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Editorial

# Grassland Ecological Management and Utilization for Sustainability

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## 1. Introduction

Grasslands, covering 40% of the land surface area [1], are important components of terrestrial ecosystems which provide multiple functions and services, including but not limited to livestock production, biodiversity conservation, the maintenance of soil and water, carbon sequestration, and habitats for wildlife [2,3]. To date, studies have made considerable contributions toward addressing major challenges and problems associated with identifying the internal mechanisms of various grasslands to provide ecological services and functions and develop knowledge-based strategies to effectively manage grasslands and restore degraded grasslands.

Many grasslands have been used as grazing lands for livestock production for centuries and have become key components of livestock production systems [4]. Animal grazing activities in livestock production systems can change the balance of the structure, composition, and functions of grassland or pasture ecosystems [5,6] and alter soil physiochemical properties and the enzyme activities of grasslands [7]. Moreover, grazing effects are likely to vary among response variables, intensity, and modes of grazing and abiotic conditions [8]. For example, light grazing is likely to induce mainly biotic shifts; moderate-to-heavy levels of grazing or prolonged intensive use, however, are likely to cause abiotic changes [9]. Currently, information on grazing grassland management is collected less widely than information on forests and cropland and tends to be of lower resolution and limited to a subset of regions and management practices [10].

Unfortunately, many grasslands are being degraded by the integration of internal drivers of grassland ecosystem fragility with external disturbances such as overgrazing, invasive species encroachment, and global climate change [11], resulting in a loss of biodiversity, water erosion intensification, carbon sequestration reduction, decreased grassland productivity, and reduced local human well-being. The degradation of grasslands can occur very rapidly, but the recovery of their multifunction is slow or does not occur at all [12]. Even so, grassland resilience has been extensively studied [13], and grassland restoration efforts are widely promoted. Consequently, many effective techniques to restore grasslands have been developed [14]. Despite this hope, significant confusion still exists regarding activities that constitute the ecological restoration of grasslands [15].

On-site studies have been conducted globally using mensurative and manipulative experiments; however, the pertinence management that optimizes livestock productivity and improves the ecosystem functions of grasslands still remains largely elusive. To understand the full potential of grasslands to deliver services and functions to society locally, regionally, and globally, further research is ongoing to address the uncertainty and context-dependency of grassland management and utilization and to explore the possible synergies and trade-offs of biodiversity conservation, climate mitigation, and food production in grassland ecosystems. This Special Issue can serve as a meaningful resource, providing valuable insights and evidence-based strategies that can help anyone interested in sustainable grassland management.

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## 2. Overview of the Special Issue

This Special Issue of *Agronomy* contains 22 research articles focused on grassland management and utilization, and these articles can be mainly grouped into three categories:

(1) The management and utilization of traditional grasslands [16–28].
(2) The restoration and management of degraded grasslands [29–34].
(3) Shrub encroachment in grasslands [35–37].

### *2.1. The Management and Utilization of Traditional Grasslands*

The management and utilization of traditional grasslands involve many corresponding factors, including grassland species, grassland production, grassland grazing, grassland nutrient, and grassland health.

As for the management of forage species, Xing et al. [16] found that the precipitation is the key climatic factor restricting the distribution of Carex alatauensis on the Qinghai–Tibet Plateau. This finding will support the conservation and restoration planning process for this species on the Qinghai–Tibet Plateau. Jayasinghe et al. [17] investigated the factors influencing the expression of persistence in perennial ryegrass populations and found significant fixed effects of cultivar, endophyte, and environment and their interactions on the persistence traits of perennial ryegrass. Wu et al. [18] investigated the current and future distribution of orchardgrass-suitable areas globally and found that the areas suitable for habitats increased at higher latitudes while decreasing at lower latitudes as greenhouse gas emissions increased. Ferreira et al. [19] evaluated the forage mass and nutritional value of Guinea Massai grass in an open pasture or the silvopastoral system at different stages of development. These valuable insights will help balance economic development and ecological conservation goals to ensure the sustainable development of forage species and the stability of the ecosystem.

As for the management of grassland production, Li et al. [20] analyzed the structural and spatial characteristics of a grassland gross ecosystem product in karst desertification control. The results of this study can provide a reference for economic decision making regarding the management of grassland ecosystem services in karst areas with similar conditions and beyond. Meng et al. [21] comprehensively assessed the effects of multiple variables on the above-ground biomass (AGB) in managed grasslands in China and found the grassland AGB depends substantially on species, environments, and management practices.

As for grazing management, Temu et al. [22] assessed the sward structural responses of some native warm-season grasses to seasonal changes in harvest regimes and emphasized the importance of taking into consideration species' inherent morphological and physiological adaptations to grazing. Wang et al. [23] investigated the effects of various grazing intensities on the physicochemical properties and bacterial communities of soil in the desert steppe of the Inner Mongolia Autonomous Region.

As for the nutrient management of grasslands, Pan et al. [24] investigated the effects of grazing grassland, mowing grassland, and enclosed grassland on C, N, and P and their ecological stoichiometry in the plant–soil–microbe interaction in the artificial grassland of the karst desertification control area in Southern China and found that the chemical properties and stoichiometric characteristics of the plant–soil–microorganism interaction were significantly changed by different grassland use methods. Yang et al. [25] studied the short-term effects of N addition and mowing on the species diversity and biomass of a typical grassland in Inner Mongolia and found that mowing significantly increased species diversity. Species richness decreased significantly with an increasing N addition rate. Mowing can alleviate the negative effects of N addition on species richness.

As for the health evaluation and management of grasslands, Shi et al. [26] developed a sound warning system to diagnose the potential degradation risk of alpine grasslands, and this study is crucial for understanding the health level of alpine grassland and its further change trends and providing an important scientific basis for rational grazing. Abakumov et al. [27] studied the influence of land use type (pasture, vegetable garden, hayfield, or secondary afforestation) on key agrochemical parameters and the parameters of soil microbial biodiversity and found that the key factor regulating soil microbiome composition shifts was the duration and degree of the irreversibility of an agrogenic impact. Xiong et al. [28] analyzed 143 pertinent works on grassland ecological assets and ecological products and proposed insights into the enhancement of karst grassland ecosystem service functions based on three perspectives: a fragile environment, trade-off synergy, and service management. This study provides valuable insights for the development of regional ecological livestock and the scientific promotion of integrated desertification control.

### *2.2. The Restoration and Management of Degraded Grasslands*

Ecosystem degradation has become a global issue which seriously affects the health of natural ecosystems and human well-being. Many measurements and methods have been investigated and evaluated by researchers for the restoration and management of degraded ecosystems. Hou et al. [29] used a conceptual framework of response–effect traits and the Community Assembly by Trait Selection model (CATS model) as a restoration strategy to achieve effective and efficient aims of restoration in degraded ecosystems.

Enclosure is a commonly used method of restoring degraded grasslands. Yang et al. [30] investigated the response of vegetation community characteristics to enclosure duration in a degraded alpine meadow in the Source Zone of the Yellow River and found that long-term enclosure (10 years) was observed to decrease the species diversity and nutrient utilization efficiency of alpine meadow vegetation. This finding is, to some extent, verified by the study of Liu et al. [31]. Liu et al. [31] evaluated the effects of enclosure on the vegetation characteristics of the main grassland types and found that different vegetation characteristics and grassland types showed different responses to enclosure duration; they suggested that management strategies for enclosed grasslands should be adjusted reasonably according to the type of grassland and the grassland management objectives in order to maintain or even improve the condition and services of grassland ecosystems.

The addition of objective materials is also a common way to retore degraded grasslands. Zhang et al. [32] explored how different strains of fungi affected plant growth and the community dynamics of different degraded levels of grasslands and found that using beneficial fungi (AMF and Trichoderma) for soil improvement and reducing harm from pathogenic Fusarium species (Fusarium boothii and Fusarium circinatum) to plant growth is of great significance for promoting the protection and management of grassland ecosystems, as well as for the restoration and recovery of grasslands. Li et al. [33] investigated the effects of effective microorganisms (EMs) and biochar addition on vegetation biomass, microorganisms, and soil properties in a degraded alpine grassland and found that the combination of the biochar and the EM addition had a synergistic effect on the restoration of degraded alpine grasslands. Chang et al. [34] used native dominant species combined with arbuscular mycorrhizal fungi (AMF) to recover grassland and restrain grassland degradation and found that various ratios of grass–legume mixtures plus AMF inoculation could be used to recover degraded grassland production and enhance grassland nutrient accumulation and stability.

### *2.3. Shrub Encroachment in Grasslands*

Shrub encroachment in grasslands has received an increasing amount of attention in the context of climate change. Xie et al. [35] examined the responses of four stages of the Caragana shrub's life cycle to sandy habitats and found that sandy habitats promoted the population growth of Caragana shrubs during their whole life cycle and highlighted the significant role of sandy habitats in facilitating shrub encroachment in grasslands. Xie et al. [36] also evaluated whether sexual reproduction was the main mechanism for Caragana encroachment into grasslands and found that climatic aridity, grazing, and their combined effects had negative effects on the sexual reproduction of Caragana shrubs and that clonal reproduction might be of considerable importance for understanding the mechanism of shrub encroachment in grasslands. Manganyi et al. [37] evaluated the role of ruminants, particularly browsers, in the dispersal of woody plant seeds and found that after ingestion, shrub seeds were mostly still viable and might still be dispersed in the rangeland, leading to further bush encroachment.

## 3. Concluding Remarks

These findings in this Special Issue partly elucidate the inner mechanisms of change or propose tangible solutions to support the sustainable, rational use of grassland and pasture. In conclusion, effective ecological management and the sustainable utilization of grasslands and pastures are essential for maintaining their ecosystem services and ensuring long-term environmental sustainability. By adopting innovative approaches, integrated land use planning, and collaborative effective models, we can ensure the long-term sustainability of grasslands and pastures for the benefit of both nature and human society.

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## References

1. Dixon, A.P.; Faber-Langendoen, D.; Josse, C.; Morrison, J.; Loucks, C.J. Distribution mapping of world grassland types. *J. Biogeogr.* **2014**, *41*, 2003–2019. [CrossRef]
2. Balvanera, P.; Pfisterer, A.B.; Buchmann, N.; He, J.S.; Nakashizuka, T.; Raffaelli, D.; Schmid, B. Quantifying the evidence for biodiversity effects on ecosystem functioning and services. *Ecol. Lett.* **2006**, *9*, 1146–1156. [CrossRef] [PubMed]
3. Bai, Y.; Francesca Cotrufo, M. Grassland soil carbon sequestration: Current understanding, challenges, and solutions. *Science* **2022**, *377*, 603–608. [CrossRef] [PubMed]
4. Erb, K.H.; Lauk, C.; Kastner, T.; Mayer, A.; Theurl, M.C.; Haberl, H. Exploring the biophysical option space for feeding the world without deforestation. *Nat. Commun.* **2016**, *7*, 11382. [CrossRef] [PubMed]
5. Liu, K.; Sollenberger, L.E.; Newman, Y.C.; Vendramini, J.M.B.; Interrante, S.M.; White-Leech, R. Grazing Management Effects on Productivity, Nutritive Value, and Persistence of 'Tifton 85' Bermudagrass. *Crop Sci.* **2011**, *51*, 353–360. [CrossRef]
6. White-Leech, R.; Liu, K.; Sollenberger, L.E.; Woodard, K.R.; Interrante, S.M. Excreta Deposition on Grassland Patches. I. Forage Harvested, Nutritive Value, and Nitrogen Recovery. *Crop Sci.* **2013**, *53*, 688–695. [CrossRef]
7. Zhang, X.R.; Zhang, W.Q.; Sai, X.; Chun, F.; Li, X.J.; Lu, X.X.; Wang, H.R. Grazing altered soil aggregates, nutrients and enzyme activities in a steppe of Inner Mongolia. *Soil Tillage Res.* **2022**, *219*, 105327. [CrossRef]
8. Eldridge, D.J.; Poore, A.G.B.; Ruiz-Colmenero, M.; Letnic, M.; Soliveres, S. Ecosystem structure, function, and composition in rangelands are negatively affected by livestock grazing. *Ecol. Appl.* **2016**, *26*, 1273–1283. [CrossRef]
9. Eldridge, D.J.; Soliveres, S.; Bowker, M.A.; Val, J. Grazing dampens the positive effects of shrub encroachment on ecosystem functions in a semi-arid woodland. *J. Appl. Ecol.* **2013**, *50*, 1028–1038. [CrossRef]
10. Conant, R.T.; Paustian, K. Grassland management activity data: Current sources and future needs. *Environ. Manag.* **2004**, *33*, 467–473. [CrossRef]
11. Stevens, N.; Erasmus, B.F.N.; Archibald, S.; Bond, W.J. Woody encroachment over 70 years in South African savannahs: Overgrazing, global change or extinction aftershock? *Philos. Trans. R. Soc. B Biol. Sci.* **2016**, *371*, 20150437. [CrossRef] [PubMed]
12. Veldman, J.W.; Buisson, E.; Durigan, G.; Fernandes, G.W.; Le Stradic, S.; Mahy, G.; Negreiros, D.; Overbeck, G.E.; Veldman, R.G.; Zaloumis, N.P.; et al. Toward an old-growth concept for grasslands, savannas, and woodlands. *Front. Ecol. Environ.* **2015**, *13*, 154–162. [CrossRef] [PubMed]
13. Jentsch, A.; Kreyling, J.; Elmer, M.; Gellesch, E.; Glaser, B.; Grant, K.; Hein, R.; Lara, M.; Mirzae, H.; Nadler, S.E.; et al. Climate extremes initiate ecosystem-regulating functions while maintaining productivity. *J. Ecol.* **2011**, *99*, 689–702. [CrossRef]
14. Li, J.; Shao, X.; Huang, D.; Liu, K.; Shang, J.; Zhang, Q.; Zhao, T.; Yang, X. Short-term biochar effect on soil physicochemical and microbiological properties of a degraded alpine grassland. *Pedosphere* **2022**, *32*, 426–437. [CrossRef]
15. Suding, K.; Higgs, E.; Palmer, M.; Callicott, J.B.; Anderson, C.B.; Baker, M.; Gutrich, J.J.; Hondula, K.L.; LaFevor, M.C.; Larson, B.M. Committing to ecological restoration. *Science* **2015**, *348*, 638–640. [CrossRef] [PubMed]
16. Xing, Y.; Shi, J.; De, K.; Wang, X.; Wang, W.; Ma, Y.; Zhang, H.; He, M.; Liu, Q. The Current Distribution of Carex alatauensis in the Qinghai–Tibet Plateau Estimated by MaxEnt. *Agronomy* **2023**, *13*, 564. [CrossRef]
17. Jayasinghe, C.; Jacobs, J.; Thomson, A.; Smith, K. Evaluation of the Relationship between Cultivar, Endophyte and Environment on the Expression of Persistence in Perennial Ryegrass Populations Using High-Throughput Phenotyping. *Agronomy* **2023**, *13*, 2292. [CrossRef]

18. Wu, J.; Yan, L.; Zhao, J.; Peng, J.; Xiong, Y.; Xiong, Y.; Ma, X. Modeling Climate Change Indicates Potential Shifts in the Global Distribution of Orchardgrass. *Agronomy* **2023**, *13*, 1985. [CrossRef]
19. Ferreira, M.R.; Cardoso, A.d.S.; Andrade, M.E.B.; Brito, T.R.; Ruggieri, A.C. How Are Warm-Season Pastures' Nutritive Value and Fermentation Characteristics Affected by Open Pasture, Silvopasture, and Sward Herbage Maturity? *Agronomy* **2023**, *13*, 1756. [CrossRef]
20. Li, Y.; Xiong, K.; Zhang, W.; Song, S.; Luo, L. Analyzing Characteristics of Grassland Gross Ecosystem Product to Inform Decision Making in the Karst Desertification Control. *Agronomy* **2023**, *13*, 1861. [CrossRef]
21. Meng, H.; Yang, J.; Sun, W.; Xiao, L.; Wang, G. Aboveground Biomass in China's Managed Grasslands and Their Responses to Environmental and Management Variations. *Agronomy* **2022**, *12*, 2913. [CrossRef]
22. Temu, V.W.; Kering, M.K. Compensatory Structural Growth Responses of Early-Succession Native Warm-Season Grass Stands to Defoliation Management. *Agronomy* **2023**, *13*, 1280. [CrossRef]
23. Wang, Y.; Guo, M.; Li, Y.; Yin, X.; Guo, J.; Wang, J. Responses of Soil Bacterial Communities and Chemical Properties to Grazing Regulation in Desert Steppe. *Agronomy* **2023**, *13*, 2817. [CrossRef]
24. Pan, G.; Song, S.; Wang, X.; Chi, Y. Using Ecological Stoichiometric Characteristics to Inform Grassland Management in the Karst Desertification Area. *Agronomy* **2023**, *13*, 1841. [CrossRef]
25. Yang, Z.; Minggagud, H.; Wang, Q.; Pan, H. Interacting Effects of Nitrogen Addition and Mowing on Plant Diversity and Biomass of a Typical Grassland in Inner Mongolia. *Agronomy* **2023**, *13*, 2125. [CrossRef]
26. Shi, H.; Liu, M.; Zhu, S.; Duan, Z.; Wu, R.; Quan, X.; Chen, M.; Zhang, J.; Qiao, Y. Construction of an EarlyWarning System Based on a Fuzzy Matter-Element Model for Diagnosing the Health of Alpine Grassland: A Case Study of Henan County, Qinghai, China. *Agronomy* **2023**, *13*, 2176. [CrossRef]
27. Abakumov, E.V.; Gladkov, G.V.; Kimeklis, A.K.; Andronov, E.E. The Microbiomes of Various Types of Abandoned Fallow Soils of South Taiga (Novgorod Region, Russian North-West). *Agronomy* **2023**, *13*, 2592. [CrossRef]
28. Xiong, K.; He, C.; Chi, Y. Research Progress on Grassland Eco-Assets and Eco-Products and Its Implications for the Enhancement of Ecosystem Service Function of Karst Desertification Control. *Agronomy* **2023**, *13*, 2394. [CrossRef]
29. Hou, J.; Wu, M.; Feng, H. Applying Trait-Based Modeling to Achieve Functional Targets during the Ecological Restoration of an Arid Mine Area. *Agronomy* **2022**, *12*, 2833. [CrossRef]
30. Yang, P.; Li, X.; Li, C.; Zhang, J. Effects of Long-Term Exclosure on Main Plant Functional Groups and Their Biochemical Properties in a Patchily Degraded Alpine Meadow in the Source Zone of the Yellow River, West China. *Agronomy* **2023**, *13*, 2781. [CrossRef]
31. Liu, C.; Li, H.; Liu, K.; Shao, X.; Huang, J.; Siri, M.; Feng, C.; Yang, X. Vegetation Characteristics of the Main Grassland Types in China Respond Differently to the Duration of Enclosure: A Meta-Analysis. *Agronomy* **2023**, *13*, 854. [CrossRef]
32. Zhang, Y.; Chang, J.; Xie, J.; Yang, L.; Sheteiwy, M.S.; Moustafa, A.-R.A.; Zaghloul, M.S.; Ren, H. The Impact of Root-Invasive Fungi on Dominant and Invasive Plant Species in Degraded Grassland at Nanshan Pasture. *Agronomy* **2023**, *13*, 1666. [CrossRef]
33. Li, J.; Li, H.; Shang, J.; Liu, K.; He, Y.; Shao, X. The Synergistic Effect of Biochar and Microorganisms Greatly Improves Vegetation and Microbial Structure of Degraded Alpine Grassland on Qinghai–Tibet Plateau. *Agronomy* **2023**, *13*, 2203. [CrossRef]
34. Chang, J.; Li, K.; Xie, J.; Zhang, Y.; Wang, S.; Ren, H.; Liu, M. Integrating Native Plant Mixtures and Arbuscular Mycorrhizal Fungi Inoculation Increases the Productivity of Degraded Grassland. *Agronomy* **2023**, *13*, 7. [CrossRef]
35. Xie, L.; Li, Y.; Guo, H.; Wang, C.; Chen, Q.; He, P.; Ma, C. Sandy Habitats Play an Important Role in Shrub Encroachment in Grasslands. *Agronomy* **2022**, *12*, 2858. [CrossRef]
36. Xie, L.; Li, Y.; Lin, M.; Guo, H.; Wang, Y.; Wang, L.; Ma, C. Sexual Reproduction Is Not Responsible for Caragana Shrub Encroachment in Grasslands. *Agronomy* **2023**, *13*, 1848. [CrossRef]
37. Manganyi, F.L.; Tjelele, J.; Mbatha, K.R.; Letsoalo, N.; Müller, F. The Potential for Endozoochorous Dispersal of Vachellia nilotica Seeds by Goats: Implications for Bush Encroachment. *Agronomy* **2023**, *13*, 1599. [CrossRef]