24	10.22	45.54	20.37	11.85	8.59	0.38	0.31
			SWA	**46.83**	**9.39**	**43.79**	**19.12**	**9.00**	**8.36**	**0.27**	**0.38**
17	**KMLmC3**	P5-1	0-15	37.46	10.29	47.56	38.56	10.78	8.30	0.28	0.62
18		P5-2	15-35	35.79	11.65	48.87	39.48	11.28	8.51	0.26	0.59
19		P5-3	35-65	34.78	12.88	49.66	40.75	12.49	8.64	0.59	0.48
20		P5-4	65-92	32.25	13.49	50.49	41.58	13.76	8.73	0.63	0.46
		P5-5	92-110	31.43	14.05	51.08	42.88	14.28	8.76	0.72	0.34
			SWA	**34.16**	**12.64**	**49.67**	**40.77**	**12.64**	**8.61**	**0.52**	**0.49**

Table 5: Physico-chemical properties of soils of Kamblihal sub-watershed.

Sr. No.	Series	Name of the soil samples	Depth	N (kg/ha)	P (kg/ha)	K (kg/ha)	Ca (m.eq /100g)	Mg (m.eq/100)	S (ppm)	$CaCO_3$ (%)
1	**BHLiC2**	P1-1	0-20	285.46	41.24	310.48	28.54	15.87	19.64	14.23
2		P1-2	20-48	260.12	39.68	285.52	34.71	18.64	17.85	16.83
3		P1-3	48-73	237.81	36.41	274.19	37.52	19.53	14.54	17.68
4		P1-4	73-94	190.87	32.87	250.66	40.84	21.79	12.49	19.95
5		P1-5	94-119	186.22	29.23	212.83	44.76	23.67	10.61	20.50
			SWA	**212.62**	**32.75**	**243.19**	**34.33**	**18.29**	**13.66**	**16.36**
6	**MSTiC2**	P2-1	0-9	290.78	36.28	297.83	31.78	14.55	14.23	8.96
7		P2-2	9-22	245.13	31.87	266.80	33.62	16.82	11.58	10.78
8		P2-3	22-42	198.43	29.45	241.34	39.25	19.13	9.63	12.54
			SWA	**232.67**	**31.66**	**261.33**	**35.91**	**17.43**	**11.22**	**11.23**
9	**GRJmC2**	P3-1	0-18	275.86	47.21	520.12	19.56	10.25	13.08	16.81
10		P3-2	18-28	245.63	42.36	450.63	21.37	12.58	11.57	18.54
11		P3-3	28-72	205.39	38.56	430.61	28.46	14.89	10.48	20.99
12		P3-4	72-102	185.76	32.25	400.08	32.14	17.82	9.66	22.10
13		P3-5	102-130	179.48	30.60	380.37	35.67	20.58	8.46	24.44
			SWA	**208.13**	**36.88**	**426.68**	**29.08**	**15.97**	**10.30**	**21.22**
14	**CHKiC2**	P4-1	0-20	236.79	36.28	396.12	22.19	13.25	10.28	6.31
15		P4-2	20-42	212.84	39.26	345.86	24.78	15.79	9.47	7.89
16		P4-3	42-60	197.86	41.85	298.71	30.49	18.35	8.12	9.18
			SWA	**216.33**	**39.04**	**348.47**	**25.63**	**15.71**	**9.34**	**7.75**
17	**KMLmC3**	P5-1	0-15	310.85	44.16	469.95	15.50	6.35	17.25	9.54
18		P5-2	15-35	295.86	39.68	306.43	20.00	11.56	15.66	11.25
19		P5-3	35-65	241.79	38.27	301.39	22.50	12.96	13.28	13.22
20		P5-4	65-92	238.45	31.29	298.03	27.50	13.89	10.15	15.88
		P5-5	92-110	198.76	29.05	290.75	28.50	15.96	9.63	17.42
			SWA	**253.18**	**36.11**	**322.73**	**23.30**	**12.52**	**12.89**	**13.70**

Table 6: Association between physic-chemical properties of pedons of Kamblihal SWS.

Parameter	pH	EC	OC	N	P	K	Ca	Mg	S	$CaCo_3$	FC	PWP	Sand	Silt	Clay
pH	1														
EC	0.646	1													
OC	0.456	0.534	1												
N	0.348	0.542	**.913****	1											
P	0.132	0.301	0.215	0.224	1										
K	0.447	0.294	0.204	-0.058	0.606	1									
Ca	-0.426	-0.254	0.155	-0.074	0.176	0.158	1								
Mg	-0.445	-0.297	0.168	-0.043	0.312	0.224	.978**	1							
S	-0.479	-0.02	0.232	0.152	0.062	0.011	.745*	.692*	1						
Caco3	-0.226	0.288	-0.246	-0.272	0.06	0.165	-0.044	-0.057	0	1					
FC	0.424	.693*	0.644	0.444	0.428	.719*	0.201	0.199	0.345	0.317	1				
PWP	0.056	0.385	0.114	-0.033	0.04	0.475	-0.057	-0.056	0.092	.810**	0.661	1			
Sand	-0.066	-0.46	-0.577	-0.416	-0.407	-0.582	-0.422	-0.425	**-0.671***	-0.249	**-0.907****	-0.573	1		
Silt	0.227	.669*	0.45	0.517	0.079	0.066	-0.264	-0.31	0.043	0.474	0.584	0.509	-0.482	1	
Clay	0.496	0.552	**0.693***	0.455	0.515	**0.805****	0.295	0.318	0.338	0.015	**.937****	0.432	**-0.860****	0.352	1
IR	-0.622	-0.246	-0.619	-0.324	-0.175	-0.662	-0.261	-0.254	-0.168	0.423	-0.62	-0.079	0.52	0.009	**-.817****

*. Correlation is significant at the 0.05 level (2-tailed); **. Correlation is significant at the 0.01 level (2-tailed).

Table 7: Descriptive Statistics of physico-chemical properties of profile soil.

property	pH	EC (dS/m)	OC (%)	Sand (%)	Clay (%)	Silt (%)	FC (%)	PWP (%)	IR (cm/hr)
Mean	8.30	0.37	0.41	42.26	44.01	12.19	28.00	11.90	0.180
Maximum	8.61	0.52	0.54	48.83	50.78	14.51	44.16	15.84	0.35
Minimum	7.1	0.23	0.30	34.16	38.63	9.39	19.12	9.00	0.09
SD	0.46	0.08	0.07	6.09	5.01	1.36	10.43	1.92	0.108
Kurtosis	7.45	-0.189	0.003	-1.931	-1.736	2.354	-1.546	1.938	-1.480
Skewness	-2.657	-0.145	0.059	-0.409	0.395	-0.583	0.812	0.619	0.864
CV (%)	0.218	0.008	0.005	37.15	25.19	1.87	108.91	3.69	0.012

Table 8: Descriptive Statistics of soil fertility properties of profile soil.

Property	Avail. N (kg/ha)	Avail. P (kg/ha)	Avail. K (kg/ha)	Avail. S (kg/ha)	Exch. Ca (ppm)	Exch. Mg (ppm)	$CaCo_3$ (%)
Mean	229.23	34.56	304.85	10.29	22.31	12.54	14.26
Maximum	270.11	39.04	426.68	13.66	35.91	18.29	21.22
Minimum	202.43	27.51	243.19	7.67	8.98	5.24	7.75
SD	22.36	3.59	59.79	2.03	9.96	4.75	4.12
Kurtosis	-0.336	0.507	0.806	-0.776	-1.436	-1.298	-0.335
Skewness	0.693	-0.797	1.025	0.497	-0.033	-0.413	0.158
CV (%)	500.34	12.89	3576	4.13	99.25	22.58	16.98

Table 9: Multiple regression analysis.

Dependent variable	Linear Regression parameters					
	Variables	**Constant**	**Co-efficient**	**t**	**F**	**R^2**
FC (df=8)	Silt	-75.371	2.211	3.038*	59.554**	0.952
	Clay		1.736	8.744**		
FC	Clay	-57.76	1.948	7.106**	50.493**	0.878
IR	Clay	0.96	-0.018	-3.752**	14.08**	0.668

FC= -75.371+2.211silt*+1.736clay** R^2=0.952; Infiltration rate = 0.96 -0.018 (clay) ** R^2=0.668

CONCLUSIONS

Kamblihal sub watersheds (SWS) area has soil depth of shallow to deep; the texture was found to be clay, The soil reaction (pH) was neutral to strongly alkaline, low to medium EC, organic carbon content was found to be low. Available nitrogen was low to medium, phosphorus was medium and potassium was high. The prediction of FC and PWP through the developed PTFs was satisfactory with high R2 (0.952). 95 per cent of the variation was explained by the silt and clay for field capacity at 5% and 1% level significantly. Infiltration rate (mm/h) increased with decreasing clay content. The R2 value (R2 = 0.668). 67 per cent of the variation was explained by the clay for infiltration rate at 1% level significantly.

FUTURE SCOPE

The prediction of soil hydrological properties such as FC and IR are widely dependent on soil texture variables. Therefore, PTFs developed could be used for predication of FC and IR in the rest of the areas where similar soil types were found. Similarly other soil hydrological properties namely PWP, WHC and runoff may be predicted by using available soil input physico-chemical properties which will reduce the laborious time in estimating their properties using conventional laboratory or field instrumental methods.

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Conflict of Interest. None.

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