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Interrelationships Between Soil Quality Indicators and Alfalfa 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 alfalfa productivity at 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 indicators determination. The investigated indicators 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 highest values of mean standard deviation and the relative weight of physical and chemical indicators were obtained for organic matter represents the important relative weight followed by cation exchange capacity, total nitrogen, clay content, total porosity, field capacity and quickly drainable pores. Concerning the relationship of some soil parameters and alfalfa productivity, the data of correlation studies showed that the most suitable indicators for evaluation of soil quality under different soil management of study area were organic matter, cation exchange capacity, total nitrogen, clay content, total porosity, field capacity and quickly drainable pores.

Keywords: Soil Quality, Soil Quality Indicators, Alfalfa Yield

1. Introduction

The soil is one of the most important environmental factors, it's 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) [3].

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 [4]; Singh and Khera, 2009) [23]. Larson and Pierce (1991) [12] outlined five soil functions that may be used as the criteria for judging the 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) [3].

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) [19].

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 [13]; Gomez *et al*., 1996 [5]; Karlen *et al.,* 1998 [7]; Aparicio and Costa, 2007) [2]. Liu *et al*. (2013) [14] 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) [5] and Shukla *et al*. (2004) [21] 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) [19].

Therefore, the objective of this research is to estimate soil quality indicators in some soils of Monufyia Governorate and study relationship with alfalfa productivity during 2013/2015 seasons.

2. Materials and Methods

The current study was carried out to estimate soil quality indicators (physical and chemical) in El-Sadat area, Monufyia Governorate during winter seasons of 2013 to 2015 and their relationships with alfalfa 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 Figure 1.

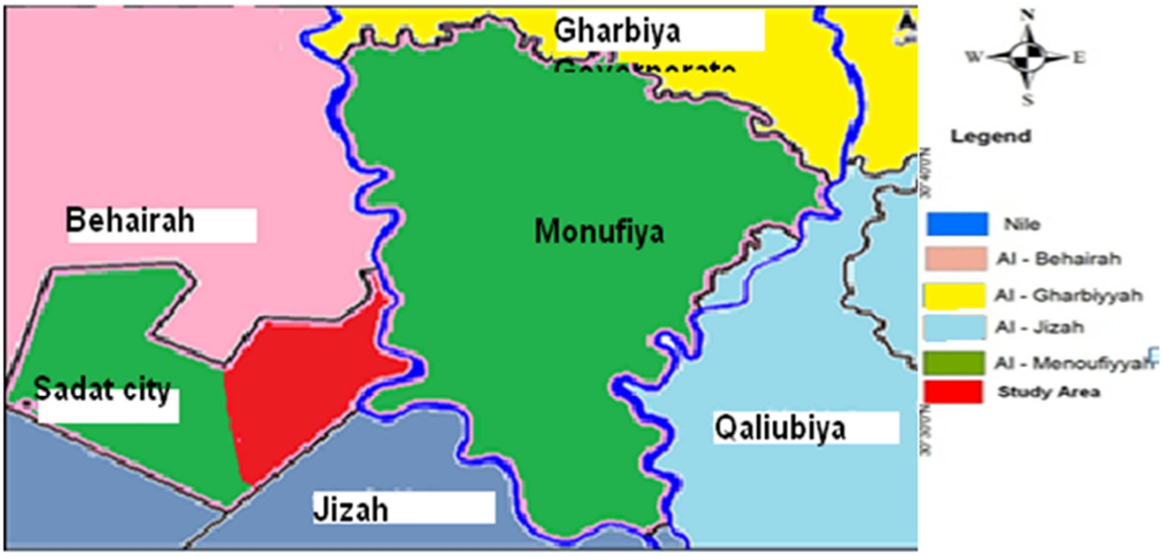

Figure 1. *Map of the studied locations.*

2.2. Laboratory Analysis

The soil functions are difficult to measure directly, so they are usually assessed by measuring soil quality indicators. 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) [10]. 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) [20]. Aggregates stability was estimated aggregate size distribution by dry sieving to calculate the mean weight diameter (MWD) according to Six *et al.* (2002) [24] as follows: MWD = ∑ 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) [18].

2.3. Statistical Analyses

SYSTAT Statistical software (SPSS, 2014) [26] 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 alfalfa 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) [15] and all the figures were obtained using Sigma Plot (2012) [22].

3. Results and Discussion

Data in Table 1 showed that the texture of the studied soil samples were loam, sandy clay loam, sandy clay and clay loam, whereas clay content ranged between 24 to 36%. The values of soil bulk density ranged between 1.20 to 1.46 Mg m^{-3}; real density particles ranged from 2.57 to 2.73 Mg m^{-3}, total porosity ranged between 44 to 54.72%; hydraulic conductivity between 0.83 to 8.31 cm/ h. For the soil moisture constants, the values of the studied samples were ranged from 19.10, 10.6 and 8.5 to 29.40, 15.4 and 12.9 for field capacity, available water and wilting coefficient, respectively. The physical analysis of soil samples showed that most properties are in the optimum range.

Values of soil chemical indicators were showed in Tables 2, 3. It appears that the electric conductivity values ranged between 0.21 to 0.42 dS m^{-1}; pH values ranged between 7.12 to 8.10, the cation exchange capacity between 24 to 32 C mol / kg; calcium carbonate content ranged from 0.49 to 2.56%; organic matter between 1.6 to 2.3%; total nitrogen ranged from 15.4 to 28 mg / kg; available potassium between 42.9 to 111.15 mg / kg. The variation in values of soil chemical properties may be affected by the management processes of these locations such as organic manure and crop rotation.

Table 1. *Soil physical properties of the studied locations.*

location	Particle size distribution (%)				TC	B. D (Mg. m^{-3})
	C. S	F. S	Silt	Clay		
1	6.5	32.5	37	24	L	1.2
2	4.5	41.5	20	34	SCL	1.37
3	5.3	41.7	17	36	SC	1.24
4	7.2	38.4	20.4	34	SCL	1.46
5	7.9	42.7	19.8	29.6	SCL	1.3
6	12.1	41.2	22.1	24.6	SCL	1.33
7	8.4	36.1	23.9	31.6	CL	1.35
8	8.3	39.3	19.4	33	SCL	1.3

Table 1. *Continue.*

location	RD (Mg. m^{-3})	T. P%	H. C (cm/h)	Soil moisture constants		
				W. C%	F. C%	A. W%
1	2.65	54.72	4.7	12.9	28.3	15.4
2	2.72	49.6	4.1	12.8	26.5	13.7
3	2.7	48.15	4.2	12.15	26.25	14.1
4	2.61	44	0.83	8.5	19.1	10.6
5	2.73	52.3	8.31	14	29.4	15..4
6	2.57	48.2	0.94	9.2	21.3	12.1
7	2.67	49.4	4.4	11.3	22	10.7
8	2.7	51.8	5.82	12.7	27	14.3

Table 2. *Soil chemical properties of the studied locations.*

Location	pH (soil past)	EC (dSm^{-1})	Soluble ions							
			Cations (meq/L)				Anions (meq/L)			
			Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{-2}
1	8.10	0.42	0.80	0.20	2.40	0.81	----	1.00	2.10	1.11
2	7.12	0.27	0.70	0.40	1.35	0.24	----	1.00	0.60	1.09
3	8.10	0.21	0.60	0.30	1.10	0.17	----	1.30	0.50	0.37
4	7.72	0.25	0.40	0.20	1.20	0.45	----	1.45	0.40	0.40
5	7.37	0.27	0.40	0.30	1.20	0.37	----	0.90	0.60	0.77
6	7.65	0.25	0.90	0.32	1.20	0.09	----	1.20	0.80	0.51
7	7.71	0.27	0.75	0.33	1.10	0.50	----	0.75	0.84	1.09
8	7.77	0.25	0.70	0.40	1.30	0.20	----	1.30	0.65	0.65

Table 3. *Soil chemical indicators of the studied locations.*

location	CEC (cmol/kg)	Ca CO_3%	O. M%	Av-k (mg/kg)	T. N (mg/kg)
1	38	2.56	2.3	111.15	21
2	39	1	2.1	87.75	17.5
3	40	2	1.6	60.45	28
4	36	2.11	1.9	70.2	22.4
5	39	0.49	2	54.6	15.4
6	42	1.48	2.16	46.8	21
7	34.7	1.12	1.98	42.9	22.4
8	32	1.12	2.06	50.7	19.6

3.1. The Correlation Matrix Between Soil Indicators

Among the highly correlation parameters Table 4, it is found a positive significant correlation between coarse sand and QDP (r = 0.791*); Real density and both of F. C (r = 0.757*), WC (r = 0.871**) and HC (r = 0.845**); total porosity and both of WHC (r = 0.794*), F. C (r= 0.837**), WC (r = 0.813**), HC (r = 0.733*); quickly drainable pores and OM (r = 0.64*); water holding capacity and both of F. C (r = 0.960**), WC (r = 0.841**) and HC (r = 0.719*); field capacity and both of WC (r = 0.959**) and HC (0.857); wilting coefficient and HC (r = 0.926**); pH and both of $CaCO_3$ (r = 0.766*) and TN (r = 0.755*); calcium carbonate content and TN (r = 0.65*). Also, it is shown in Table (4) a highly negative significant correlation between coarse sand and both of clay (r = - 0.58) and RD (r=- 0.65); fine sand and both of silt (r = - 0.868**), EC (r = - 0.786*); silt and clay (r = - 0.732*); clay content and both of QDP (r = - 0.708*), EC (r = - 0.68*), OM (r = - 0.776); real density and QDP (r = - 0.67); bulk density and both of TP (r = -0.771*), WHC (r = -0.765*), F. C (r = -0.727*) and WC (r = -0.63*); quickly drainable pores and SDP (r = -0.69*); hydraulic conductivity and MWD (r = -0.723*).

Generally, the highest significant correlations between indicators are obtained for silt and EC (r = 0.966**), water holding capacity and F. C (r = 0.960**), field capacity and WC (r = 0.956**), wilting coefficient and HC (r = 0.926**).

These results are in agreement with those obtained by Karlen and Andrews, (2004) [8]; Andrews et al. (2004) [1] and Mohanty *et al*. (2007) [16], who found correlations between electrical conductivity, calcium carbonate, volumetric water content and sand content, also, they reported that available water holding capacity (AWC) more is better functions on water availability for crop productivity and biological activity. In addition, Nishant et al. (2014) [17] stated that the soil properties such as BD, MWD, Av-P, Av-K, EC and pH influenced or significant correlated with soil organic matter due to cropping systems. Also, Jaedson et al (2014) [6] noted that a correlation between soil indicators (clay, sand, silt, soil bulk density, mean weight diameter, stable aggregates and organic matter).

Table 4. *Correlation matrix of soil quality indicators and alfalfa productivity (n = 21).*

	productivity	CS	FS	SILT	CLAY	R.D	B.D	T.P	Q.D.P	S.D.P	W.H.C
productivity	1.00										
CS	-0.30	1.00									
FS	-0.15	0.04	1.00								
Silt	-0.17	0.02	-.868**	1.00							
Clay	0.60	-0.58	0.41	-.732*	1.00						
R.D	0.07	-0.65*	0.29	-0.28	0.50	1.00					
B.D	-0.16	0.12	0.24	-0.45	0.38	-0.28	1.00				
T.P	0.60	-0.08	-0.33	0.57	-0.50	0.44	-.771*	1.00			
Q.D.P	0.55	.791*	-0.47	0.48	-.708*	-0.67*	0.19	0.08	1.00		
S.D.P	0.32	-0.65*	-0.06	-0.08	0.49	0.35	-0.25	-0.05	-0.69*	1.00	
W.H.C	0.04	-0.33	0.09	0.22	-0.21	0.58	-.765*	.794*	-0.37	0.02	1.00
F.C	0.58	-0.42	0.08	0.18	-0.09	.757*	-.727*	.837**	-0.42	0.12	.960**
W.C	-0.08	-0.47	0.06	0.12	0.04	.871**	-0.63*	.813**	-0.44	0.20	.841**
H.C	-0.08	-0.28	0.11	0.00	0.06	.845**	-0.50	.733*	-0.27	-0.05	.719*
M.W.D	0.15	-0.13	0.01	0.04	0.01	-0.43	0.09	-0.35	-0.20	0.44	-0.16
E.C	-0.21	-0.12	-.786*	.966**	-0.68*	-0.09	-0.45	0.67*	0.37	-0.11	0.39
pH	0.47	0.03	-0.54	0.40	-0.15	-0.30	-0.55	0.10	0.07	0.20	0.07
OM	0.71*	0.32	-0.46	0.70*	-.776*	-0.26	-0.11	0.55	0.64*	-0.40	0.19
$CaCO_3$	0.49	-0.18	-0.60*	0.53	-0.19	-0.51	-0.24	-0.14	0.05	0.24	-0.08
CEC	0.68*	0.08	0.39	0.00	-0.35	-0.24	-0.20	-0.09	-0.18	0.04	0.17
Av-k	0.00	-0.59	-0.49	0.66*	-0.24	0.06	-0.28	0.35	-0.17	0.23	0.42
T.N	0.65*	-0.12	-0.18	-0.07	0.30	-0.29	-0.17	-0.43	-0.27	0.57	-0.32

Table 4. *Continue.*

	F.C	W.C	H.C	M.W.D	E.C	pH	OM	$CaCO_3$	CEC	Av-k	T.N
productivity											
CS											
FS											
Silt											
Clay											
R.D											
B.D											
T.P											
Q.D.P											
S.D.P											
W.H.C											
F.C	1.00										
W.C	.959**	1.00									
H.C	.857**	.926**	1.00								
M.W.D	-0.31	-0.43	-.723*	1.00							
E.C	0.36	0.30	0.17	-0.03	1.00						
pH	-0.03	-0.13	-0.15	0.08	0.25	1.00					
OM	0.15	0.10	0.02	0.08	.735*	-0.22	1.00				
$CaCO_3$	-0.24	-0.38	-0.53	0.52	0.42	.766*	-0.01	1.00			
CEC	0.04	-0.09	-0.23	0.36	-0.02	-0.11	-0.02	0.11	1.00		
Av-k	0.35	0.25	-0.02	0.39	.757*	0.12	0.42	0.56	0.15	1.00	
T.N	-0.38	-0.40	-0.46	0.36	-0.26	.755*	-0.63*	0.65*	0.07	-0.09	1.00

* Correlation is significant at $P < 0.05$ level. ** Correlation is significant at $P < 0.01$ level

3.2. Descriptive Statistics of Soil Quality Indicators Under the Studied Locations

The descriptive statistics data of 21 soil quality indicators of alfalfa have been presented in Table 5. It is revealed that weight and relative weight of soil indicators and the importance of each indicators contribution to soil quality are usually different, and can be indicated by a weighting coefficient. The weights and relative weights of each indicator calculated according to (Kock and link, 1971) [11].

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

Descriptive statistic				
indicators	**Mean**	**St. deviation**	**weight**	**Relative weight**
OM	2.01	6.21	0.157	15.7
CEC	37.58	4.45	0.112	11.2
T. N	0.29	3.69	0.093	9.3
Clay	30.85	3.44	0.086	8.6
T. P	49.77	3.24	0.081	8.1
F. C	24.98	3.19	0.080	8.0
Q. D. P	14.35	2.67	0.067	6.7
H. C	4.16	2.44	0.061	6.1
CS	7.52	2.32	0.058	5.8
Silt	22.45	0.20	0.050	5.0
W. H. P	13.28	1.93	0.048	4.8
W. P	11.69	1.91	0.048	4.8
S. D. P	10.43	1.26	0.031	3.7
M. W. D	2.12	0.77	0.019	1.9
CaCO3	1.48	0.68	0.017	1.7
F. S	39.17	.053	0.013	1.3
PH	7.69	0.33	0.008	0.8
Av-k	0.33	0.11	0.002	0.2
R. D	2.66	0.05	0.001	0.1
B. D	1.31	0.07	0.001	0.1
E. C	0.27	0.06	0.001	0.1

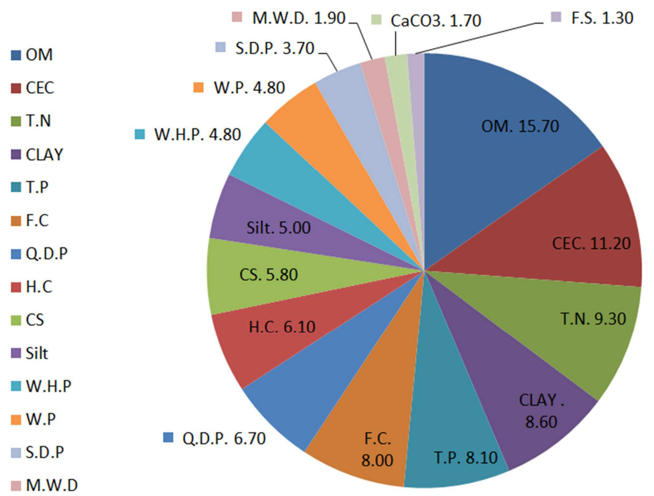

Figure 2. *Contribution of important soil quality indicators in alfalfa productivity.*

The results in Table 5 and Figure 2 reveal that organic matter represents the important relative weight (15.7%) followed by cation exchange capacity, total nitrogen, clay content, total porosity, field capacity and quickly drainable pores (11.2, 9.3, 8.6, 8.1, 8.0 and 6.7% respectively). Then come, hydraulic conductivity (6.1%), coarse sand (5.8%), silt (5.0%) and finally other soil indicators.

These results and interpretation in harmony with Wang *et al.* (2003) [27] and Somasundaram et al. (2013) [25], who stated that the soil organic matter accumulation can improve soil quality by increasing aggregate stability of soil.

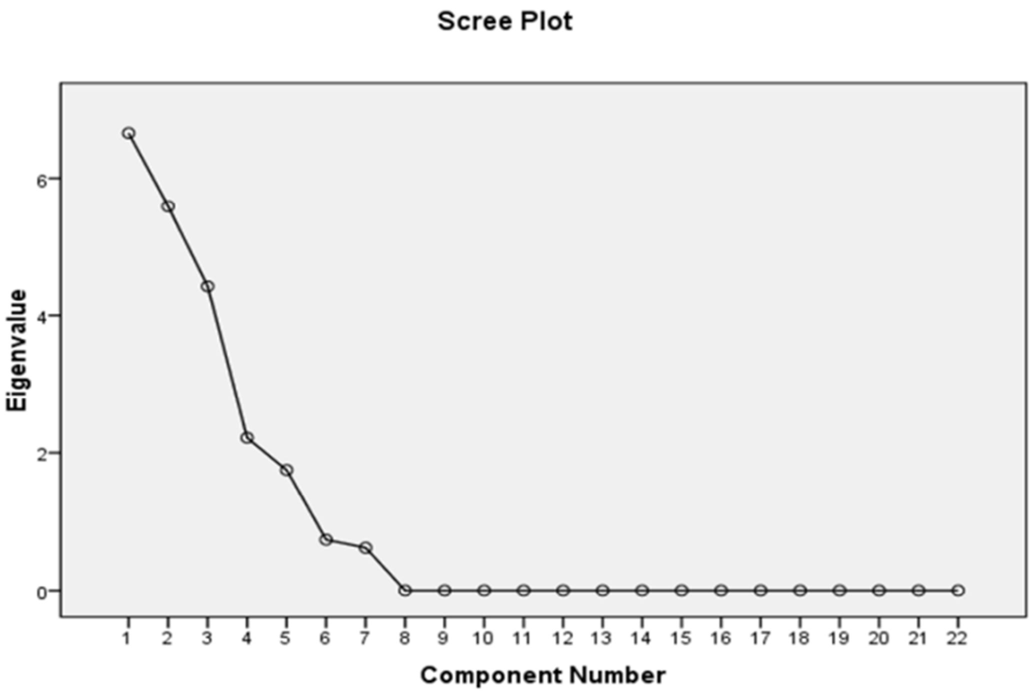

Figure 3. *Eigenvalues of the correlation matrix – the Cattell test.*

3.3. Wheat Productivity as Affected by Soil Quality Indicators

The important function of soils is crop productivity, which is one of the good ways to evaluate the soil quality. In the present investigation, high and significant correlations were observed between some soil indicators and alfalfa yield. The data are presented in Tables 4, 5 showed a significant correlation between alfalfa yield and some soil indicators ($P < 0.05$) of the selected 21 soil indicators. The correlation and relative weight were observed with productivity for the following parameters: organic matter ($r = 0.71$ and rw = 15.7%), CEC ($r = 0.68$ and $w = 11.2\%$), total nitrogen ($r = 0.65$ and $w = 9.3\%$), clay content ($r = 0.60$ and $w = 8.6\%$), total porosity ($r = 0.60$ and $w = 8.1\%$), field capacity ($r = 0.58$ and $w = 8.0\%$), and quickly drainable pores ($r = 0.55$ and $w = 7.6\%$), compared with the other indicators. This may be due to the beneficial effect of organic matter on many soil properties.

4. Conclusion

From the above mentioned results, it can be concluded that there are main soil indicators more effective on the yield of alfalfa such as OM, CEC, TN, clay content, TP, FC and QDP are responsible on most other soil properties and consequently soil productivity.

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