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Hydraulic conductivity and its relationship with other properties of soil in cultivated land.

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ABSTRACT

A study was undertaken at farmer's field at "Khatra" block in Bankura district of West Bengal to investigate the effect of hydraulic conductivity of the cultivated soil under different cropping sequence with soil properties and develop schematic model for predicting the hydraulic conductivity under different soil factors. Soil sample were collected from cultivated farmer field under six cropping sequences like: (i) rice-fallow, (ii) rice-mustard -fallow, (iii) rice–potato -fallow, (iv) rice-vegetable-fallow, (v) rice-rice-fallow (vi) groundnut -rice-fallow. Bulk density decreases 11.8%, 5.14%, 2.20%, 1.47%, 1.46% and 0.73% respectively under different cropping sequences than the fallow plots and also increase with the soil depth; porosity and water holding capacity, hydraulic conductivity, electrical conductivity, organic carbon also increases under different cropping sequences than the fallow plots and also decreases with the soil depth. Highest coefficient of correlation between Hydraulic conductivity (HC) and water holding capacity ($r=0.40^{**}$) has been observed and negative correlation was found in silt and clay. The multiple regression model was developed by six important soil factors that is sand, organic carbon (OC), bulk density (BD), water holding capacity (WHC), porosity and silt fraction for predicting hydraulic conductivity of the cultivable soil under different sequences.

Keywords: Cultivated land, hydraulic conductivity, soil parameters, soil properties

Soil and water are the most vital resources to meet the basis necessities of all beings like food, fodder, fuel and fiber. Productivity of soil determines by the nutrient uptake with water influenced by some soil physical characteristics like bulk density, porosity, hydraulic conductivity and structural stability *etc.* The rate of movement of water will depend on the magnitude of the forces, gradients and also on the factors determining the coefficient of hydraulic conductivity of the soil.

Dynamics of soil moisture storage in the potential crop root zone of primary importance to plant growth and agricultural production. Soil physical characteristics such as hydraulic conductivity and infiltration rate co-determined the magnitude of water flow rate in soil. Different land management practices like cultivation, tillage operation, cropping system, mulches and land cover effect soil physical properties (Mathan and Mahendran 1993).

Aberrant weather conditions and associated soil related constraints are the major factors of lowering crop productivity in red and lateritic zone of West Bengal. Due to topography and erratic nature of precipitation these tracts suffer from water scarcity. High intensity of rainfall on sloping ground, poor soil structure, low soil depth that provides little scope of retain rain water on the surface or underground. So water retention influenced hydraulic conductivity.

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The present study aims to investigate the effect of hydraulic conductivity of the cultivated soil under different cropping sequence with soil properties and develop schematic model for predicting the hydraulic conductivity under different of soil factors.

MATERIALS AND METHODS

The present study has been carried at Khatra block in Bankura district of West Bengal represented by subtropical to hot sub humid climate region lies between $22^0$382 N latitude and $86^0$362 E longitude with altitude of 300 to 515 m above MSL having average rainfall of 1461 mm/year. The soil of the area characterized by acidic in nature, low organic carbon, low water holding capacity, low soil depth with slope of 3-5%.

The present investigation involves with six cropping sequences like (i) rice (*Oryza sativa*)-fallow-fallow, (ii) rice-mustard(*Brassica spp.*)-fallow, (iii) rice–potato (*Solanum spp*)-fallow, (iv) rice-vegetable-fallow, (v) rice-rice-fallow (vi) groundnut (*Arachis hypogea*)-rice-fallow. The above cropping sequences were followed by farmers with own package and practices for the period of several years. Only composite soil samples were collected from three different depth of 0-15cm, 15-30cm, 30-45cm of each selected cropping sequence.

Collected samples were air dried; pass through 2mm sieve and prepared for relevant analysis. Bulk density, water holding capacity and porosity of the soil were estimated by normal procedure (Piper 1966). The soil pH was determined by glass electrode pH meter from soil water suspension (1:2.5). The organic carbon was estimated by wet digestion method of Black (1965). Electrical conductivity of the soil was measured with the help of conductivity meter followed by Jackson (1973). Hydraulic conductivity of the soil samples were determined by constant head method (Ghosh, 1990). In to the soil container (Brass core) fitted with a filter paper air dry representative soil samples passed through a 2 mm sieve were damped in one motion. The cylinder containing the soil was dropped 20 times through a distance of 2.5 cm into the packing block to facilitate uniform filling and to avoid trapping air in the soil. Two filter papers were placed one at the bottom and another at the top of the soil. A beaker placed under the outlet of the container for containing deionised water overnight for saturation using a constant head maintaining device (connecting soil container by siphon tube to water supply). When the outflow became constant, the quantity of water passing through soil column was collected and measured against time. The hydraulic conductivity was calculated by the following formula (Ghosh, 1990).

$$K_S = \frac{Q \quad \Delta L}{\Delta H \quad A \quad T}$$

Where, Q = volume of water passing through the soil in the time, T (cc/hr)

A = Cross sectional area of the soil, (cm^2)

“L= Soil height, (cm)

“H= Hydraulic head differences (cm)

Ks = Saturated hydraulic conductivity, ($cm\ hr^{-1}$)

RESULT AND DISCUSSION

The bulk density of soil ranged between 1.20 to 1.49 Mg m^3; irrespective of soil depths and land uses the values were generally lower in the surface soils as compared to sub-soils (Table 1). Bulk density of the soil shows to be significantly decreased by 11.8%, 5.14%, 2.20%, 1.47%, 1.46% and 0.73% respectively for Groundnut-fallow-fallow, rice-potato-fallow, rice-fallow-fallow, rice-mustard-fallow, rice-rice-fallow and rice-vegetable-fallow cropping sequence under

Table 1: Mechanical composition of the cultivated soils under different cropping system

Cropping systems	Soil depth (cm)	Clay	Silt	Sand	Textural class
Rice-	D_1	27.97	27.59	44.43	Clay loam
Fallow-	D_2	29.87	30.70	40.07	Clay loam
Fallow	D_3	30.03	31.87	38.10	Clay loam
	LSD (0.05)	**1.03**	**1.13**	**0.66**	
Rice-	D_1	27.70	37.83	34.47	Loamy
Mustard-	D_2	28.60	38.80	32.60	Loamy
Fallow	D_3	28.97	39.77	31.27	Loamy
	LSD (0.05)	**0.50**	**0.47**	**0.31**	
Rice-	D_1	25.04	47.25	27.70	Loamy
Potato-	D_2	26.07	48.46	25.47	Loamy
Fallow	D_3	27.18	50.13	22.69	Loamy
	LSD (0.05)	**0.82**	**0.64**	**0.44**	
Rice-	D_1	21.95	43.53	34.52	Clay loam
Vegetable-	D_2	23.41	44.33	32.27	Clay loam
Fallow	D_3	23.87	45.29	30.83	Clay loam
	LSD (0.05)	**0.64**	**0.42**	**0.46**	
Rice-	D_1	27.33	44.29	28.38	Clay loam
Rice-	D_2	27.59	45.62	26.79	Clay loam
Fallow	D_3	28.53	49.00	22.47	Clay loam
	LSD (0.05)	**0.58**	**0.42**	**0.37**	
Groundnut-	D_1	16.00	35.70	48.29	Loamy
Fallow-	D_2	16.30	36.02	47.68	Loamy
Fallow	D_3	17.12	38.25	44.64	Loamy
	LSD (0.05)	**0.62**	**0.28**	**0.37**	

Note : *D_1= 0-15cm, D_2=15-30cm, D_3=30-45cm (Different depths of soil)*

Table 2: Physical and phsico-chemical properties of the cultivated soils under different cropping system

Cropping systems	Soil depth (cm)	Bulk density (Mg m^{-3})	Water holding capacity (%)	Porosity (%)	Hydraulic conductivity (cm hr^{-1})	Electrical conductivity (dS m^{-1})	Organic carbon (g kg^{-1})
Rice-	D_1	1.33	46.26	46.99	18.90	0.22	5.4
Fallow-	D_2	1.36	40.11	46.25	18.21	0.20	5.2
Fallow	D_3	1.42	38.30	45.41	17.89	0.17	4.7
	LSD (0.05)	**0.03**	**0.61**	**0.69**	**0.10**	**0.01**	**0.03**
Rice-	D_1	1.34	41.68	48.09	15.89	0.34	4.8
Mustard-	D_2	1.39	41.20	46.89	15.52	0.31	4.3
Fallow	D_3	1.43	40.31	44.44	15.25	0.28	4.1
	LSD (0.05)	**0.03**	**0.58**	**1.57**	**0.06**	**0.02**	**0.02**
Rice-	D_1	1.29	40.61	45.16	16.23	0.22	5.7
Potato-	D_2	1.34	38.26	44.38	15.88	0.15	5.2
Fallow	D_3	1.39	37.85	43.15	15.43	0.07	4.9
	LSD (0.05)	**0.02**	**1.35**	**0.25**	**0.07**	**0.08**	**0.04**
Rice-	D_1	1.35	45.31	47.30	18.98	0.17	5.1
Vegetable-	D_2	1.44	42.24	46.58	18.53	0.14	4.8
Fallow	D_3	1.47	39.44	45.76	17.93	0.11	4.4
	LSD (0.05)	**0.02**	**1.02**	**0.07**	**0.03**	**0.03**	**0.02**
Rice-	D_1	1.38	45.31	49.34	16.34	0.25	3.9
Rice-	D_2	1.42	42.24	48.19	16.08	0.24	3.7
Fallow	D_3	1.44	39.44	47.71	15.38	0.20	3.3
	LSD (0.05)	**0.02**	**1.02**	**0.43**	**0.07**	**0.03**	**0.04**
Groundnut-	D_1	1.20	44.17	46.30	15.90	0.20	4.5
Fallow-	D_2	1.36	42.41	45.76	15.45	0.18	4.1
Fallow	D_3	1.39	37.63	44.43	15.17	0.13	3.6
	LSD (0.05)	**0.03**	**0.79**	**0.52**	**0.09**	**0.02**	**0.06**

Note : *D_1= 0-15cm, D_2=15-30cm, D_3=30-45cm (Different depths of soil)*

Table 3 : Coefficients of correlation (r) amongst hydraulic conductivity and different physical and physico-chemical parameters of the cultivated soils.

Soil parameter	Bulk density	Porosity	Organic carbon	Water holding capacity	Sand	Silt	Clay
Hydraulic conductivity	0.03**	0.19**	0.57**	0.40**	0.86**	-0.79**	-0.38**

** Significant at 5% level, ** Significant at 1% level*

Table 4: Stepwise regression equation of hydraulic conductivity (Y) with different physical parameters of soils

Model	Regression equation	R^2	Adj. R^2	SE(est)
1	Y= 1.809 + 0.14 Sand	0.743	0.738	0.6731
2	Y= 10.16 + 0.124 Sand + 4.952 OC	0.786	0.777	0.6198
3	Y= 3.895 + 0.115 Sand + 6.32 OC + 0.129 Porosity	0.805	0.793	0.598
4	Y= -6.099 + 0.101 Sand + 9.443 OC + 0.167Porosity + 5.29 BD	0.827	0.813	0.5678
5	Y= -0.552 + 0.0928 Sand + 10.251 OC + 0.135 Porosity + 7.852 BD	0.849	.833	0.5362
6	Y= 2.462 + 0.114 Sand + 8.93 OC + 0.135 Porosity + 6.283 BD - 0.17 WHC	0.863	0.845	0.5171
7	Y= 0.001+0.16 Sand+1.840 OC+0.33 Porosity+8.65 BD - 0.15 WHC+0.068 Silt	0.877	0.858	0.4943

Note : *BD = Bulk density, OC = Organic carbon, WHC = Water holding capacity*

D_1(0-15cm).Similar result also found in different cropping sequence under D_2(15-30cm) and D_3(30-45cm). Reverse result also found in porosity under some cropping sequence and depth; water holding capacity, electrical conductivity and organic carbon also found same trend. Hydraulic conductivity of the soil shows to be significantly increased by 112.5, 56.25, 37.8, 37.2, 12.5 and 6.25 respectively for rice- mustard-fallow, rice-rice-fallow, rice-potato-fallow, rice-rice-fallow, groundnut-fallow-fallow and rice-vegetable-fallow cropping sequences under D_1. Similar result also found in different cropping sequence under D_2 and D_3.

Bulk density increased with soil depth, but the total porosity decreased with increasing depth. However, Hydraulic conductivity was affected by soil depth and different cropping sequences, Castrignano and Colucci (1988).

The coefficients of correlation between hydraulic conductivity and the different physical parameters of soil are given in table 2. It has been observed that hydraulic conductivity had a highly significant and positive correlation with bulk density ($r = 0.03^{**}$) and porosity (r = 0.14*) water holding capacity(r = 0.40**) and sand fraction ($r = 0.86^{**}$) of soils, while it had significant negative correlation with silt (r = 0.79**) and clay fraction (r = 0.38**) of soil. Above results find support with the results by Lami *et al*. (1990).

A multiple regression model involving six important soil factors *viz.* sand, organic carbon, porosity, bulk density, water holding capacity and silt fraction was developed with a view to improve the predictability of hydraulic conductivities of the cultivated soils (Table 3).

From the multiple regression tables, dependence of hydraulic conductivity on the soil properties is shown in the following equation:

$$HC = 0.001 + 0.16\ sand + 1.84\ OC + 0.33\ porosity + 8.65\ BD - 0.15\ WHC + 0.068\ silt\ (R^2 = 0.877)$$

From critical examination of this regression equation showed that sand fraction alone could contribute about 74.3% of total variation in hydraulic conductivity and the remaining 13.4% of variation in hydraulic conductivity was contributed by the organic carbon, porosity, bulk density, water holding capacity.

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