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Modeling cation exchange capacity in multi geochronological-derived alluvium soils: An approach based on soil depth intervals

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ABSTRACT

Knowledge of soil chemical properties is indispensable to conduct sustainable land use management in alluvial areas. In this study we developed specific pedotransfer functions for cation exchange capacity (CEC-PTFs) in alluvial soils based on soil depth intervals. A soil data set (n = 1094 samples) at different depths from three different Nile River terraces (lower, middle, and upper) and the lower and upper Blue Nile terraces in Sudan was randomly collected and divided into a training data set (n1 = 900 samples) and a testing data set (n2 = 194 samples) for validation. Soil pH, texture, and organic matter were used as predictor variables to estimate CEC. PTF performance was evaluated with the coefficient of determination (R^2), root mean square error (RMSE), and standard error for the estimate (SEE) between the observed and predicted values. Fourteen predictive equations were developed. Results revealed that the CEC of topsoil layers of the lower Nile River terrace were the most difficult to predict (r^2 = 0.29 for training) while the deep soil layers (60–120 cm) of the Blue Nile terraces were predicted well (r^2 = 0.99 for training). Sixty to 76% of CEC variation of the subsoil of the Nile River terraces could be explained by clay alone. From 85 to 90% of the CEC variation in the deep soils could be explained by organic matter, total silt, and total clay. Validated results indicate that the predictive models based on total clay were less reliable at predicting CEC in the top soil layers. Overall, the CEC-PTFs generated by multiple linear regression models (MLR) provided a reasonable estimate of CEC for most soils investigated.

1. Introduction

Soil cation exchange capacity (CEC) is important in agronomy, soil chemistry, and soil fertility (Khaledian et al., 2017a, 2017b). Despite this importance, there is a lack of global CEC datasets because traditional measurement is costly and time-consuming (Carpena et al., 1972; Fernando et al., 1977; McBratney et al., 2002; Amini et al., 2005; Budiman and Alfred, 2011).

There has been a recent emphasis on predicting unknown soil chemical properties using commonly measured properties. According to Viscarra et al. (2006), soil properties can be directly predicted by infrared absorption associated with functional groups, including organic carbon, total nitrogen, clay composition, soil CEC, and soil texture. However, as stated by Naes et al. (2002), soil properties can only be predicted if they fall within the calibration settings.

Numerous studies have attempted to develop pedotransfer functions (PTFs) to predict the CEC in various soils over the world. This has been accomplished using models that linked CEC to other soil properties using statistical tools such as multiple linear regression (MLR) (Bell and Van Keulen, 1995; Drake and Motto, 1982; Sahrawat, 1983; Yuan et al., 1967; Yukselen and Kaya, 2006; Olorunfemi et al., 2016), the combination of MLR and artificial neural networks (ANNs) (Bayat et al., 2014), of MLR, ANNs and adaptive neuro-fuzzy inference (ANFI) (Hadi et al., 2015), and more recently a combination of genetic expression programming (GEP) and multivariate adaptive regression splines (MARS) (Emamgolizadeh et al., 2015).

Despite the considerable progress in CEC prediction using the above-mentioned models, it appears that studies to develop CEC-PTFs for alluvial soils have not yet been conducted. This is attributed to the fundamental differences in the natural environmental conditions close to flood areas and specifically mechanisms of pedogenesis. Consequently, there are difficulties in CEC prediction in these soils

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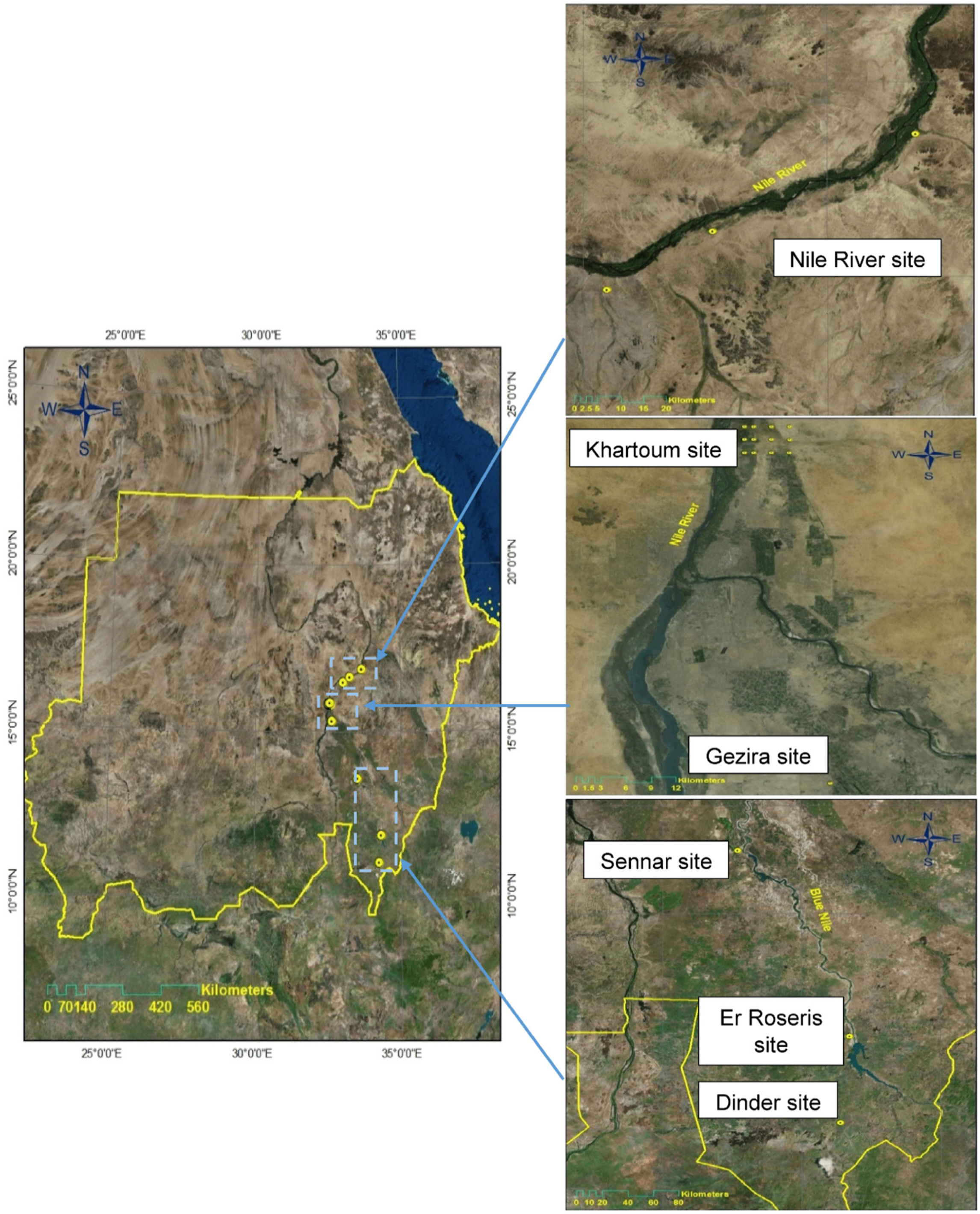

Fig. 1. The study area showing some of the selected profiles sites along the Nile River and Blue Nile.

using conventional pedotransfer functions.

Alluvial soils are widely used for intensive agricultural production around the world due to their high quality (Bertalan et al., 2016). However, non-suitable land use management can negatively affect soil properties and only well-planned decisions by farmers and policy makers can correct this situation (Lam et al., 2011; Acín-Carrera et al., 2013).

In Sudan, most of the irrigated intensive vegetable and fruit cropping areas are largely situated within the alluvial plains of the Blue Nile, White Nile, and River Nile terraces. Little research has been conducted on the soil properties of these terraces (Sulieman et al., 2016). Thus, this study seeks to develop pedotransfer functions to estimate the CEC in these alluvial soils based on soil depth intervals. The main aims of this study are to: (1) Test the hypothesis that the establishment of CEC-PTFs in alluvial soils based on soil depth intervals could provide a reasonable estimate of soil CEC; and, (2) develop CEC-PTFs models that work comprehensively for the alluvial soils in Sudan that could be applied in other research areas.

Soil pH, texture, and organic matter were the predictor variables used. The general performance of PTFs was evaluated based on the coefficient of determination (R^2), mean error (ME), root mean square error (RMSE), and standard error for the estimate (SEE) between the