Water Erosion Effects on Soil's Plant Nutrients Pool in Some Soils of Al-Jabal Al-Akhder, Libya

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ABSTRACT:

Abstract

Soil nutrient loss caused by accelerated soil erosion after deforestation and change land use is becoming more of a concern in the world. As well, soil erosion removes topsoil, which is the richest layer of soil in both organic matter and nutrient value. Therefore, the objective of this research was to quantify the effects of accelerated soil erosion caused by deforestation and change land use on soil organic matter (OM), total nitrogen (TN), available phosphorus (P) losses, and change in other soil properties in newly-deforested hilly lands at Al-Jabal Al-Akhder region. Results showing clear differences between soils profiles on upper slope and foot slope of the studied transect. The foot slope profiles had higher clay content, organic carbon, cation exchange capacity, available phosphorus, total nitrogen and $CaCO_3$ contents than upper slope profiles. Surface horizon thickness and rooting depth have been found to increased as a result of sedimentation in foot slope profiles. Values of the enrichment ratio higher than 1 are observed for most studied soil properties. These research findings will help improve the understanding

on effects of erosion processes on soil's plant nutrients pool in some soils of Al-Jabal Al-Akhder, Libya.

Introduction

Soil nutrient loss caused by accelerated soil erosion after deforestation and change land use is becoming more of a concern in the world. A large number of studies have been designed to investigate soil nutrient loss with eroded sediments. For instance, Flanagan and Foster (1989) found that nutrients in eroded sediment were significantly enriched; Monke *et al.*, (1977) showed that nutrient enrichment ratios in sediment ranged from 1.2 to 2.3; Young *et al.*, (1986) showed that nutrient enrichment in eroded sediment decreased with an increasing runoff rate and suspended sediment concentration; and Johnson and Baker (1983, 1984) after analyzing over 650 individual runoff samples from corn and soybean fields discovered that Kjeldahl-N and total P contents in sediment were closely related to sediment concentration in runoff. In addition, Sharpley *et al.*, (1991) measured erosion and associated N and P losses with sediment under natural rainfall as affected by management and found that both N and P contents in sediment were strongly related to sediment concentration of individual runoff events.

During the past 10 years in the United States much effort has been devoted to studying the effects on soil quality when converting vegetation to cultivation, such as the Conservation Reserve Program (CRP). The results showed that converting CRP lands to cultivation significantly increased runoff and erosion and accelerated soil quality degradation (Davie and Lant, 1994; Gilley et al., 1996, 1997a, b).

Hudson (1981); Ferderick *et al.*, (1980); Morgan (1986); McDowell and Sharpley, (2002) and Arbelo *et al.*, (2004) stated that water erosion leads to loss of fertile top soil, texture is changed, structure deteriorates; productivity capacity is reduced and fields are dissected. They found that the most apparent damaged caused by water erosion is the removal of the soil from eroding surface. Erosion from land covered with perennial vegetation, grass or trees, amounts to only a fraction of a ton per hectare annually. On the other hand, erosion from bare cultivated fields amounts up to 200 to 450 t ha^{-1} for a single winter season (Arbelo *et al.*, 2004).

Concerning for losses of plant nutrients, Arbelo *et al.*, (2004) stated that soil erosion is a selective process in which soil particles and aggregates are selectively sorted and removed from surface soil. Because this process occurs at the soil surface, eroded materials are normally high in organic matter and nutrient contents. Selective removal of these nutrients rich soil particles by erosion leave behind a soil surface depleted to various degrees, of plant available nutrients. The major plant nutrients losses are nitrogen, phosphorus and potassium. From the pervious argument, some studies in small plots have examined the flows of dissolved nutrients or associated with suspended sediments, showing a great variability in nutrient losses related to rainfall events (Schlesinger *et al.*, 2000, Ramos and Mart?nez-Casasnovas, 2004, Pardini *et al.*, 2003).

With respect to the soil textural changes, Schwab *et al.*, (19[illegible]) stated that, the soil erosion process also changes the environment in the remaining surface soil. The coarser grains are left near the original location while the finer ones are transported some distance. If soil texture is not significantly changed by erosion, depletion of organic matter and organic rich soil aggregates by erosion may result in a higher bulk density in the remaining soil surface.

The effects of soil erosion on soil productivity are highly dependent upon landscape position. For example, Jones *et al.*, (1989) found for five soil catena in Nebraska that most or all top soil had been eroded from soils located on shoulder, upper linear, or lower linear parts of hill. On interfere or foot slope positions, they usually found 20cm or more of top soil. They found little relationship between soil thickness (Mollisols) and soil nutrient status, but top soil thickness was related to crop yields.

In Libya, studies of soil erosion and soil degradation are limited and conducted on large scale (Selkhozprom Export, 1980). However, little attention has been paid to quantifying soil nutrient loss and soil quality deterioration after deforestation and change land use (Ben Mahmud, 1993).

The objective of this research was to quantify the effects of accelerated soil erosion caused by deforestation and change land use on soil organic matter (OM), total nitrogen (TN), available phosphorus (P) losses, and change in other soil properties in newly-deforested hilly lands at Al-Jabal Al-Akhder region. This information will help to improve understanding of the relationship between accelerated soil erosion after deforestation and soil quality degradation.

MATERIALS AND METHODS

The research area is located on selected slope side at Shahat cultivated land, Al-Jabal Al-Akhder, Northeast Libya, with coordinates 32° 49' 53" N and 21° 53' 67" E and elevated to about 640 m. a.s.l. Soils are developed on calcareous soft lime stone parent material. The mean annual precipitation and temperature are around 600 mm and 14.4 °C in the province. The soil temperature and moisture regimes are thermic and xeric respectively.

Five soils transect with olive tree plantations were examined in this research. Along with slope length (70 m.), slope gradient increased, i.e., the slope shape was convex. Slopes were very steep ranging from 3°-12° with dominant sheet erosion. Ten soil profiles were digging; two profiles in each transect (one on upper slope and the other on foot slope). The total number of soil profiles were five on the upper slope (profiles 1 to 5) and other five on foot slope (profiles 6 to 10).

The soil samples were taken from the surface and subsurface horizons in each profile. Morphological properties of the profiles were described according to Soil Survey Manual (1993). According to Page *et al* (1982), the soil samples were analyzed for particle-size distribution, pH in a 1:2 soil: water ratio, organic carbon, total nitrogen, calcium carbonate, electrical conductivity, available phosphorus, CEC, and exchangeable cations.

RESULTS AND DISCUSSION

Soil characteristics and classification

All the soil profiles had color (dry) of 5 YR hue. The values and chromas of soils ranged from 3 to 5 and 3 to 6, respectively. All soil profiles were situated on north aspect and formed on hill landforms and cultivated with olive trees. These soils are well drained, leached and have clay enriched in the Bw horizons. The Bw horizons had stronger structure than Ap horizons due to the high clay content of the soils. The soil structures were granular in foot slope profiles (6 to 10) and cloddy in the investigated profiles located at upper slope. Surface horizon thickness and rooting depth have been found to decrease as a result of erosion in upper slope profiles with average thickness 17.5 cm, while the foot slope surface horizons had average thickness 23.4 cm.

Some selected physical and chemical properties of the soils are presented in Table 1. The clay content varied from 28.4 to 44.8% and increased with depth from Ap to Bw horizons in all profiles. These soils had more silt than sand in the Ap and Bw horizons. The highest clay content occurred from profiles 5 to 10 due to their position in foot slope. pH values ranged from 7.2 to 7.7 and increased with depth. The organic carbon and total nitrogen values varied from 0.43 to 1.94% and 0.05 to 0.16% respectively. C/N values ranged from 8.6 to 13.8. These soils had low CaCO3 content due to accelerate leaching process and values varied from 1.0 to 4.5%. Electrical conductivity values ranged from 0.38 to 0.80 dS m^{-1} and these low values were indicated that soils were not saline due to high amounts of rainfall and good drainage in all the studied profile. Available phosphorus values varied from 13.07 to 25.48 p.p.m and increased gradually with depth. The highest values were occurred in the surface horizons and these values were in moderate to high levels to support the plant growth. The cation exchange capacity values ranged from 20.7 to 31.0 meq /100g soil and increased with depth. This feature is probably related with high clay content of the profiles in the Bw horizons.

The exchangeable Ca and Mg values varied from 16.1 to 27.8 and 1.1 to 2.2 meq /100g soil respectively. The exchangeable K and Na values ranged from 1.1 to 2.0 and 1.0 to 1.9 meq /100g soil.

The differences occurred in soils (Figs 1 and 2) may be due to the location of the profiles on upper slope and foot slope of the studied transects. The upper slope profiles from 1 to 5 had lower clay, organic carbon, cation exchange capacity, available phosphorus, total nitrogen and CaCO3 contents than other profiles. Nevertheless, all profiles had higher phosphorus values because farmers were fertilized all the soil sites with triple super phosphate and ammonium nitrate to obtain enough yields in the region.

Based on morphological, chemical and physical properties of the different soil horizons, these soils were classified according to USDA Soil Taxonomy (1999) as Lithic Xerochrepts.

Effects of erosion on soil nutrients pool

Tables 1 and 2 show that clay particles are the most eroded soil fraction, although not in a disperse state, but rather in the form of highly stable granular and crumb aggregates. Hence, values of the enrichment ratio higher than 1 are only observed for the clayey fraction (ER = 1.20). While enrichment ratio for sand and silt were 1.00 and 0.85, respectively. We can, therefore, observe a clear tendency for the fine particles (mainly clay) to be eroded more easily. Similar trend was also obtained by Fredrick *et al* (1980) and Jones *et al* (1989).

Table (1): Some chemical, nutrimental and physical properties of the soil profiles along studied transects

Transect no	profile no.	depth, cm	pH	EC $dS m^{-1}$	$CaCO_3$ %	O.C. %	T.N. %	C/N	P p.p.m.	CEC meq/100 soil	Exchangeable cations meq/100 g soil Ca	Mg	K	Na	Sand %	Silt %	Clay %	Texture class
I	1*	0-18	7.3	0.65	1.5	1.60	0.13	12.3	17.87	24.1	19.7	2.0	1.9	1.4	27.7	40.1	32.2	C.L.
		18-35	7.4	0.52	2.1	0.72	0.07	10.3	15.62	25.8	22.2	1.7	1.1	1.7	20.2	42.3	37.5	C.L.
	6**	0-25	7.4	0.80	2.1	1.85	0.14	13.2	22.03	28.8	24.3	2.2	2.2	1.4	29.4	33.5	37.1	C.L.
		25-50	7.5	0.76	2.9	0.82	0.07	11.7	20.17	30.5	26.9	1.4	1.4	1.7	20.3	37.3	42.4	C.
II	2*	0-22	7.4	0.72	1.7	1.43	0.13	11.0	15.95	22.3	18.2	2.1	2.1	1.0	33.3	38.3	28.4	C.L.
		22-40	7.5	0.60	2.5	0.52	0.06	8.70	13.07	25.1	21.7	1.5	1.5	1.3	23.1	43.9	33.0	C.L.
	7**	0-20	7.5	0.74	2.2	1.91	0.16	11.9	25.48	24.6	20.5	2.1	2.1	1.0	32.1	32.4	35.5	C.L.
		20-55	7.6	0.70	2.9	0.85	0.08	10.6	23.05	28.2	24.8	1.3	1.3	1.3	24.9	35.9	41.2	C.
III	3*	0-15	7.2	0.57	1.1	1.54	0.12	12.8	16.83	23.7	19.4	1.9	1.9	1.5	27.5	42.4	30.1	C.L.
		15-45	7.3	0.45	1.9	0.43	0.05	8.6	14.55	26.2	22.5	1.2	1.2	1.9	18.5	45.7	35.8	C.L.
	8**	0-22	7.5	0.57	2.2	1.74	0.13	13.4	21.41	28.4	24.1	2.0	2.0	1.1	30.7	30.3	39.0	C.L
		22-45	7.6	0.55	3.1	0.92	0.08	11.5	18.50	31.0	27.8	1.2	1.2	1.6	16.7	38.5	44.8	C..
IV	4*	0-15	7.3	0.62	1.9	1.22	0.11	11.1	17.46	24.3	19.8	2.1	2.1	1.1	26.7	39.0	34.3	C.L.
		15-40	7.4	0.50	2.2	0.67	0.07	9.6	15.03	26.9	23.3	1.3	1.3	1.9	19.7	42.8	37.5	C.L.
	9**	0-25	7.6	0.51	2.0	1.80	0.15	12.0	24.71	26.9	23.2	2.2	2.2	1.0	26.8	35.3	37.9	C.L.
		25-50	7.7	0.44	2.7	0.78	0.09	8.7	21.62	29.3	25.8	1.4	1.4	1.5	19.6	37.1	43.3	C.
V	5*	0-18	7.2	0.75	1.0	1.10	0.09	12.2	18.80	20.7	16.1	2.0	2.0	1.6	33.8	36.5	29.7	C.L.
		18-45	7.3	0.62	1.8	0.55	0.05	11.0	16.51	25.1	21.5	1.5	1.5	1.8	25.6	40.3	34.1	C.L.
	10**	0-25	7.6	0.59	2.0	1.94	0.14	13.8	21.45	27.5	23.6	2.0	2.0	1.2	30.5	32.7	36.8	C.L.
		25-55	7.7	0.50	3.2	0.74	0.07	10.6	19.82	28.4	25.0	1.1	1.1	1.8	22.9	35.5	41.6	C.

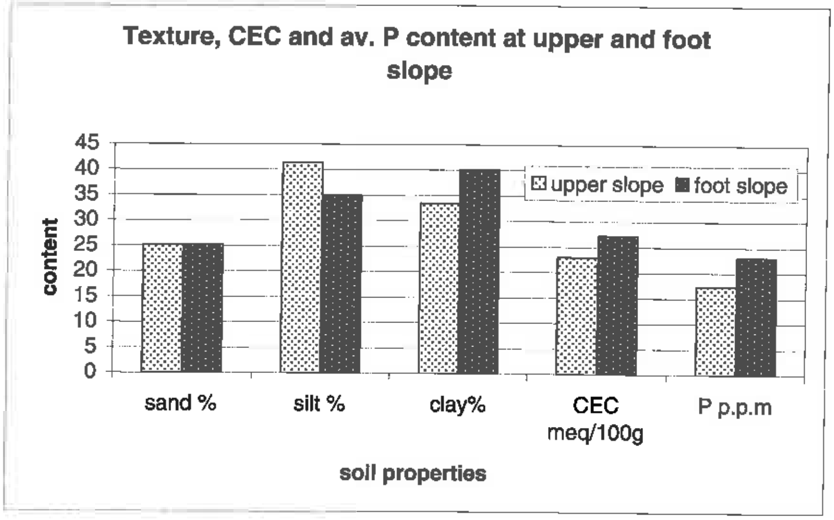
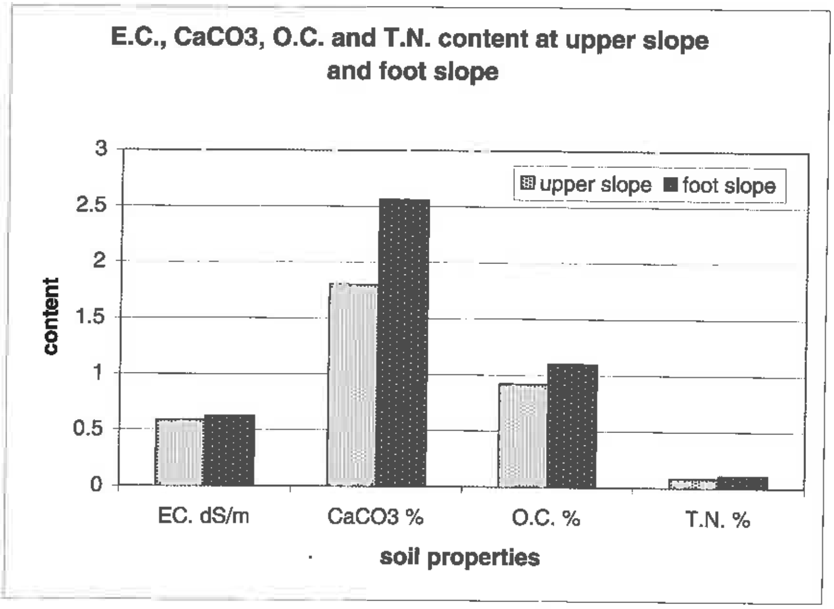


Fig (1): Distribution of weighted means of texture, CEC and available P in soil samples at upper and foot slopes



(2): Fig

Soil properties	weighted means of soil samples on upper slope (profiles 1 to 5)	weighted means of soil samples on foot slope (profiles 6 to 10)	Enrichment Ratio (ER)
Sand %	25.12	25.19	1.00
Silt %	41.36	34.98	0.85
Clay %	33.51	40.10	1.20
CEC meq/100 g soil	24.60	28.33	1.15
P p.p.m	16.02	21.79	1.36
O.C. %	0.92	1.10	1.20
T.N. %	0.084	0.108	1.29
$CaCO_3$ %	1.80	2.56	1.42
EC dS/m^{-1}	0.59	0.62	1.05

Distribution of weighted means of EC, CaCO3 ,O.C and T.N. in soil samples at upper and foot slopes

Table (2): Enrichment ratio of some soil properties in the studied soil surface samples at upper and foot slopes

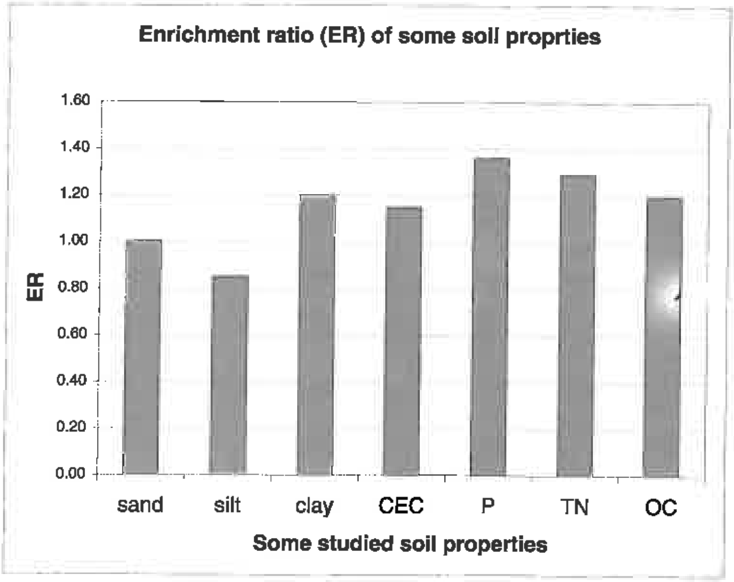


Fig (3): Enrichment ratio (ER) of some soil properties between weighted means of soil samples at upper and foot slopes

In the same way, average of cation exchange capacity was increased from 24.60 in upper slope profiles to 28.33 meq/100g soil in foot slope profiles with enrichment ratio 1.15 (Table 2 and Fig 3). These result in accordance with increasing of clay content and organic matter in foot slope soil profiles than upper slope ones. Clay particles and organic matter have negatively charged sites that hold positively charged ions on their surfaces. CEC protects soluble cations from leaching out of the plant root zone. These ions are rapidly exchangeable with other soluble ions, so when root uptake depletes the nutrient supply they replenish plant-available cations in the soil solution. Cation exchange is the major nutrient reservoir of K^+, Ca^{2+}, and Mg^{2+}, is important for holding onto N in the ammonium (NH_4^+) form, and to some extent supplies micronutrient trace metals like Zn^{2+} and Mn^{2+}. Cation exchange helps soils resist changes in pH in addition to retaining plant nutrients (McDowell and Sharpley, 2001 and Arbelo *et al*, 2004).

One major process of soil erosion is the loss of soil's plant nutrients. Several researchers have reported that N and P in eroded sediment were significantly enriched (Monke *et al.*, 1977; Flanagan and Foster, 1989; Young *et al.*, 1986). Data from this study also showed that OM, total N, available P and were greatly enriched in eroded sediments

Regarding the enrichment ratio (ER) for available phosphorus, Table 2 and Fig 3 show that the ER value was 1.36. These result due to high concentration of P in upper slope soil due to application of mineral P fertilizers in the studied area. The potential loss of P in different forms during over- land flow is a function of erosion, soil P concentration, and management. Sharpley (1985) described the concentrations of dissolved phosphorus in overland flow by a function that related soil volume and surface soil P concentration to the power of soil constituent concentrations (e.g., soil P, clay, and organic C content). The nature of the erosion process means that finer-sized particles, which also contain much more P than coarser-sized particles, are eroded first. However, the concentration of P in water in equilibrium with fine particles can be much less (relative to the total concentration of P in the particle) than from coarse particles (Maguire *et al.*, 1998).

Results in Table 2 and Fig 3 showing that organic carbon and total nitrogen were accumulated in foot slope surface horizons with enrichment value 1.20 and 1.29, respectively. Erosion induced depletion in soil organic carbon results in decline in soil quality due to a reduction in available water capacity, decrease nutrient holding capacity, reduction in water infiltration capacity and aggregation, and further increase in runoff and erosion (Doran *et al.*, 1998; and Lal, 1998). Erosion caused displacement and redistribution of soil organic carbon may accentuate mineralization and release of C to the atmosphere. Erosion breaks down aggregates, exposed soil organic carbon locked in them, and increases mineralization through increase microbial decomposition. Some of the soil organic carbon transported by erosion may buried in depositional sites (Lal, 1998).

Field observations showed that erosion caused visible changes in soil structure. The soil structure of Ap horizon was granular in soils of foot slope (profiles 6 to 10), while it was cloddy with erosion in upper slope (profiles 1 to 5) as the result of physical changes to the soil as soil organic matter lose as a binding agent. This decline in soil structure was related to the reduction in soil organic matter (O.C. %) in erode phase.

In the same way, erosion enhances nitrogen loss by many ways and nitrogen cycle could be explaining some of these mechanisms. For example, N in the nitrate form is very soluble and one of the most mobile plant nutrients in soil, so it can easily be lost from farm fields by leaching and run off during water erosion process.

Conclusions

Mineral nutrients can be lost from the soil system and become unavailable for plant uptake. Nutrient losses occur through: Runoff – loss of dissolved nutrients in water moving across the soil surface, Erosion – loss of nutrients in or attached to soil particles that are removed from fields by wind or water movement, Leaching – loss of dissolved nutrients in water that moves down through the soil to groundwater or out of the field through drain lines

In the deforested lands of the Al-Jabal Al-Akhder region, erosion and sediment transport processes caused different intensities of nutrient losses. Nutrient content decreased from upper slope to foot slopes zones, whereas the total amount of nutrient loss increased. Also, there were different nutrient enrichment ratios for total N, OM, and available P being higher. Additionally, soil nutrient loss was closely related to other soil properties such as clay content and structure.

These research findings will help improve the understanding on effects of erosion processes on soil quality degradation, and may provide reference data for eco-environmental rehabilitation on the Al-Jabal Al-Akhder.

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تأثيرات التعرية المائية علي مخزون التربة من العناصر المغذية

في بعض ترب منطقة الجبل الأخضر – الجماهيرية الليبية

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كلية الزراعة– جامعة عمر المختار
الجماهيرية الليبية

يعتبر فقد المغذيات النباتية من التربة تحت تأثير عمليات التعرية المتسارعة بعد إزالة الغطاء النباتي الطبيعي وتغيير نمط استخدام الأرض من أهم المشكلات التي تحد من الزراعة المستدامة لهذه الترب. حيث تلعب التعرية المائية تلعب دورا هاما في انجراف هذه التربة، وخاصة فقد الطبقة السطحية والتي تعتبر المخزن الرئيسي للمادة العضوية والعناصر المغذية اللازمة لنمو النبات. لذلك، تهدف هذه الدراسة إلي تقدير الفقد في المادة العضوية (الكربون العضوي) والعناصر المغذية علي امتداد عدد 5 قطاعات طولية للمنحدرات الشائعة في منطقة مدينة شحات ، حيث تمتد هذه القطاعات في شكل خمسة محاور من قمة المنحدر إلي قدم المنحدر ويمثل كل خط قطاعين من التربة احدهم يمثل منطقة الإزالة (قمة المنحدر) والأخر يمثل منطقة الترسيب (قدم المنحدر) ، وتأثير ذلك علي خصوبة التربة وبعض خصائصها الأخرى. أوضحت نتائج الدراسة أن هناك فروق واضحة بين كل خصائص التربة عند قمة المنحدرات وأدناها، فقد وجد أن كل العينات السطحية عند أقدام المنحدرات أعلي في محتواها من كل من الطين والكربون العضوي والفسفور المتيسر والسعة التبادلية الكاتيونية والنيتروجين الكلي، هذا بالإضافة إلي زيادة سمك التربة السطحية مقارنة بالتربة في أعلي المنحدرات. وقد أكدت ذلك نتائج الاغناء (الإضافة والفقد) Enrichment Ratio حيث كانت قيمتها تزيد عن الواحد الصحيح لمعظم خصائص التربة.