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Editorial

Unveiling Innovations in Grasslands Productivity and Sustainability

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1. Introduction

Grasslands represent a vital ecosystem, covering roughly 40.5% of the Earth's land surface—excluding Greenland and Antarctica—equivalent to an area of 52.5 million km^2. Moreover, they constitute approximately 70% of the world's agricultural areas, which translates to around 34.3 million km^2 [1,2]. Within these ecosystems, grasslands generate approximately 10% of terrestrial plant biomass and hold roughly 30% of the planet's soil organic carbon (SOC) reservoir [3]. They also provide a wide range of essential ecosystem services, encompassing food production, support for biodiversity, climate regulation, water-quality maintenance, management of water flows, erosion mitigation, landscape preservation, and recreational opportunities [4,5]. However, despite their ecological significance, grasslands are threatened by human activities such as overgrazing, drought, and unsustainable agricultural practices [1,6,7]. Overgrazing reduces ground cover, leading to soil degradation, reduced plant diversity, and even desertification in some regions [8]. Grasslands are also susceptible to the impacts of climate change, including extreme weather events and altered precipitation patterns, which can disrupt traditional grazing and cropping practices [9]. Conversion of grasslands for agriculture and urban development threatens these ecosystems, resulting in habitat loss and reduced carbon storage [10]. However, although grasslands play a crucial role in carbon cycling, they are also a source of greenhouse gas (GHG) emissions, especially methane (CH_4). This makes balancing carbon sequestration with emissions challenging.

Innovative research is essential, as it will help us to develop strategies that enhance grassland productivity while maintaining or improving sustainability, ensuring that these vital ecosystems continue to provide essential services for humanity and the planet. This necessitates the broader adoption of efficient, cost-effective management practices and policies. Strategies such as optimizing nitrogen fertilizer rates, managing stocking rates, utilizing legumes and supplements, implementing grazing management techniques, adjusting daily herbage allowance, addressing GHG emissions, promoting carbon sequestration, enhancing biodiversity, and the responsible utilization of grass by-products could play a major role in this regard.

The advancements in grassland productivity and sustainability not only benefit agriculture by increasing grass yields and resilience, but also have positive impacts on ecosystems through biodiversity conservation and erosion control. Moreover, these advancements contribute to carbon sequestration efforts, which are crucial for mitigating climate change, and inform more efficient and climate-resilient land management strategies. The first volume of this Special Issue (SI) focuses on recent advancements in our understanding, with the aim of enhancing the productivity and sustainability of grasslands through strategic approaches. It serves as a crucial resource, offering valuable insights and evidence-based strategies that can inform and guide policymakers, practitioners, researchers, and anyone interested in sustainable land management, facilitating informed decision-making and effective practices for a more sustainable future. The articles in this volume will enhance readers' understanding of the subject matter and broaden their knowledge of this topic.

2. Overview of the SI

The interdisciplinary studies presented in this collection highlight the importance of collaboration among agronomists, ecologists, climate scientists, and other specialists to achieve a holistic comprehension of grassland ecosystems. The SI features two systematic literature reviews and twelve research articles, covering diverse global regions, climates, grass types, and research methods that address the challenges faced by grasslands globally. This Special Issue contained two reviews: one examined the impact of N fertilization on species diversity in the EU's grasslands, revealing a negative correlation between N and species diversity [11], while the other discussed the importance of grazing management in relation to key soil quality indicators within global grasslands, emphasizing the benefits of sustainable grazing management plans and novel grassland species [12].

Simulation models represent innovative key tools for exploring GHG emissions and soil carbon dynamics. In this SI, three studies employed modeling techniques (DNDC, ECOSSE, and DayCent) to estimate GHG emissions, soil respiration, and soil carbon stock in grasslands, respectively. The DNDC model underscored the susceptibility of intensely managed and fertilized grasslands to GHG emissions amplified by global warming, highlighting climate feedback risks [13]. The ECOSSE model effectively estimated cumulative soil respiration in grasslands but requires further development, especially in dry and low-input grasslands [14]. Meanwhile, the DayCent model suggested that grazing and longer ley times can enhance soil carbon stocks, with the effectiveness of compost fertilizer hinging on crop rotation choices [15]. Subedi et al. [16] noted that strategic grazing mitigates soil compaction, preserving carbon content during drought and heavy rainfall events. Ren et al. [17] reported that precipitation and community characteristics significantly influence precipitation-use efficiency in natural grasslands. Thus, enhancing vegetation structure and species diversity can bolster grassland ecosystems' adaptability to climate change.

Kulik et al. [18] demonstrated the potential for fallow deer pasture management in Poland to support grassland conservation, with sward composition varying based on rotational management. Research by Song et al. [19] highlighted the advantages of artificial restoration over natural restoration in terms of enhancing plant, soil, and microbial nutrient concentrations in mixed-seed ecosystems. Rady et al. [20] found that intercropping of grasses and legumes improves microbial protein synthesis and forage nutritive value. Hou et al. [21] discussed how sucrose addition can enhance kudzu silage's quality and microbial communities in China. However, Malinowska & Wi'sniewska-Kadzajan [22] recommend using Tytanit combined with nitrogen fertilization for Festulolium braunii cultivation to improve its nutritional value.

Moreover, in their study, Rama and their colleagues [23] discovered that combining legume overseeding with phosphorus (P) fertilization led to a notable boost in forage production within pastoral livestock paddocks. This effect was particularly pronounced during periods of forage scarcity, yet it also resulted in heightened variability in forage production both within and between years. Further, in a study conducted by Glimskär et al. [24], data from a Swedish farmer survey were utilized to explore attitudes towards agri-environmental payments, with a specific focus on farm characteristics and sustainable grazing by cattle and sheep. Their results emphasized the importance of directing payments towards valuable grasslands, thereby underscoring the necessity for a more refined classification framework for European grasslands.

3. Concluding Remarks

Earth's grasslands are irreplaceable ecosystems that are vital to our planet's health, and this SI provides a valuable glimpse into the challenges they face and the innovative solutions that can help ensure their sustainability for generations to come. The significance of ongoing research and collaboration in advancing grassland productivity and sustainability cannot be overstated. Exploring innovative solutions, engaging interdisciplinary teams, and sharing knowledge is the key to unlocking the full potential of these vital ecosystems.

The potential positive outcomes are manifold. At the local level, communities can benefit from increased agricultural productivity, diversified livelihoods, and enhanced resilience in the face of climate challenges. The sustainable management of grasslands can also safeguard local water resources, preserve biodiversity, and support healthier ecosystems. At a global scale, the benefits are equally profound. Sustainable grassland practices contribute to carbon sequestration, mitigating climate change and reducing GHG emissions. By preserving these ecosystems, we bolster the planet's capacity to regulate the climate, ensure food security, and maintain clean water sources. In essence, the ongoing research and collaboration to improve grassland's productivity and sustainability not only hold the potential to improve the lives of local communities, but also play a pivotal role in safeguarding the global environment. Together, we have the power to cultivate a more sustainable and harmonious relationship with our grasslands, fostering a brighter future for generations to come. The forthcoming second volume of this Special Issue will collate additional advancements related to grassland productivity and sustainability.

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