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Laboratory and Statistical Methods for Estimating Soil Erosion on Al-Jabal Alkhdar Slopes

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طرق معملية وإحصائية لتقدير تعرية التربة على منحدرات الجبل الأخضر

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Abstract

The study applied some dynamic laboratory methods to estimate soil susceptibility to water erosion. Non-dynamic laboratory methods such as statistical methods were also applied. Tests were carried out on topsoil samples (0-10 cm) collected from five sites located on the semi-arid southern slopes of Al-Jabal Alkhdar: Meseliba (Taknes); Marawa; Sirat Alia (Gandulah), Grehat (Gandulah), and Qasar Mestashi (Salantah). The results showed compatibility between the results of all the dynamic methods, which showed that the soil of Qasar Mestashi is the most susceptible to erosion, which corresponds to the deterioration of its physical and hydraulic properties and the low content of organic matter. It was also found that the soil of the Sirat Alia area was the least erosive, which corresponds to the high content of clay, organic matter, and soil water-stable aggregates. On the other hand, the statistical method using the K-USLE nomograph (diagram) did not succeed in producing results consistent with the dynamic laboratory methods, the K-USLE nomograph results unexpectedly showed that the soil of Grehat is relatively the most susceptible to erosion, although these soils have a good content of clay, organic matter, and soil water-stable aggregates. The high content of silt at Grehat soils could be the reason for the high susceptibility estimation when the statistical method is applied. Accordingly, the variance in the results of statistical methods is expected due to the slight changes in the soil fractions, which raises doubts about the efficiency of statistical methods in providing a reliable characterization of soil susceptibility to water erosion. Dynamic laboratory methods were the closest to soil characteristics and field conditions, which could make them more realistic and reliable indicators as low-cost and easy-to-apply methods, and contribute to more efficient erosion measurement at Al-Jabal Alkhdar region.

Keywords: *Al-Jabal Alkhdar, Soil erosion, Soil properties, Libya.*

الملخص

قامت الدراسة بتطبيق بعض الطرق المعملية الديناميكية لقياس وتقدير قابلية التربة للتعرية المائية، كما تم تطبيق اختبارات أخرى مثل الطرق المعملية غير الديناميكية والطرق الإحصائية. تمت الاختبارات على عينات تربة سطحية بعمق (0–10سم) تم جمعها من خمسة مواقع تقع على المنحدرات الجنوبية شبه الجافة بالجبل الأخضر وهي (المصيليبة، مراوة، قندولة القريعات، قندولة سيرة عليا، قصر المستاشي). النتائج أظهرت انسجاما وتوافقا بين نتائج كل الطرق الديناميكية والتي بينت أن ترب منطقة قصر المستاشي هي الأكثر قابلية للانجراف وهو ما يتوافق مع تدهور خصائصها الفيزيائية والهيدروليكية وانخفاض محتواها من المادة العضوية، كما تبين ان ترب منطقة سيرة عليا كانت الأقل انجرافيه وهو ما يتوافق مع ارتفاع محتواها من الطين والمادة العضوية وتجمعات التربة الثابتة مائيا. من ناحية أخرى لم تنجح الطريقة الإحصائية باستخدام الشكل البياني لويشماير (K-USLE) في اعطاء نتائج تتفق مع الطرق المعملية الديناميكية حيث أظهرت نتائجه ان ترب القريعات هي الأكثر نسبيا في القابلية للانجراف رغم أن هذه الترب ذات محتوى جيد من

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الطين والمادة العضوية وتجمعات التربة الثابتة مائيا. ويرجع السبب في التقدير العالي للطريقة الاحصائية لارتفاع محتوى ترب القريعات من مفصول السلت، وعليه يلاحظ التذبذب في نتائج الطرق الاحصائية بسبب التغيرات الطفيفة في مستويات أحد مكونات عينة التربة تحت الدراسة، وهو ما يضع شكوكا حول كفاءة الطرق الإحصائية في اعطاء توصيف موثوق لقابلية التربة للتعرية المائية، بينما كانت الطرق المعملية الديناميكية هي الأقرب لخصائص التربة وظروفها الحقلية مما قد يجعلها مرجعا أكثر واقعية ويمكن الاعتماد عليها كطرق قليلة الكلفة وسهلة التطبيق تساهم في قياس الانجرافيه بكفاءة أكبر وتوصيف مخاطر التعرية المائية بمنطقة الجبل الأخضر.

الكلمات الدالة: الجبل الأخضر، تعرية التربة، خصائص التربة، ليبيا.

1. Introduction

Al-Jabal Alkhdar area suffers from significant water soil erosion compared to the rest of Libya. The FAO study (1969) noted that the region receives relatively good rainfall which encourages runoff on slope lands. Many researchers also noted that the removal of natural vegetation and agricultural activity on the slopes contribute to the erosion phenomenon. Ali (1995) the latter noted in his field study significant amounts of soil movement by runoff. Aburas (1997) also observed a significant increase in the rate of soil loss by water erosion at agricultural lands compared to neighboring natural vegetation lands. There are several methods to measure soil erosion, including laboratory experiments such as rainfall simulation or wet sieving tests. Other methods are field applications such as erosion and runoff plots in which direct soil loss measurements are conducted (Lal, 2001). Stocking and Murnaghan (2001), and Morgan (1996) suggested some indicators that have been used in arid, semi-arid and the Mediterranean regions, and have been used in some FAO-funded land degradation studies such as FAO LADA Project (Mathilde and Alexandra, 2002). Other tests also mentioned and applied by well-known researchers such as Romkens (1985) and Le Bissonnais (1996, 2007). Laboratory methods can be divided into two types: dynamic methods and static or statistical methods (Morgan, 1996):

1) Dynamic laboratory tests: Experiments in which water runoff movement and soil aggregates detachment are simulated, for example:
    A) Indicator of soil aggregates stability in water (water aggregate stability indicator): which has been used in the present experiment using wet sieving method on Topsoil samples. The method was listed by Morgan (1996) as an index of erosion, and were used in the soil laboratory of the University of Cranfield in the United Kingdom on soils from Africa by Ekwue (1984), and based on the work of Adam *et al*. (1958). This indicator has been widely applied on Mediterranean soils by the well-known French Researcher Le Bissonnais (1996 and 1997). In Libya, Aburas (2009) used the indicator on samples from the northern foot of Al-Jabal Alkhdar.
    B) Instability Index: The index = %Silt + %Clay/(%aggregates> 0.2 mm after wet sieving) - 0.9 (% coarse sand) (Combeau and Monnier, 1961), and listed by Morgan (1996) within the indicators of soil susceptibility to erosion. The greater the index value, the weaker the soil structure and its resistance to erosion.

C) Detachability index: By dividing the residual weight on the sieve in experiment (a) by the shaking time to obtain the detachment rate in grams per minutes. The greater the residual weight in the sieve, it indicates lower detachment rate, greater stability in soil structure and greater resistance to erosion factors. The index was used by Russell and Feng (1947), and referred to by Kemper *et al*. (1985).

2) Statistical methods for estimating soil erosion based on correlations between the amount of erosion measured using experimental erosion plots with the physical and chemical characteristics of soil under investigation, for example, proposed diagram (nomograph) by Wischmeier *et al*. (1971).

At the local level in the eastern region, there have been several studies investigated desertification, degradation and erosion using different indicators, (Saad, 2009; Lama, 1996; Ali, 1995; GEFLI, 1975; and Selkhoz Prom Export, 1980). The latter has produced erosion maps for most of the northern Libyan territory, including Al-Jabal Alkhdar region. In many of these studies, the field survey of surface erosion features and soil depth measurements confirmed the active and extensive erosion process within the entire region, which already suffers from degradation of protective vegetation, causing the thickness of the soil to decrease. The study of soil characteristics also showed an alarming level of soil degradation, especially characteristics related to the soil depth and some land surface features which should be taken into account when assessing the degradation. Therefore, it is important to find suitable methods and methodologies for assessing the risks of soil erosion and degradation under arid and semi-arid conditions, especially on the southern slopes of Al-Jabal Alkhdar. These methods should be characterized by acceptable accuracy to provide reliable information, mapping and preparation of plans to face the threat of expanding and very active land degradation. At the same time, when developing plans, methodologies and methods for soil conservation, these methods should be affordable and easy to apply in a manner that is commensurate with the limited resources and lack of well-trained staff, both at the level of relevant institutions and at the community.

So, the aim of this study is to use some easy-to-use and low-cost methods in obtaining a realistic assessment of water erosion risks, and can be used to build a database that can contribute to the preparation of soil conservation plans and sustainable spatial development of the degraded slopes of Al-Jabal Alkhdar.

2. Materials and Methods

The study was carried out on the southern slopes of Al-Jabal Alkhdar and five areas were selected from west to east: Meseliba (Taknes); Marawa; Sirat Alia (Gandulah), Grehat (Gandulah), and Qasar Mestashi (Salantah), as shown in Figure (1). These areas within the most degraded lands in Al-Jabal Alkhdar, where grazing and rainfed cultivation represent the basic activity for many residents. Also, the indicators of desertification in this area are clear as a result of uncontrolled human activities, soil erosion and consequently decreasing the quantity and quality of natural vegetation.

Laboratory experiments: The analysis of surface soil samples (0-10 cm), Figure (2), also included the estimation of soil susceptibility to water erosion by rain using some laboratory and statistical methods as shown in Table (1).

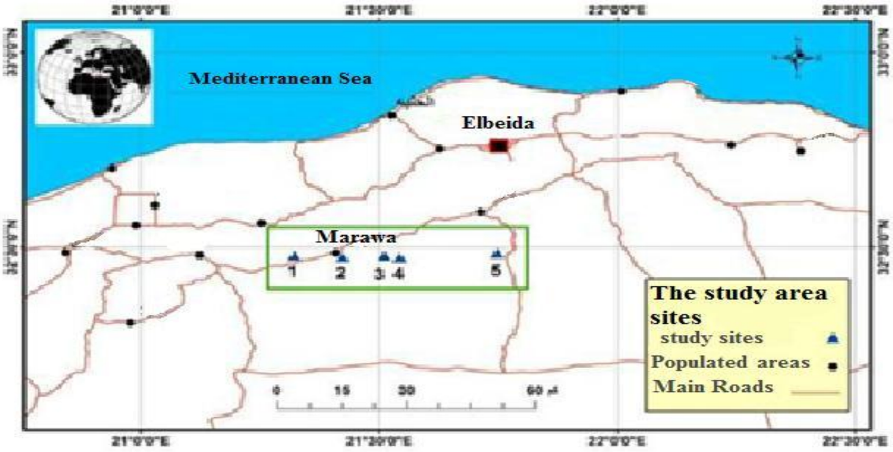

Figure 1. The study sites on the southern slopes of Al-Jabal Alkhdar

Figure 2. The field measurements at the study sites

Table 1. Methods of measuring soil erodibility applied in the present study

The used indicator for erodibility measurement	***The method***	***Reference***
Water aggregate stability indicator(AgSt)	Wet sieving using sieves with multiple sizes in 2,1,0.5,0.2 (mm)	Ekwue (1984)
Instability Index	%(silt + clay)/aggre.> 0.2 mm (%) – 0.9 (coarse sand %)	Morgan (1996)
Detachability index (gm min^{-1})	Weight remaining on sieve/shaking time	Kemper *et al.* (1984)
Clay Ratio	=% sand + % 5silt /% clay	Morgan (1996)
K – USLE	Using the nomograph diagram	Wischmeier *et al.* (1971)

The estimation of K-USLE: It is based on a set of physical and chemical properties that must be obtained first before obtaining the value of K (estimated soil erodibility factor), which is the percentage of organic matter, the percentage of very fine sand + silt, the percentage of sand greater than 0.1 mm and the degree of soil permeability and the degree of soil structure using the diagram (nomograph), or the equation (statistical relation using multiple regression). The equation is :

$$K = 2.1(10\text{-}6)\ M1.14\ (12\text{-}OM) + 3.25(10\text{-}2)\ (S\text{-}2) + 2.5(10\text{-}2)\ (P\text{-}3) \qquad \dots\dots\dots \quad (1)$$

where,

M : is the product of the primary particle size fractions: (silt percent + very fine sand) × (100 – clay percent).

OM : percent organic matter.

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

P : class of permeability; 1 = rapid, 2 = rapid to moderate, 3 = moderate, 4 = slow to moderate, 5 = slow, 6 = very slow.

Note that the value of factor K is without units and ranges from 0 to 1 and the soil is more susceptible to erosion as the value increases. According to Goldsmith (1977) the characterization of the degree of erodibility is as follows: Less than 0.10 Low erodibility; 0.10 to 0.19; Low to medium; 0.20 to 0.39 Medium to high erodibility; 0.40 to 0.59 High; 0.60 and above Very high erodibility

Table 2. Some physical and chemical properties of the investigated soils

Property	***A***	***B***	***C***	***D***	***E***
OM (%)	2.8	1.8	2.5	2.3	0.4
Clay (%)	24.6	23.7	27.2	21.9	17.9
Silt (%)	42.1	30.0	16.9	.465	.293
Sand (%)	33.3	.461	.559	31.6	.528
Aggregates stability (%)	28.1	.282	37.9	34.1	.127
Infiltration R. ($mm.min^{-1}$)	0.11	0.13	0.15	0.20	0.03
Res. to penetration ($N.cm^{-2}$)	104	167	173	188	198
Bulk density ($g.cm^{-3}$)	1.30	1.28	1.09	1.08	1.32
pH	.89	.83	8.3	.79	8.0
$CaCO_3$ (%)	21.5	26.9	11.8	19.2	15.2
Exchan. Ca ($Cmol.kg^{-1}$)	14.6	.74	8.7	11.2	7.2
EC ($dS.m^{-1}$)	4.54	6.57	6.62	6.94	5.37

The sites: A= Meseliba, B= Marawa, C= Sirat Alia, D= Grehat, E= Qasar Mestashi

Statistical tests: The normal distribution of the studied properties was tested, then, completely Randomized Design was applied, and Minitab (16.1.0) was used for data analysis. The comparison between means of soil erodibility indicators were carried out using Tukey test.

3. Results and Discussion

Several dynamic laboratory methods have been applied to measure soil susceptibility to water erosion, which is low cost and easy to apply under different soil sizes (between 2 and 0.2 mm). These dynamic tests are considered to be related to soil resistance to erosion and soil aggregation elements, such as clay content, soil organic matter and soil content of $CaCO_3$. At the same time, resistance to water erosion factors seems to be varied at each specific size range of the soil aggregates under study, which requires taking into account this changing behavior at each given size. Aggregates Stability Index>2 mm (Table 3) revealed the weakness and instability of soil structure of Qasar Mestashi site. While, Gandulah sites (Sirat Alia and Grehat) showed medium stability when compared with Qasar Mestashi (Table 2), this could be due to the relative higher content of clay and organic matter in Gandulah soils. The importance of this index lies in the importance of its close relationship with some physical properties of the soil with a hydraulic effect on the movement of water within the soil profile, water holding capacity, runoff and erosion. This may support the validity of the AgSt ›2 mm index to describe the soil susceptibility to erosion. Figure (3) shows the standard error value and the mean of index values for the samples under study.

Table 3. AgSt › 2 mm index values (%) for the study sites

Sample no.	*Meseliba*	*Marawa*	*S. Alia*	*Grehat*	*Q. Mestashi*
1	29.20	22.00	36.00	40.82	12.60
2	25.16	30.40	34.00	32.38	15.00
3	30.78	33.20	35.00	39.84	16.10
4	29.20	23.42	40.60	33.74	13.34
5	39.6	26.2	37.8	34.26	12.4
6	29.8	30.6	35.54	39.42	15.28
7	24.52	20.5	41.9	31.36	11.03
8	31.34	34.8	38.8	27.5	12.6
9	29.2	33.4	35.8	27.2	10.54
10	21.86	34.8	39.7	36.54	11.6
11	26.38	23.6	43.2	35.4	10.52
12	19.8	25.4	36.5	31.12	11.38
Means	28.07b	28.19b	37.903a	34.13a	12.69c

Tukey value = 4.16

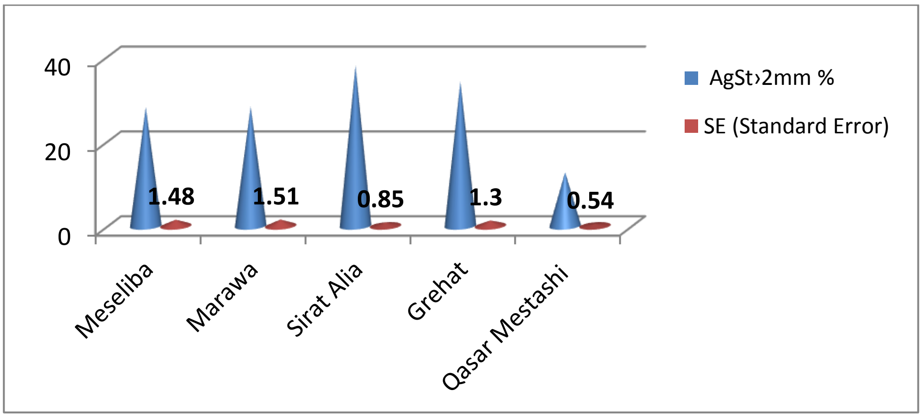

Figure 3. Mean and standard error of AgSt > 2 mm index values

The results of Aggregates Stability Index> 1 mm (Table 4) were very similar to the results of Aggregates Stability Index> 2 mm. According to this measure (index) Qasar Mestashi soils suffer from deterioration in its capability to resist erosion due to low organic matter and clay content (Table 2). Figure (4) shows the standard error value and the mean of index values for the samples under study.

Table 4. AgSt › 1 mm index values (%) for the study sites

Sample no.	*Meseliba*	*Marawa*	*S. Alia*	*Grehat*	*Q. Mestashi*
1	34.02	29.66	41.40	47.98	16.40
2	28.16	39.06	39.80	42.56	17.40
3	33.18	39.32	41.40	48.04	18.30
4	32.80	31.40	45.36	43.02	17.94
5	42.00	34.60	43.28	43.76	15.40
6	32.00	37.40	42.08	48.22	18.90
7	26.84	27.40	46.90	40.76	14.83
8	34.14	39.80	43.84	33.50	15.60
9	31.40	41.20	42.20	37.38	13.54
10	26.38	41.54	45.10	44.52	15.40
11	28.58	31.60	47.80	43.20	13.32
12	23.80	34.76	42.00	39.58	15.18
Means	31.11b	35.65b	43.472a	42.71a	16.02c

Tukey value = 5.6

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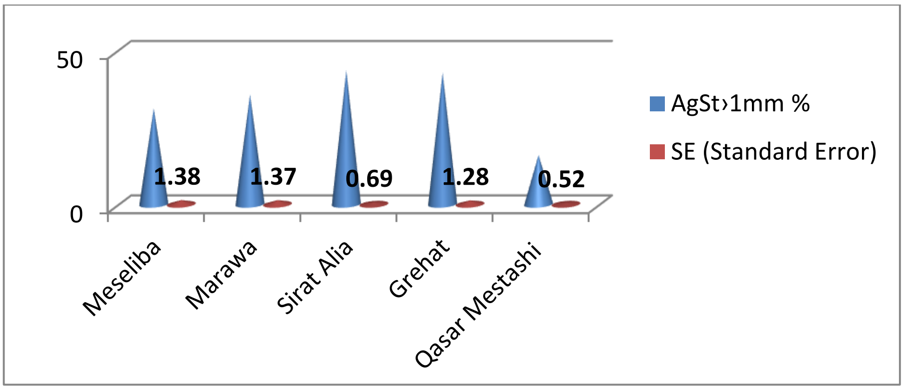

Figure 4. Mean and standard error of AgSt >1 mm index values

The index AgSt ›0.5 mm values (Table 5, and Figure 5) are consistent with the previous two indicators, Qasar Mestashi soils have low values of aggregates stability. When comparing the three previous indicators, AgSt › 2 mm index remains the least expensive in time and effort, since it considers only the contents of the upper sieve. While the other indicators need the results of the specific sieve and the sieve above it, which will take a longer time.

Table 5. AgSt › 0.5 mm index values (%) for the study sites

Sample no.	*Meseliba*	*Marawa*	*S. Alia*	*Grehat*	*Q. Mestashi*
1	34.82	35.34	43.80	50.18	20.20
2	29.96	44.62	41.86	44.16	19.80
3	34.18	44.72	44.80	49.84	21.30
4	35.20	36.52	49.88	45.42	22.34
5	43.40	38.40	48.36	47.36	19.80
6	33.20	42.58	46.90	51.62	21.50
7	27.84	31.44	51.30	42.76	17.63
8	34.74	43.00	45.84	36.50	19.60
9	32.60	44.68	47.80	40.98	15.54
10	27.18	45.66	48.90	49.32	17.80
11	29.38	36.04	52.60	46.80	16.52
12	24.80	39.32	47.20	42.98	17.78
Means	32.28c	40.19b	47.44a	45.66a	19.15d

Tukey value = 3.9

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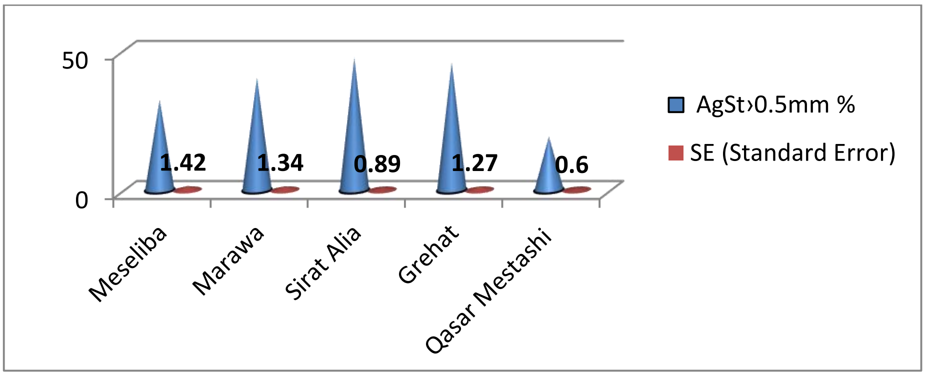

Figure 5. Mean and standard error of AgSt > 0.5 mm index values

According to AgSt > 0.2 mm index, (Table 6, and Figure 6), the trend of stability levels in general has not changed compared to the previous indicators, especially with regard to the less stable location, Qasar Mestashi. Although, relative increase in soil stability were recorded at the site using the index AgSt > 0.2 mm compared to the index AgSt > 2 mm. This could be due to the fact that the index AgSt > 2 mm is more closely related to clay and organic matter contents in the soil.

Table 6. AgSt › 0.2 mm index values (%) for the study sites.

Sample no.	*Meseliba*	*Marawa*	*S. Alia*	*Grehat*	*Q. Mestashi*
1	36.87	38.64	47.2	53.18	23.5
2	32.16	49.12	44.86	47.81	24.6
3	36.03	48.67	47.6	52.94	24.8
4	37.35	40.12	53.5	48.02	26.84
5	45.0	42.14	53.12	50.08	23.06
6	34.7	47.24	51.7	54.32	24.74
7	29.6	34.53	55.06	46.5	21.41
8	36.84	46.72	48.24	40.4	23.08
9	36.44	48.6	52.4	44.6	18.26
10	29.56	49.68	52.92	53.38	20.14
11	32.92	41.74	57.2	50.6	19.72
12	27.48	43.54	52.82	45.8	20.62
Means	34.5c	44.23b	51.38a	48.97a	22.56d

Tukey value = 4.08

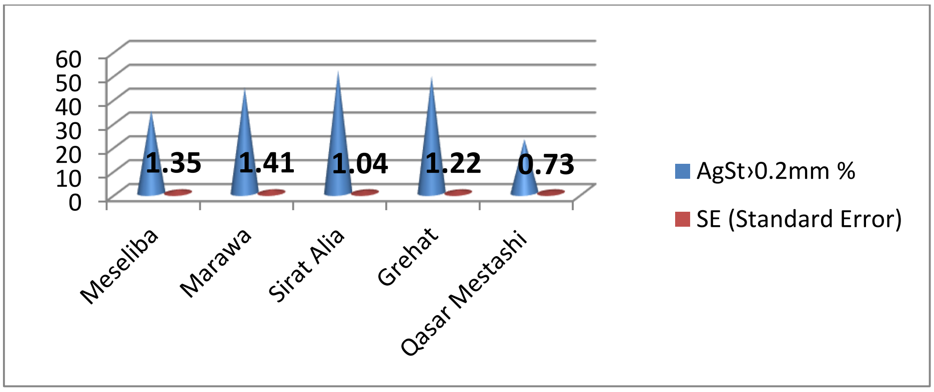

Figure 6. Mean and standard error of AgSt > 0.2 mm index value

The Instability Index (Table 7, and Figure 7) is a flexible dynamic indicator as it depends on all the components of the soil texture and is particularly affected by the soil content of coarse sand. The ratio of soil aggregates > 0.2 mm could also play an important role in determining the values of this index. In this index, less stable soils have higher values compared to more stable ones. Qasar Mestashi soils, as expected were the least stable while the soils of Sirat Alia were the most stable, which means the results of Instability Index are in consistence with the results of the aggregates stability indicators (AgSt).

Table 7. The Instability index values (unit-less) for the study sites.

Sample no.	***Meseliba***	***Marawa***	***S. Alia***	***Grehat***	***Q. Mestashi***
1	1.64	2.11	1.22	1.72	2.99
2	1.66	1.37	1.31	1.99	3.65
3	1.75	1.58	1.31	1.52	3.68
4	2.43	1.78	0.90	1.59	2.77
5	1.78	1.87	0.82	1.56	3.24
6	2.40	1.46	0.84	1.45	3.01
7	2.07	2.45	0.78	1.53	1.39
8	1.88	1.52	0.93	2.12	2.69
9	1.82	1.59	0.83	1.90	2.88
10	1.78	1.54	0.82	1.37	3.58
11	1.82	2.06	0.76	1.51	3.10
12	2.17	1.62	0.82	1.68	3.41
Means	1.93b	1.74b	0.94c	1.66b	3.03a

Tukey value = 0.49

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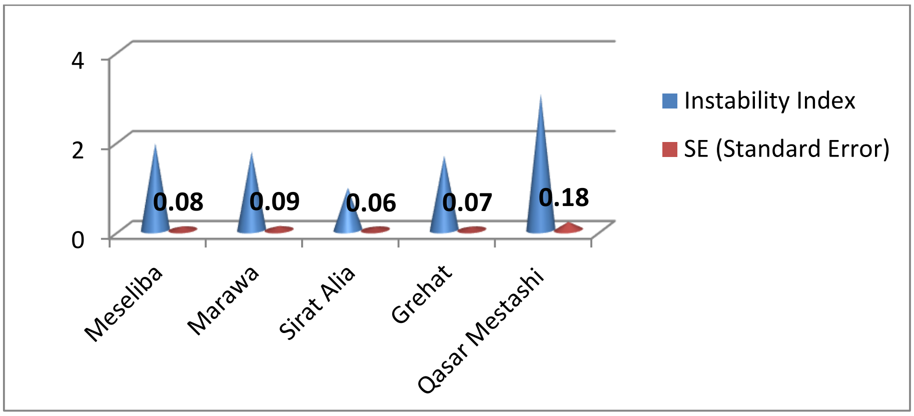

Figure 7. Mean and standard error of Instability index value

The results of Detachability index (for different aggregates sizes), Tables (8-10) confirmed the fragility and deterioration of the stability of the soil structure and the high risk of erosion at the site of Qasar Mestashi. Detachability rate were significantly less at Sirat Alia soils. Figures (8-10) show the mean and standard error values of Detachability Index for the samples under study.

Table 8. Detachability index > 2 mm aggregates values (gm\min) for the study sites

Sample no.	*Meseliba*	*Marawa*	*S. Alia*	*Grehat*	*Q. Mestashi*
1	1.77	1.95	1.60	1.48	2.01
2	1.87	1.74	1.65	1.69	1.99
3	1.73	1.67	1.63	1.50	1.98
4	1.77	1.91	1.49	1.66	2.00
5	1.51	1.85	1.56	1.64	1.70
6	1.76	1.74	1.61	1.51	1.93
7	1.89	1.99	1.45	1.72	1.91
8	1.72	1.63	1.53	1.81	2.01
9	1.77	1.67	1.61	1.82	1.80
10	1.95	1.63	1.51	1.59	1.97
11	1.84	1.91	1.42	1.62	2.14
12	2.01	1.87	1.59	1.72	2.04
Means	1.80b	1.80b	1.55c	1.65c	1.96a

Tukey value = 0.11

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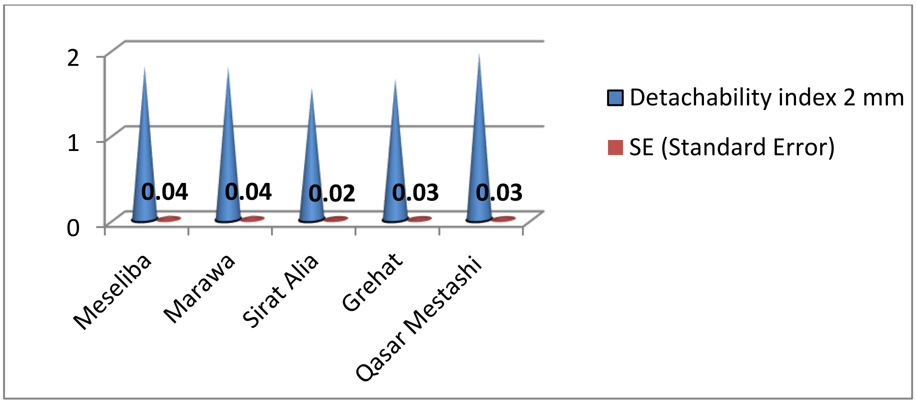

Figure 8. Mean and standard error of Detachability index > 2 mm values

Table 9. Detachability index > 1 mm aggregates values (gm\min) for the study sites

Sample no.	*Meseliba*	*Marawa*	*S. Alia*	*Grehat*	*Q. Mestashi*
1	1.65	1.76	1.47	1.30	1.91
2	1.80	1.52	1.51	1.44	1.93
3	1.67	1.52	1.47	1.30	1.92
4	1.68	1.72	1.37	1.42	1.88
5	1.45	1.64	1.42	1.41	1.62
6	1.70	1.57	1.45	1.29	1.84
7	1.83	1.82	1.33	1.48	1.82
8	1.65	1.51	1.40	1.66	1.93
9	1.72	1.47	1.45	1.57	1.72
10	1.84	1.46	1.37	1.39	1.88
11	1.79	1.71	1.31	1.42	2.07
12	1.91	1.63	1.44	1.51	1.95
means	1.70b	1.61b	1.42c	1.43c	1.87a

Tukey value = 0.10

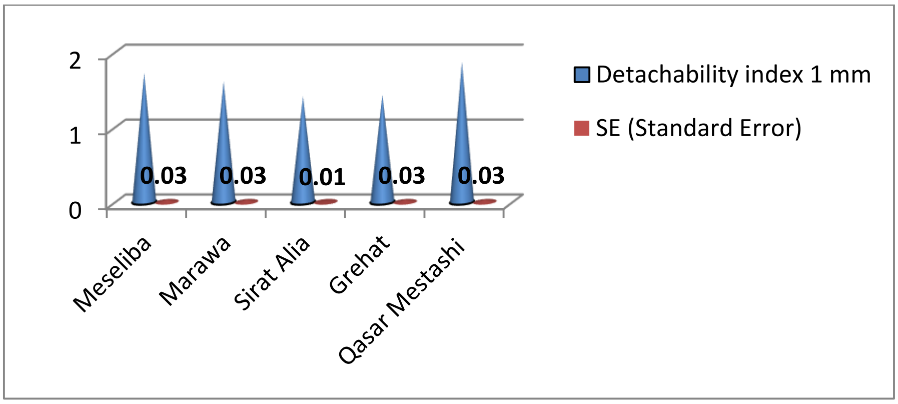

Figure 9. Mean and standard error of Detachability index > 1 mm values

Table 10. Detachability index > 0.5 mm aggregates (gm\min) for the study sites

Sample no.	*Meseliba*	*Marawa*	*S. Alia*	*Grehat*	*Q. Mestashi*
1	1.63	1.62	1.41	1.25	1.82
2	1.75	1.38	1.45	1.40	1.87
3	1.65	1.38	1.38	1.25	1.85
4	1.62	1.59	1.25	1.36	1.77
5	1.42	1.54	1.29	1.32	1.51
6	1.67	1.44	1.33	1.21	1.78
7	1.80	1.71	1.22	1.43	1.75
8	1.63	1.43	1.35	1.59	1.83
9	1.69	1.38	1.31	1.48	1.67
10	1.82	1.36	1.28	1.27	1.82
11	1.77	1.60	1.19	1.33	1.99
12	1.88	1.52	1.32	1.43	1.88
Means	1.69a	1.49b	1.32c	1.36c	1.79a

Tukey value = 0.11

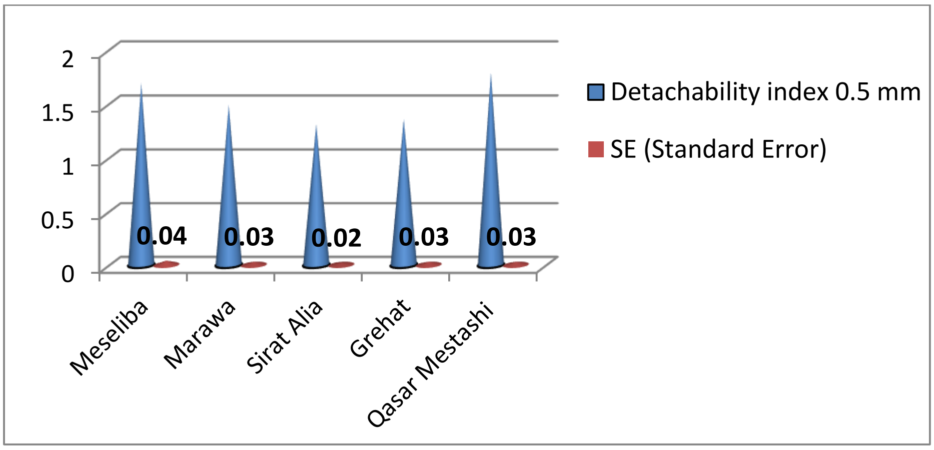

Figure 10. Mean and standard error of Detachability index > 0.5 mm values

The empirical indicator (K-USLE) of the statistical equation USLE proposed by Wischmeier *et al*. (1971), the results (Table 11, and Figure 11) showed relatively different trend and described the soils of the site of Qasar Mestashi as medium to highly erodible, and within the same description of the most sites under study. In contrast to all dynamic-laboratory indicators used in this study, K-USLE index described the soils of Grehat site as the most erodible. These results raise questions about the realism and validity of statistical indicators, hence, their validity and suitability to the conditions of the study areas need to be tested.

Table 11. K-USLE index values (Wischmeier *et al.*, 1971) for the study sites

Sample no.	*Meseliba*	*Marawa*	*S. Alia*	*Grehat*	*Q. Mestashi*
1	0.29	0.22	0.16	0.42	0.28
2	0.37	0.20	0.16	0.42	0.30
3	0.28	0.22	0.16	0.37	0.25
4	0.27	0.21	0.21	0.34	0.32
5	0.42	0.19	0.20	0.39	0.30
6	0.35	0.19	0.20	0.42	0.33
7	0.31	0.20	0.20	0.39	0.32
8	0.28	0.19	0.21	0.44	0.35
9	0.30	0.21	0.22	0.44	0.33
10	0.29	0.20	0.21	0.47	0.32
11	0.31	0.22	0.22	0.42	0.34
12	0.31	0.22	0.22	0.42	0.34
Means	0.32b	0.21c	0.20c	0.40a	0.32b

Tukey value = 0.03

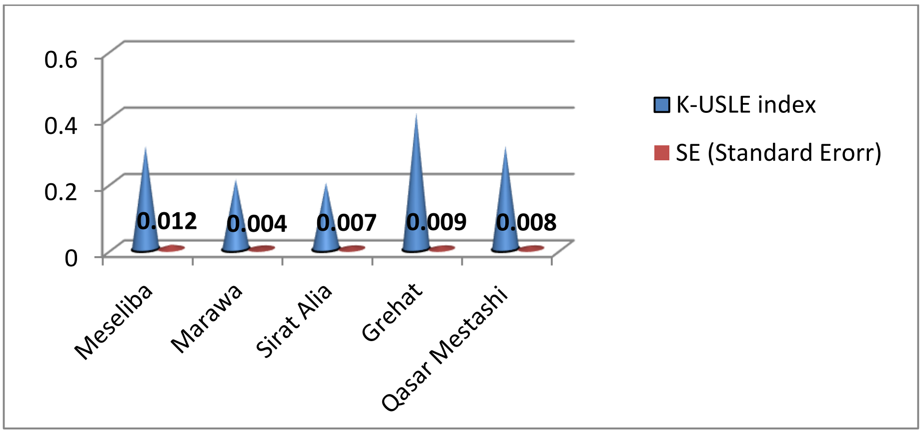

Figure 11. Mean and standard error of K-USLE index values

Several researchers have discussed the disadvantages of statistical empirical indicators. Diaz-Fierros and Benito (1996) found that the K-USLE of Wischmeier nomograph shows only one part of the erosion process, that part is related to the inherent soil properties, which makes the index limited in effectiveness. The statistical index ignores the interaction of soil properties with the surrounding environmental factors, where the USLE equation expresses soil erodibility separately from the other factors (rain, topography and vegetation).Rainfall and the stages of vegetation growth can affect the state of soil structure and the water infiltration capacity within it. Therefore, soil erodibility is a dynamic property that is changeable over time and cannot be isolated from surrounding conditions as USLE did with factor K when it was linked to soil properties only. Barthes and Rosse (2002), Kuhn and Bryan (2004) considered that soil erosion would be better expressed when considering the intensity of rainfall, slope, soil managementm and topsoil aggregates. Thus, the erodibility factor cannot be viewed as a constant number in the sense that each soil type has a fixed annual value of K as applied to the equation of the K-USLE model, but in fact it is a dynamic variable (Abu Hammad, 2005, and Hussien *et al*., 2007). The success of the dynamic indicators in expressing erosion-related soil degradation has been widely mentioned by several previous studies which have considered that the aggregates stability indicators measured using wet sieving methods were able to predict soil susceptibility to water erosion and degradation. This was due to its simulation of natural conditions in the field, and direct relationship to the role of climate, parent material, Plant cover and land uses, enabling it to characterize soil erodibility and to assess the risk of erosion and soil degradation (Cerda, 2000; and Barthes and Rosse, 2002). The indicators of soil structure measured in the laboratory can be a useful tool for describing the risk of erosion when comparing different types of soils, land or uses. However, these indicators cannot be able to give absolute values of soil erodibility compared to the actual situation in the field conditions when rainfall falls on degraded slope lands. Despite the ability of these low cost and easy to apply laboratory measurements to carry out a comparative investigation of soil susceptibility to erosion between soils with different properties, but they need to be validated using direct field experiments under natural rain conditions, so that, soil erodibility would reasonably be described under the conditions of Al-Jabal Alkhdar.

5. Conclusion

Dynamic laboratory methods tested in this study showed consistency in their results to characterize and estimate soil susceptibility to water erosion. In general, the dynamic measurements agreed that Qasar Mestashi soils were the most erodible and the least resistant to erosion, which is consistent with the physical soil characteristics of that site and its organic matter content, which is generally degraded. While, Sirat Alia soils were the most resistant to erosion which is in consistence with their general characteristics that characterized by high content of clay and organic matter. On the other hand, the results of the statistical method (K-USLE) did not agree with the results of the dynamic laboratory methods, which put doubts about the validity and accuracy of applying statistical methods in measuring soil susceptibility to water erosion under the study area conditions.

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