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ECOLOGICAL DYNAMICS OF PROTECTED AND UNPROTECTED RANGELANDS IN THREE CLIMATIC ZONES OF SYRIA

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Although rangelands cover approximately 10.5 million ha in Syria, no comprehensive description of rangelands or benchmark sites is available. This study describes some important characteristics on both ecologically healthy and unhealthy sites in three broad eco-zones. Maximum total bare ground was in the arid zone and declining in semi arid and moist zones. Percentage litter and plant cover were both lowest in the arid zone and increased in the semi-arid and moist zones with significant variation ($p < 0.05$). Invasive species were most pronounced in the moist zone. Plant cover was significantly higher on protected sites as compared to unprotected sites ($p < 0.05$). Invasive plant species were statistically much more prevalent on unprotected sites ($p < 0.05$), indicating degradation of the plant community based on grazing. Contrary to protected sites, the most common species in the unprotected site in the arid zone included both invasive and poisonous plants. Plant community changes in the semi arid zone under grazing pressure were reflected in a dramatic decrease in the number of annual species from 87% on the protected site to 57% on the unprotected site. In the moist zone, plant cover was significantly higher in protected rather than unprotected sites (LSD 13.98 < 24) and a very large increase in invasive species was noted on the unprotected site, showing a significant change (LSD 17.48 < 26.08).
Keywords: Rangelands, overgrazing, agro-ecological zones, invasive species, rangeland health, Syrian Badia

INTRODUCTION

Rangelands, a vital ecological resource, have historically been the backbone of pastoral livelihoods worldwide. Land degradation due to overgrazing and harsh climatic conditions has been much contested in the literature. To determine the impartial condition of any given site, 17 eco-health indicators are easily applicable in all rangeland ecosystems (Pyke *et al.*, 2002), though they require a local relic site for comparison.

Rangelands cover approximately 10.5 million ha in Syria, being more than 55% of the country's landmass (Serra *et al.*, 2003 and Al-Khatib, 2008). About 80% of the country is semi-arid and arid where the principal agricultural commodities are barley and sheep. The Badia is home to 500,000 people and an additional one million benefit directly from it (Edwards-Jones, 2002). It is largely populated by semi-nomadic 'Bedouin' people whose main occupation is the herding of sheep (Jaubert, 1991).The Badia ecosystem has been diagnosed as degrading over the last 50 years probably due to over-exploitation and harsh climatic conditions including frequent droughts (Dutilly-Diane *et al.*, 2006), hence modifying their livelihood style. The Bedouins are gradually changing their traditional way of living by shifting to grazing their animals in other eco-regions.

Officially, Syria is divided into five agro-ecological zones based on annual precipitation (Table 1). This study further simplified the official categories into three major zones; arid areas receiving < 200 mm mean annual rainfall, semi-arid areas receiving anywhere between 200 and 600 mm and moist areas with > 600 mm mean annual rainfall. There is considerable variation within and across all three zones in terms of vegetal cover and plant species composition. In arid zones covering the Badia, landscape tends to be flat or undulating plains or uplands with rocky cliffs and plateaus (Serra *et al.*, 2003). The mean annual rainfall is highly variable and is mostly below 127 mm along with extended dry periods (Serra *et al.*, 2003). Rain generally falls between October and April (Dutilly-Diane *et al.*, 2006). Summer in the Badia is long, dry, and hot, with temperatures sometimes exceeding 45°C in July and August (Dutilly-Diane *et al.*, 2006). (Serra *et al.*, 2003) reported range productivity in the Badia (Table 2) indicating the extent of dependency of annual plants on rainfall.

The vegetation in the Badia is composed primarily of dwarf shrubs with a few annual forbs and grasses. The most common species are *Poa bulbosa, Anabasis syriaca*, and *Artemisia herba-alba*. Dominant but unpalatable shrub species like *Anabasis syriaca* and *Noea mucronata* are used only for fuel (Dutilly-Diane et

Table 1. Agricultural zones as defined by the Ministry of Agriculture and Agrarian Reform (Central Bureau of Statistics, 1995)

Zone	Area {1000 ha)	% out of total country area	Annual rainfall	Rainfall amount (billion m^3/year)
1st	2,682.5	14.5	< 350 mm (1)	14.752
2nd	20,460.5	13.3	350	8.612
3rd	1,332.0	7.2	250	3.330
4th	1,905.5	10.3	> 250 mm	4.763
5th	11,119.5	54.7	> 200 mm (2)	15.179
Total	18,500.0	100.0	-	46.636

Source: The Annual Agricultural Statistical Abstract 2005
Rainfall amount is calculated in 1st agro-ecological zone at a rate of 550 mm/year.

Table 2. The relation between rainfall and vegetation growth in the Syrian steppe (Serra *et al.*, 2003)

Year	Annual rainfall (mm)	Total dry matter Kg/ha	Annual plants Kg/ha	% of total production
1997	198	2019	1515	75
1998	181	2369	1931	82
1999	27	178	0	0
2000	71	144	0	0

al., 2006). The semi-arid region is generally known for the production of wheat, barley, pulses and fodder legumes. The annual and perennial grasses including *Avena, Dactylis, Hordeum*, and *Stipa* species represent higher in natural plant communities. Common leguminous species are *Trifolium, Medicago, Vicia*, and *Trigonella*. Shrubs such as *Asphodelus microcarpus, Centaurea dumulosa*, and *Sarcopoterium spinosum* continue to figure prominently across the landscape (Masri, 2001). The moist zone is highly productive in terms of wheat and fruit crops such as watermelon and citrus (Masri, 2001). Forest lands are typically dominated by *Quercus calliprinos, Juniperus* and *Pinus* species. Open rangelands exist mostly where disturbance, such as fire or land clearing has set back succession to an earlier stage. These lands are composed of *Hyparrhenia hirta, Sarcopoterium spinosum*, and *Verbascum* species, as well as leguminous species like *Ononis* species. The grass component consists of *Aegilops, Bromus, Piptatherum*, and *Rostraria* species.

Until the end of the 1940s, most of the Bedouin occupying the Syrian steppe were nomadic in all aspects, relying on natural grazing as feed for their flocks (Leybourne *et al.*, 1993) under the traditional Hema system (Masri, 1991). The migratory pastoral Hema system and lack of water in the summer were probably the most determining factors for regeneration of forage plants (Draz, 1978) through periodic resting (Dutilly-Diane *et al.*, 2006). However, this situation has changed drastically over recent decades. Sedentarization and the extension of cultivation extended rapidly (Leybourne *et al.*, 1993) and induced changes in the livestock feeding patterns as more cereal stubble became available for grazing in the summer months. Bedouin mobility was gradually limited to Syrian territory due to political implications (Dutilly-Diane *et al.*, 2006). The post Second World War national policies targeted sedentarisation of the Bedouins. The abolishment of tribal law in 1958 further caused the death of grazing rights (Masri, 2001). The Badia was subsequently declared state property with open access to grazing while restraining the traditional tribal ability to manage grazing land (Dutilly-Diane *et al.*, 2006). A subsequent national barley subsidy policy to boost up the drought stricken sheep population radically changed the flocks' feeding patterns (Lewis, 1987). A multiplied increase in sheep population put unusual pressure on the already degraded pastures (Mirreh *et al.*, 2000). Eventually, over the last 60 years, the number sheep in the Badia has increased from an estimated 3 million in 1950, to approximately 15 million (Serra *et al.*, 2003, and Dutilly-Diane *et al.*, 2006).

Policy pushes affected not only the Bedouin's lifestyle, but took a toll on the ecological vitality of the Badia because of higher stocking rates and prolonged grazing periods (Masri, 2001). In 1995, crop cultivation was banned in the area while keeping in view the enhancing degradation (Dutilly-Diane *et al.*, 2006). Consequently, the steppe, fallow and mountain areas as estimated provide just 8.6 percent of their sheep feed while 91.4 comes from concentrates and residues (Nordblom, 1992). Additional unregulated activities such as fuel wood collection by uprooting shrubs and cutting down trees, the extraction of underground water and salt extraction salt from seasonal salt lakes have adversely altered the range ecosystem (Serra *et al.*, 2003; Zoebisch and Masri, 2002).

Periods of excessive stress (whether caused by climate or grazing) must be followed by rest for plants to regenerate and reproduce (Zoebisch and Masri, 2002; Louhaichi *et al.,* 2009). If plant communities are not allowed to regenerate sufficiently, they will slowly decrease both in total biomass and plant diversity. If these processes continue in the long run, the productive potential of the land will decrease below recoverable limits, and the feed basis will be destroyed (Le Houerou, 1993). To control degradation processes, it is important to assess the regenerative capacity of overgrazed rangelands. Assessment will also help to establish location-specific carrying capacities for different management systems (Zoebisch and Masri, 2002).

Rangeland health, as defined by the USDA and NRCS (1997) is the degree to which the integrity of the soil, vegetation, water and air as well as the ecological processes of rangeland ecosystems are balanced and sustained. Integrity is defined as the maintenance of functional attributes characteristic of a locale, including normal variability. Ability to sustain livestock production is based on maintaining healthy rangelands; therefore the ecological conditions of a site must be the determining factor of stocking rates and other elements of management systems. In a technique developed by panels of experts from the Society for Range Management and the National Research Council in the United States, 17 observable indicators are used to rapidly assess three ecosystem attributes, these being soil and site stability, hydrologic function, and biotic integrity (Pellant *et al.* 2003). Indicators include number and extent of rills, presence of water flow patterns, pedestals and terracettes, bare ground, gullies, wind scour and depositional areas, litter movement, soil resistance to erosion, soil surface loss or degradation, plant composition relative to infiltration, soil compaction, plant functional/structural groups, plant mortality, litter amount, annual production, invasive plants, and reproductive capability (Pyke *et al.*, 2002 and 2003).

The first step before engaging in any rangeland rehabilitation and management activities should be centered toward inventorying and assessing rangeland condition for each agro-ecological zone. An understanding of the spatial changes in vegetation characteristics is crucial for a sustainable management of the range-livestock production system. This study aimed to describe and quantify some important vegetation characteristics on both ecologically healthy and unhealthy sites across the three climatic zones under protected and unprotected conditions.

MATERIALS AND METHODS

Study sites

This study was conducted in following three broad climatic zones; arid, semi-arid and moist as described above. In each of these climatic zones, protected sites where grazing prohibited and other open to grazing i.e. unprotected were monitored. Typically, four sites were chosen in each broad climatic zone–two protected and two unprotected.

The field work for this study was carried out during June, 2008 in rather late growing season. Meanwhile, Syria had been experiencing prolonged drought conditions for the last nine months. Total annual rainfall ranged between 15-30 percent of a normal year except western coastal regions within the moist zone (Figure 1).

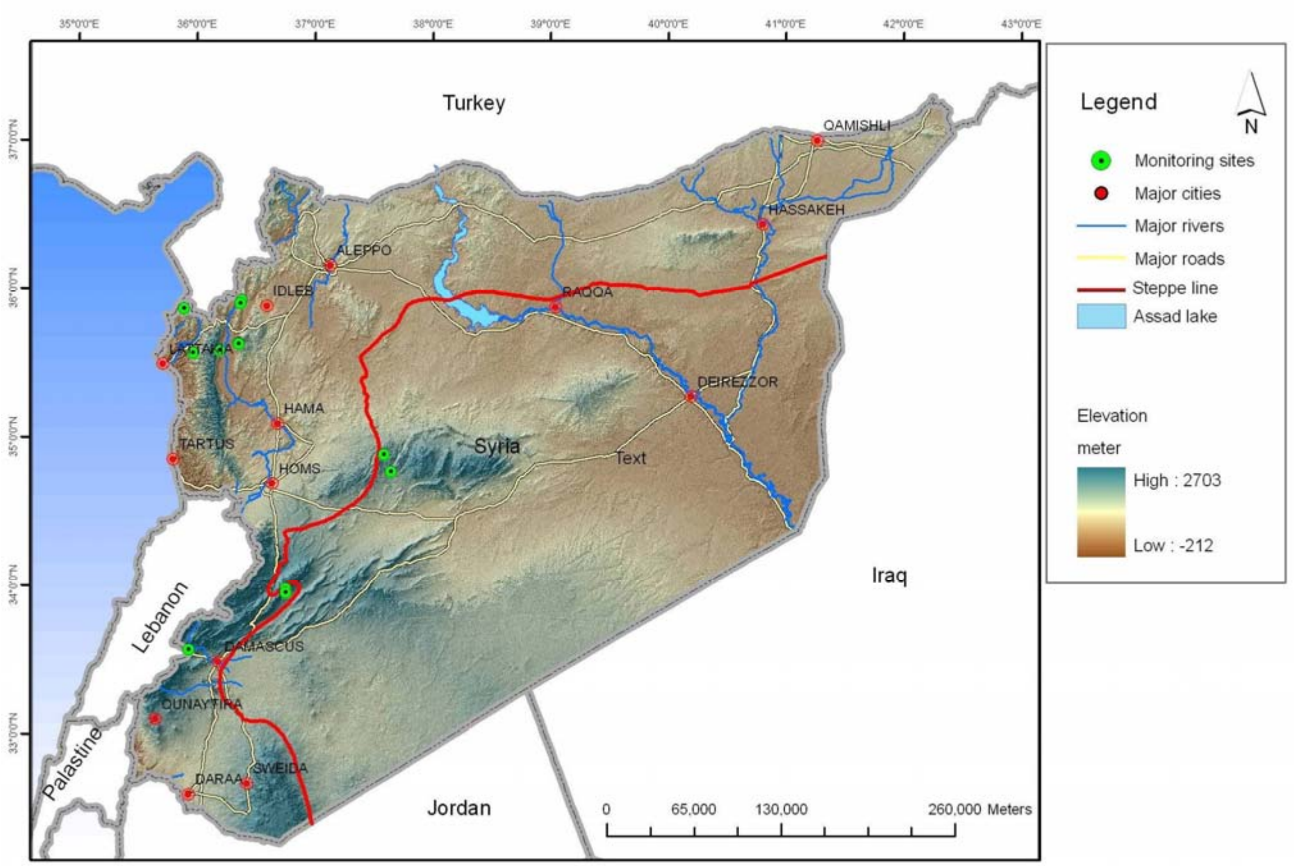
Data collection

At each rangeland site, a starting point was chosen at random from which two transects would radiate out at different compass bearings. General location, altitude, physiography, habitat characteristics, plant community, and perceived level of grazing pressure each site were also recorded. A digital photograph of the site was taken. A compass and an inclinometer were used to record micro-environment (i.e. plain, valley, hilltop), aspect, and slope of each 100 m long transect. Distances were measured with a long measuring tape. Data on rangeland health indicators were recorded in total 10 quadrates per site. Each time a 1 m^2 quadrate was randomly placed along transect to designate a plot. Of seventeen health indicators, only percent cover of bare soil, stones, bedrock, litter, and plants were estimated and recorded. These were chosen because of certain time and budget constraints. Table 3 lists the main species, family names, life form and forage value surveyed per climatic zone in Syria.

Data analysis

Each plant species found in each quadrate was identified as per scientific description using Flora Palaestina (Zohary, 1962), and its density and cover were also recorded. Finally, a complete list of species was generated which provided information regarding plant family, life form, forage value, and other economic uses of each plant. Conclusively, all plants species of each transect were classified into annual, biennial and perennial and their relative proportion was determined.

Figure 1. Map showing monitoring sites across climatic zones in Syria



Monitored sites within the same zone were compared based on their similarity (i.e. proximity, soil type, topography, etc), and paired accordingly. Sites that were truly protected with a perceived grazing pressure of zero were compared with their corresponding unprotected sites. The general characteristics of sites are outlined in Table 4.

In order to analyze differences of rangeland health indicators between protected and unprotected sites as well as across three climatic zones, a two-way classified analysis of variance (ANOVA) with m-observations was carried out. The specified significance level for all analyses was $p < 0.05$. Fisher's Least Significant Difference (LSD) Test was used to determine if the difference found between treatments was due to the treatment or simply due to random chance.

Other changes in the plant communities and their characteristics were discussed purely based on the interaction between the two variables i.e. protection from grazing and climatic zone.

RESULTS AND DISCUSSION

Effects of climate

Variation in bare soil amongst the zones was not statistically significant ($p = 0.059$), and therefore not based on climate. This is likely due to the fact that the arid sites were predominantly covered with stones instead of bare soil (Table 5). Percent cover of stones was highest in the arid zone with highly significant variation based on climate ($p < 0.001$). Changes in percent bedrock were also found to be significant ($p = 0.001$) with a maximum in the semi-arid zone. The variation of total bare ground across zones followed an expected trend; maximum in the arid zone, and declined across the subsequent zones. Percent litter and plant cover, both were also at a minimum level in the arid zone and increased across the semi-arid and moist zones (Table 5) with significant variation ($p < 0.001$). As indicated in Table 4, invasive species were most pronounced in the moist zone with relative equivalence in other two zones.

Table 3. Main species found per climatic zone for protected and grazed sites based on percent cover

	Arid		Semi Arid		Moist	
	Protected	**Grazed**	**Protected**	**Grazed**	**Protected**	**Grazed**
Achillea aleppica	12.8					
Aegilops geniculata						1.0
Aegilops triuncialis				3.0		
Ajuga chia		4.3				
Asphodelus microcarpus		10.9				
Avena barbata				6.0		
Avena sterilis			19.0		8.0	3.0
Bromus lanceolatus			7.5	3.7		
Carduus pycnocephalus			3.2		3.6	
Carduus pycnocephalus						1.0
Centaurea dumulosa	12.5					
Centaurea pallescens				3.0		
Cynodon dactylon				6.0		
Dactylis glomerata			3.0		5.9	
Diplotaxis harra	1.0					
Echinops gaillardotii	2.4	15.2				
Echinops polyceras					5.8	
Filago contracta		21.7				
Helianthemum salicifolium			6.0			
Hordeum murinum	13.5					
Hordeum murinum subsp. glaucum	3.4					
Hordeum spontaneum					6.0	
Hyparrhenia hirta					6.0	
Hypericum triquetrifolium						5.4
Medicago monspeliaca		4.3				
Noaea mucronata	10.8	4.3				
Notobasis syriaca			6.2			
Ononis natrix						1.0
Paronychia palaestina		4.3				
Phagnalon barbeyanum	2.4					
Phlomis syriaca						3.0
Picris damascena			5.0	9.7		
Piptatherum miliaceum					12.6	
Plantago lanceolata				13.4		
Poa bulbosa	6.8	4.3	7.3	6.0		
Rhagadiolus stellatus			3.4			
Salsola vermiculata	28.4					
Sarcopoterium spinosum					12.5	53.2
Senecio glaucus		6.5				
Sinapis arvensis						1.3
Sonchus oleraceus						2.9
Stipa barbata		6.5				
Torilis leptophylla			4.7		4.0	
Unidentified moss				7.5	4.5	
Verbascum gaillardotii				7.5		22.0

Table 4. General characteristics of study sites (Ilaiwi, 1985)

Climatic Zones	Name	Grazing status*	Elevation (m)	General Topography	Soil (Texture)
Arid	Kalamon	P	1195	Level to moderately	Aridisol (medium-lithic)
<200mm		U	1165	steep	
Semi-Arid	Al Daher	P	503	Rock outcrops, steep	Inceptisol/Vertic (fine)
200-600mm		U	213		
Moist	Biodiversity	P	358	Rock outcrops, steep	Entisol (medium-fine)
>600mm	Project	U	340		

Table 5. Effect of climatic zones on rangeland health indicators

Indicator Percent	Mean Value by Climatic Zone			P-value
	Arid	Semi-Arid	Moist	
Bare Soil	8.65	19.30	16.35	0.059
Stones	56.55	7.80	11.85	<0.001
Bedrock	11.90	27.80	7.45	0.001
Total Bare Ground	77.10	54.90	35.65	<0.001
Litter	5.85	15.15	21.25	<0.001
Plant Cover	17.10	29.95	45.60	<0.001
Invasive Species	11.34	11.02	43.46	<0.001

Table 6. Effect of grazing on rangeland health indicators

Indicator Percent	Mean value of rangeland health indicators (?) by grazing status*		P-value
	Protected	Unprotected	
Bare Soil	8.10	21.43	<0.001*
Stones	18.97	31.83	0.004*
Bedrock	14.13	17.30	0.483
Total Bare Ground	41.20	70.57	<0.001*
Litter	14.63	13.53	0.697*
Plant Cover	44.57	17.20	<0.001*
Invasive Species	14.34	29.54	0.004*

Effects of grazing

On average, the protected sites had a significantly lower percentage of bare soil ($p < 0.001$), stones ($p = 0.004$), and total bare ground ($p < 0.001$) than unprotected sites (Table 6). Average percent cover of litter was not statistically different between protected and unprotected sites ($p = 0.697$) contrary to expectations. Animal feces were considered as litter and with in heavily grazed sites increased presence of feces thereby made up litter. Future monitoring should take this into account and record litter and feces separately. Plant cover was significantly more on protected sites as compared to unprotected ($p<0.001$). Invasive plant species were statistically much more prevalent on unprotected sites ($p = 0.004$), indicating degradation to the plant community based on grazing (Table 6).

Combined effects of climate and grazing

The interactions between the two variables–climatic zone and protection from grazing are listed in Table 7. There was no statistical interaction of the two factors affecting percent bare soil or total bare ground. However, percent stones ($p = 0.001$) and bedrock ($p = 0.045$) were both affected. Litter is also statistically subject to the interaction of climate and grazing ($p = 0.043$), whereas plant cover is not ($p = 0.602$). Invasive species, however, did show variation based on a combination of these two factors ($p < 0.001$).

Table 7. Interactions of climatic zones and grazing

Indicator (Percent)	P-value
Bare Soil	0.062
Stones	0.001*
Bedrock	0.045*
Total Bare Ground	0.144
Litter	0.043*
Plant Cover	0.602
Invasive Species	< 0.001*

The results concerning the combined effect of protection from grazing and climatic zones are far more complex than reflected in the generated P-values in Table 7. Therefore, within each climatic zone, the specific effects of grazing as evidenced on the study sites are shown in Table 8. The research findings are in agreement with Hussain and Ali (2006) and Hussain *et al.*, (2009). Both studies concluded that the vegetation compositions of rangelands varied in space and in time depending on topography, climate and soil fertility.

Arid zone

a) Rangeland health indicators

The LSD values for each indicator are shown in Table 9, as well as the difference between means of each treatment (protected and unprotected). Note that a difference greater than the LSD value indicates a significant change, whereas a difference less than the LSD value indicates no significance. Plant cover was

Table 8. Mean values of rangeland health indicators by climatic zone and grazing status

Climatic Zones	Indicator (Percent)	Mean Value by Grazing Status	
		Protected	Unprotected
Arid <200mm	Bare Soil	3.9	13.4
	Stones	38.4	74.7
	Bedrock	18.3	5.5
	Total Bare Ground	60.6	93.6
	Litter	9.9	1.8
	Plant Cover	29.6	4.6
	Invasive Species	11.9	10.8
Semi-Arid 200-600mm	Bare Soil	6.5	32.1
	Stones	8.9	6.7
	Bedrock	20.9	34.7
	Total Bare Ground	36.3	73.5
	Litter	17.2	13.1
	Plant Cover	46.5	13.4
	Invasive Species	10.7	11.3
Moist >600mm	Bare Soil	13.9	18.8
	Stones	9.6	14.1
	Bedrock	3.2	11.7
	Total Bare Ground	26.7	44.6
	Litter	16.8	25.7
	Plant Cover	57.6	33.6
	Invasive Species	20.4	66.5

Table 9. LSD values of combined effects on health indicators

Zone	Indicator (Percent)	LSD	Difference Between Means Grazing Status	
			Protected	Unprotected
Arid	Bare Soil	12.75	9.5	-9.5
	Stones	14.70	36.3	-36.3
	Bedrock	15.58	-12.8	12.8
	Total Bare Ground	14.37	33.0	-33.0
	Litter	9.74	-8.1	8.1
	Plant Cover	13.98	-25.0	25.0
	Invasive Species	17.48	-1.1	1.1

greater on the protected site and difference between two treatments was significant (LSD 13.98 < 25).The number of invasive species did not change significantly between sites (Table 9). Since the historical pattern of disturbance (including grazing) was unknown, the protected site might have been subject to pressure in the past.

b) Plant community changes

The main species of both protected and unprotected sites are listed in Table 10. There was no dramatic shift towards invasive species on the unprotected site in this zone. *Salsola vermiculata* was the dominant species of the protected site (28 percent) Grasses were *Poa bulbosa* and two *Hordeum* species, in contrast to the unprotected area where only *Poa* was found in very low density. The top species of the unprotected site was *Filago contracta*, followed by *Echinops gaillardotii* (a thistle), and *Asphodelus microcarpus,* both invasive and poisonous.

Semi-arid zone

a) Rangeland health indicators

Bare soil in unprotected sites was significantly more than protected (LSD 12.75 < 24.6). Neither percent stones nor percent bedrock changed significantly between the sites however, total bare ground was significant (LSD 14.37 < 37.2). Plant cover in protected site was also significantly more than the unprotected site (LSD 13.98 < 33.1). However, percents of plant litter and invasive species were once again statistically equivalent.

Table 10. List of main species, family names, life form and forage value surveyed per climatic zone in Syria

Species	Family	Life form	Forage Value	Other Notes
Achillea aleppica	*Asteraceae*	Perennial forb	Very Low	Medicinal
Aegilops geniculata	*Poaceae*	Annual grass	Good (in green stage)	
Aegilops triuncialis	*Poaceae*	Annual grass	Good (in green stage)	
Ajuga chia	*Lamiaceae*	Perennial forb		Medicinal
Asphodelus microcarpus^	*Liliaceae*	Perennial sub-shrub	Poisonous	Medicinal, erosion control, used by bees
Avena barbata	*Poaceae*	Annual grass	High (in green stage)	Mulch, paper
Avena sterilis	*Poaceae*	Annual grass	High (in green stage)	
Bromus lanceolatus	*Poaceae*	Annual grass	Medium (in green stage)	
Carduus pycnocephalus	*Asteraceae*	Annual forb	Low (good for camels)	Medicinal, erosion control
Centaurea dumulosa	*Asteraceae*	Perennial Shrub	Medium	Sand stabilization
*Centaurea pallescens**	*Asteraceae*	Annual forb	Low (good for camels)	Medicinal, sand stabilization
Cynodon dactylon	*Poaceae*	Perennial grass	High	Medicinal, erosion control
Dactylis glomerata	*Poaceae*	Annual grass	High	Erosion control
Diplotaxis harra	*Brassicaceae*	Biennial forb		
Echinops gaillardotii	*Asteraceae*	Perennial forb	Low (good for camels)	Medicinal, erosion control
*Echinops polyceras**	*Asteraceae*	Perennial forb	Low (good for camels)	Erosion control
Filago contracta	*Asteraceae*	Annual forb	Medium	Medicinal
Helianthemum salicifolium	*Cistaceae*	Annual forb	Medium	Indicator of *Terfezia leonis*
Hordeum murinum	*Poaceae*	Annual grass	High (in green stage)	
Hordeum spontaneum	*Poaceae*	Perennial grass	High (in green stage)	
Hyparrhenia hirta	*Poaceae*	Perennial grass	Very Low	
Hypericum triquetrifolium	*Clusiaceae*	Perennial forb	Poisonous	Medicinal
Medicago monspeliaca	*Fabaceae*	Annual forb	High	Improves soil fertility
*Noaea mucronata**	*Chenopodiaceae*	Perennial sub-shrub	Low (good for camels)	Fuel, erosion control
*Notobasis syriaca**	*Asteraceae*	Annual forb	Low (good for camels)	Medicinal, food, erosion control
Ononis natrix	*Fabaceae*	Perennial sub-shrub	Low	Used by bees, improves soil fertility
Paronychia palaestina	*Caryophyllaceae*	Perennial forb	Good	Medicinal
Phagnalon barbeyanum	*Asteraceae*	Perennial sub-shrub	Poisonous	Medicinal
Phlomis syriaca	*Lamiaceae*	Perennial sub-shrub	Very Low	Medicinal
Picris damascena	*Asteraceae*	Annual forb	Poisonous	
Piptatherum miliaceum	*Poaceae*	Perennial grass	High	
Plantago lanceolata	*Plantaginaceae*	Perennial forb	High	Medicinal, used by bees
Poa bulbosa	*Poaceae*	Perennial grass	High	Erosion control
Rhagadiolus stellatus	*Asteraceae*	Annual forb		
Salsola vermiculata	*Chenopodiaceae*	Perennial shrub	High	Fuel, rehabilitation of degraded rangeland
*Sarcopoterium spinosum**	*Rosaceae*	Perennial sub-shrub		Erosion control
Senecio glaucus	*Asteraceae*	Annual forb	Poisonous	Medicinal
Sinapis arvensis	*Brassicaceae*	Annual forb	Low	Medicinal
Sonchus oleraceus	*Asteraceae*	Annual forb	Poisonous	Food, used by bees
Stipa barbata	*Poaceae*	Perennial grass	High (in green stage)	Sand stabilization
Torilis leptophylla	*Apiaceae*	Annual forb	Low	Medicinal
Unidentified moss				
Verbascum gaillardotii^	*Scrophulariaceae*	Perennial forb	Unpalatable	
Verbascum jordanicum^	*Scrophulariaceae*	Perennial sub-shrub	Unpalatable	Medicinal, dye

*Invasive species; ^Other invasive forbs

b) b) Plant community changes

As in the arid zone, changes were noted in the plant community composition of the unprotected site of semi-arid. On the protected site, shrubs were virtually non-existent, whereas *Verbascum jordanicum*, an invasive and unpalatable sub-shrub was prevalent on the grazed area (Table 10). The protected area was mostly dominated by grasses, including *Avena sterilis, Bromus lanceolatus*, and *Poa bulbosa.* It should be noted that the number of annual species decreased dramatically under grazing pressure – from 87 percent on the protected site, to 57 percent on the unprotected site.

Moist zone

a) Rangeland health indicators

Unlike two other zones, bare soil, stones, or bedrock did not show any significant changes between protected and unprotected sites. This may be a function of the climate, as abundant moisture makes bare ground uncommon, and degradation is expressed in different ways (i.e. presence of invasive species). When taken accumulatively, however, there was actually a significant shift in percent bare ground in between the protected and unprotected areas, so grazing clearly did has an effect on this indicator in the moist zone (LSD 14.37 < 17.9). Plant cover was significantly higher in protected than unprotected (LSD 13.98 < 24). A massive increase in invasive species was noted on the unprotected site; showing a significant change (LSD 17.48 < 26.08).

b) Plant community changes

The protected site had a balance of annual and perennial species, and had more or less equal numbers of grasses and forbs (Table 10). While the invasive *Sarcopoterium spinosum* was found within the protected site, it was far more dominant in the unprotected area, making up more than 50 percent of the plant community in terms of cover. The second most prevalent species in the unprotected area, accounting for 22 percent of plant cover, *Verbascum gaillardotii*, was another invasive and unpalatable plant. In fact, only one of the top ten species in this area was palatable (i.e. *Avena sterilis*), and it only comprised 3 percent of the plant community. Not surprisingly then, the number of annual species was seen to be highly reduced in this area, with very few grasses present compared to the protected site.

CONCLUSIONS

This study has generated useful information regarding rangeland health indicators based on climatic zones and protection status. It has succeeded in defining the broad characteristics that are to be expected on healthy rangelands across Syria. This information contained may serve as a first approximation of 'ecological site descriptions', and may therefore aid in the identification of specific indicators of degradation on rangelands across the country.

Measurable differences have conclusively been shown for all indicators based on protection as well as on climatic zone. Not only the sites that have been analyzed, but an entire database that has been developed can continue to be useful in the future when studying indicators of rangeland health and plant community composition on Syrian rangelands. However, percentage plant litter needs a more accurate method for its assessment in future if monitoring of range health is to provide reliable results. The possibility remains for future comparison of sites based on even finer criteria, such as aspect and micro-environment. Clearly these factors can have a strong effect, and it is important to recognize that every site will not look the same purely based on its climatic zone and protection status.

Long-term monitoring of rangeland health using the seventeen indicators as employed in this study appears essential in monitoring at the landscape level, and so also for those who rely on these resources. Although this study only examined six, many of the other indicators could be monitored simply with low inputs, and would contribute to a larger understanding of the ecological processes occurring on rangelands. This is vital, because by being aware of the expected parameters of healthy range sites, managers will be able to react to early signs of degradation, rather than waiting until the problems have advanced to almost beyond repair.

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