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Benefits of Short-Duration, High-Stocking Rate Opportunistic Grazing on Arid Rangelands During Favorable Conditions

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The aim of this study was to assess the impact of short grazing periods with high-stocking density on vegetation during weather conditions favorable to plant growth. Continuous grazing is widely practiced in Tunisian arid rangelands and across most drylands and deserts of the Middle East and North Africa. In the early 1990s, the Tunisian government combined a variety of incentives and restrictions on rangeland grazing practices and initiated a national strategy for rangeland improvement. The strategy emphasizes grazing exclusion for three consecutive years, a practice known locally as *gdel*. At the end of this period, grazing is allowed with no restrictions or with some guidelines. However, these regulations created discontent among pastoral communities, mainly when local rainfall conditions result in a considerable quantity of green biomass. High stocking-density grazing for a short period would help satisfy pastoralist concerns and achieve the government's strategic goal. This study was implemented in three arid rangeland types of southern Tunisia that have been under restricted grazing for 2 years. Each area in the study was grazed for short periods in late May (about 7 days) with a flock of 150 head of sheep. Measurements of vegetation cover, forage productivity, density, and species richness were taken before and after grazing. Our results suggest that perennial vegetation is more stable under grazing than annual vegetation. The presence of annual species would enhance rangeland vegetation cover and diversity and at the same time offers an opportunity for livestock to select a high-quality diet rich in protein. Opportunistic grazing, applied to heterogeneous rangelands in late spring and the beginning of the annual temperature increase, encouraged animals to select annual plants due to their higher palatability, higher digestibility, and water content rather than heavily grazing perennial species. Perennial biomass materials that die and do not fall through rapid biological decay tended to decline with increased period of placement, resulting in further oxidation to CO_2 which affects photosynthetic performance negatively and may eventually cause plant death. Trampling from high-density stocking enhances the litterfall rates and removes the oxidized plant material. These findings may contribute to strategies for addressing the extreme climatic variations that threaten rangeland and livestock sustainability.

Keywords: grazing exclusion, spring grazing, stocking rate, rapid grazing, gdel

INTRODUCTION

Rangelands cover nearly 45% of the world's land area (Squires et al., 2018). As a common resource, they are mainly used for livestock grazing supporting 50% of the world's livestock and 78% of global grazing area (Asner et al., 2004; MEA, 2005; Creamer and Horback, 2021). Despite the vital role of rangelands in sustaining the livelihoods of rural people, they are subject to human and climate drivers that can result in reduced production (Jama and Zeila, 2005; Ouled Belgacem and Louhaichi, 2013). Rangelands are especially vulnerable as semi-arid ecosystems experience extreme stress associated with low rainfall (Gamoun, 2016), prolonged periods of drought (Köchy et al., 2008; Gamoun et al., 2011), poor soil fertility, mismanagement, and other human-induced activities (Hanafi and Jauffret, 2008; Vetter, 2009; Zhou et al., 2013). All these factors negatively impact rangeland plant communities (Ouled Belgacem et al., 2013; Belgacem et al., 2019) and lead to changes in soil-plant-water dynamics (Fay et al., 2008; Heisler-White et al., 2009), sparse vegetation, and increases in the spread of invasive species (McNeely, 2004; Wang et al., 2018).

Rangelands offer habitats for wildlife and provide multiple goods and services of economic value (Yu et al., 2010). However, as rangelands become degraded, their potential to provide these services diminishes (Favretto et al., 2016). Overgrazing remains the primary anthropogenic factor impacting arid and semi-arid vegetation (Smet and Ward, 2005; Gamoun, 2013; Louhaichi et al., 2019). Associated with overstocking and drought, overgrazing further contributes to degradation resulting in reduction in biodiversity and rangeland productivity (Harris, 2010; Squires, 2010; Teague et al., 2011; Gamoun et al., 2016).

The impact of grazing on rangelands depends mainly on its intensity and timing (Holechek et al., 1998; Henkin et al., 2007). For example, light to moderate grazing may not affect productivity or species richness while heavy grazing often reduces vegetation by preferential removal of the more palatable species preferred by grazing animals (Louhaichi et al., 2009; Schönbach et al., 2009; Gamoun, 2014). Under heavy grazing, shrubs develop very dense small branches that protect their leaves and allow continued plant growth (van Duivenbooden, 1993).

In the late 1960s, the concept of high-stocking-density grazing for short periods was first introduced in North America by Goodloe (1969) and further developed by Savory in the 1980s (Savory, 1978). It quickly became a widely popular but controversial tool for grazing management. In this grazing scheme, a rangeland is divided into several paddocks grazed one at a time, allowing plants enough time to recover (Goodloe, 1969; Savory, 1978; Joseph et al., 2002). Another widespread grazing strategy is herd mobility. Livestock mobility is based on a deep knowledge of rangeland vegetation and is referred to as "opportunistic grazing" (Behnke et al., 1993; Scoones, 1995). This type of grazing management is often independent of stocking density and is guided more by inter-annual rainfall variation. Through their pastoral networks, herders know where the best rangelands are and when to use them (Bassett and Koné, 2006). Eventually, opportunistic grazing formalizes optimal relationships between livestock and the environment (McCabe, 2004) and has proven to be effective in terms of enhancing livestock performance and vegetation productivity (Suttie et al., 2005).

Rangelands in some areas of Tunisia continue to degrade with no restrictions on stocking rate (Belgacem et al., 2019). Their future sustainability will depend on identifying and promoting sustainable rangeland management practices that are environmentally sustainable and socially acceptable to local pastoral communities. Toward this end, the Government of Tunisia launched a national strategy for rangeland improvement in 1990. Since then, thousands of hectares covering natural rangelands, including private and collective lands, have been managed by simply excluding livestock grazing for 3 years. The program has played a paramount role in alleviating pressure on already fragile degraded arid rangelands, especially during dry years. Nevertheless, during years with sufficient rainfall, vegetation response to the wet season is phenomenal, even after only a few months of protection (Sullivan and Rohde, 2002).

Unfortunately, banning livestock grazing for three consecutive years has created conflict between administrations in charge of implementing the strategy and pastoral communities, especially when local rainfall conditions produce a considerable quantity of green biomass suitable for opportunistic livestock grazing.

To improve the current policy and procedures and to allow more flexibility in grazing practices when certain conditions are met, this study was undertaken to assess the effect of short-duration, high-stocking-rate opportunistic grazing on the arid rangelands of southern Tunisia. The findings of this study may prove useful to policymakers who make recommendations to national and international development agencies to enhance livestock production while conserving the natural resource base.

METHODOLOGY

Site Description

Tataouine Governorate is located in the extreme south of Tunisia and 38% of the land area is rangeland (1.5 million ha), which is roughly 27% of the total rangeland area in Tunisia. Rangelands in Tataouine are grazed by more than 1.3 million head of sheep and goats (18% of the total livestock population in Tunisia) with sheep the most dominant species (84.4% sheep, 15.6% goats) and 12,000 head of camels (25% of the total camel population in Tunisia). The study sites were 30 km east of Tataouine. Each site has a dominant plant type. Dominant plant types provide important information about the plant associations growing in one area due to factors that affect their growth and characteristics. This dominant plant species is often used to name the plant community and to indicate the rangelands' site potentials. In this study, the target plant communities were classified as *Anthyllis henoniana, Haloxylon schmittianum,* and *Retama raetam.* Annual precipitation averaged over 80 mm with recorded extremes of 253 mm during 2017–2018 and 120 mm during 2018–2019 (**Figure 1**). Mean daily temperatures in the coldest (January) and warmest (August) months are 11 and 33°C, respectively. The major soils are Regosols and Sierozems. For over half a century, these rangelands have been prone to intense human use contributing to the continued deterioration of natural vegetation such that natural recovery is no longer possible (Jauffret and Visser, 2003).

Methods

The three sampled areas were excluded from livestock grazing for two consecutive years by implementing a resting technique known locally as *gdel* until the first vegetation sampling in May 2019. In desert environments, plants react quickly when heat and moisture trigger blooming. After a rainfall, annual species flower within a few weeks and seed pods burst and expel their seeds before the branches dry out.

Grazing on the study sites began toward the end of spring, just after seed dispersal and before plants began to dry out and become less nutritious for grazing animals. After the first sampling, livestock were allowed to graze for 1 week in late May. Each six-hectare paddock was grazed using a fixed density of 150 head of sheep. Measurements were taken before and after grazing using the line intersect method as described by Daget and Poissonet (1971).

To provide a more detailed understanding of the effects of overgrazing, for each plant community, there was a control site that was subjected to continuous grazing. However, since all these control sites were homogeneous in structure and dominated by different annuals with some perennial species, and due to heavy continuous grazing, the vegetation in these sites becomes sparsely distributed over time, resulting in a pattern of similar vegetation patches alternating with areas of bare soil, which made it difficult to identify reference vegetation types. Three permanent transects (50 m length) were laid randomly within each plant community and control sites. A pin was inserted into the ground at 50-cm intervals along the transect tape. At each of the 100 points on the line, the plant species were recorded. The percentage cover of each plant was obtained by dividing the number of points at which a particular species was encountered by the total number of samples taken for all species and multiplying by 100. Because habitat heterogeneity had a positive influence on species density, annual density was estimated by establishing nine quadrants (each 1 m^2) per plant community and nine were placed in the continuously grazed sites. In sparsely vegetated communities, larger quadrats were required with the possibility of reduction of replication for perennial density measurement. Perennial plant density was determined by counting the number of tufts of each species within three quadrants of 50 m^2 per plant community and three in each continuously grazed site.

In each plant community and continuously grazed site, total botanical composition and species richness were identified and measured by counting the number of species in the area. Plant species cover and the palatability or acceptability index determine rangeland productivity according to the following formula (INRA., 1978):

$$\mathbf{P = 1.5 \sum_{i=0}^{n} SC\textit{i} \times PF\textit{i} \times TPC / 100}$$

where P is total rangeland productivity in forage units or FU/ha/year, SC*i* is the specific cover of species *I* (%), PF*i* is the palatability factor of species *i*, and TPC is the total plant cover (%).

An ANOVA test was performed to determine the effects of the two-grazing systems in each plant community (*A. henoniana, H. schmittianum,* and *R. raetam*) with respect to vegetation cover, plant density, rangeland forage productivity, and species richness. To avoid the incidence of pseudo-replication, the transects and the samples taken inside the quadrats on each plant community and continuous grazing sites were considered as replicates for comparison and the sampling design was spatially autocorrelated as the transects were well spaced and sample locations were spatially separated covering an area of ∼60,000 m^2 for each plant community and continues grazing site (Hurlbert, 1984; Waite, 2000).

RESULTS

Vegetation Cover

Grazing exclusion led to a significant increase in both perennial and annual species cover in all plant communities ($p > 0.05$). Grazing exclusion results in up 2.7, 3.6, and 4.7-fold increase ($p > 0.05$) of perennial species cover in *H. schmittianum*, *A. henoniana,* and *R. raetam* plant communities, respectively, compared to their paired open grazing sites (controls), however, high-density grazing for a short period had no significant effect on the cover of perennial species for all plant communities and the perennials cover remained unchanged compared to before grazing. In the *R. raetam* community, the perennial grass *Cynodon dactylon* was consistently the most abundant species and its contribution to the total cover of perennial species reached 28%.

Compared with open grazing sites (controls), all plant communities exhibited significantly greater annual species cover after 2 years grazing exclusion ($P < 0.05$). Generally, restricted grazing increased the annual spices cover in *A. henoniana, R. raetam,* and *H. schmittianum* plant communities (41, 73, and 74%, respectively) compared with their paired open grazed sites.

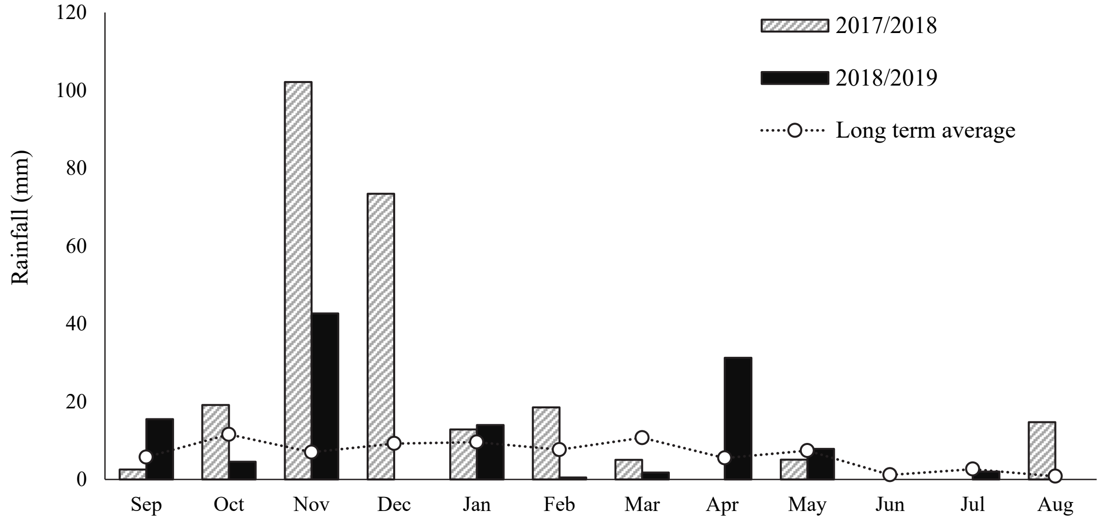

FIGURE 1 | Amount and distribution of rainfall during 2017–2018 and 2018–2019 and the long-term average (20 years) monthly rainfall data in Tataouine, Tunisia.

The cover of annual species after a short period of high-density grazing was significantly lower compared to before grazing for all plant communities ($p < 0.05$). When introducing sheep to graze at a high stocking rate for a short time, they are attracted to annual species. Therefore, the cover of annual species became extremely low in all plant communities, for example, the cover of annual species in the *H. schmittianum* community decreased from 25% before grazing to 1% after grazing which was much less than under continuous grazing *H. schmittianum* control site (**Figure 2**).

Plant Density

After 2-year grazing exclusion, the values of the density of perennial species in *H. schmittianum, A. henoniana,* and *R. raetam* plant communities were 4, 6, and 9 plant m^{-2} respectively, and were significantly greater than those in their paired continuous grazing sites (controls) 1, 1, and 2 plant m^{-2} ($P < 0.05$). Moreover, the density of perennial species was not affected by high-density grazing for a short period and did not differ before and after grazing in all plant communities.

Annual species density increased significantly after 2-year grazing exclusion in all plant community sites. *H. schmittianum*, and *R. raetam* plant communities' annual species density was substantially higher 28 plant m^{-2} in a 2-year grazing exclusion sites than in their paired continuous grazing sites (controls) 7 plant m^{-2}. Similarly, grazing exclusion increased the annual density in *A. henoniana* plant community from 7 plant m^{-2} in continuous grazing site to 9 plant m^{-2} in grazing-excluded site. However, high-density grazing for a short period significantly affected the annual species density compared to before grazing in all plant communities. For example, the annual density in the *H. schmittianum* community decreased from 29 plant m^{-2} before grazing to 3 plant m^{-2} species after high-density grazing for a short period, while the annual density in continuous grazing site was 7 plant m^{-2} (**Figure 3**).

Rangeland Forage Productivity

Forage productivity varied significantly among plant community types and grazing systems ($p < 0.05$). Yet, there was no significant interaction between grazing systems and plant community types ($p = 0.363$). The forage productivity was notably higher after 2-year grazing exclusion of all plant communities than those continuous grazing sites. Forage productivity was the highest at *R. raetam* plant community, followed by *A. henoniana* plant community. Accordingly, *R. raetam* forage productivity of grazing-excluded site (341 FU/ha/year) was significantly higher compared to that of continuous grazing site (31 FU/ha/year). In *A. henoniana* plant community, mean forage productivity of grazing-excluded site was approximately 87% higher than that of continuous grazing site (control). Nevertheless, although forage productivity of all plant communities has seen a slight decline, the high-density grazing for a short period had no significant effect on rangeland forage productivity. In spite of the significantly higher stocking rate combined with the short-duration grazing system, *R. raetam* community recorded higher forage productivity at 274 FU/ha/year compared to other plant communities before and after grazing (**Figures 4**, **5**).

Species Richness

Species richness of perennial species did differ greatly among plant community types. The highest proportion of species richness of perennial species was recorded in *A. henoniana,* followed by *R. raetam* (**Figure 6**). Grazing exclusion increased species richness in all plant community sites and had a positive effect on number of perennial species. The differences in perennial species richness between grazing-excluded sites and continuous grazing sites (controls) recorded 12, 8, and 3 species in *A. henoniana, R. raetam,* and *H. schmittianum* plant communities, respectively,

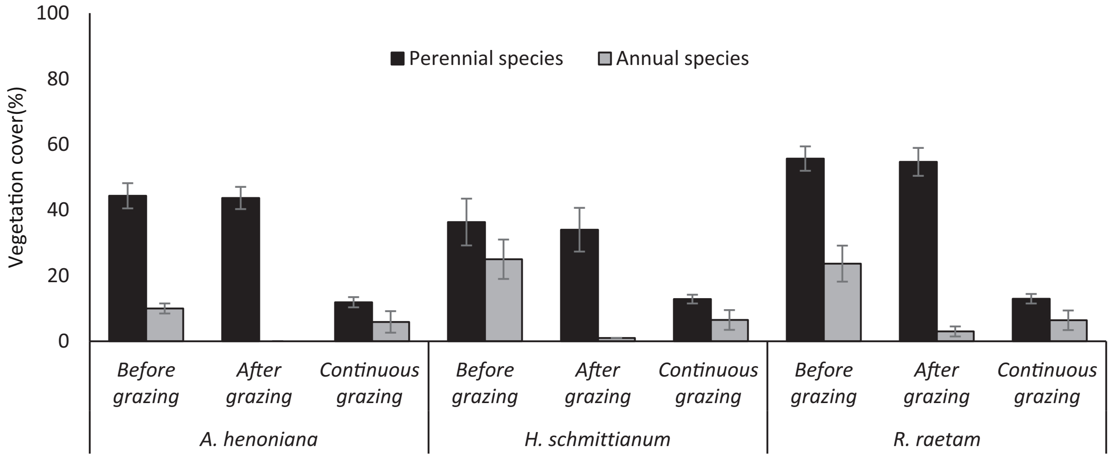

FIGURE 2 | Mean percentage of perennial and annual species vegetation cover in 2 years protected plant communities (*A. henoniana, H. schmittianum*, and *R. raetam*) sites before and after subjecting to 1 week of intense grazing compared to continuous grazing sites in Tataouine, Tunisia.

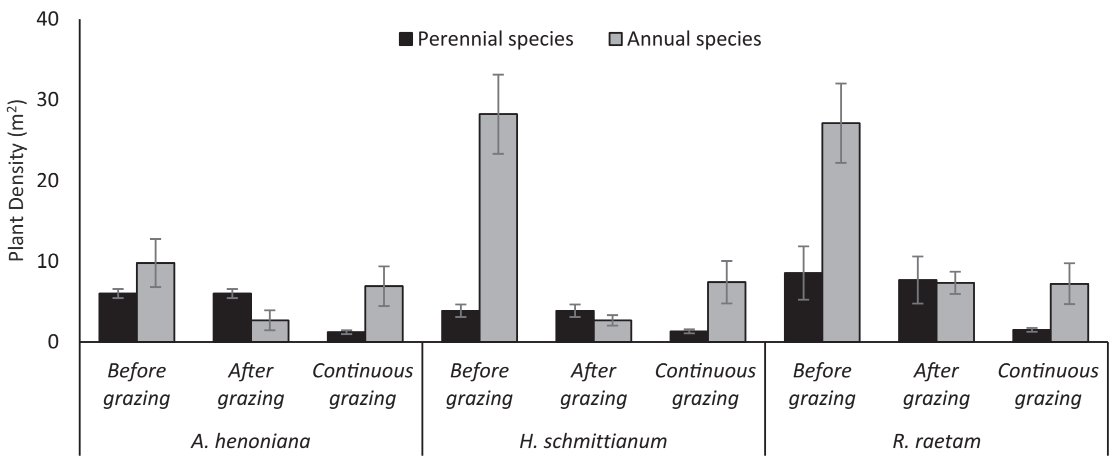

FIGURE 3 | Perennial and annual species density in 2 years protected plant communities (*A. henoniana, H. schmittianum*, and *R. raetam*) sites before and after subjecting to 1 week of intense grazing compared to continuous grazing sites in Tataouine, Tunisia.

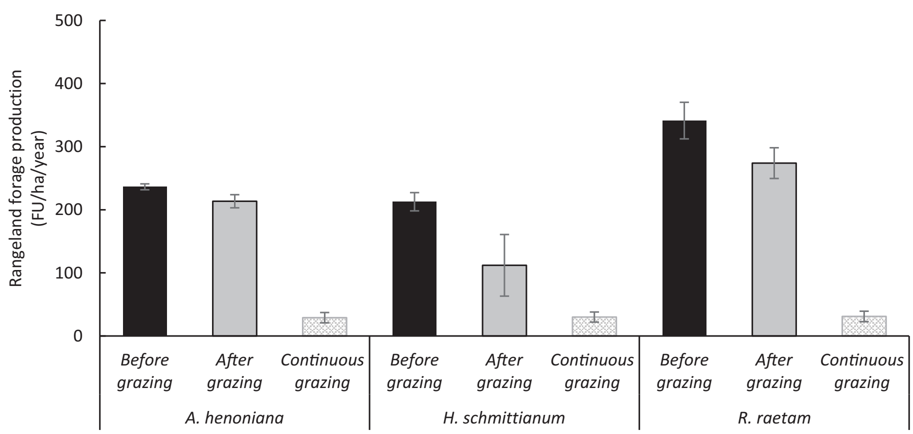

FIGURE 4 | Rangeland forage productivity (FU/ha/year) in 2 years protected plant communities (*A. henoniana, H. schmittianum*, and *R. raetam*) sites before and after subjecting to 1 week of intense grazing compared to continuous grazing sites in Tataouine, Tunisia.

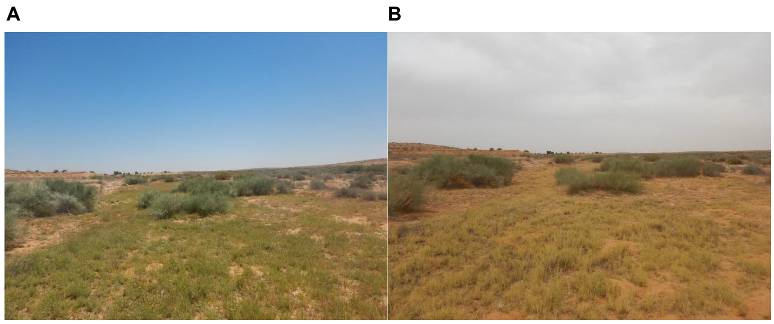

FIGURE 5 | Perennial grass (*Cynodon dactylon*) conditions before **(A)** and after **(B)** 1-week intense grazing in Tataouine, Tunisia.

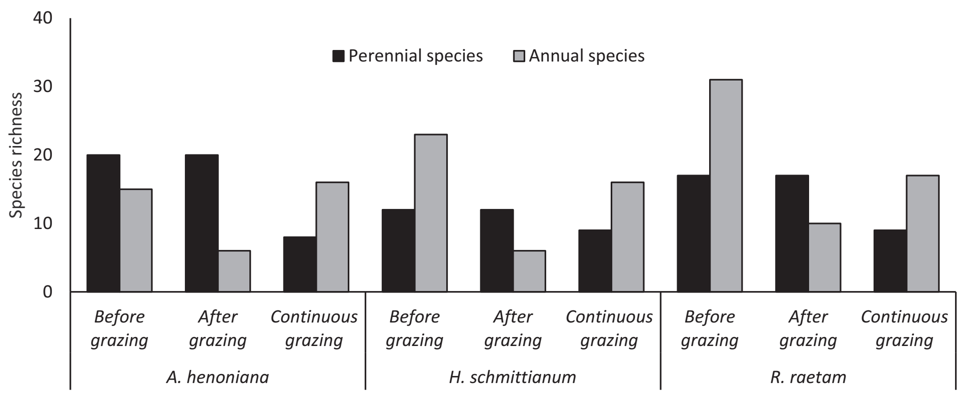

FIGURE 6 | Species richness of perennial and annual species in 2 years protected plant communities (*A. henoniana, H. schmittianum, and R. raetam*) sites before and after subjecting to 1 week of intense grazing compared to continuous grazing sites in Tataouine, Tunisia.

(**Supplementary Appendices 1, 2**). In contrast, high-density grazing for a short period did not affect species richness of perennial species for all plant communities either positively or negatively.

The species richness of annual plants was affected significantly among plant community types and grazing systems (**Figure 6**). The annual vegetation was highly diverse in the *R. raetam* community, with 31 species identified before livestock grazing followed by *H. schmittianum* and *A. henoniana* (22 and 15 species respectively; **Supplementary Appendix 3**). The grazing exclusion increased the annual species numbers in *R. raetam* and *H. schmittianum* by 14 and 7 annual species when compared with their paired continuous grazing sites (controls). However, *A. henoniana* annual species number remained the same in both grazing-excluded site and continuous grazing site (control) without any hint of an exclosure effect (**Figure 6**). Compared to continuous grazing, annual plants were more sensitive and vulnerable to high-density grazing for a short period. This practice decreased the proportion of annual species. The annual vegetation diverse decreased in the *R. raetam* community to 10 species and to six annual species in both *A. henoniana* and *H. schmittianum* plant communities after livestock grazing at high stock-density for a short period (**Supplementary Appendix 3**).

DISCUSSION

Rangeland management strategies can be used as a tool to improve sustainability (Louhaichi et al., 2019, 2021a). A growing number of studies have shown the positive contributions of grazing and how it can be a cost-effective practice for enhancing productivity, species diversity, and ecosystem health (Hodgson et al., 2005; Dorrough et al., 2007; Kohyani et al., 2008). This study highlighted the effects of a short period of high-density grazing on vegetation cover, rangeland productivity, plant density, and species richness. As found in previous studies, these results showed that continuous grazing was linked with poor rangeland conditions, scattered vegetation, low forage productivity, and a low level of diversity.

Grazing livestock at a high density for a short period provides different results in late spring. Under intensive short-duration grazing, there were no effects on perennial shrub species but a high reduction in annual species. The abundance of annuals increased rapidly during spring in the rested (protected) areas. During late spiring period, grazing animals focus mainly on annuals and rarely select woody species, particularly if they are less palatable. Allowing animals to browse the leaves of perennial species does not retard plant growth because they retain the capacity to provide enough energy for further growth and strengthening their root system reserves (Le Floc'h, 2001).

In general, green forage in late spring is high quality, particularly for annual plants. As summer progresses and temperatures increases, herbaceous plants begin to dry out and lose nutritional value. As plant growth progresses, high forage-quality indicators such as protein, energy, vitamins, and minerals decline. As forage plants mature, indicators of low quality or feed value such as fiber and lignin increase (George et al., 2001). The digestibility of annual plants declines with progression through flowering to seed-set and senescence (Kemp and Michalk, 1993), although Louhaichi et al. (2021b) found that the indigenous Tunisian range species contain high nutritional value due to moderate to high protein, low fiber, and high digestibility content and can be used as feed for livestock to enhance local livestock production and contribute to economic development.

For rangelands rested for 2 years, late spring grazing at high-density stocking rates for a short period had no effect on cover, density, and richness of perennial species. Delayed grazing after maturation of forage species and seed dispersal in late spring provides an opportunity for flash-grazing annual species. Skipping woody and perennial species provides an opportunity for selective grazing of annual species. It is well known that sheep are more selective of annual and herbaceous species in their diet than goats for example, which are more likely to browse perennial species (Yiakoulaki and Papanastasis, 2005).

The grazing regimes in this experiment were not detrimental to rangeland productivity because they reduced selectivity, which encouraged the growth of palatable species and enhanced rangeland diversity. Martin (1975) also reported that heavy grazing for a short period results in a more even use of forage, both from place to place and among different species. The grazing and trampling resulting from high-density grazing for a short period did not favor perennial over annual species. This is important because long-term sustained rangeland productivity is strongly dependent on conserving key perennial vegetation (Curry and Hacker, 1990). Grazing and trampling can improve rangeland conditions and plants may stay upright for a long time by removing accumulated dead forage due to senescence or disturbances such as drought and heavy grazing (Heukes and Cowling, 2000). A few months of rest immediately after each period of late spring-early summer grazing can be expected to reduce the effect of intensity of grazing and regrazing on favored plants in the spring.

The critical timing for high-intensity, short-duration grazing may vary from year to year and is influenced by multiple factors, including precipitation, temperature, and vegetation type. Therefore, it is important to base grazing plans on the state of the vegetation cover rather than simply on the length of resting times. This result supports findings highlighting the need for flexible grazing management depending on weather and climate variability (Louhaichi et al., 2021a) and offers an opportunity to develop grazing strategies that exploit these results.

CONCLUSION

The current national rangeland improvement programs simply ban livestock grazing for a minimum duration of 3 years at a time when sources of supplementary feed to fill feed-gap periods are expensive and where animal demand exceeds rangelands supply. During rainy years, the vegetation response is impressive. Such positive responses do not occur every year as the most common scenario under arid conditions is recurrent drought. Therefore, it would be a lost opportunity for pastoral communities if they are not allowed to use this abundant and rich biomass. From this perspective, development agencies have been keen to revise and update projects and programs for a more flexible approach linking administration with end-user needs based on scientific evidence. The suggested grazing scheme in this study produced satisfactory results compared to protected sites (livestock exclusion) or continuous grazing (control). These findings have implications for the health of the arid rangelands of Tunisia and the livelihoods of pastoral communities. Properly managed, arid rangelands can provide sustainable forage resources that reduce feeding costs and enhance livestock productivity. The findings of this pilot study may offer evidence for designing approaches that could be scaled out to other regions, such as the Middle East and North Africa.

DATA AVAILABILITY STATEMENT

The data analyzed in this study are subject to the following licenses/restrictions: Data are restricted for 5 years. Requests to access these datasets should be directed to ML, m.louhaichi@cgiar.org.

AUTHOR CONTRIBUTIONS

ML and MG conceptualized the study, did a general literature review, led the formal analysis, and contributed to writing manuscript drafts and revisions. MG and FG collected the data. ML acquired research funding. All authors have read and agreed to the published version of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2021.757764/full#supplementary-material

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