

Wheat yield prediction modeling by soil properties: a case study in North-west of Iran

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Crop yields are dependent on a number of factors such as soil type, weather conditions and farming practices. Crop yield estimates in different soil types are required to meet the needs of farmers, land appraisers, and governmental agencies in Iran as around the world. This study was conducted to model the wheat-grain yields [*Triticum aestivum L.*] by soil properties in Khoy area, the north-west of Iran. The wheat yields (mean of 5 years) were applied to predict and model the wheat yields under an average level of management used through the area. The prerequisite data on main soil physicochemical characteristics was collected and measured to clarify the correlation and multiple regression analysis which are used to establish the relationships between the soil properties and the wheat-grain yields. Based on the calculated soil index, the general equation (GE) taking the soil index ranging from 0 to 100 % into account was proposed to predict the wheat-grain yields applicably. The results herein markedly proposed other two regression equations for the areas having soil index higher and lower than 70 %, respectively. The results indicated that within three obtained regression models, the equation suggested for the area having soil index higher than 70 % is appreciably more accurate than the model outlined by the FAO and potentially could be recommended for predicting the wheat yield in study area. Moreover, the GE regression model and the proposed model for the area having the soil index lower than 70 % showed the same accuracy compared with the FAO model but calibrated based on the study area condition. Therefore, our proposed regression models for the wheat-grain yields prediction could be used instead of performing the FAO models across the country with approximately same soil and climate status. [Morovvat et al. Wheat yield prediction modeling by soil properties: a case study in North-west of Iran. International Journal of Agricultural Science, Research and Technology, 2012; 2(1):23-26].

Key words: Modelling, Soil index, Wheat yields

1. Introduction

Inappropriate land use leads to inefficient exploitation of natural resources, destruction of the land resource, poverty and other social problems (Ruiee et. al., 2004). Land use type must ensure that land is not degraded and that it is used according to its capacity to satisfy human needs for present and future generations while also sustaining the earth's ecosystems (Rossiter, 1994). Part of the solution in the land-use problem is land evaluation in support of rational land-use planning and appropriate and sustainable use of natural and human resources (Rossiter, 1996). Land evaluation is concerned with the assessment of land performance for specific land utilization purposes and provides a rational basis for taking land-use decisions based on analysis of relations between the land use and land, giving estimates of required inputs and predicted outputs

(FAO, 1995; Sys et al., 1991 a,b). There is an abundance of agronomic research using mathematical expression to describe the relationship between crop yields and the soil physical and chemical properties (Sopher and McCracken, 1973; Kiniry et al., 1983; Pierce et al., 1983; Olson and Olson, 1986; Lindstrom et al., 1992). Sopher and McCracken (1973) used correlations between soil properties, management practices, and crop yields on Atlantic Coastal Plain soils. They showed the most soil factors that affected crop yields were soil moisture-holding capacity, cation exchange capacity (CEC), soil texture, pH, extractable P, and base saturation. Khidir (1986) made square root method for calculation of soil index, by multiplying soil index by production potential, and indicated that prediction of special crop is able to be measured. The soil characteristics that define wheat yield are different in yield prediction.



Abstract

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There are not a considerable work on evaluation of the FAO established land evaluation process in west of Iran on calcareous soils. Therefore, an attempt was made to test performance the FAO method and compare the results with other fitted regression models. Hence, the objective of this study was to collect different soil characteristics in West-Azerbaijan province to offer several multiple regression models for prediction of wheat-grain yields. This study was also conducted to calibrate the FAO yield prediction equations for calcareous soils of semi-arid regimes and updates the wheat [*Triticum aestivum* L.] grain yield estimates for the predominant soil types in the Khoy city of the West-Azerbaijan province, Iran, under the conventional land management by taking the wheat yield from the years of 2002 to 2006 into account.

2. Materials and methods

The study area, Khoy city, is located in the semi-arid plains of the West-Azerbaijan province in north-western Iran. The area lies between longitude 38°21' to 38°41' east, and latitude 44°48' to 45°07' north. In this area the cultivated land under the predominantly sunflower-wheat rotation occupies most of cultivated lands. Based on the last thirty years metrological reports the mean maximum and minimum daily temperature were 33 and -5.5 °C, respectively, the average annual temperature was 11.72°C, and total annual precipitation about 500 ml that mostly precipitated in fall and spring. The soil samples at the 30 sampling sites covering 1000 ha were collected from the 0-30 cm depth, georeferenced using GPS (accuracy of ± 5m). Accordingly, the required characteristics for predicting wheat yield based on FAO (1995) including the climatic data (temperature, solar radiation) and the characteristics of land (slope, drainage, flood, microrelief, texture, soil structure, coarse fragments, soil depth, CaCO₃, cation exchange capacity, soil pH, organic carbon, ESP and salinity) were properly collected and measured. To develop and parameterize a best-fitting empirical model for wheat yield prediction in the study area, the multivariate stepwise regression models was performed to quantitatively describe the relationship within soil properties and last 5-years yields under a conventional land management. The statistical software of SAS 9.2 was used for calculation of stepwise multiple regression and the SPSS software was used for comparing the proposed predicting models with FAO model and testing performance of the obtained results.

3. Results and discussion

The soil indices (SI) of land characteristics in the studied sampling sites are presented in Table 1. Soil characteristics were functionally converted between 0-100 depending on direct impact on crop yield (FAO, 1995). Values of the observed wheat-grain yields in the study area varied from 1.22 to 6.0 t ha⁻¹ with a mean of 4.37 t ha⁻¹ (Table 1). The calculated soil indices based on FAO procedures (square root method) varied from 17.28 to 86.86, with the mean and standard deviation of 62.78 and 16.53, respectively. The correlation between the observed yield (OY) and predicted yield (PY) in FAO equation was high ($r=0.922$, $n=30$) but graphic curve of OY and PY exhibited a disharmonious between OY and PY. The wheat-grain yield predictions were unsuitable for the study area at least at the area having the higher amount of SI that 70 (Fig. 1). Therefore, all analyzed soil properties were categorized into two main groups according to the amount of SI content (greater and lower than 70). Later on, linear regression between OY and PY was illustrated and changed as shown in Fig. 1. Following Cochran and Cox (1962), the productivity (Y) of each crop is analyzed as a polynomial function of the type

$$Y = b_0 + \sum_{i=1}^n b_i X_i + \sum_{i < j < n} b_{ij} X_i X_j$$

where Y is the prediction of productivity, and the a and b are independent term and the partial coefficients of the independent variables: ESP (X1), salinity (X2), pH (X3), carbonate content (X4), Soil depth (X5), coarse fragments (X6), texture (X7), drainage (X8), microrelife (X9) and slope (X10) and of their second order interactions. The quadratic terms were not included so as to simplify the model. The calibration of these polynomial models was performed statistically as a particular case of multiple regressions from the information generated in the representative reference point of study area; three equations were formulated by calculating the coefficients of single correlation (r) between pairs of variables (Table 2.)

The first equation belongs to the whole range of obtained SI in the study area that is so-called general equation (GE). The second one is dedicated to range of SI lower than 70, which is so-called Low soil index's equation (LSIE) and the third equation is for SI levels of greater than 70, which is so-called high soil index's equation (HSIE).

As shown in Table 2 and Table 3, HSIE showed the highest correlation at high amounts of SI and the GE model following the FAO model had the highest correlation at low and total ranges of SI.

Table 1. Soil Indices (SI) of land characteristics that affect wheat-grain yield prediction in the FAO model

	ESP ₁	Salinity	pH	Lime	Soil depth	Gravel	Texture	Drainage	Relief	Slope	SI	Yield (t ha ⁻¹)
Mean	98.9	94.1	85.5	96.4	96.3	96.4	89.5	91.2	96.7	94.0	62.8	4.37
Minimum	85	45	20	88	77	88	80	60	80	80	17.3	1.22
Maximum	100	100	98	99	100	100	100	100	100	100	86.8	6.00
Standard deviation	3.31	11.98	16.1	2.03	7.92	5.21	6.61	12.57	5.47	8.94	16.5	1.07

1-Exchangeable sodium percentage

Table 2. Results of calibrating the polynomial equations after multiple regression analysis for wheat

Prediction models	Polynomial equation	R ²
GE	$Y = -23.05965 + 0.14649X_1 + 0.045X_3 + 0.03058X_5 + 0.0361X_8 + 0.03045X_{10}$	79.89
LRSE	$Y = -10.90615 + 0.10095X_1 + 0.0351X_3 + 0.0218X_8$	73.24
HRSE	$Y = -6.577 + 0.1203X_9$	65.48

Table 3. Correlation between predicted amounts with average of last 5 years yield trend, divided on the base of Soil Index.

Prediction models	Soil Index <70	Soil Index >70	Total SI Ranges
LRS	0.856 ^{**}	0.062 ^{ns}	0.817 ^{**}
HRS	-0.218 ^{ns}	0.809 ^{**}	0.165 ^{ns}
GE	0.861 ^{**}	0.517 ^{ns}	0.894 ^{**}
FAO	0.958 ^{**}	0.322 ^{ns}	0.922 ^{**}

Ns= not significant at p>0.05. ** significant at p>0.05

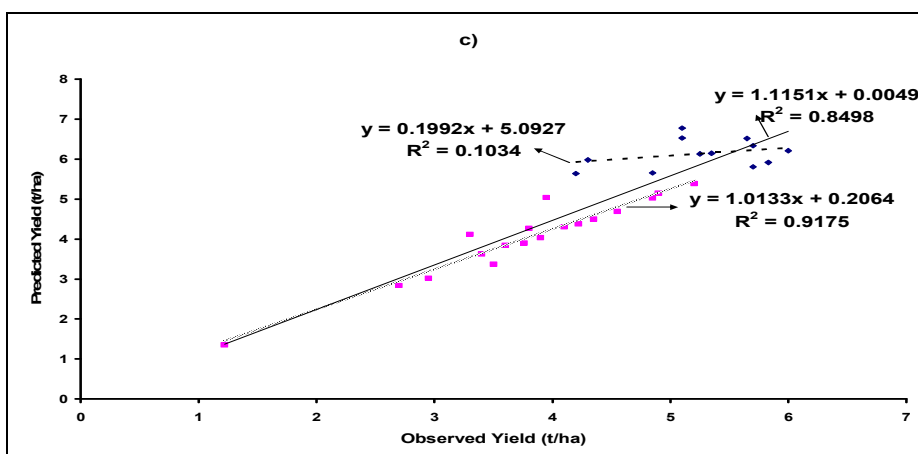


Fig. 1. Relationship between observed and predicted wheat-yield in high (greater than 70 of SI) (a), low (lower than 70 of SI) indexes (b) as well as their comparison with whole detected SI ranging from 0 to 100 %.

The results herein indicated and demonstrated that categorizing the soil index into the two groups i.e. greater and lower than 70 is more confident and practicable approach to gain the best predicted wheat yield in the study area and in the similar soil and climatic situations of semiarid regions in Iran and as around the world. In general, testing performance of step-wise multiple regressions of GE, HSIE, and LSIE models that was taken into account six variables including ESP, pH, soil depth, drainage, relief, and slope explained successfully 65, 73, and 79% of the variation (Table 2) in the wheat yields, respectively. Results emphasized that the FAO procedure for predicting the wheat-grain yield is not always the best method and it could be obtain more precise results in crop yield prediction from the developed fitted model by multiple regression procedure especially whenever we had sufficient and numerous data. Based on the results the HSIE model is the best equation for wheat yield prediction when soil index be upper than 70 and FAO is wiser for lower amounts of SI.

4. Conclusions

Crop yield prediction in different soil types are required to meet the needs of farmers, land appraisers, and governmental agencies in most of the countries like Iran as in the world. This study is trying to develop an empirical model for the wheat-yields [*Triticum aestivum L.*] by soil properties in Khoy area, the north-west of Iran. The GE regression model and the specified model for the area having the soil index lower than 70 % showed the same accuracy compared with the FAO model but could be applicable given that it is calibrated based on the study area condition. Results emphasized that the FAO procedure for predicting the wheat-grain yield is not always the best comprehensive method. The more precise results in crop yield prediction from the developed fitted model by multiple regression procedure is applicable especially whenever there are sufficient soil and climate data. The results indicated that within three proposed regression models, the equation suggested for the area having soil indices higher than 70 % have appreciably more accurate than the model outlined by the FAO and could be recommended for the wheat yield predicting in arid and semi arid regions.

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