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Application of artificial neural network for prediction of Sudan soil profile

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Abstract

The aim of this paper is to predict the natural geotechnical profile of Sudan country, which is very important and vital for all civil engineering work. Availability of pre-predicted profile before performing drilling and boring minimize time and cost. To achieve this goal Artificial Neural Networks (ANNs) program is used. This program has capabilities to study and process the problems that have complex variable, such as Sudan topographical profile. Five main ANN models were constructed based on the soil data of 1909 boreholes from 417 sites. These models use the three dimensional coordinates as input data to predict soil profile and soil parameters at different locations. Artificial Neural Networks is found to have the acceptable ability to predict the soil classification and soil parameters in Sudan. The lack in accuracy in some predicted data when compared with the soil profile obtained from actual boreholes is due to inconsistency of coordinates and depth.

Keywords

Soil Profile, Artificial Neural Networks, Sudan, Prediction

1. Introduction

The type of soil and rock is the main factor that determines the type of foundations. Therefore, the foundation engineer must be able to distinguish among the various deposits of different character, to identify their principal constituents and to determine their physical properties [6], [7].

Recently Artificial Neural Network (ANN) models have been applied on civil engineering areas such as geotechnical engineering .It can be used to model complex relationships between input and output.

2. Application of neural network on Sudan Soil profile

Neural networks are typically organized in layers. Layers are made up of a number of interconnected 'nodes' which contain an 'activation function'. Patterns are presented to the network via the 'input layer', which communicates to one or more 'hidden layers' where the actual processing is done via a system of weighted 'connections'. The hidden layers then link to an 'output layer' where the answer is output.

There are hundreds of different neural network types that can be classified in various ways, e.g. in the way they are trained (supervised, unsupervised, or reinforced), how the information flow in the network is organized (feedback, feed forward), how the topology is built (static or self-organizing). Another way to classify neural networks is by distinguishing between the training algorithms that are used to adjust the weights. In this case, the number of different training algorithms is even larger than the number of neural network types.

In this study Multi-layer Back propagation neural networks was developed to demonstrate the feasibility of ANNs to predict soil classification and soil parameters networks. The output is based on the available sites data provided from borehole logs bored by Building and Road Research Institute (BRRI) of the University of Khartoum,

Dreams Tower Company, Sudan Pile Company and Itgan Company for different purpose. Five models were developed to predict soil profile explained in table (1), [1], [2], [3], [4] &[5].

Table 1. *No of Models in Sudan.*

Model No	Model name
Model 1	Sudan (center)
Model 2	Sudan (east)
Model 3	Sudan (west)
Model 4	Sudan (south)
Model 5	Sudan(north)

Eight classifier sub-models and two parameter sub-models were developed for the different five models to predict their soil profile. These models are defined as the input and the output of the network as explained in Table (2). Classifier sub-models in any models are used to classify soil layers at different locations and depth in Sudan depend on type of soil, while parameters sub-models are used to estimate some value of soil's parameters in different layers. The results were evaluated according to the value of the coefficient of multiple determinations (R^2).

The value of R^2 is ranged between (0-1). The general formula of neural network used for R^2 is as follows: [5]
R^2

Where:

$$SSE = \sum (Y - \hat{Y})^2$$

$$SSyy = \sum (Y - \bar{Y})^2$$

Y is acual value.
($\hat{Y}$) is predict value of Y.
And $\bar{Y}$ is mean of the Y value.

In this paper the models performance is evaluated depending on R^2. A perfect model fit would result in an R^2value of 1, a very good fit near 1, and a very poor fit is it less than 0.But $R^2$is not the ultimate measure of whether or not network is producing good results. It might be decided of that network is accepted without obtaining a high level of R^2 value and the judgment in this case is due to the number of correct classifications.

Table 2. *Input and Output Data of ANN*

Input data	Output Data				
Models	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
E,N coordinate and depth	Silty/clay Sand	Silty/gravel Silty/sand	Silty/sand Sandy	Silty/clay clayey	Sand Silty/sand
E,N coordinate and depth	Clayeysilt Clayeysand	Silty/clay Sandy/clay	Silty/clay Sandy/clay	Silty/sand clayey/Sand	Silty/clay Sandy/clay
E,N coordinate and depth	GW	GW GP	GS GC	GP	GM GC
E,N coordinate and depth	GC	GS	GM	GC GM	GS GS
E,N coordinate and depth	SP	GC GM	SW SP	SP	SW SP
E,N coordinate and depth	SC SM	SP	SC SM	SM	SM
E,N coordinate and depth	CH CL	SC SM	CH CL	CH CL	CH CL
E,N coordinate and depth	MH ML	ML CL	MH ML	MH ML	MH ML
E,N coordinate and depth	Pass200%	Pass200%	Pass200%	Pass200%	Pass200%
E,N coordinate and depth	L.L P.I	L.L PI	L.L PI	L.L P.I	L.L P.I

3. Results

Regarding to the available data and their quality, the input data are chosen to cover all the area of Sudan and the output concentrated on ten predicted models for areas at Sudan (center) , Sudan (east) , Sudan (west), Sudan (south) and Sudan (north) shown in Figures (1), (2), (3), (4) and (5). This zoning depends on type of soil.

The notation of the soil groups in Table 2 followed the classification of the Unified System of Classifying Soils (USCS). L.L and PL stand for liquid limits and Plastic Index.

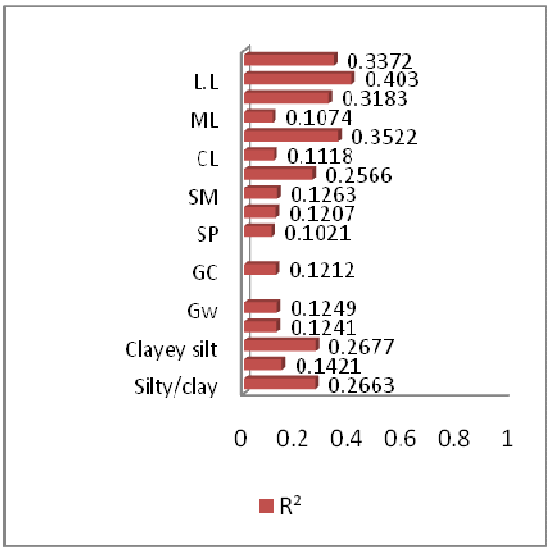

Fig1. The performance of artificial neural networks in Sudan (center)

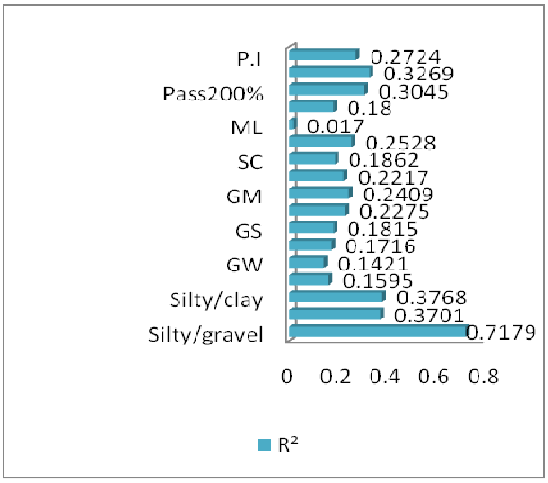

Fig 2. The performance of artificial neural networks in Sudan (east)

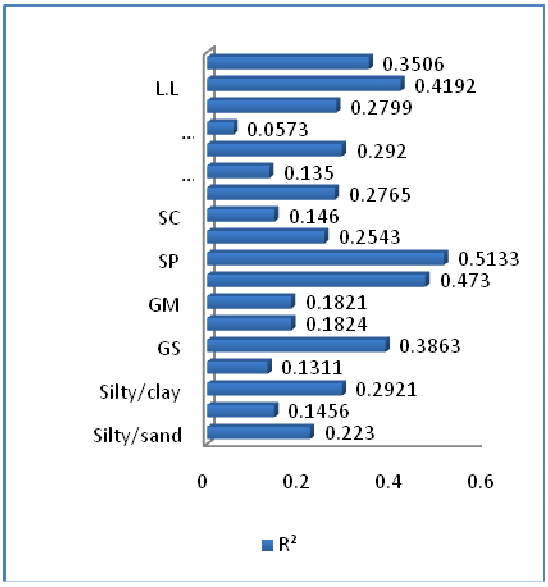

Fig3. The performance of artificial neural networks in Sudan (west)

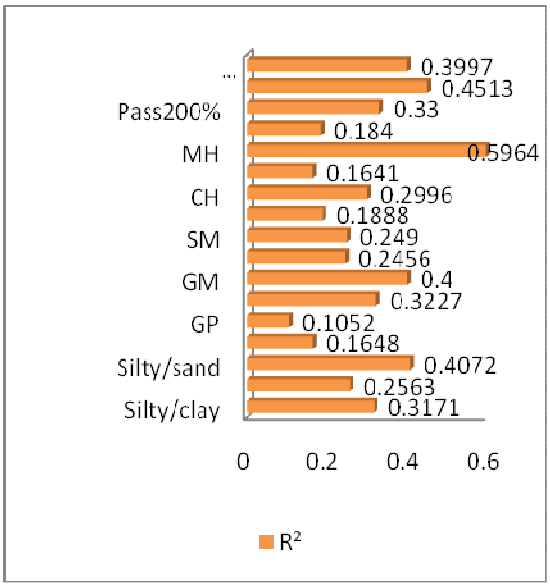

Fig4. The performance of artificial neural networks in Sudan (south)

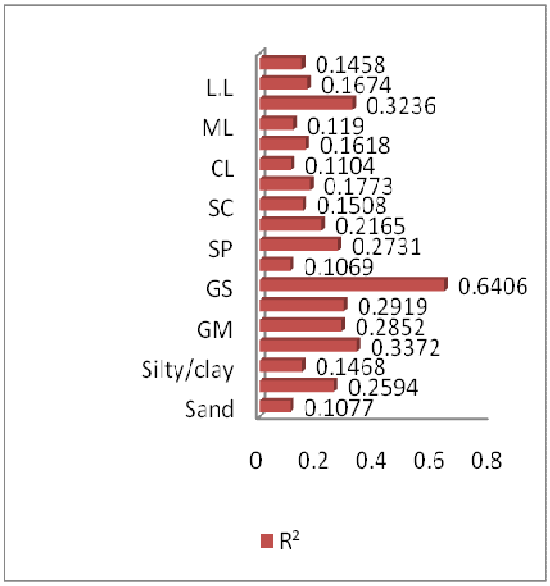

Fig5. The performance of artificial neural networks in Sudan (north)

4. Discussions

The values of R^2 indicate the performance of the model at different zones. In centre zone the model gives a maximum value of R^2 equal to 0.4. This value is considered low but acceptable for preliminary investigation. A very good prediction is expected from east model (R^2= 0.72) followed by the north one (R^2 = 0.64).

South model give values of R^2 = 0.6 for Silty soils of high plasticity. The values of R^2 in west model reaches 0.51 for poorly graded sand. This confirms the well known fact that sands are encountered at the top layers of this area.

The information provided from soil reports are used for prediction of soil classification and parameters using neural network technology.

The predicted values of liquid limit and plastic index have

always low values of R^2. This may be due to lack of parameters data. Also inconsistency of coordinates and depth may play a big role in prediction.

Evaluation for models performance depends on R^2. From previous figures it can be seen, in general, reasonable result of prediction is obtained. A considerable amount of data was made available for the training process. A good prediction of soil profile was produced from this model. ANNs are efficient tools when used as pattern classifier. Results obtained from the ANNs Atterberg limits model show that ANNs with proper training is a good tool for prediction especially for liquid limit value. Results obtained from ANN sieve analyses model show that ANNs with proper training gives high performance in prediction.

5. Conclusion

From the results obtained from this study, it can be concluded that:

The advantages of using neural networks to predict soil profiles is that neural networks are able to automatically create an internal distributed model of the problem during training, that make them a powerful and practical tool for soil classification prediction.

ANNs are efficient tools when used as pattern classifier more than used for parameters prediction.

ANNs may be used as a good decision support and source of information for Sudan if divide all data to zones.

The predicted values of soil parameters e.g. liquid limit and plastic index have always low values of R^2. This may be due to lack of parameters data as well as the inconsistency of coordinates and depths.

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