



Conservation of Biodiversity in the Hot Arid Rangelands of India

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Abstract: Interest, awareness and discussions about biodiversity conservation in India have increasingly expanded to include rangelands on both national and international platforms. Rangeland ecosystems are characterized by a vital interplay between plant species that serve as forage and grazing animals that act as consumers. The hot arid rangelands in India provide a habitat for a distinctive array of flora and fauna that have evolved to thrive in harsh climatic conditions. This paper explores the biodiversity and conservation issues of hot arid rangelands and highlights the role of traditional conservation practices in addressing these challenges.

Key words: Biodiversity, hot arid rangelands, traditional conservation.

Rangelands encompass diverse vegetation types like shrub lands, grasslands, steppes, and woodlands, covering about 50% of the world's land area (Heitschmidt and Stuth, 1991; Friedel *et al.*, 2000). They support millions of people by providing economic and ecological services such as feed for grazing animals, medicinal plants, fuel-wood, and building materials. Rangelands also serve as vital reserves for biodiversity and play a role in carbon sequestration. They uphold longstanding customs and traditions and protect soil integrity, ensuring sustainable production of animal feed, firewood, and other societal benefits.

In India, rangelands span a vast area and boast rich biodiversity due to diverse climatic conditions, physiography, and heterogeneous land use patterns (Shankar *et al.*, 1995). Covering over 40% of the country's land surface (121 mha), these lands serve as seasonal grazing grounds while supporting various other uses. The arid and semi-arid tropics, including the Thar Desert and the Himalayan rangelands exhibit seasonal patterns of animal migration and forest grazing, showcasing the diversity of Indian rangelands. The hot arid region of Rajasthan features diverse landforms such as barren gravel plains, rocky hills, shifting sand dunes, riverbeds, floodplains, alluvial plains, sandy plains, and saline flats. Researchers describe these landforms as polygenic in origin (Moharana *et*

al., 2023), with significant physiographic units like playa lakes or ranns in this ecosystem (Moharana *et al.*, 2022). The region experiences extreme temperature fluctuations, ranging from sub-zero temperatures in winter to over 50°C in summer, with erratic rainfall varying between 100 and 500 mm annually. The region frequently faces hot, dry winds and dust storms originating from the southwest and west, which are common occurrences.

Changes in plant biodiversity within these rangelands, which are used for activities ranging from hay harvesting to on-site grazing and browsing, provide evidence of the potential for reversing rangeland degradation. Grazing intensity in hot arid rangelands often exceeds optimal carrying capacity by more than five times. These rangelands have evolved into fragile ecosystems currently experiencing advanced degradation due to factors like high livestock populations, unregulated grazing, inadequate management practices, and shifts away from traditional grazing methods. Migratory grazing becomes prevalent during periods of drought and famine in hot arid rangelands. Further, introduction of Indira Gandhi Nahar Pariyojna (IGNP) and other irrigation facility with mechanization converted rangeland to crop land which also leads to changing biodiversity.

Large ungulates and other substantial herbivores are essential in rangeland ecosystems, crucial for sustaining diverse communities of plants, birds, and invertebrates associated with grasslands (Duncan and Jarman, 1993). They play pivotal roles as consumers, influencing overall biodiversity (Shankar *et al.*, 1995). Herbivores, parasites, and predators collectively form the consumer food web, crucial for maintaining equilibrium in grassland production and consumption dynamics. The close interplay between plants and animals in the grazing food chain suggests co-evolution between these groups. The selective extinction of ungulate species has disrupted ecosystems, leading to issues such as increased populations of rodents, reptiles, and termites, reaching alarming proportions in certain situations.

The causes of biodiversity loss in rangelands are primarily linked to human activities and climatic changes, while the effects impact the entire ecosystem (Timis-Gansac *et al.*, 2025).

Biodiversity loss in drylands (rangelands) is driven primarily by human activities and climate change, with consequences that affect the entire ecosystem. Species once thriving in grasslands now face severe threats, many listed among the most endangered. Singh and Rathore (2022) highlighted habitat destruction, overexploitation, and increased agricultural mechanization as factors sharply reducing woody perennials in hot arid regions. Arid rangeland biodiversity is crucial amid global climate change, serving as repositories of plant genetic material vital for restoring degraded environments into multi-tiered silvi-pastoral systems. This review paper highlights the rangeland biodiversity, conservation issues and restoration, and discusses traditional conservation methods specific to hot arid rangelands.

Rangeland Biodiversity

Floral diversity

In hot arid rangelands, floral biodiversity extends beyond mere genetic counts, species richness, and ecosystems. Though less abundant compared to semi-arid and temperate zones, these elements hold profound significance. This ecosystem features highly resilient shrubs, select succulents, and a limited array of grass species. The grass flora includes about 57 genera and over 110 species. Notably, the genus *Cenchrus* stands out with six species valued for their significant forage potential. *C. ciliaris* L. (Anjan/Dhaman) and *C. setigerus* Vahl (Moda Dhaman) exhibit notable diversity in the region. Various genotypes of *C. ciliaris* vary significantly in traits such as earliness, plant height, tillering, leafiness, and dry matter accumulation (Rajora, 1998). *Lasiurus sindicus* Henr. (Sewan) is a pivotal grass species in the Thar Desert, showing notable diversity. Essential for sustaining livestock in hot arid rangelands are low perennial species such as *Ochthochloa compressa* (Forsk.) Hilu and *Dactyloctenium indicum* Boiss. In dry, arid soils, genera like *Aristida* (with 7 species) serve as important forage, albeit of lower quality, consumed by animals when no better options are available. In saline areas, characteristic grasses include species of *Aeluropus*, *Chloris*, and *Sporobolus*. Additionally, species like *Aristida royleana* Trin. & Rupr. and *Cenchrus rajasthanensis* Kanodia

& Nanda are endemic to western Rajasthan (Bhandari, 1990).

Leguminous species in the region showcase notable diversity. *Rhynchosia aurea* (Willd.) DC., *Crotalaria burhia* Buch.-Ham., and *Indigofera hochstetteri* Baker., are confined to the arid parts of Rajasthan. *Indigofera oblongifolia* Forssk. contained considerable amounts of phytochemicals which make its suitability as a browse species to ruminants in rangelands (Singh *et al.*, 2023). Bhandari (1993) documented extensive diversity within the genus *Tephrosia* in Rajasthan, encompassing nearly 12 species, most inhabiting various ecozones of the Thar Desert and closely related to *Tephrosia purpurea* (L.) Pers. This species alone exhibits several distinct morphotypes. Two endemic *Tephrosia* species, *T. falciformis* Ramaswami and *T. uniflora* Pers., are particularly significant in rangelands as forage sources for grazing animals.

Rangeland shrubs such as *Acacia jacquemontii* Benth., *Calligonum polygonoides* L., *Capparis decidua* (Forsk.) Edgew., *Cordia gharaf* (Forsk.) Ehrenb. ex Asch., *Grewia tenax* (Forsk.) Fiori, *Haloxylon salicornicum* (Moq.) Bunge ex Boiss., *Leptadenia pyrotechnica* (Forsk.) Decne, *Maytenus emarginata* (Willd.) Ding Hou, *Ziziphus nummularia* (Burm. f. Wight & Arn.) exhibit significant intra- and interspecific diversity in size, morphology, growth, phenology, and reproductive behavior.

Mahla and Singh (2013) documented significant in situ variability in *Capparis decidua* from western Rajasthan, noting diverse plant types, canopy structures, and flowering and fruiting characteristics within its natural population. Similarly, the germplasm of *Haloxylon salicornicum* exhibited notable variability among different accessions (Singh *et al.*, 2015). *Grewia tenax* from the Thar Desert showed considerable variations in seed characteristics (Venkatesan *et al.*, 2019). The germplasm of *G. tenax* showed genetic diversity for fodder and economic traits in the hot-arid Kachchh region of India (Dev *et al.*, 2023). The leaves and fruits of *G. tenax* are rich in phytochemicals such as total soluble protein, total antioxidant capacity, total phenols, and total flavonoids, making it suitable for utilization in rangelands or alternative land use systems to support livelihoods in the hot

arid region of western Rajasthan (Patidar *et al.*, 2022).

Tree species like *Acacia nilotica* (L.) Del. ssp. *cupressiformis* (J.L. Stewart) Ali & Faruqi, *A. nilotica* ssp. *indica*, *Acacia Senegal* (L.) Willd., *Prosopis cineraria* (L.) Druce, *Salvadora oleoides* Decne., *Salvadora persica* L., *Tecomella undulata* (Sm.) Seem., and *Tamarix* spp. are highly significant, exhibiting diverse growth patterns and quality attributes. Salt-tolerant species from hot arid regions show considerable variation in plant forms (Singh *et al.*, 2019a). Halophytic chenopod shrubs such as *Haloxylon recurvum* (Moq.) Bunge ex Boiss., *Salsola baryosma* (Schult.) Dandy, and *Suaeda fruticosa* (Forsk.) ex J.F. Gmel. thrive prominently in saline depressions in western Rajasthan. Recently, major halophytic species reported in the Meetha and Khara Rann of Jaisalmer includes *Aeluropus lagopoides* (L.) Thwaites and *Cressa cretica* L. (Moharana *et al.*, 2022).

Seasonal diversity of vegetation in rangelands is crucial for their utilization, especially for grazing animals in arid ecosystems. Kumar *et al.* (2017) highlighted that arid rangelands inherently display species composition heterogeneity, comprising a blend of seasonal and perennial plants. The lifecycle of seasonal plants aligns well with meeting the nutritional requirements of livestock. Grazing on such seasonal vegetation supports the sustained use of perennial tussocky rangelands over extended periods. This diverse floral composition enhances their resilience under varied edapho-climatic conditions.

Faunal diversity

Hot arid rangelands harbor a diverse array of fauna. Alongside resilient domesticated animals like cattle, sheep, goats, camels, horses, and donkeys, these regions also host a rich variety of birds, reptiles, other vertebrates, invertebrates, and microorganisms. However, the decline of grasslands in Indian ecosystems has led to the rarity of many species (Rahmani, 1988). Birds such as the Great Indian Bustard (*Ardeotis nigriceps* Vigors) and the Lesser Florican (*Sypheotides indicus* Miller) are now critically endangered. Key wild ungulates such as the Blackbuck (*Antelope cervicapra* L.), Wild Ass (*Equus hemionus khur* Lesson), and Chinkara (*Gazella bennettii* Sykes) thrive in these arid grasslands, playing essential roles

in ecosystem maintenance. Dominant rodent species like the Indian desert jird (*Meriones hurrianae* Jerdon), Indian gerbil (*Tatera indica* Hardwicke), and Indian hairy-footed gerbil (*Gerbillus gleadowi* Murray) are also integral to the rangelands (Idris, 2009). This rich faunal diversity underpins rangeland biodiversity and supports long-term ecosystem sustainability.

Rangeland Conservation Issues

(i) Grazing vs. Rangeland Protection

Grazing and browsing by animals play a vital and impactful role in maintaining rangeland biodiversity. However, it is crucial to strike the right balance, as improper grazing practices can lead to negative consequences. Overgrazing, for instance, can result in retrogression, where the ecosystem regresses in its development. On the other hand, moderate grazing can slow down the rate of ecological succession, while light grazing and complete protection can accelerate this process. Overgrazing not only encourages the growth of undesirable species but also promotes weed proliferation within rangelands. This, in turn, leads to a loss of diversity, as these species dominate the landscape. For instance, the habitat of the Great Indian Bustard requires controlled grazing or grass harvesting to prevent overgrowth of trees and shrubs. These developments can degrade the habitat of the Great Indian Bustard, which thrives in open grassland areas (Rahmani, 1988). Hence, a pivotal question arises: Should protected areas be opened to regulate grazing by local livestock? This issue holds significant importance.

In fact, addressing a range of management-related issues requires a comprehensive approach, particularly in balancing protection with promoting plant successional thresholds (Shankar *et al.*, 1995). Protection measures can lead to the accumulation of energy and habitat buildup, eventually facilitating the growth of higher plant life-forms. As these life-forms develop fully, they can trigger positive or negative effects by altering the vegetation composition and microclimates of the area. This complex situation prompts us to consider appropriate management strategies for protected areas. It is vital to deliberate on whether controlled grazing, complete protection, or other methods are best suited to maintain

the ecological balance and biodiversity of these regions.

(ii) Grazing Pressure

The livestock population in Rajasthan state totals approximately 57.7 million, with about 30.2 million located in the arid districts of western Rajasthan. In hot arid regions, rangelands serve as the primary source of forage for livestock grazing. The grazing area available in arid districts averages 0.61 hectares per Animal Cattle Unit (ACU), with a grazing pressure of 1.65 ACU per hectare. However, the density of livestock has increased, reducing the availability of grazing lands and intensifying grazing pressure on rangelands. This overexploitation of existing plant species leads to loss of biodiversity and deterioration of rangelands. For instance, approximately 80% of the grasslands in the Jaisalmer area are in poor to very poor condition and face severe erosion hazards (Mertia, 1992). To address these challenges, it is crucial to manage natural rangelands through controlled grazing based on carrying capacity. Additionally, efforts should focus on improving the productivity of existing grazing resources.

(iii) Single-Species vs. Mixed-Herd Grazing

Single-species or mixed-herd grazing practices have a significant impact on maintaining productivity and diversity in rangelands. In the context of single-species grazing, there is a risk that unpalatable plant species, compared to grazed species, might rapidly dominate rangeland vegetation. This indiscriminate and disproportionate grazing poses a threat to numerous plant species, pushing them towards extinction within their natural habitats. This dilemma not only jeopardizes biodiversity but also endangers the very existence of the grassland ecosystem. On the other hand, mixed-herd grazing offers a range of benefits. One notable advantage is the potential for achieving high output per unit area (Nolon and Connolly, 1977). This approach is particularly relevant in arid rangelands, such as those found in the Jaisalmer district, where a distinct phenomenon is observable: the management of tree and shrub canopies through browsing by camels. Embracing mixed herds comprising various animal species like cattle, sheep, goats, and camels becomes

instrumental in fostering both diversity and production within the rangeland setting.

(iv) *Sharing of Common Grazing Areas by Livestock and Wildlife*

In rangelands, domestic livestock and wild animals often coexist within shared grazing areas. However, the practice of sharing these areas presents several challenges that need to be addressed. One significant consequence of overstocking in arid rangelands is the depletion of forage resources for wild ungulates. Among these wild herbivores, the Blackbuck (*Antelope cervicapra*) is particularly affected due to its grazing habits closely resembling those of cattle and sheep. This disproportionate grazing has not only altered the composition of plant species but has also negatively impacted the wildlife dependent on these areas. Two rodent species, the Desert gerbil (*Meriones hurrianus* Jerdon) and the Indian gerbil (*Tatera indica* Hardwicke), exhibit specific feeding patterns. They primarily consume seeds during winter, shift to rhizomes and stems in summer, and focus on leaves and flowers during the rainy and post-monsoon seasons (Prakash, 1962). Furthermore, the presence of domestic livestock poses a threat to the health of wild ungulates that share common grazing grounds and water holes (Ghosh *et al.*, 1988). Therefore, when managing rangelands, it becomes imperative to prioritize the interests and well-being of wildlife inhabiting these areas. In light of these considerations, a comprehensive approach to rangeland management should include strategies that mitigate overstocking, preserve suitable forage for both domestic livestock and wildlife, and safeguard the overall ecological balance of hot arid ecosystems.

(v) *Indiscriminate cutting and digging of roots of rangeland shrubs*

The indiscriminate cutting and digging of rangeland shrubs represent significant issues in rangeland conservation, especially in hot arid regions. A prime example of this is the excavation of *Calligonum polygonoides* roots within its distribution range in western Rajasthan (Singh *et al.*, 2004). This species plays a crucial role within the sand dune habitat and holds substantial ecological significance within the Thar Desert. Additionally, rangeland browse species like *Acacia jacquemontii*, *Capparis*

decidua, and *Haloxylon salicornicum* face similar challenges.

(vi) *Ineffective Techniques for Extracting Gums and Resins from Woody Perennials*

The use of unscientific methods to extract gums and resins from rangeland shrubs and trees poses a significant concern, as it contributes to the decline in the population of certain species within their natural habitats. A prominent example of this issue is observed with *Commiphora wightii* (Arn.) Bhandari in the Thar Desert. The excessive and improper incisions made in the stems for resin collection have led to a substantial reduction in the species' population in the region, putting its existence at critical risk.

(vii) *Ex-situ vs. In-situ Conservation*

Conserving rangeland biodiversity requires a long-term management program. Shankar *et al.* (1995) highlighted that in *ex-situ* conservation, where germplasm is preserved in controlled environments, there is a risk of isolating species from natural competition, thereby removing them from evolutionary processes. Reintroducing such species into their native systems may lead to a loss of their natural resistance and adaptation. The frequency of introducing conserved genes back into the natural environment to ensure compatibility with the ecosystem remains a topic of debate and requires specific research, particularly for rangeland species. Given these complexities, the focus should lean towards *in situ* conservation for key hot arid grasses (such as *Cenchrus ciliaris*, *C. setigerus*, *Cymbopogon jwaruncusa*, *Lasiurus indicus*, *Panicum turgidum*) and shrubs (including *Acacia jacquemontii*, *Calligonum polygonoides*, *Capparis decidua*, *Grewia tenax*, *Haloxylon salicornicum*). This can be achieved through the protection and preservation of existing areas encompassing a variety of habitats.

Furthermore, lesser-known threatened species are found in the arid rangelands of western Rajasthan, such as *Caralluma edulis* (Edgew.) Benth. & Hook., *Dipcadi erythraeum* Webb. & Berth., *Ephedra foliata* Boiss. & Kotschy ex Boiss., and *Glossonema varians* (Stocks) Benth. ex Hook.f. These species hold significant ecological importance but are currently facing threats that jeopardize their existence. Among

these, *G. variens* is a small perennial herb with both food and medicinal value for desert inhabitants, particularly in Jaisalmer and Barmer districts (Singh *et al.*, 2017). *D. erythraeum* is another notable species characterized by its scapigerous bulbous herb, traditionally used as a famine food source and for medicinal purposes (Singh *et al.*, 2019b). These species typically thrive along runnels on shallow sandy and gravelly soils, as well as depressions within rocky and gravelly terrains where rainwater accumulates for a certain period. *C. edulis* is a traditional food and medicinal plant of the Thar Desert, often found within the tussocks of *Panicum turgidum* grass in Jaisalmer district. *E. foliata* is a climbing shrub with both ecological and economic significance, notable as the sole Gymnosperm species in western Rajasthan. Unfortunately, the populations of these species are rapidly declining within their natural habitats due to various threats. As a result, urgent attention and concerted efforts are required for effective *in situ* conservation measures to safeguard these species and their delicate ecosystems.

(viii) Conversion of Rangeland areas for Agricultural purposes

With the introduction of canals and tube well irrigation in desert regions, the irrigated area has expanded significantly. However, this expansion has led to the conversion of crucial grassland areas into agricultural fields, posing a threat to the existence of native grasslands. Particularly affected are the grasslands dominated by *Lasiurus indicus* Henr. (Sewan grass) and *Panicum turgidum* (Murath grass). Among these grasses, *L. indicus* plays a pivotal role due to its robust growth and high productivity. Recognized as the “queen of the desert grasses,” it serves as a primary source of sustenance for the renowned Tharparker cattle breed, which relies on it for nourishment. Furthermore, the transformation of *P. turgidum* dominated grasslands into agricultural fields in the Jaisalmer district has resulted in a significant loss of the natural habitat of *Caralluma edulis*.

(ix) Dilution of Traditional Conservation Practices

Conservation of biodiversity has always been crucial in primitive human societies. Ethnobotanical studies indicate that inhabitants of tribal and rural areas are intimately familiar

with the local flora and fauna, and they understand the ecological interrelationships among various components of the ecosystem. In India, certain plants and animals hold sacred significance, ensuring they are not harmed in any way. For instance, in the hot arid regions, the Bishnoi community refrains from cutting or allowing the cutting of Khejri trees (*Prosopis cineraria*) due to their sacred significance. Similarly, in the Thar Desert, trees like Khejri and Bordi (*Ziziphus* species), and grass species like Sewan (*Lasiurus indicus*), play a crucial role as fodder. Traditional farmers in these areas rarely cut or uproot these species even when ploughing their farmlands.

The density of *P. cineraria* trees in the 300-500 mm rainfall zone of the Thar Desert is approximately 40-100 trees per hectare (Agrawal, 1993). However, the utilization of tractors for ploughing has led to the elimination of *L. indicus* clumps and roots of *Z. nummularia*. Pastoral traditions also significantly impact the conservation of grazing land resources. In the Gols system of grazing in Rajasthan, herders move forward or change pastureland after utilization. The concept of sacred groves, locally known as *Orans* in different parts of western Rajasthan (Singh and Singh, 2024, 2025), is vital in conserving the diverse gene pool of many woody perennial climax or near-climax species such as *Prosopis cineraria*, *Acacia senegal*, and *Salvadora oleoides*. Moreover, various *Ziziphus* species exhibit significant diversity in most Orans in western Rajasthan. Therefore, there is a need to revive and promote traditional conservation practices, particularly for rangeland management. Conducting extensive folklore surveys is necessary to assess the potential of these traditional conservation measures, which will aid in planning for the conservation of rangeland biodiversity.

(x) Planting of Exotic vs. Native Woody Perennial in Rangeland Development Program

Within the framework of rangeland development programs, there has been a notable emphasis on exotic woody species such as *Acacia tortilis* (Forssk.) Hayne (Israeli babool) and *Prosopis juliflora* (Sw.) DC. (Vilayti babool). These species were favored for their high plant survival rates and rapid growth, particularly in sand dune stabilization, where *A. tortilis* was prioritized. However,

the unchecked proliferation of *P. juliflora* in rangelands, including sacred groves (Orans), poses a significant threat to the habitats of indigenous species. Indigenous species like *Calligonum polygonoides* (Phog) and *Acacia jacquemontii* (Bawli), which serve as pioneer species and are well-suited for stabilizing sand dunes, were unfortunately overlooked during the development of these areas. Yadav *et al.* (2020) rightly highlighted that afforestation with inappropriate woody perennials (substituting native species with exotic ones) poses a threat to rangeland biodiversity and affects ecosystem services at the local level. Therefore, it is imperative to shift the focus towards prioritizing indigenous arid species that play a pivotal role in rangeland development programs. This approach ensures the conservation of native biodiversity and supports sustainable ecosystem management practices.

Restoration of Degraded Rangelands

The restoration of degraded rangelands involves reintroducing indigenous species into the ecosystem. Ecosystem degradation can be reversed by replacing species adapted to specific niches such as eroded slopes and alkaline/saline soils. This process includes surveys, collection, evaluation, and conservation of diverse rangeland germplasm, with a particular focus on forage grasses, legumes, and browse shrubs. Germplasm conservation plays a crucial yet often overlooked role in restoring degraded rangelands. The range grasses like *Lasiurus indicus*, *Cenchrus ciliaris*, *C. setigerus*, *Cymbopogon jwaruncusa* and *Panicum turgidum*, play an important role in restoration of degraded rangelands by phytoremediation, carbon sequestration, abiotic stress resistance, soil conservation, nutritional security for livestock with high fodder value, and medicinal and aromatic property (Singh *et al.*, 2022). Among various browse species, indigenous shrubs like *Acacia jacquemontii*, *Calligonum polygonoides*, *Capparis decidua*, and *Haloxylon salicornicum* are significant for revitalizing the fertility of degraded sand dune areas. The adaptability of *A. jacquemontii* and *C. polygonoides* to sand dune environments underscores their potential for stabilizing sand dunes and mitigating wind erosion. Rathore *et al.* (2015) emphasized that the establishment of *H. salicornicum* and *C. polygonoides* shrubs alters physical soil traits

and enhances soil nutrients, facilitating the development of surrounding herbaceous plant communities. Furthermore, *H. salicornicum*, an important feed source particularly for camels, exhibits tolerance to abiotic stresses, making it suitable for arid rangelands (Singh *et al.*, 2009). *Grewia tenax* and *Indigofera oblongifolia* are significant for degraded rangelands due to its capacity to withstand severe drought and high temperatures (Patidar *et al.*, 2022; Singh *et al.*, 2023), despite excessive browsing pressure. *Indigofera oblongifolia* and *I. cordifolia* are important fodder species for sheep, goats, camels and cattle in hot arid regions. The seed of *I. cordifolia* is the source of food during times of scarcity and famine. The seeds of *I. cordifolia* serve as a source of food during periods of scarcity and famine (Singh *et al.*, 2025). Introducing elite genotypes of these shrubs in suitable habitats can provide fodder and fuelwood supplies during both normal and prolonged drought periods. Additionally, species of *Indigofera* found in the wild in the Thar Desert are useful for erosion control, greening bare areas, and serving as soil cover on degraded lands.

Species of woody perennials such as *Acacia*, *Calligonum*, *Cordia*, *Crotalaria*, *Grewia*, *Haloxylon*, *Salvadora*, and *Ziziphus*, along with forage grasses like *Cenchrus*, *Lasiurus*, *Panicum*, *Cymbopogon*, *Dactyloctenium*, and *Dichanthium*, are vital for restoring degraded rangelands. The promising genotypes of *Cordia gharaf* and *Grewia tenax* were identified for above ground biomass, fodder quality and other traits for introduction in rangelands for improvement of degraded rangelands (Dev *et al.*, 2020; Dev *et al.*, 2023; Dev *et al.*, 2024).

Halophyte shrubs such as *Haloxylon recurvum*, *Salsola baryosma*, *Suaeda fruticosa*, and *Tamarix* species, as well as grasses like *Aeluropus lagopoides*, *Sporobolus* species, and *Urochondra setulosa*, along with forbs like *Cressa cretica*, play crucial roles in restoring saline degraded rangelands. For example, the highly salt-tolerant *H. recurvum* holds immense economic significance as it is used to produce Saji, supporting the *bhujia* and *papad* industry in Bikaner. Extensive areas affected by salinity can be covered with *H. recurvum*, making it a promising industrial crop species for arid saline lands with significant development potential (Rathore *et al.*, 2012).

Role of Rangeland Biodiversity in Imparting Adaptation to Climate Change

The hot arid region is primarily a livestock-based economy, heavily reliant on native rangelands to sustain livestock. However, these rangelands have undergone significant degradation due to intensive grazing and browsing pressure, resulting in a substantial reduction in their production potential. Consequently, livestock are compelled to migrate frequently during periods of low food availability, disrupting the local economy. Rangeland diversity offers numerous potential solutions for adapting to climate change. Perennial grasses and browse shrubs play a crucial role in the vegetation of arid rangelands due to their adaptability to adverse climatic and soil conditions. Besides serving as grazing and browsing resources, their deep and fibrous root systems effectively control soil erosion. Nevertheless, the condition of these rangelands deteriorates under the pressure of excessive grazing and browsing. In this context, changes in root and rhizome growth often go unnoticed, despite their significant role in sustaining forage yield. Optimizing effective soil volume plays a crucial role in maximizing the utilization of soil moisture and nutrients. Rhizomes, acting as storage sites for nutrients, exert a significant influence on the regrowth of perennial grasses.

The Thar Desert in India and its neighboring semi-arid regions of western India are often perceived as having limited phyto and genetic diversity with agricultural and horticultural value (Arora and Nayar, 1983). Nonetheless, these regions hold unique importance due to their adaptive mechanisms. Rangeland forage grasses, including species such as *Lasiurus*, *Cenchrus*, *Cymbopogon*, *Dactyloctenium*, *Ochthochloa*, *Panicum*, and *Sporobolus*, possess invaluable genes that confer tolerance to abiotic stresses. Notably, *Lasiurus indicus* stands out as a perennial component within various production systems in desert ecosystems (Rani *et al.*, 2022). Furthermore, the genetic resources of woody perennials from arid rangelands represent a valuable source of diverse genetic materials essential for the restoration and rehabilitation of degraded arid rangelands to establish multitier silvi-pastoral systems. Arid shrubs like *Calligonum polygonoides*, *Capparis decidua*, and *Haloxylon salicornicum* show promise in mitigating the effects of inevitable

climate change. Therefore, they warrant significant attention for both *in-situ* and *ex-situ* conservation efforts.

Conclusions

Compared to other arid regions worldwide, the hot arid region of India boasts remarkable biodiversity richness. Particularly noteworthy is the diverse array of rangeland species that have adapted to both biotic and abiotic stresses, presenting significant potential for utilization in plant improvement programs. However, this biodiversity is facing decline due to various factors, with overgrazing and browsing being the most prominent. These activities lead to soil degradation and reduced water conservation potential. Additionally, the uprooting of rangeland browse species, notably *Calligonum polygonoides*, for use as fuel wood, alongside shifts in land use patterns through the conversion of grasslands, specifically *Lasiurus indicus* grasslands, into irrigated croplands, further exacerbates the situation. The encroachment and destruction of habitats by invasive species like *Prosopis juliflora* also contribute to the deterioration of rangeland biodiversity. Moreover, traditional conservation practices are also being diluted, adding to the challenges.

Several methods for biodiversity conservation are currently being applied. Two particularly concerning examples include the excessive exploitation of *Calligonum polygonoides* and *Commiphora wightii*, woody perennial species in western Rajasthan that are at risk of extinction within their natural habitat. The *in-situ* conservation of these key species should be encouraged because of their crucial and multipurpose roles. This can be achieved by safeguarding and preserving existing areas that house diverse types of germplasm. It is essential to identify hotspots of arid rangelands for *in-situ* conservation, with particular attention to the existing *Lasiurus indicus* grasslands in the Jaisalmer district. Traditional conservation approaches adapted by desert inhabitants, such as the provision of *Orans* and *Gochars*, reveals a wealth of wisdom. Many of the practices they employ remain pertinent and can be embraced with minor modifications if necessary. In programs aimed at developing wastelands, rehabilitating mining areas, and regenerating degraded rangelands, it is imperative to

prioritize the biodiversity of indigenous key arid species. This focus will contribute to their sustainable utilization.

Declarations

The authors have no competing interests.

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