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Characterizing the Error Structure of Selected Soil Particle Size Distribution Models

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Introduction: Particle size distribution (PSD) is one of the most fundamental features of soil physics that is widely used as the most common input to predict several key soil attributes. The mathematically representing the PSD provides several benefits to soil mechanics, physics, and hydrodynamics as well as helps to convert PSD data of various particle size classification systems to the desired one. Consequently, the correct and consistent descriptions of soil PSD using mathematical functions is necessary.

The PSD models have often been evaluated in terms of their general performances to predict the entire PSD curve. Although given model may be feasible and globally perform well to generate the whole PSD curve, locally may fail to predict some specific points on the curve. To our knowledge, as well as, PSD models have not been widely tested for salt-affected soils with different levels of salinity and sodicity.

The aim of this study was to determine the error structure of several more accurate PSD models in selected soil samples with different levels of salinity and sodicity.

Materials and Methods: 24 locations neighboring the western edge of threatened hypersaline Lake Urmia were sampled in this study. The locations were selected based on the available soil maps and soils with wide range of salinity/sodicity were sampled. Selected physical and chemical properties of the soil samples were determined by standard methods. The performance of six PSD models including Modified Logistic Growth (MLG), Fredlund type models with three (Fred-4p) and four (Fred-3p) parameters, Anderson (AD), ONL, and Weibull (Wei), which have been reported as the most accurate PSD models by previous studies, was evaluated using different efficiency criteria that offer various performances depending on the range of particle sizes.

An iterative nonlinear optimization procedure was used to fit the observed cumulative PSD data of the soils to the PSD models. Since every statistical criterion evaluates a part and some (and not all) aspects of the correspondence between measured and predicted values, we suggest that an effective assessment of model performance should include a suitable combination of criteria. Furthermore, dependency of the models performance was examined to the range of soil particle sizes.

Results and Discussion: The soils differed widely in their EC (range = 85dS/m and CV = 159%), ESP (range = 67 % and CV = 71 %), and PSD (CV of clay and silt particles, 48 and 55 %, respectively). Soil textural class of the soils was differed widely from sandy loam to clay. All the soils were calcareous and alkaline.

The results showed that according to the efficiency criteria, including R^2 (coefficient of determination), RMSE (Root Mean Square Error) and Er (Relative Error), all of the models have high efficiency, so that, the lowest average value of R^2 in models was 0.992 and the maximum value of RMSE and Er was 0.028 and 0.045, respectively.

Prediction error of the models was dependent on the diameter for which we predict the cumulative fraction and decreases with increasing of the soil particles diameter. The performance of the models showed a significant quadratic polynomial relationship with sand content of the samples, so that, the studied models had the lowest performance in soils containing 30 to 45 percent sand.

The point-to-point error structure of the model represents a decrease in systematic error in estimating coarse soil particles, while the models over-estimated the relative frequency of the fine soil particles. In addition, the values of relative error were also lower for coarse particles of the soil, so that, the Wei model (for example) had the lowest Er value for 100 to 500 μm diameter soil particles. The relatively high correlations between parameters of Fred-3p, MLG and ONL models show insights to reduce the number of their parameters.

Furthermore, parameters a and c of MLG model, parameters μ and α of ONL model and parameter α and m of Fred-3p model had a statistically significant correlations. The relatively high correlations between parameters

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of the PSD models show insights to reduce the number of their parameters which increases their applicability.

Conclusion: The studied models generally performed well to predict the whole PSD curve, but their performances were particle size dependent. This implies that, one should consider the range of sizes of soil particles for different models. A model might be accurate enough to predict some ranges of particle diameter or the whole PSD, but not for particular range of particle sizes. Using such models might lead to large errors in predicting the specific PSD range of interest.

Keywords: Lake Urmia, Prediction error, Saline-sodic soil, Soil texture