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Editorial

Understanding ecosystem functions in grasslands under climate change for sustainable development of the Inner Mongolian Plateau

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This Special Issue focuses on processes and mechanisms of bio-physical change in grassland ecosystems of north-east Asia by assessing vegetation dynamics, studying the response of plants to experimental manipulations of climate and modelling plant dynamics under predicted future climate. This focus complements the scope of two earlier Special Issues that addressed social and ecological aspects of climate change adaptation in northern China grasslands, including Inner Mongolia [Vol. 36 (6)] (Li and Whalley 2014), and resilience in the social-ecological systems of the high altitude rangelands on the Qinghai-Tibetan Plateau [Vol. 37 (1)] (Dong and Sherman 2015).

Rangeland, of various types including extensive grassland, covers more than 40% of China (Ren *et al*. 2008) and much of the land in adjoining countries of eastern and central Asia including Mongolia. As Li *et al*. (2015*a*) show for the Qinghai-Tibetan plateau, the ecosystem services generated by China's grassland ecosystems are substantial, diverse and spatially heterogeneous. They underpin the well being of substantial numbers of people, both residents and distant populations.

In recent decades, degradation has become an increasing threat to these ecosystem services. Papers in other Special Issues about China's rangelands include research on the extent and characteristics of this degradation (Han *et al*. 2008; Tang *et al*. 2015; Wang *et al*. 2015*b*) and how it is perceived by local people (Hou *et al*. 2014*b*). Climate change, overgrazing and other factors have all contributed to degradation in different parts of Inner Mongolia and on the Qinghai-Tibetan Plateau (Wu *et al*. 2014; Wang *et al*. 2015*a*). Management of livestock grazing is an ancillary theme in these two Special Issues (Wang *et al*. 2014*a*; Zhang *et al*. 2014; Su *et al*. 2015; Zhang *et al*. 2015) reflecting the importance of sound management for vegetation recovery and preventing future degradation.

Although not necessarily the main cause of observed degradation, climate change has had substantial impacts on productivity and livelihoods in China's rangelands as is evidenced by contributions to past Special Issues (Ding *et al*. 2014; Wang *et al*. 2014*b*; Yang *et al*. 2014; Zhang *et al*. 2015) and other scholarship (e.g. Li *et al*. 2012; Liu and Wang 2012; Li *et al*. 2014*a*; Yang *et al*. 2017). For example, monitoring at ecological observation stations in Inner Mongolia, where grazing has been excluded over a long period of time has shown decreases in aboveground biomass and biodiversity in response to climate change (Zhang *et al*. 2011; Li *et al*. 2015*b*). The impact of climate changes on China's rangelands has been exacerbated by degradation caused by grazing, cropping and other land uses, severely hampering sustainable development (EBNCCA 2011; Zhao *et al*. 2015). Increased scientific understanding about the likely trajectory of future climate change, as described below, continues to raise questions about how flows of ecosystem services will be affected. The focus of this current Special Issue, on the response of ecosystem functions to global change and particularly to changes in climate, provides underpinning research for addressing such questions.

Ecosystem functions are biological, chemical and physical processes, including carbon and nutrient cycling, that involve interactions among ecosystem components such as the atmosphere, soils, water, vegetation types and species populations (Boyd and Banzhaf 2007; Bastian *et al*. 2012). As shown conceptually in Fig. 1, these processes are the foundation for ecosystem services which include the end products from the ecosystem that are used or consumed by people (Brown and MacLeod 2017; Sala *et al*. 2017). Ecosystem services also include supporting services such as biodiversity, habitat and primary productivity. Unlike other ecosystem services, supporting services are not directly used by people. However they are necessary for production of other ecosystem services. Their dependence on ecosystem functions is very direct (Sala *et al*. 2017) which may account for a lack of consistent distinction between the terms 'ecosystem functions' and 'supporting ecosystem services' that has been noted in the literature (Boyd and Banzhaf 2007; Bastian *et al*. 2012). Indeed, the focus of this Special Issue does extend beyond a strict definition of ecosystem functions to include research

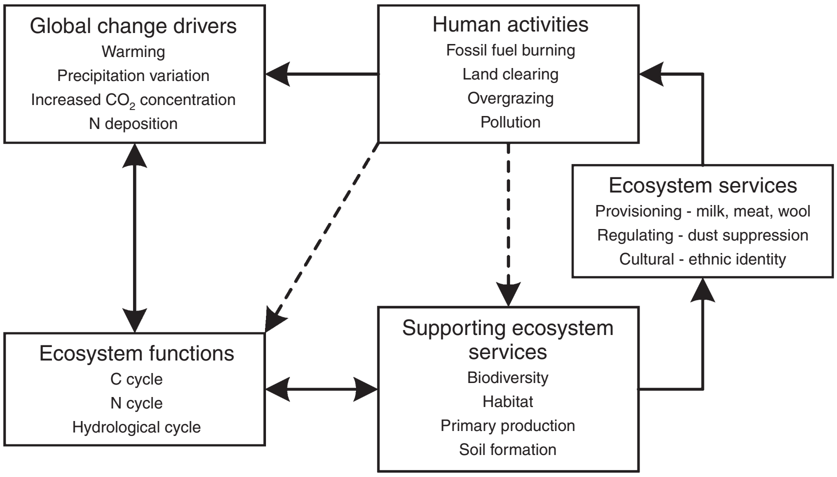

Fig. 1. Interactions between global change and ecosystem functions. Human activities are generating global scale climate change drivers which affect ecosystem functions. These and other global scale impacts are indicated by solid arrows. Ecosystem functions also affect supporting ecosystem services. These are necessary for production of provisioning, regulating and cultural ecosystem services which are the end products or benefits that people gain directly from ecosystems, shown with examples from Inner Mongolian grasslands. Ecosystem functions may also directly affect climate change drivers, reducing their magnitude, such as carbon sequestration reducing atmospheric carbon dioxide. As well as global impacts, human activities also directly affect ecosystem functions and supporting ecosystem services at local scales, indicated by dashed lines (Carpenter *et al*. 2009; Bastian *et al*. 2012; Brown and MacLeod 2017; Polley *et al*. 2017).

on supporting ecosystem services, notably plant biodiversity and primary production, under climate change on the Mongolian Plateau.

The Mongolian Plateau covers 2.6 million km^2 and ranges between ~900 m and 1500 m in elevation. It is divided politically between the republic of Mongolia in the north-west, occupying ~55% of the plateau, and China in the south and east. Mongolia and the Inner Mongolia Autonomous Region of China have contrasting socioeconomic characteristics and land use policies (Chen *et al*. 2015). Other than remote sensing studies (e.g. Tao *et al*. 2015; John *et al*. 2016), research that investigates the same phenomena in both jurisdictions is comparatively rare (but see Brown *et al*. 2013; Chen *et al*. 2015; Fan *et al*. 2016; for example). This special issue is no exception. One paper (Cao *et al*. 2018) analyses data from the Mongolian Plateau as a whole and other papers concern all or parts of Inner Mongolia.

The Inner Mongolia Autonomous Region, which closely coincides with the area of the Mongolian Plateau that is within China, is large and diverse in climate, vegetation and land use. It extends more than 1700 km north to south, across 16 degrees of latitude, from 37 to 53°N. It extends more than 2000 km east to west, across nearly 50 degrees of longitude, from 77 to 126°E. Its climate is semiarid to arid in the west and sub-humid monsoonal in the east. Very cold winters restrict the growing season to a few months. The north-east, with mean annual precipitation of more than 500 mm, is dominated by forest. Agriculture is common in lower altitude areas in the east and south-east. The balance of Inner Mongolia, ~70% of the region's area, is rangeland. Most of this comprises grassland, in three major zones: meadow steppe, in the humid north-east; typical steppe in the semiarid conditions of central Inner Mongolia, and desert steppe in the west. The latter grades into sparse and very sparse shrubland in the far west of the region where mean annual precipitation is less than 100 mm (Angerer *et al*. 2008; Chuai *et al*. 2013; Mu *et al*. 2013; Wu *et al*. 2014; Yin *et al*. 2018).

Temperatures have increased across Inner Mongolia in recent decades and precipitation has shown a small decrease or no trend (Lu *et al*. 2009; EBNCCA 2011; Chuai *et al*. 2013; Mu *et al*. 2013; Li *et al*. 2014*b*; Wu *et al*. 2014). A warming trend has also been apparent in other Chinese rangelands, such as on the northern Qinghai-Tibetan Plateau (Liu *et al*. 2015) where its impact on vegetation growth has been positive (Piao *et al*. 2015). For Inner Mongolia, climate change projections are for continuation of the increasing trend in temperature (Ma *et al*. 2011; Hijioka *et al*. 2014). Trends in future precipitation are less certain but a 10–20% increase is forecast by the late 21st century in some parts of the region under some scenarios (Ma *et al*. 2011; Christensen *et al*. 2013; Hijioka *et al*. 2014; Li *et al*. 2014*a*).

Sustainable development requires that economic and ecological imperatives be balanced, but multiple obstacles exist to doing so. For example, poor prospects of achieving increased economic returns can preclude adoption of ecologically sustainable but costly management practices. Climate change will exacerbate such challenges if it impacts negatively on production as is happening in hot environments where climate change is reducing livestock growth rates and yields of meat and milk (Nardone *et al*. 2010). Tensions between short-term economic imperatives, for the viability of livestock enterprises and improved living standards for livestock breeders, and maintaining healthy ecosystem functioning are characteristic of many global rangelands (e.g. MacLeod and McIvor 2006).

Institutional obstacles to sustainable development are common as a result of mismatches between the temporal and spatial scale of ecosystem processes and the scale of management (Cumming *et al*. 2006). Improved understanding of how climate change will impact on the spatiality and dynamics of ecological processes is important to addressing such obstacles. This Special Issue's contributions update and build on other research published in *The Rangeland Journal* on ecosystem functions and supporting ecosystem services in Inner Mongolia. That research has examined the impact of grazing management on carbon stocks and cycles (Hou *et al*. 2014*a*; Wang *et al*. 2017) on primary productivity (Wang *et al*. 2014*a*) and on abundance of C4 plants (Zhang *et al*. 2014); and has modelled net primary productivity under emissions scenarios prepared for the IPCC 3rd Assessment Report (Lin *et al*. 2013; Li *et al*. 2014*a*).

The research presented in this Special Issue was undertaken at regional, community and individual scales. The influence of climatic factors on variation in NDVI across the grasslands of the Mongolian Plateau is investigated by Cao *et al*. (2018). Studies of the Inner Mongolian Plateau as a whole address the incidence of drought and its impact on vegetation growth of different grassland types (Miao *et al*. 2018) and model the impact of predicted climate change on aboveground biomass and soil organic carbon using emissions scenarios prepared for the IPCC's 5th Assessment Report (Li *et al*. 2018). Community-scale research includes a series of papers that examine the effects of projected climate change on ecosystem function in *Stipa krylovii* steppe (Hu *et al*. 2018*b*), a type of typical steppe of key importance to livestock husbandry (DAHV and GSAHV 1996). For this research predicted climate change, involving an increase in average air temperatures of 3°C and a 20% increase in precipitation, was simulated through an experimental design described by Wan *et al*. (2018*a*). The impact of this changed climate was investigated on plant species diversity and sward characteristics (Wan *et al*. 2018*b*), on soil respiration (Wang *et al*. 2018*a*) and on carbon exchange (Chao *et al*. 2018) with results synthesised by Hu *et al*. (2018*b*). Also at the community-scale, Wang *et al*. (2018*b*) report on an experiment that assessed the impact of increasing atmospheric nitrogen deposition on the spatial distribution and interspecific associations of plant species in meadow steppe. Two further studies are at the scale of individual plants and species. The potential for irrigation to augment grassland productivity is assessed by Yan *et al*. (2018) using four varieties of forage plant. The response of plant species to grazing management is assessed by Zhang *et al*. (2018) through plant functional traits.

The focus of these papers, on ecosystem function and supporting ecosystem services, particularly complements previous Special Issues that explored the causes of grassland degradation, vulnerability, resilience and adaptation in China's northern grasslands [Vol. 36 (6)] (Li and Whalley 2014) and the Qinghai-Tibetan Plateau [Vol. 37 (1)] (Dong and Sherman 2015). The final paper in the current Special Issue (Hu *et al*. 2018*a*) draws from all these contributions and other research to explore implications of climate change trajectories for sustainable development in Inner Mongolia.

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