PREDICTING FIELD CAPACITY AND WILTING POINT FOR LOWER KOSI FLOODPLAIN, INDIA

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ABSTRACT

Soil water content at field capacity (FC) and wilting point (WP) is an important input parameter. Soil water content is required in various environmental and hydrological models and plays a crucial role in partitioning the rainfall into infiltration and surface runoff. Direct measurements of FC and WP are difficult, time-consuming and expensive. In the present work soil samples from fourteen different locations were collected from the Kosi floodplain, India. These soil samples were analyzed in the laboratory to determine the physical properties i.e. bulk density (BD), sand, silt, clay, organic matter (%) and water content at different pressures (33 kPa, 100 kPa, 500 kPa, 1500 kPa). This study is conducted to evaluate (1) an applicability of point, function and retention pedotransfer functions (PTFs) to predict FC and WP using basic soil properties for its validity. Statistical indices, i.e., coefficient of determination (R^2), root mean square error (RMSE), degree of agreement (d) correlation coefficient (r), are computed to evaluate the soil water retention functions. Campbell retention function performed better for FC (R^2=0.8448, RMSE=0.5513 m^3/m^3) and WP (R^2=0.9568, RMSE=0.0716 m^3/m^3). Results are significant because FC and WP data are in the development stage for Kosi floodplain.

Keywords: Field capacity, wilting point, soil water retention, pedotransfer functions.

1. INTRODUCTION

The Kosi basin has plain topography and most of the area is fertile cultivated land. The soil is mostly alluvium and very fertile, most suitable for multiple cropping and irrigated agriculture. A high amount of rainfall is received during the rainy season (June-September) in a relatively short period of time, which make the agricultural lands inundated/waterlogged. The winter crop is raised on residual water content after the rainy season. Understanding of soil hydraulic properties (FC and WP) is a prerequisite for any irrigation planning or hydrologic simulation, a lack of information on soil-water content is a major constraint faced in developing countries. Therefore, point pedotransfer functions (PTFs) to estimate FC/WP draw attention from parametric PTFs to predict soil water retention curve (SWRC). However, parametric PTFs offer an advantage of continuous simulations of soil water retention at any level of pressure head. The accurate measurements of FC and WP from laboratory or field procedures are laborious, tedious, time-consuming and expensive. Large-scale laboratory data on soil-water retention are rarely available primarily because of a lack of facilities and the costs involved. Many indirect methods for estimation of water content at FC and WP have been proposed in the literature. Most of these methods can be called pedotransfer functions (PTFs) (Bouma and Van Lanen, 1987), because they translate existing surrogate data into soil hydraulic data (Schaap et al., 2001). A number of PTFs can be found in the literature (Rawls and Brakensiek, 1982), (Rawls et al., 1982), (Russo, 1988), (Vereecken et al., 1989), (Campbell and Shizawa, 1990), (Mayr and Jarvis, 1999), (Minasny, et al., 1999), (Schaap, et al., 2001), (Minasny and McBratney, 2002), and (Tomasella, et al., 2003). The objective of this study is to evaluate the general applicability and the prediction accuracy of some pedotransfer functions in estimating soil water content at field capacity and wilting point for Kosi floodplains, India.

2. STUDY AREA AND DATA COLLECTION

2.1 The Kosi basin

The Kosi basin is an important sub-basin of the Ganga basin. Upper catchment of the basin lies in Nepal and Tibet at great heights of the Himalayan range. The total drainage area of the Kosi River is 74,030 km^2 out of which 11,410 km^2 lies in India and the rest 62,620 km^2 lies in Tibet and Nepal (FMIS, 2013). The topography of the basin is very steep in upper reaches and mild in lower reaches. The location of the lower Kosi basin in India lies between 86°22'24''-87°37'40' East and 25°19'25''- 26°35'16'' North.

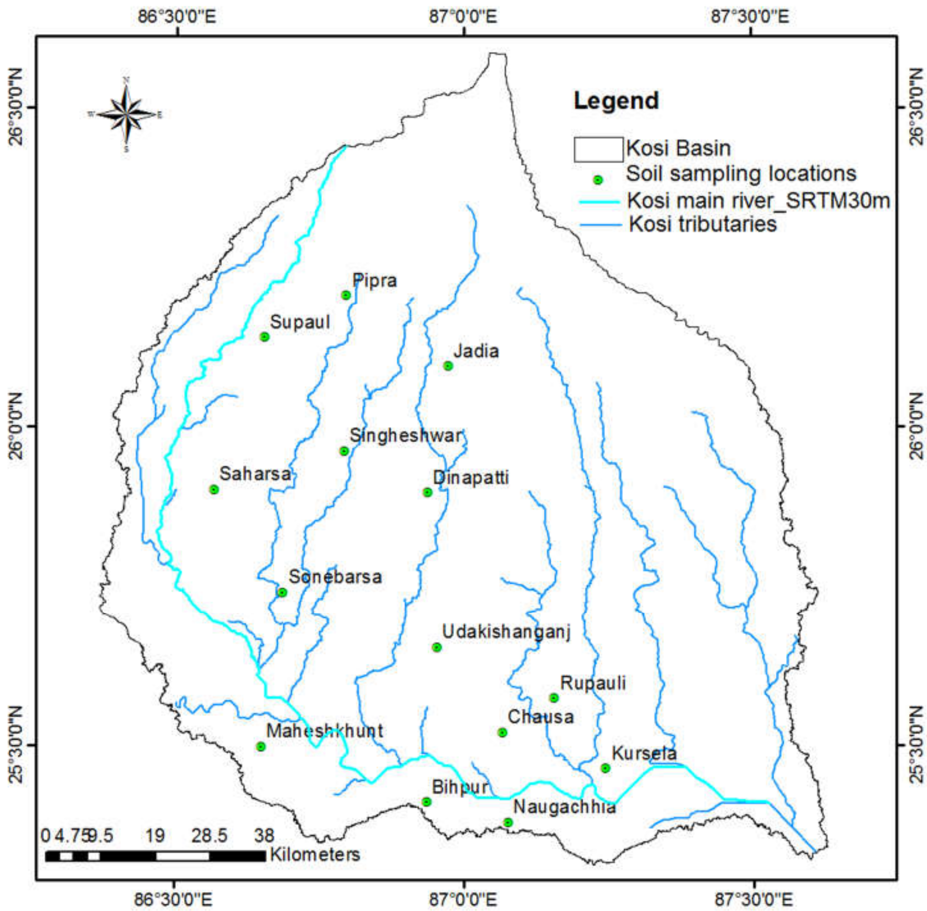


Figure 1. Study area and location map of soil sampling sites

The upper catchment of the Kosi basin lies totally in mountainous region. The soils encountered in these regions are usually classified as (GFCC, 1983): Mountain Meadow Soil, Sub-Mountain Meadow Soil, and Brown Hill Soil. The entire lower area of the Kosi Basin in the plains can be regarded as a large inland delta formed by the huge sandy deposit of the Kosi River. Disturbed and undisturbed soil core samples have been collected from 14 different locations of the Kosi floodplain (at the depth of 50cm). The location of soil sampling site is shown in Figure 1. Soil physical properties i.e. bulk density, particle size distribution, specific gravity, porosity, organic carbon, and water content at different pressures are calculated in the laboratory.

3. METHODOLOGY

3.1 Soil water retention functions

Four widely used soil water retention functions proposed by Brooks and Corey (BC), Campbell, Cass and Hutson (CH) and VG are evaluated for this study. A power law equation suggested by Brooks and Corey (1964) describes this θ(h) relationship as

$$\theta(h) = \begin{cases} \theta_r + \frac{(\theta_s - \theta_r)}{(\alpha h)^{\lambda}} & \alpha h \geq 1 \\ \theta_s & \alpha h < 1 \end{cases} \quad (1)$$

where, θ(h) is the volumetric water content (m^3/m^3) at pressure head h, θs and θr are the saturation and residual volumetric water content (m^3/m^3), respectively; λ is the pore distribution index, α (> 0, in 1/kPa) is a parameter whose inverse $h_e = 1/\alpha$ is frequently referred to as the air entry value.

Another most widely used function suggested by van Genuchten (1980) describes the relationship as

$$\theta(h) = \begin{cases} \theta_r + \frac{(\theta_s - \theta_r)}{[1+(\alpha h)^n]^m} & h < 0 \\ \theta_s & h \geq 0 \end{cases} \quad (2)$$

where, θ(h) is the volumetric water content (m^3/m^3) at pressure head h, θs and θr are the saturation and residual volumetric water content (m^3/m^3), respectively; α (> 0, in 1/kPa) is related to the inverse of the air entry suction, n and m are the shape parameters of soil water characteristic n (> 1) is a measure of the pore-size distribution, and m = 1-1/n.

Campbell (1974) described water retention function as

$$\theta(h) = \begin{cases} \theta_s \left(\frac{h}{h_e}\right)^{-1/b} & h < h_e \\ \theta_s & h \geq h_e \end{cases} \quad (3)$$

Where, b is empirical constant.

Campbell's function was modified by Hutson and Cass (1987), known as the Campbell-Hutson-Cass function is function

$$\theta = \begin{cases} \theta_s \left(\frac{h}{a}\right)^{-1/b} & \theta < \theta_i \\ \theta_s - \left[\theta_s h^2 \frac{\left(1-\frac{\theta_i}{\theta_s}\right)}{a^2\left(\frac{\theta_i}{\theta_s}\right)}\right] & \theta \geq \theta_i \end{cases} \quad (4)$$

Where, $\theta_i = 2b\theta_s / (1+2b)$; a, b are the empirical parameters; and h_e is the air entry pressure.

3.2 Performance evaluation

Measured and estimated water retention data are compared and the performance of the functions was evaluated using statistical indices to identify the best-suited function for describing FC and WP of Kosi basin soils. The following statics are used to performance evaluation:

Root mean squared error (RMSE)

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(E_i - M_i)^2}{n}} \quad (5)$$

Mean Absolute Error (MAE)

$$MAE = \sum_{i=1}^{N} \frac{|E_i - M_i|}{N} \quad (6)$$

Maximum absolute error

$$ME = max|E_i - M_i| \quad (7)$$

Index of agreement

$$d = 1 - \frac{\sum_{i=1}^{n}(E_i - M_i)^2}{\sum_{i=1}^{n}(|E_i - \bar{M}| + |M_i - \bar{M}|)^2} \quad (8)$$

Linear correlation coefficient (r)

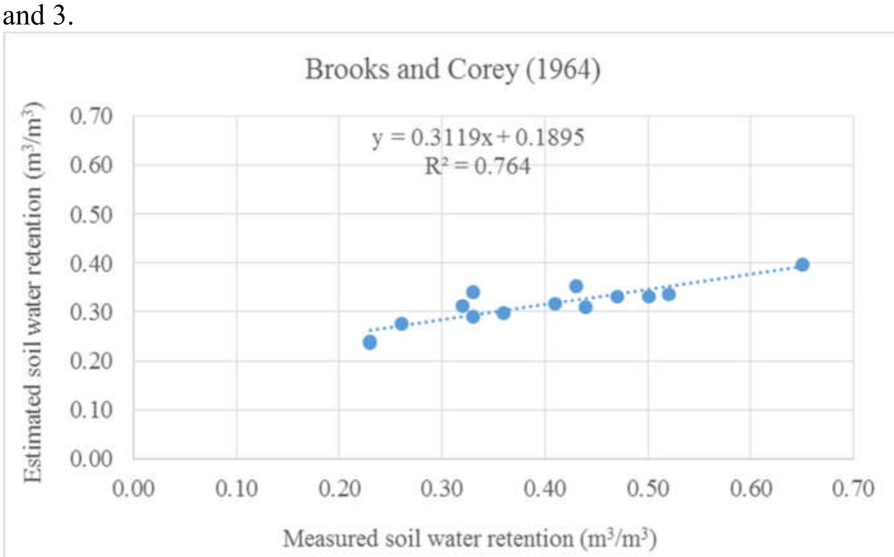
$$r = \frac{1}{n-1}\sum_{i=1}^{n}\frac{(E_i - \bar{M})(E_i - \bar{E})}{S_M S_E} \quad (9)$$

Coefficient of determination (R^2) is the square of the correlation coefficient (r).

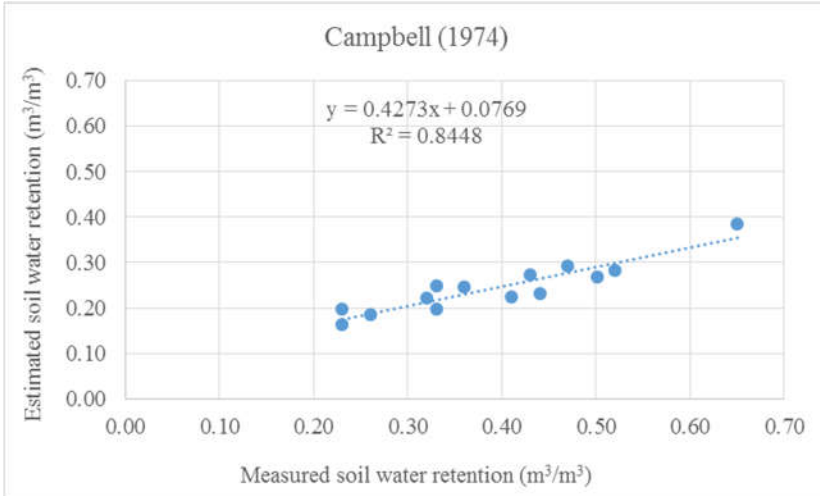
where, E_i is estimated water content (m^3/m^3) at pressure h for i_{th} value, M_i is measured water content (m^3/m^3) at i_{th} value, N is total number of observations, $\bar{M}$ is mean of measured water content, $\bar{E}$ is mean of estimated water content, S_M is sum of measured water content and S_E is sum of estimated water content.

4. RESULTS AND DISCUSSION

Retention functions are evaluated to estimate field capacity and wilting for the soils of Kosi floodplains. The performance of these PTFs are evaluated using various statics indices, root mean squared error (RMSE), mean absolute error (MAE), maximum error (ME), degree of agreement (d), correlation coefficient (r) (Table 1 and 2). The Campbell retention function performed well for both FC and WP. It is found that Campbell retention function fitted better than any other method for WP, with highest coefficient of determination ($R^2 = 0.9568$), lowest root mean square error (RMSE = 0.0716), highest degree of agreement (d = 0.9785), and highest correlation coefficient (r = 0.9782), and a mean absolute error (MAE = 0.0191) (Table 1 and 2). Comparison between measured and estimated soil water retention data is shown in figure 2 and 3.



(a)



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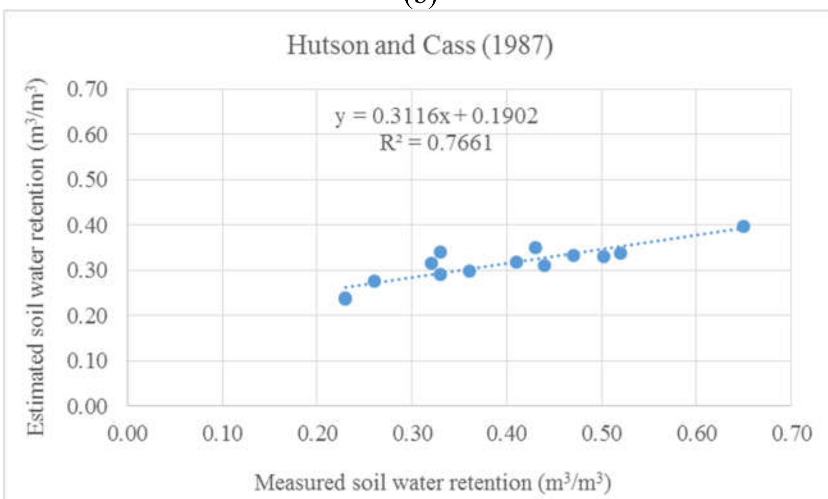

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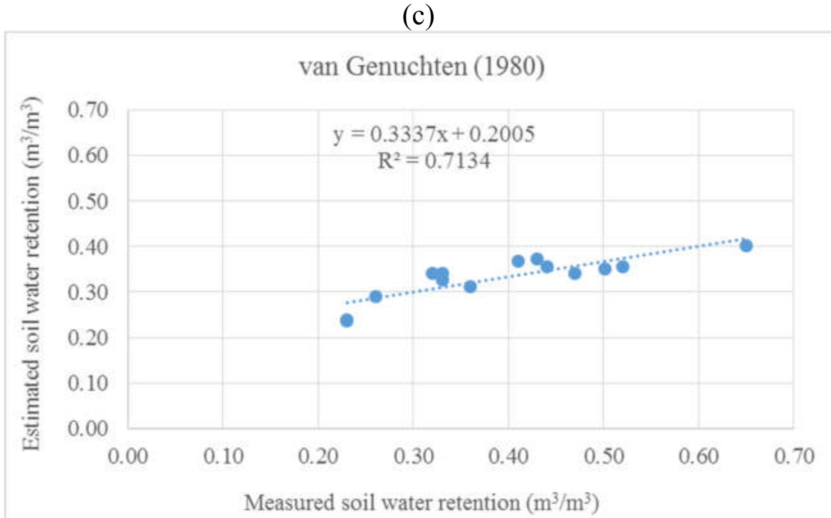
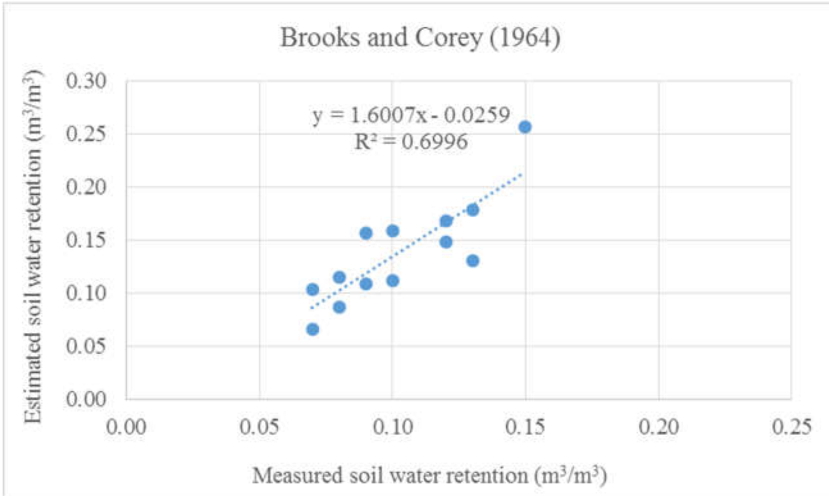
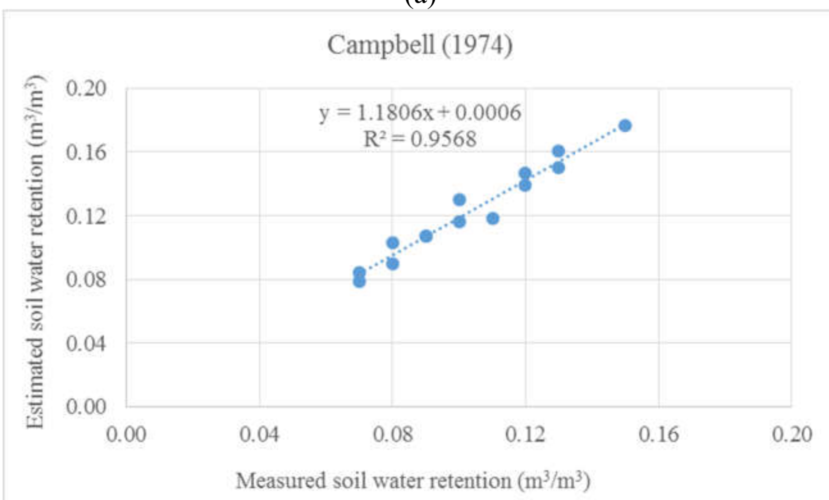


(d)

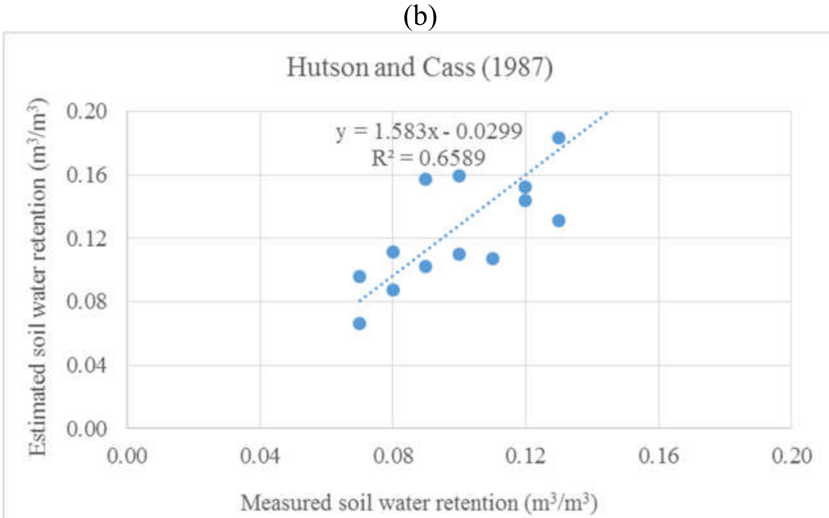
Figure 2. Measured and estimated field capacity using different retention functions (a) Brooks and Corey (1964), (b) Campbell (1974), (c) Hutson Cass (1987), and (d) van Genuchten (1980)


Brooks and Corey (1964)
y = 1.6007x - 0.0259
R² = 0.6996
Estimated soil water retention (m³/m³)
Measured soil water retention (m³/m³)
0.00
0.05
0.10
0.15
0.20
0.25
0.30

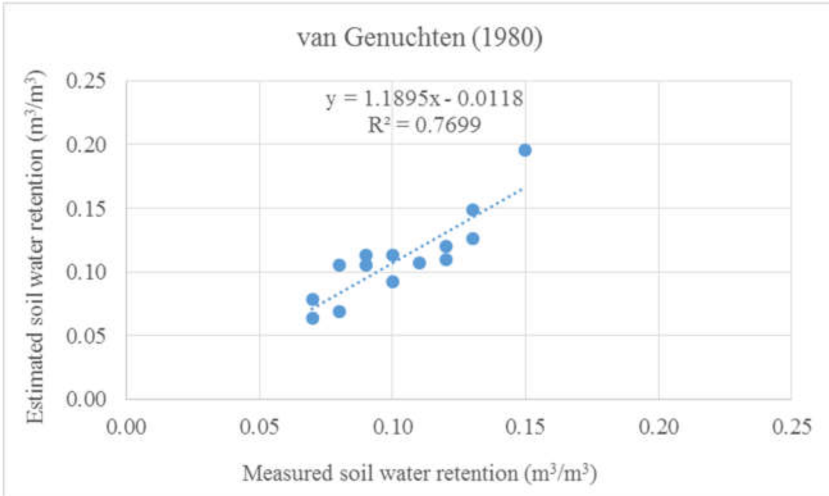
(a)


Campbell (1974)
y = 1.1806x + 0.0006
R² = 0.9568
Estimated soil water retention (m³/m³)
Measured soil water retention (m³/m³)
0.00
0.04
0.08
0.12
0.16
0.20

(b)


Hutson and Cass (1987)
y = 1.583x - 0.0299
R² = 0.6589
Estimated soil water retention (m³/m³)
Measured soil water retention (m³/m³)
0.00
0.04
0.08
0.12
0.16
0.20

(c)



(d)

Figure 3. Measured and estimated wilting point using different retention functions (a) Brooks and Corey (1964), (b) Campbell (1974), (c) Hutson Cass (1987), and (d) van Genuchten (1980)

Table 1. Evaluation of the PTFs for estimating field capacity

	R^2	r	RMSE	MAE	ME	d
Brooks & Corey	0.7640	0.8741	0.2990	0.0859	0.0160	0.8670
Campbell	0.8448	0.9191	0.5513	0.1473	0.0330	0.8471
Hutson Cass	0.7661	0.8753	0.2968	0.0852	0.0160	0.8668
van Genuchten	0.7134	0.8447	0.2260	0.0715	0.0310	0.8748

Table 2. Evaluation of the PTFs for estimating wilting point

	R^2	r	RMSE	MAE	ME	d
Brooks & Corey	0.6996	0.8364	0.1227	0.0338	0.1070	0.9444
Campbell	0.9568	0.9782	0.0716	0.0191	0.0310	0.9785
Hutson Cass	0.6589	0.8117	0.1125	0.0311	0.1060	0.9445
van Genuchten	0.7699	0.8775	0.0286	0.0136	0.0460	0.9773

5. CONCLUSIONS

Retention functions are evaluated to predict FC and WP for the soils of Kosi floodplains India Based upon the above analysis Campbell retention function performed well to predict water content at FC and WP for the soils of Kosi flood plains. Campbell retention function performed better for FC (R^2=0.8448, RMSE=0.5513 m^3/m^3) and WP (R^2=0.9568, RMSE=0.0716 m^3/m^3). Results are significant because FC and WP data are in the development stage for Kosi floodplain.This method could be useful to provide information of water content at FC and WP, for crop-water management and hydrological models.

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