INTERACTIVE EFFECTS OF GRAZING ACTIVITY ON PLANT DIVERSITY AND COMMUNITY STRUCTURE IN THE HIGH-ALTITUDE PRINCE SAUD AL-FAISAL CENTER FOR WILDLIFE RESEARCH, SOUTH TAIF PROVINCE, SAUDI ARABIA

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(Received 26th Jan 2024; accepted 13th Jun 2024)

Abstract. The current study assessed the negative influence of grazing on the diversity and community structure of the local flora along environmental gradients in the Prince Saud Al-Faisal Center for Wildlife Research (PSCWR), Taif, Saudi Arabia. Seventy-five stands (20 × 20 m) were used to examine these vegetative characteristics and palatability for excluded and grazed sites. The study identified 80 species of local flora belonging to 27 families with an increased prevalence of Poaceae, Monoregionals, and therophytes. The un-grazing sites included the highest number of species (60 species), while the grazing enclosures had the lowest (15 species). About 75% of the total species were grazing, and 55% were medicinal. Eight vegetation groups (VGs) were produced through two-way indicator species analysis (TWINSPAN), with *Argemone ochroleuca -Vachellia flava* community dominating the un-grazing area was the most diverse. The PCA diagram showed that soil NO_3^-, SO_4^{2-}, Na^+, Mg^{2+}, and Cl^- significantly affected the dominant plant communities. The findings imply that implementing livestock exclusion could be a helpful, long-term management strategy for the degraded rangelands of the study area. According to the hypothesis of the study, grazing activity and environmental factors are the most effective for differentiating plant communities and the variability in plant diversity.
Keywords: *rangelands, livestock, vegetation type, plant diversity, wildlife reserve*

Introduction

The concentration of water and nutrients in dry areas create favorable conditions for forming, vegetation, resulting in the varied pattern that characterizes plant populations and vegetation (Al-Rowaily et al., 2015). Low vegetation, decreased resource retention, and changed proportions of plant life-form may react differently to rainfall, which are thus the results of the rapid rates of biomass loss and the species-specific eradication of palatable ones (Elaidarous et al., 2022). Consequently, there is complexity in the interaction between grazing and vegetation (Al-Rowaily et al., 2015).

Even though plant-plant interactions have been extensively studied along gradients of abiotic stresses, recent research has suggested that biotic pressures may be the driving force behind these relationships. Thus, intricate interactions between biotic and abiotic variables may impact the organization of plant communities (Catorci et al., 2016). The relationships between coexisting species across biotic stressor gradients, like herbivory pressure, have been the subject of a few studies (Al-Namazi,2019).

The stress gradient theory states that biotic stress brought on by grazing pressure ought to benefit relationships between coexisting species (Bertness and Callaway, 1994). Through experimentation, Veblen (2008) discovered that herbivory could affect the equilibrium of plant-plant interactions. Nonetheless, it is debatable how herbivore grazing affects the overall result of interactions between coexisting species. Numerous studies back up this theory, indicating that herbivory benefits interactions between coexisting species (Filazzola et al., 2018). A few investigations, however, refute this theory (Rousset and Lepart, 2003; Baraza et al., 2006). Furthermore, numerous studies demonstrate that herbivory has little effect on the interactions between different kinds of plants (Rand, 2004; Smit et al., 2007; Howard et al., 2012).

Grazing has impacted various ecosystem processes and functions, including the nutrient pool and cycling, soil moisture and structure, vegetation composition, and productivity. The intensity of grazing varies depending on the type of grazing animal and the host plant species; grazing may have varying effects on floristic composition and diversity (Hao et al., 2022). Furthermore, the characteristics of interacting plants, such as whether they are palatable or unappealing, as noted by Smit et al. (2009), affect how grazing affects interactions between plant species.

Due to their critical role in developing rural areas, Saudi Arabia’s rangelands are essential terrestrial natural resources vital for society, the economy, and the environment. In general, they provide feed for wild herbivores and livestock alike, as well as the chance to engage in outdoor recreation and take in the beauty of nature (Al-Rowaily, 2003). They also contribute significantly to the ecological preservation of biodiversity. However, persistent overgrazing jeopardizes these rangelands’ sustainability, productivity, and biodiversity, accelerating desertification (Al-Rowaily et al., 2012). This is especially true given the lack of a dedicated policy for managing and conservating these rangelands.

Inside Saudi Arabia, it is possible that a stressful environment or persistent overgrazing reduces the benefits of facilitation and encourages the interactions between nearby species to end poorly. For instance, Acacia tortilla trees positively interact with the herbaceous species that grow beneath them, but the strength of this interaction diminishes when grazing occurs (Abdallah et al., 2008). Since the local Bedouins rely almost exclusively on these species for food, fuel, grazing, medical care, etc., the plant resources of the Prince Saud Al-Faisal Center for Wildlife Research (PSCWR) assume significance (Mosallam, 2007). Therefore, it is necessary to comprehend and manage rangeland ecosystems more effectively while trying to understand interactions between vegetation and environmental elements (Brinkmann et al., 2009).

In the Arabian Peninsula, especially in Saudi Arabia, data about the impact of livestock (over-) grazing on the composition of plants and local variety are limited despite some prior work (CBD, 1997). Therefore, this study aimed to assess how grazing methods affected the local flora richness, species composition, and community structure of plants over environmental gradients in the PSCWR.

Materials and methods

Study sites

A research facility connected to the National Wildlife Research Center Development (NWRC) is the Prince Saud Al-Faisal Center for Wildlife Research (PSCWR). It is 1400 m above sea level, 45 km southeast of Taif Governorate, Saudi Arabia (Mosallam, 2007). The PSCWR was designated as a 4-km fenced nature reserve research center in 1986, and an extension area measuring 19 km^2 was fenced in 1992 next to the PSCWR. Relocating species released in protected areas inside Saudi Arabia’s Kingdom within the confines of their geographic range, the center is dedicated to caring for and breeding endangered animals. The center also conducts fieldwork and research projects. Its limits are located between longitudes 40°40’53”, 40°41’51”, 40°42’36”, and 40°41’36” E and

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2206_50835104

latitudes 21°15’20”, 21°15’56”, 21°15’50”, and 21°14’5” N. The extension borders are located between longitudes 40°41’22.13”, 40°43’45.19”, 40°44’24”, 40°44’8”, and 40°41’22” E and latitudes 21°15’2”, 21°16’43”, 21°15’5”, 21°13’57”, and 21°13’21” N (*Fig. 1*). (Mosallam, 2007). In the reserve area, some enclosures with perimeter fences have kept domestic livestock inside allowing overgrazing, while outside there are some enclosures used for the prerelease of livestock animals in protected areas in the Kingdom, and then allow for vegetation to recover from grazing (controlled grazing). Outside the fenced enclosures, the area is kept without grazing. Standard definitions define an enclosed site as a portion of rangeland used for biological and ecological research and closed to animal grazing (Amiri et al., 2008). The PSCWR reserved area was created expressly to offer a refuge for reproduction and research on captive breeding of Arabian oryx, sand gazelles, Asian houbara, mountain ibex, the antelope edame, wild rabbit, and red-necked ostrich (Haque and Smith, 1996).

The climate of the study location is tropical and arid; the mean monthly ambient air and soil temperatures, relative humidity, speed of wind, and rainfall are displayed in *Table 1*. The study site was characterized by spring rains, with the highest monthly rainfall of 26.5 mm during May and the lowest 3.2 mm during June. Besides, August is the hottest, with a mean air temperature of 29.0°C, while January is the coldest (15.9 C).

Table 1. *Monthly variation in the average climatic variables recoded in Taif South Meteorological Station (2005–2022)*

Month	Air temperature (°C)	Relative humidity (%)	Soil temperature (°C)	Wind speed (m/s)	Rainfall (mm)
January	<u>15.9</u>	<u>53.8</u>	<u>19.1</u>	3.1	6.1
February	18.0	46.8	22.1	3.4	3.5
March	20.6	39.1	25.7	3.4	4.7
April	23.0	39.7	27.9	3.3	19.4
May	26.0	32.0	30.3	2.7	<u>26.5</u>
June	28.8	<u>17.3</u>	34.3	2.9	<u>3.2</u>
July	28.9	20.2	<u>34.5</u>	<u>3.5</u>	11.4
August	<u>29.0</u>	24.7	34.2	3.2	7.5
September	27.6	24.3	32.8	2.4	7.3
October	23.4	31.2	28.4	<u>2.2</u>	5.5
November	19.4	49.5	23.4	2.3	7.0
December	16.6	52.6	19.8	2.5	4.7

Maximum and minimum values are underlined

Data and soil sampling procedure

Seventy-five stands were selected in the Prince Saud Al-Faisal Center for Wildlife Research, south Taif Province, Saudi Arabia, during the spring of 2022 to study the impact of grazing activity on plant diversity and community structure. The stands were distributed in three different microcosms with different grazing activities: a) grazing area, including some enclosures in which overgrazing is allowed for livestock animals; b) controlled grazing area, where prerelease animals grazed for about six months, and then the area was kept without grazing for about eight years to allow vegetation recover; and c) un-grazing area, where grazing is prohibited with no grazing activity (*Fig. 1*).

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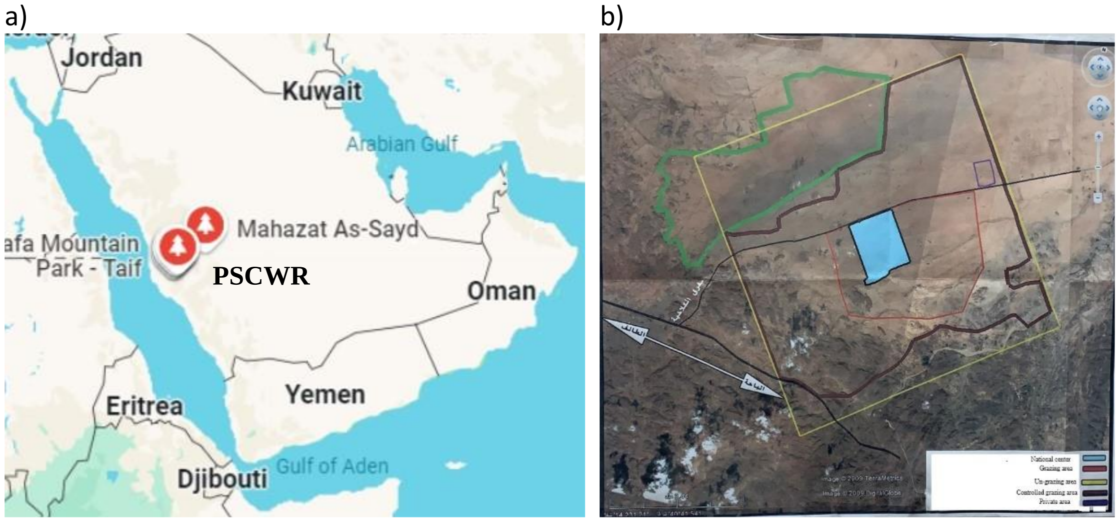

Figure 1. *Location map showing the study area: (a): Prince Saud Al-Faisal Center for Wildlife Research (PSCWR), Taif Province; (b): boundaries between the newly protected (extension) and existing protected area (21°15'37.29" N and 40°18'08.17" E. Source: Google Earth 10 November 2020)*

The stand size was about 20 x 20 m, which approximates the minimal area of the plant communities in the study area. In each stand, a visual estimate of the total plant cover (%) and the cover of each species were recorded using the Braun-Blanquet scale (Mueller-Dombois and Ellenberg, 1974). Based on the method described by Collenette (1999), the nomenclature of recorded species in the examined stands has been used. The life form spectrum of the recorded species was identified following the Raunkiaer scheme (Raunkiaer, 1937), while the recorded species' global geographical distribution was determined according to Al-Sodany et al. (2011), Al-Yasi et al. (2019), Elaidarous et al. (2022). Based on the information collected from residents, the field observations, and the literature, the economic importance of medicinal, fuel, grazing, and edible of the recorded species was assessed (Al-Yasi et al., 2019; Elaidarous et al., 2022). From each stand, a composite soil sample was taken at a depth of 0-50 cm, and it was brought into the lab in plastic bags. In preparation for chemical analysis, samples were allowed to air dry before being sieved to remove pebbles and debris. A pH meter (Model 9107 BN, ORION type) and a conductivity meter (60 Sensor Operating Instruction Corning) were used for the measurement of pH and electrical conductivity (EC), respectively in the soil-water extracts (1:5 w/v). Direct titration against silver nitrate and HCl was used to measure the amounts of bicarbonates and chlorides, respectively. Barium sulphate was used as a turbidimetric method to test sulphates, while sodium salicylate was used to determine nitrates. Versenate solution was used to evaluate the amounts of magnesium and calcium, while a flame photometer (Model 410) was used to estimate the amounts of sodium and potassium. These procedures were all documented in Rui et al. (2011).

Data analysis

The matrix of the cover estimates of the 80 species recorded in 75 sample stands in the different microcosms in the study area was analyzed by using two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DCA) as a technique of

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classification and an ordination (Hill, 1979; Hill and Gauch, 1980) respectively. Principal component analysis (PCA) was used for the relationships between the dominant plant communities resulting from TWINSPAN, with their environmental variables and plant diversity for the produced vegetation groups (VG) Kent and Coker (1992). According to the method described by Pielou (1975) and Magurran (1988), species richness, turnover, a relative of evenness, and concentration were conducted as the Shannon-Wiener index calculated. Using SPSS software, a one-way analysis of variance (ANOVA) was used to evaluate the variation in the soil variables among the resulting vegetation groups after the homogeneity and normality of the data were tested (SPSS, 2012).

Results

Floristic analysis

Data in *Figure 2* showed that the highest-dominated plant was Poaceae, followed by Asteraceae, Amaranthaceae, Fabaceae, and Zygophyllaceae, represented as 12, 10, 8, 6, and 5 species, respectively, in the study sites. In addition, the life-form spectrum of the identified species indicated the dominant therophytes (43.8%) over, followed by chamaephytes (27.5%) and geophytes (22.5%) of the total species (*Fig. 3a*). Correspondingly, parasitic species were represented by one species (*Plicosepalus acaciae*; 1.1%). Interestingly, the phytogeographical distribution of the remaining taxa showed that mono-regional taxa predominated (38.8%) over the other chorotypes followed by bioregional elements (33.8%), and the pluriregional taxa had the lowest representation (10.0%) of the entire species (*Fig. 3b*).

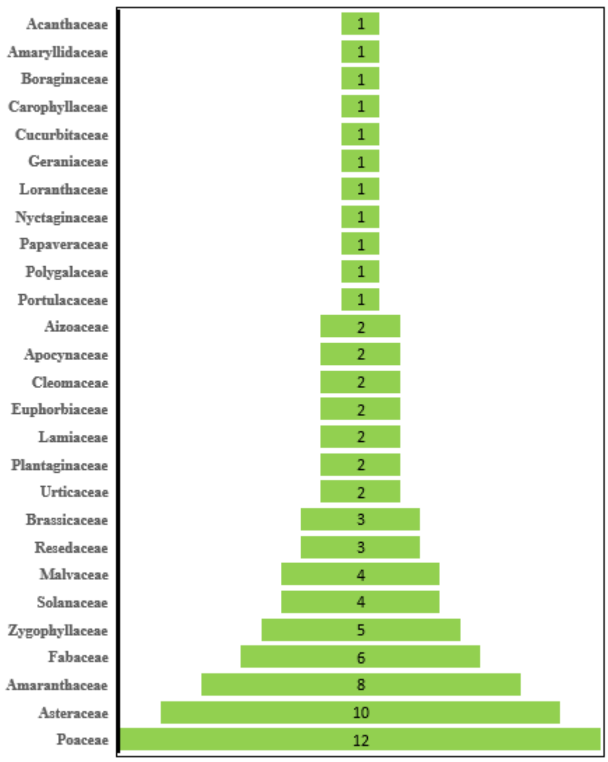

Figure 2. *Families and their relative number of species recorded in the various locations of Prince Saud Al-Faisal Center for Wildlife Research, south Taif Province*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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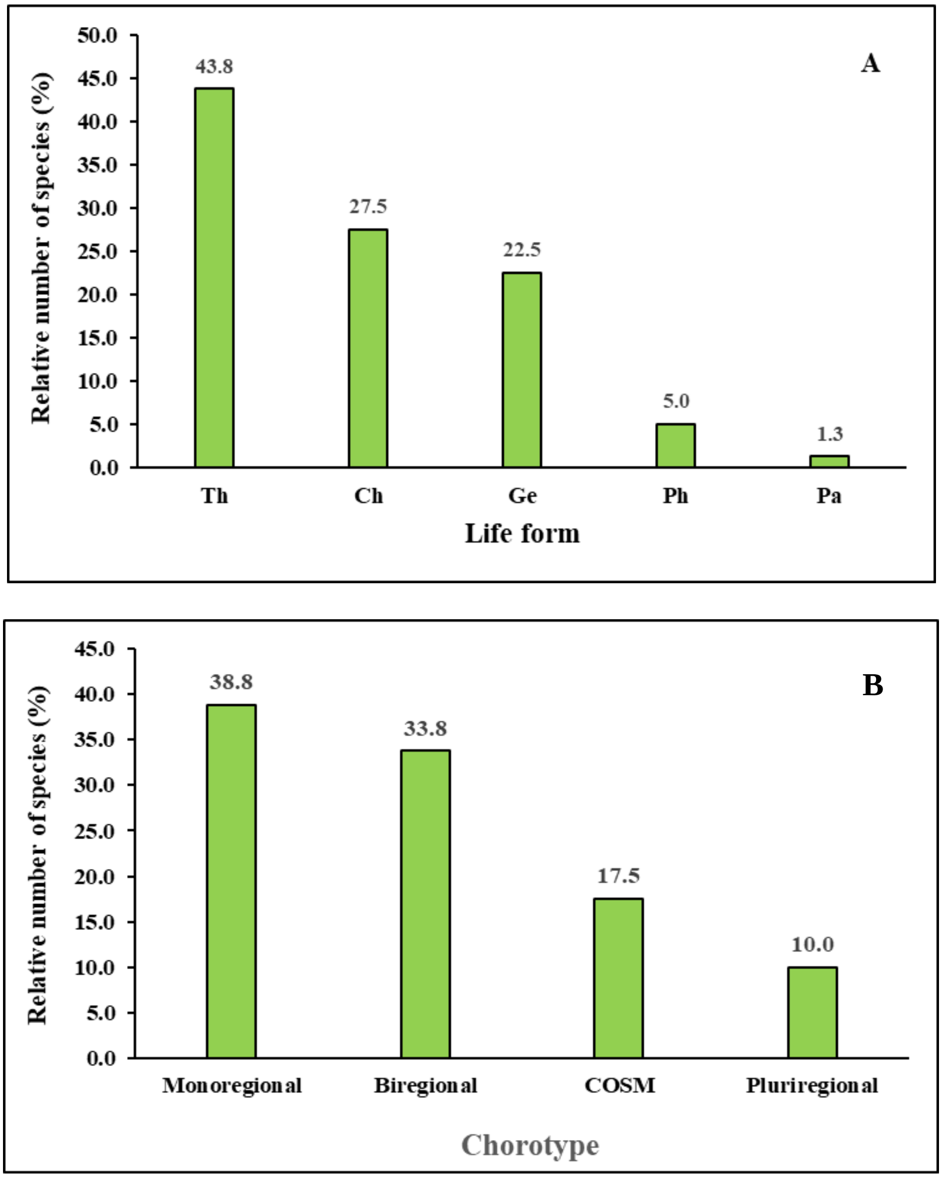

Figure 3. *Floristic features of the recorded species in the various locations of Prince Saud Al-Faisal Center for Wildlife Research, south Taif Province. b) life forms, and b) Chronological elements. Th: therophytes, Ch: chamaephytes, Ph: phanerophytes, Ge: geophytes, and Pa: parasites*

Exclusively, the present study remarked 11 families (e.g., *Acanthaceae*, *Caryophyllaceae*, and Portulacaceae) represented by one species. Moreover, the present study pointed out that 80 species of different plants were distributed in more than 27 families and 69 genera at diverse microcosms of PSCWR (*Table A1* in the *Appendix*).

Data (*Fig. 4*) noted that grazing animals could use the highest number of species (60), represented 45, and 8 species belonged to the grass family, followed by 54 species in controlled grazing areas representing 37 grazing plants and 7 grass species and the lowest number of species (15 species) in grazing enclosures which comprised of 11 grazing plants of them *Cynodon dactylon* was exclusively recorded grass.

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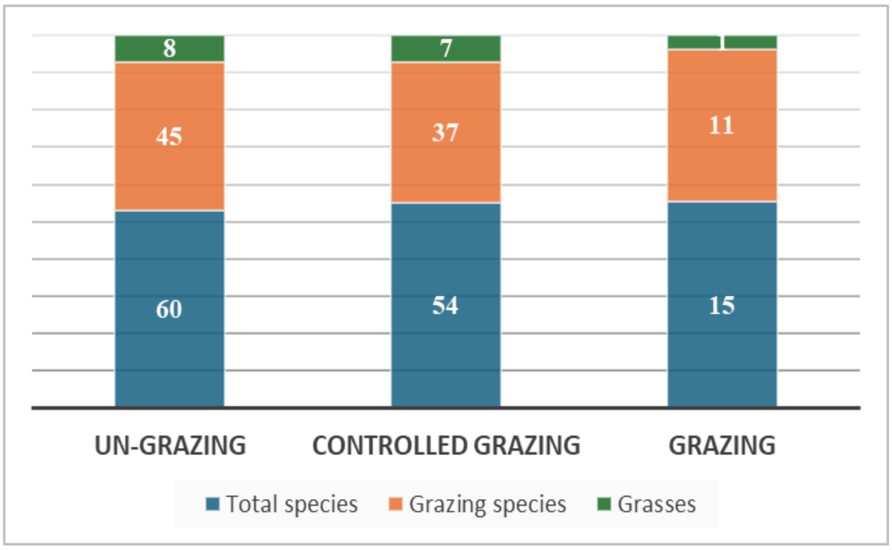

Figure 4. *Species characteristics of the different microcosms of Prince Saud Al-Faisal Center for Wildlife Research, south Taif Province*

Potential economic value

Figure 5 elevated the potential economic value of the recognized species in the selected microcosms of the PSCWR, southeast Taif. For grazing, (75.0%) of the total species were used (e.g., *Panicum turgidum, Stipagrostis plumosa,* and *Vachellia flava*). Also, 55.0% of medicinal plants (e.g., *Pergularia tomentosa*, *Citrullus colocynthis*, and *Ricinus communis*), 33.8% are used for fuel (e.g., *Nitrosalsola orientalis, Psiadia punctulate,* and *Lycium shawii*), and 22.5% of plants used as human food (e.g., *Malva valdesii*, *Malva valdesii,* and *Solanum nigrum*). Moreover, 52.2% of the identified species (e.g., *Anastatica hierochuntica*, *Argemone ochroleuca*, and *Forsskaolea tenacissima*) had other uses like popular folklore, ornament, and manufacturing rope, respectively.

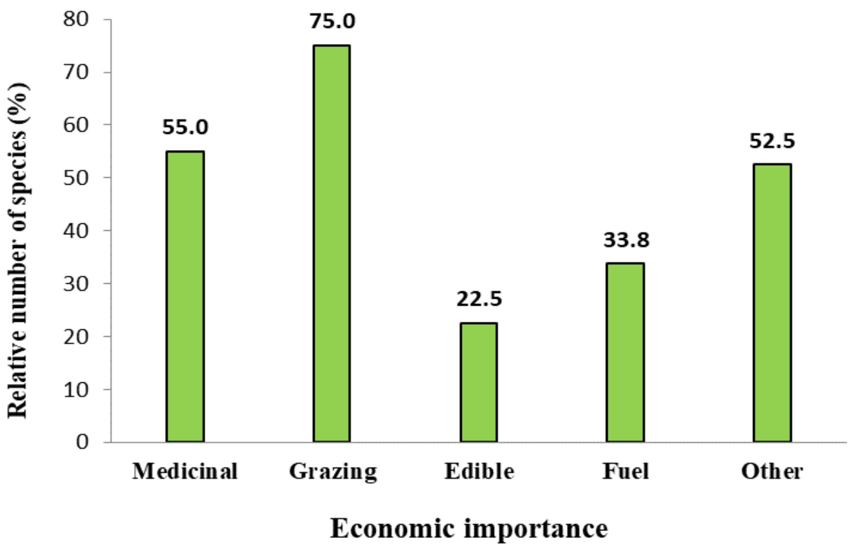

Figure 5. *The economic importance of the species was recorded in the various locations of Prince Saud Al-Faisal Center for* Wildlife *Research, south Taif Province*

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DOI: http://dx.doi.org/10.15666/aeer/2206_50835104

Vegetation analysis

The multivariate analysis was applied to the cover estimates of 80 species recorded in 75 sampled stands in the different microcosms of the PSCWR (*Table A2; Table 2*). The TWINSPAN analysis resulted in eight vegetation groups (VGs), which were distinctly segregated on the two axes of DECORANA (*Figs. 6* and *7*).

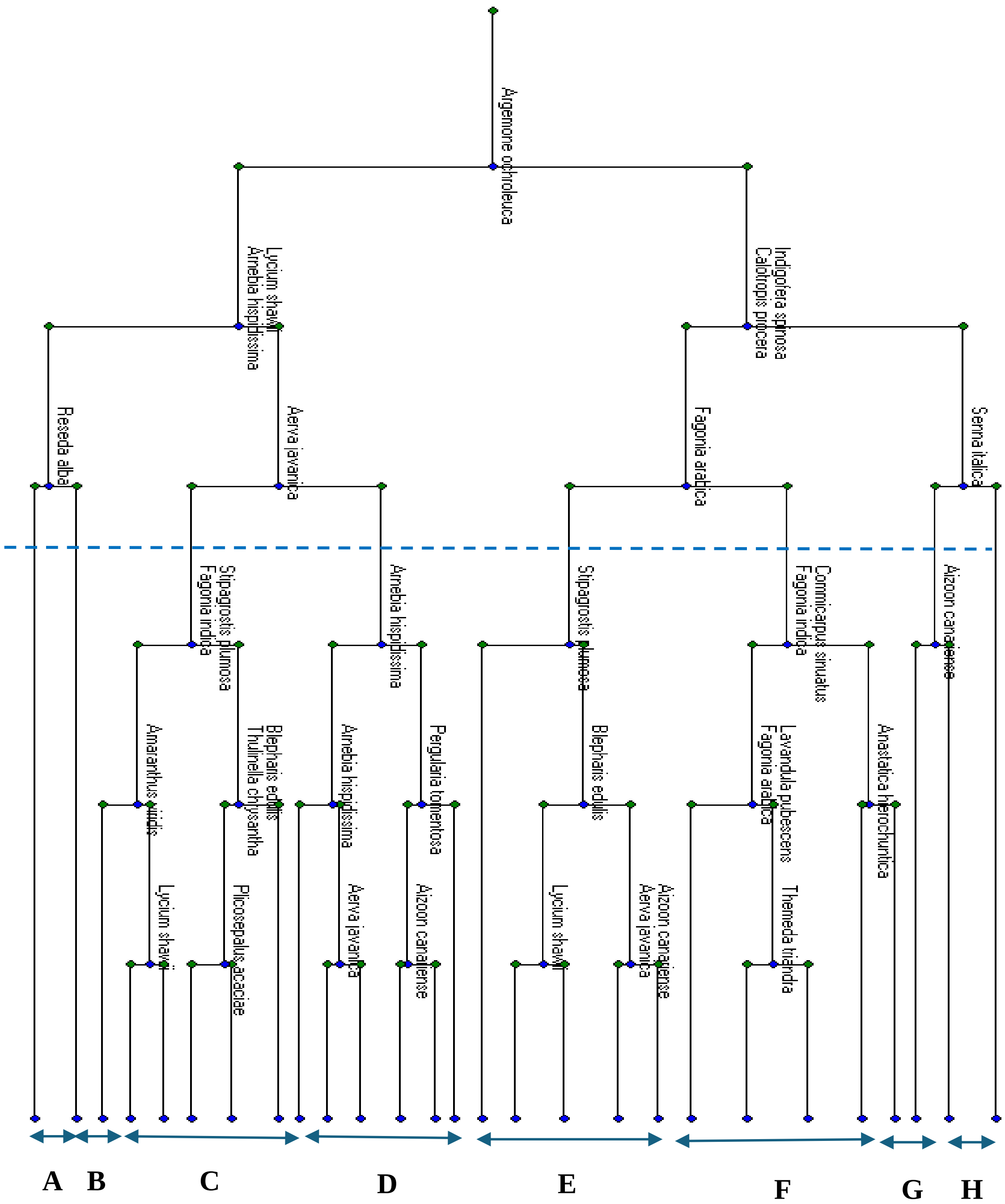

Figure 6. *The dendrogram resulting from applying TWINSPAN on the 75 sampled stands in the various locations of Prince Saud Al-Faisal Center for Wildlife Research, south Taif Province. Indicator species of each group are indicated. The dotted line indicates the classification level. A, B, C, D: un-grazing, E, H: controlled grazing, F, G: grazing*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
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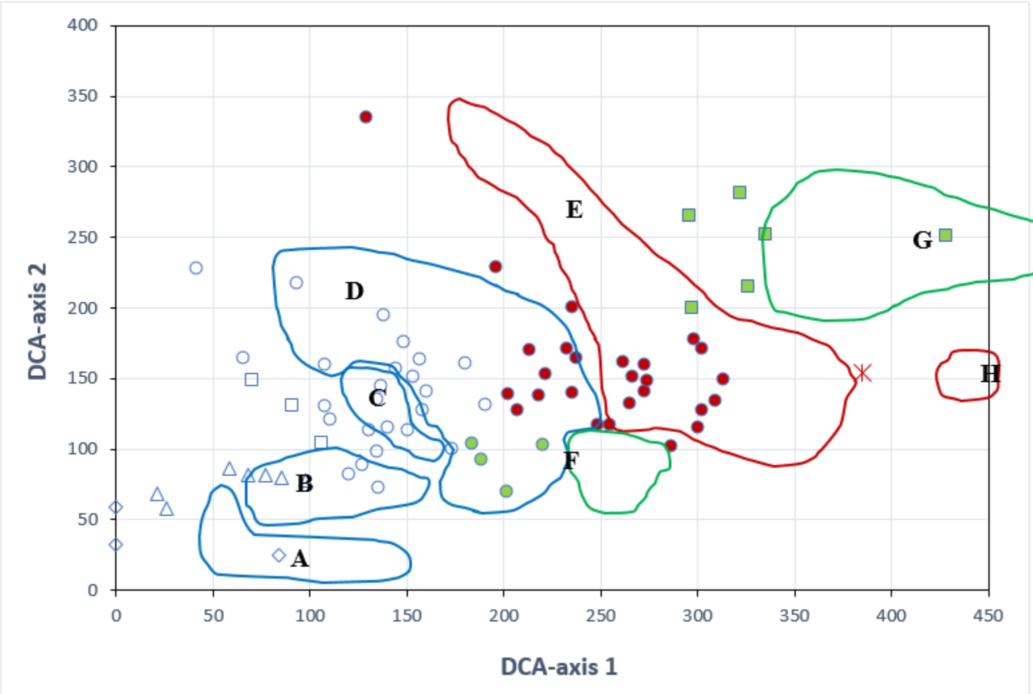

***Figure 7.** DCA-ordination of the eight vegetation groups identified after applying TWINSPAN on the 75 sampled stands in the various locations of Prince Saud Al-Faisal Center for Wildlife Research,* south *Taif Province. A, B, C, D: un-grazing, E, H: controlled grazing, F, G: grazing*

***Table 2.** Characteristics of the 8 vegetation groups produced after the application of TWINSPAN on the 75 stands of the different locations of Prince Saud Al-Faisal Center for Wildlife Research, south Taif Province*

VG.	NS	G/P	Location			1st Dominant	P (%)	2nd Dominant	P (%)
			CG	GR	UG				
A	3	4.0		33.3	67.7	*Calotropis procera*	66.7	*Echinops spinosissimus*	66.7
B	7	9.3			100.0	*Vachellia flava*	100.0	*Senna italica*	100.0
C	3	4.0			100.0	*Aizoon canariense*	100.0	*Argemone ochroleuca*	100.0
D	26	34.7	7.7	3.8	88.5	*Argemone ochroleuca*	92.3	*Vachellia flava*	84.6
E	26	34.7	84.6	15.4		*Lycium shawii*	84.6	*Aizoon canariense*	84.6
F	4	5.3		100.0		*Reseda alba*	100.0	*Vachellia flava*	75.0
G	5	6.7		100.0		*Arnebia hispidissima*	100.0	*Aizoon canariense*	80.0
H	1	1.3	100.0			*Stipagrostis plumosa*	100.0	*Fagonia indica*	100.0

VG: vegetation group; NS: number of stands; G/P: number of stands of each group to the total number of stands; CG: controlled grazing; GR: grazing; UG: un-grazing; P: species presence

The VGs are named after the first and second dominant species, respectively (based on the presence percentage). Four VGs (A, B, C, and D) dominated the un-grazing area, while two VGs (E and H) dominated the controlled grazing area, and two other VGs (F and G) contributed to the grazing enclosures. *Calotropis procera*, *Vachellia flava*,

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Aizoon canariense, and Argemone ochroleuca dominated the un-grazing VGs (A, B, C, and D, respectively). In contrast, *Lycium shawii and Stipagrostis plumosa* dominated the controlled grazing VGs (E and H). Moreover, the grazing microcosm VGs (F and G) were defeated by the *Reseda alba* and *Arnebia hispidissima* communities, respectively.

Community diversity

The *Argemone ochroleuca- Vachellia flava* community (VG D), which dominates the un-grazing area, has the highest species diversity among the eight VGs (*Table 3*), with 61 species, 9.96 species per stand in species richness, 6.12 species turnover, 3.60 relative evenness, and 25.43 relative concentration of dominance. *Reseda alba-Vachellia flava* community (VG F), which inhabited the grazing area, on the other hand, was the least diverse; it had the lowest concentration of dominance (4 species, 3.00 species per stand, 1.86, and 3.83), as well as the lowest number of species, species richness, and relative evenness.

Soil characteristics

According to *Table 4*, chemical analysis of the soil supporting the communities created by TWINSPAN analysis, the study sites' soils are alkaline, with *Stipagrostis plumosa-Fagonia* indica (VG H) having the lowest pH value at 7.06 and *Vachellia flava-Senna italica* (VG B) having the highest pH value at 8.14. Besides, the soil supporting *Reseda alba- Vachellia flava* community (VG F) had the maximum EC (341.33 µS m^{-1}) in addition to the highest HCO_3^-, Cl^-, Na^+, and Mg^{2+} (7.53, 10.34, 37.38, and 3.90 mg kg^{-1}), respectively. Also, VG (D) had the higher NO_3^- and Ca^{2+} (50.66 and 23.33 mg kg^{-1}), and VG (H) had the more elevated SO_4^{2-} and K^+ (4.45 and 9.56 mg kg^{-1}). However, *Aizoon canariense-Argemone ochroleuca* (VG C) had the lower soil HCO_3^-, Cl^-, SO_4^{2-}, Na^+, and Ca^{2+} (4.76, 6.13, 1.75, 8.72, and 12.45 mg kg^{-1}, respectively), while *Calotropis procera- Echinops spinosissimus* (VG A) had the lowest K^+ (3.21 mg kg^{-1}). Moreover, *Arnebia hispidissima-Aizoon canariense* (VG G) had the most inferior soil EC (203.67 µS m^{-1}) as well as the lowest soil NO_3^- and Mg^{2+} (32.75 and 2.35 mg kg^{-1}).

Vegetation-soil relationship

The relationship between common plant communities (derived from TWINSPAN categorization) and their respective soil properties was shown by the PCA diagram (*Fig. 8*). It was discovered that soil NO_3^-, SO_4^2, Na^+, Mg^{2+}, and Cl^- significantly impacted the dominating plant communities. The communities of *Stipagrostis plumosa-Fagonia indica* and *Lycium shawii-Aizoon canariense* that defined the controlled grazing microcosm were primarily affected by soil K^+ and Na^+, respectively. Furthermore, significant gradients of soil NO_3^- and HCO_3^- were home to the *Reseda alba-Vachellia flava* and *Arnebia hispidissima-Aizoon canariense* communities that inhabited the grazing region. The un-grazing area's most diverse community, the *Argemone ochroleuca-Vachellia flava* community, was impacted mainly by Mg^{2+} and EC.

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DOI: http://dx.doi.org/10.15666/aeer/2206_50835104

Table 3. *Diversity indices of the 8 vegetation groups produced after the application of TWINSPAN on the 75 stands of the different locations of Prince Saud Al-Faisal Center for Wildlife Research, south Taif Province*

Diversity index	Vegetation group							
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Number of species	5	12	14	61	52	4	6	6
Species richness	2.66	5.71	7.33	9.96	8.76	3.00	3.20	6.00
Species turnover	1.88	2.10	1.91	6.12	5.94	1.33	1.88	1.00
Shannon index	1.56	2.27	2.54	3.60	3.40	1.36	1.66	1.67
Simpson index	4.62	8.45	11.65	25.43	20.90	3.83	4.80	5.23

Minimum and maximum values were underlined

Table 4. *Soil chemical characteristics (means ± standard deviations) of the 8 vegetation groups of the various locations of Prince Saud Al-Faisal Center for Wildlife Research, south Taif Province*

Soil variable		Vegetation group								F-value
		A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	
pH		8.13 ± 0.27	8.14 ± 0.27	7.96 ± 0.22	7.81 ± 0.38	7.39 ± 0.19	7.25 ± 0.21	7.49 ± 0.06	7.06 ± 0.16	8.06***
EC (µS cm^{-1})		210.33 ± 20.21	237.67 ± 38.75	205.01 ± 15.10	327.86 ± 60.99	315.10 ± 37.36	341.33 ± 21.57	203.67 ± 16.56	278.00 ± 24.06	4.53**
HCO_3	mg kg^{-1}	5.68 ± 0.91	5.01 ± 0.58	4.76 ± 0.11	5.05 ± 0.50	5.04 ± 0.41	7.53 ± 0.40	5.34 ± 0.54	5.81 ± 0.28	17.57***
Cl	mg kg^{-1}	7.08 ± 0.39	6.54 ± 0.42	6.13 ± 0.48	6.34 ± 0.82	6.49 ± 0.32	10.34 ± 0.23	6.82 ± 0.16	7.60 ± 1.32	14.92***
SO_4	mg kg^{-1}	4.20 ± 1.06	2.96 ± 0.39	1.75 ± 0.13	2.39 ± 0.30	2.56 ± 0.22	4.38 ± 0.93	4.01 ± 0.38	4.45 ± 0.32	2.51*
NO_3	mg kg^{-1}	50.10 ± 6.95	35.14 ± 3.19	45.62 ± 7.27	50.66 ± 4.34	36.87 ± 6.85	40.38 ± 8.64	32.75 ± 5.43	36.45 ± 2.93	1.49
Na	mg kg^{-1}	13.16 ± 1.23	9.57 ± 1.68	8.72 ± 0.74	23.41 ± 2.69	24.07 ± 3.63	37.38 ± 6.84	9.37 ± 2.26	27.04 ± 4.46	8.65***
K	mg kg^{-1}	3.21 ± 0.38	5.41 ± 1.67	8.03 ± 1.03	8.41 ± 1.90	8.04 ± 2.29	8.97 ± 2.47	5.68 ± 0.70	9.56 ± 0.72	3.79**
Ca	mg kg^{-1}	17.19 ± 2.81	18.98 ± 3.08	12.45 ± 2.81	23.33 ± 4.6	21.84 ± 3.50	22.00 ± 1.69	16.25 ± 1.70	22.50 ± 2.35	3.36*
Mg	mg kg^{-1}	3.4 ± 0.28	3.85 ± 0.83	2.50 ± 0.34	3.73 ± 0.96	3.79 ± 0.74	3.90 ± 0.74	2.35 ± 0.29	3.12 ± 0.14	2.60*

Minimum and maximum values are underlined

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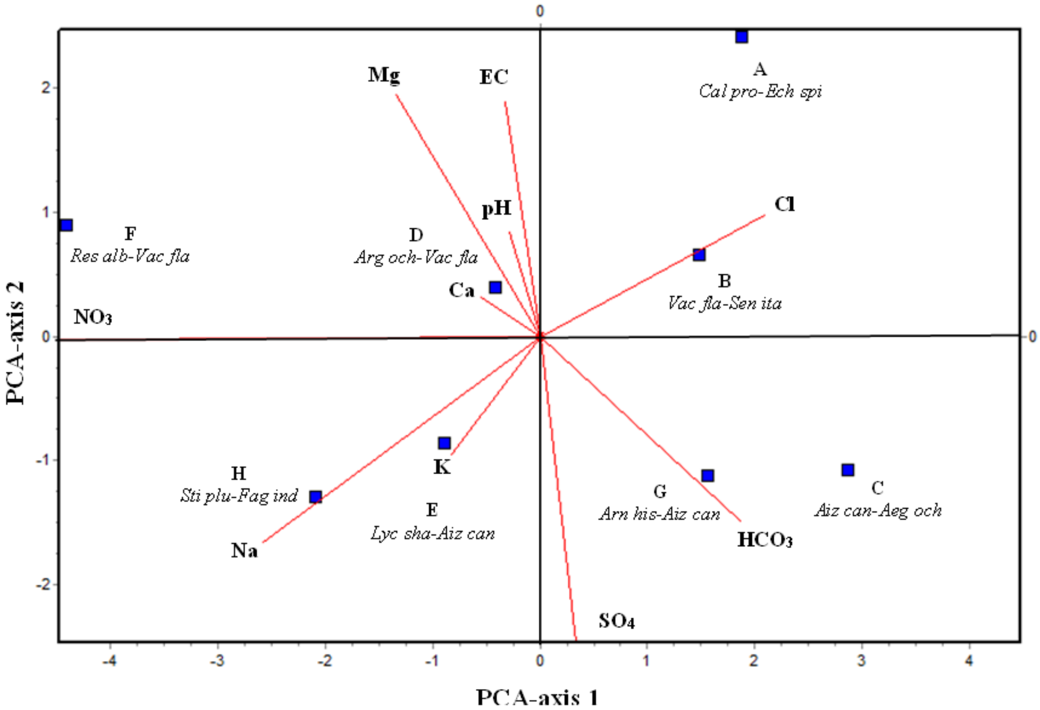

Figure 8. *PCA*-ordination *of the dominant plant communities along the soil gradients in the various locations of Prince Saud Al-Faisal Center for Wildlife Research, south Taif Province*

Discussion

Our results confirmed that the abiotic environment and grazing activity are the most effective at differentiating between the plant communities and the amount of variability in plant diversity in Taif Province. In this context, Elaidarous et al. (2022) elucidated that overgrazing, environmental stress and pollution can degrade vegetation, especially in arid or semi-arid areas. Nonetheless, in both the herbaceous and woody communities, the significant spatial influence on overall plant beta diversity obscured the independent impact of grazing, possibly indicating the spatially autocorrelated character of the grazing regime (Al-Rowaily et al., 2015).

According to our research, the absence of grazing activities increased the amount, density, and richness of woody shrubs and trees and the annual and perennial forb species. In Taif, Saudi Arabia, 80 vascular plant species were investigated in microcosms of PSCWR. Results were parallel to the previous study with Al-Sodany et al. (2011) and Al-Yasi et al. (2019).

Concurrent with the present study, Mosallam (2007), Al-Sodany et al. (2011), and Al-Robai et al. (2019) showed that Poaceae was the most common family followed by Asteraceae, Amaranthaceae, and Fabaceae; whether flora of the southern highlands or entire Saudi Arabian. Attractively, Therophytes dominated the other life forms, followed by chamaephytes and geophytes; this could be attributed to the dominance of therophytes to overgrazing in the research region, the sampling time, rainfall, and the wet meadows’ climate which is a significant representation of therophytes (Galal et al., 2021; Elaidarous et al., 2022). Moreover, the grazing area has the lowest number of therophytes compared to controlled and un-grazing sites. It may be because livestock are subject to selective pressure, and grazing livestock prefer annuals because they are

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more pleasant and more accessible to consume (Mosley and Roselle, 2006; Al-Yasi et al. (2019). Similarly, Herrero-Jáuregui and Oesterheld (2018) illustrated that plant diversity peaked at light to moderate grazing intensity; nevertheless, overgrazing may decrease species diversity, as in the present study. Additionally, by altering the species' composition, grazing can influence plant communities' floristic composition and structural changes (Ren et al., 2012; Duan et al., 2023).

Concurrent with the present study, Al-Sodany et al. (2011) and Hao et al. (2022) implemented that the potential economic value of the identified species in the area study microcosms revealed that 75.0% of the total species were utilized for grazing. In this way, grazing by livestock is the primary anthropogenic disturbance of native rangelands, and it plays an essential role in determining vegetation composition and plant species diversity (Ren et al., 2012; Hao et al., 2022). Correspondingly, the grazing and un-grazing areas were dominated by the *Vachellia flava* community as they offer high-quality animal feed (Al-Sodany et al., 2011). Also, in dry and fertile regions, grazing typically increases the dominance of species with resistance strategies (Rahmanean et al., 2019).

In the current study, species diversity, abundance, and community structure are significantly impacted by grazing. These results indicate that excessive grazing decreases species diversity because it leaves rangelands barren, and moderate grazing may increase the diversity of plant species in rangelands (Xiang et al., 2021) by stimulating plants' ability to photosynthesis (Hao et al., 2022). Furthermore, Kikoti and Mligo (2015) found that moderately grazed and un-grazed areas had higher plant species diversity than severely grazed regions.

The results displayed that the soil's chemical properties caused the rise in the number of plant species in both the controlled and un-grazing microcosms; however, rangelands that were not grazed had more significant total nitrogen transfers to the soil from decomposing dead roots and litter and direct disruptions from grazing, such as trampling and nutrient addition from dung and urine inputs, alter the physicochemical properties of the soil. This finding aligns with the study of Shaltout et al. (1996) and Barthelemy et al. (2019). Moreover, soil properties substantially impact vegetation (Galal et al., 2021); the current study's findings serve as a foundation for assessing the plant-soil interaction in the PSCWR. However, it was clear that the major plant communities in the PSCWR rangelands were significantly impacted by soil NO_3^-, SO_4^2, Na^+, Mg^{2+}, and Cl^- based on Using Principal Component Analysis (PCA). Similarly, Galal et al. (2021) and Hamed et al. (2018) stated that claimed NO_3^-, Mg^{2+}, Cl^-, and HCO_3^- had a significant impact on desert communities as well as elevated soil K levels in the controlled grazing areas might be connected to animal dung buildup and cattle trampling. In this sense, the results also showed grazing sites are more prosperous in nitrogen than un-grazed areas because the nitrogen cycle is accelerated by the passage of herbage through the intestines of grazing animals and its excretion as feces (Shaltout et al., 1996).

Conclusion

In conclusion, grazing operations significantly impact plant species' diversity and plant communities' makeup; hence, the semi-natural rangelands of PSCWR must be maintained to preserve plant diversity. Additionally, the plants' potential role as a climate refugium emphasizes the importance of controlling anthropogenic activities like grazing to protect plant diversity and ecosystem health in this vulnerable area.

Acknowledgments. The author extends his appreciation to Taif University, Saudi Arabia, for supporting this work through project number (TU-DSPP-2024-163).

Funding. This research was funded by Taif University, Taif, Saudi Arabia (TU-DSPP-2024-163).

Conflict of interests. The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability. Data of the present article are available under the request.

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DOI: http://dx.doi.org/10.15666/aeer/2206_50835104

APPENDIX

Table A1. *Floristic characteristics of the recorded species in the different locations of Prince Saud Al-Faisal Center for Wildlife Research, southeast Taif Province*

Species	Habit	Life form	Chorotype	Uses	Location		
					CG	GR	UG
Acanthaceae							
Blepharis edulis (Forssk.) Pers.	Per.	Ch	SA+SZ	M, G	+		+
Aizoaceae							
Aizoon canariense L.	Ann.	Th	COSM	G, O	+	+	+
Zaleya pentandra (L.) C.Jeffrey	Per.	Ge	SZ	M, G, O			+
Amaranthaceae							
Aerva javanica (Burm.fil.) Juss.	Per.	Ch	SA	M, G, F	+		+
Aerva lanata Juss.	Per.	Ch	SA	M, G, F			+
Amaranthus graecizans L.	Ann.	Th	COSM	M, G, E			+
Amaranthus viridis L.	Ann.	Th	TR	M, G, F, O	+	+	+
Caroxylon imbricatum (Forssk.) Akhani & Roalson	Per.	Ch	SA+SZ	G, F, O			
Chenopodium murale L.	Ann.	Th	COSM	G, E	+		+
Kali turgidum (Dumort.) Gutermann	Per.	Ge	SA	M, G, F, O	+		
Nitrosalsola orientalis (S.G.Gmel.) Theodorova	Per.	Ch	SA+SZ	G, F, O			+
Amaryllidaceae							
Pancratium sickenbergeri Asch. & Schweinf. ex Boiss.	Per.	Ge	ME	E, O			+
Apocynaceae							
Calotropis procera (Aiton) Aiton fil.	Per.	Ph	SZ	M, G, O	+		+
Pergularia tomentosa L.	Ann.	Th	SA+SZ	M	+		+
Asteraceae							
Centaurea sinaica DC.	Ann.	Th	ME	G, O	+		+
Echinops spinosissimus Turra	Per.	Ch	ME+IT	M, G, E, F	+		+
Helichrysum glumaceum DC.	Per.	Ch	ME	G	+		
Launaea capitata (Spreng.) Dandy	Ann.	Th	IT+ME+SZ	G		+	+
Osteospermum vaillantii (DC.) Norl.	Per.	Ch	SA+SZ	G	+		
Picris hieracioides L.	Per.	Ge	ME+IT	G			+
Psiadia punctulata (DC.) Oliv. & Hiern ex Vatke	Per.	Ch	SA+SZ	M, F, O	+		+
Rhanterium epapposum Oliv.	Ann.	Th	SA	G	+		
Sonchus oleraceus L.	Per.	Ge	COSM	G			+
Verbesina encelioides (Cav.) Benth. & Hook.fil. ex A.Gray	Ann.	Th	COSM	E, O	+		+
Boraginaceae							
Heliotropium arbainense Fresen.	Per.	Ch	ME+SZ	M, F	+		
Brassicaceae							
Anastatica hierochuntica L.	Per.	Ge	SA	M, O	+		
Arnebia hispidissima (Lehm.) DC.	Ann.	Th	SA+SZ	M, G, O	+	+	
Farsetia longisiliqua Decne.	Ann.	Th	SZ	G			+
Caryophyllaceae							
Polycarpaea repens (Forssk.) Asch. and Schweinf.	Ann.	Th	SZ	G	+		+

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Table A1. *Continued*

Species	Habit	Life form	Chorotype	Uses	Location		
					CG	GR	UG
Cleomaceae							
Gynandropsis gynandra (L.) Briq.	Per.	Ge	SA	O	+		
Thulinella chrysantha (Decne.) Roalson & J.C.Hall	Ann.	Th	IT+SZ	M, O	+	+	+
Cucurbitaceae							
Citrullus colocynthis (L.) Schrader	Per.	Ch	SA	M, E, F	+		+
Euphorbiaceae							
Euphorbia granulata Forssk.	Ann.	Th	SA+SZ	M, G, O	+		+
Ricinus communis L.	Per.	Ch	COSM	M, E, O			+
Fabaceae							
Astragalus atropilosulus (Hochst.) Bunge	Per.	Ch	IT+SA	G, F, O			+
Indigofera spinosa Forssk.	Ann.	Th	TR	M,G, E, F, O	+	+	+
Senna italica Mill.	Per.	Ch	SZ	M, E, F, O	+		+
Vachellia flava (Forssk.) Kyal. & Boatwr.	Per.	Ph	SA+SZ	M,G, F, O	+	+	+
Vachellia tortilis subsp. *raddiana* (Savi) Kyal. & Boatwr.	Per.	Ph	SZ	M,G, F, O			+
Vachellia tortilis (Forssk.) Galasso & Banfi	Per.	Ph	SZ	M,G, F, O	+	+	+
Geraniaceae							
Erodium pelargoniiflorum Boiss. & Heldr.	Ann.	Th	ME	G	+	+	+
Lamiaceae							
Lavandula pubescens Decne.	Ann.	Th	SA+SZ	M,G, E, F			+
Otostegia fruticosa (Forssk.) Schweinf. ex Penzig	Per.	Ch	SA	M, G, F			+
Loranthaceae							
Plicosepalus acaciae (Zucc.) Wiens & Polhill	Per.	Pa	SZ	F	+		
Malvaceae							
Abutilon pannosum (G.Forst.) Schltdl.	Per.	Ch	IT+SA+SZ	M, G, F			+
Hibiscus micranthus L.fil.	Ann.	Th	SZ	G			+
Malva parviflora L.	Ann.	Th	IT+ME	M, G, E, O		+	+
Malva valdesii (Molero & J.M.Monts.) Soldano, Banfi & Galasso	Ann.	Th	ES+SA+SZ	M, G, E	+		
Nyctaginaceae							
Commicarpus sinuatus Meikle	Ann.	Th	SA+SZ	M, G, O	+		+
Papaveraceae							
Argemone ochroleuca Sweet	Ann.	Th	TR	M, O	+		+
Plantaginaceae							
Kickxia pseudoscoparia V.A.W.Sm. & D.A.Sutton	Ann.	Th	ME+SA+SZ	M, O			+
Plantago ovata Forssk.	Per.	Ch	IT+SA+SZ	G, O			+
Poaceae							
Aristida pennei Chiov.	Per.	Ge	SA	G			+
Cenchrus orientalis (Rich.) Morrone	Per.	Ge	COSM	G			
Cenchrus setigerus Spreng. ex Steud., 1840	Per.	Ge	SA+SZ	G			+
Cynodon dactylon (L.) Pers.	Per.	Ge	COSM	M, G	+	+	+
Eragrostis minor Host	Per.	Ge	COSM	G, F			+
Eragrostis papposa (Roem. & Schult.) Steud.	Ann.	Th	TR	G, F	+		+
Panicum turgidum Forssk.	Ann.	Th	IT+ME+SZ	M, G, E, F	+		
Poa annua L.	Per.	Ge	COSM	D, E, O	+		

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Table A1. *Continued*

Species	Habit	Life form	Chorotype	Uses	Location		
					CG	GR	UG
Polypogon monspeliensis (L.) Desf.	Per.	Ge	COSM	G	+		+
Stipagrostis obtusa (Delile) Nees	Per.	Ge	SA+SZ	G, O			+
Stipagrostis plumosa (L.) Munro ex T.Anderson	Per.	Ge	COSM	G, O	+		
Themeda triandra Forssk.	Per.	Ge	COSM	G, F	+		+
Polygalaceae							
Polygala schweinfurthii Chodat	Per.	Ch	SZ	G	+		
Portulacaceae							
Portulaca oleracea L.	Ann.	Th	COSM	M, G, E,O	+		+
Resedaceae							
Caylusea hexagyna (Forssk.) M.L.Green	Per.	Ge	SA+SZ	M, O	+		+
Ochradenus baccatus Delile	Per.	Ch	SA+SZ	M, G	+		+
Reseda alba Delile	Ann.	Th	IT+ME	M	+	+	
Solanaceae							
Datura innoxia Mill.	Ann.	Th	NEO+PAL	M, E, F	+		
Lycium shawii Roem. & Schult.	Per.	Ch	IT+SA+SZ	M, G. E, F, O	+	+	+
Solanum incanum L.	Per.	Ch	SZ	M, G. F, O	+		+
Solanum nigrum L.	Ann.	Th	SZ	M, G. E, F			+
Urticaceae							
Forsskaolea tenacissima L.	Per.	Ch	SA+SZ	G, O	+		+
Urtica pilulifera L.	Ann.	Th	ES+IT+ME	M, O	+		+
Zygophyllaceae							
Fagonia arabica L.	Ann.	Th	IT+SA	M, O	+		+
Fagonia indica Burm.fil.	Ann.	Th	IT+SA	M, O	+	+	+
Tetraena simplex (L.) Beier & Thulin	Ann.	Th	IT+SA	G	+		
Tribulus arvensis Rojas Acosta	Ann.	Th	SA	O	+	+	+
Tribulus parvispinus C.Presl	Ann.	Th	SA	G	+		

Per.: perennial, Ann.: annual, Ph: phanerophytes, Ch: chamaephytes, Ge: geophytes, Gh: geophytes-helophytes, Pa: parasite and Th: therophytes ME: Mediterranean, COSM: Cosmopolitan, SA: Saharo-Arabian, Tr: Tropical, SZ: Sudano-Zambezian, ES: Euro-Siberian, IT: Irano-Turanian, PAL: Palaeotropical, and PAN: Pantropical, M: medicinal, G: grazing, E: edible, F: fuel, O: other, CG: controlled grazing; GR: grazing area; UG: un-grazing

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DOI: http://dx.doi.org/10.15666/aeer/2206_50835104

Table A2. *Characteristics of the 8 vegetation groups produced after the application of TWINSPAN on the cover estimates of 80 species recorded in 75 sampled stands in the different locations of Prince Saud Al-Faisal Center for Wildlife Research, south Taif Province*

Species	Vegetation group							
	A	B	C	D	E	F	G	H
Abutilon pannosum				3.85				
Aerva javanica				26.92	38.46			
Aerva lanata			33.33					
Aizoon canariense		28.57	100.00	57.69	84.62	75.00	80.00	100.00
Amaranthus graecizans				15.38				
Amaranthus viridis				7.69	11.54			
Anastatica hierochuntica					23.08			
Argemone ochroleuca	33.33	71.43	100.00	92.31	3.85			
Aristida pennei				3.85				
Arnebia hispidissima					57.69		100.00	10.00
Astragalus atropilosulus				3.85				
Blepharis edulis				38.46	34.62			
Calotropis procera	66.67	85.71	33.33	15.38	3.85			
Caroxylon imbricatum								
Caylusea hexagyna				3.85	3.85			
Cenchrus orientalis								
Cenchrus setigerus				3.85				
Centaurea sinaica				19.23	11.54			
Chenopodium murale				3.85	3.85			
Citrullus colocynthis				3.85	3.85			
Commicarpus sinuatus				23.08	7.69			
Cynodon dactylon				11.54	3.85		40.00	
Datura innoxia					3.85			
Echinops spinosissimus	66.67			11.54				
Eragrostis minor				3.85				
Eragrostis papposa		28.57		23.08	7.69			
Erodium pelargoniiflorum				7.69	7.69	50.00		
Euphorbia granulata			33.33	15.38	3.85			
Fagonia arabica		14.29	66.67	19.23	11.54			
Fagonia indica	33.33	28.57	33.33	61.54	46.15			100.00
Farsetia longisiliqua				7.69				
Forsskaolea tenacissima			66.67	7.69	7.69			
Gynandropsis gynandra					3.85			
Helichrysum glumaceum					3.85			
Heliotropium arbainense					15.38			
Hibiscus micranthus				3.85				
Indigofera spinosa		42.86	33.33	65.38	34.62			

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Table A2. *Continued*

Species	Vegetation group							
	A	B	C	D	E	F	G	H
Kali turgidum					3.85			
Kickxia pseudoscoparia				3.85				
Launaea capitata				7.69	7.69			
Lavandula pubescens				7.69				
Lycium shawii		42.86	33.33	61.54	84.62		40.00	
Malva parviflora				23.08				
Malva valdesii					3.85			
Nitrosalsola orientalis				3.85				
Ochradenus baccatus				7.69	23.08			
Osteospermum vaillantii				3.85	3.85			
Otostegia fruticosa			33.33	3.85				
Pancratium sickenbergeri				3.85				
Panicum turgidum					7.69			
Pergularia tomentosa				15.38	7.69			
Picris hieracioides				3.85				
Plantago ovata				7.69				
Plicosepalus acaciae								100.00
Poa annua					11.54			
Polycarpaea repens				26.92	3.85			
Polygala schweinfurthii					3.85			
Polypogon monspeliensis				7.69	15.38			
Portulaca oleracea				15.38	3.85			
Psiadia punctulata				3.85	3.85			
Reseda alba					23.08	100.00		
Rhanterium epapposum					7.69			100.00
Ricinus communis				3.85				
Senna italica		100.00	66.67	7.69	15.38			
Solanum incanum				7.69				
Solanum nigrum				3.85				
Sonchus oleraceus				7.69				
Stipagrostis obtusa				3.85				
Stipagrostis plumosa				7.69	69.23			100.00
Tetraena simplex					3.85			
Themeda triandra		14.29	66.67	11.54	7.69			
Thulinella chrysantha				7.69	19.23			
Tribulus arvensis		14.29		30.77	11.54		20.00	
Tribulus parvispinus					3.85			
Urtica pilulifera				3.85	3.85			
Vachellia flava	66.67	100.00		84.62	73.08	75.00		
Vachellia tortilis subsp. raddiana				3.85				
Vachellia tortilis			33.33	11.54	3.85		40.00	
Verbesina encelioides				15.38	11.54			
Zaleya pentandra				15.38				

P: presence percentage

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DOI: http://dx.doi.org/10.15666/aeer/2206_50835104

Grazing microcosm Un-grazing microcosm Controlled grazing microcosm

Plate A1. *Sampling microcosms with different grazing activities*

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DOI: http://dx.doi.org/10.15666/aeer/2206_50835104