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Assessment of soil quality indicators on different slope aspects in Duhok's highlands (Kurdistan region – Iraq)

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Abstract

This study was conducted to assess the influence of slope aspect on some physical, chemical and biological indicators of soil quality in Mountain in Brifka village that located at about 20 km east of Duhok province in Iraqi Kurdistan region, having the same climatic, and vegetation. Soil samples were collected randomly and at uniform intervals along north and south facing slopes aspect. The soil quality has been represented by some physical, chemical and biological indicators such as: soil texture, bulk density, moisture content, organic carbon, pH, electrical conductivity, soil basal respiration, microbial biomass C, potentially mineralizable N and metabolic quotient. The results indicated that, except in few cases, the majority of studied soil quality indicators were significantly affected by slope aspect. The mount of soil moisture content, silt mineral fraction, soil organic C, soil basal respiration, microbial biomass was significantly higher in north facing slope compared to south facing slope, while sand fraction and bulk density were significant higher on south aspect than north aspect. No significant differences were found in clay fraction, soil pH, electrical conductivity, potentially mineralizable N and metabolic content. It was suggested that the slope aspect has effects on soil quality indicators and for better rangeland and landscape management it is very important to take the topographic aspect into consideration.

I. Introduction

Environmental factors such as climatic conditions and landscape features that include position, gradient, aspect, topography, parent material and vegetation have a significant influence on spatial variation of soil properties [1, 2, 3]. It has been stated that landscape attributes such as slope aspect and position in woody ecosystems influence locale microclimates by changing the pattern of precipitation, temperature and relative humidity [4, 5, 6]. These features can in turn have significant influences on soil properties, such as soil organic carbon, bulk density, pH, nutrients levels, water holding capacity, which considered as important indicators of soil quality because of their senility to changes in environmental factors as well as soil management practices [7] and consequently affecting the soil and plants productivity [8]. Slope aspect can also have significant influences on the rate of weathering and soil development [9, 10].

The influence of slope orientation with respect to sun is very important in the development of soil especially in areas locating at mid latitudes. In such area, the aspect of a slope was found to be a huge influencer of the microclimatic conditions of the area mainly influenced by the temperature levels [11]. It has been general accepted that south facing slopes in the Mediterranean region receive higher solar radiation than north facing slope thus affecting temperature, soil moisture, nutrients and soil aggregation processes [12, 13, 14]. A variation in the proportions of these elements in soil can have a profound effect on plant growth due its effect on nutrient balance, and microbial activity in the soil [15].

For better understanding the response of soil to slope aspects, the term of soil quality must be taken to assess. Soil quality is use to describe the combination of chemical, physical, and biological characteristics that give soil the ability to perform a wide range of functions [16]. [17], defined soil quality as "the continued capacity of a soil to function, within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant, animal and human health" [18]. According to [19] any assessment in soil quality must consider the multiple soil uses such as agricultural production, forest, rangeland, nature conservation, recreation, or urban development. Soil quality is assessed by indicators to evaluate how soil factions as it are difficult to measure directly. For correct selection of soil quality indicators are very important particularly those that enable the quantification of soil quality. The selected of indicators must have a series of characteristics including: correlated well with ecosystem process, integrate physical, chemical and biological properties, accessible to many users and applicable to field conditions, sensitive to variations in management and climate, and, be components of existing soil data bases, where possible [20].

The Kurdistan Region is characterized by semi-arid clime (Mediterranean-type climate) with various landforms including mountains, large rolling hills and plains. Stability of these landforms directly influences soil quality and consequently affects vegetation productivity [21]. A lot of research has been conducted on the influences of various climatic and environmental factors on the type of vegetation and the type of soils found in certain areas of this region and on the influence of pH, soil density, moisture content, soil texture, EC, calcium carbonate and nitrogen. However, there exists very scanty data of the influence of slope aspect on the soil quality indicators that is found in a certain area, this therefore has necessitated an intensive study of the various environmental factors that affect soil quality in this area. In addition, no researchers have attempted to assess the influence of the slope aspect on soil quality indicators in Duhok's highland, and this research will open up the area for further research which has been neglected by researcher. Therefore, the main aim of this study is to investigate some physical, chemical and biological properties as indicators to assess the soil quality along north and south facing slope aspects in Duhok's highlands (Iraqi Kurdistan region).

II. Materials and Methods

A. Site description

This study was conducted along sides a Mountain in Brifka village, located at about 20km east of Duhok province (36°47'45"N; 43°12'85"E) (Fig. 1.). It belongs to Zawa Mountain and the later belongs to the Zagross Mountain with calcareous (limestone) soil bedrock. In general both aspect of slope was typified by Clay texture class. The topography of the area is characterized by moderate to steep slope where the gradient ranges from 14% to 49%, with an elevation ranged between 790 to 886m above sea level. The climate of the area is belong to semi-arid and semi-humid region (Mediterranean - type climate) with a mean annual precipitation of (570–750 mm) per year and mean annual temperature of 17.4 ºC.

B- Sample collection

In this study the sampling process was conducted on two different slope aspect (north and south facing slope) so that the difference in soil properties could be assessed. At each site, the sampling area was selected carefully (uniform in slope) so they could best represent the effect of slope aspect. The sampling area was selected carefully (uniform in slope). At each site ten composite soil samples was collected randomly as replicates for statistical analysis. Soil samples were collected at depth of 0 – 30 cm. In addition, ten undisturbed soil samples (using cylindrical core) were taken from topsoil of each aspect for determining soil bulk density. Soil samples was then be taken to the laboratory, except for soil moisture content, on the same day a portion of approximately 250g of each soil sample was sieved through 2 mm sieve (in order to be free from any stones and other debris) and stored immediately at 4ºC for biological analysis. Further portion of about 500 g was air – dried crushed with a mortar and pestle and sieved through (2mm sieve) for further physiochemical analysis to be carried out. All the parameters will be measured according to the standard methods relating to the region.

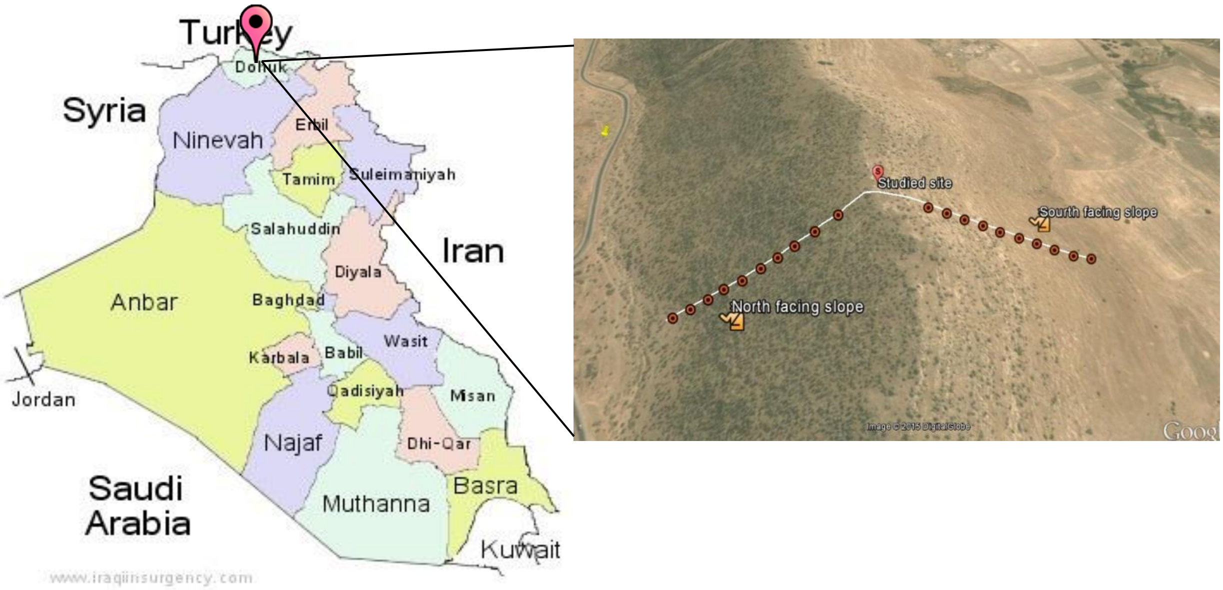

Figure – 1: Map of Iraq with satellite image showing studied site and sampling locations.

C- Laboratory analysis

1- Physicochemical analysis

Particle size analysis was carried out by the hydrometer method [22]. Soil moisture content was determined gravimetric method [23]. Bulk density was determined using core method [24]. Soil Organic matter was determined by [24]. Soil pH was estimated using a pH meter method that was described by [25]. The electrical conductivity was measured with using EC – meter, model HI 9635 as described by [25].

2- Biological analysis

Substrate-Induced Respiration (SIR)

The substrate induced respiration was measured following the methods adopted by [26], after slight modification has been made. This method is detects the response of soil microbial biomass to the application of readily available substrate which is glucose [27]. Soil microbial biomass C was calculated from SIR using the equation described by [26] as follows: µg C g^{-1} soil = (ul CO2 g-1 soil h^{-1} ×40.04) + 0.37.

Soil Basal Respiration (SBR)

Soil basal respiration was measured following the same procedure which has been used for soil induced respiration, without the addition of substrate. The Metabolic quotient (qCO_2) was calculated as the ratio of soil basal respiration to soil microbial biomass and expressed in mg CO_2 – C g^{-1}mic C h^{-1} using the following equation: qCO_2 = SBR × (12/44) × 1000/SIR.

Potentially Mineralizable Nitrogen (PMN)

The rate of N mineralization was measured by an aerobics incubation method following the one proposed by [28]. This method involved measurement the amount of organic –N (NH_4 – N) released in the soil by the action of soil microbial activity under anaerobic (waterlogged) incubation at 37 ºC. for 1 week [29].

D- Statistical Analysis

For statistical analysis, One-way, ANOVA and GLM were applied to examine the significant effects of slope aspects (as main factors) on soil quality indicators at significant level ($P < 0.05$). All statistical analyses were performed using the Minitab software package 16. Significant differences between means were tested using Tukey's test. Pearson's correlation coefficient was also used for assessing the significance in the relationship amongst physical, chemical and biological indicators of soil quality.

III. Results

A- Physicochemical indicators of soil quality

Tables 1 and 2 summarize the soil physical and chemical properties of the north and south facing slope. North aspect had a higher percent of clay and silt mineral (46.3% and 33.5%) compared to south aspect (46.3 and 31.7%) respectively while the percent of sand was lower on north aspect (18.2%) than south (22.0%). However, these trends of soil mineral texture were only significant for silt ($F_{1,18}$ = *6.75; P- value = 0.018*) and sand ($F_{1,18}$= *13.67; P – value = 0.002*), while the clay trend was not significantly different ($F_{1,18}$ = *2.61; P – value = 0.124*). In general both aspect of slope was typified by Clay texture class.

Soil moisture content was significantly different on both north and south facing ($F_{1,18}$ = *6.49; P-value = 0.02*) . It was higher at north aspect (25.7%) compared to south aspect (20.2%). There was also a significant difference in soil bulk density in terms of slope aspects ($F_{1,18}$ =*36.13; P- value = 0.0000*), with mean value of (1.02g cm^{-3}) and (1.21g cm^{-3}) for both north and south slope aspect respectively.

Soil pH was neutral and slightly alkaline on both north and south aspect and the trends were not significantly difference ($F_{1,18}$ = *0.08; P – value = 0.787*) with average value of (7.79) and (7.80) respectively. The EC of studied area also didn't show any significant effect of slope aspect ($F_{1,18}$ = *1.05; P- value = 0.319*). In spite of the existence of little increase in EC value on north facing slope (0.33dS m^{-1}) compared to south slope (0.36dS m^{-1}), statistically these trends were significantly different. Soil organic carbon (SOC) was significantly influenced ($F_{1,18} = 8.57; p = 0.008$) by slope aspect (Table 2). It has been found that soil organic carbon was higher on north than south facing slope and the values were (33.36 g kg^{-1}) and (23.5g kg^{-1}) respectively.

Table – 1: Physicochemical soil quality indicators examined on north and south-facing slope.

Slope Aspect	**pH (H_2O)**	**$EC_{1:2}$ (dS m^{-1})**	Organic Carbon (g/kg)	**Moisture content (%)**	**Bulk density (g/cm^3**	**Clay %**	**Silt %**	**Sand %**	**Soil texture class**
North	7.79±0.09 a	0.33±0.1 a	33.36±9.03 a	25.7±3.7a	1.02±0.01 b	48.3±1.4 a	33.5±0.9 a	18.2±1.7 a	Clay
South	7.80±0.12 a	0.36±0.1 a	23.50±5.65 b	20.2±5.5b	1.21±0.10 a	46.3±3.6 a	31.7±2.0 b	22.0±2.7 b	Clay
				ANOVA summary P-values					
Effect of slope aspect	NS	NS	< 0.05	< 0.05	< 0.05	NS	< 0.05	< 0.05	

Means with the same letter are not significantly different (Tukey's test, P < 0.05).
± denotes standard deviation of the mean total of each variable at each site (n=10).

Table – 2: Summary of one-way ANOVA results examining the effect of slope aspects (North vs South) on soil quality indicators

	Effect of slope aspects	
Indicators	F1,18	P - value
Moisture Content %	6.49	0.02
Bulk density	36.13	0.0000
EC	1.05	0.319
pH	0.08	0.787
Organic Carbon	8.57	0.008
Soil Basal Respiration	48.63	0.0000
Microbial Biomass Carbon	27.98	0.0000
Metabolic Quotient	1.09	0.310
Potentially Mineralizable Nitrogen	2.64	0.122
Clay	2.61	0.124
Silt	6.75	0.018
sand	13.67	0.002

B- Biological indicators of soil quality

The amount of soil basal respiration was strongly and significantly affected ($F_{1,18} = 48.63; P - value < 00001$) by slope aspect (Table 2). The higher amount of soil basal respiration was found on north facing slope, up to 1.07 mg CO_2-C kg^{-1} h^{-1} compared to the amount of soil basal respiration which was detected on south facing slope with mean value of 0.77 mg CO_2-C kg^{-1} h^{-1} (Table 3). Likewise, soil microbial biomass carbon also being strongly affected by slope aspect and this effect was significant at ($F_{1,18} = 27.98; P - value <$

0.0001). It has been observed that the size of soil microbial biomass carbon was greater in north aspect with average value of 270.88 mg C kg^{-1} compared to south aspect with average value of 200.5 mg C kg^{-1} (Table 3).

Regarding the effect of slope aspect on metabolic content (qCO_2) and potentially mineralizable nitrogen (PMN), in spite of the existence of slight deference between the means of qCO_2 and PMN at both types of aspects, statistically there were not significantly different ($P > 0.05$) (Table 2). However, higher amount of PMN was recorded in soil under north aspect, while lower amount was recorded in soil under south aspect, with mean value of 9.25 to 7.67 mg N kg^{-1} d^{-1} for north and south aspect respectively (Table 3). Similarly, the pattern qCO_2 was higher in north aspect than south aspect, but this difference was quite low, which was 1.08 mg CO_2 – C g^{-1}mic C h^{-1} for north aspect and 1.04 mg CO_2 – C g^{-1}mic C h^{-1} for south aspect (Table 3).

Table 3. Biological soil quality indicators examined on north and south-facing slope.

Slope Aspect	Soil basal respiration (mg CO_2-C kg^{-1} h^{-1})	Microbial biomass C (mg C kg^{-1})	qCO2 (mg CO_2–C g^{-1} mic C h^{-1})	Potential Mineralizable N (mg N kg-1 d^{-1})
North	1.07±0.1a	270.88±27.6a	1.08±0.08a	9.25±2.9a
South	0.77±0.1b	200.5±31.8b	1.04±0.06a	7.67±1.0a
		ANOVA summary P-values		
Effect of slope aspect	< 0.05	< 0.05	NS	NS

Means with the same letter are not significantly different (Tukey's test, P < 0.05). ± denotes standard deviation of the mean total of each variable at each site (n=10).

C- Correlations among soil quality indicators

According to the Pearson Correlation analysis, it has been observed that the soil organic carbon was strongly and positively correlated with soil moisture ($r = 0.77; p – value < 0.01$), soil basal respiration ($r = 0.83; p – value < 0.01$), soil microbial biomass ($r = 0.805; p\text{-}value < 0.01$) and potentially mineralizable nitrogen ($r = 0.74; p – value < 0.01$) (Table 4). Similarly, soil moisture content was also strongly and positively correlated with soil basal respiration ($r = 0.74; p – value < 0.01$) and soil microbial biomass ($r = 0.72; p – value < 0.01$). Other strong positive correlations that have been found were between soil basal respiration and soil microbial biomass ($r = 0.93; p – value < 0.05$) and between bulk density and sand mineral particles ($r = 0.79; p – value < 0.05$). Potentially mineralizable nitrogen was positively correlated with moisture content ($r = 0.55; p – value < 0.05$), soil basal respiration ($r = 0.54; p – value < 0.05$) and metabolic quotient ($r = 0.55; p – value < 0.05$).

Concerning the significant negative correlation which have been recorded among the studied parameters, bulk density was strongly and negatively correlated with soil quality indicators such as soil basal respiration ($r = - 0.72; p –value < 0.01$), microbial biomass ($r = - 0.67; p – value < 0.01$) and clay mineral particles ($r = - 0.63; p –value < 0.01$) (Table 4). In addition, bulk density was negatively correlated with soil moisture ($r = - 0.45; p – value < 0.05$) and soil organic carbon ($r = - 0.45; p – value < 0.05$). Significant negative relations were also found between EC and microbial biomass ($r = - 0.52; p – value < 0.05$), between sand and soil basal respiration ($r = - 0.55; p – value < 0.05$) and between sand and microbial biomass ($r = - 0.51; p – value < 0.05$). Correlations between the rest of the parameters were very weak (p > 0.05) (Table 4).

Table – 4: The relationship (r) among physical, chemical and biological indicators of soil quality on both North and South aspect. (Pearson correlation matrix).

	SOC	MC	BD	EC	pH	SBS	Cmic	qCO_2	PMN	Clay	Silt
MC	0.77**										
BD	-0.45*	-0.45*									
EC	-0.41	-0.37	0.05								
pH	-0.26	-0.38	0.20	-0.19							
SBR	0.83**	0.74**	-0.72**	-0.44	-0.30						
Cmic	0.81**	0.72**	-0.67**	-0.52*	-0.12	0.93**					
qCO2	0.09	0.05	-0.15	0.22	-0.50*	0.21	-0.15				
PMN	0.74**	0.55*	-0.36	-0.36	-0.09	0.54*	0.55*	-0.02			
Clay	0.27	0.24	-0.63**	-0.11	0.01	0.30	0.28	0.04	0.18		
Silt	0.20	0.07	-0.29	-0.28	-0.04	0.44*	0.40	0.15	-0.04	-0.26	
Sand	-0.37	-0.26	0.79**	0.27	0.01	-0.55	-0.51*	-0.13	-0.15	-0.81**	-0.35

*Correlation significant at $p < 0.05$, ** Correlation significant at $p < 0.01$. *MC, moisture content;* BD, bulk density; SOC, soil organic carbon; EC, electrical conductivity; pH; SBR, soil basal respiration; Cmic, microbial biomass carbon; qCO_2, metabolic content; PMN, Potentially meniralizable nitrogen.

IV. Discussion

A- Physicochemical indicators of soil quality

Bulk density is considered as useful indicator of soil quality since it can provide information about soil characteristics crucial to plant growth such as soil compaction, porosity and movement of water, air, solutes and roots through soil profile [30]. It has been found that Soil bulk was significantly higher in south aspect than south aspect. This higher amount of soil bulk density on south facing slope agreed with finding of other researchers [31, 8]. The greater trend of soil bulk density on south aspect could be due to lower content of soil organic carbon as strong negative correlation was found between soil organic carbon and soil bulk density. This negative correlation which indicates lower content of organic carbon has resulted in increased bulk density under south facing slope. [32], demonstrated that bulk density will not limit root growth until is greater than 1.47 g cm^{-3} in clayey soil or 1.80 g cm^{-3} in sandy. So, it can be stated these trends of soil bulk density is normal (below the threshold value).

Soil moisture content indicates the capacity of soil to store water for plant productivity particularly during water stress condition is an important indicator of soil quality. Significantly higher moisture content was observed on north aspect compared to south aspect. The greater silt mineral fractions and organic carbon could be the main reasons on enhancing the soil moisture content on north facing slope [7, 33]. In addition, it was claimed that the higher solar radiation that south aspects received might be also be another factors governed soil temperature and consequently lowered soil moisture content [4].

Soil pH is a useful indicator of soil quality because it gives valuable information for evaluating soil conditions for plant growth, nutrient cycling and availability and biological activity. However, soil pH values did not show significant difference with respect to slope aspect. The data of current study on pH value are consistent with the data reported by [31] who also found the insignificant difference in soil pH as aspect changes. This insignificant deference in soil pH value with respect to aspect cloud be explained that the higher amount of clay mineral fraction and inherited underlying calcareous bedrock results in higher buffering capacity of soil in both aspect to be and consequently can resist any changes in soil pH. In addition, it can be noticed that the

values of pH that have been found in both aspects were slightly alkaline. This is not surprising, because the amount of rain fall generally in area is very low and this did give any chance to basic nutrient to be leach out from the soil and resulted to high soil pH in both aspect.
Soil electrical conductivity is another useful indicator of soil quality since it is generally associated with determining soil salinity and soluble nutrients. The EC value was slightly greater along north aspect in comparison to south aspect, but these results were not significant. The results of current study did not agree with results of previous research. However, no possible evidence has been found for explaining these contradictory results to previous studies. The content of soil organic carbon was significantly higher on north facing aspect than south facing aspect. Similar findings were reported by other researchers [8, 34, 35]. The higher value of soil organic carbon along north aspect could attributed to the affect of microclimate as north-facing sites are usually cool and moist which probably considered the main factors responsible in reducing the rate of soil organic matter decomposition and thus the accumulation of SOC at north facing aspect [36, 7, 31]. This season can be confirmed by the strong positive correlation that has been found in current study between soil organic carbon and soil moisture content.

B- Biological indicators of soil quality

It was found that the Soil basal respiration, which reflects the microbial respiration (activity), was markedly influenced by slope aspect and higher value of soil basal respiration was found on north facing aspect compared to south aspect. On the other hand, there was a strong correlation between soil basal respiration and organic carbon, which is claiming that the soils on north aspects contain higher levels of soluble organic C and other available nutrients, comes from the decomposition organic residues and therefore supporting higher level of soil microbial activity [37, 38].

The soil microbial biomass (Cmic) reflects the active portion of soil organic matter and may indicate the degradation or aggregation of soil organic matter because it response rapidly to conditions that eventually alter the level of soil organic matter [39]. In current study, the size of soil microbial biomass C was significantly greater in soil taken from north aspect. It was observed that the factors influencing the soil basal respiration was also controlled soil microbial biomass C and this can be confirmed be the correlation. The higher size of Cmic indicated the highest substrate availability (labile organic carbon and nutrient) in the soils of north aspect. This finding is consistent with the findings of other studies of [40, 37] where they claimed that the higher amount of Cmic on north aspect cloud to the accumulation of soil organic matter or organic residues resulted in soluble organic C in the soil as proved by the significantly positive correlations between Cmic and SOC [40, 37]. It has been claimed that the high sand content and pH is disadvantageous to microbial growth [41]. Accordingly significant negative correlation was found between Cmic and sand and this could be another reason caused the Cmic to be lower in soil collected from south aspect.

The metabolic quotients, which measure the efficiency of metabolism, were not significantly controlled by slope aspect. Although the value of qCO_2 was slightly higher on north aspect, the values were not statistically different. In addition, the rates of qCO_2 detected in this study are relatively low compared to the finding of other studies [41, 42]. This relatively low qCO_2 values indicate lower soil chemical stress to microbial population, more efficient nutrient cycling in of both aspect [43, 44]. Potential Mineralizable N is another widely used biological indicator of soil quality since it predict the capacity of soil to provide N for plant growth through the action of soil organism [29]. However, the rate of PMN was greater on north aspect than compared to south aspect but there trend were statistically not significantly different. This higher rate of potentially available nitrogen on north aspect could be related to greater amount of SOC detected on this site and this not surprising because increased mineralizable N is often associated with high organic matter content as described by the correlation analysis [45]. On the other hand, PMN was significantly correlated with SBR and Cmic. In this case, it can also stated that the favorable moisture content and higher temperature in particular could stimulate microbial activity and the decomposition of available substrates within the soil of south aspect, and resulted in a long – term decline in the N and C content and consequently the size soil microbial biomass on south facing aspect. The higher rate of PMN (although not significantly different) indicated that the soil on north facing aspects have a higher potential to supply N for plant growth. However, in order to know which site provides a more balanced nitrogen proportion further studied on N transformation and regulation are required.

V. Conclusion

According to the results that have been found in this study, in spite of the existence of non-significant effects in few indicators, in most cases, the data collected show that there was a significant effect of slope aspect in soil quality indicators. North facing aspect showed higher moisture content, silt mineral fraction, soil organic carbon, soil basal respiration, soil microbial biomass, potentially meniralizable nitrogen and lower bulk density and sand fraction as compared to south aspect. Soil pH, EC and qCO_2 and clay content were not significantly different in term of slope aspect. Depending on these results it could be suggested that the soil on north facing aspect is more productive in term of soil quality indicators. It can also be added that topographic aspects in our region are likely to influence the physical, chemical and biological indicators of soil quality and they should be considered in the action plans for rangeland improvement, development projects and sustainable ecosystem management.

VI. Recommendation

1. Further studies should be done in different location among the Kurdistan region to study the effect the slope aspect on some soil properties as soil quality indicators.
2. Also other studies should be done to study the effect of slope aspect on soil erosion.

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