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Original Research Article

Climate-dependent shifts in vegetation diversity and composition following grazing removal along an aridity gradient☆

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ABSTRACT

Despite extensive studies, substantial uncertainties remain regarding the effects of grazing removal on vegetation dynamics, plant diversity and richness. We investigated aboveground vegetation responses to grazing exclusion across five different regions spanning arid (one region), semiarid (two regions), and humid (two regions) climates. In each region, vegetation was sampled using 4 m^2 plots equally distributed numbers between grazed and ungrazed areas. Vegetation composition was compared between regions and grazing treatment using dissimilarity analysis and non-metric multidimensional scaling (NMDS), while generalized linear mixed models (GLMMs) assessed differences in total vegetation cover, functional group cover, plant diversity and species richness between regions and between treatments. NMDS revealed significant differences in vegetation composition across regions and grazing treatments. Plant composition separation between grazed and exclosure plots was more pronounced in humid regions compared to the other regions. In the driest region, no significant differences were detected between grazed and ungrazed plots for any functional group nor for vegetation covers neither for species richness. In contrast, the most humid region showed increased mean cover percentages of perennials, grasses, and forbs under grazing removal. Plant diversity and evenness indices exhibited contrasting patterns after grazing exclusion, increasing in humid regions but decreasing in arid and semiarid regions. Overall, the magnitude of vegetation changes to grazing removal decreased with regional aridity. This study advances our understanding of how removal of intensive grazing in historically continuous ecosystems and climate interact shape grassland dynamics, highlighting the context-dependent effects of grazing removal on ecosystem functions under different climates.

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1. Introduction

Grasslands cover approximately 40% of the global terrestrial surface, and play a substantial role in regulating the material circulation and energy flow in the biosphere, maintaining terrestrial biodiversity, and providing both material (e.g., food production and carbon storage) and non-material benefits (e.g., livelihoods, recreational and educational opportunities) to humans (Wu et al., 2023). Grazing plays an essential role in preservation of grassland ecosystems, and well-managed grazing can promote soil quality, biodiversity and other related ecosystem services and functioning (Zhang et al., 2023). Grazing activities exerts significant influences on aboveground vegetation structure, species composition and diversity through combined effects of biomass removal, physical disturbance and soil trampling (Nakano et al., 2020). However, overgrazing can promote several soil and vegetation degradation processes affecting entire grassland ecosystems. Indeed, overgrazing, is threatening grasslands by reducing grass diversity and productivity (Milazzo et al., 2023). Although, livestock grazing is needed for food production and local economic viability, growing concerns surround the sustainability of current grazing regimes, particularly in habitats experiencing intensive grazing livestock (Zhang et al., 2023). Importantly, vegetation responses to both grazing or/and its exclusion supposed to be strongly dependent on local environmental conditions such as climate type (e.g. arid, semiarid and humid) (Török et al., 2016; Rahmanian et al., 2019).

Biodiversity is the variety of life on Earth in all its forms, from genes and bacteria to entire ecosystems. It is widely recognized as an important cornerstone for ecosystem health, and among its components, plant diversity is one of the most vital resources (Wu et al., 2023). Higher levels of plant species richness and diversity increased microhabitat and spatial variability (beta diversity), and enhanced ecosystem stability, leading multiple ecological benefits for the ecosystems (Hallikma et al., 2023). Plant communities with higher diversity show greater resilience and spatial stability (Wagg et al., 2022). Grassland degradation and shifts in plant diversity are often associated with intensive grazing or, conversely, with the grazing removal in previously overgrazed ecosystems, though the underlying mechanisms remain unclear. Some studies suggest that grazing removal can reduce grassland species diversity and richness (Valko et al., 2018; Heinsoo et al., 2020). Conversely, other research highlights that removal of grazing by different livestock species can affect positively species richness and diversity, either in general (Metera et al., 2010) or for a specific plant communities (Hutchings, 2010; Köse et al., 2019). Given these contrasting findings, there is a need for comparative multi-regional studies to evaluate vegetation responses to ongoing grazing versus grazing exclusion.

Despite extensive studies, considerable uncertainties remain regarding the effects of grazing exclusion on vegetation diversity and ecosystem functions. A literature review showed that although grazing impacts on ecosystems varied with environmental conditions (Niu et al., 2025) and specifically climatic conditions are known to mediate grazing impacts, comparative studies across multiple climatic regions are still scarce (Rahmanian et al., 2019). Mostly, results from the predominant focus of grazing/grazing removal impact on single-site reported (Li et al., 2025). So, there is a need for multi-regional studies to establish whether livestock removal grazing produces consistent effects on ecosystems or these outcomes are contingent on local environmental conditions. In addition, some of the current studies on climate-grazing interactions comes from meta-analyses (e.g. Wang et al., 2025), which are often limited by methodological inconsistencies in vegetation sampling and data analyses. To establish robust causal relationships, we need similar methodologies in paired comparisons across multiple regions to assess grazing/exclusion effects. Given the high sensitivity of vegetation to grazing disturbance, the grazing cessation in historically intensive grazed ecosystems may lead to significant ecological changes, with outcomes likely varying across climatic regions. Therefore, studies are essential to capture the effects and better understand climate-dependent vegetation responses to grazing removal after long-term grazing.

In grazed ecosystems, the responses of vegetation to grazing removal are dependent on local conditions, shaped by the complex interplay of factors such as grazing intensity, herbivore and vegetation type. This complexity necessitates studies that systematically examine grazing exclusion impacts across diverse habitat and climatic types. Such comparative studies would provide the scientific foundation needed to develop evidence-based grazing management strategies that help to balance biodiversity conservation with ecosystem services (Török et al., 2024).

In Iran, intensive grazing, dominantly by sheep (27 distinct sheep breeds), occurs across more than 64 million hectares of the country (Haghiyan and Nejatiyanpour, 2021). Sheep exhibit selectivity in foraging, preferentially certain plant species depending on availability and preference. Forbs (broadleaf herbaceous plants) often dominate their diet (Heady and Child, 1994). This selectivity in grazing may differentially affect the abundance of plant functional groups such as grasses, forbs and shrubs in their habitats. Beside the intensity of grazing, grazing had a more pronounced influence on vegetation composition, leading to greater dissimilarity between grazed and ungrazed sites in grasslands with higher productivity (Osem et al., 2004). In productive ecosystems, such as humid habitats, intensive livestock grazing often resulted in the dominance of clonal plant species (Johansen et al., 2016) and maximized plant diversity (Zanella et al., 2021). In this regard, the *intermediate disturbance hypothesis* further supports this pattern, suggesting that the highest plant diversity in productive, humid systems occurs under moderate grazing intensity (Hobbs and Huenneke, 1992), whereas in arid areas grazing affects diversity negatively regardless of grazing intensity (Gao, Carmel, 2020). This climate-dependent pattern can also be explained by the stress-gradient hypothesis (SGH), which predicts that the relative importance of abiotic stress versus biotic competition shifts along environmental gradients. The SGH predicts that interactions among plants are context dependent, shifting from facilitation (in dryest area) to competition (in wettest areas) as environmental stress decreases (in arid regions, plant communities are primarily structured by harsh abiotic conditions (e.g., water scarcity), and grazing removal may not lead to significant changes in diversity because competition remains a secondary force. Conversely, in humid regions where resources are abundant, plant communities are more structured by competitive interactions (see also Plant community theory: Ariza and Tielbörger, 2011). Here, grazing acts as a key disturbance that prevents competitive exclusion by dominant species. Therefore, the removal of grazing in humid climates is expected to trigger a stronger vegetation shift, as competitive release allows dominant species to potentially exclude subordinates, leading to greater changes in composition and diversity. We mainly hypothesize that: (i) vegetation composition and plant diversity are shaped by both grazing and climate type (arid, semiarid and humid), with removal grazing-induced changes being more pronounced in humid than in arid regions due to greater resource availability and enhanced regeneration potential in humid regions, which allows for a stronger vegetation recovery response following grazing cessation. Meanwhile, we expect that: (ii) the magnitude of the effect of (sheep) grazing removal on plant diversity and species richness will depend on plant functional groups, with forbs responding more strongly than other functional groups.

2. Materials and methods

2.1. Study area and sampling

The investigation focused on five ecologically distinct areas in northern Iran, spanning a gradient of climatic zones: two humid and one semiarid region in Mazandaran province, and one semiarid and one arid region in Golestan province (Table 1; Fig. 1). Despite hosting a wide range of plant species, all regions are classified as grassland ecosystems. They share a similar physiognomy and general structure, with very few shrub species present. Each region represents two distinct grazing intensities: an overgrazed area with high livestock pressure and a fully protected grazing exclosure, both located within geographically confined and ecologically comparable landscapes. Annual precipitation patterns vary significantly across the regions, from less than 300 mm in the driest region to over 750 mm in the wettest. Sheep (*Ovis aries*) grazing is the dominant management activity, with reported nominal stocking densities of approximately five mature animals per hectare (5 Animal Unit ha^{-1}) in humid and semiarid regions (Hazhir et al., 2024) and approximately three Animal Unit ha^{-1} in the arid region. Official government reports indicate that livestock grazing in Iranian rangelands exceeds grazing capacity by more than 2.2-fold at the national scale (Savari, 2023). Although we did not estimate local grazing capacity for each study site, the national overgrazing ratio exceeds the threshold for severe overgrazing commonly recognized in rangeland science (Heady and Child, 1994). Furthermore, all selected sites exhibited visible signs of overgrazing including bare eroded soil, short stubble height, unpalatable species dominance. Therefore, while we cannot assert that grazing intensity was identically intensive across sites, we are confident that all grazed areas experienced severe overgrazing of a comparable magnitude. The observed ecological responses across regions are thus interpretable as reflecting similarly degraded conditions rather than fine-scale variation in grazing pressure.

In addition, Zel sheep (the only thin tailed sheep of Iran: Taheri et al., 2022) are commonly bred in Mazandaran, whereas Dalagh sheep (semi fat-tailed) dominate in Golestan. Although different livestock species can differentially influence plant communities (Tóth et al., 2018), sheep breeds demonstrate similar ecological impacts because of their precision grazing, using specialized teeth to selectively consume specific plants, reproductive structures, and tender growth (Oliván and Osoro, 1998). To investigate long-term vegetation dynamics following grazing cessation, permanent exclosures were established in typical grazing areas more than 20 years prior to data collection (2023) (Fig. 1). Positioned within actively grazed rangelands, these exclosures facilitated the monitoring of plant community regeneration across different climate regimes (Marco and Páez, 2000). The selected study locations included Khachak rangelands in Chalus county, representing humid conditions with temperature extremes ranging from −9.2°C in winter to 22.0°C in summer, a mean annual temperature of 10.9°C, and precipitation of 462 mm. Kiasar rangelands in Behshahr county represents a semi-arid region with an annual mean temperature of 12.0°C and precipitation of 600 mm. Pasperes rangelands in Chalus county represents another humid climate with a mean annual temperature of 15.5°C and precipitation of 751 mm, experiencing pronounced seasonal variation from 0.8°C in January to 30.2°C in July. Chaparghoymeh (briefly Chapar) rangelands in Gonbad-e-Kavus county, a semiarid region with a recorded mean annual temperature of 17.1°C and precipitation of 311 mm, with particularly dry conditions from November through May, averaging ca. 27.5 mm of cumulative precipitation. Gonbad-e-Kavus (hereafter called Gonbad) rangelands in Gonbad-e-Kavus county in Golestan province: the climate is arid with an average annual temperature of 18.5 °C and precipitation of 290 mm.

2.2. Vegetation sampling

The study employed a rigorous stratified sampling approach across all regions, establishing a 20–30 vegetation plots (4 m^2 each) per region. Plots were equally divided between grazed and ungrazed areas (10–15 plots per treatment), with the exception Pasperes region (10 plots in ungrazed and 20 plots in grazed areas) (Table 1). To ensure statistical independence and account for landscape variability, we implemented a multi-level sampling framework based on key areas, discrete, homogeneous units representing characteristic conditions of each treatment (grazed and ungrazed) in each region. Six key areas were identified per region (three grazed and three ungrazed), separated by 200–2000 m to capture natural environmental variation. Each key area contained 3–7 randomly positioned plots, totalling 10–20 replicates per treatment (a total of 140 sampling plots were established across five regions, with 30 plots each in Kiasar, Chapar and Gonbad, and 20 plots in Khachak, equally divided between grazed and ungrazed areas in each region and 30 plots in Pasperes including 10 plots in ungrazed and 20 plots in grazed areas) (Table 1). Key area selection followed standard ecological protocols (Heady and Child, 1994; Erfanzadeha et al., 2016), with verification through uniform vegetation composition and consistent management history. Topographic controls were implemented by restricting key areas to gentle slopes (<10% gradient) to minimize geomorphic influences. Within each key area, plot placement followed a constrained randomization protocol: homogeneous vegetation zones were first delineated, after which plot centres were randomly located a minimum spacing of 50 m between adjacent plots. This design ensured both spatial independence and ecological representativeness of each land-use type (Fig. 1).

Field surveys documenting vascular plant composition were conducted across all study plots during the growing period. Species

Table 1
Geographic location and, climatic and soil conditions of the five study regions along the aridity–humidity gradient in northern Iran: Khachak, Kiasar, and Pasperes (Mazandaran Province) and Chapar and Gonbad (Golestan Province). Climatic values are based on long-term meteorological records.

Province	Region	Climate	Coordinates	Elevation (m)	Mean annual precipitation (mm)	Mean annual temperature (°C)	Minimum temperature (°C)	Maximum temperature (°C)	Soil pH	Soil EC (Ms/cm)	Soil organic matter (%)	no. sampled plots	
												Grazed	Ungrazed
Mazandaran	Khachak	Humid	36° 23′ 25″ N 51° 40′ 31″ E	1650	462	5.5	-2.6	25.6	8.27	139.65	2.46	10	10
	Kiasar	Semiarid	36° 28′ 48″ N 53° 48′ 00″ E	1600	320	12.2	-1.1	37.1	8.38	126.58	1.63	15	15
	Pasperes	Humid	36° 22′ 88″ N 51° 14′ 75″ E	1540	750	15.3	6.8	19.5	7.32	250.00	2.58	20	10
Golestan	Gonbad	Arid	37° 23` 39" N 55° 08` 11" E	74	290	27.7	5.1	31.2	8.48	178.00	1.23	15	15
	Chapar	Semiarid	37° 25′ 57″ N 55° 05′ 33″ E	80	311	13.4	4.4	30.3	8.80	282.71	1.71	15	15

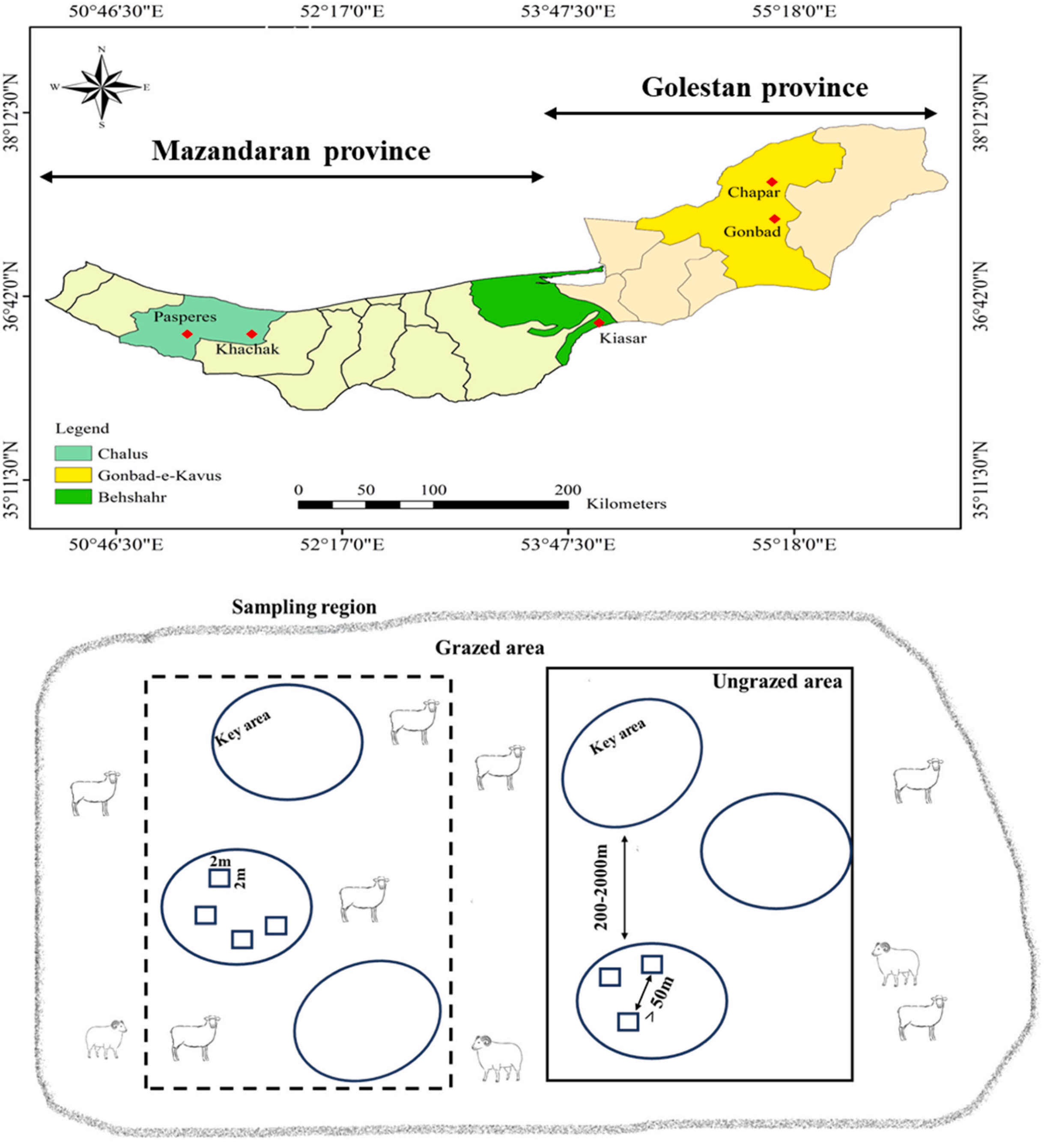

Fig. 1. The location of five studied sampling regions in northern Iran; Pasperes, Khachak and Kiasar in Mazandaran province and, Chapar and Gonbad in Golestan province. Soil and vegetation sampling design in grazed and formerly-grazed (fenced rectangle-shape shown as Ungrazed area) areas. Map lines delineate study areas and do not necessarily depict accepted national boundaries.

coverage was visually estimated and recorded as percentage of covered area. Botanical identification and nomenclature adhered to the taxonomic standards established by Rechinger (1964) and Mozaffarian (1998), with updates based on the International Plant Names Index (IPNI; https://www.ipni.org/).

2.3. Soil sampling and laboratory analyses

In each vegetation plot, soil samples were collected for laboratory analyses. Soil sampling involved taking 3–4 random soil cores per plot, which were pooled into a composite sample for subsequent laboratory analysis. Soil cores were collected using a 5 cm diameter auger at a depth of 5 cm (60–80 cm^3 soil per plot). Although some deep-rooted shrubs are present, this depth was selected because it captures the critical surface layer where seed germination occurs and where the highest density of fine roots and soil organic matter is concentrated. For organic matter content, we applied the loss-on-ignition technique following established protocols. To measure soil pH and electrical conductivity (EC), soil-water suspensions were prepared at a 1:2.5 wtto-volume ratio. pH was measured using a glass-electrode pH meter, and EC was measured using an EC meter. All analytical methods were conducted according to standardized methods (organic matter: Lal et al., 2001; pH/EC: Zandi et al., 2017). These soil variables were not included as covariates in the statistical models because they were strongly correlated with climate zones (e.g. see organic matter in Table 1, highest values in the humid regions and lowest value in the arid region) and thus considered inherent properties of the climate gradient rather than independent predictors.

2.4. Statistical analyses

Vegetation composition was analysed using non-metric multidimensional scaling (NMDS) based on Bray-Curtis dissimilarity (k = 2 dimensions) of species abundance data (i.e. a species cover matrix) to examine species distribution patterns across regions and treatments (grazed/ungrazed plots). Samples were categorized into ten groups representing all region-treatment combinations. Statistical significance was evaluated through permutational multivariate ANOVA (PERMANOVA) using the 'adonis2' function (999 permutations, Bray-Curtis distances), supplemented by post-hoc pairwise comparisons ('pairwise.adonis'). In addition, vegetation dissimilarity between treatments within regions was quantified using Bray-Curtis index analysed via the 'anosim' function. All multivariate analyses were conducted in R v4.5.0 (R Core Team, 2025) utilizing the '*vegan*' and '*pairwiseAdonis*' packages (Oksanen et al., 2019), following established methodologies (Hao et al., 2019).

Total vegetation cover percentages and species richness were calculated in each plot. In addition, plant species in each plot were classified into annuals, perennials, grasses, forbs, and shrubs. Moreover, diversity indices including Shannon, Simpson, Fisher alpha diversity, and Pielou`s evenness were calculated using the *vegan* package in R software, (Hill, 1973; Magurran, 2004).

To compare vegetation characteristics across regions and grazing treatments (grazed vs. ungrazed), we fitted generalized linear mixed models (GLMMs; Bolker et al., 2008). Each vegetation characteristic was analysed as a separate response variable. The models included fixed effects for region and grazing treatment, with plot (nested within key area) and key area (nested within region) included as a random effect to account for spatial dependencies. We applied distinct model structures based on the data type and distribution of each response variable:

1. Total plant cover and functional group covers (transformed to proportional data, 0–1) were modelled using Beta GLMMs with a logit link (family = beta_family). Beta regression does not assume normality and is suitable for bounded continuous data. As the Beta distribution requires values strictly between 0 and 1, we made a minor adjustment to the data, replacing 0 with 0.001 and 1 with 0.999.
2. Species richness (total and functional groups; count data, integers ≥ 0) was analysed using Poisson GLMMs (log link) via the glmer function (Sun et al., 2023). Overdispersion was checked; if present, a negative binomial distribution was used.
3. Diversity indices (continuous, non-negative) were analysed using Gaussian linear mixed models (LMMs). We tested residual normality with the Shapiro-Wilk test; non-normal data ($P < 0.05$) were log-transformed (log(*x*)) and analysed using lmer.

All models were implemented in R 4.5.0 using the *glmmTMB*, *lme4*, and *DHARMa* packages for diagnostics. Post-hoc pairwise comparisons between regions and grazing treatments were conducted using Tukey's HSD tests via the *emmeans* package.

3. Results

3.1. Vegetation composition and dissimilarities

A total of 54, 36, 20, 40, and 83 plant species were recorded in Kiasar, Chapar, Gonbad, Khachak, and Pasperes, respectively. Species richness was generally higher in ungrazed plots, with the exception of Chapar where grazed plots had higher richness, and Gonbad where richness was similar between treatments. Dominant species composition shifted with grazing exclusion. In Kiasar, *Artemisia sieberi* and *Festuca ovina* dominated both treatments, but with higher cover in ungrazed plots. In Chapar, grazed plots were dominated by *Medicago minima* and *Plantago coronopus*, while ungrazed plots were dominated by *Lolium temulentum* and *Hordeum murinum*. At Gonbad, *Halocnemum strobilaceum* dominated both treatments. In Khachak, *Hordeum murinum* and *Artemisia fragrans*

Table 2
Permutational multivariate analysis of variance to test multivariate group differences in plant compositions in five regions in northern Iran (Khachak, Kiasar, and Pasperes in Mazandaran Province and, Chapar and Gonbad in Golestan Province) and grazing treatments (grazed and removal grazed) based on Bray-Curtis dissimilarity matrices.

	df	Sum of Square	R2	F	P value
Model	1	5.17	0.08	12.55	0.001
Residual	138	56.87	0.91		
Total	139	62.04	1.00		

dominated grazed plots, while *Chrozophora tenella* and *Phlomis olivieri* dominated ungrazed plots. At Pasperes, *Trifolium repens* and *Hordeum glaucum* dominated grazed plots, with *Dactylis glomerata* and *Lolium multiflorum* dominant in ungrazed plots. A full species list is provided in Appendix 1.

NMDS results revealed significant differences in vegetation composition among 10 categories ($P < 0.01$; Table 2), though pairwise comparisons indicated non-significant differences between grazed and ungrazed areas in Kiasar and Gonbad ($P > 0.05$) (Table 3). In addition, Fig. 2 showed greater visualized separation of vegetation composition in Khachak and Pasperes than the other three regions between grazed and ungrazed plots.

Analysis of vegetation composition dissimilarities using permutation tests (*anosim* function) showed significant differences between grazed and ungrazed plots ($p = 0.001$: Appendix 2).

3.2. Total vegetation cover, total richness and diversity indices

The analysis revealed significant differences in total vegetation cover, total species richness, Fisheŕs alpha diversity, and Shannon diversity index among the five studied regions (Table 4). The main significant effect of grazing removal on total vegetation cover, total species richness, Shannon diversity index was detected (Table 4). Furthermore, we observed a significant region × grazing removal interaction effect on total cover, total species richness and Shannon diversity index (Table 4).

Total vegetation cover differed significantly between grazed and ungrazed plots in Kiasar, Chapar, and Pasperes, with ungrazed plots showing the highest values. In contrast, Khachak had the highest cover in grazed plots (Fig. 3). Species richness varied significantly only in Chapar, where ungrazed areas had the highest values. The Shannon diversity index decreased after grazing removal in Chapar, while the Simpson diversity index significantly increased in Pasperes but decreased in Chapar and Kiasar (marginally significant, $p = 0.06$). Fisher's alpha diversity was highest in grazed plots in Kiasar but highest in ungrazed plots in Khachak and Pasperes. Finally, Pielou's evenness index decreased significantly in Kiasar, Chapar, and Gonbad after grazing exclusion but increased in Khachak and Pasperes (Fig. 3).

3.3. Plant functional group responses to grazing exclusion

The effects of region were significant for both cover percentage and species richness across all studied plant functional groups, except shrub richness (Table 4). Grazing exclusion had a significant main effect on the cover of annuals, perennials, forbs, grasses, and shrubs, as well as on the richness of perennials and grasses. Additionally, we found a significant region × grazing removal interaction affecting the cover of annuals, perennials, forbs, grasses, and shrubs, as well as the richness of annuals, perennials, and grasses (Table 4).

In Kiasar, the highest cover percentages of perennial and grass were recorded in ungrazed plots, while other functional groups showed no significant differences between grazed and ungrazed plots (Table 5). In Chapar, grazing exclusion significantly increased the mean cover and species richness of annuals. However, no grass or shrub covers were feasible to compare statistically between grazed and ungrazed plots, since the number of grass/shrub species found in the plots was negligible; for example, only *Halocnemum strobilaceum* shrub was found in grazed plots (Table 5). In Gonbad, no significant differences were found between grazed and ungrazed plots for any functional group (cover percentage or species richness) (Table 5). In Khachak, grazed plots had the highest annual and grass cover percentages compared to ungrazed plots, while other functional groups remained unaffected by grazing treatment (Table 5). In Pasperes, grazing exclusion led to increased mean cover percentages of perennials, grasses, and forbs, but there was no significant difference in species richness between treatments for any functional group (Table 5).

4. Discussion

Our findings support the hypothesis that the impact of grazing removal on vegetation parameters was more pronounced in humid ecosystems, highlighting the role of climatic conditions/climate type in mediating these responses. In addition, the effects of grazing exclusion on vegetation are strongly dependent on the type of plant functional groups (grasses vs. forbs and annuals vs. perennials) and vegetation characteristics (cover percentage, diversity and richness). Notably, plant cover exhibited greater sensitivity to grazing removal compared to species richness, suggesting that cover serves as a more responsive indicator of vegetation recovery following

Table 3
Pairwise comparisons of vegetation composition conducted among 10 categories (two grazed and removal grazed areas in each region) using PERMANOVA with the 'pairwise.adonis' function in the "pairwiseAdonis" package. Pairs including: 1: ungrazed plots in Kiasar, 2: grazed plots in Kiasar, 3: ungrazed plots in Chapar, 4: grazed plots in Chapar, 5: ungrazed plots in Gonbad, 6: grazed plots in Gonbad, 7: ungrazed plots in Khachak, 8: grazed plots in Khachak, 9: ungrazed plots in Pasperes and 10: grazed plots in Pasperes.

Pairs	df	Sums of Sqs.	F Model	R_2	P value
1 vs 2	1	1.17	4.08	0.13	0.061
3 vs 4	1	3.01	10.87	0.28	0.001
5 vs 6	1	0.32	2.50	0.08	0.052
7 vs 8	1	2.75	12.49	0.41	0.001
9 vs 10	1	2.05	8.35	0.23	0.001

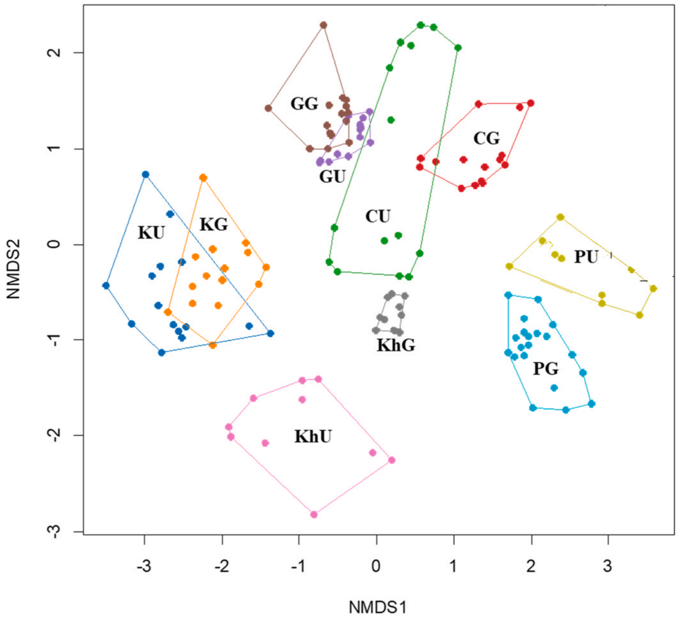

Fig. 2. Non-metric multidimensional scaling (NMDS) of the vegetation composition in grazed and ungrazed plots across regions in northern Iran, based on Bray–Curtis dissimilarity (Stress=0.084). KU: plots in Kiasar, ungrazed area, KG: plots in Kiasar, grazed area, CU: plots in Chapar, ungrazed area, CG: plots in Chapar, grazed area, GU: plots in Gonbad, ungrazed area, GG: plots in Gonbad, grazed area, KhU: plots in Khachak, ungrazed area. KhG: plots in Khachak, grazed area, PU: plots in Pasperes, ungrazed area and PG: plots in Pasperes, grazed area. Pairwise comparisons of species composition were performed using the *pairwise.adonis* function from the *vegan* package in R.

Table 4
The effects of region (five regions including Khachak, Kiasar, and Pasperes in Mazandaran province and Chapar and Gonbad in Golestan province), grazing treatment (grazed and grazed removal) and their interaction on vegetation characteristics, testing by generalized linear models.

		df	Chi square	p-value		Chi square	p-value
	Region	4	6.13	0.01		1.29	0.25
Total cover	Grazing	1	20.16	0.00	Perennial cover	11.05	0.00
	Region × Grazing	4	11.04	0.00		3.72	0.05
	Region	4	566.89	0.00		2334.26	0.00
Total richness	Grazing	1	5.400	0.00	Perennial richness	4.98	0.03
	Region × Grazing	4	29.54	0.02		31.86	0.00
	Region	4	3.45	0.32		0.02	0.88
Simpson diversity	Grazing	1	0.14	0.71	Forb cover	0.90	0.34
	Region × Grazing	4	0.24	0.97		0.24	0.62
	Region	4	20.69	0.00		1393.55	0.00
Fisher alpha diversity	Grazing	1	0.39	0.53	Forb richness	0.05	0.82
	Region × Grazing	4	1.20	0.75		2.86	0.58
	Region	4	224.52	0.00		8.41	0.00
Shannon diversity	Grazing	1	8.60	0.00	Grass cover	24.46	0.00
	Region × Grazing	4	85.78	0.00		15.04	0.00
	Region	4	1.08	0.78		308.42	0.00
Pielou's evenness	Grazing	1	0.44	0.51	Grass richness	6.35	0.01
	Region × Grazing	4	0.47	0.92		20.62	0.00
	Region	4	0.09	0.29		29.23	0.00
Annual cover	Grazing	1	13.91	0.00	Shrub cover	6.23	0.02
	Region × Grazing	4	10.20	0.00		0.68	0.60
	Region	4	99.99	0.00		7.99	0.09
Annual richness	Grazing	1	0.04	0.85	Shrub richness	0.11	0.74
	Region × Grazing	3	19.94	0.00		2.39	0.66

disturbance removal.

Previous studies on vegetation responses to removal grazing focused on two main topics including biotic factors such as grazing intensity and abiotic factors such as soil and climatic condition. These studies have reported divergent vegetation responses to livestock grazing exclusion (Gebremedhn et al., 2023). For instance, while some emphasized grazing intensity as the dominant driver (Pricope et al., 2013) others attributed post-exclusion vegetation dynamics primarily to climatic factors (e.g. Booker et al., 2013). Our

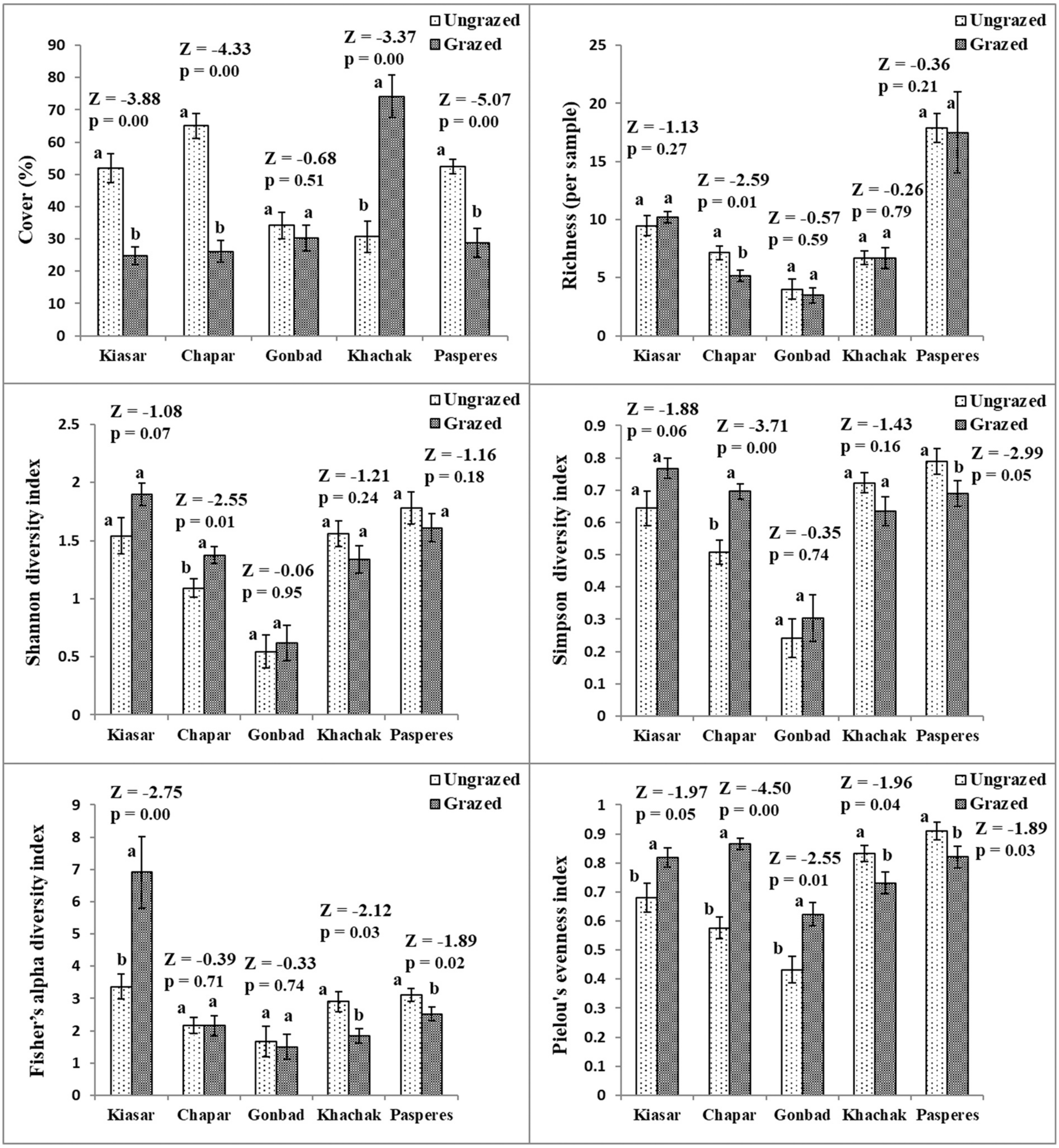

Fig. 3. Impact of grazing removal on total vegetation cover (%), total species richness (per plot), and diversity indices across five study regions (Kiasar, Chapar, Gonbad, Khachak, Pasperes) in northern Iran. Lowercase letters denote significant differences ($p < 0.05$) between grazed and ungrazed plots within each region.

results build on these findings by showing that, even when grazing is completely removed, vegetation recovery trajectories still differ substantially across regions with contrasting climatic conditions. These findings have critical implications for grassland management. The differential responses of vegetation cover and plant diversity and richness to grazing removal, particularly the intensify sensitivity of humid regions, suggest that region-specific conservation strategies are essential. For instance, in humid areas, short-term grazing exclusion may rapidly improve vegetation cover in overgrazed sites, whereas in arid systems, longer-term interventions or alternative approaches may be required to enhance both biodiversity and ecosystem function. Therefore, special attention should be paid in dry habitats when introducing grazing.

Table 5
Effects of grazing removal on functional group cover (%) and species richness (per plot) across five regions in northern Iran (Kiasar, Chapar, Gonbad, Khachak, and Pasperes). Shrub cover in the grazed area of Khachak was zero, and grasses were present in only a few plots in the grazed area of Chapar. Therefore, we did not proceed with further statistical analyses.

Region	Grazing treatment		Annual cover	Annual richness	Perennial cover	Perennial richness	Forb cover	Forb richness	Grass cover	Grass richness	Shrub cover	Shrub richness
		Mean	6.46	3.20	45.46	6.26	30.40	6.40	21.50	3.06	15.33	1.27
	Ungrazed	SE	0.69	0.53	4.61	0.59	5.88	0.63	3.44	0.34	4.71	0.21
		N	15	15	15	15	15	15	15	15	15	15
		Mean	3.26	2.66	21.53	7.53	18.73	6.73	5.26	2.93	0.80	0.53
Kiasar	Grazed	SE	0.44	0.28	2.60	0.56	2.48	0.33	0.55	0.26	0.32	0.13
		N	15	15	15	15	15	15	15	15	15	15
		Z	-1.53	-0.22	-3.49	-1.38	-1.35	-.78	-3.89	-0.09	-2.28	-0.11
		p-value	0.13	0.83	0.01	0.17	0.31	0.46	0.00	0.93	0.01	0.78
		Mean	39.20	3.13	25.8	4.00	30.00	5.00	35.00	2.13	3.27	0.67
	Ungrazed	SE	5.01	0.35	5.14	0.42	5.50	0.47	4.48	0.25	0.91	0.13
		N	15	15	15	15	15	15	15	15	15	15
		Mean	10.73	2.13	15.40	3.00	25.73	4.93	0.40	0.20	2.40	0.40
Chapar	Grazed	SE	1.82	0.30	2.63	0.32	3.31	0.34	0.40	0.20	1.13	0.13
		N	15	15	15	15	15	15	15	15	15	15
		Z	-3.45	-2.21	-1.14	-1.61	-0.35	-0.26	-	-	-1.20	-0.78
		p-value	0.01	0.03	0.25	0.12	0.70	0.81	-	-	0.09	0.96
		Mean	1.33	1.26	32.86	2.73	33.13	3.33	0.46	0.46	0.60	0.20
	Ungrazed	SE	0.53	0.51	4.26	0.39	4.24	0.60	0.22	0.22	0.33	0.11
		N	15	15	15	15	15	15	15	15	15	15
		Mean	1.00	0.93	29.26	2.53	29.46	2.86	0.40	0.40	0.40	0.20
Gonbad	Grazed	SE	0.35	0.31	4.17	0.41	4.09	0.49	0.13	0.13	0.21	0.11
		N	15	15	15	15	15	15	15	15	15	15
		Z	-0.12	-0.09	-0.42	-0.54	-0.42	-0.62	-0.29	0.29	-0.18	0.00
		p-value	0.93	0.93	0.69	0.62	0.69	0.58	0.80	0.80	0.90	1.00
		Mean	10.10	2.20	20.60	4.50	25.30	5.50	5.40	1.20	2.50	0.30
	Ungrazed	SE	1.72	0.29	4.99	0.50	5.24	0.40	1.43	0.29	1.97	0.15
		N	10	10	10	10	10	10	10	10	10	10
		Mean	43.43	2.80	32.93	4.00	42.96	5.70	33.40	1.10	0.00	0.00
Khachak	Grazed	SE	3.40	0.29	7.65	0.74	9.17	0.95	5.24	0.10	0.00	0.00
		N	10	10	10	10	10	10	10	10	10	10
		Z	-3.78	-1.38	-1.22	-0.84	-1.40	-0.03	-3.71	-0.14	-	-
		p-value	0.00	0.22	0.21	0.43	0.16	0.97	0.00	0.912	-	-
		Mean	11.30	3.10	41.10	14.80	33.10	12.60	15.30	4.50	4.00	0.80
	Ungrazed	SE	2.81	0.43	4.11	1.12	4.12	1.34	2.59	0.40	1.85	0.36
		N	10	10	10	10	10	10	10	10	10	10
		Mean	5.15	4.20	23.60	13.30	21.80	12.40	6.25	4.55	0.70	0.55
Pasperes	Grazed	SE	0.49	0.39	2.30	0.83	1.74	0.67	0.85	0.35	0.19	0.14
		N	20	20	20	20	20	20	20	20	20	20
		Z	-1.68	-1.65	-3.05	-1.02	-2.48	-0.64	-3.14	-0.50	-0.48	-0.17
		p-value	0.10	0.11	0.00	0.32	0.01	0.53	0.00	0.65	0.68	0.88

4.1. Differences in vegetation among regions

Our study showed that vegetation characteristics vary substantially across regions, reflecting underlying differences in vegetation composition, plant functional group distribution, and plant diversity patterns. These biogeographic differences could provide strong support for the habitat-specific species pool concept (Helm et al., 2015), which assumes that environmental filtering of regional flora play important role in grassland ecosystems development and distinct species assemblages (Cheng et al., 2025). The observed patterns suggest that local abiotic conditions probably limit species establishment and persistence. For instance, in Gonbad with its arid climate, a total of 20 plant species was recorded, while in Pasperes with humid conditions, the number of plant species was four times higher than in Gonbad. Similarly, vegetation cover in ungrazed areas was significantly higher in Pasperes compared to Gonbad. Indeed, humid regions were characterized by a higher number of plant species, whereas dry habitats showed lower plant species richness, primarily due to severe drought stress (Sun et al., 2021). In this regard, we conclude that climate change toward global warming, may pose a serious threat to northern Iranian ecosystems and could lead to fundamental changes in plant community composition and ecosystem structure, including decreases in plant species richness and cover percentage. These changes need to be investigated in future studies to better understand the underlying processes.

Beyond the deterministic local factors, the results indicate that stochastic processes also may contribute to the assembly of plant communities across the regions. Climatic factors could serve as primary environmental filters that shape the fundamental niche space available to species (see also He et al., 2023). We argue, here, that abiotic factors should be considered in restoration projects while the failure of seeding and planting projects in arid and semiarid regions of Iran was reported due to insufficient knowledge about environmental abiotic factors (Karimian et al., 2018). However, even within climatically similar areas, we observed notable differences in species composition that likely reflect the influence of stochastic processes such as dispersal limitation and colonization history (Varzinczak et al., 2018). This is particularly evident in two similar semiarid and two similar humid regions, where we could compare climatically similar sites. These findings carry important implications for grassland conservation and restoration. The strong regional differentiation in vegetation characteristics suggests that management strategies must be tailored to local environmental contexts rather than employing uniform approaches across diverse ecosystems.

4.2. Effects of grazing exclusion on vegetation

Grazing exclusion has become an established grassland restoration technique, recognized for its ability to enhance ecosystem functions and services while promoting rapid vegetation recovery (Filazzola et al., 2020; Li et al., 2022). Our study of northern Iranian grasslands largely supports this approach, demonstrating significant improvements in total vegetation cover and most functional group covers following grazing removal. These findings align with numerous global studies documenting similar positive responses in rangeland ecosystems (Li et al., 2012; Bakhshi et al., 2020; Karatassiou et al., 2022). However, while our results showed increased cover for most functional groups under grazing exclusion, we observed an important exception at the Khachak region, where total vegetation cover actually declined in ungrazed conditions. This unexpected pattern may be explained by the competitive advantage gained by unpalatable species like *Hordeum murinum* under grazing pressure. *H. murinum* dominant species in grazed areas in Khachak (33.30% mean percentage cover) is known as hare barley or foxtail, is unpalatable to livestock, since the seedheads have sharp, barbed awns that can cause injury to grazing animals. Our findings indicate that intensive grazing in grazed areas, while potentially detrimental to plant organs (Dupre and Diekman, 2001), may paradoxically benefit certain species such as these unpalatable annuals through a combination of competitor removal, disturbance-mediated establishment, and enhanced dispersal. Grazing can exert a selective pressure by preferentially removing more palatable, competitive species that would otherwise suppress unpalatable species in the absence of disturbance. This selective removal reduces competition for light and resources, creating an "empty niche" that unpalatable species are well-adapted to fill (Molvar et al., 2024). In addition, physical disturbance from livestock trampling can create small patches of bare soil, providing ideal microsites for the germination and establishment of annuals like *H. murinum*, which may be less effective at establishing in dense, undisturbed litter layers. Also, in some cases, trampling had profound effects on seedling emergence, that is it induced a 3.5-fold increase in the number of emerging seedlings (Eichberg and Donath, 2018). Moreover, livestock can act as effective seed dispersal agents. The barbed awns of *H. murinum* are specifically adapted for epizoochory, allowing seeds to attach to fur and be transported to new, potentially disturbed, microsites within the grazed area, further reinforcing its dominance. The observed reduction in total and grass cover following grazing exclusion at Khachak suggests that complete removal of grazing pressure can sometimes lead to unintended vegetation changes in humid ecosystems, a consideration for ecosystem management.

4.3. Interactive effects of grazing exclusion and climate on vegetation

Generally, the plant composition similarity between grazed and ungrazed areas showed relatively low across all climatic regions. These findings align with those of Xiang et al. (2021), who reported a low similarity between exclosure and intensively grazed sites. However, we observed that the differences in total and functional group cover percentages and plant richness between grazed and ungrazed sites generally increased with increasing humidity. In Pasperes and Khachak with humid climate, changes in vegetation characteristics through grazing removal were much higher in comparing with dryer climates (Kiasar, Chapar and Gonbad). This pattern is comparable with findings by Zhao et al. (2016) and Xiang et al. (2023), who reported that certain vegetation characteristics, particularly plant biomass, decreased under grazing exclusion when subjected to abiotic stresses such as high-altitude cold conditions. This could be due to several mechanisms:

i) Different vegetation types in different regions had different dominant species and plant abundances due to region-specific deterministic factors, particularly climatic conditions as a key driver of vegetation composition and plant abundance (Zhu et al., 2025). On the other hand, the impacts of livestock grazing on grassland vary depending on vegetation types. For instance, a recent systematic review revealed distinct grazing effects in different ecosystems, including arid lands, deserts, and alpine steppes (Munkhzul et al., 2021). In our study, we observed different vegetation types with different dominant plant species across the studied regions: 1) semiarid grasslands occurred at Kiasar, dominated by *Artemisia sieberi*. This shrubby aromatic species is widely distributed across Central Asia and Iran's Irano-Turanian floristic region. Although *A. sieberi* has low grazing appeal, our data showed its cover percentage increased drastically following grazing removal (14.4% vs. 6.20%). Another dominant species at Kiasar, the perennial grass *Festuca ovina*, exhibited an eight-fold increase after grazing exclusion (9.33% vs. 1.13%). This is in agreement with previous studies such as Ghorbani and Mashkoori (2017) that reported this species' response to grazing intensity varies with abiotic habitat factors, showing highest abundance under grazing exclusion on southeast-facing slopes. 2) Semiarid grassland at Chapar featured different dominant species in grazed versus ungrazed areas: the herbaceous *Lolium temulentum* (16.73% in cover) dominated ungrazed areas, while *Medicago minima* prevailed in grazed areas. *L. temulentum*, as a relatively high palatable species (Class II in palatability classification), its increased vegetation cover under grazing removal likely results from enhanced sexual and vegetative growth. In contrast, the annual palatable herb *M. minima* dominated grazed areas. This species' seeds have high epizoochorous dispersal potential, enabling widespread distribution throughout grazed areas and resulting in high percentage cover. Like other typical Fabaceae species in rangelands, *Medicago* spp. are frequently found in sheep wool and demonstrate high sheep-mediated dispersal capacity (Kaligarič et al., 2016). 3) Arid shrubby grassland occurred at Gonbad, dominated by the shrub *Halocnemum strobilaceum* in both grazed and ungrazed areas. Shrubs that are more prevalent in this region have more resistant to grazing may explain the smaller differences in vegetation cover between grazed and ungrazed sites (Ludvikova et al., 2014). *H. strobilaceum* appears to have high recovery potential after grazing. Previous studies report that compared to other halophytes, this species can sustain up to 75% allowable use while maintaining health and vigor under grazing pressure (Soltanipoor et al., 2022). 4) Changes in humid Khachak region was more pronounced compared with three arid and semiarid regions. In fact, this highly change inserted by low palatable grass species of *Hordeum murinum* that completely disappeared after grazing removal while it was prevail in grazed areas with 33.30% cover. Surprisingly, *H. murinum* was a dominant species in ungrazed areas in Chapar. These contrasting responses indicate that the effect of grazing on a plant species is not uniform across climatic zones; this variability needs to be investigated and accounted for in future research. 5) In humid Pasperes region, grazing removal increase drastically palatable plant species such as *Dactylis glomerata*, resulting a huge increasing in vegetation cover in ungrazed plots.

ii) Dryer climates may influence vegetation characteristics differently in grazed versus ungrazed areas compare with wetter climates. These differential responses could stem from dryness impact on plant growth and biomass production. Aridity typically exhibits less soil organic matter, soil moisture contents and great stress levels compared to humidity, potentially restricting plant growth. This may explain the smaller differences in vegetation cover, richness and diversity indices between grazed and ungrazed areas under arid conditions (arid region vs. semiarid and humid regions).

iii) The greatest differentiation between grazed and ungrazed areas in humid regions likely reflects faster vegetation recovery and turnover following grazing removal, facilitated by more favourable growing conditions compared to arid environments. Wang et al. (2023) demonstrated that abiotic stresses (e.g., aridity) influence post-grazing recovery rates, noting that grazing removal enhanced carbon sequestration more effectively in humid versus arid Chinese grasslands.

The observed patterns of functional group responses to grazing in different regions are comparable to findings by Tahmasebi Kohyani et al. (2008), who reported greater differentiation in grazed versus ungrazed areas for annuals and perennials under high soil acidity (pH) compared to low pH conditions. As Grime (2001) noted, only a limited number of stress-tolerant species can persist in arid climate and nutrient-poor soils like those in Gonbad, even without grazing pressure. Drought strongly constrains species diversity in dry environments, whereas decreasing aridity facilitates an increase in both species' richness and abundance, including more competitive and palatable species (Gonbad vs. Pasperes). This demonstrates that the greater shifts in species composition observed in humid regions compared to arid regions can be attributed to a clear gradient of species richness and abundance along the aridity spectrum. Previous studies (e.g., Osem et al., 2004) have similarly documented more pronounced effects of grazing exclusion on vegetation characteristics and greater dissimilarity between grazed and ungrazed areas in humid nutrient-rich environments. In humid regions, where resource availability supports plant growth, competition shifts from nutrient to light (Tilman, 1988) favoring the establishment of competitive, leafy species. However, these species typically exhibit lower resistance to grazing (Díaz et al., 2001). As a result, vegetation changes following grazing exclusion occur more rapidly and markedly in non-stressful conditions due to this reduced grazing tolerance compared to dry stressful environments.

Grazing exclusion did not alter plant diversity in arid climate (Gonbad) but reduced diversity indices in semiarid regions (Kiasar and Chapar). While grazing removal did not change species richness in Kiasar and increased in Chapar, some diversity indices unexpectedly decreased in Kiasar and Chapar (e.g. Shannon diversity) under exclusion. This apparent contradiction may arise because diversity reflects both species richness (number of species) and evenness (abundance distribution) (Anderson et al., 2011). Although grazing removal did not change or boosted richness, it likely reduced evenness, leading to an overall decline in diversity. In grazed areas, total abundance was distributed more evenly among fewer species compared to ungrazed areas, where higher richness coincided with lower evenness. However, in dry stressful habitats, grazing exclusion did not reduce plant diversity as observed in humid non-stressful habitats. Finally, the low species richness in arid plots may partially reduce the sensitivity of the Bray-Curtis dissimilarity index to grazing-induced changes in NMDS results, meaning that the apparent lack of response in arid regions should be interpreted with caution.

5. Conclusions

Our findings demonstrate that climate, particularly along the aridity-humidity gradient, are critical determinants of how livestock grazing influences vegetation structure and diversity. The impact of grazing exclusion was most pronounced in humid regions, where inherently higher plant coverage may facilitate faster community recovery. This highlights the need for climate-adaptive grazing management, where strategies are tailored to regional environmental conditions. In humid grasslands, grazing exclusion can significantly enhance vegetation recovery, making it a viable restoration tool. In contrast, arid and semi-arid ecosystems appear more resilient to grazing pressure, likely due to the dominance of stress-tolerant species. Overall, this study provides a framework for region-specific grazing strategies, helping to balance intensive livestock grazing and plant conservation goals. Future research should further explore interactions between grazing intensity and climate variability to refine adaptive management approaches.

CRediT authorship contribution statement

Reza Erfanzadeh: Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Narges Imani:** Visualization, Formal analysis, Data curation. **Hassan Ghelichnia:** Validation, Investigation, Data curation, Conceptualization. **Péter Torok:** Writing – review & editing, Visualization, Validation, Methodology, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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Appendix 1. Mean vegetation cover (%) of plant species in grazed and ungrazed plots across five regions (Kiasar, Chapar, Gonbad, Khachak, and Pasperes) in Mazandaran and Golestan provinces, Northern Iran. Bold values indicate the two dominant species in each region for both grazing treatments. P: perennial, A: annual (or biennial), F: forb, G: grass, S: shrub. Palatability index: I (highest palatable), II (intermediate palatable), III (lowest palatable), IV (no-palatable/ harmful), N (non-information available)

Region				Kiasar		Chapar		Gonbad		Khachak		Pasperes	
Grazing treatment	Life span	Life form	Platability index	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed
Achillea millefolium	P	F	II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	0.10
Aegilops tauschii	A	G	IV	0.27	0.00	0.00	0.00	0.27	0.20	0.00	0.00	0.00	0.00
Agropyron elongatum	P	G	II	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agropyron pectiniforme	P	G	I	1.13	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agropyron tauri	P	G	II	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aizoanthemum hispanicum	A	F	N	0.00	0.00	0.20	0.13	0.20	0.27	0.00	0.00	0.00	0.00
Ajuga chamaecistus	P	S	IV	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allium atroviolaceum	P	F	N	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Allium rubellum	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00
Alyssum linifolium	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Alyssum minus	A	F	N	0.87	0.67	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
Alyssum montanum	P	F	N	0.53	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Anagallis arvensis	A	F	N	0.00	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Androsace maxima	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.20	0.00	0.00
Arabis sagittata	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00
Arenaria gypsophiloides	P	F	N	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arenaria leptoclados	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.85
Artemisia annua	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
Artemisia fragrans	P	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**12.60**	0.00	0.00
Artemisia sieberi	P	S	III	**14.40**	**6.20**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Astragalus asterias	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.00	0.00

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(*continued*)

Region				Kiasar		Chapar		Gonbad		Khachak		Pasperes	
Grazing treatment	Life span	Life form	Platability index	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed
Astragalus aureus	P	F	N	0.00	1.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Astragalus linneatus	P	F	N	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Astragalus lunatus	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00
Astragalus sp.	P	F	III	4.40	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Astragalus verus	P	S	III	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00
Bassia prostrata	P	S	N	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00
Bombycilaena erecta	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.00	0.00	0.00
Boraginaceae	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00
Bromus danthoniae	A	G	N	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bromus madritensis	A	G	N	0.53	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bromus racemosus	A	G	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.15
Bromus sterilis	A	G	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.55
Bromus tectorum	A	G	N	1.27	1.20	0.00	0.00	0.00	0.00	0.90	0.00	0.00	0.00
Bupleurum falcatum	P	F	N	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cakile maritima	A	F	N	0.20	0.07	0.00	0.00	0.20	0.13	0.00	0.00	0.00	0.00
Calendula palestina	A	F	N	0.00	0.00	0.40	0.87	0.00	0.00	0.00	0.00	0.00	0.00
Capsella bursa-pastoris	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.40
Cardaria draba	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Carduus nutans	A	F	III	0.00	0.00	4.40	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Carduus pycnocephalus	A	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55
Carex divulsa	P	G	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.10
Carex grioletii	P	G	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00
Centaurea ovina	P	F	III	0.07	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Centaurea sp.	P	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Ceratocephala testiculata	A	F	N	0.93	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chenopodium album	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00
Chrozophora tenella	A	F	IV	0.27	0.00	0.00	0.00	0.00	0.00	**6.20**	0.00	0.00	0.00
Convolvulus arvensis	P	F	IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.05
Convolvulus commutatus	P	F	N	0.53	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coronilla varia	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00
Cousinia commutata	P	F	III	1.80	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crataegus pseudomelanocarpa	P	S	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.60	0.65
Crepis demavendi	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.95
Crepis sancta	A	F	N	0.20	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Crepis sp.	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
Crepis willemetioides	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.10
Crepis neglecta	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Crucianella filifolia	A	F	N	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cynodon dactylon	P	G	II	0.00	0.00	0.07	0.27	0.00	0.00	0.00	0.00	0.00	0.00
Dactylis glomerata	P	G	I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**4.30**	0.15
Descurainia sophia	A	F	N	0.13	0.07	0.00	0.00	0.13	0.20	0.00	0.00	0.00	0.00
Echium amoenum	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00
Erodium cicutarium	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.30	6.90	0.00	0.60
Eryngium bungie	P	F	III	0.00	0.00	0.00	0.00	0.00	0.00	2.30	0.90	0.00	0.00
Eryngium caucasicum	P	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.40
Euphorbia helioscopia	A	F	III	1.33	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Euphorbia saratoi	A	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00
Euphrasia pectinata	A	F	III	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eurotia ceratoides	P	S	N	0.87	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00
Falcaria vulgaris	P	F	III	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Festuca ovina	P	G	I	**9.33**	**1.13**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Filago vulgaris	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
Froriepia subpinnata	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Fumaria vaillantii	A	F	N	0.07	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gagea lutea	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
Galium humifusum	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	0.80
Galium spurium	A	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.00	0.00
Geranium pyrenaicum	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25
Glyceria maxima	P	G	N	0.07	0.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gnaphalium luteo album	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
Gundelia tournefortii	P	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.00	0.00
Halocnemum strobilaceum	P	S	IV	0.00	0.00	3.27	2.40	**30.00**	**23.87**	0.00	0.00	0.00	0.00
Heliotropium aucheri	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.80	0.00	0.00
Heliotropium europaeum	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.20	0.00	0.00
Herniaria incana	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00

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Region				Kiasar		Chapar		Gonbad		Khachak		Pasperes	
Grazing treatment	Life span	Life form	Platability index	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed
Hordeum glaucum	A	G	IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.85**
Hordeum murinum	A	G	IV	0.07	0.00	**11.47**	0.00	0.20	0.20	0.00	**33.30**	0.00	0.00
Hypericum perforatum	P	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Hypericum scabrum	P	F	III	0.27	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Isatis cuspidata	A	F	N	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lathyrus chloranthus	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.00
Lepidium draba	P	F	N	0.00	0.00	0.47	0.00	0.20	0.07	0.00	0.00	0.00	0.00
Linaria simplex	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Lolium multiflorum	A	G	I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**3.50**	0.00
Lolium perenne	P	G	I	0.00	0.00	0.00	0.00	0.00	0.00	2.20	0.00	0.40	0.55
Lolium temulentum	A	G	II	0.00	0.00	**16.73**	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lonicera bracteolaris	P	S	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.30
Malva neglecta	A	F	N	0.00	0.00	7.33	0.53	0.13	0.00	0.20	2.53	0.00	0.00
Malva sylvestris	P	F	N	0.00	0.00	3.33	2.20	0.00	0.00	0.00	0.00	0.00	0.00
Marrubium sp.	P	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.25
Medicago minima	A	F	II	0.00	0.00	0.00	**8.13**	0.00	0.00	0.00	0.00	0.60	0.70
Medicago orbicularis	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.60
Medicago polymorpha	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.10	0.90
Medicago radiata	A	F	N	0.00	0.00	0.00	1.13	0.00	0.00	0.00	0.00	0.00	0.00
Medicago rigidula	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	1.20	1.20	0.00	0.00
Medicago sativa	P	F	I	0.00	0.00	0.00	0.00	**1.40**	0.00	0.00	0.40	1.10	0.05
Melilotus officinalis	A	F	II	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minuartia litwinowii	P	F	N	0.00	0.00	0.40	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Minuartia recurva	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60
Minuartia verna	P	F	N	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Myosotis olympica	P	F	N	0.20	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00
Nepeta cataria	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.05
Noea mucronata	P	F	III	0.00	0.80	0.00	0.00	0.60	0.40	0.00	0.00	0.00	0.00
Nonnea caspica	A	F	N	0.00	0.00	0.13	0.87	0.00	0.00	0.00	0.00	0.00	0.00
Nonnea lutea	A	F	N	0.00	0.00	0.13	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Onobrychis sativa	P	F	I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00
Oxalis corniculata	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30
Papaver decaisnei	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00
Peganum harmala	P	F	III	0.00	0.00	0.13	2.93	0.00	0.00	0.00	3.60	0.00	0.00
Phalaris tuberosus	P	G	N	0.00	0.00	6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phleum bertolonii	P	G	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
Phleum paniculatum	A	G	N	0.33	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phlomis herba-venti	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00	0.00
Phlomis olivieri	P	F	III	0.00	0.00	0.00	0.00	0.00	0.00	**5.50**	0.00	0.00	0.00
Picris strigosa	P	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20	0.00
Plantago coronopus	A	F	N	0.00	0.00	0.27	**5.27**	0.00	0.00	0.00	0.00	0.00	0.00
Plantago lanceolata	P	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.00
Poa annua	A	G	N	0.00	0.00	0.13	0.07	0.00	0.00	0.00	0.10	0.40	0.70
Poa bulbosa	P	G	II	0.07	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poa nemoralis	P	G	II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.20
Poa nemorosa	P	G	II	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Poa pratensis	P	G	I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.40	0.70
Polygonum aviculare	A	F	N	0.00	0.00	0.33	0.47	0.00	0.00	0.00	0.00	0.00	0.00
Polygonum hydropiper	A	F	N	0.00	0.00	0.67	0.27	0.00	0.00	0.00	0.00	0.00	0.00
Polygonum sp.	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Potentilla reptans	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	0.25
Prunus spinosa	P	S	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.05
Pteridium aquilinum	P	F	IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
Puccinellia distans	P	G	N	0.00	0.00	0.13	0.07	0.00	3.07	0.00	0.00	0.00	0.00
Ranunculus circinatus	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70
Rumex acetosa	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.00
Rumex sp.	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Salicornia europaea	A	F	IV	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00
Salsola aucheri	A	F	N	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salsola turkomanica	P	S	IV	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	0.00	0.00
Salvia sp.	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Sambucus nigra	P	S	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00
Sanguisorba minor	P	F	I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00
Scandix aucheri	A	F	N	0.00	0.00	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scorzonera fruticosa	P	F	N	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Secale montanum	P	G	II	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sedum sp.	P	F	N	0.07	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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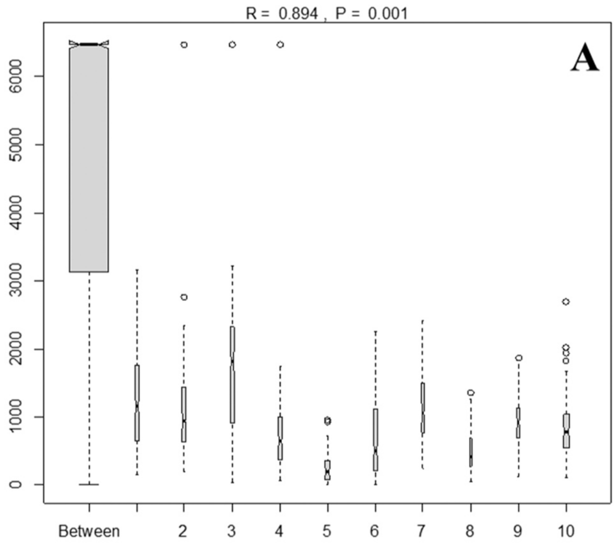
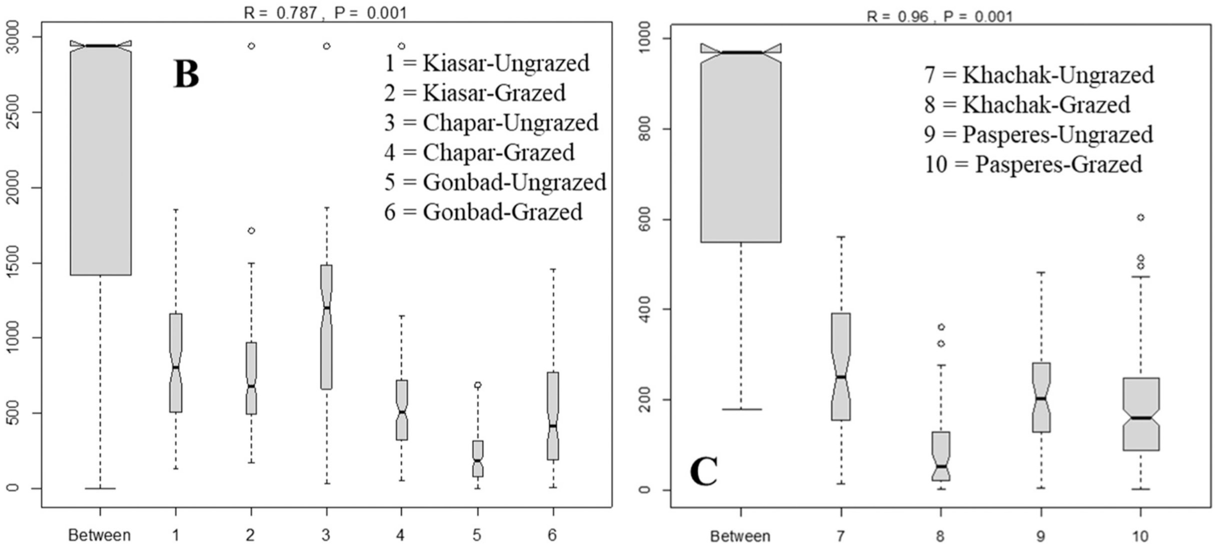
Region				Kiasar		Chapar		Gonbad		Khachak		Pasperes	
Grazing treatment	Life span	Life form	Platability index	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed	Ungrazed	Grazed
Setaria viridis	A	G	N	0.00	0.00	0.07	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Silene latifolia	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.40	0.05
Sinapis arvensis	A	F	N	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sinapis olympica	A	F	N	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sonchus oleraceus	A	F	N	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Spergularia diandra	A	F	N	0.00	0.00	0.07	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Stachys byzantina	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.90	0.00	1.35
Stachys inflata	P	F	III	1.13	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stachys laxa	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.60	3.40	0.00	0.00
Stachys persica	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.65
Stachys turcomanica	P	F	N	0.27	2.07	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00
Stipa hohenackeri	P	G	II	7.93	1.00	0.00	0.00	0.00	0.00	2.30	0.00	0.00	0.00
Taraxacum montanum	P	F	N	0.13	0.67	0.00	0.00	0.00	0.00	0.30	5.70	0.00	0.00
Taraxacum neospurium	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65
Taraxacum officinale	P	F	N	0.00	0.00	0.13	0.07	0.20	0.20	0.00	0.00	0.00	0.00
Taraxacum serotinum	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Teucrium polium	P	S	III	0.40	0.87	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00
Torilis arvensis	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.10
Torilis radiata	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.05
Tournefortia sibirica	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.10
Tragopogon acanthocarpus	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00
Trifolium pratense	P	F	I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
Trifolium repens	P	F	I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.40	**2.50**
Trigonella monspeliaca	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15
Trisetum flavescens	P	G	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.25
Urtica dioica	P	F	IV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.05
Valerianella uncinata	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.10
Verbascum aucheri	A	F	III	0.00	0.07	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00
Verbascum sp.	A	F	III	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70	0.20
Veronica persica	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
Vicia hirsuta	A	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.40	0.00
Viola odorata	P	F	N	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75
Ziziphora clinopodioides	P	F	N	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ziziphora tenuior	A	F	N	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total cover				51.93	24.80	65.00	26.13	34.20	30.27	30.70	76.36	52.40	28.75
Total richness				43	35	32	21	14	13	29	22	50	64

Appendix 2. Analysis of vegetation composition dissimilarities using permutation tests (*anosim* function in the vegan package for R), comparing grazing treatments across region plots in northern Iran. (A) shows visual differences between ten groups (grazed and ungrazed areas in five regions) divided into graphs for three regions (B) and two other regions (C). The Table shows the quantiles of the permutation distribution. Axis Y shows the number of permutations



	0%	25%	50%	75%	100%	N
Between	1.0	3129.0	6482.5	6482.5	6482.5	8775
1	140.0	644.5	1161.0	1753.5	3157.5	105
2	182.5	627.0	939.5	1447.5	6482.5	105
3	34.0	908.0	1815.0	2318.5	6482.5	105
4	54.0	372.0	646.0	1005.0	6482.5	105
5	2.0	79.0	195.0	365.5	955.0	105
6	6.0	201.5	506.5	1106.5	2256.0	105
7	241.5	765.0	1051.5	1496.5	2425.0	45
8	45.0	270.0	418.0	687.5	1352.0	45
9	119.5	689.5	911.5	1126.5	1868.0	45
10	106.0	538.0	787.5	1046.5	2695.0	190



Data availability

Data will be made available on request.

References

Anderson, M.J., Crist, T.O., Chase, J.M., 2011. Navigating the multiple meanings of diversity: a roadmap for the practicing ecologist. Ecol. Lett. 14, 19–28.

Ariza, C., Tielbörger, K., 2011. An evolutionary approach to studying the relative importance of plant–plant interactions along environmental gradients. Func. Ecol. 25, 932–942.

Bakhshi, J., Javadi, S.A., Tavili, A., Arzani, H., 2020. Study on the effects of different levels of grazing and exclosure on vegetation and soil properties in semi-arid rangelands of Iran. Acta Ecol. Sin. 11, 425–431.

Bolker, B.M., Brooks, M.E., Clark, C.J., Geange, S.W., Poulsen, J.R., Stevens, M.H.H., White, J.S.S., 2008. Generalized linear mixed models: a practical guide for ecology and evolution. Trends Ecol. Evol. 24, 127–135.
Booker, K., Huntsinger, L., Bartolome, J.W., 2013. What can ecological science tell us about opportunities for carbon sequestration on arid rangelands in the United States? Glob. Environ. Change 23, 240–251.
Cheng, Y., Li, D., Maaroufi, N.I., You, J., Zhou, W., 2025. Environmental filtering effect drivesthe plant species distribution in alpine grasslands on the Qinghai-Tibetan Plateau. Ecol. Evol. 15, e71599.
Díaz, S., Noy-Meir, I., Cabido, M., 2001. Can grazing response of herbaceous plants be predicted from simple vegetative traits? J. Appl. Ecol. 38, 497–508.
Dupre, C., Diekman, M., 2001. Differences in species richness and life-history traits between grazed and abandoned grasslands in southern Sweden. Ecography 24, 275–286.
Eichberg, C., Donath, T.W., 2018. Sheep trampling on surface-lying seeds improves seedling recruitment in open sand ecosystems. Restor. Ecol. 26, 11–19.
Erfanzadeha, R., Kamali, P., Ghelichnia, H., Pétillon, J., 2016. Effect of grazing removal on aboveground vegetation and soil seed bank composition in sub-alpine grasslands of northern Iran. Plant Ecol. Divers 9, 309–320.
Filazzola, A., Brown, C., Dettlaff, M.A., Batbaatar, A., Grenke, J., Bao, T., 2020. The effects of livestock grazing on biodiversity are multi-trophic: a meta-analysis. Ecol. Lett. 23, 1298–1309.
Gao, J., Carmel, Y., 2020. Can the intermediate disturbance hypothesis explain grazing–diversity relations at a global scale? OIKOS 129, 493–502.
Gebremedhn, H., Ndiaye, O., Mensah, S., Fassinou, C., Taugourdeau, S., Tagesson, T., 2023. Grazing effects on vegetation dynamics in the savannah ecosystems of the Sahel. Ecol. Process 12, 54.
Grime, J.P., 2001. Plant strategies, vegetation processes, and ecosystem properties, 2nd. ed. Wiley, New York, NY, US.
Haghiyan, I., Nejatiyanpour, E., 2021. Energy efficiency and productivity in traditional herding in semi-steppe rangeland (case study: Kalat Rangelands, North-east of Iran). Acta Ecol. Sin. 41, 336–340.
Hallikma, T., Tali, K., Melts, I., Heinsoo, K., 2023. How is plant biodiversity inside grassland type related to economic and ecosystem services: an estonian case study. Agric. Ecosyst. Environ. 349, 108429.
Hao, M., Corral-Rivas, J., González-Elizondo, M.S., Ganeshaiah, K.N., Nava-Miranda, M.G., Zhang, C., 2019. Assessing biological dissimilarities between five forest communities. For. Ecosyst. 6, 30.
Hazhir, Sh, Erfanzadeh, R., Ghelichnia, H., Razavi, B.S., Török, P., 2024. Effects of livestock grazing on soil seed banks vary between regions with different climates. Agric. Ecosyst. Environ. 364, 108901.
He, X., Arif, M., Zheng, J., Ni, X., Yuan, Z., Zhu, Q., et al., 2023. Plant diversity patterns along an elevation gradient: the relative impact of environmental and spatial variation on plant diversity and assembly in arid and semi-arid regions. Front. Environ. Sci. 11, 1021157.
Heady, H.F., Child, R.D., 1994. Rangeland ecology and management. Westview Press, Boulder (CO).
Heinsoo, K., Sammul, M., Kukk, T., Kull, T., Melts, I., 2020. The long-term recovery of a moderately fertilised semi-natural grassland. Agric. Ecosyst. Environ. 289, 106744.
Helm, A., Zobel, M., Moles, A.T., Szava-Kovats, R., Pärtel, M., 2015. Characteristic and derived diversity: implementing the species pool concept to quantify conservation condition of habitats. Divers. Distrib. 21, 711–721.
Hill, M.O., 1973. Diversity and evenness: a unifying notation and its consequences. Ecology 54, 427–473.
Hobbs, R.J., Huenneke, L.F., 1992. Disturbance, diversity and invasion: implications for conservation. Conserv. Biol. 6, 324–337.
Hutchings, M.J., 2010. The population biology of the early spider orchid Ophrys sphegodes Mill. III. Demography over three decades. J. Ecol. 98, 867–878.
Johansen, L., Wehn, S., Hovstad, K.A., 2016. Clonal growth buffers the effect of grazing management on the population growth rate of a perennial grassland herb. Flora 223, 11–18.
Karatassiou, M., Parissi, Z.,M., Panajiotidis, S., Stergiou, A., 2022. Impact of grazing on diversity of semi-arid rangelands in Crete Island in the context of climatic change. Plants 11 (7), 982.
Karimian, V., Jahantab, E., Farzin, M., Golzar, E., 2018. An overview of the Atriplex lentiformis cultivation history and evaluate the reasons for lacks of its natural regeneration. 7th National Conference in Rangelands and Range Management in Iran. Kalak, Alborz, Iran.
Köse, M., Liira, J., Tali, K., 2019. Long-term effect of different management regimes on the survival and population structure of Gladiolus imbricatus in Estonian coastal meadows. Glob. Ecol. Conserv 20, e00761.
Lal, R., Kimble, J.M., Foliel, R.F., Stewart, B.A., 2001. Assessment methods for soil carbon advance in soil science, 1st Edn. CRC Press, Boca Raton. FL. ISBN: 9781566704618.
Li, L., Liu, J., Luo, Y., Sun, Y., Zhang, J., Wang, T., Zhu, N., Bao, Y., Xu, N., Yan, Y., 2025. Grazing-induced enhancement of shrub 'multifunctional island' effect is associated with altered soil bacterial β diversity in shrub-encroached grasslands. J. Appl. Ecol. https://doi.org/10.1111/1365-2664.70025.
Li, M., Wang, L., Li, J., Peng, Z., Wang, L., Zhang, X., 2022. Grazing exclusion had greater effects than nitrogen addition on soil and plant community in a desert steppe, Northwest of China. BMC Plant Biol. 22, 60.
Li, Y., Zhao, X., Chen, Y., Luo, Y., Wang, S., 2012. Effects of grazing exclusion on carbon sequestration and the associated vegetation and soil characteristics at a semi-arid desertified sandy site in Inner Mongolia, northern China. Can. J. Soil Sci. 92, 807–819.
Ludvikova, V., Pavlu, V.V., Gaisler, J., Hejcman, M., Pavlu, L., 2014. Long term defoliation by cattle grazing with and without trampling differently affects soil penetration resistance and plant species composition in *Agrostis capillaris* grassland. Agric. Ecosyst. Environ. 197, 204–211.
Magurran, A., 2004. Measuring Biological Diversity. Blackwell, Oxford.
Marco, D.E., Páez, S.A., 2000. Soil seed banks on Argentine seminatural mountain grasslands after cessation of grazing. Mt. Res. Dev. 20, 254–261.
Metera, E., Sakowski, T., Słoniewski, K., Romanowicz, B., 2010. Grazing as a tool to maintain biodiversity of grassland-a review. Anim. Sci. Pap. Rep. 28, 315–334.
Milazzo, F., Francksen, R.M., Abdalla, M., 2023. An Overview of Permanent Grassland Grazing Management Practices and the Impacts on Principal Soil Quality Indicators. Agronomy 13 (5), 1366.
Molvar, E.M., Rosentreter, R., Mansfield, D., Anderson, G.M., 2024. Cheatgrass invasions: History, causes, consequences, and solutions. Western Watersheds Project, Hailey, ID, p. 128.
Mozaffarian, V., 1998. Dictionary of Iranian plant names: Latin-English-Persian. Mazda Publisher, Tehran, Iran.
Munkhzul, O., Oyundelger, K., Narantuya, N., Tuvshintogtokh, I., Oyuntsetseg, B., Wesche, K., Jäschke, Y., 2021. Grazing effects on Mongolian steppe vegetation- A systematic review of local literature. Front. Ecol. Evol. 9, 703220.
Nakano, T., Bavuudorj, G., Iijima, Y., Ito, T.Y., 2020. Quantitative evaluation of grazing effect on nomadically grazed grassland ecosystems by using time-lapse cameras. Agric. Ecosyst. Environ. 287, 106685.
Niu, W., Ding, J., Fu, B., Zhao, W., Eldridge, D., 2025. Global effects of livestock grazing on ecosystem functions vary with grazing management and environment. Agric. Ecosyst. Environ. 378, 109296.
Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., Minchin, P.R., O'Hara, R.B., Simpson, G.L., Solymos, P., Stevens, M.H.H., Szoecs, E., Wagner, H., 2019. Vegan: Community Ecology Package. R. Package Version 2.5–5. ⟨https://CRAN.R-project.org/package=vegan⟩.
Oliván, M., Osoro, K., 1998. Foraging behaviour of grazing ruminants in rangelands. In: Riordan, E.G.O. (Ed.), Pasture ecology and animal intake (Keane MG. Teagasc, Meath, Ireland, pp. 110–126.
Osem, Y., Perevolotsky, A., Kigel, J., 2004. Site productivity and plant size explain the response of annual species to grazing exclusion in a Mediterranean semi-arid rangeland. J. Ecol. 92, 297–309.
Pricope, N.G., Husak, G., Lopez-Carr, D., 2013. The climate-population nexus in the East African Horn: emerging degradation trends in rangeland and pastoral livelihood zones. Glob. Environ. Change 23, 1525–1541.
R Core Team. 2025. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL ⟨http://www.R-project.org⟩.

Rahmanian, S., Hejda, M., Ejtehadi, H., Farzam, M., Memariani, F., Pysek, P., 2019. Effects of livestock grazing on soil, plant functional diversity, and ecological traits vary between regions with different climates in northeastern Iran. Ecol. Evol. 9, 8225–8237.
Rechinger, K.H., 1964. Flora Iranica, Akademische Druck-und Verlagsanstalt Graz. Iran: University of Tehran.
Savari, M., 2023. Explaining the ranchers' behavior of rangeland conservation in western Iran. Front. Psychol. 13, 1090723.
Soltanipoor, M., Nateghi, S., Hajebi, A., Souri, M., 2022. The allowable use of Desmostachya bipinnata, Halocnemum strobilaceum and Aeluropus lagopoides in Zaminsang Region of Hormozgan province. Iran. J. Range Desert Res. 29, 145–155.
Sun, Y., Jia, W., Guo, H., Zhang, X., Wang, F., Zhao, H., Li, T., Zhao, Z., 2023. Comparison of global and local Poisson models for the number of recruitment trees in natural forests. Forests 14 (4), 739.
Sun, Y., Sun, Y., Yao, S., et al., 2021. Impact of climate change on plant species richness across drylands in China: from past to present and into the future. Ecol. Indic. 132, 108288.
Taheri, S., Zerehdaran, S., Javadmanesh, A., 2022. Genetic diversity in some domestic and wild sheep and goats in Iran. Small Rumin. Res. 209, 106641.
Tahmasebi Kohyani, P., Bossuyt, B., Bonte, D., Hoffmann, M., 2008. Importance of grazing and soil acidity for plant community composition and trait characterisation in coastal dune grasslands. Appl. Veg. Sci. 11, 179–186.
Tilman, D., 1988. Plant strategies and the dynamics and structure of plant communities. Monographs in Population Biology. Princeton University Press, Princeton, NJ, US.
Török, P., Hölzel, N., van Diggelen, R., Tischew, S., 2016. Grazing in European open landscapes: how to reconcile sustainable land management and biodiversity conservation? Agric. Ecosyst. Environ. 234, 1–4.
Török, P., Lindborg, R., Eldridge, D., Pakeman, R., 2024. Grazing effects on vegetation: biodiversity, management, and restoration. Appl. Veg. Sci. 27, e12794.
Tóth, E., Deák, B., Valkó, O., Kelemen, A., Miglécz, T., Tóthmérész, B., Török, P., 2018. Livestock type is more crucial than grazing intensity: Traditional cattle and sheep grazing in short-grass steppes. Land Degrad. Dev. 29, 231–239.
Valko, O., Venn, S., Zmihorski, M., Biurrun, I., Labadessa, R., Loos, J., 2018. The challenge of abandonment for the sustainable management of Palaearctic natural and semi-natural grasslands. Hacquetia 17, 5–16.
Varzinczak, L.H., Lima, C.S., Moura, M.O., Passos, F.C., 2018. Relative influence of spatial over environmental and historical processes on the taxonomic and phylogenetic beta diversity of Neotropical phyllostomid bat assemblages. J. Biogeogr. 45, 617–627.
Wagg, C., Roscher, C., Weigelt, A., et al., 2022. Biodiversity–stability relationships strengthen over time in a long-term grassland experiment. Nat. Commun. 13, 7752.
Wang, H., Li, X., Pang, C., Chen, H.Y.H., He, Y., Tao, T., Gao, Y., Zhu, W., Liu, H., Xu, J., Chen, Z., Li, Y., Sun, X., 2025. Contrasting effects of short- and long-term grazing exclusion on plant diversity in humid grasslands. Agric. Ecosyst. Environ. 381, 109420.
Wang, D., Zhang, Y.T., Chen, C.Y., Chen, R.X., Bai, X.C., Qiang, Z.Q., 2023. The genetic variation in drought resistance in eighteen perennial ryegrass varieties and the underlying adaptation mechanisms. BMC Plant Biol. 23, 451.
Wu, Y., Du, Y., Liu, X., Wan, X., Yin, B., Hao, Y., Wang, Y., 2023. Grassland biodiversity response to livestock grazing, productivity, and climate varies across biome components and diversity measurements. Sci. Total Environ. 878, 162994.
Xiang, M., Wu, J., Duo, L., Niu, B., Zhang, X., 2023. The effects of grazing and fencing on grassland productivity and diversity in alpine grassland ecosystem in the Tibetan highland. Glob. Ecol. Conserv 44, e02495.
Xiang, M., Wu, J., Wu, J., Guo, Y., Lha, D., Pan, Y., Zhang, X., 2021. Heavy grazing altered the biodiversity–productivity relationship of alpine grasslands in Lhasa River Valley, Tibet. Front. Ecol. Evol. 9, 698707.
Zandi, L., Erfanzadeh, R., Joneidi Jafari, H., 2017. Rangeland use change to agriculture has different effects on soil organic matter fractions depending on the type of cultivation. Land Degrad. Dev. 28, 175–180.
Zanella, P.G., Giustina Junior, L.H.P.D., Pinto, C.E., Baldissera, T.C., Werner, S.S., Garagorry, F.C., Jaurena, M., Lattanzi, F.A., Sbrissia, A.F., 2021. Grazing intensity drives plant diversity but does not affect forage production in a natural grassland dominated by the tussock-forming grass Andropogon lateralis Nees. Sci. Rep. 11, 16744.
Zhang, M., Delgado-Baquerizo, M., Li, G., et al., 2023. Experimental impacts of grazing on grassland biodiversity and function are explained by aridity. Nat. Commun. 14, 5040.
Zhao, J., Luo, T., Li, R., Li, X., Tian, L., 2016. Grazing effect on growing season ecosystem respiration and its temperature sensitivity in alpine grasslands along a large altitudinal gradient on the central Tibetan Plateau. Agric. For. Meteorol. 218, 114–121.
Zhu, L., Chen, T., Chen, X., Liu, S., Zhou, S., Wang, S., Li, W., 2025. Investigation of the Key Drivers of Vegetation Change Based on a Paired Land Use Experiment Approach-A Case Study of the Emin River Transboundary Basin. Land 14 (2), 437.