ARPN Journal of Agricultural and Biological Science

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MODELING OF SOIL TOTAL NITROGEN BASED ON SOIL ORGANIC CARBON

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ABSTRACT

There are many cases in which it is desirable to determine empirical relationships among some soil physical and chemical properties. For instance, soil total nitrogen (TN) are often determined using laborious and time consuming laboratory tests, but it may be more suitable and economical to develop a method which uses easily available soil properties. In this study, a linear regression model for predicting soil TN from soil organic carbon (OC) was suggested and soil TN was estimated as a function of soil OC. The soil TN predicted from the soil TN-OC model was compared to the soil TN determined by laboratory test using the paired samples t-test and the Bland-Altman approach. The soil TN predicted by the soil TN-OC model was not significantly different from the soil TN determined by laboratory test ($P > 0.05$). The mean difference between the soil TN-OC model and laboratory test was -0.002% (95% confidence interval: -0.008 and 0.004%; $P = 0.510$). The standard deviation of the soil TN differences was 0.011%. The statistical results of the study indicated that the soil TN-OC model provides an easy, economic and brief methodology to estimate soil TN and in order to predict soil TN based on soil OC the soil TN-OC model TN = 0.026 + 0.067 OC with $R^2 = 0.83$ can be recommended.

Keywords: model, soil, total nitrogen, organic carbon, prediction.

INTRODUCTION

Soil organic carbon (OC) and soil total nitrogen (TN) have long been identified as factors that are important to soil fertility in both managed and natural ecosystems (Kucharik *et al.*, 2001). It is well established that nitrogen (N) is the macronutrient often limiting the growth of plants on soil (Vitousek, 1982; Vitousek and Farrington, 1997; Michopoulos *et al.*, 2008). Moreover, soil organic matter, and consequently soil OC is one of the most important attributes of a soil because it affects nutrient cycling, soil structure and water availability. Maintaining, or better yet, increasing soil OC content is an important measure of the sustainability of a cropping system. In this direction, the USDA has developed a soil conditioning index that is a tool that can predict the consequence of cropping systems and tillage practices on the trend of soil OC accumulation (USDA, 2002). A positive index is the first criteria used in the conservation security program (USDA, 2004). Overall, management practices that contribute to increasing soil OC levels include those that add more OC to the soil than the amount removed from the system (e.g. crop residues), increase the diversity of OC added (e.g. manure), or decrease the rate of OC loss (e.g. reduced tillage) (Magdoff and Weil, 2004).

Numerous field studies have shown that crop management practices can either enhanced or diminish quantities of soil OC and soil TN together (Bauer and Black, 1981; Voroney *et al.*, 1981; Campbell and Souster, 1982; Odell *et al.*, 1984; Mann, 1986; Darmody and Peck, 1997; Paustian *et al.*, 1997; Buyanovsky and Wagner, 1998; Dick *et al.*, 1998; Potter *et al.*, 1998; Knops and Tilman, 2000; Kucharik *et al.*, 2001). One hypothesized goal of sustainable agriculture is to increase soil OC and soil TN, or to maintain these quantities close to native levels (Odell *et al.*, 1984).

For almost 50 years many attempts have been made to predict some complex soil properties from some easily available soil properties using empirical models. In soil science, such empirical models are named pedotransfer functions (MacDonald, 1998; Krogh *et al.*, 2000). Up to now many of the models have been developed to predict various soil properties. MacDonald (1998) developed two models to predict soil Cation Exchange Capacity (CEC) based on soil Organic Carbon (OC) and soil Clay (CL) as CEC = 2.0 OC + 0.5 CL and CEC = 3.8 OC + 0.5 CL for Quebec and Alberta soil state in Canada, respectively. Seilsepour and Rashidi (2008c) studied Varamin soils in Iran and proposed a model to predict soil Cation Exchange Capacity (CEC) based on soil Organic Carbon (OC) and soil pH (PH) as CEC = 26.76 + 8.06 OC – 2.45 PH with $R^2 = 0.77$. Seilsepour and Rashidi (2008a) also predicted soil Cation Exchange Capacity (CEC) from soil Organic Carbon (OC) using the model CEC = 7.93 + 8.72 OC with $R^2 = 0.74$ for Varamin soils in Iran. Moreover, the United States Salinity Laboratory (USSL) developed one of the earlier model to predict soil Exchangeable Sodium Percentage (ESP) from soil Sodium Adsorption Ratio (SAR) as ESP = – 0.0126 + 0.01475 SAR for United States soils (Richards, 1954). Besides, Rashidi and Seilsepour (2008) proposed a model to predict soil Exchangeable Sodium Percentage (ESP) based on soil Sodium Adsorption Ratio (SAR) as ESP = 1.95 + 1.03 SAR with $R^2 = 0.92$ for Varamin soils in Iran. Furthermore, Al-Busaidi and Cookson (2003) predicted soil Sodium Adsorption Ratio (SAR) from soil Electrical Conductivity (EC) using the model SAR = 0.464 EC + 7.077 with $R^2 = 0.83$ for saline soils in Oman. Seilsepour

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and Rashidi (2008b) also developed a model to predict soil Sodium Adsorption Ratio (SAR) based on soil Electrical Conductivity (EC) as SAR = 1.91 + 0.68 EC with R^2 = 0.69 for Varamin soils in Iran.

Since, the above empirical models have been derived from different zone soils, the general empirical models between soil properties may be assumed to be similar to those. However, these empirical models have been shown not to be constant, but to vary substantially with both solution ionic strength and the dominant clay mineral present in the soil (Shainberg *et al.* 1980; Nadler and Magaritz 1981; Marsi and Evangelou 1991; Evangelou and Marsi 2003; Rashidi and Seilsepour 2008). Therefore, the empirical models are not constant and should be determined directly for the soil of interest.

In view of the fact that previously researches report a relationship between soil OC and soil TN, soil OC can be used to approximate or estimate soil TN. Therefore, the specific objective of this study was to develop a soil TN-OC model for calcareous soils of Varamin region in Iran, and to verify the developed model by comparing its results with those of the laboratory tests.

MATERIALS AND METHODS

Experimental procedure

One hundred and three soil samples were taken at random from different fields of experimental site of Varamin, Iran. The site is located at latitude of 35°-19'N and longitude of 51°-39'E and is 1000 m above mean sea level, in arid climate in the center of Iran. The soil of the experimental site was a fine, mixed, thermic, Typic Haplocambids clay-loam soil.

In order to obtain required parameters for determining soil TN-OC model, some soil physical and chemical properties i.e. sand, silt, clay, pH, organic carbon and total nitrogen of the soil samples were measured using laboratory tests as described by the Soil Survey Staff (1996). Physical and chemical properties of the one hundred and three soil samples used to determine the soil TN-OC model are shown in Table-1.

Also, in order to verify the soil TN-OC model by comparing its results with those of the laboratory tests, fifteen soil samples were taken at random from different fields of the experimental site. Again, sand, silt, clay, pH, organic carbon and total nitrogen of the soil samples were determined using laboratory tests as described by the Soil Survey Staff (1996). Physical and chemical properties of the fifteen soil samples used to verify the soil TN-OC model are shown in Table-2.

Regression model

A typical linear regression model is shown in Eq. (1):

$$Y = k_0 + k_1 X \tag{1}$$

Where

Y = Dependent variable, for example TN of soil
X = Independent variable, for example OC of soil
k_0, k_1 = Regression coefficients

In order to develop the soil TN-OC empirical model based on soil OC, a linear regression model as Eq. (1) was suggested.

Table-1. The mean values, Standard Deviation (S.D.) and Coefficient of Variation (C.V.) of soil physical and chemical properties of the one hundred and three soil samples used to develop the soil TN-OC model.

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Sand (%)	14.0	44.0	33.1	6.31	19.1
Silt (%)	30.0	56.0	45.3	4.13	9.12
Clay (%)	9.00	50.0	22.0	6.65	30.2
pH	7.00	8.10	7.50	0.27	3.60
Organic carbon (%)	0.31	1.60	0.77	0.36	47.1
Total nitrogen (%)	0.04	0.13	0.08	0.03	34.1

Table-2. The mean values, Standard Deviation (S.D.) and Coefficient of Variation (C.V.) of soil physical and chemical properties of the fifteen soil samples used to verify the soil TN-OC model.

Parameter	Minimum	Maximum	Mean	S.D.	C.V. (%)
Sand (%	10.0	34.0	24.1	5.87	24.4
Silt (%)	40.0	56.0	48.2	4.40	9.13
Clay (%)	18.0	50.0	28.2	7.90	28.0
pH	7.00	8.00	7.31	0.33	4.51
Organic carbon (%)	0.25	1.70	0.77	0.42	54.8
Total nitrogen (%)	0.05	0.14	0.08	0.03	35.8

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Statistical analysis

A paired samples t-test and the mean difference confidence interval approach were used to compare the soil TN values predicted using the soil TN-OC model with the soil TN values measured by laboratory tests. The Bland-Altman approach (1999) was also used to plot the agreement between the soil TN values measured by laboratory tests with the soil TN values predicted using the soil TN-OC model. The statistical analyses were performed using Microsoft Excel (Version 2003).

RESULTS

The p-value of the independent variable, Coefficient of Determination (R^2) and Coefficient of Variation (C.V.) of the soil TN-OC model is shown in Table-3. Based on the statistical result, the soil TN-OC model was judged acceptable. The R^2 value and C.V. of the soil TN-OC model were 0.83 and 9.5%, respectively. The soil TN-OC model is given in Eq. (2).

$$TN = 0.026 + 0.067OC \quad (2)$$

Table-3. The p-value of independent variable, Coefficient of Determination (R^2) and Coefficient of Variation (C.V.) of the soil TN-OC model.

Model	**Independent variable**	**p-value**	R^2	**C.V.** (%)
$TN = k_0 + k_1$ OC	OC	7E-41	0.83	9.5

DISCUSSIONS

A paired samples t-test and the mean difference confidence interval approach were used to compare the soil TN values predicted using the soil TN-OC model with the soil TN values measured by laboratory tests. The Bland-Altman approach (1999) was also used to plot the agreement between the soil TN values measured by laboratory tests with the soil TN values predicted using the soil TN-OC model.

The soil TN values predicted by the soil TN-OC model were compared with the soil TN values determined by laboratory tests and are shown in Table-4. A plot of the soil TN values determined by the soil TN-OC model and laboratory tests with the line of equality (1.0: 1.0) is shown in Figure-1. The mean soil TN difference between two methods was -0.002% (95% confidence interval: -0.008 and 0.004%; P = 0.510). The standard deviation of the soil TN differences was 0.011%. The paired samples t-test results showed that the soil TN values predicted with the soil TN-OC model were not significantly different than the soil TN measured with laboratory tests (Table-5). The soil TN differences between these two methods were normally distributed and 95% of the soil TN differences were expected to lie between $\mu+1.96\sigma$ and $\mu-1.96\sigma$, known as 95% limits of agreement (Bland and Altman 1999). The 95% limits of agreement for comparison of soil TN determined with laboratory test and the soil TN-OC model were calculated at -0.024 and 0.020% (Figure-2). Thus, soil TN predicted by the soil TN-OC model may be 0.024% lower or 0.020% higher than soil TN measured by laboratory test. The average percentage differences for soil TN prediction using the soil TN-OC model and laboratory test was 12.4%.

Table-4. Chemical properties of soil samples used in evaluating the soil TN-OC model.

Sample No.	**Organic carbon** (%)	**Total nitrogen** (%)	
		Laboratory test	**Soil TN-OC model**
1	0.25	0.05	0.04
2	0.40	0.07	0.05
3	0.45	0.05	0.06
4	0.50	0.05	0.06
5	0.53	0.07	0.06
6	0.56	0.07	0.06
7	0.60	0.07	0.07
8	0.64	0.08	0.07
9	0.66	0.08	0.07
10	0.70	0.06	0.07
11	0.73	0.07	0.08
12	1.00	0.08	0.09
13	1.30	0.13	0.11
14	1.50	0.12	0.13
15	1.70	0.14	0.14

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Table-5. Paired samples t-test analyses on comparing soil total nitrogen determination methods.

Determination methods	**Average difference** (%)	**Standard deviation of difference** (%)	**p-value**	**95% confidence intervals for the difference in means** (%)
Laboratory test and soil TN-OC model	-0.002	0.011	0.510	-0.008, 0.004

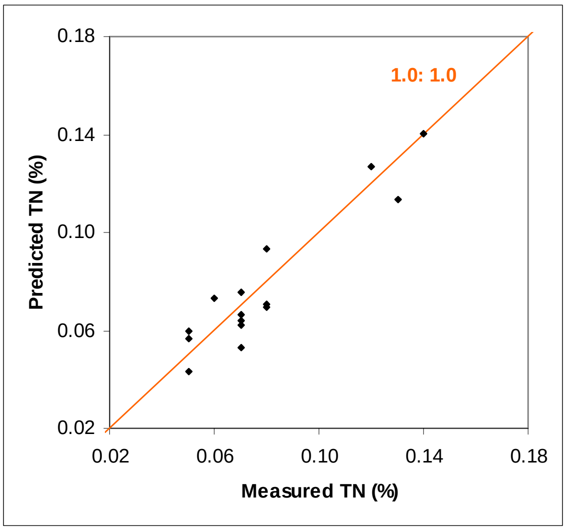

Figure-1. Measured TN and predicted TN using the soil TN-OC model with the line of equality (1.0: 1.0).

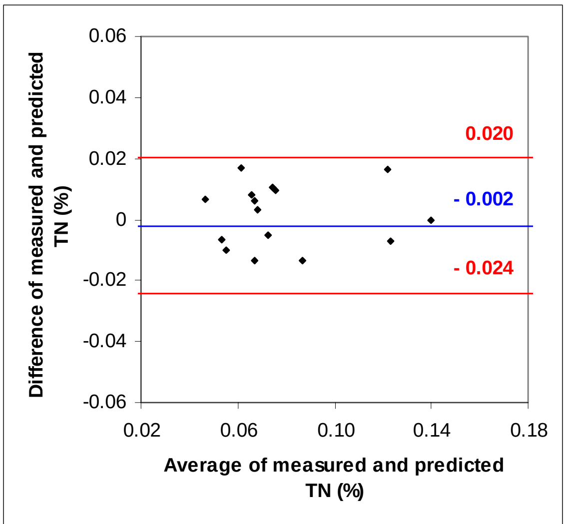

Figure-2. Bland-Altman plot for the comparison of measured TN and predicted TN using the soil TN-OC model; the outer lines indicate the 95% limits of agreement (-0.024, 0.020) and the center line shows the average difference (-0.002).

CONCLUSIONS

A linear regression model based on soil organic carbon (OC) was used to predict soil total nitrogen (TN) of calcareous soils of Varamin region in Iran. The soil TN values predicted using the soil TN-OC model was compared to the soil TN values measured by laboratory tests. The paired samples t-test results indicated that the difference between the soil TN values predicted by the soil TN-OC model were not significantly different from the soil TN values determined by laboratory test ($P > 0.05$). Therefore, the soil TN-OC model can provide an easy, economic and brief methodology to estimate soil TN.

ACKNOWLEDGMENTS

Thanks to Eng. Borzoo Ghareei Khabbaz for technical helps. As well, the financial support provided by the Agricultural Extension, Education and Research Organization of Iran under research award number 100-15-76048 is gratefully acknowledged.

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