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Original article

Effects of Slope on Soil Properties in The Rangeland of Southern Al-Jabal Al -Akhdar Region, Northeastern Libya

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ABSTRACT

Aims. *This study was conducted on southern slope of Al-Jabal Al-Akhdar, Libya to estimate some soil properties, and to study effects of slope on those properties.* ***Methods.*** *Twelve sites were selected. Slope in the study area was divided into three levels (high slope, medium slope and low slope). Soil samples were collected for each site and analyzed in laboratory. We applied LFA technique to assess soil surface condition. One-way ANOVA (LSD test) was applied, where slope is independent factor and soil properties are dependent variables.* ***Results.*** *The results did not show any significant differences between soil properties, except for soil PH and calcium carbonate. Also, there were no significant differences between the means of soil surface indices except for SSCI. Our results confirmed that the effect of slope became significant when its rate exceeds 10%, for this reason, most of the statistical differences between soil properties means were insignificant in our study, as the highest rate of slope in the study area is 7%.* ***Conclusion.*** *It is necessary to conduct future studies to cover a larger area in the region for a comprehensive understanding about soil properties at the local level, and thus knowing the proper ways to maintain and benefit from it.*

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INTRODUCTION

Soil is one of the most important natural resources in sustaining human life, as it is the natural medium on which agriculture is based, and which contains nutrients necessary for plants growth. However, this natural resource is exposed in many regions of the world to erosion problem, which is one of the serious environmental problems due to the serious damage it causes, represented in the loss of surface and subsurface layers of soil, then causes deterioration of its fertility and decrease production. Soil erosion negatively affects the production of food, which is increasingly needed to achieve food security. Soil erosion is one of the most important naturally occurring processes that adversely affect soil properties, it consists of two stages that include the process of separating soil particles and then transferring them with water or wind [1]. Slope is an important factor in the soil loss equation, where its angle and length affect water runoff and soil erosion [2]. then causes important differences in soil physical and chemical properties. Previous studies showed that the general slope factors that affect soil erosion are slope angle, slope length and slope shape [3]. Slope position also affects movement and deposition of soil moisture and materials, which leads to changes in soil properties along the slope [4]. Several studies confirmed that soil erosion naturally will increase with an increase in

slope degree and its length, due to increasing in surface water runoff speed [5]. In general, erosion becomes more extensive with increasing in slope rate more than 10% [6;7;8]. Slope is one of the most important factors that affect soil biological processes. The enzymatic activity of soil microbes is not symmetrically distributed along the slope. It was found that the lowest sufficient activity observed in the highest areas of slope and the largest sufficient activity observed in the lower areas of slope [9;10]. Slope is an important factor in erosion process, as the accumulated water transports soil particles that contain organic matter and plant nutrients, which negatively affects soil physical and chemical properties [11]. Southern Al-Jabal Al-Akhdar area in northeast Libya is considered one of the most important pastoral areas in Libya, but it is subjected to severe deterioration due to climatic changes and irrational human activities. Until today, few studies were conducted on the soils of study area, and for this reason there is a small amount of information available on soil physical and chemical properties in the area. From here came the importance of this research through studying some physical and chemical properties of soils in the study area. Therefore, we tried through this study to identify soil chemical and physical properties and finding relationships between them and land slope on the south slope of Al-Jabal Al-Akhdar region.

METHODS

Study area

The study area is located on the southern slope of Al-Jabal Al-Akhdar rangeland, northeast Libya, located approximately 32°N, and 21°E, occupying an area of about 200 ha (Figure 1). In general, most of the study area is characterized by semi-arid climate. Nature of earth's surface is hilly. Precipitation period in the region extends from September to February and characterized by fluctuation and irregularity, as the largest annual amount of precipitation is about 350 mm / year. The temperature ranges from 10-30°C, with an average minimum of 0.5°C and a maximum of 50°C. Humidity is relatively low, and the monthly average of humidity is more than 50%, starting from February until September, and it is close to 80% in December and January [12]. The dominance winds are northwest in summer and northeast in winter, as well as southeasterly (Gibli) winds blowing over the region, which are hot winds accompanied by sand waves. Permanent vegetation cover is dwarf shrub steppe consisting of Artemisia herba-alba and Haloxylonscoparium occupies the low hills, and the undulating and narrower alluvial plains [13].

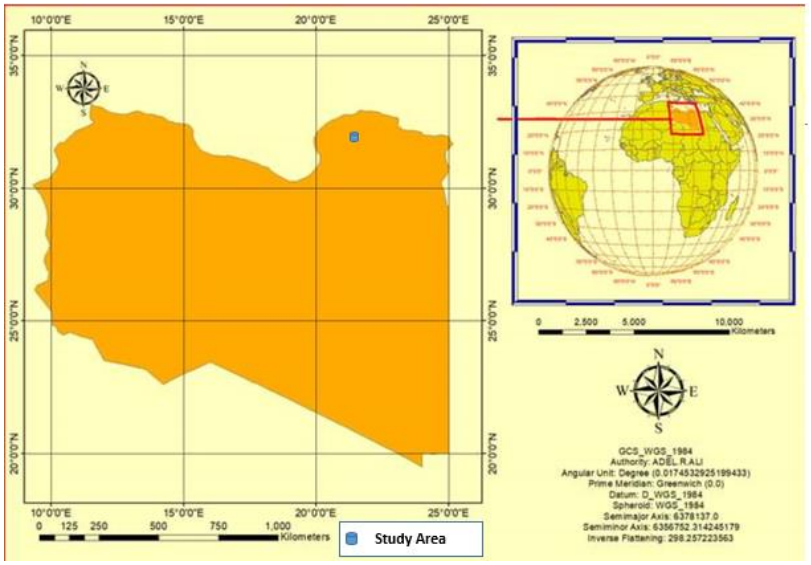

Figure 1. Map of Libya showing the study area

Twelve sites (hills) in the study area were selected. Aspect and Orientation of each site were determined using a GPS device, and the slope gradient using an inclinometer. To achieve research objectives, the slope was divided into three levels: high slope, medium slope and low slope (4 sites for each level) (Table 1).

Table 1. Description of the Study Sites

Site num.	GPS		Aspect	Orientation degree	Slope	Slope level
	N	E				
1	32°.26'.711"	21°.18'.801"	NNE	20	4	Medium
2	32°.26'.711"	21°.18'.704"	SSW	207	5	High
3	32°.26'.298"	21°.18'.604"	SSW	211	2	Low
4	32°.26'.291"	21°.18'.511"	SSW	200	4.5	Medium
5	32°.26'.208"	21°.18'.444"	SSW	190	2.5	Medium
6	32°.26'.641"	21°.18'.151"	SSW	260	07	High
7	32°.26'.461"	21°.18'.787"	NW	311	4.5	Medium
8	32°.26'.466"	21°.18'.879"	NE	75	6.5	High
9	32°.26'.523"	21°.18'.953"	SSE	154	2	Low
10	32°.26'.468"	21°.18'.840"	SSE	149	05	High
11	32°.26'.168"	21°.18'.901"	SSW	213	01	Low
12	32°.26'.974"	21°.18'.876"	NW	40	2	Low

Soil Surface Condition Assessment

To assess Soil Surface Condition, we applied LFA methodology [14]. Field data are collected using quadrate 1m2 on a line transect (100m length) oriented in the direction of water flow. Once data has been inserted in specialized software it summarizes three major soil habitat quality indices, namely: (1) Soil Stability Index (SSI), (2) Water Infiltration Index (WII) and (3) Nutrient Cycling Index (NCI). For each site, three line transects were used to collect field data. Soil Surface Condition index (SSCI) was applied in this study, it is the average of SSI, WII, and NCI, reflecting the overall soil surface condition.

Soil Sampling and Testing Laboratory

Four soil samples (three replicates) were taken from each site at a depth of 20 cm (144 samples). After the samples were purified from impurities and gravel, it was dried in the shade for three days, then it was ground and passed through a 2 mm sieve, then it was taken to Al-Kufra Agricultural Project laboratory to conduct some appropriate physical and chemical analyzes. Soil PH was measured using a PH meter JENWAY 3305 [15]. Electrical conductivity (EC) of soil solution was measured using an E.C meter [16]. Mechanical analysis of soil using hydrometer method to determine the proportions of clay, silt and sand. [17]. Percentage of soil organic matter was estimated by a burning oven. 10 g of each sample was entered at a temperature of (105Co) for 24 hours, then the dry weight was taken and returned to the oven at a temperature of (450 Co) for 24 hours, after which the difference in weight was measured. It expresses the percentage of soil organic matter. Determination of quantitative calcium carbonate by titration method. Calcium carbonate was expressed as a percentage based on oven dry weight [18]. Total nitrogen percentage in the soil was measured using the Kjeldahl method [19]. Available phosphorous was estimated using a spectrophotometer. Microelements of iron, zinc, manganese and copper were determined using an atomic absorption device and expressed as parts per million (ppm).

Statistical Analysis

One-way ANOVA - the Least Significant Difference (LSD) test was applied using SPSS software, where slope is independent factor and soil properties are dependent variables (19). Significant differences were regarded as probability values less than 5 %.

RESULTS

Soil Surface Condition Assessment and Slope Effects

All the sites are characterized by a medium to low slope topography and a low soil cover ratio, except for site5, where total coverage of soil is rather good with an average of 15-30%. Litter cover percentage was low in most of the sites as well as cryptogam cover. Gravel and stones Deposited Materials covers most of the studied sites in close proportions, with a slight increase in sites 1 and 2. Crust Broken-ness was slight in all sites, as well as the degree of erosion. Erosion features was low in most of the sites except for site2 and 3, as it was very extensive. Erosion features mostly were of sheeting type in addition to rill type, which appears in the sites near wadis. Soil micro topography is zigzag at different heights (3-8 mm) in all sites (Appendix 1).

SSI index values converged (Table 2), as it was slightly lower than the average in most of the sites, the highest mean was in site2 by 49.5% and the lowest was in site12 by 36.5%. WII index was very low in all sites with very close percentages. The highest WII was 35.4% and the lowest was 23.7%. A very low nutrient cycle rate was observed in all

selected sites except site5. Generally, the overall soil surface condition index SSCI in the study area is low. As Table 3 shows, the results of the statistical analysis did not show significant differences between the means of the three indices. Significant differences were found between SSCI means for medium slope and low slope (p=0.032). The highest total soil surface functionality was observed in the medium Slope.

Table 2. Soil Surface Condition Indices in the Study Sites

Site	Stability Index SSI %	Infiltration Index WII %	Nutrients Cycling Index NCI %	Soil Surface Condition index SSCI %
1	51.0	33.0	25.1	36.7
2	49.5	34.6	27.7	37.3
3	44.3	27.8	18.5	30.2
4	42.7	28.0	22.5	31.1
5	45.8	35.4	32.4	37.9
6	46.4	29.2	24.4	33.3
7	47.4	24.6	19.8	30.6
8	41.7	26.8	18.6	29
9	40.6	23.7	18.6	27.6
10	38.5	30.6	22.0	30.4
11	41.1	26.0	20.2	29.1
12	36.5	26.1	17.8	26.8
Mean	43.8	28.8	22.3	31.7

Table 3. Multiple Comparisons between Soil Surface Condition Indices Means.

Dependent Variable	(I) slope	(J) slope	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SSI	1.00	2.00	-2.70000	2.76970	.355	-8.9655	3.5655
		3.00	3.40000	2.76970	.251	-2.8655	9.6655
	2.00	1.00	2.70000	2.76970	.355	-3.5655	8.9655
		3.00	6.10000	2.76970	.055	-.1655	12.3655
	3.00	1.00	-3.40000	2.76970	.251	-9.6655	2.8655
		2.00	-6.10000	2.76970	.055	-12.3655	.1655
WII	1.00	2.00	.05000	2.49009	.984	-5.5830	5.6830
		3.00	4.40000	2.49009	.111	-1.2330	10.0330
	2.00	1.00	-.05000	2.49009	.984	-5.6830	5.5830
		3.00	4.35000	2.49009	.115	-1.2830	9.9830
	3.00	1.00	-4.40000	2.49009	.111	-10.0330	1.2330
		2.00	-4.35000	2.49009	.115	-9.9830	1.2830
NCI	1.00	2.00	-1.77500	2.74292	.534	-7.9799	4.4299
		3.00	4.40000	2.74292	.143	-1.8049	10.6049
	2.00	1.00	1.77500	2.74292	.534	-4.4299	7.9799
		3.00	6.17500	2.74292	.051	-.0299	12.3799
	3.00	1.00	-4.40000	2.74292	.143	-10.6049	1.8049
		2.00	-6.17500	2.74292	.051	-12.3799	.0299
SSCI	1.00	2.00	-1.57500	2.23252	.498	-6.6253	3.4753
		3.00	4.07500	2.23252	.101	-.9753	9.1253
	2.00	1.00	1.57500	2.23252	.498	-3.4753	6.6253
		3.00	5.65000*	2.23252	.032	.5997	10.7003
	3.00	1.00	-4.07500	2.23252	.101	-9.1253	.9753
		2.00	-5.65000*	2.23252	.032	-10.7003	-.5997

**The mean difference is significant at the 0.05 level. 1= high slope, 2= medium slope and 3= low slope.*

Soil Physical and Chemical Properties

In general, the results of the statistical analysis did not show significant differences between the means of soil properties under study, except for calcium carbonate and soil PH (0.038 and 0.001 /p<0.05) in that order (Tables 4, 5), where the highest mean for calcium carbonate appeared in the low slope (13.85%) and with a large difference with high slope and significantly with medium slope. Soil PH of all sites was moving towards basicity (7.31 - 7.81), and the highest mean of soil PH was observed in the high slope (7.63), and with a high significant difference with the medium and low slope. (0.001, 0.009) respectively.

Table 4. Multiple Comparisons between CaCo3 Means

(I) Slope	(J) Slope	Mean Difference (I-J)	Std. Error	Sig. p<0.05	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	0.94500	4.74980	0.847	-9.7998	11.6898
	3.00	-10.60000	4.74980	0.053	-21.3448	0.1448
2.00	1.00	-.94500	4.74980	0.847	-11.6898	9.7998
	3.00	-11.54500*	4.74980	0.038	-22.2898	-0.8002
3.00	1.00	10.60000	4.74980	0.053	-0.1448	21.3448
	2.00	11.54500*	4.74980	0.038	0.8002	22.2898

**The mean difference is significant at the 0.05 level. 1= high slope, 2= medium slope and 3= low slope.*

The results showed that soil field moisture was very low in most of the studied sites, with an average of 4.75% (Tables 6). This was expected due to what is known about weak field capacity shown by the soils of arid and semi-arid areas. As shown in Table 7, salinity degree was very fluctuating between the sites (2.82 – 26.12). The lowest degree of salinity appeared in high slope, which may be due to increasing in soil washing with an increase in slope, as the velocity of water runoff increases. However, there were no significant differences between the three means (Appendix 2).

Table 5. Multiple Comparisons between PH Means

(I) Slope	(J) Slope	Mean Difference (I-J)	Std. Error	Sig. p<0.05	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.25250*	.07549	.009	.0817	.4233
	3.00	.37500*	.07549	.001	.2042	.5458
2.00	1.00	-.25250*	.07549	.009	-.4233	-.0817
	3.00	.12250	.07549	.139	-.0483	.2933
3.00	1.00	-.37500*	.07549	.001	-.5458	-.2042
	2.00	-.12250	.07549	.139	-.2933	.0483

**The mean difference is significant at the 0.05 level. 1= high slope, 2= medium slope and 3= low slope.*

Table 6. Descriptive Statistics Results of Soil Field Moisture

Slope	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	4	5.2475	1.43725	.71863	2.9605	7.5345	3.66	7.12
2.00	4	4.3275	1.24503	.62251	2.3464	6.3086	2.63	5.62
3.00	4	4.6550	1.19874	.59937	2.7475	6.5625	3.40	5.93
Total	12	4.7433	1.23942	.35779	3.9558	5.5308	2.63	7.12

1= high slope, 2= medium slope and 3= low slope

The mechanical analysis showed that soil texture was silty clay in all the sites, and showed a decrease in clay

percentage in the soils of high slopes (43.5%), although there were no significant differences (Fig. 2). This is normal, as clay particles washing increases with increasing in the speed and strength of water runoff with an increase in slope degree, as well as due to the small size of clay particles compared to silt and sand.

Table 7. Descriptive Statistics Results of EC

Slope	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	4	12.6800	10.05786	5.02893	-3.3243	28.6843	2.82	26.12
2.00	4	16.0025	3.76782	1.88391	10.0071	21.9979	13.13	21.14
3.00	4	15.3100	7.08483	3.54242	4.0364	26.5836	6.80	22.63
Total	12	14.6642	6.88368	1.98715	10.2905	19.0379	2.82	26.12

1= high slope, 2= medium slope and 3= low slope.

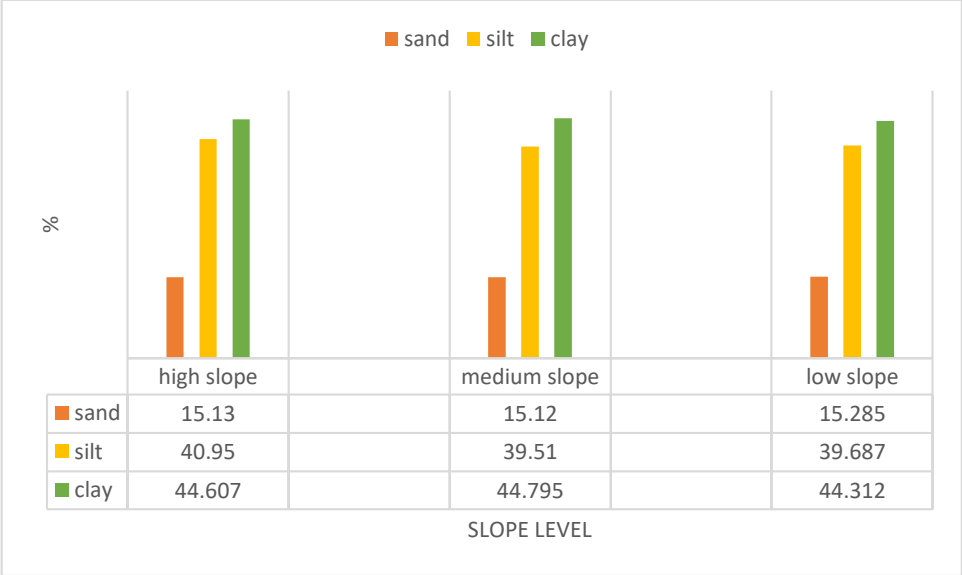

Figure 2. Descriptive Statistics Results of Soil Mechanical Analysis

As usual in arid and semi-arid areas, the percentage of soil organic matter was generally low (2.47%). Soils of all the studied sites suffered from a nitrogen deficiency (Table 8) with an average of 0.13%, and a high variation (0.31 - 0.02%). The results also showed a shortage of available phosphorous in all the studied sites.

Table 8. Descriptive Statistics Results of Nitrogen

Slope	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	4	0.1450	0.07724	.03862	0.0221	0.2679	0.06	0.22
2.00	4	0.1750	0.11958	.05979	-0.0153	0.3653	0.06	0.31
3.00	4	0.0625	0.02872	.01436	0.0168	0.1082	0.02	0.08
Total	12	0.1275	0.09067	.02617	0.0699	0.1851	0.02	0.31

1= high slope, 2= medium slope and 3= low slope.

As for micro-nutrients, all the sites suffer from a lack of iron, with an average of 9.14 ppm, and from a scarcity of zinc, where its concentration did not exceed 2.56 ppm. Manganese values are good in most of the studied sites, in contrast to Copper, which was found in very scarce quantities (Fig. 3).

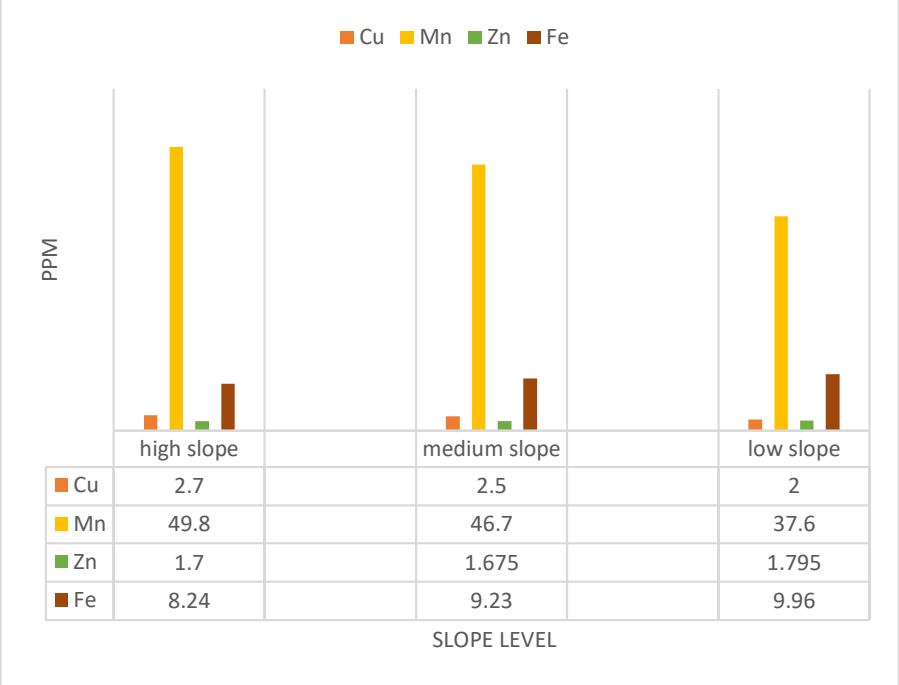

Figure 3. Slope Effect on Soil Micro-Nutrients

DISCUSSION

Soil surface condition indices, were close and slightly below average, it is may be due to soil mechanical composition, where the proportion of silt is medium., and this consistent with what was stated, where vegetation cover and soil texture were the most important factors affecting soil stability and infiltration [11]. As for nutrients cycling, its index is characterized by a decrease with the direction to south, which indicates an increase in deterioration rate in the southern part, where rainfall rate is much less. Notably, the high slope and medium slope have a high NCI whilst lower slope levels predominantly have low NCI [21]. The values of NCI for all sites represent harsh conditions. The results of this research support results of previous studies in similar environments [6-8]. It confirmed that the significant effect of slope starts when its rate exceeds 10%, for this reason, most of statistical differences between the means of soil properties were insignificant in our study, as the highest slope in the study area is 7%. The highest mean of soil PH was observed in the high slope, this could be attributed to increasing in washing of soil organic matter by water run-off with increasing in slope gradient rate. This will increase soil acidity, and therefore the values were high at the high slope, while the medium and low slopes obviously has the lower values. The results of soil PH were consistent with what was mentioned in the final report of a Swedish Environmental Consultancy [12], and what was stated in the final report of the preliminary study by Omar Mukhtar University [22], where the interaction of the soil was basic, This could be due to low rate of precipitation and its scarcity in the study area which increases the accumulation of basic calcium carbonate, and lack of organic matter in the soil which usually has an acidic effect when decomposing and reduces soil PH. Serious salinity problems are not common in the area. Only 24 samples of 264 investigated samples had serious salinity problems.

Soil organic matter is very low due to the high temperature, especially during the dry season, and a very low vegetation cover, and therefore low rate of plant litters, which has a major role in supplying topsoil with organic matte (23). mentioned that organic matter content in the soil decreases with increasing temperature under similar moisture conditions. The highest percentage of organic matter was in site5 (5.17%) and the lowest in site1 (0.9%), and it is likely that the reason is the effect of aspect, where site5 aspect is north, while site1 is south, and this brings us back to what was mentioned about the effect of temperature on soil organic matter, where The temperature is higher on the southern facade than it is on northern façade of hill.

Nitrogen is the most basic nutrient for plants that are deficient in dry soils, followed by phosphorous, iron and zinc, as mentioned in previous study [24], it is linked to organic matter which is generally considered poor in the soils of study area. According to the results, soil in the study area is poor in its content of available phosphorous, this may be attributed to the inverse relationship between phosphorus and calcium carbonate [25], where it was concluded that the PH and the activity of relatively high calcium ions encourage the formation of moderate to highly insoluble Calcium

phosphate. It was noted that in sites with severe sheet erosion, the fertile upper layers with sufficient phosphorus have been washed away and lack of phosphorus is may be a limitation factor for vegetation recovery in the study area.
Soils of the region in general are suffering from a deficiency in most of the micronutrients, as most of them were below the normal limits of these elements in soil. These elements are in small quantities in mother rock, all micronutrients were originally derived from a mineral substance, and their total concentration in soils is usually related to their quantity in the soil origin material. The normal zinc content of the soil ranges from 10-300 ppm [26]. Therefore, the soil of study area is considered very poor for zinc with a mean of 1.7ppm, and since the diameter of the zinc ion is similar to the diameter of iron and magnesium ions, zinc has the ability to replace these elements in iron magnesia and biotite minerals [27], and the validity of zinc increases with decreasing soil PH, where symptoms of deficiency appear when the PH rises above 6.

CONCLUSION

In summary, there was no significant effect of slope on most soil properties in the steppes of southern AL- Jabal Al-Akhdar, except for soil PH and calcium carbonate which greatly affect the rest of the soil properties. In other words, the slope factor may indirectly affect most of soil properties in the study area. The results of this study confirm what many previous studies have concluded, where there is no significant effect of slope on soil properties with a rate of less than 10%. It seems that wind erosion has a stronger effect than water erosion in the study area, as its effects were clearly observed on soil surface (sheet erosion). Most of the natural factors contribute to creating a fragile and highly sensitive environment for erosion in the study area with a semi-arid climate under an irrational human use, and due to the fact that study area is located in a transitional region between the sea and the Sahara Desert, which made it more vulnerable to the occurrence of climate change. Due to a large rangeland area of southern Jabal Al-Akhdar and the diversity of its soil, it is recommended to conduct extensive studies in the future for a broader and more comprehensive understanding of soil properties as a very important natural resource, and the impact of human and natural factors on it, and thus knowing the proper ways to maintain and benefit from it.

Conflict of Interest

There are no financial, personal, or professional conflicts of interest to declare.

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آثار الانحدار على خصائص التربة في مراعي جنوب منطقة الجبل الأخضر شمال شرق ليبيا

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المستخلص

الأهداف. أجريت هذه الدراسة على المنحدر الجنوبي للجبل الأخضر بليبيا لتقدير بعض خواص التربة ودراسة تأثير الانحدار على تلك الخصائص. **طُرق الدراسة**. تم اختيار اثني عشر موقعا. تم تقسيم المنحدر في منطقة الدراسة إلى ثلاثة مستويات (منحدر عالي ، منحدر متوسط ومنحدر منخفض). تم جمع عينات التربة لكل موقع وتحليلها في المختبر. طبقنا تقنية LFA لتقييم حالة سطح التربة. تم تطبيق ANOVA أحادي الاتجاه) اختبار (LSD ، حيث يكون المنحدر عاملًا مستقلاً وخصائص التربة متغيرات تابعة. **نتائج الدراسة**. لم تظهر النتائج أي فروق معنوية بين خواص التربة ماعدا PHالتربة وكربونات الكالسيوم. كما لا توجد فروق ذات دلالة إحصائية بين متوسطات مؤشرات سطح التربة ماعدا SSCI. أكدت نتائجنا أن تأثير المنحدر أصبح معنوياً عندما تجاوز معدله 10٪ ، ولهذا السبب كانت معظم الفروق الإحصائية بين خواص التربة غير معنوية في دراستنا ، حيث كانت أعلى نسبة من المنحدر في منطقة الدراسة 7٪. **الخاتمة**. من الضروري إجراء دراسات مستقبلية لتغطية مساحة أكبر في المنطقة من أجل فهم شامل لخصائص التربة على المستوى المحلي ، وبالتالي معرفة الطرق المناسبة للحفاظ عليها والاستفادة منها.

الكلمات الدالة. WII، SWECO، منحدر متوسط ، SSCI.