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Interrelationships Between Soil Quality Parameters and Wheat Productivity for Some Soils of Monufyia Governorate

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Abstract: The present study was carried out to investigate the interrelationships between some physical and chemical soil characteristics and wheat productivity at seven locations; El-Sadat area, Monufyia Governorate during 2013/2015 years. Eight surface soil samples (0-30 cm) from each location were correlated for the investigated soil parameters determination. The investigated parameters were the coarse sand (CS), fine sand, silt and clay content, bulk density (BD), real density (RD), total porosity (TP), quickly drainable pores (QDP), slowly drainable pores (SDP), water holding capacity (WHC), hydraulic conductivity (HC), field capacity (F. C), wilting coefficient (WC); mean weight diameter (MWD); pH, electric conductivity (EC), organic matter (OM), cation exchange capacity (CEC), calcium carbonate ($CaCO_3$), available potassium (Av-K) and total nitrogen (TN). The results showed a high significant correlation ($P < 0.05$) between some physical and chemical soil quality parameters**.** The observed a positive significant correlation was: WHC (water holding capacity), F. C (field capacity), pH and CEC (cation exchange capacity) correlated with clay content. QDP (quickly drainable pores) correlated with fine sand content. TP (total porosity), F. C, RD (real density), and WC (wilting coefficient) correlated with (HC) hydraulic conductivity. Also, the observed that a negative significant correlation was: OM (organic matter), WHC, clay content, RD and silt correlated with fine sand content. QDP (quickly drainable pores) correlated with water holding capacity and clay content Bulk density correlated with the hydraulic conductivity, total porosity and silt. The highest values of mean, standard deviation and the relative weight of physical and chemical parameters were obtained for cation exchange capacity, clay content, fine sand content, silt content, quickly drainable pores, field capacity and water holding capacity compared with the other soil parameters. Concerning the relationship of some soil parameters and wheat productivity, the data of correlation studies showed that the most suitable parameters for evaluation of soil quality under different soil management of study area were CEC, clay content, fine sand content, silt content, QDP, FC and WHC. On the other hand, the data showed an insignificant correlation between wheat productivity and some physical and chemical parameters such as coarse sand, slowly drainable pores, pH, $CaCO_3$ and total nitrogen.

Keywords: Soil Quality, Soil Quality Parameters, Wheat Yield

1. Introduction

The soil is one of the most important environmental factors;-it is considered as the main source in providing essential plant nutrients, water reserves and a medium for plant growth. Soil quality is defined as the capacity of a soil function within an ecosystem and land use boundaries, to sustain biological activity, maintain environmental quality, and promote plant, animal, and human health (Doran and Parkin, 1994).

Soil quality (SQ) depends partially on the natural composition of the soil, and also on changes related to human use and management. Soil quality indices are considered the most common methods for soil quality evaluation due to ease of use, flexibility and quantification. These indices represent the cumulative effects of different soil properties (physical, chemical and ecological) as an index from the role of each parameter in soil quality (Drury *et al.,* 2003; Singh and Khera, 2009). Larson and Pierce (1991) outlined five soil functions that may be used as the criteria for judging soil quality: to hold and release water to plants, streams, and subsoil; to hold and release nutrients and other chemicals; to promote and sustain root growth; to maintain suitable soil biotic habitats; and to respond to management and resist degradation.

As a complex function state, soil quality cannot be measured directly, but may be inferred from soil quality parameters. Soil quality parameters are measurable properties of soil or plants that provide clues about how well the soil can function. Soil quality parameters must provide a sensitive and timely measure of the soil's ability to function and be able to identify whether the change in soil quality is induced by natural processes or it occurs because of management (Doran and Parkin, 1994).

Soil quality parameters can be divided into physical, chemical, and biological parameters such as available water holding capacity, relative field capacity to water saturation, macroporosity, bulk density, cation exchange capacity, contaminant presence, electrical conductivity of soil: water extracts, exchangeable sodium, pH, available potassium, and available phosphorus…. etc. (Reynolds *et al.,* 2009).

Several authors have proposed various soil quality parameters that can be easily measured and they are sensitive to change of soil condition and therefore, they must be able to identify appropriated sustainable soil conditions (Larson and Pierce, 1994; Gomez *et al*., 1996; Karlen *et al.,* 1998; Aparicio and Costa, 2007). Liu *et al*. (2013) established a soil quality index based on twenty-six soil physical, chemical and microbiological properties in a paddy soil of China by using both Traditional Dimension System (TDS) and Multidimensional System (MDS) methods.

In general, most researchers used a set of predefined soil parameters indicators suggested by Gomez *et al*. (1996) and Shukla *et al*. (2004) to assess soil quality and sustainability of the agricultural land. The process of degradation in arid and semiarid regions such as Egypt has intensified due to lack of farmers' knowledge of agricultural soil conditions, and lack of proper equipment's. Under these conditions, the soil quality is often influenced by limiting factors such as high temperature, poor soil fertility, low available water holding capacity (AWHC), soil organic carbon (SOC) and high concentrations of salt and pH.

A soil's physical properties affect crop performance in many ways. Plant health and growth are heavily influenced by the soil's texture, bulk density (a measure of compaction), porosity, water-holding capacity, and the presence or absence of hard pans. These properties are all improved through additions of organic matter to soils. Soil physical properties also influence soil-water and plant-water relationships. The partitioning of water at the soil surface is important because it determines both the quantity and the quality of surface and groundwater, as well as the amount of water that will be available for plant growth. When soil quality parameters are in the optimum range, crop yield response would be optimal (maximum obtainable yield) (Reynolds *et al.,* 2009).

Therefore, the objective of this research is to estimate soil quality parameters in some soils of Monufyia Governorate and study their relationship with wheat productivity between the farming periods of 2013 to 2015.

2. Materials and Methods

The current study was carried out to estimate soil quality parameters (physical and chemical) in El-Sadat area, Monufyia Governorate during winter seasons of 2013 to 2015 and their relationships with wheat productivity. The present materials and methods are introduced under the follows topics; Map of locations; Data collection; laboratory analysis; and statistical analyses.

2.1. Maps of Locations

The studied seven locations located within El-Sadat area, Monufyia Governorate between 30°40'13" and 31°50'12" eastern longitudes, and 30°22'50" and 31°31'10" northern latitudes, shown in Table 1 and Figure 1.

Table 1. *Locations of the tested seven areas.*

No.	Sites location name	longitude-Latitude
1	Almaris basin area (Rashid branch – Kafr Dawod).	30°50'26"E 30°27'41" N
2	Algemmiza basin, Almahder basin large area (Kafr Dawod-west Alrriah the Behairy).	30°49'10"E 30°28' 8" N
3	Khatatba village.	31°45'10"E 31°25' 8" N
4	Abu Nashaba village.	31°50'12'E 31°31'10" N
5	Alakhmas west Alrriah the Behairy.	30°59'15"E 30°26'20" N
6	Alakhmas east Alrriah the Behairy.	30°50' 9"E 30°25'61" N
7	Altranh west Alrriah the Behairy.	30°40'13"E 30°22'50"N

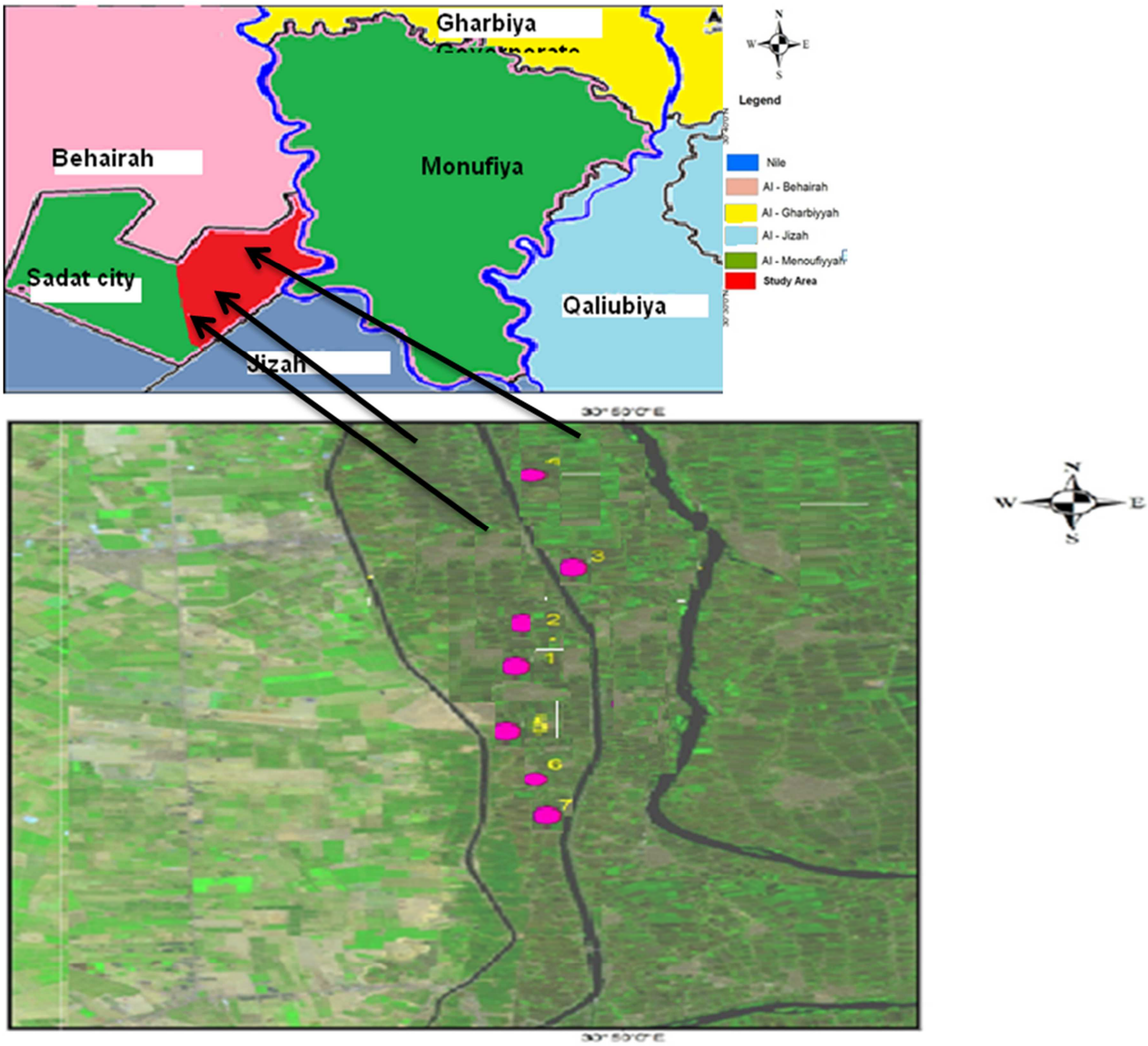

Figure 1. *Map of the studied locations.*

2.2. Data Collection

Data for seven locations and the details of soil management and crop rotations are given in Table 2. The data show the management processes for each location i.e. tillage and land preparation for agriculture, mineral or organic fertilization, system and source of irrigation, drainage system, and all the data about the area under investigation. The surface irrigation was applied and drainage system dominant in all location was an open system. At the end of the agricultural season, wheat productivity was estimated as kg per feddan for each location whereas productivity is the basic factor in determining soil quality using parameters or soil quality indicators.

Table 2. *Data collection of seven locations under investigation.*

Location	Cropping systems	Tillage	Fertilization		Resistant of grasses	Production
			Organic	Mineral		
1	Bean-wheat-maize	chisel plow	10m^3/f organic manure	100kg/fed NH_4NO_3 100kg $CO\text{-}NH_2$	Pesticides use (Jeranstar+Topic)	2015kg/f 14 Ard
2	Bean-wheat-maize	chisel plow	10m^3/f organic manure	100kg/fed NH_4NO_3 100kg $CO\text{-}NH_2$	Pesticides use (Jeranstar+Topic)	2170kg/f 15 Ard
3	Bean-wheat-Bean	Sub soiler plow	15m^3/f organic manure	150kg/f NH_4NO_3 150kg $CO\text{-}NH_2$ 150kg $(CaH_2PO_4)CaSO_4.2H_2O$	Pesticides use (Jeranstar+Topic)+ manually	1800kg/f 12.5Ard
4	Maize-wheat-Bean	chisel plow	12m^3/f organic manure	100kg/f NH_4NO_3 100kg $CO\text{-}NH_2$ 150kg $(CaH_2PO_4)CaSO_4.2H_2O$	Pesticides use (Jeranstar+Topic)	2000kg/f 13.8Ard
5	Maize-wheat-Bean	chisel plow	12m^3/f organic manure	150kg $CO\text{-}NH_2$ 150kg $(CaH_2PO_4)CaSO_4.2H_2O$	Pesticides use (Jeranstar+Topic)+ manually	2160kg/f 15Ard

Location	Cropping systems	Tillage	Fertilization		Resistant of grasses	Production
			Organic	Mineral		
6	Bean-wheat-Maize	chisel plow	15m^3/f organic manure	150kg/f NH_4NO_3 150kg $CO\text{-}NH_2$ 150kg $(CaH_2PO_4)CaSO_4.2H_2O$	Pesticides use (Jeranstar+Topic)+ manually	2160kg/f 15 Ard
7	Maize-wheat-Bean	Sub soiler plow	30m^3/f + humic Acid litter/f	150kg/f $NH_4NO_{3+\,Na\,c\,l}$ 100kg $CO\text{-}NH_2$ 150kg $(CaH_2PO_4)CaSO_4.2H_2O$	Pesticides use (Jeranstar+Topic)	1944kg/f 13.5Ard

Maximum productivity of wheat: 2590-2880 kg (18-20 Ardab)

2.3. Laboratory Analysis

The soil functions are difficult to measure directly, so they are usually assessed by measuring soil quality parameters. There are two main categories of soil indicators: physical and chemical.

Soil physical parameters: Particle size distribution, particle density, bulk density, total porosity, and hydraulic conductivity coefficient were determined according to Klute (1986). Field capacity, wilting coefficient, available water or water holding capacity, quickly drainable pores and slowly drainable pores were determined from moisture characteristic curve (pF curve) according to Saxton and Rawls (2006). Aggregates stability was estimated aggregate size distribution by dry sieving to calculate the mean weight diameter (MWD) according to Six *et al*. (2002) as follows: MWD = $\sum$ Xi Wi where: I = 1, X = mean diameter of the considered fraction mm, W = weight of the dry sieving fraction g.

Soil chemical parameters: pH, EC, organic matter, calcium carbonate, cation exchange capacity, available potassium and total nitrogen were determined according to Page et al., (1982).

2.4. Statistical Analyses

SYSTAT Statistical software (SPSS, 2014) was used for all Statistical analyses. Soil properties were plotted with each other and with crop productivity variables to determine the nature of these relationships. Linear equation was used to determine the relationship among soil indicators and wheat productivity. All values are presented as means standard deviations of eight fields or laboratory measurements. Significant differences between treatments were analyzed using correlation matrix test in SPSS version 21 (2014). Treatment differences were deemed significant at $p>0.05$. The principal component analysis (PCA) was performed in SPSS version 21. Descriptive statistics and linear regressions were computed in Microsoft Excel (2007) and all the figures were obtained using Sigma Plot (2012).

3. Results and Discussion

Data in Table 3 show that, the mean values of physical and chemical parameters of 7 locations. Soil texture of these soils is sandy clay loam, whereas clay content ranged between 24.20 to 35.59%, soil bulk density ranged between 1.25 and 1.35 Mg. m^{-3}, the highest value of quickly drainable pores was 20.40% and the lowest value was 11.10%, cation exchange capacity ranged in seven locations between 20 and 40%, also, the highest value of organic matter was 2.23% in the first location and the lowest value was 1.30% in the second location.

Table 3. *The mean values of selected soil quality parameters of the studied locations.*

Soil properties \ Location	1	2	3	4	5	6	7
Sand%	52.00	61.00	53.50	48.61	47.84	51.50	56.60
Silt%	16.00	14.00	22.80	17.80	22.40	22.10	19.20
Clay%	32.00	25.00	23.70	33.59	29.76	26.40	24.20
Texture class	SCL	SCL	SCL	SCL	SCL	SCL	SCL
Bulk density Mg. m^{-3}	1.33	1.32	1.31	1.34	1.29	1.25	1.35
Particle density Mg. m^{-3}	2.70	2.68	2.66	2.69	2.72	2.75	2.64
Total porosity%	50.74	50.74	50.70	50.20	52.50	54.50	48.80
Quickly drainable pores%	20.40	11.10	17.70	19.21	18.40	16.20	15.40
Slowly drainable pores%	7.30	9.40	10.10	9.70	8.40	9.80	8.20
Water holding porosity%	11.32	19.04	14.20	11.70	14.10	14.90	13.70
Field capacity%	23.04	30.24	22.90	21.29	25.70	28.50	25.20
Welting coefficient%	11.72	11.20	8.70	9.59	11.60	13.60	11.50
Hydraulic conductivity cm.h^{-1}	4.30	4.60	0.94	1.00	5.00	8.15	3.24
Mean weight diameter mm	1.84	1.85	0.55	1.55	1.08	1.57	1.82
pH (soil paste)	7.92	7.61	7.36	7.60	7.5	7.26	7.30
EC (1:2.5) dS/m	0.26	0.16	0.69	0.26	0.29	0.26	0.37
OM%	2.23	1.30	2.19	2.14	2.09	2.15	1.98
$CaCO_{3\%}$	2.97	1.75	1.97	1.83	0.57	0.42	0.57
CEC (Cmol/kg)	33	40	28	36	40	22	20
Available potassium (Meq/100gm)	0.50	0.17	0.22	0.18	0.16	0.24	0.18
Total nitrogen (Meq/100gm)	0.70	0.30	0.30	0.20	0.28	0.22	0.20

3.1. The Correlation Matrix Between Soil Parameters for Seven Locations

Results of statistical analysis can be summarized as follows:

1. A positive significant correlation were found between either of WHC (r = 0.671), FC (r = 0.549), pH (r = 0.583) or CEC (0.645) with soil content of clay.
2. A positive significant correlation were found between quickly drainable pores and fine sand (r = 0.668).
3. Total porosity (TP) (r = 0.765), field capacity (FC) (r = 0.687) wilting coefficient (WC) (r = 0.943) and RD (r = 0.702), positively correlated with the hydraulic conductivity (HC).
4. OM, WHC, clay content, real density (RD) and silt, negatively correlated with fine sand content, whereas the values of correlation coefficient (r) were-0.743,-0.625,-0.605,-0.600 and – 0.512 respectively.
5. QDP negatively correlated with Water holding capacity (r = -0.936).
6. QDP negatively correlated with clay content (r = -0.699).
7. BD negatively correlated with HC, whereas r value was–0.729.

Similar results have been observed by Sakin (2012), who showed a significant correlation between OM and the following physical parameters; bulk density, porosity, hydraulic conductivity, field capacity, water holding capacity and mean weight diameter.

Also, the data showed that correlation matrix of soil quality parameters showed a different correlation between all studied parameters. The important correlation that can be noticed a highly significant positive correlation was observed between yield with fine sand (r = – 0.853), CEC (r = 0.778) and clay content (r = 0.704), while it is found a moderately positive correlation with silt content (r = 0.640), FC (r = 0.631) and WHC (r = 0.596). The main negative correlation was found between yield and QDP (r = – 0.505).

Table 4. *Correlation matrix of soil quality indicators (n = 22).*

	C.S	F.S	yield	SILT	CLAY	R.D	B.D	T.P	Q.D.P	S.D.P	W.H.C
C.S	1.000										
F.S	0.082	1.000									
yield	0.044	-0.853*	1.000								
SILT	-0.319	-0.512	0.640*	1.000							
CLAY	-0.412	-0.605*	0.704*	-0.161	1.000						
R.D	0.254	-0.600*	-0.167	0.159	0.335	1.000					
B.D	0.025	0.395	-0.255	-0.596*	0.101	-0.719*	1.000				
T.P	0.062	-0.499	0.369	0.466	0.071	0.875*	-0.965*	1.000			
Q.D.P	-0.664*	-0.668*	-0.505	0.412	-0.699*	0.111	-0.049	0.085	1.000		
S.D.P	0.463	-0.143	-0.142	0.233	0.583*	0.113	-0.293	0.246	-0.366	1.000	
W.H.C	0.507	0.625*	0.596*	-0.273	0.671*	0.041	-0.186	0.139	-0.936*	0.423	1.000
F.C	0.555	0.440	0.631*	-0.231	0.549	0.336	-0.391	0.389	-0.841*	0.186	0.882*
W. C	0.316	-0.120	0.237	-0.028	-0.030	0.635*	-0.508	0.581*	-0.200	-0.315	0.180
H.C	0.197	-0.104	0.344	0.103	-0.088	0.702*	-0.729*	0.765*	-0.210	-0.169	0.296
M.W.D	0.030	0.221	0.489	-0.605*	0.266	-0.023	0.206	-0.145	-0.151	-0.495	-0.017
E.C	-0.092	0.013	- 0.073	0.552	-0.456	-0.419	0.066	-0.211	0.190	0.328	-0.157
pH	-0.088	0.104	0.081	-0.711*	0.360	0.108	0.439	-0.251	0.201	-0.471	-0.192
OM	-0.426	-0.743*	-0.377	0.645	0.420	0.160	-0.204	0.202	0.903*	-0.185	0.878*
$CaCO_3$	-0.323	0.198	-0.334	-0.489	0.390	-0.247	0.411	-0.357	0.339	-0.227	-0.303
CEC	-0.696*	-0.126	0.778*	-0.076	0.645*	0.100	-0.023	0.075	0.384	-0.205	-0.169
Av.K	-0.447	-0.057	-0.057	-0.146	0.420	0.076	-0.018	0.055	0.580*	-0.613*	-0.544
T.N	-0.268	0.144	-0.059	-0.387	0.352	0.094	0.167	-0.071	0.369	-0.641*	-0.313

Table 4. *Coneinued.*

	F.C	W.c	H.C	M.W.D	E.C	pH	OM	$CaCo_3$	CEC	Av.K
C.S										
F.S										
yield										
SILT										
CLAY										
R.D										
B.D										
T.P										
Q.D.P										
S.D.P										
W.H.C										
F.C	1.000									
W. C	0.621*	1.000								
H.C	0.687*	0.943*	1.000							

	F.C	W.c	H.C	M.W.D	E.C	pH	OM	$CaCo_3$	CEC	Av.K
M.W.D	0.228	0.506	0.372	1.000						
E.C	-0.412	-0.598*	-0.539	-0.802*	1.000					
pH	-0.191	-0.080	-0.165	0.262	-0.368	1.000				
OM	0.737*	-0.077	-0.103	-0.295	0.399	-0.117	1.000			
$CaCO_3$	-0.466	-0.470	-0.447	0.090	0.063	0.747*	0.071	1.000		
CEC	-0.279	-0.302	-0.158	-0.004	-0.311	0.440	0.003	0.377	1.000	
Av.K	-0.358	0.158	0.152	0.341	-0.103	0.509	0.443	0.671*	0.162	1.000
T.N	-0.207	0.089	0.056	0.188	-0.097	0.794*	0.177	0.747*	0.216	0.856*

3.2. Descriptive Statistics of Soil Quality Parameters Under Study

The descriptive statistics data of 21 soil quality parameters have been presented in Table 5. It is revealed that weight and relative weight of soil parameters and the importance of each indicators contribution to soil quality is usually different, and can be indicated by a weighting coefficient. The weights and relative weight of each parameter calculated according to (Kock and link, 1971) as follows:

1-The sum squared deviation from the mean was obtained for each observation.

2-This amount was summed up for all observation for a specific indicator.

3-Obtaining the total sum squared deviation from the mean for all indicators.

4-The weight was obtained by dividing step 2 by step 3 and multiplying by 100.

5-Soil indicators that had a value less than 1 were dropped from consideration.

6-The sum of all weights was normalized to 100%.

The results in Table 5 and figure 2 reveal that CEC represent the important relative weight (20%) followed by clay content, fine sand, silt, quickly drainable pores and field capacity (9.85, 9.72, 8.73, 8.12 and 8.07% respectively). Then come, water holding capacity (6.42), hydraulic conductivity (6.08), coarse sand (5.82), total porosity (4.45) and finally other soil indicators. These results and interpretation in harmony with Wang *et al*. (2003) who stated that the selection of the suitable soil properties for crop productivity in the study region should consider the properties that account for the most variability. Ideally, the selected properties should be easy to measure and the results should be reproducible (Wang *et al*., 2003). As such, the CEC is a property of a soil that describes its capacity to supply nutrient cations to the soil solution for plant uptake, and consequently affected plant productivity. Also, measuring the CEC of a soil is a good parameter of the nutrients content and capacity of the soil, but is not by itself sufficient for managing soil nutrients.

Based on the results of relative weight values, the properties that explained the greatest proportion of the total variance in the present study included CEC, clay content, fine sand content, silt content, QDP, FC and WHC. These soil characteristics seem to be the suitable parameters for assessing the effects of soil parameters on wheat productivity in the study region.

Table 5. *Descriptive statistic of soil quality parameters under study (n = 21).*

Descriptive Statistics				
Parameters	**Mean**	**Standard deviation St. D**	**Weight W = St D. of indicator/ sum. of St. D**	**Relative weight**
CEC	31.63	7.63	0.20	20.00
Clay	28.08	3.76	0.098	9.85
Fine Sand	43.98	3.71	0.097	9.72
Silt	19.54	3.33	0.087	8.73
Q. D. P	17.34	3.10	0.081	8.12
Field Capacity	24.98	3.08	0.080	8.07
W. H. C	13.89	2.45	0.064	6.42
H. C	3.95	2.32	0.06	6.08
Coarse Sand	8.52	2.22	0.058	5.82
Total Porosity	51.23	1.70	0.044	4.45
W. C	11.09	1.47	0.038	3.85
S. D. P	8.91	0.98	0.025	2.57
$CaCO_3$	1.48	0.89	0.023	2.33
M. W. D	1.51	0.47	0.012	1.23
OM	2.04	0.31	0.008	0.81
pH	7.49	0.22	0.005	0.57
E. C	0.32	0.16	0.004	0.41
Total N	0.31	0.16	0.004	0.41
Available K	0.25	0.12	0.003	0.31
Real Density	2.69	0.03	0.0007	0.08
Bulk Density	1.31	0.03	0.0007	0.08

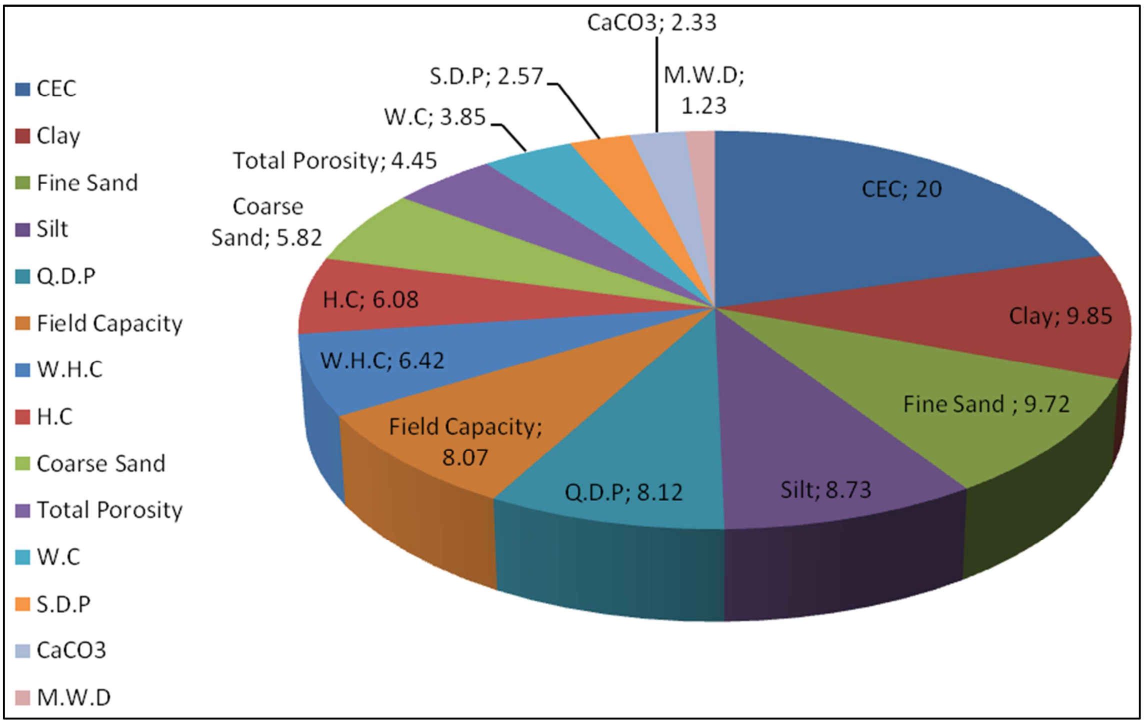

Figure 2. *Contribution of important soil quality parameters in wheat productivity.*

Definition of Eigenvalue:

Eigenvalues are a special set of scalars associated with a linear system of equations (i.e., a matrix equation) that are sometimes also known as characteristic roots; characteristic values (proper values, or latent roots (Marcus and Minc., 1988). Eigenvalues are most commonly reported in factor analyses. They are calculated and used in deciding how many factors to extract in the overall factor analysis (James, 2001).

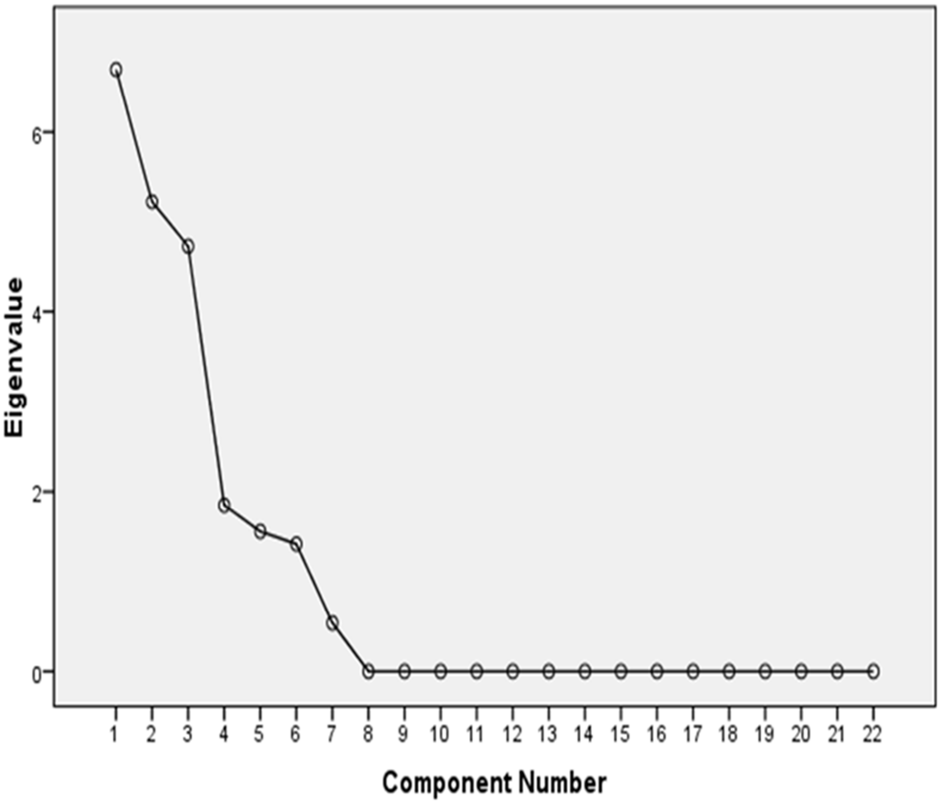

Figure 3. *Eigenvalues of the correlation matrix – the Cattell test.*

3.3. Wheat Productivity as Affected by Soil Quality Parameters

Crop productivity is one of the reliable ways to evaluate the soil quality. In the present investigation, high and significant correlations were observed between some soil parameters and wheat yield. The data are presented in Tables 4 and 5 showed a significant correlation between wheat yield and some soil parameters ($P < 0.05$) of the selected 21 soil indicators. The highest correlation and weight were observed with the following parameters: CEC (r = 0.778 and w = 0.20), clay content (r = 0.704 and w = 0.09), fine sand (r =-0.853 and w = 0.097), silt content (r = 0.640 and w = 0.087), quickly drainable pores (QDP) (r =-0.505 and w = 0.081), field capacity (FC) (r = 0.631 and w = 0.080) and water holding capacity (WHC) (r = 0.596 and w = 0.064) compared with the other indicators.

On the other hand, it is found insignificant correlation between wheat yield and some indicators such as CS (r = 0.044 and w = 0.058), SDP (r =-0.142 and w = 0.025), pH (r = 0.081 and w = 0.005), $CaCO_3$ (r =-0.334 and w = 0.023) and total nitrogen (r = 0.059 and w = 0.003). These results are in agreement with those of Araujo *et al*. (2009), who suggested that measurement of soil properties such as clay content, RD, TP, FC, WHC and WP provides a relative value of soil compaction and reflects significant changes in macro-porosity and soil aeration and consequently effects on soil productivity.

4. Conclusion

From the abovementioned results, it can be concluded that soil quality parameters are considered the important tool for expecting soil productivity and also which indicators are more effective than others. Also, it can be concluded that under this research conditions that the main soil quality indicators which limit soil quality were CEC (cation exchange capacity), clay content, fine sand content, silt content, QDP (quickly drainable pores), F. C (field capacity) and WHC (water holding capacity).

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