Rangeland Biodiversity and Climate Variability

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Rangeland biodiversity related closely with climate variability. Rainfall plays an important role in arid rangeland restoration. Under favorable conditions, one-year grazing exclusion considerably enhanced species richness and evenness diversity compared to longer resting durations under dry to average rainfall conditions. The decision to how long livestock grazing exclusion would last should not be decided upfront as it depends on the climatic and the site-specific conditions.

Keywords: Hill's diversity ; Tunisia ; plant community ; climate variability ; grazing strategy ; opportunistic grazing

1. Introduction

Arid rangelands occupy approximately 60% of the global rangelands and 70% of drylands and sustain 14% of the world's population and 50% of global livestock [1][2]. The vegetation dynamics of arid rangelands have long been a focus for numerous scientists trying to understand their relationship with climate and human activities [3][4]. Several researchers have challenged the findings of many previous studies that indicate the importance of natural arid rangeland diversity as the major driving force of rangeland health [5][6].

Natural rangelands in Tunisia cover about 33% (5.5 million ha) of the country's total territory, 87% of which are located in the south described as arid and desert areas (45% and 42%, respectively). Southern Tunisia is the driest area of the country as it includes the Great Eastern Erg. These arid rangelands suffer from accelerated degradation due to the combined effects of human pressure and climatic precarity. As human and livestock populations continue to increase, the pressures from livestock grazing due to reduced herd's mobility, encroachment of cultivation into best rangeland sites, and other types of mismanagement—combined with recurrent drought—can ignite local conflicts over resources [7][8][9][10]. In fact, the impact of these factors is considered as the most detrimental for rangeland vegetation and reflected through the apparition of invasive species and loss of key desirable species [10][11]. Given this alarming situation, it is therefore necessary for local government authorities and development agencies to take urgent restoration measures.

Livestock grazing exclusion or the rangeland resting technique is a common traditional practice in the region. In fact, most rangeland improvement projects in southern Tunisia are using the resting technique (locally known as *Gdel* or *Hima*) to restore degraded arid rangelands [12]. This technique is considered by many authors among the most cost-effective restoration practices [5][12][13]. Under the *Hima* system, the grazing land is protected by the local pastoral communities from livestock grazing and wood harvesting for a certain period of time. Unfortunately, certain development agencies who adopted such practice use a fixed resting period of three consecutive years without evaluating the effectiveness of the resting duration on the rangeland ecosystem . In the literature, there are conflicting results. While certain studies conducted in arid environments suggest that species composition and diversity increase with short-term protection, others suggest that long-term benefits are reduced [8].

2. Rangeland Biodiversity and Climate Variability: Supporting the Need for Flexible Grazing Management

The impact of biotic stress, particularly grazing pressure, on plant diversity is quite controversial . On one hand, grazing is considered as a key factor to promote diversity [14][15], on the other hand, grazing can reduce plant diversity and lead to the homogenization of rangeland [16]. Furthermore, other studies carried out in arid areas have shown that climate variability is more important in affecting plant diversity than grazing, and moderate grazing does not damage vegetation [8].

The assessment of different resting durations in four plant communities during the two different years (favorable and normal) showed distinct variability in Hill's diversity indices, which characterize plant communities of arid rangelands. Our results showed the effect of grazing exclusion compared to free continuous grazing on the spatial and temporal dynamics of rangeland vegetation in this arid area.

Grazing pressure is recognized as a regulator of vegetation dynamics, altering diversity indices such as species richness and evenness [17][18]. In our study, these indices varied significantly with resting duration. The N_0 was higher when the rangeland site was rested, with an increasing trend of E_{20} compared to treated areas, where the lowest value occurred for the *S*. *pungens* community subjected to two years of rest. Both abundant and very abundant species remained stable whatever the management mode. Our findings confirm several previous studies conducted in arid rangelands in which resting improved N_0 [19]. In contrast, the E_{20} index increased in the continuously grazed sites, corroborating the results of many studies that showed an increase of this index with disturbance . The decrease in E_{20} after applying the rest technique supports the “competitive exclusion hypothesis” described by Grime [20] and Huston . It seems that competition is inversely related to diversity as an increase in the intensity of competition results in a decrease in the evenness and, eventually, the species richness .

Although arid-zone vegetation is mostly composed of xerophytes, rainfall intensity and distribution are the major drivers of species diversity and can potentially lead to changes in species composition. In this study, the year with good rainfall played a more important role than any management mode in explaining species diversity. All species diversity indices (N_0, N_1, N_2, and E_{20}) varied significantly with yearly climatic conditions, with higher values in the rainy year. Several recent studies showed that rainfall is a key driver of rangeland structure and function in arid areas [11]. However, exceptional highly favorable years can greatly change the diversity of arid rangelands. Additionally, good rainfall in both amount and distribution can increase species diversity by enhancing the establishment and survival of new seedlings. This statement is confirmed by the indigenous knowledge of the local pastoralists and rangeland researchers in southern Tunisia. It is known that when the seasonal rainfall occurring between September and December does not exceed 60 mm, at best we are expecting a normal year with an average rangeland productivity. However, when the rainfall exceeds 80 mm during the same period, this will definitely lead to a favorable year with high rangeland production . Surprisingly, Tielbörger et al. found that species richness did not change after nine years of drought, which they attributed to a ‘climatic comfort zone’ linked to species adaptation.

In general, in drylands, the increasing demand for water availability following rain events may cause considerable disruption to diversity and species richness [21][22].

Our findings showed an increase in species richness for the *R*. *raetam* community on sandy soil (Appendix A), but the lowest species richness was recorded for the *A. henoniana* community on limestone soil. However, this response varied with soil and vegetation type. These results corroborate the findings of other studies for arid ecosystems . In southern Tunisia, Floret and Pontanier explained that rainfall and soil type were decisive factors and higher response of vegetation and soil moisture levels were observed in deep sandy soils compared to limestone soils. This is opposite to what has been found in other arid areas of the world [23].

Regardless of climate condition and plant community, all diversity indices (N_0, N_1, N_2, and E_{20}) were higher at the sites subjected to only one year of rest than those that were protected for longer periods or that were continuously grazed. The results also indicated that, under reasonable rainfall amounts and distributions, resting a previously grazed rangeland for one year was sufficient to maintain N_0. Consequently, our results support other findings suggesting that excluding grazing is one of several strategies that need to be adopted to facilitate and restore rangeland biodiversity [24].

In general, annual plants are less resistant to trampling, grazing, and drought than perennial plants [25]. Complete protection from grazing can be beneficial to productivity and diversity [26]. The short-term effect of grazing exclusion during a favorable year was found to be related to soil surface compaction caused by grazing [26]. One beneficial effect of trampling is the creation of a patchwork that results in a microclimatic change, with positive effects on seedling establishment due to collecting runoff in the soil surface depressions. In arid rangelands, grazing exclusion at specific periods is required. Nonetheless, the duration of these rest periods depends on the plant community, the degree of prior grazing pressure, and the climatic conditions [12].

As the pressure on rangelands continues to mount, it would be wise to combine pastoral indigenous knowledge with science-based evidence to tackle big challenges and find solutions that are technically sound and socially accepted. In southern Tunisia, even though the resting technique requires total exclusion of animal grazing, the pastoral communities have always respected the rules based on social awareness. The approach has been successfully implemented through closely involving tribal institutions, with one of the main objectives to strengthen sustainable rangeland restoration through the revival of the traditional grazing system known as *Gdel* [12]. However, there was no consensus to how long the resting period should be. Results from this study show that there are no valid justifications for banning livestock grazing for three consecutive years. In fact, as demonstrated, short-term exclusion (1 year), with sufficient precipitation greatly increased plant diversity underlining the high resilience capacity of these arid ecosystems. These findings could be very useful for

policy-makers in reviewing the current rangeland management strategy in the country to offer more flexibility for the pastoral communities to sustainably manage their natural resources.

3. Conclusions

In arid rangelands, plant diversity is one of the most important key functions of healthy ecosystems. Human-induced disturbances combined with recurrent droughts represent the main causes of ecosystem disequilibrium leading to threats to key plant species and consequently its floristic cortege. Inappropriate grazing that causes declines in plant diversity alerts rangeland managers to consider suitable management changes. During the 2017/2018 period, the recoded rainfall in the southern arid rangelands of Tunisia was 200% higher than the long-term average, which had a considerable positive impact on species richness, abundance, and evenness. Our findings suggest that for the arid rangelands of southern Tunisia, the exceptional favorable wet season was very helpful in mitigating the negative effects of continuous grazing pressure and recurrent drought regardless of the duration of the resting period. This scenario led to significant increases in plant diversity for most plant communities, mainly *A*. *henoniana* and *R*. *raetam*. Maintaining rangeland plant diversity serves as an insurance policy for the survival of healthy rangelands to provide a sustainable ecosystem of goods and services. Under these conditions, it is important to consider a flexible approach to grazing management, depending on climate conditions and site specificity.

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