*Available online www.jsaer.com*

***Journal of Scientific and Engineering Research*, 2019, 6(3):171-180**

**Research Article**

**ISSN: 2394-2630**
**CODEN(USA): JSERBR**

# Applicability of Pedotransfer Models between Agronomic Parameters and Some Physical Soil Properties of Wheat Plant

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**Abstract** The aim of this study was to determine some physical properties of soil and agronomic characteristics of wheat plant (plant height, thousand seed weight and seed yield) grown in Turkey's Samsun Çarşamba plain, to set pedotransfer models between these properties and to determine applicability of obtained models in estimation of yield in the plain soils. In the pedotransfer model between plant height and soil parameters as BD, Clay, $(Db)^2$, (Clay×BD), AW, $(AW)^2$ was statistically significant (p=0.047) and regression coefficient (R = 0.654) was high. In the model between thousand seed weight of wheat and Clay, BD, AW, $(Clay)^2$, $(BD)^2$, $(AW)^2$, (Clay×BD), $\sqrt{Clay}$,$\sqrt{BD}$, PWP, $(FC)^2$parameters wasn't statistically significant (p=0.612) and the high regression coefficient (R=0.602) was determined. Performance of the model between wheat seed yield and Sand, BD, (Sand×BD), (BD×PWP), $(BD)^2$, $(Sand)^2$, WP, $\sqrt{BD}$ ,$\sqrt{Clay}$ ,$\sqrt{Sand}$ parameters was high (R=0.748; p=0.078). R, RMSE, $d$, ME, MAE, MBE and MRE were evaluated together to determine validity of the pedotransfer models between yield components and some physical properties of soils. In general, statistical parameters were within validity limits.

**Keywords** plant height, thousand seed weight, yield, physical soil properties, pedotransfer models

## 1. Introduction

In order to meet nutritional needs of growing world population with existing agricultural lands, need to obtain higher yields from unit agricultural land has emerged. Increasing and estimating of yield is one of the current and primary research topics. High efficiency is depend on physical, chemical and biological soil properties with various ecological, environmental and genetic factors. Determination of relationship between the physical soil properties and the agronomical indicators of plants is necessary to establish methods for preserving, estimating and increasing the efficiency [1-5]. In many studies, it was reported that plant height, thousand seed weight and grain yield varied significantly depending on genotypes, environmental conditions, sowing frequency, as well as factors such as soil properties [6-10].

It is important to create pedotransfer (regression) models between the agronomic characteristics of wheat plant and the physical soil properties and provide the possibility to be used in the estimation of the yield. Pedotransfer models have wide applications in agricultural areas such as ecology, hydrology and various engineering branches. Setting and using pedotransfer models in soil and plant ecosystems is easier and more practical than theoretical models expressed by simple differential, algebraic and partial differential equations [11-27]. The term pedotransfer function used by Bouma and van Lanen (1987) was developed more understandably by Bouma in 1989 and its use in soil science was demonstrated [28, 29]. It was emphasized that need of accepting many assumptions in setting of Pedotrasfer models [29, 30]. Parallel to the accumulation of adequate values of soil properties in soil science, the use of pedotransfer models in accordance with the purpose has emerged. With the help of these models, quantitative relations between the plant's agronomic characteristics (plant height, thousand seed weight, grain yield) and some physical soil properties can be explained. Physical soil properties determined experimentally more easily are preferred as independent parameters in pedotransfer models set by researchers [31- 35]. This research was carried out with the aim of setting pedotransfer models between the agronomic properties of wheat plant (plant height, thousand seed weight, seed yield) and some physical soil properties and to determine the applicability of the obtained models in the estimation of plant yield.

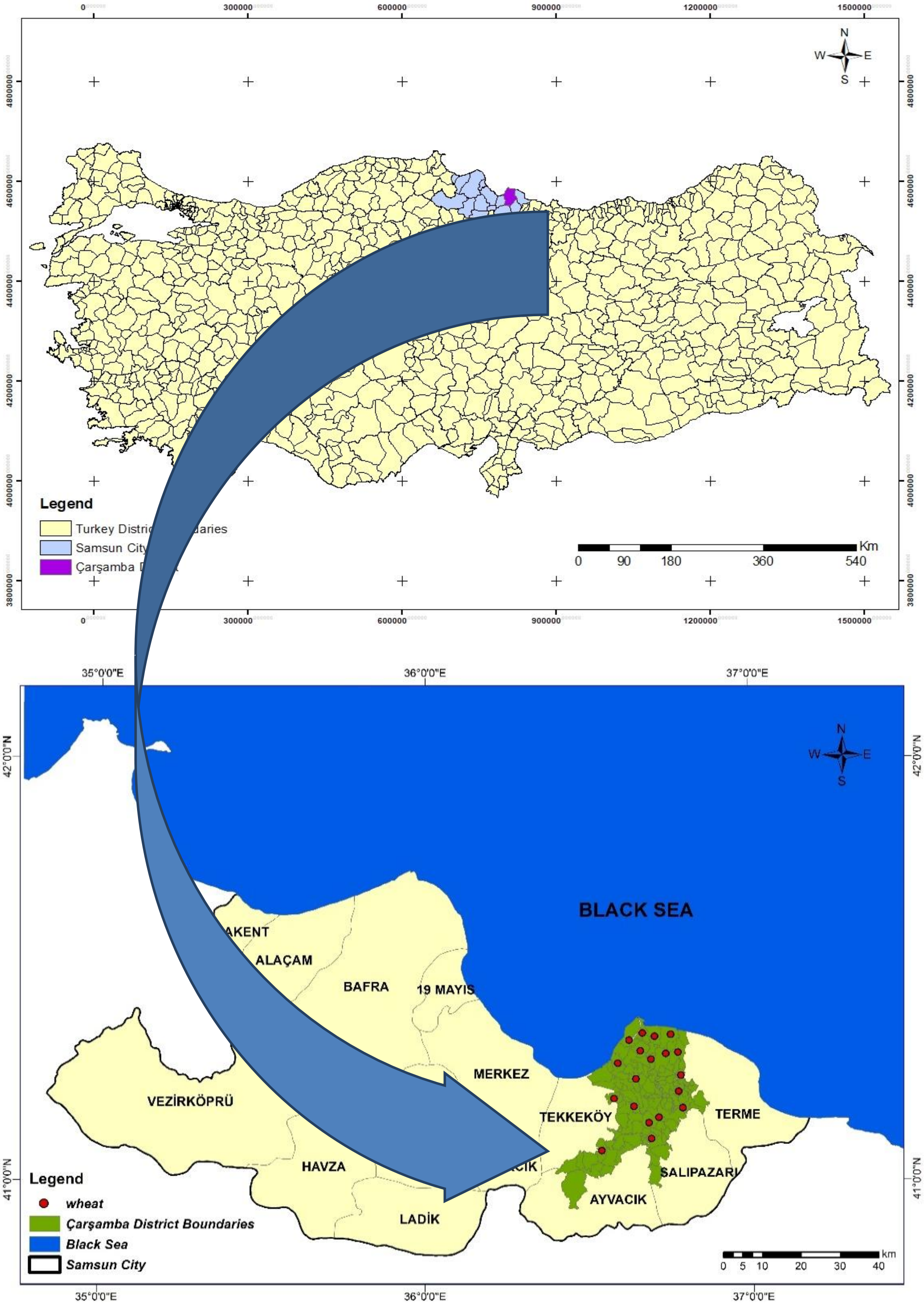



*Figure 1: Locations where soil and plant samples were taken*

## 2. Materials and Methods

The research was carried out in 20 villages wheat grown representing the Çarşamba Plain in 2013-2014 by taking 20 soil and plant samples from 0-20 cm depth for each year. The research area is a delta plain formed by Yeşilırmak river in the east of Samsun province between Canik mountains and the Black Sea. The plain covers an area of 103766 hectares between 0-50 m elevations. The plain is very rich in vegetation and has 58921 hectares of agricultural land. The wheat plant is grown on an area of 1700 hectares. The plain areas are alluvial and partly colluvial. Total annual rainfall is 985.9 mm and average annual temperature is 15-17 °C. Figure 1 shows locations where soil and plant samples were taken. Soil particle size distribution was determined according to hydrometer method [36]. Moisture contents in field capacity (FC) and permanent wilting point (PWP) were determined at a pressure plate apparatus under 1/3 and 15 atm pressure after soils reached a hydraulic balance state, available water content(AWC) was determined from difference between field capacity and permanent wilting point; bulk densities (BD) were determined on undisturbed soil samples [37]. Measurements related to the agronomic characteristics of the plants were made according to the Technical Instructions for Measurement of Agricultural Values Experiments of the Variety Registration and Seed Certification Center of the General Directorate of Protection and Control of the Ministry of Food and Forestry [38].

## 3. Statistical Analysis

Some descriptive statistics of soil and plant analysis results were calculated in SPSS 17.0 statistic program and pedotransfer models formed between agronomic parameters and some physical soil properties were made in Minitab 17.0 statistic program. The coefficient of standard deviation (σ) or variation (CV) was determined by the following expressions:

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2} \qquad (1)$$

$$CV = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\frac{\left(X_i - \overline{X}\right)^2}{\overline{X}}} \qquad (2)$$

Where; $X_i$ - is measured or estimated values; $\overline{X}$ - is the average of measured or estimated values; $n$ –is the number of measured or estimated values.In general, when the standard deviation is small, the deviation from the mean and the risk are low; when the standard deviation is large, it shows that the deviations from the mean and the risk are very high.When the variation or variation coefficients are compared, it is understood that the distribution is more intense around the arithmetic mean in the data with small coefficients of variation. The root mean square error (RMSE), mean of absolute error (MAE), maximum relative error (MRE), mean arithmetic error or mean bias error (MBE), index of agreement ($d$), model efficiency (ME)were calculated using the following expressions, respectively:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(x_i - y_i\right)^2} \qquad (3)$$

(where, $n$ -is the number of data,if $n < 30$ $m = n-1$, if $n > 30$ $m = n$; $x_i$ - estimaded values; $y_i$ -measured values)

$$MAE = \frac{\sum_{i=1}^{n}\left|x_i - y_i\right|}{n} \qquad (4)$$

$$MRE = \underset{i=1,2,3,..n}{mak}\left(\left|\frac{x_i - y_i}{y_i}\right|\right) \quad (5)$$

$$MBE = \sum_{i=1}^{n} \frac{x_i - y_i}{n} \quad (6)$$

$$d = 1 - \frac{\sum_{i=1}^{n}\left(x_i - y_i\right)^2}{\sum_{i=1}^{n}\left(\left|x_i - \bar{y}\right| + \left|y_i - \bar{y}\right|\right)^2} \quad (7)$$

(where, $\bar{x}$ and $\bar{y}$ are the mean estimaded and measured values, respectively)

$$ME = 1 - \frac{\sum_{i=1}^{n}\left(x_i - y_i\right)^2}{\sum_{i=1}^{n}\left(y_i - \bar{y}\right)^2} \quad (8)$$

The root mean squares error is the standard deviation of the estimation errors. It is preferred that MRE values are close to zero. When MBE is close to zero, it indicates that the difference between estimation and the actual values is small. A positive or negative value is an indication of over-prediction or under-prediction, respectively. The index of agreement $(d)$ is an indicator of the validity of the model and the $d$is close to 1 indicates the applicability of the model.In a study of the experimental hydrological model by Krause et al. (2005), ME values were shown to vary between 1 and $\infty$, and if the ME was smaller than zero, the measured mean value was more effective than the calculated value. As seen in the comparison of analytical expressions of $d$ and ME, $d$ value is generally greater than ME [18, 39-45].

## 4. Results and Discussion

### 4.1.Distribution of agronomic properties of wheat plant

Some descriptive statistics of some agronomic properties of wheat plant grown in the research area were given in Table 1.

**Table 1:** Some descriptive statistics of some agronomic properties of wheat plant (n=40)

| Properties | Minimum | Maximum | Mean | Std. Deviation | CV, % | Skewness |
|---|---|---|---|---|---|---|
| PH, cm | 66.47 | 113.53 | 82.98 | 11.39 | 0.13 | 1.611 |
| TSW, g | 44.52 | 60.11 | 51.51 | 4.05 | 7.86 | 0.259 |
| SY, kg da$^{-1}$ | 332.72 | 653.66 | 515.17 | 102.10 | 19.81 | -0.149 |

PH: Plant height; TSW: Thousand seed weight; SY: Seed yield; CV: Coefficient of variation.

As shown in Table 1, minimum plant height of the wheat plant was 66.47 cm, maximum plant height was113.53 cm and the average plant height was 82.98 cm. The standard deviation was 11.39; the coefficient of variation was 0.13%; the coefficient of skewness was found as 1.611. Minimum thousand seed weight of the wheat plant was 44.52 g, maximum thousand seed weight was 60.11 g and the average thousand seed weight was 51.51 g. The statistical indicators were found to be 4.05; 7.86%; 0.259, respectively. Minimum seed yield per decare of the wheat plant was 332.72 kg, maximum seed yield was 653.66 kg and the average seed yield was 515.17 kg. The standard deviation, coefficient of variation and skewness were 102.10; 19.81%; -0.149, respectively. As is seen, statistical indicators vary within valid limits. When compared to the standard deviation values of plant height and thousand seed weight, the reason for the high standard deviation of seed yield may be the wide variation of seed yield.

### 4.2. Pedotransfer models between the plant height of wheat and some physical soil properties

Pedotransfer models between the plant height of wheat and some physical soil properties were given in Table 2.

**Table 2:** Pedotransfer models between the plant height of wheat and some physical properties of soils

| No. | Models | R | F | p |
|---|---|---|---|---|
| 1. | HP = 97.5 + 0.469 Clay -11.7 BD - 0.903 AWC | 0.516 | 2.90 | 0.056 |
| 2. | HP = 92.7 + 0.469 Clay - 11.1 BD - 0.877 AWC + 0.254 PWP | 0.527 | 2.21 | 0.099 |
| 3. | HP = 129 - 3.13 Clay + 54 BD - 2.78 AWC - 59 $(BD)^2$ + 2.66 (Clay×BD) + 0.0570 $(AWC)^2$ | 0.654 | 2.62 | 0.047 |

HP: Plant height, cm; BD: Bulk density, g $cm^{-3}$; AWC: Available water content, %; PWP: Permanent wilting point, %.

As seen from (1) - (3) pedotransfer models (Table 2) between plant height of wheat and some physical soil properties, regression coefficients were between 0.516 and 0.654; F values were between 2.21 and 2.90; p values were within the limits of significance (p <0.10) and ranged from 0.047 to 0.099.The model number 3, which included clay, bulk density and available water content, was more sensitive (R= 0.654) and statistically significant (p= 0.047 <0.05).The model 1, which included clay, bulk density and available water content, gave a lower regression coefficient (R= 0.516) compared to the others. In the model 2, use of permanent wilting point values as well as parameters such as clay, bulk density, available water content, increased the performance of the model. In other studies, it has been shown that the expression of pedotransfer models with polynomials including the square, square root and product of soil properties increases the regression coefficient of the model and thus the importance of the estimation [15, 46].

### 4.3. Pedotransfer models between the thousand seed weight of wheat and some physical soil properties

Pedotransfer models between the thousand seed weight of wheat and some physical soil properties were given in Table 3.

**Table 3:** Pedotransfer models between the thousand seed weight of wheat and some physical soil properties

| No. | Models | R | F | p |
|---|---|---|---|---|
| 1. | TSW = - 107 + 1.68 Clay + 190 BD + 0.00986 $(Clay)^2$ - 47.3 $(BD)^2$ - 1.73 (Clay×BD) | 0.557 | 2.01 | 0.117 |
| 2 | TSW = - 97 + 1.71 Clay + 177 BD - 0.067 AWC + 0.00957 $(Clay)^2$ - 42.5 $(BD)^2$ - 1.74 (Clay×BD) | 0.567 | 1.65 | 0.182 |
| 3. | TSW= 5758 + 9.4 Clay + 8971 BD + 0.7 AWC - 1.36 (Clay×BD) - 63 $\sqrt{Clay}$ - 13389 $\sqrt{BD}$ - 0.0302 $(Clay)^2$ - 1166 $(BD)^2$ + 0.85 PWP + 0.0046 $(AWC)^2$ - 0.0126 $(FC)^2$ | 0.602 | 0.83 | 0.612 |

TSW: Thousand seed weight, g; BD: Bulk density, g $cm^{-3}$; AWC: Available water content, %; PWP: Permanent wilting point, %; FC: Field capacity, %.

As seen from (1) - (3) pedotransfer models (Table 3) between thousand seed weight of wheat and some physical soil properties, regression coefficients were between 0.557 and 0.602; F values were between 0.83 and 2.01; p values ranged from 0.117 to 0.612. Irregular changes in soil properties during the growing of wheat plants can cause high p values. The regression coefficient (R= 0.602) was the highest in the regression model between TSW and clay, bulk density, permanent wilting point, available water content, and field capacity; and was the lowest (R= 0.557) in the model expressed by clay and bulk density. Yakupoglu et al. (2013) have expressed the functional relationship between some physical soil properties and moisture constants with pedotransfer model ($R^2$= 0.846).

### 4.4. Pedotransfer models between the seed yield of wheat and some physical soil properties

Pedotransfer models between the seed yield of wheat and some physical soil properties were given in Table 4.

**Table 4:** Pedotransfer models between the seed yield of wheat and some physical soil properties

| No. | Models | R | F | p |
|---|---|---|---|---|
| 1 | SY = 224 + 412 BD + 21.0 Sand - 18.4 (Sand×BD) - 8.26 (BD×PWP) | 0.529 | 2.23 | 0.097 |
| 2. | SY = 10456 + 1411 BD + 729 Sand + 4.7 (Sand×BD) - 43.8 (BD×PWP) - 436 $(Db)^2$ + 48.5 PWP - 3.98 $(Sand)^2$ - 5363 $\sqrt{Sand}$ | 0.685 | 2.10 | 0.088 |
| 3. | SY = - 47372 - 96512 BD + 915 Sand + 10.2 (Sand×BD) - 45.2 (BD×PWP) + 12534 $(BD)^2$ + 47.8 PWP - 5.13$(Sand)^2$ - 6726 $\sqrt{Sand}$ - 62.7 $\sqrt{Clay}$ + 145835 $\sqrt{BD}$ | 0.748 | 2.16 | 0.078 |

SY: Seed yield, kg $da^{-1}$; BD: Bulk density, g $cm^{-3}$; PWP: Permanent wilting point, %.

As seen from (1) - (3) pedotransfer models (Table 3) between seed yield of wheat and some physical soil properties, regression coefficients were between 0.529 and 0.748; F values were between 2.10 and 2.23; p values ranged from 0.078 to 0.097.The lowest regression coefficient (R= 0.529) in the model 1, which includes clay, bulk density, permanent wilting point characteristics and the highest regression coefficient were found in the model 3 (R= 0.748).

**4.5. The validity of pedotransfer models formed between the agronomic parameters and some physical soil properties**

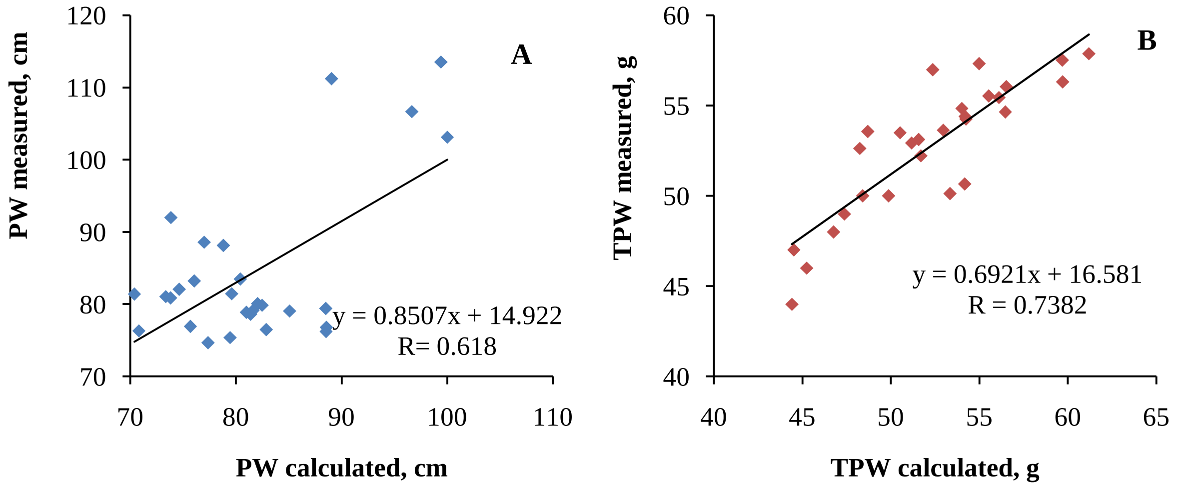
In determining the validity of the pedotransfer models obtained according to the experimental data, it is necessary to use the values different from the values that set the model or from the values in the data bank [42]. Statistical parameters for determining the validity of pedotransfer models between wheat plant height, thousand seed weight and seed yield with some physical properties of soils were given in Table 5.

**Table 5:** Some descriptive statistics of pedotransfer models of plant height, thousand seed weight and seed yield

| Models (No) | R | RMSE | *d* | ME | MAE | MBE | MRE |
|---|---|---|---|---|---|---|---|
| BB (3) | 0.654 | 9.992 | 0.976 | -1.061 | 8.058 | 3.465 | 0.301 |
| BTA (3) | 0.602 | 4.800 | 0.977 | -3.085 | 3.565 | -2.230 | 0.233 |
| BY (3) | 0.748 | 74.131 | 0.985 | 0.021 | 54.335 | -38.092 | 0.279 |

PH:Plant height; TSW: thousand seed weight; BY: Seed yield; R:Regression coefficient; RMSE:Root mean square error; *d*: index of agreement; ME: Model efficiency; MAE: Mean of absolute error; MBE: mean bias error; MRE: Maximum relative error.

The statistical parameters of pedotransfer models formed between the agronomic parameters and soil properties were determined by using the soil and agronomic properties of 28 different areas of the research area.As shown in Table 5, descriptive statistics of pedotransfer models are generally within the validity limits. In Figure 2, comparison of calculated and measured values of plant height, thousand seed weight and seed yield of wheat according to the third model were given.



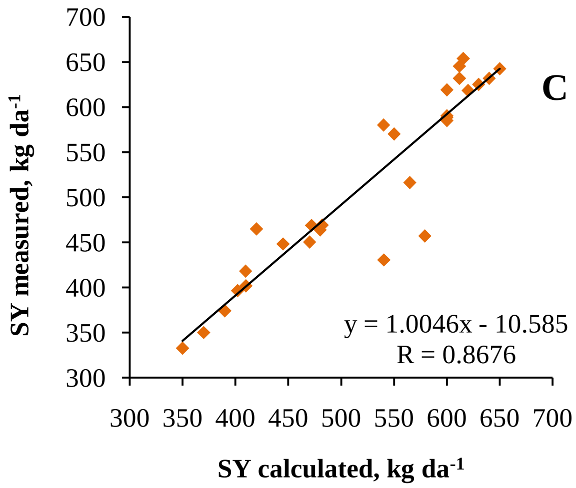



*Figure 2: The relationship between calculated and measured plant height (A), thousand seed weight (B), seed yield (C) and physical soil properties according to pedotransfer models*

## 5. Conclusion

In this study, some physical soil properties and the agronomic characteristics of the wheat plant grown in Turkey's Samsun Çarşamba plain were determined, pedotransfer models were set between the agronomic properties of plants and some physical soil properties and the applicability of the models were shown. Change in physical soil properties is one of the factors that have a significant effect on plant yield. Factors such as the lack of regular agricultural processes (fertilization, irrigation, etc.) and the change of climatic conditions cause the physical properties not to be within optimum limits and change rapidly. As is seen from the values of the regression coefficients, it is possible to use the pedotransfer models in the research area to estimate the agronomic factors in the wheat grown soils. Moreover, the performance of the 3rd models (Table 2-4) is higher. Considering the ease of implementation of pedotransfer models, in order to set pedotransfer models at the local and regional level, it is necessary to create soil and plant data bank suitable for the purpose. In general, in setting of models between yield and soil properties, the applicability of the model becomes more difficult if the parameters are many (> 10-15). The use of pedotransfer models in the form of polynomials including the square, square root and multiplying of the soil properties values increases the validity of the model. Considering the validation of the different processes by the statistical parameters, it is more appropriate to evaluate the R, RMSE, $d$, ME, MAE, MBE and MRE together in determining the validity of the models. The experimental data used in the setting of the pedotransfer models should be different from the values used in determining the validity of the models.

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