Environment and Ecology 41 (1C) : 684—692, January-March 2023
ISSN 0970-0420

Pedo-Transfer Function for Prediction of Mean Weight Diameter of Soil Aggregates from Physico- Chemical Properties of Soil Affected by Long Term Organic Cropping Systems

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Received 29 October 2022, Accepted 10 January 2023, Published on 16 March 2023

ABSTRACT

Mean weight diameter (MWD) of soil aggregates is an indicator of good soil quality but not measured routinely. An alternative approach to the physical measurement of MWD is calculation through pedo-transfer functions. Therefore objective of present study was to develop a pedo-transfer function for prediction of mean weight diameter of wet aggregates from soil properties affected by long term organic cropping systems. Soil samples were collected after *rabi* and *kharif* seasons from five organic cropping systems (Poplar + turmeric (CS_1), sugarcane + (bottle gourd – broccoli) (CS_2), basmati–wheat (CS_3), sugarcane fodder (CS_4) and maize + summer moong – wheat (CS_5) practiced in cycle at Bhagat Puran Singh Natural Agriculture Farm and Research Center, Amritsar, Punjab. These samples were analyzed for sand, silt, clay, soil organic carbon (SOC), soil pH, soil electrical conductivity (EC), MWD and bulk density (BD). Results showed that CS_1 has significantly higher SOC and MWD than CS_2, CS_3, CS_4 and CS_5. Significantly higher soil pH and BD were observed respectively in CS_4 and CS_5 than other cropping systems. Meanwhile CS_3 has significantly lower EC compared to other cropping systems. MWD was significantly positively correlated with clay content (R=0.729), SOC (R=0.756) and EC (R=0.488) and negatively with BD (R= -0.64). The regression model developed for estimation of MWD of the soil was calibrated (R=0.90, R^2=0.81, SE= ±0.0432, n=80) and validated with root mean square error (RMSE), model efficiency (ME), coefficient of residual mean (CRM), correlation coefficient (R) and coefficient of determination (R^2) values 0.0468, 0.58, -0.054, 0.845 and 0.714 respectively.

Keywords Soil organic carbon, Bulk density, Electrical conductivity, Mean weight diameter, Pedo-transfer function.

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INTRODUCTION

The advent of high yielding nutrient responsive varieties and increased area under assured irrigation has led to a major shift from organic based nutrient application to use of chemical fertilizers. Indiscriminate use of chemical fertilizers without additions of organic materials to soils has led to gradual decline in soil structure (Biswas *et al.* 2014). Most research indicated that the application of organic manure in combination with inorganic fertilizer improve soil structure through linear increase in SOC (Brar *et al.* 2015, Bassouny and Chen 2016). During the last decades, the decline in SOC in most of agricultural cropping systems and the awareness towards the importance of global carbon budgets have boosted the interest in organic farming to enhance crop production and maintain soil quality under increasing world population and climate change conditions (Meemken and Qaim 2018, Williams *et al.* 2017). Organic farming relies on the use of organic manures, inclusion of legume and cover crops in rotations (Fernández *et al.* 2018) and recycling of crop residues for enhancing the organic matter content in the soil to improve soil structure (Bahadur *et al.* 2015). Mostly, inappropriate cropping practices involving excessive tillage, increase SOC losses and significant degradation in soil structure (Hussain *et al.* 2021) while the cropping systems involving crop residue recycling (Jat *et al.* 2019), manure application (Gross and Glaser 2021), conservation tillage (Kar *et al.* 2021) and keeping soil fallow (Mechri *et al.* 2016), can significantly increase SOC storage and soil structure. There is thus a need to improve the understanding of how different cropping systems in organic farming contribute to changes in soil structure. Cropping systems that maintain and improve levels of SOC may also improve soil structure. Soil structural stability has been quantified by mean weight diameter (MWD) of wet aggregates (Choudhury *et al.* 2014). The direct measurement of MWD in field is very difficult and not standardized (Besalatpour *et al.* 2013). Therefore, in the present study the pedo-transfer function (PTF) was developed for prediction of MWD from routinely measured soil properties varied under long term use of organic manures in different cropping systems. The results of PTF were also validated using independent data set.

MATERIALS AND METHODS

Cropping systems

The research work was conducted at Bhagat Puran Singh Natural Agriculture Farm and Research Center, Dherekot, Jandiala Guru, Amritsar (31^0 34’ 24″ N, 75^0 03’ 58″E) situated at an altitude of 230 m above mean sea level. The total area of the organic farm is 12 ha. The impact of long term five organic cropping systems viz., poplar + turmeric as intercrop (CS_1), sugarcane+(bottle gourd – broccoli) as intercrop (CS_2), basmati – wheat (CS_3), sugarcane fodder (CS_4) and maize + summer moong (cover crop) – wheat (CS_5) was studied on soil physico-chemical properties and build up of soil organic carbon. In CS_1, the poplar + turmeric as intercrop is practiced in cycle since fifteen years. Every year turmeric is being sown as inter crop in the poplar during the month of April and harvested by the end of December. Before sowing of turmeric two preparatory tillage operations with rotavator were done. Two rows of turmeric were sown on 37.5 cm wide beds with plant to plant spacing of 18 cm. Paddy straw mulch was applied @ 9 t ha^{-1} after the first irrigation. No other chemical fertilizer was added to this cropping system. Irrigation was applied through flooding in the rows as and when required. In CS_2, sugarcane (Co J 85 var) was sown as two rows (in 4’) and 12’ inter row spacing in the North-South direction. The inter row spacing (12’) was used for sowing of vegetables since 15 years. Preparatory tillage with cultivator followed by rotavator was done before sowing of bottle guard and broccoli in the inter row spacing. Bottle gourd was sown during the month of March and harvested in September. Broccoli was transplanted in the month of October after bottle gourd and harvested in December to February. Only organic manures (added through compost @ 5 t ha^{-1} + Jeeva Amrita) were used to raise vegetables and sugarcane. In CS_3, basmati (Pusa Basmati 1121 var) was transplanted in the month of July and harvested in October. After incorporation of basmati straw with discing+ rotavator, wheat (Sona Moti var) was sown as 8 rows on 120 cm beds and furrows of 30 cm. In CS_5, maize (var. local) was sown (after one preparatory tillage with rotavator) in the month of April after harvesting of wheat at a 60 cm row to row spacing and two rows of summer moong (SML 668 var) were sown as inter/cover crop in maize during April every year. After maize, wheat was sown (after preparatory tillage of one discing+rotavator) in October as 8 rows on the beds (120 cm width and 30 cm furrow). In CS_4, sugarcane fodder (KRF093-1 var) was sown on 75 cm beds at 75 cm plant to plant spacing during 2016 (after preparatory tillage with cultivator) and it was a 3 year ratoon crop during 2019. During three years no any tillage operation was carried out in sugarcane fodder.

Soil sampling and analysis

The soil samples were taken from four sites and four depths (0-7.5, 7.5-15, 15-22.5 and 22.5-30 cm) under each cropping system after the harvest of *rabi* (2018-19) and *kharif* crops during 2019. The collected soil samples were dried, grounded and passed through 2-mm sieve for analysis. Soil texture, soil pH and electrical conductivity of 1:2 soil:water suspension of each depth was determined as per procedure described by Singh *et al.* (2016). Soil organic carbon (SOC), Soil bulk density (BD), different size soil aggregates (percent) and the mean weight diameter (MWD) of the soil aggregates were determined using the procedure described by Singh and Singh (2021).

Statistical analysis

Data were all analyzed using analysis of variance at a 0.05 level, with the help of SPSS10.0 for Windows (SPSS Inc, Chicago, USA). A correlation matrix of different soil properties was based on linear correlation coefficients ($p<0.05$ and $p<0.01$). One-way analysis of variance (ANOVA) procedures were used to test for significant differences in variables among treatments. Correlations between variables were calculated with the Pearson correlation coefficients.

Mean weight diameter prediction model: Stepwise multiple linear regression (MLR) analysis was done using MWD as dependent variable and clay (%), SOC (g/kg), BD (Mg/m^3), and EC (dS/m) as independent variables using SPSS 10.0. The data of all these parameters of the soil samples collected after *rabi* (2018-19) were used to predict and calibrate MWD. The results of the statistical analysis are shown in Table 1. Developed MLR model equation for predicting MWD is as follows:

MWD (mm) = 0.566 + 0.01315 clay + 0.01618 SOC - 0.362 BD + 0.379 EC.

Soil MWD was very significantly regressed by soil properties (Table 1). The developed model showed that MWD is negatively correlated with bulk density and positively with clay, SOC and EC of the soil. The organic carbon was selected to predict MWD by the stepwise regression, which is to fit with the highest coefficient of determination (i.e., $R^2=0.571$) of the estimated model and probability of significance ($p<0.01$). The inclusion of clay content, bulk density and EC increased coefficient of determination by 0.689, 0.787 and 0.81 respectively (Table 1). Percent sand, silt and soil pH were excluded from the regression model being non significant values ($p>0.05$) of 0.561, 0.131 and 0.464 respectively.

Model performance

The performance of the model was compared with predicted values of MWD from dependent variables (independent data collected after *kharif* 2019) and MWD observed (for the samples collected after *kharif* 2019) season using following statistical tools:

Root mean square error (RMSE): RMSE was calculated as

$$RMSE = \frac{\sqrt{\sum_{i=1}^{n} (Pi - Oi)^2}}{N} \quad (1)$$

where, Pi and Oi are the predicted and observed values of MWD respectively and N is the number of observations. The value equal to zero for a model showed perfect fit between the observed and predicted data.

The model efficiency (EF): Its value 1.0 showed a perfect fit between measured and predicted by the model as

$$EF = 1 - \frac{\sum_{i=1}^{n} (Pi - Oi)^2}{\sum_{i=1}^{n} (Pi - Oa)^2} \quad (2)$$

where, O_a is the average of the observed data of MWD.

Coefficient of residual mass (CRM): CRM was calculated as

$$CRM = \frac{(\sum_{i=1}^{n} (Oi - \sum_{i=1} Pi)^2}{\sum_{i=1}^{n} Oi} \quad (3)$$

Table 1. Descriptive statistics of the regression model, ANOVA, coefficients and significance.

Coefficients							ANOVA					
	Coeff B	SE	t	Sig	95% Confidence interval for B LB	UB		Sum of squares	df	Mean squares	F	Sig
Constant	0.566	0.140	4.042	0.000	0.287	0.845	Regression	0.599	4	0.150	80.07	0.000
SOC	0.01618	0.004	4.511	0.000	0.009	0.023	Residual	0.140	75	0.00187		
Clay	0.01315	0.002	6.541	0.000	0.009	0.017	Total	0.739	79			
BD	-0.362	0.074	-4.917	0.000	-0.508	-0.215	Excluded variables were percent sand and silt and soil pH being non significant					
EC	0.379	0.153	2.474	0.016	0.074	0.684	values (p>0.05) of 0.561, 0.131 and 0.464 respectively					

Linear model parameters					Results of stepwise regression				
Model	R^2	df	F	Sig.	Model	R	R^2	Adj R^2	SE
MWD=0.034+0.0229 clay	0.532	78	88.62	0.000	MWD= Constant, SOC	0.756	0.571	0.566	0.0637
MWD=0.067+0.0390 SOC	0.571	78	104.0	0.000	MWD=Constant, SOC, Clay	0.830	0.689	0.681	0.0547
MWD=1.5669-0.7483BD	0.409	78	54.05	0.000	MWD= Constant, SOC, Clay, BD	0.892	0.795	0.787	0.0446
MWD=0.1440+1.2947EC	0.239	78	24.44	0.000	MWD= Constant, SOC, Clay, BD, EC	0.900	0.810	0.800	0.0432

Note: Coeff.-Coefficient, SE-Standard error, Sig-Significance, LB-Lower boundary, UB- Upper boundary, Adj-Adjusted, df-Degree of freedom.

Its zero value denotes perfect fit, negative and positive values over- and under-prediction, respectively.

t-test: Independent samples of Student t-tests were performed to describe significant differences between the measured and predicted values of MWD.

RESULTS AND DISCUSSION

Soil texture

Soil particle size analysis (Table 2) of the experimental area revealed that soils were sandy loam in texture according to International Society of Soil Science Classification. Averaged over depths indicated that sand content was significantly higher in CS_4 and CS_5 compared to CS_1, CS_2 and CS_3 while CS_4 and CS_5 were at par. There was no significant difference in silt content among cropping systems. Clay content was significantly higher in CS_1 and CS_2 compared to other cropping systems while these both were at par.

Soil organic carbon

The long term cropping systems had varying and statistically significant ($p<0.05$) effects on SOC (Table 3). The data of soil organic carbon of both the seasons was pooled and found that irrespective of depths, CS_1 has significantly higher SOC (8.8 g/kg) than CS_2 (7.3 g/kg), CS_3 (6.3 g/kg), CS_4 (4.9 g/kg), and CS_5 (6.8 g/kg). However no significant differences in soil organic carbon were observed in CS_2, CS_3 and CS_5 but these have significantly higher SOC than CS_4. Higher SOC in CS_1 could be due to the higher biomass addition by mulching of paddy straw in turmeric and addition of leaf litter of poplar during winter months particularly in the surface soil layers and higher clay content (Table 2). Similar results have been reported by Benbi *et al.* (2012) where total organic carbon (TOC) was higher in soils under agroforestry systems.

Table 2. Soil particle size distribution among different organic cropping systems.

Cropping system	Percent Sand	Silt	Clay
CS_1	54.7^a	27.6^a	17.7^a
CS_2	56.4^a	26.7^a	17.0^a
CS_3	56.8^a	28.8^a	14.5^{ab}
CS_4	61.2^b	28.6^a	10.2^b
CS_5	59.1^b	27.6^a	13.4^{ab}

*Values followed by the same letter within a row indicate no significant difference at 0.05 level.

Table 3. Effect of different organic cropping systems on soil organic carbon (g/kg), pH, EC (dS/m), MWD (mm) and bulk density of soil (Mg/m^3).

Soil depths (cm)	CS_1	CS_2	CS_3	CS_4	CS_5	Mean*
			Organic carbon			
0-7.5	10.3	8.7	7.5	6.0	7.7	8.1^a
7.5-15	9.4	7.8	6.7	5.2	7.2	7.3^{ab}
15-22.5	8.4	6.9	5.9	4.8	6.6	6.5^b
22.5-30	7.0	5.8	5.2	3.6	5.7	5.5c
Mean*	8.8^a	7.3^b	6.3^c	4.9^d	6.8^{bc}	
			pH			
0-7.5	7.59	7.80	7.24	8.05	7.63	7.66^a
7.5-15	7.70	7.86	7.41	8.08	7.72	7.76^{ab}
15-22.5	7.81	7.95	7.63	8.20	7.75	7.87^{bc}
22.5-30	7.94	8.07	7.75	8.21	7.89	7.97^c
Mean*	7.77^a	7.92^b	7.51^c	8.13^d	7.75^a	
			EC			
0-7.5	0.2125	0.2020	0.1511	0.1724	0.1678	0.1812^a
7.5-15	0.1772	0.1824	0.1191	0.1699	0.1708	0.1638^b
15-22.5	0.1550	0.1582	0.1104	0.1521	0.1503	0.1452^c
22.5-30	0.1256	0.1384	0.1051	0.1304	0.1329	0.1265^d
Mean*	0.1676^a	0.1703^a	0.1214^b	0.1562^a	0.1554^a	
			MWD			
0-7.5	0.568	0.443	0.337	0.275	0.374	0.399^a
7.5-15	0.473	0.365	0.276	0.248	0.316	0.336^b
15-22.5	0.333	0.301	0.231	0.161	0.232	0.252^c
22.5-30	0.272	0.236	0.146	0.125	0.156	0.187^d
Mean*	0.412^a	0.337^b	0.247^c	0.202^d	0.269^c	
			Bulk density			
0-7.5	1.51	1.54	1.64	1.56	1.51	1.55^a
7.5-15	1.59	1.63	1.74	1.73	1.59	1.65^b
15-22.5	1.74	1.79	1.85	1.76	1.76	1.78^c
22.5-30	1.74	1.77	1.79	1.80	1.79	1.78^c
Mean*	1.64^a	1.68^a	1.75^b	1.71^{ab}	1.66^a	

*Values followed by the same letter within row and column indicate no significant difference at 0.05 level.

The lower soil carbon in CS_4 may be due to less addition of organic manures in *ratoon* sugarcane fodder compared to other cropping systems having more number of crops per season which can sequester more carbon in the top 30 cm soil (Valkama *et al.* 2020). Irrespective of cropping systems, SOC generally decreases with soil depth (Table 3). In 0-7.5 cm and 7.5-15 cm depths SOC was significantly higher than 22.5-30 cm depth. Significant difference in SOC was also observed in 0-7.5 cm and 15-22.5 cm layer. However no significant difference in SOC was observed in 7.5-15 cm and 15-22.5 cm depth. The higher SOC in surface layers was because of additions of organic manures on the surface and more root biomass in the surface layers compared to lower depths (Liu *et al.* 2013).

Soil pH

Among cropping systems significant difference in pH was observed (Table 3). Irrespective of depths, the pooled data of two seasons in the table shows that CS_4 has significantly higher ($p<0.05$) pH value (8.13) than CS_1 (7.77), CS_2 (7.92), CS_3 (7.51) and CS_5 (7.75). No any significant difference in pH was observed between CS_1 and CS_5. Soil pH of CS_3 was significantly lower than all other cropping systems. Lowering of soil pH of alkaline soil in basmati-wheat cropping system may be attributed to effect of puddling and submergence (Sharma *et al.* 2015) compared to poplar based cropping system. Irrespective of cropping systems pH generally increased with soil depth. In 15-22.5 cm and 22.5-30 cm depths pH was significantly higher than 0-7.5 cm depth. In 0-7.5 cm and 15-22.5 cm depth significant difference in pH was also observed. However no significant difference in pH was observed in 15-22.5 cm and 22.5-30 cm depths. The increase in soil pH with addition of manures and organic residues has also been reported by Bhatt *et al.* (2019).

Soil electrical conductivity

Irrespective of depths, CS_3 has significantly lower EC than CS_1, CS_2, CS_4 and CS_5 (Table 3). No any significant difference in EC was observed among CS_1, CS_2, CS_4 and CS_5. The increase in soil electrical conductivity as impacted by manure addition might be due to the amount of dissolved salts in the manures (Ozlu and Kumar 2018). The decrease in EC in CS_3 may correspond to leaching of soluble salts in basmati. Irrespective of cropping systems, EC was maximum in 0-7.5 cm and it significantly decreased with depth. Similar results were reported by Sharma *et al.* (2015) where EC decreased with soil depth.

Mean weight diameter of soil aggregates

Irrespective of depths, CS_1 has significantly higher

MWD ($p<0.05$) than CS_2, CS_3, CS_4 and CS_5 (Table 3). However no significant difference in MWD was observed in CS_3 and CS_5 but MWD in these cropping systems was significantly higher than CS_4. The order of decrease in MWD with different cropping systems is $CS_1>CS_2>CS_5>CS_3>CS_4$. Irrespective of cropping systems, maximum MWD was in 0-7.5 cm depth which significantly decreases with soil depths. Significantly higher MWD was observed in both 0-7.5 and 7.5-15 cm depths compared to 15-22.5 and 22.5-30 cm depths. Significant difference in MWD was in the order of 0-7.5>7.5-15>15-22.5> 22.5-30 cm depths.

Soil bulk density

The pooled data of two cropping seasons pertaining to soil bulk density (BD) in different cropping systems at varying depths is presented in Table 3. Among cropping systems, CS_3 has significantly higher ($p<0.05$) bulk density than CS_1, CS_2 and CS_5. However, no significant difference in BD was observed in CS_3 and CS_4 cropping systems. Among soil depths, BD was significantly lower in 0-7.5 cm depth compared to 7.5-15, 15-22.5 and 22.5-30 cm depths. Bulk density of 7.5-15 cm was also significantly lower than 15-22.5 and 22.5-30 cm depths. However, no significant difference in bulk density was observed in 15-22.5 and 22.5-30 cm depths. Higher bulk density in CS_3 may be attributed to compaction during puddling (Kalita *et al.* 2020). Lower bulk density in CS_1 may be attributed to addition of more organic carbon (Table 3). Similarly Ramanandan and Jogan (2019) observed lower bulk density in organic farming compared to conventional farming. Higher bulk density of lower soil depths is in accordance with Kalita *et al.* (2020) where higher subsoil bulk density was reported due to formation of subsoil compact plough pan.

Descriptive statics of the measured soil properties

Descriptive statistics of measured soil properties is presented in Table 4. The percent mean value of sand, silt, and clay after *rabi* and *kharif* season was 57.5 and 59.8, 27.8 and 28.1, 14.5 and 12.0 respectively. Mean bulk density after, *rabi* and *kharif* season was 1.60 and 1.78 g/cm^3 respectively. The SOC mean value was 7.71 g/kg after *rabi* season and 2.98 g/kg

Table 4. Descriptive statistics of measured soil properties.

Soil Property	Maximum value	Minimum value	Mean	SD	CV
After *rabi* season, the data used for calibrating the model (n=80)					
Sand (%)	64.8	53.1	57.7	3.02	9.00
Silt (%)	29.9	24.5	27.8	1.12	1.25
Clay (%)	19.0	8.0	14.5	3.08	9.35
BD (g/cm^3)	1.80	1.48	1.60	0.08	0.07
SOC (g/kg)	11.1	3.8	7.71	1.87	3.48
pH	8.25	7.1	7.71	0.28	0.08
EC (dS/m)	0.25	0.07	0.17	0.03	0.001
After *kharif* season, the data used for validation of the model (n=80)					
Sand (%)	65.7	53.4	59.8	3.13	9.12
Silt (%)	29.3	24.3	28.1	1.78	1.11
Clay (%)	19.0	5.0	12.0	3.71	13.6
BD (g/cm^3)	1.88	1.68	1.78	0.04	0.02
SOC (g/kg)	11.0	1.5	5.98	1.84	3.35
pH	8.30	7.0	7.92	0.25	0.06
EC (dS/m)	0.23	0.05	0.13	0.03	0.001

Note: Standard deviation (SD); Coefficient of variation (CV).

kharif season. The mean value of soil pH was 7.71 after *rabi* season and 7.92 after *kharif* season. Soil EC mean value was 0.17 dS/m after *rabi* season and 0.13 dS/m after *kharif* season. The standard deviation for sand, silt, clay, BD, SOC, pH and EC were 3.02, 1.12, 3.08, 0.08, 1.87, 0.28 and 0.03 respectively after *rabi* season while these were 3.13, 1.78, 3.71, 0.04, 1.84, 0.25 and 0.03 respectively after *kharif* season.

Relationship between mean weight diameter and soil properties : Mean weight diameter (MWD) was negatively correlated (Table 5) with sand ($R = -0.599$, $p<0.01$), silt ($R = 0.403$, $p<0.01$) and bulk density ($R=0.64$, $p<0.01$) and positively with clay content ($R = 0.729$, $p<0.01$), SOC ($R= 0.756$, $p<0.01$) and EC ($R=0.488$, $p<0.01$).

MWD tend to decrease with the increasing of sand and silt content. This could be explained that the sand and silt cannot form flocculated clay-polyvalent cations-organic matter complex (Totsche *et al*. 2018). MWD increased with the increase in clay content. Clay charged negatively and has been considered as a main parts of soil aggregates forming clay-polyvalent cations-organic matter complex. MWD was significantly correlated to the EC (containing Ca cation) as

Table 5. Pearson correlations among soil properties after rabi season used for calibration of the model.

	MWD	Sand	Silt	Clay	SOC	BD	EC	pH
MWD (mm)	1.00							
Sand (%)	-0.599**	1.00						
Silt (%)	-0.403**	-0.059	1.00					
Clay (%)	0.729**	-0.918**	-0.255*	1.00				
SOC (g/kg)	0.756**	-0.530**	-0.255*	0.604**	1.00			
BD (g/cm^3)	-0.640**	0.120	0.363**	-0.267*	-0.484**	1.00		
EC (dS/m)	0.488**	-0.151	-0.236*	0.271*	0.278*	-0.468**	1.00	
pH	-0.204	0.379**	-0.171	-0.327**	-0.267*	-0.057	0.218	1.00

Number of observations = 80, **Correlation is significant at p<0.01 (2-tailed), *Correlation is significant at p<0.05 (2-tailed).

Table 6. Model validation and statics.

t-test for two samples assuming unequal means			Model performance indicators	
Parameters	Observed MWD	Predicted MWD	Parameters	Values
Mean	0.217	0.228	RMSE (mm)	0.0468
Variance	0.0052	0.0073	Model efficiency (EF)	0.58
Observations	80	80	CRM	-0.054
df	154		R	0.845
t-stat	-0.937		R^2	0.714
P (T<=t) one tail	0.175			
T critical one tail	1.654			
P (T<=t) two tail	0.350			
T critical two tail	1.975			

the soils were calcareous in nature. Soil bulk density was positively correlated with sand and silt and negatively with MWD, clay, SOC and EC. EC increased with increase in clay and SOC.

Model performance: The model predictions for MWD estimation were made based on independent data collected for soil properties after *kharif* 2019 season. The predictions of MWD were compared with the observed values of MWD after *kharif* 2019 season. Results of the MWD estimation were statistically validated (Table 6). The data of predicted and observed MWD were compared through five parameters for testing performance of the model. Coefficient of determination (R^2=0.714) shows significant good correlation and it was also supported by other tests as RMSE (0.0468), ME (0.58), CRM (-0.054). The plot of observed vs predicted MWD shows good correlation (Fig. 1) indicating statistically validation of the model. Based on t-test value (-0.937) and P (T<=t) two tail (0.350), the hypothesis of no significant difference among means of the observed and predicted MWD was accepted indicating the good performance of the regression model.

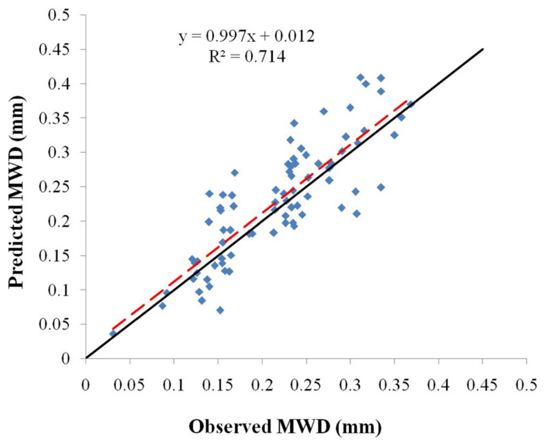

Fig. 1. Deivation of linear relation between predicted and observed MWD (red doted line) from 1:1 line (black line).

CONCLUSION

Conclusively, maximum carbon sequestration was observed in cropping system where carbon recycling through paddy straw mulching and crop residues incorporation with rotavator tillage during every year which further resulted improvement in mean weight diameter, bulk density, pH and electrical conductivity of soil. The improvement in soil physical properties in different cropping systems followed the trend of poplar + turmeric > sugarcane + bottle gourd – broccoli > maize + summer moong – wheat > basmati – wheat > sugarcane fodder. Favorable changes in soil properties were more in surface layers compared to sub surface soil layers. The cropping systems involving less tillage compared to heavy tillage during puddling (in rice (basmati)-wheat) helps in build-up of organic carbon and improvement in soil physico-chemical properties. Soil structural stability indicator MWD tended to decrease with increase in sand (%), silt (%) and bulk density and increased with the increase in clay (%), organic carbon and EC. Results of the MWD estimation model were statistically validated. The comparison of predicted and observed MWD indicated close agreement between means. Significant values of correlation coefficient (R), R^2, RMSE, ME, CRM and t-test statistically validated the model.

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