Fundamental Research 3 (2023) 149–150

Contents lists available at ScienceDirect

Fundamental Research

journal homepage: http://www.keaipublishing.com/en/journals/fundamental-research/

Editorial

Grassland Science in a New Era

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Grasslands are one of the major biomes on Earth, covering approximately 25% of the terrestrial planet. Human history is deeply intertwined with grassland biomes, where we, as a natural species, first walked upright 2 million years ago. Today, grassland ecosystems continue to play an important role in people's livelihoods by producing meat and dairy products, providing habitats for biodiversity, and delivering essential ecosystem services such as climate regulation and cultural heritage. Grass and grassland thus have been important research subjects for ecology and agronomy. The earliest experiment mentioned by Darwin in The Origin of Species was performed with different monocultures and mixtures of grasses and herbs in the early 19th century. The longest-running ecological experiment of modern science, the Park Grass Experiment, Rothamsted, UK, started in 1843 and provides extremely valuable long-term data for research on natural selection and biodiversity. Grasslands are also the place where many theories of modern ecology and conservation biology were hatched, such as the Cedar Creek Grassland Experiment (Minnesota, USA, since 1994) and Jena biodiversity and ecosystem functioning experiment (Germany, since 2002).

Even so, grass species and grassland systems are often undervalued, resulting in the relatively slow development of grassland science, especially in China. One of the reasons is that products from grassland systems were not an integral component of food security until the recently developed ideology of the "Big Food Concept". Insufficient attention has been given to the reality that the dietary structure of developing countries, especially China, has changed dramatically, largely leading to a late start of forage breeding, relatively backward technology, a small research team and limited investment. The second reason is that the focus has long been on the productive function of grassland, and not enough attention has been given to its ecological function, especially its multifunctionality.

Grassland science provides the scientific basis for the management, monitoring and conservation of rangelands and cultivated pastures. Grassland science in China has distinctive characteristics and a different development path from other countries. It integrates the content of forage science and rangeland science and includes the features of turf science, management of grassland pests, economics and management of grassland agriculture. In general, it has characteristics of both grassland agriculture and grassland ecology. One particular challenge for grassland science is to resolve the conflict between the rapid increase in demand for grassland-enabled animal products and grassland degradation caused by climate change and human interventions. Grassland science ought to find measures to tackle these challenges via integrated and interdisciplinary approaches.

To promote the development of grassland science, the National Natural Science Foundation of China (NSFC) held a 'Shuangqing Forum' on the theme of "Grassland Science in a New Era: Major Issues and Challenges" in Beijing from August 17 to 18, 2022. More than 40 leading experts and scholars gathered to discuss the current challenges and future directions of grassland science. At the forum, experts and scholars shared their insights on the theoretical and technological issues that urgently need to be solved and proposed the priority research directions in the next 5-10 years.

This special issue stems from several rounds of valuable discussions before and during the Shuangqing Forum - an effort of nearly two years. It consists of 3 reviews, 1 perspective, and 5 research articles that contribute solutions to sustainable grassland development and advance the state of knowledge in grassland science. Zhao provided a comprehensive review of the shifts in research themes in grassland science over the past 120 years, highlighting the need to balance the development between traditional production-oriented fields and cutting-edge research using new techniques such as molecular breeding and remote sensing [1]. Three articles identified gaps related to grass plant breeding and grassland agriculture. Wang and Zhang proposed research priorities for the sustainable development of alfalfa pasture in China [2]. Nandety et al. reviewed the potential and genomic resources of *Medicago truncatula* as a model to study the biology of legumes and molecular mechanisms of symbiotic nitrogen fixation [3]. Yang et al. investigated the national forage demand and supply state and dynamics in China using 500 m-resolution satellite data and livestock data [4].

As grasslands contribute to approximately 30% of the terrestrial C stock and could play an important role in mitigating climate change, the grassland C cycle has received intensive research efforts. Three arti-

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https://doi.org/10.1016/j.fmre.2023.02.001

cles in this special issue are related to this topic. Liu et al. reviewed the current state of knowledge on the mechanisms that control grassland C cycling rates and patterns and offered suggestions for future research on grassland C conservation and restoration [5]. Alpine wetlands are among the most vulnerable grassland systems to climate change, and Wang et al. demonstrated that biogeomorphic succession and lateral carbon exchange are both important for understanding the long-term dynamics of the climate footprint [6]. Using a state-of-the-art terrestrial laser scanning technique, Zhao et al.showed that canopy structure is an important intermediary factor regulating grassland diversity- net primary productivity relationships under human disturbances [7]. Finally, two articles used manipulated experimental approaches to assess how grassland ecosystems responded to global changes. Zhang et al. carried out nitrogen deposition experiments for six consecutive years and found that adding nitrogen in autumn rather than during the growing season resulted in a decrease in ecosystem stability [8]. Qin et al. studied how whole-soil warming could affect species composition and productivity in an alpine meadow [9]. They found that plant diversity, biomass and productivity in the alpine meadow were highly resistant to climate warming even though plant community composition was significantly altered.

The articles in this issue cover different aspects of the current challenges and progress of grassland science. The findings contribute to the theoretical understanding from forage breeding to grassland ecological processes and facilitate the development of multidisciplinary approaches for the sustainable use of grasslands. As grassland science enters a critical era, we hope that this issue can spark more comprehensive studies that better address social, economic and ecological needs of grasslands.

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