The Role of Climate on The Aggregate Stability and Soil Erodibility of Selected El-Jabal Al-Akhdar Soils-Libya

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ABSTRACT

The carried research work was as an attempt to develop an idea about the relations between some independent climate components represented in rainfall and temperature and soil hydraulic properties, evaluating the relevance of this relation with regards to soil erodibility. To achieve this goal, taking into account the total average precipitation rate and temperature dissimilarity, three soil profiles were investigated at different areas in the El-Jabal Al-akhdar region, north east of Libya. The obtained results, propped by the statistical analyses, proved that the rainfall and temperature are very important factors, because they play a significant role on the clay formation; as a result of the chemical weathering acceleration, as well as augmentation of the organic matter content leading to more stability of the soil aggregates yielded to reduce of the erodibility hazards.

Keywords: aggregate stability, erodibility, Hydraulic properties, Libya, organic matter

INTRODUCTION

Soil structure, is one of the basic characteristics which describe the soil hydraulic properties. It is a limiting factor for characterizing the soil conditions (Habel et al., 2007).

Soil structure defined as the size, shape and arrangement of the peds made of primary soil particles; sand, silt, and clay, together with voids into grouping called aggregates. These aggregates form as a product of complex interactions among biological, chemical, and physical processes in the soil (Tisdall and Oades, 1982).

It is widely believed that many factors play significant role in the soil aggregation. They may be classified as follows: 1- abiotic (clay minerals types, sesquioxides, and exchangeable cations such as calcium, magnesium and sodium cations); 2- biotic (soil organic matter, activities of plant roots, soil fauna, and soil microorganisms), and 3- environmental such as soil moisture and temperature (Chen et al., 1998).

Soil structure has strong influences on the physico-chemical properties such as the total and effective porosity (Shaver et al., 2007), soil strength, water flow, and contaminant transport in soils (Kodesova et al., 2009). In addition, it is controlling the top soil hydrology and susceptibility to crusting of the soil surface (De Ploey and Poesen, 1985), thus determining the soil tendency to wind and water erosion (Vermang et al., 2007).

Taking into consideration all the previous impacts, we may derive that the aggregate stability can provide key information about the soil quality (Castro Filho et al., 2002).

On the other hand, the opposite process to soil aggregation is soil degradation. The mechanisms of this process could be grouped in two categories; the first is related to the human impact. This category involves soil management and human disturbances, such as soil practices at improper soil moisture, crossing of heavy machinery, irrigation, use of fertilizers, and cropping under annual crops. All can lead to soil structure degradation (Angers et al., 1999; Pagliai et al., 2004; Olchin et al., 2008). The second category includes roles played by the climate. According to Jenny (1941), the soil profile development is determined to some extent by five factors (parent material, climate, topography, organisms and time). However, climate is considered to be the most influential factor (Jenny, 1980). This is because climate includes rainfall and temperature, which have major impacts upon the weathering processes, leaching or accumulation of salts, biological activity, and vegetation cover, and thus inevitably influencing the soil degradation process.

Under arid conditions, as in Libya, soils are generally shallow and less developed with inadequate vegetative cover as a result of low annual precipitation accompanied with high temperature. On the other hand, the chance of salinity or alkalinity; due to the lack of enough water for leaching excessive salts from the soil solum, is high. All these factors lead to instability of soil aggregates, and hence the soil erodibility hazards are more likely in comparison with soils in semiarid and humid regions (Cerda`, 1998).

Soil erodibility is the inherent susceptibility of soil particles or aggregates to become detached or transported by erosive agents such as rainfall, runoff, and wind (Toy et al., 2002; Morgan, 2005). It is affected by the soil mechanical composition, structural stability, organic matter content, soil chemistry and clay mineralogy. Furthermore, there are factors associated with soil structure, such as slaking and water transmission characteristics (Lal, 1994).

In spite of the considerable amount of work on this subject, on agriculture lands in temperate and semiarid climates, relatively few studies have been focused on the arid regions especially in Libya. The work presented here constitutes an attempt to study the relations between some independent climate components, the soil physico-chemical properties, and the effect of this relation on the susceptibility to the soil erodibility for selected Libyan soils.

MATERIALS AND METHODS

2.1. Hydro- geological Description of Study sites

With regards to climate, Libya is known as an arid country, where the annual precipitation covers only 7 % of total area. In general, there is a steady decrease in rainfall rates, to the drought indices from February to August followed by rapid rise from September to October with maximum precipitations in December and January. The most prone areas to intense rainy storms in winter are limited to the coastal strip, especially in El-Jabal Al-akhdar Mountains. For this reason, three soil profiles representing the main arable soils of the coastal areas of Mediterranean in El-Jabal Al-akhdar region, northeast of Libya, were used in this study. Two of them are red soils with fine clay; a mixed family of Typic Rhodoxeralf and Calcic Rhodoxeralf (Terra Rosa), developed on a residuum material of limestone. They were located at Ras Elhelal (profile 1) and Shahat (profile 2) areas. The third soil profile was located at the alluvial strip between Benghazi and Tokra (profile 3), representing Tokra area. The soils of this area are dominated by calcareous rocks belonging to the Cainozic era. According to the American soil classification system, they may be classified as Typic Ustochrepts; they have no lithic contact in the first 50 cm depth, calcium carbonate content below 40% and no cracks as wide as 1 cm or longer than 50 cm.

The sites have typical Mediterranean shrub vegetation, with some difference in species induced by altitude and the different precipitation rates.

The locations of soil profiles as well as the precipitation distribution in El-Jabal Al-akhdar region are shown in Figure (1), while Table (1) presents the basic hydro-geographical information of the different study sites.

After identifying the morphological structure as based on the criteria for soil structure assessment (FAO, 1990), disturbed and undisturbed core samples with volumes 100 cm^3 were taken at depth of 5-10 cm, in order to determine the bulk density of tested soils (USDA, 2011). Assuming a particle density is 2.65 g cm^{-3}, the total porosity was calculated as:

$$\text{Porosity} = [1 - (\text{Bulk density}/\ \text{Particle density})] \times 100 \qquad \text{Eq. (1)}$$

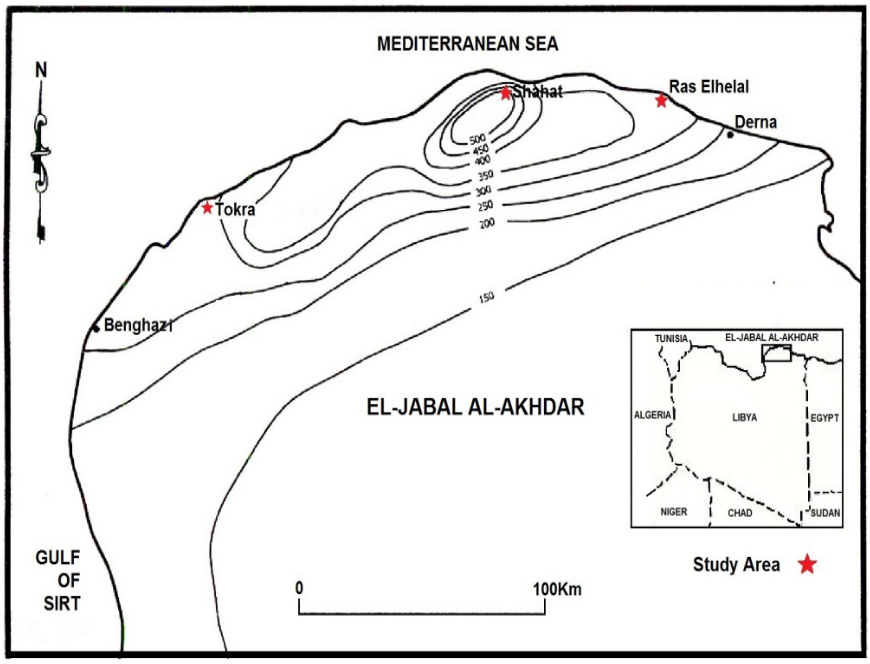

Fig. 1: The locations of experimental soil profiles and average precipitation data during1970-2003

Table 1: Some relevant Hydro-geographical information of the studied areas

Soil Profile Number	Area	Geographic coordinate	Elevation a. s. l. (m)	Distance from the sea (km)	Mean annual rainfall (mm/year)	Mean annual temperature (C^0)
1	Ras El Helal	$32^0\ 54^{'}$ N $22^0\ 12^{'}$ E	50	1.1	383	20
2	Shahat	$32^0\ 49^{'}$ N $21^0\ 51^{'}$ E	685	8.0	542	17
3	Tokra	$32^0\ 33^{'}$ N $20^0\ 35^{'}$ E	13	1.2	292	21

2.2. Physico-chemical analysis of soil samples

For laboratory examination, soil samples were collected from the upper layers of soil profiles, air-dried and then screened through 2-mm sieve for separating the skeleton fractions. The particle size distribution for the soil samples was determined using the pipette method (Klute, 1986). The sand fraction, as classified by USDA, was separated by wet-sieving, oven-dried, and then fractionated by dry sieving.

The organic matter and calcium carbonate contents were measured using Walkley-Black and the calcimetry methods, respectively (Klute, 1986).

The soil permeability of the study sites was determined in situe using the constant head double cylinder method (Klute, 1986). The vertical permeability was calculated by solving Darcy's equation using as follows:

$$Ks = Q\,L / H\,A \qquad \text{Eq. (2)}$$

Where Ks saturated hydraulic conductivity, (cm h^{-1}); Q the amount of water that passes through the soil in one hour, (cm^3); H the total head in (cm); A cross section area of the internal cylinder (cm^2), and L the thickness of the soil layer (10 cm).

2.3. Soil aggregates characteristics

In this work for characterizing the soil aggregate stability, the methods were based on original methodologies published in the years 1983-2007 (Rzasa and Owczarzak, 1983; Owczarzak et al., 1994; Rzasa and Owczarzak, 2004; Habel et al., 2007) where concept, principals, and detailed analytical processes were presented.

Before discussing details these methods, it is worth to have a general view about some of the known methods in this regard.

In principal, the selected methods as well as interpretation of the results of the aggregate stability depend on the purpose of the study. The most common method used for aggregate stability determination is wet sieving.

Most of the known methods emulate a specific technique of aggregate collapse. Le Bissonnais (1996) reported four main mechanisms of aggregate breakdown: (a) slaking due to compression of entrapped air during wetting, (b) breakdown by differential swelling, (c) mechanical breakdown by raindrop, and (d) physicochemical dispersion due to the osmotic stress.

The results acquired by these methods are characterized by low repeatability, stemming mostly from a considerable differences among aggregate shapes and sizes, indirect evaluation of certain characteristics based the others, and from the impossibility of creating stable, controlled conditions of moisture content, consolidation and temperature during the tests. It is not possible in these methods to obtain a congruent object of study in order to repeat the analysis, not to mention an identical one.

As an attempt to eliminate those deficiencies, or at least diminishing them, the soil aggregate stability in the considered methods attached with a soil aggregates of clearly defined shape (cylindrical with height = 10.0 mm, and diameter = 11.28 mm, thus volume = 1 cm^3) collected from the upper layer (5-8 cm) in mid March after the seasonal precipitation. The sampled aggregates were brought to their air dry state.

The structural condition and the variability of the arable layer of the investigated soils were assessed by the determination of the following physical and mechanical parameters of soil aggregates:

a- Static water resistance (SW) of soil aggregates: determined in a plastic container with nylon threads spread every 0.6 cm on which the aggregates are placed, and the next container is filled with water. This property is determined by the measurement of "soaking time" of the aggregates submerged in water. For this purpose 5 aggregates were placed on tightened threads at a distance of 1 cm from one another. Then the water was released gradually, up to the level of ca 1 cm above the submerged aggregates. The soaking time was counted from the first contact of water with soil aggregates. The conclusive result is an average of 5 repetitions and is expressed in seconds. The maximum time period of the measurement was set at 24 hours (Rzasa and Owczarzak, 1983; Owczarzak et al., 1994; Rzasa and Owczarzak, 2004; Habel et al., 2007).

b- Dynamic water resistance (DW) of soil aggregates: this analysis was performed with the help of aggregate dynamic water resistance analyzer. The device is equipped with a feeder discharging 0.05 ml water drops, which fall from the height of 1.0 m, at 1 second intervals, hitting the surface of the cylindrical aggregate with a kinetic energy of 4.905×10^{-4} J. The following methods of water consumption measurement were employed: in case of small amounts (up to 100 drops) counting was used, between 100 and 500 drops –weighing, and above 500 drops- volume measurement. Results describing the resistance of soil aggregate to dynamic action of water were expressed in number of standard drops and in values of kinetic energy (J).

c- State of secondary aggregation after the SW and DW: a complete analysis of the resistance of soil aggregates to static and dynamic water action requires the determination of a degree of disintegration or washout of ‘primary’ aggregates; and the determination of the amount and quality of newly created (secondary) aggregates (Kemper and Rosenau, 1986). These secondary aggregates are determined using the sieve method in the wet state on a set of sieves with mesh diameters: 7, 5, 3, 1, 0.5 and 0.25 mm. The sieves were submerged in water where, as a result of horizontal and vertical movements, aggregates disintegrated into fractions.

The evaluation of water resistance and secondary aggregation was conducted on the grounds of the 10-degree scale as presented in Table 2.

2.4. Estimation of soil erodibility

Soil erodibility was estimated using the proposed equation by Wischmeier and Smith (1978), (Equation 2). The equation is valid for calculating the erodibility for soils with less than seventy percent of very fine sand and silt, which is suitable in the case of the soils considered here.

$$K= [(2.1\times10^{-6})\ M^{1.14}\ (12\text{-}OM)] + [(3.25\times10^{-2})\ (S\text{-}2)] + [(2.5\times10^{-2})\ (K_s\text{-}3)] \qquad \text{Eq. (2)}$$

Where,

M: the product of primary particle size fractions (silt % + very fine sand %) × (100- clay %);

OM: the organic matter percent;

S: the structure class (1= very fine granular, 2= fine granular, 3= medium or coarse granular, and 4 = blocky);

K_s: class of permeability (saturated hydraulic conductivity), (1= rapid > 12.5 cm h^{-1}, 2= rapid to moderate 12.5 – 4 cm h^{-1}; 3 = moderate 4-1.5 cm h^{-1}; 4= moderate to slow 1.5 – 0.5 cm h^{-1}; 5= slow 0.5-0.05 cm h^{-1} and 6= very slow < 0.05 cm h^{-1}.

2.5. Statistical analysis

In order to understand the interaction between evaluated parameters, correlation coefficients were calculated. Regression analyses were utilized to test the dependency or not between these parameters. All statistical work was executed by using statistical package software SPSS Version 20 (2011).

RESULTS AND DISCUSSION

3.1. Hydro-geographical characteristics of the study sites

The hydro-geographical conditions of the studied areas are presented in Table 1. The study areas represent the Mediterranean climate. They are characterized by the alternation of a moist cool winter and a hot long dry summer. As a result soil formation and weathering processes in these soils are more active during the rainy winter season than in summer.

Soil structure type in the investigated soil profiles, may be considered as medium to coarse angular structure.

As shown in Table 3, clay is the major fraction in soil profiles 1 and 2, representing in (A) horizon 58.4% to 62.3%, respectively; therefore they are classified as clay or heavy clay soils. The amounts of precipitation at Ras El Helal (profile 1) and Shehat (profile 2) areas, are optimal for chemical weathering such as the hydrolysis

Table 2: Classification of water resistance of soil aggregates and secondary aggregation after water action, (after Rzasa and Owczarzak, 1983)

Degree of water resistance and secondary aggregation	Name of water resistance and degree of secondary aggregation	Dynamic water resistance		Static water resistance (min or h)	Index of secondary aggregation (%)
		Number of standard drops	Kinetic energy ($\times10^{-2}$ J)		
1	Extremely low	< 40	< 2	< 40’’	< 5
2	Very low	40-100	2-5	40’’ – 1’ 30’’	5-10
3	Medium low	101-200	6-10	1’ 30’’ – 3’	11-20
4	Low	201-500	11-25	3’ 1’’ – 8’	21-35
5	Medium	501-1000	26-50	8’ 1’’ – 15’	36-50
6	Medium high	1001-2000	51-100	15’ 1’’ – 30’	51-65
7	High	2001-5000	101-250	30’ 1’’ – 1h 30’	66-80
8	Very high	5001-10 000	251-500	1h 30’ 1’’ – 6h	81-90
9	Extremely high	10 001- 20 000	501-1000	6h 1’ – 24h	91-99
10	Full	> 20 000	> 1000	>24h	100

processes leading to evolution of clay fraction, the migration of clay from the ground surface to (B) horizon; Argilization processes, and effective dissolution and leaching of calcium carbonate to deeper soil layers. The color of these soils is red. This can be linked to the long hot and dry summer where the soils desiccate, causing the development of the crystalline iron oxides such as hematite or magnetite, i.e. rubification processes. In the third soil profile (Tokra area), the mechanical composition is to some extent similar (36 % sand, 29 % silt and 35 % clay), with abundant calcium carbonate content (13.6 %). This fact is not surprising as a result of lower precipitation rates in this area. According to these results, it could be recognized as clay loam calcareous soil.

Climate exerts a strong influence over vegetation type, biomass and diversity. Generally, high temperature and low precipitation rates in arid and semiarid regions lead to poor organic matter production and rapid oxidation (Pal et al., 2000). This is well backed up by the correlation analysis, where we may observe a high positive correlation between rainfall rates and organic matter content (0.935), while a negative correlation was prevailed with the temperature (-0.883). Another correlation was well noted between the mechanical composition of the studied soils and their contents of organic matter. Adverse correlation coefficients were dominated between the sand and silt fractions with the organic matter, while this relation was highly positive with clay content (Table 5). This is natural as the sand and silt fractions are mostly developed through rocks and minerals weathering processes; positive correlation coefficients with the atmospheric temperature, while clay fraction was correlated positively with rainfall. Moreover, the positive correlation between the organic matter content and clay fraction, may be linked to three mechanisms. Firstly, the greater clay percent in the soil means the higher water retention and supply for plant growth. Secondly, bonds between the surface of clay particles and organic matter retard the decomposition process, and, thirdly soils with higher clay content increase the potential for aggregate formation, resulting in macro aggregates which physically protect organic matter molecules from further mineralization caused by microbal attack (Rice, 2002).

We may observe a respectable negative correlation (-0.965) between the organic matter content and calcium carbonate. Since plant residues and roots contribute to soil organic matter, these materials during the decomposition processes release organic acids, which may solubilize inorganic calcium carbonate. Furthermore the released carbon dioxide, resulting from both roots and soil organism respiration, will react with water producing carbonic acid, which also affects the solubilization of calcium carbonate as soluble calcium bicarbonate.

The bulk density, followed by the total soil porosity, did not show any unexpected results. Examining Table 5, we may deduce a high positive correlation coefficients for the bulk density with sand contents (0.996 for very fine sand, and 0.990 for sand), and negatively with the fine fractions; clay percent (-0.962). That reflects the tendency of increasing bulk density values as the soils are coarser, this is well related to the particle sorting. On the other hand, the total porosity was correlated negatively with the coarse fractions; total sand class (-0.998), while highly positive with the clay fraction (0.953); this can be expounded by the enhancement in the total pore space as a sequel of the good aggregation.

Bulk density negatively correlated with organic matter (-0.748), where as the total porosity correlated positively with organic matter (0.728). The decrease in bulk density; increase in porosity, was probably due to the role of organic matter in the soil aggregation (Clapp et al., 1986).

On the other hand, the presence of calcium carbonate as chemical compound in soils may leads to greater compaction that increases bulk density and then reducing total porosity values (Table 5); this can be explained by the binding role of calcium carbonate between the clay particles, causing a greater cohesion between them.

Results of measured permeability of the test soils were generally characterized with slow infiltration rates; (0.20, 0.10 and 0.32 cm h^{-1}) respectively, (Table 3). As shown in Table 5, the permeability correlated negatively with rainfall, clay content, organic matter and total porosity with correlation coefficients (-0.978, -0.823, -0.998 and -0.614) respectively. Where it correlated positively with other parameters; temperature (0.945), very fine sand (0.562), sand (0.521), silt (0.733), calcium carbonate (0.914), and bulk density (0.637). The decrease of permeability with rainfall may be linked to the high antecedent soil moisture content during precipitation as compared with soil under high temperature, and drained off soils; increasing in the permeability initial rate. Excluding the climatic parameters, these relations contradict the general assumptions. However, the positive correlations between sand and silt contents may be attributed to the fact that the presences of these fractions will promote fast infiltration rates as a result of large pore space between particles. The strong correlation between permeability and calcium carbonate content may be attributed to the fact that calcium carbonate will inhibit clay swelling and therefore enhance their flocculation (Mustafa and Ibrahim, 2001).

Table 3: General properties of the studied soil profiles

Profile No.	Genetic horizon	Depth (cm)	Mechanical composition (USDA classification) V.F. Sand (%)	Sand (%)	Silt (%)	Clay (%)	Texture class	Calcium carbonate (%)	O.M. (%)	Bulk density (g cm^{-3})	Porosity (%)	saturated hydraulic conductivity (cm h^{-1})	Erodibilty
1	A	0-32	3.7	6.6	31.1	62.3	C	0.8	1.65	1.20	54.7	0.20	0.24
	B	33-79	-	7.7	26.8	65.5	C	5.0	-	-	-	-	-
	C	80-120	-	11.1	30.5	58.4	C	8.1	-	-	-	-	-
2	A	0-25	13	22	19.6	58.4	C	0.0	2.0	1.28	51.5	0.10	0.27
	B	26-55	-	16.6	20.4	63	C	0.0	-	-	-	-	-
	C	56-125	-	12	11	77	C	0.7	-	-	-	-	-
3	A	0-30	23	36	29	35	CL	13.6	0.9	1.40	47.2	0.32	0.56
	B	31-60	-	43	33	24	L	8.0	-	-	-	-	-
	C	61-100	-	22	36	42	C	14.0	-	-	-	-	-

Table 4: Disintegration time of air-dried soil aggregates and distribution of secondary aggregates after static and dynamic water action

Profile No	Disintegration time (s.) after static water action	Percentage of aggregates after static water action								Disintegration time (s.) after dynamic water action	Percentage of aggregates after dynamic water action							
		Diameter > (mm)						Total (mm)			Diameter > (mm)						Total (mm)	
		7	5	3	1	0.5	0.25	<0.25	>0.25		7	5	3	1	0.5	0.25	< 0.25	> 0.25
1	105	0	0	0.9	37.7	26.8	16.3	18.3	81.7	6.5	0	0	0.4	40	28	18.1	13.5	86.5
2	1170	0	0	19.8	50.6	11.7	10.3	7.6	92.4	32.37	0	0	12.5	54	13	8.1	12.6	87.4
3	95	0	0	0.9	30.3	33.2	24.7	10.9	89.1	35.7	0	0	2.2	2.2	15	29.2	51.4	48.6

Table 5: Correlation matrix among studied soil properties

Soil property	Rainfall	Temp.	V.F. Sand	Sand	Silt	Clay	$CaCO_3$	O.M.	BD	Porosity	Permeability	D.T.SW	ASW < 0.25	ASW > 0.25	D.T.DW	ADW < 0.25	ADW > .25
Temp (C^0)	-0.992																
V. F .Sand (%)	-0.379	0.260															
Sand (%)	-0.334	0.213	0.999														
Silt %	-0.858	0.915	-0.151	-0.198													
Clay %	0.688	-0.592	-0.932	-0.914	-0.217												
$CaCO_3$ (%)	-0.810	0.730	0.850	0.823	0.393	-0.983											
Organic Matter (%)	0.935	-0.883	-0.683	-0.647	-0.619	0.901	-0.965										
Bulk density (g cm^{-3})	-0.464	0.350	0.996	0.990	-0.057	-0.962	0.896	-0.748									
Porosity (%)	0.437	-0.321	-0.998	-0.994	0.088	0.953	-0.882	0.728	-1.000								
Permeability (cm h^{-1})	-0.978	0.945	0.562	0.521	0.733	-0.823	0.914	-0.998	0.637	-0.614							
Disint .Time SW (s)	0.936	-0.973	-0.029	0.019	-0.984	0.389	-0.551	0.750	-0.123	0.092	-0.843						
ASW < 0.25 (mm)	-0.445	0.554	-0.660	-0.695	0.842	0.343	-0.165	-0.099	-0.586	0.611	0.251	-0.732					
ASW > 0.25 (mm)	0.445	-0.554	0.660	0.695	-0.842	-0.343	0.165	0.099	0.586	-0.611	-0.251	0.732	-1.000				
Disint. Time DW (s)	0.051	-0.176	0.905	0.924	-0.558	-0.689	0.544	-0.306	0.861	-0.876	0.156	0.400	-0.197	0.917			
ADW < 0.25 (mm)	-0.791	0.708	0.866	0.841	0.363	-0.988	0.999	-0.956	0.909	-0.896	0.900	-0.524	-0.196	0.196	0.571		
ADW > 0.25 (mm)	0.791	-0.708	-0.866	-0.841	-0.363	0.988	-0.999	0.956	-0.909	0.896	-0.900	0.524	0.196	-0.196	-0.571	-1.000	
Erodibility	-0.722	0.630	0.914	0.893	0.263	-0.999	0.991	-0.920	0.948	-0.938	0.849	-0.432	-0.298	0.298	0.654	0.994	-0.994

ASW: total aggregates after static water action; ADW: total aggregates after dynamic water action .

Otherwise, the clay particles in the soil may swell as they become wet and thereby reduce the sizes of the pores, this reducing soil permeability (Brouwer et al., 1988; Reichert and Norton., 1994). As for the other parameters; organic matter and porosity correlated negatively with permeability, while the bulk density was correlated positively. These negative relations were a product of a strong reflection of the clay and sand contents with these properties.

3.2. Water resistance of soil aggregates and aggregate stability

Considering the time of destruction of soil aggregates after static water action (Table 2), resistance may be classified as extremely low (Table 4). The correlation coefficients showed that as these aggregates are moist, they will be more durable (r = 0.936), and mostly fragile when they are dried (r = -0.973). These results are reasonable, because of as these aggregates are dry, the fast wetting may leads to an increase the extent of differential swelling of clay particles and the volume of entrapped air, that in turn increase the aggregate slaking . Although, the clay content was weakly correlated with disintegration time (0.389), this may be interpreted by the two opposing effects of the clay fraction; an increase in aggregate stability by diminishing the seal formation and an increase in aggregate slaking on wetting (Lado et al., 2004). On the other hand the correlation analyses indicated that the soil organic matter may have a significant stabilizing influence on soil aggregate stability after the static water action (r = 0.750). Negative notable correlation coefficients were observed between silt (-0.984), permeability (-0.843), and in lower degree with calcium carbonate (-0.551). The negative relation between silt content with the time of disintegration may be connected to the poor aggregation capacity of the silt fraction as compared with clay. Due to the prevailed climatic conditions, we suggest that the present calcium carbonate in the investigated soils is coarse as a result of slowly chemical weathering. So, its beneficial effect on soil aggregation is reduced during the slaking of the soil aggregates. With regard to the relation between soil permeability and slaking time (-0.843), permeability probably is a product of the indirect effect of the silt content.

According to Table 2, the resistance of the studied soil aggregates to dynamic water action; i.e. raindrop impact, may be classified as extremely low too. These observations revealed considerable differentiation in the correlation coefficients with the soils properties, as compared with the static water action. As presented in Table 5, the climate components showed negligible relations with the rain drop impact. Whereas we may note an evident positive correlation coefficient (0.861) between the disintegration time after raindrop impact and the measured bulk density. This signifies the higher bulk density, the more persistence of soil aggregates to dynamic water action. As previously emphasized the dependency of bulk density on the coarse soil fractions as well as the calcium carbonate content, we observe, as a reflection of this fact, high correlation coefficients between the disintegration time and total sand fraction (0.924), while for calcium carbonate was rather lower; about (0.554). On the other hand, the negative correlations of both silt and clay portions were expected, because these fractions work to reduce the bulk density and increasing the total porosity.

3.3. State of secondary aggregate

The secondary aggregation, represented by the quality and quantity of aggregates produced from the basic aggregates after they have been subjected to water action, is an important feature for understanding the dynamics of transformations of soil structure, and for agriculture practices. It is the feature which determines tendency of soil structure to positive or negative changes of basic physical properties of the soil, first of all determining the total porosity.

As shown in Table 4, we note the absence of aggregates in size range from 5 - 7 mm; this may be well contributed to the aridity, where the soil conditions are unfavorable for good aggregation (Lavee et al., 1996; Cerda, 1998). Results of correlation coefficients for the micro and macro aggregates after the static water action did not catch attention. However, we may conclude that there is a tendency to form macro aggregates; > 0.25mm, with increasing in sand content (r = 0.695), and decreasing in silt (r = -0.842).

Concerning the correlation coefficients of the percentage of aggregates > 0.25 mm after rain drop impact with the examined parameters, they could be distinguished into two groups according to their correlation sign (Table 5). Rainfall, clay, organic matter and porosity were correlated positively; 0.791, 0.988, 0.956, and 0.896 respectively. The second group consists of temperature (-0.708), very fine sand content (-0.866), sand content (-0.841), silt content (-0.363), calcium carbonate (-0.999), bulk density (-0.909) and permeability (-0.900). The linear correlation of rainfall with the macro aggregates is well referred to the cohesive forces of water molecules which play a significant role in the aggregation processes. Additionally, the more water availability the higher organic matter content, and clay content (Boix-Fayos et al., 2001). The beneficial effect of clay content could be explained by the important role of clay fraction on the soil aggregation (Gollany et al., 1991). On the other hand, the good correlation of macro aggregate with the organic matter is not surprising, since organic matter is one of the most important factors determining the aggregate stability in soil (Tisdall and Oades, 1982; Cerda, 1998; Castro-Filho et al., 2002).

3.4. Erodibility

Correlation's results of the soil erodibility with studied soil properties are presented in Table 5. They indicate that soil erodibility depends on contents of the soil size fractions. For example, we found that there is a tendency of soils to be more erodible at higher contents of the very fine sand (r = 0.914) and sand fraction (r = 0.893), while the soils are more stable with increasing in the clay content (r = -0.999). This could be explained by the fact that the sand and very fine sand fractions are the easiest removable constituents, while clay fraction has a more difficult removal because of its better aggregation capacity (Morgan, 2005). Moreover, the ability of clay particle to mass together into larger aggregates that resist detachment and transportation (Abbas et al., 2010).

Soil organic matter seems to be the second most important factor after clay content, decreasing the susceptibility of soil erodibility (r= -0.920). As previously discussed, soil organic matter helps in developing the stable macro aggregates, by means of the binding agents of organic matter and the formation of macro aggregates around plant roots (Cerda`, 1998).

As mentioned earlier, calcium carbonate works on the reduction of total porosity; by accretion of the bulk density, so it was correlated linearly with the soil erodibility (r= 0.991). Furthermore, the higher bulk density indicated more soil erodibility (r= 0.948); as a result of reduction in the total pore spaces which is responsible for infiltration rate. The manner of the soil permeability is absolute disagreeing; it should have a negative sign. Anyway, accordingly to the prior discussion, this is a mere reflection of the dependency of permeability rate on the coarse fraction as well as on the calcium carbonate content. The coefficient of correlation of the macro aggregates after dynamic water action, was evidently higher (-0.994), which means the greater resistance of soils to erosion; this may be linked to the good created aggregation and then higher porosity. Whereas the micro aggregates after the dynamic water action showed the more vulnerability of soils to erosion (0.994).

The relation of the climate components; rainfall and temperature, with soil erodibility was probably anticipated, negative for the rainfall (-0.772), and positive for temperature (0.630). The role of rainfall may lie in its effect on the developing of clay, the enhancement of vegetation cover resulting in an increase in the organic matter content as, well as the formation of macro aggregates, leading to improved resistance to erodibility.

In order to reveal which of these soil parameters is most influential on soil erodibility, stepwise regression was accomplished. It improved the interpretation of the results by revealing interactions of soil parameters on the erodibility (Table 6). The developed model displayed that there is a negative relation between soil erodibility and the clay content. The clay content revealed through coefficient estimate partial record (β) that its importance relative (0.999) on average erodibility, while the coefficient of determination (R^2) average within good fit about (0.997), which refer to 99% of clay reduce the soil erodibility.

CONCLUSION

The final deduceds points can be summarized up in the following statements:

a. Rainfall enhances the clay formation through the acceleration of the weathering processes as well as augmentation the vegetation cover, and thus leading to increment in the organic matter content.

b. The correlation analysis emphasized that the soil aggregates are more resistance to static water action as they were moist.

c. The soil aggregates were more durable to the dynamic water action as they were denser.

d. As a result of aridity, the macro aggregates after the static and dynamic water action were absent.

e. Rainfall, clay and organic matter help in developing the macro aggregates.

f. Erodibility is dependent on the basic properties of soil, like mechanical composition, organic matter, bulk density, moisture status and calcium carbonate content.

g. Resistance to water activity is a basic feature, presenting a stability of soil structure, its susceptibility to erosion and durability.

h. The analysis of stepwise regression proved that the clay particles are the most influential parameter which may reduce the erodibility hazards.

i. It worth to cite that the methods of statistical analysis of results proved to be helpful and extremely valuable for precise and documented evaluation and interpretation of data, where it would be difficult without them to understand considerable subtle relations between individual parameters

Table 6: Stepwise regression analysis of the soil erodibility

Model	Standardized coefficient Beta (β)	Standard error	t	sig.	R^2	Adj. R^2	Standard error of estimate
Erodibility = (1.024) – (0.013) clay	-0.999	0.036	28.629	0.022	0.997	0.994	0.01402

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الملخص العربى

دور المناخ في ثبات الحبيبات المركبة والقابلية للأنجراف لبعض ترب الجبل الأخضر- ليبيا

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يمثل هذا العمل محاولة لتحديد العلاقات بين عناصر المناخ و المتمثلة في معدل هطول الأمطار ودرجة الحرارة من جهة وخواص التربة من جهة أخري، وذلك من أجل استنتاج العلاقات المتبادلة بينها ومدى تأثيرهذه العلاقة علي قابلية التربة للانجراف. لتحقيق هذه الدراسة، تم اختبار ثلاثة قطاعات لترب تقع في مناطق ذات معدلات هطول ودرجات حرارة متباينة ضمن نطاق منطقة الجبل الأخضر بإقليم برقة، شمال شرق القطر الليبي. أكدت نتائج هذه الدراسة، المدعومة بالتحاليل الأحصائية، علي الدور الهام للأمطار والمتضمن في تكوين الطين، زيادة المحتوي العضوي للتربة وتحسين ثبات الحبيبات المركبة مؤدية إلي تقليل مخاطر الإنجرافية.