The Effect of Slope Aspect on Soil and Vegetation Characteristics in Southern West Bank

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Abstract

This study aims to investigate the effect of south and north slope aspect on soil properties and vegetation characteristics (plant cover, biomass, and density) in a semi-arid area in the southern part of the West Bank. The results indicate that the amount of organic matter, electrolyte concentration (EC), NH_4+, available phosphorus and soil moisture content were significantly higher in the north aspect compared to the south aspect. However, pH and $CaCO_3$ were significantly higher in the south than the north aspect. The results of vegetation characteristics showed that total dry biomass, density and cover were higher in north aspects than south aspect. Forbs dry biomass was significantly higher in the southern slope (67.8 g/m^2) than that of the northern slope (46.6 g/m^2). While, the total grass biomass was significantly higher in the north aspect (35 g/m^2) compared to the south aspect (11.3 g/m^2). The results also showed that plant attributes were mainly different at the level of individual plant species. Echinops polyceras, Asphodelus aestivus, and Eryngium creticum are dominant plant species in the south facing slope and they have higher dry biomass by 96 %, 95%, and 88 % compared to the north facing slope. These results show that slope aspect in the arid and semi-arid region have an effect on spatial heterogeneity and distribution of moisture and nutrients resources this effect also is expressed in vegetation attribute between the two aspects.

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1. Introduction

The vegetation patterns of most Mediterranean ecosystems are shaped by various factors such as climatic variation, nature of the soil, topography, cultivation, grazing and fire. Research has shown that south facing slopes in the Mediterranean receive higher solar radiation affecting temperature, soil moisture, nutrients and evaporation (Kutiel 1992; Kutiel and Lavee 1999; Marcelo and Maxim, 2001). This also has an important effect on the distribution of vegetation (Kutiel, 1992). Auslander et al. (2003) indicate that south-facing slopes are warmer and dryer and may receive six times the amount of solar radiation as north facing slopes. Moreover, landscape attributes including slope, aspect, and elevation affect plant growth through indirect influences involving soil properties (Rezaei and Gilkes, 2005 a, b). Lower soil temperature and less moisture evaporation on a north facing slope have numerous effects on different soil properties resulting in less organic matter decomposition and consequently more organic carbon and total nitrogen accumulation in the soil (Rezaei and Gilkes, 2005 a, b; Kutiel and Lavee, 1999; Zaady et al., 2001). Consequently, the soil nutrient pool and general fertility on north facing slopes become greater than those on south facing slopes, which lead to a high variability in plant species, vegetation type and plant community existing on the same site (Rezaei and Gilkes 2005 a b; Kutiel and Lavee 1999; Marcelo and Maxim, 2001).

Under favorable growing conditions in north facing slopes it is possible to hypothesize that plant community characteristics such as percentage cover, biomass, volume and density would be greater in this aspect than in opposite slopes. Carmel and Kadmon (1999) studied the effect of slope aspect on vegetation change and concluded that slope aspects strongly affect the rate of vegetation change with the largest change occurring on north-west facing slopes. However, Kutiel and Lavee (1999) found that along a climatic transect, the most significant differences in soil and vegetation properties exist between north facing slopes and south facing slopes in the Mediterranean zone, although in arid and semi-arid zones the differences are small and negligible.

This study aims to assess the effect of slope aspect on soil and natural vegetation characteristics (cover, biomass and density) under a semi-arid region in Bani No’em rangeland in the southern West bank.

1.1. Study site

The study was conducted at the southern part of eastern slope in Bani No’em rangeland (35^{o}1' E, 31^{o}4' N; Fig.1) 15 km east of Hebron city. It has a mountainous topography with an elevation range from 596 to 704 m above sea level. The study site lies within a semi-arid region with a mean annual precipitation about 250-300 mm per year, which falls mostly in winter (GIS unit, 2006). The soil bedrock is calcareous (limestone) with shallow depth (Al-Sheikh, 2006); the soil has relatively low amounts of organic matter (2.4%), moderate to alkaline pH, and generally low amounts of soil nutrients. The site covers an area of about 50 hectares and had been used for many years as rangelands, until it was fenced in 1995. According to Al-Jubeh, (2006) and Mohammad (2008), the dominant plant species in natural vegetation in this area include: *Torilis tenella*, *Poa bulbosa*, *Anthemis spp*, *Vicia sp*, *Crithopsis delileana*, Medicago *sp* and *Helianthemum salicifolium*

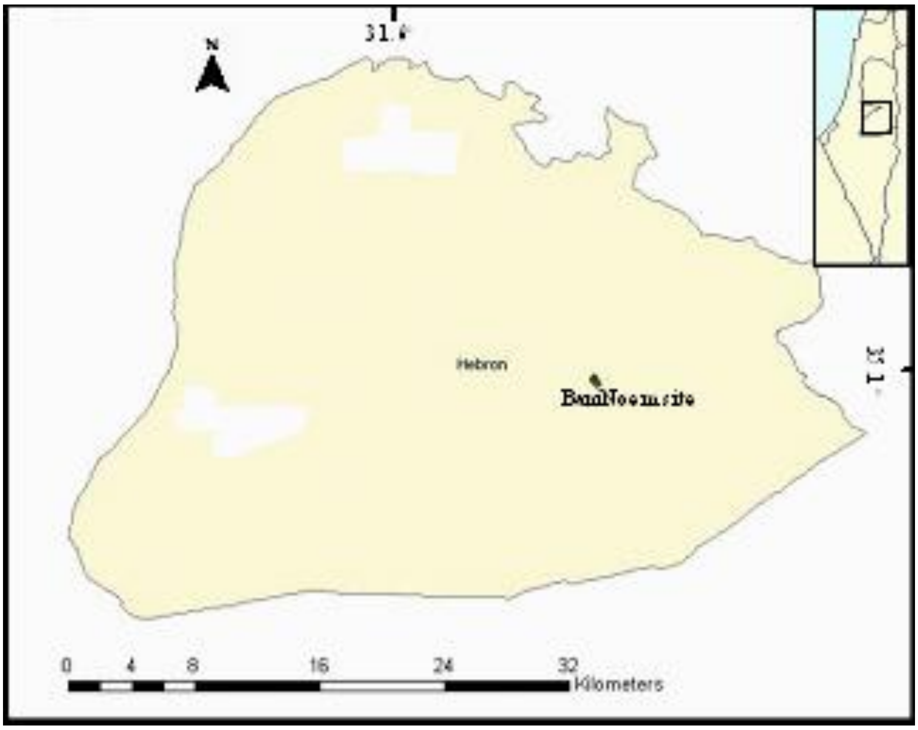

Figure 1. Location of study site - Hebron District/West Bank

2. Materials and methods

2.1. Soil sampling

Soil properties were investigated in 2006. Three replicates soil samples (0-10 cm depth) were randomly collected from each slope aspect for soil analysis. Each sample was air-dried, crushed with a mortar and pestle and sieved to remove coarse (> 2 mm) fragments. Particle size distribution was determined by using the pipette method (Bouwer, 1986). Bulk density was determined by the clod method (Kim, 1995). Soil pH was determined by using an electrode pH-meter for a saturated soil past (1:2.5) using distilled water, electrical conductivity (EC) was also measured in a saturated paste (1:2.5) (Skoog and West, 1976; FAO 1980). Organic matter was determined as organic carbon ratio by using the Walkey and Black method (Nelson and Sommers, 1982). Extractable bases were determined following displacement with 1 M NH_4OAc (Thomas, 1982). The Olsen method was used to determine extractable phosphorus using a molybdate reaction for colorimetric detection (Olsen and Sommers, 1982), $CaCO_3$ content was determined by using the calcimeter instrument.

For soil moisture content, soil samples were collected at the end of the rainy season (April, 1) and at mid September (September-12) from each aspect, and from two soil layers 15 and 30 cm deep, totaling 10 samples from each layer. Samples were weighed and dried at 105^o C to constant weight. Volumetric soil moisture percentage was computed on a dry weight basis.

2.2. Vegetation sampling

The study was conducted by selecting two opposing aspects, south and north facing slopes. Vegetation characteristics were evaluated in April during the peak of primary production (Mohammad, 2007). Plants were identified according to Al-Eisawi (1998), Zohary (1966) Burnie (1995) and Ori et al. (1999). Vegetation attributes were evaluated in terms of ground cover, biomass, plant density, species richness and diversity, and similarities.

2.2.1. Ground cover

To estimate the ground cover percentage at each aspect, a one hundred step point method was used in randomly located transects (with four transects used as replicates), whatever appeared below the tip of the boot was recorded (soil, rock, or plant by species), and the percent of soil, rock, and plant were calculated (Evans and Love, 1957).

2.2.2. Vegetation biomass

At each aspect, thirty 1 m^2 quadrate (square plots) were randomly allocated (used as replicates), and all the current year growth of each plant species inside the quadrate was clipped to the soil surface , and placed in labeled paper bags. The plant samples were taken to the lab and the fresh and dry weights (at 65 o C) were recorded.

2.2.3. Plant density

At each aspect thirty 0.25 m^2 square quadrates were allocated randomly (used as replicates). The number of all species, and the number of individuals of each species was recorded for each quadrate.

2.2.4. Species richness and diversity

Species richness is the number of species in a certain area within a community (Barbour et al., 1987). Richness was calculated as the number of species per m^2, regardless of their density.

The Shannon-Weiner index was used as a diversity index .This index assumes that individuals were sampled from a very large population and that all species are represented in the sample. It was estimated according to the following formula (Gurevitch et al., 2002):

$$H' = -\sum_{i=1}^{s} (p_i \ln p_i)$$

Where s is the number of species, P*i*= is the proportion of individuals found in the *i*th species.

2.2.5 Similarities

The Jacard index was used to compare the similarity in plant composition between the two aspects. It was calculated as the following (Gurevitch et al., 2002).

Jacard index = a / a+b+c

a = number of species present in both aspects.

b = number of species present in aspect A only.

c = number of species present in aspect B only

2.3 Statistical analysis

The data of vegetation attributes, soil properties and soil moisture content between north and south facing slopes were analyzed using Sigmastat® program, according to Fisher LSD test at $P \leq 0.05$.

The data was collected during 2006 and 2007, then the average of the two years were calculated (60 replicates, 30 each year).

3. Results and Disscussion

3.1. Soil properties

The results show that slope aspect has an effect on soil properties (Table 1). In general, the soil of the two aspects has light or medium texture and can be classified as loam soil (Kim, 1995). Soil texture is known to reflect landscape position (Kreznor et al., 1989). The results indicate that higher amounts of course sand fragments (7.2 %) and low clay content (24.9 %) at southern aspect compared to northern aspect (4.6 %) and (30.8 %), respectively. This result might reflect the influence of water runoff by eroded clay particles. On the other hand, many other factors affect the amount of clay percentage within the same area as the amount, types and percentage of vegetation cover (Anderu, 1995; Casermerio et al., 2004; Dunjo et al., 2004), slope angle (Rezaei et al., 2005; Fu et al., 2004) and the history of land use (Fu et al., 2003; Evrendilek et al., 2004).

The amount of organic matter, EC, NH_4+, and phosphorus is significantly higher in north facing slope compared with south aspect (Table 1). This is consistent with the findings of similar research in the Mediterranean region (Kutiel 1992; Kutiel and Lavee, 1999) and in arid and semi-arid regions (Zaady et al., 2001; Rezaei et al., 2005). This association is generally considered to be the result of higher soil temperatures on south facing slope than north facing slope and consequently more rapid soil moisture evaporation, less plant growth and greater organic matter mineralization (Holechek et al., 1989) Organic matter is the most important soil quality and certainly can be cited as one of the most effective predictors in rangeland. In addition, Rezaei et al. (2005) found that there is a positive correlation between soil organic carbon and the capacity of the soil to supply essential plant nutrients including nitrogen, phosphorus, and potassium, which may explain the significant higher soil phosphorous and $NH4^+$ at the north aspect than that at the south aspect.

The pH values were found to be significantly higher in the southern aspect (Table1). This might be due to wetter conditions on north-facing aspects that facilitate greater leaching which increase the H ion in the soil. In addition, the higher amount of $CaCO_3$ in southern aspects (Table 1) also contributes to the relatively alkaline pH in this aspect. Similar results were obtained by Kutiel (1992) and Al-Seikh (2006) in a study of Mediterranean and semi-arid climatic regions. The significantly higher EC value at northern aspect (0.34 dsm^{-1}) compared to southern aspect (0.27 dsm^{-1}) is probably affected by the hydrological processes as leached salt, and also it might be related to the differences in nutrient elements between aspects (Table 1).

Table 1. Average soil properties in north and south slope aspect.

Treatments	Soil texture				Bulk Density	O.M %	EC (dsm^{-1})	pH (1:2.5)	NH_4^+ (ppm)	NO_3^- (ppm)	P (ppm)	$CaCO_3$
	Course sand%	Fin sand %	Silt %	Clay %								
South aspect	7.2	38.2	29.7	24.9	1.41 a*	1.86 b	0.27 b	7.63 a	3.84 b	0.48 a	4.6 b	29.6 a
North aspect	4.6	33.6	31.0	30.8	1.35 a	2.61 a	0.34 a	7.46 b	5.85 a	0.46 a	8.1 a	23.4 b

* Means in the same column with different letters are significantly different, according to Fisher LSD test at $P \leq 0.05$

Table 2. Average plant characteristics in north and south slope aspects.

Life form	Biomass(g/m^2)		Density (no. of individual /0.25 m^2)		Cover %	
	South	North	South	North	South	North
Forbs	67.8 a*	46.5 b	47.1 a	45.5 a	71.5 a	71.6 a
Grasses	11.3 b	35 a	35 a	42.2 a	22.7 a	23.1 a
Shrubs	7.3 a	7.8 a	0.2 a	0.2 a	5.8 a	5.3 a
Total	86.4 a	88.8 a	82.4 a	88 a	88 a	91.9 a
Soil	-	-	-	-	5.1 a	4.1 a
Rock	-	-	-	-	7 a	4 a

* Means in the same column with different letters are significantly different, according to Fisher LSD test at $P \leq 0$.

3.2. Soil moisture

Soil moisture is one of the primary limiting factors for plant growth in semi-arid regions where rainfall is infrequent and evaporation rate is high. The difference in soil moisture content was significantly higher at north aspect 25 % and 23 % compared with south aspect 15 % and 14.7 % at 30 and 15 cm soil depths, respectively in 1 April. In addition the difference in soil moisture was significant also between the aspects during the second reading toward the end of the summer season (12 September) (Fig. 2). High solar radiation intensity on the south facing slope compared to north facing slope is might be the main reason for such results, this claim agrees with an other research under similar conditions (Kutiel and Lavee1999; Al-Seikh, 2006). On the other hand, higher organic matter and clay content at northern aspect compared to south aspect (Table 1) also play an important role in such results.

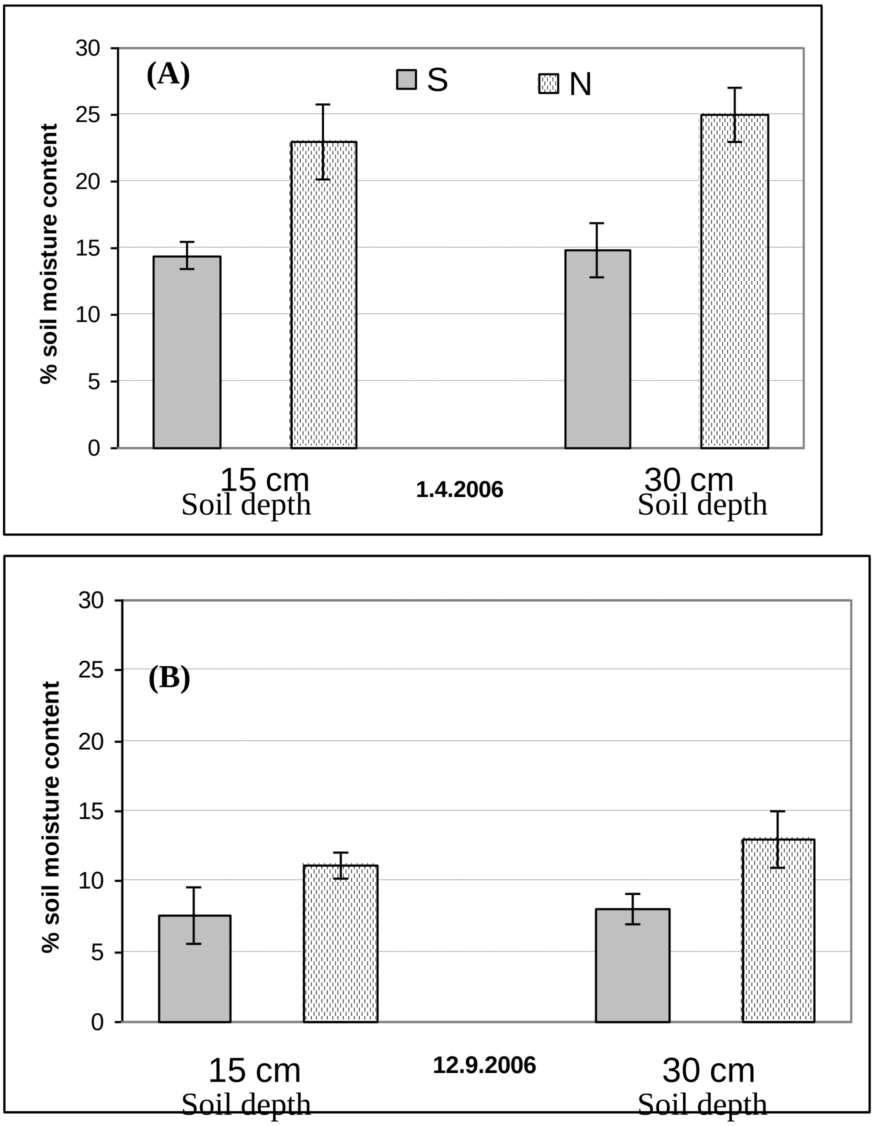

Figure 2: Soil moisture content at different soil depth at north and south facing slopes during 1-April (A) and 12-september (B)

3.3. Vegetation

In rangeland the interdependency of vegetation type and soil properties lead to a variety of species, vegetation types, and plant communities existing at the same parent material and single climatic regime (Rezaei et al.,2005).

Total dry biomass, cover and density were higher in north facing aspect compared to south facing aspect, but these differences were not statistically significant (Table 2). However, forbs dry biomass represents the main component of vegetation at both aspects, and it was significantly higher at the southern slope (67.8 g/m^2) than at the northern slope (46.6 g/m^2) (Table 2) while the total grass biomass was significantly higher in north aspect (35 g/m^2) compared to south aspect (11.3 g/m^2). Total cover and density for forbs, grasses and shrubs were not significantly different between the two aspects.

One of the most important findings of the present study is that vegetation attributes were different between the north and south facing slope under semi-arid conditions, and the differences were more obvious at the level of plant species than in the total vegetation attributes. A similar result was found by Sternberg and Shoshany (2001) who found differences between slope aspects under semi-arid conditions.

The results of the Shannon-Weiner index showed that species diversity at the south facing slope (2.81) was higher than the north facing slope (2.69) (Table 3). On the other hand, the difference in species richness between both aspects was very small, (330 plants per m^2) and (350 plants per m^2) in south and north slope aspects, respectively (Table 3).

The results of the Jacard index for similarity in plant composition between the two aspects indicated that there were medium similarities (60%) between the north and south slope aspects (Table 3). A larger number of plant species was recorded at the south facing slope (61 species) compared to (52 species) at north facing slope (Table 3). Many species were recorded at both aspects, including: Rhagadiolus stellatus, Anthemis sp., Onobrychis caput-galli, Helianthemum salicifolium, Filago contracta, Erodium gruinum, Phalaris sp,and Phagnalon rupestre. Other species were recorded only at northern aspect mainly; Pallenis spinosa, Alcea setosa, Sinapis alba, Rubia tenuifolia,and Noaea mucronata,. Several other species appeared only at the southern slope, such as Urginea maritime, Daucus carota, Lactuca orientalis, Tragopogon coelesyriacus, Linum sp, Sonchus oleraceus, Scrophularia xanthoglossa, and Thymelaea hirsute.

Table 3. Species diversity, richness and similarities at north and south slope aspect.

	South	North
Diversity	2.81	2.69
Species richenss	329.9 / m^2	351.4 / m^2
Similarites	60 %	

Individual plant species showed variation between the south and north slope aspects (Table 4). Some plant species showed higher dry biomass at the southern slope aspect; Echinops polyceras (12.24 g/m^2), Asphodelus aestivus (17.46 g/m^2), Eryngium creticum (3.52 g/m^2), Erodium gruinum (4.52 g/m^2) and Thymelaea hirsuta (3.01 g/m^2). On the other hand, Trifolium sp.(5.76 g/m^2), Astomaea seselifolium (1.26 g/m^2), Torilis tenella (5.02 g/m^2), Sinapis arvensis (5.92 g/m^2), Bromus sp.(21.08 g/m^2) and Avena sterilis (8.31 g/m^2) have higher dry biomass at northern slope aspect.

As for species density, the following species show a higher density at the southern slope aspect Poa bulbosa (90.6 plants/m^{-2}), Anthemis sp. (45.3 plants/m^{-2}) and Phalaris sp (29.9 plants.m^{-2}). While Bromus sp.(124 plants.m^{-2}), Torilis tenella (34.3 plants/m^{-2}) and Avena sterilis (17.4 plants/m^{-2}) had the highest density at the north facing slope (Table 4).

Table 4. Average plant biomass, density and cover for each species at north and south slope aspect.

Scientific .name	Biomass (g/m^2)		Density (No. of individual /m^2)		Cover %	
	South	North	South	North	South	North
Trifolium spp.	0.51	2.06	4.32	22.72	2.25	5.50
Salvia palaestina	3.41	3.61	0.92	0.52	0.00	1.13
Erodium acaule	0.16	0.42	0.2	1.72	0.00	0.13
Echinops polyceras	12.24	0.53	3.12	0.4	9.00	0.63
Rhagadiolus stellatus	1.90	2.63	9.88	13.2	0.75	2.38
Anthemis sp.	7.36	5.31	45.28	14.88	5.75	2.63
Vicia sp.	0.80	0.44	4.52	3.52	1.00	1.38
Urginea maritima	0.54	0.00	0.08	0	0.13	0.00
Astomaea seselifolium	0.15	1.26	0.2	1.72	0.00	1.13

Cont Table 4.

Onobrychis caput-galli	1.23	1.66	3.2	3.72	2.63	5.38
Alcea setosa	0.00	0.05	0	0.08	0.00	0.25
Sinapis alba	0.00	0.72	0	1.48	0.00	0.50
Tragopogon coelesyriacus	0.20	0.00	0.48	0	0.38	0.00
Cephalaria joppensis	0.06	0.00	0	0	0.00	0.00
Paronychia argentea	0.12	0.00	0.12	0	0.38	0.00
Crepis spp.	0.00	0.19	8	2.72	0.00	0.00
Helianthemum salicifolium	1.18	0.77	14.12	2.88	2.75	2.45
Sonchus oleraceus	0.24	0.00	0.12	0	0.75	0.00
Asphodelus aestivus	17.46	0.78	7.4	0.48	4.88	0.38
Eryngium creticum	3.52	0.46	1.52	0.2	3.38	1.00
Carthamus tenuis	0.35	0.18	0.92	0.52	0.00	0.00
Medicago sp	0.06	0.19	0.72	3.8	0.38	2.63
Filago contracta	0.37	0.40	22.68	14.8	1.63	2.50
Torilis tenella	1.14	5.02	17.08	34.32	1.00	5.88
Sinapis arvensis	0.61	5.92	0.8	6.68	0.88	6.00
Medicago scutellata	0.37	1.42	3.4	6.48	0.63	1.63
Erodium gruinum	4.52	2.87	8.6	4.32	4.88	4.75
Aegilops geniculate	0.23	0.59	0.48	4.72	0.50	0.63
Bromus sp.	1.48	21.08	10.12	124	4.38	6.75
Stipa capensis	0.94	0.40	3.72	0	1.75	0.00
Hordeum spontaneum	0.00	0.39	0	2.52	0.13	0.50
Avena sterilis	1.28	8.31	2.6	17.4	1.25	2.50
Phalaris sp	1.78	0.57	28.88	2.6	0.50	2.13
Poa bulbosa	5.68	4.18	90.6	19.88	11.63	8.25
Phagnalon rupestre	1.11	0.91	0.2	0.28	1.13	1.38
Thymelaea hirsuta	3.01	0.00	0.08	0	0.75	0.00
Sarcopoterium spinosum	2.63	6.90	0.32	0.52	3.55	2.88

Cover percentage of individual plant species varied according to slope aspects. At south facing slope the following species were dominant: Poa bulbosa (12.7 %), Echinops polyceras (10.4 %), Erodium gruinum (5.6 %), Asphodelus aestivus (5.6 %) Eryngium creticum (3.9%) and Bromus sp.(5.3 %). On the other hand, Poa bulbosa (9.1 %), Sinapis arvensis (6.6%), Torilis tenella (6.4%) and Trifolium sp.(6.8 %) had the highest plant cover at the north slope aspect. This means that the variation in aspect may have great influence on vegetation composition. Individual plants growing on the sunny slopes may show great incidence of water and nutrient stress than will individuals of the same species growing in shaded slopes.

The level of spatial heterogeneity is related to patchy distribution of resources. Therefore, although resources are more limited at the southern slope, there was an increase in patchiness which provided a greater chance for different plant species with different habitat requirements to grow. This may explain the higher species diversity at southern than northern slope. Similar results were observed by Kuitel (1992).

These results are in agreement with previous studies in similar areas such as Kutiel (1992), Kutiel and Lavee (1999), Marcelo and Maxim (2001), and Holechek et al. (1989). These studies have indicated that the differences in resources availability, particularly soil moisture, and soil radiation between the two aspects were the main reasons to more vegetation developed in the north facing slope compared to the south facing slope. This result was also supported by the significant increase in soil moisture content (Fig. 2) and soil nutrients (Table 1) at the northern aspect compared to southern aspect. The presents results also showed that plant diversity was higher at southern slope, while the species richness higher at northern slope.

Recommendation

We can conclude form these results that slope aspect should be considered in the action plan for rangeland improvement and development projects.

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