www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(6): 99-102

www.thepharmajournal.com
Received: 16-03-2023
Accepted: 26-04-2023

PA Mahadule
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, M.P.K.V., Rahuri, Maharashtra, India

NJ Ranshur
Professor, Department of Soil Science and Agricultural Chemistry, M.P.K.V., Rahuri, Maharashtra, India

MR Patil
Assistant Professor, Department of Statistics, M.P.K.V., Rahuri, Maharashtra, India

Corresponding Author:
PA Mahadule
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, M.P.K.V., Rahuri, Maharashtra, India

Particle size distribution models fitting in silty clay and silty clay loam textures soils of Pune district

PA Mahadule, NJ Ranshur and MR Patil

Abstract
The foundation for understanding diverse soil processes is how soil particles work. One of the fundamental and unchanging physical characteristics of soil that is intrinsic is its PSD. By defining the PSD using mathematical models, one can acquire a better understanding of soil texture. The aim of this study was to evaluate the fitting ability of 4 models *i.e*. the Skaggs, Fooladmand, Fredlund, and Gray model on 30 soil samples from Pune district, Maharashtra and to determine the best model among them for the PSD of silty clay and silty clay loam texture soil samples. PSD models were fitted to experimental data using evaluation criterions like root mean square error (RMSE), coefficient of determination (R^2), adjusted coefficient of determination (Adj-R2), Akaike's information criterion (AIC), mean absolute error (MAE), mean absolute percentage error (MAPE) and Chi- square. The result showed that the Fooladmand model were the best suited models for predicting the particle size distribution of silty clay texture soils while In silty clay loam soil texture of Pune district Fredlund model is best fitted for prediction of PSD.

Keywords: Particle size distribution (PSD), Predictor PSD models, Skaggs, Fooladmand, Fredlund, Gray (1,1) model

Introduction
Soil particles function is the basic for understanding various soil processes. The PSD of soil is one of the fundamental and static soil physical properties. Many complex hydrological, geological, (geo) physical, chemical, and biological processes are related in the PSD of a specific soil [3]. It has an impact on the chemical characteristics of soil, including cation exchange capacity, organic carbon content, buffering capacity, and chemical adsorption qualities [1]. PSD has an impact on a variety of soil-related physical characteristics, such as how water and other substances move through the soil, thermal conductivity, available water capacity, water retention, permeability, residual water content, soil aggregate formation, soil colour, soil aeration, specific surface area, erodibility, bulk density, porosity, aggregate stability, and saturated and unsaturated hydraulic conductivities [10].

By using mathematical models to describe the PSD, one can learn more about soil texture. To describe PSD, a variety of models are suggested. The few research compared several PSD models based on mathematics. PSD must be accurately described by a mathematical model in order to reduce the discrepancy between measured and estimated data. This study's goal was to determine how well four PSD models—the Skaggs model [9], the Fooladmand model [4], the Fredlund model [5] and the Gray model (1,1) [11]—fit data on particle-size distribution in silty clay and silty clay loam soil textures found in Pune district, Maharashtra, India.

Material and Methods
The investigation was conducted in the Pune district of Maharashtra, India, at the coordinates (18°31'13" N, 73°51'24" E) (Fig.1). In the aim of studying the physical property i.e. soil texture, and chemical properties like pH, electric conductivity, organic carbon and calcium carbonate, in soils from the Pune district, thirty surface soil samples weighing at least 1.5 kg each were taken and for laboratory analysis, the soil samples were air-dried and put through a 2 mm filter.

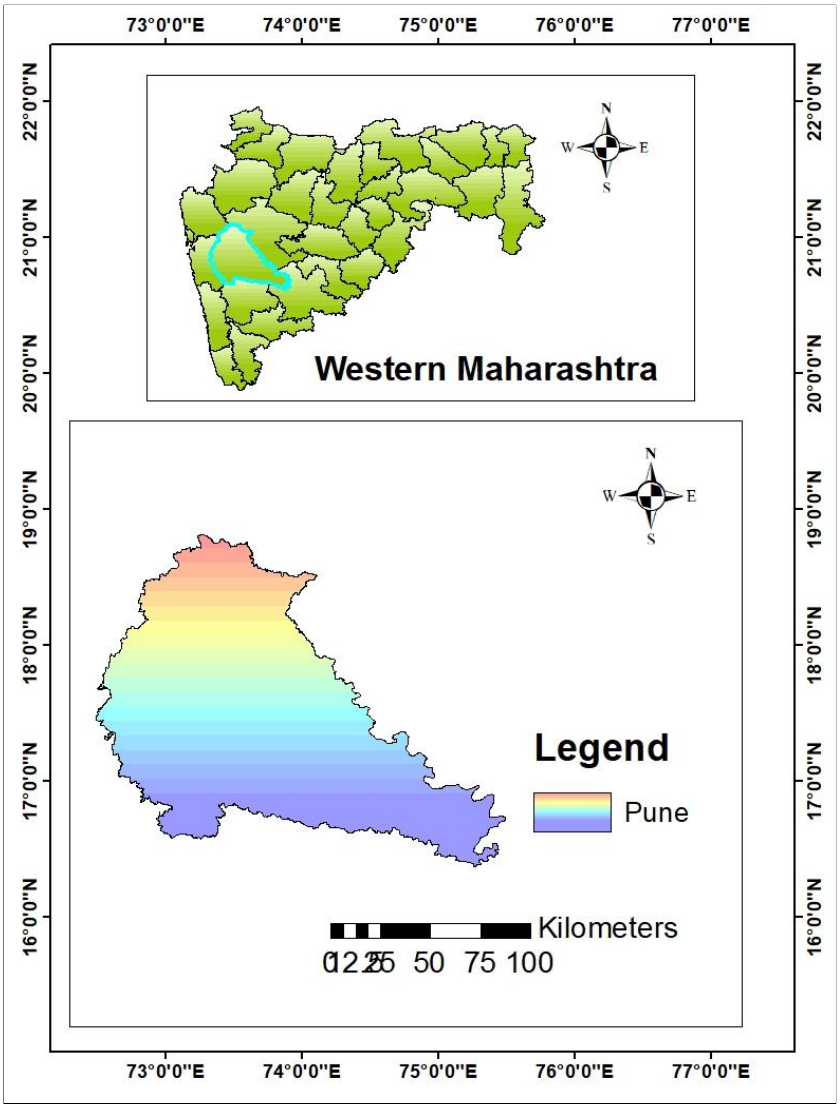

Fig 1: Study Area

After an organic matter-removing H2O2 pretreatment, conventional techniques were employed to determine the PSDs. The identification of the fine size fractions was done using the hydrometer technique, while the estimation of the coarse size fraction was done using sieving [6]. PSD measurements were modelled using 4 PSDs. Fractional data were arranged into categories using the USDA's classification system.

Particle-Size Distribution Models

Several mathematical models were applied in this study to produce continuous PSD curves (Table 1). For fitting PSD soil textural data, we took into account the Skaggs model [9], Fooladmand model [4], Gray model GM (1,1) [11], and unimodal Fredlund equation [5].

Table 1: Particle size distribution models

Name	Model equations	Parameter
Skaggs	$P(r) = \frac{1}{1+\left(C_1^{-1}-1\right) exp\{-\mu(R-1)^c\}}$	μ, c are coefficients
Fooladmand	$P(r) = \frac{1}{1+\left(C_1^{-1}-1\right) exp\{-\mu(R-1)^c\}}$	μ, c are coefficients
Gray	$\hat{P}^{(0)}(r_{k+1}) = \left[P^{(0)}(r_1) - \frac{b}{a}\right][1-\exp(a)]\, exp(-ak)$	a, b are coefficients
Fredlund (F_4p)	$P_p(d) = \frac{1}{\left\{\ln\left[\exp(1)+\left(\frac{a_{gr}}{b}\right)^{n_{gr}}\right]\right\}^{m_{gr}}}\left\{1-\left[\frac{ln\left(1+\frac{d_{rgr}}{d}\right)}{ln\left(1+\frac{d_{rgr}}{d_m}\right)}\right]^7\right\}$	a_{gr}, n_{gr}, m_{gr} and d_{rgr} are parameter showing inflection point, steepest slope, shape of the curve and amount of fines in a soil respectively.

Fitting procedure

The observed cumulative PSD data were used to fit the parametric functions using an iterative nonlinear optimization process. The SAS routine operator of the Microsoft Excel programme was used for this. Several selection criteria, including the root mean square error (RMSE), coefficient of determination (R^2), adjusted coefficient of determination (Adj-R^2), and Akaike's information criterion, were used to assess the suitability of the fitted model (AIC).

Results and Discussion

The soils of Pune district differed widely in their PSD. The data showed that, the sand per cent of the analysed soil samples of various locations ranged from 8.5 to 79.4 per cent with mean value 44.0 with a standard deviation of 20.6. The silt percentage of the soil samples analyzed ranged from 4.2 to 52.3, with a mean of 28.3 and a standard deviation of 12.7. While the percentage of clay in the analyzed soil samples ranged from 7.9 to 53.8 per cent, with a mean value of 30.9 per cent and a standard deviation of 11.8.the clay content ranged from 10.9 to 66.6 per cent with mean value of 38.8 per cent. The particle size distribution of 30 samples of Pune district were evaluated and it was observed that 26.67 per cent samples belonged to clay texture, 26.67 per cent samples to clay loam texture, 23.33 per cent samples to sandy clay loam texture, 6.67 per cent samples to sandy loam texture, 3.33 per cent sample to loam texture, 6.67 per cent samples to silty clay texture and 6.67 per cent samples to silty clay loam soil texture.

The value of pH in the soils of Pune district ranged from 6.37 to 8.43, with an average value of 7.40 and with an standard deviation of 0.47. It was observed from the data that, EC (dSm^{-1}) of soils of Pune district ranged from 0.12-0.83 dSm^{-1} with an average value of 0.48 dSm^{-1} and with an standard deviation of 0.21. The organic carbon content of soils of Pune district ranged from 0.15-1.10 per cent and with an average value of 0.63 per cent and with a standard deviation of 0.21 and calcium carbonate content varied in between 0.43-10.88 per cent with an average value of 5.66 per cent and with a standard deviation of 3.39.

Evaluation criteria comparison for goodness-of-fit of the PSD models on silty clay and silty clay loam soil texture found in Pune district

The data on evaluation criteria comparison for goodness-of-fit of the PSD models on silty clay and silty clay loam texture soils of Pune district was represented in Table 2.

In silty clay and silty clay loam soil texture, RMSE values for Fredlund model is low *i.e* 0.038 and 0.032 respectively. The high value (0.054) was found in Gray (1,1) model in silty clay texture. While in silty clay loam texture, the Fooladmand model had a high value (0.044).

In silty clay soil texture the mean values of R^2 and Adj R^2 ranged from 0.934 to 0.971 and 0.930 to 0.962, respectively. while Gray (1,1) model had the lowest R^2 and Adj R^2 values. In silty clay loam soil texture the R^2 and Adj R^2 mean values varied from 0.950 to 0.982 and 0.946 to 0.975. The Fredlund model had the highest values in both soil texture.

The AIC values ranged from -107.49 to -82.64 and -103.89 to -83.87 in silty clay ad silty clay loam soil texture. The Skaggs model performed the poorest as reflected by their high mean AIC values, whereas the Fooladmand model and Fredlund model performed well as indicated by low mean AIC values

The mean values of MAE among the models differed widely from 0.001 to 0.261 and 0.0001 to 0.013. This does not showed the significant difference among models performance. In silty clay soil texture, the highest MAPE value was obtained with Fredlund model (4.63%) and the lowest MAPE value was obtained for Gray (1,1) model (1.0%). While the Skaggs model yielded the highest MAPE value (2.46%) and the lowest MAPE (per cent) value was (0.1%) in silty clay loam soil texture.

The chi-square values of the studied models in silty clay and silty clay loam soil texture ranged from 0.003 to 1.81 and 0.005 to 0.037 respectively. Highest value was showed by Fredlund model and Gray (1,1) model in silty clay and silty clay loam soil texture respectively however lowest value showed by Fooladmand model.

According to validation of all regression criterion for best fitting models to particle size distribution data, it was observed that rank sum of Fooladmand model is lowest in silty clay soil texture so it performed well for fitting of models and closely followed by Fredlund model. It might be due to particle size distribution of sandy clay loam texture may followed logistic type equation [1, 8]. In silty clay loam soil texture the Fredlund model was found to be better fitted model.

Table 2: Evaluation criteria comparison for goodness-of-fit of the PSD models on silty clay and silty clay loam texture soils of Pune district

Texture	Models	Evaluation criteria							
		RMSE	R^2	Adj R^2	AIC	MAE	MAPE (%)	Chi-Sq.	Rank sum
Silty clay	Skaggs model	0.040	0.956	0.952	-83.87	0.009	1.50	0.004	20
	Fooladmand model	0.039	0.967	0.962	-103.89	0.009	1.46	0.003	13
	Fredlund model	0.038	0.971	0.962	-101.25	0.261	4.63	1.81	17
	Gray (1,1) model	0.054	0.934	0.930	-93.57	0.001	1	0.054	20
Silty clay loam	Skaggs model	0.042	0.950	0.946	-82.64	0.013	2.46	0.009	25
	Fooladmand model	0.044	0.960	0.957	-99.84	0.012	2.00	0.005	20
	Fredlund model	0.032	0.982	0.975	-107.49	0.0001	0.1	0.018	9
	Gray (1,1) model	0.041	0.964	0.962	-102.71	0.001	1	0.037	16

Conclusion

In study of prediction of PSD, Skaggs, Fooladmand, Fredlund, and Gray (1,1) were extremely successfully fitted to the data sets. According to the goodness of fit statistics, there were only slight variations amongst the models in terms of RMSE, R^2 Adj-R^2, AIC, MAE, MAPE, and chi-sq. Overall results showed that the Fooladmand model were the best suited models for predicting the particle size distribution of silty clay texture soils. In silty clay loam soil texture of Pune district Fredlund model is best fitted for prediction of PSD.

References

1. Bayat H, Rastgo M, Zadeh MM, Vereecken H. Particle size distribution models, their characteristics and fitting capability. Journal of hydrology. 2015;529:872-889.
2. Esmaeelnejad L, Siavashi F, Seyedmohammadi J,

Shabanpour M The best mathematical models describing particle size distribution of soils. Modeling Earth Systems and Environment. 2016;2(4):1-11.
3. Filgueira RR, Fournier LL, Cerisola CI, Gelati P, García MG. Particle-size distribution in soils: A critical study of the fractal model validation. Geoderma. 2006;134(3-4):327-334.
4. Fooladmand HR, Sepaskhah AR. Improved estimation of the soil particle-size distribution from textural data. Biosystems Engineering. 2006;94(1):133-138.
5. Fredlund MD, Fredlund DG, Wilson GW. An equation to represent grain-size distribution. Canadian Geotechnical Journal. 2000;37:817-827.
6. Gee GW, Bauder JW. Particle-size analysis. In Klute, A. (ed.) Methods of Soil Analysis–part 1, 2nd education, Agronomical Monograph 9, ASA and SSSA, Madison. WI; c1986. p. 383-411.
7. Hwang SI, Lee KP, Lee DS, Powers SE. Models for estimating soil particle-size distributions. Soil Science Society of America Journal. 2002;66:1143-1150.
8. Vishkaee F, Davatgar N. Evaluation of different predictor models for detailed soil particle-size distribution. Pedosphere. 2018;28(1):157-164.
9. Skaggs TH, Arya LM, Shouse PJ, Mohanty BP. Estimating particle-size distribution from limited soil texture data. Soil Science Society of America Journal. 2001;65:1038-1044.
10. Vereecken H, Weynants M, Javaux M, Pachepsky Y, Schaap MG, Van Genuchten MT. Using pedotransfer functions to estimate the van Genuchten–Mualem soil hydraulic properties: A review. Vadose Zone Journal. 2010;9(4):795-820.
11. Wu CM, Wen JC, Cheng KC. Evaluation of the Gray model GM (1,1) applied to soil particle distribution. Soil Science Society of America Journal. 2009;73:1775-1785.