Grassland resources and protections in the yellow river source zone on the Qinghai-Tibet plateau

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ABSTRACT

This paper summarises resources and protections of the Yellow River Source Zone on the Qinghai-Tibet Plateau. A concerted effort has been made to address concerns for overgrazing on the alpine steppe and alpine meadow landscapes in the source zone of the Yellow River. An assessment of the impacts of overgrazing includes consideration of the role of small mammals (on the one hand they are considered as a critical ecosystem engineer, on the other they are perceived as a major threatening pest). Analyzed in this paper are management options in the restoration of degraded grasslands.

Key words: Grassland degradation; Grassland restoration; Yellow River Source Zone

Introduction

The Qinghai-Tibet Plateau is one of the world's major pastoral areas, covering an area of 131 million ha. As the Qinghai-Tibet Plateau is a sparsely populated area, it contributes little to China's overall economy. However, its rangelands have a rich cultural and geographic diversity and high biodiversity. Alpine grasslands of the Qinghai-Tibet Plateau provide numerous ecosystem services, such as plant diversity conservation, carbon sequestration, soil and water conservation, as well as maintenance of the Tibetan culture and traditions, etc. As one of the major pastoral production bases in China, the Qinghai-Tibet Plateau supported 30 million sheep (including goats) and 12 million yaks in 2005 (Wen *et al.*, 2013). As the soil holds more than twice as much carbon as can be found in the vegetation or the atmosphere, changes in the concentration of carbon in soil can have a great effect on the global carbon budget. Carbon and nitrogen in soil impact upon not only soil quality, but also ecosystem productivity. Soils at high latitudes, especially those associated with the greater thick and active layer related to the melting of permafrost, respond sensitively to climate change. Alpine grassland ecosystems are key components of global environmental change, especially in terms of carbon and nitrogen sequestration. Grasslands are also an important alpine genetic pool. High biodiversity increases the stability of most ecosystems and enhances the sustainability of resource exploitation. Wen *et al.* (2013) reported that almost 30% of alpine grasslands atop the Qinghai-Tibet Plateau were severely degraded due to the integrated effects of climate change, population increase, overgrazing and rodent (plateau pika, *Ochotona curzoniae*) damage. Grassland degradation affects not only the livelihood of pastoralists, but also others who suffer from resultant changes to soil and water resources, dust storms, commodity scarcity, and the social consequences of uprooted people (Li *et al.*, 2014). As grassland degradation threatens a suite of environmental and socio-cultural values, isolating underlying causes of degradation, and consideration of appropriate measures to address them, are critical concerns atop the Qinghai-Tibet Plateau.

Grassland resources in the Yellow River Source Zone

The Yellow River Source Zone makes up the eastern half of the Sanjiangyuan region in southern Qinghai Province. It covers a total area of 137,700 km^2, accounting for 19.03% of the total area of Qinghai Province. Prior to 2013, it only covered a total area of 106,400 km^2 (Figure 1). The reason for increase in area is that these areas are similar geographical positions for protection of water resource in the Yellow River Source Zone. Grasslands are the primary vegetation community in the Yellow River Source Zone.

The Sanjiangyuan region makes up the southern half of Qinghai Province. The region is divided into 22 administrative districts. The Yellow River Source Zone (YRSZ) is made up of fifteen counties in south eastern Qinghai Province (demarcated with the black line). This does not include counties in Sichuan and Gansu provinces.

Grasslands on the Qinghai-Tibet Plateau were formed about a million years ago (Li, 1997). The present pastures of Northeast Tibet originate largely from the conversion of forests to grasslands at least 8,000 years ago (Miehe *et al.*, 2008), with a grazing history extending back over 9,000 years (Miehe *et al.*, 2009). Grassland in the Yellow River Source Zone falls into two broad types, alpine steppe (21%) and alpine meadow (72%) (NDRC, 2014). The main grassland species include *Kobresia* (*kobresia* spp.), needlegrass (*Stipa* spp.), sedge (*Carex* spp.), saussur (*Saussurea* spp.), roegneria (*Roegneria*, spp.), bluegrass (*Poa* spp.), wild ryegrass (*Elymus* spp.) and speargrass (*Achnatherum* spp.). All of these species have a low productivity and their forage height is low ranging between 10-30 cm. Alpine steppe is a variant of the temperate steppe that is evident

Fig. 1. Map of Qinghai Province, Sanjiangyuan Region and the Yellow River Source Zone (modified from Li *et al.*, 2012)

a. Alpine steppe

b. *Stipa purpurea*

c. Alpine meadow

d. Kobresia pygmaea of a uniform height

Fig. 2. Alpine steppe and meadows (Photos: Li Xilai)

under the cold conditions of the Yellow River Source Zone without the sod layer found in gravel and coarse sandy loam. *Stipa purpurea* is the dominant species of alpine steppe on the Plateau (Figure 2 a & b).

Alpine steppe is dominated by mainly *Stipa purpurea*. Plant height of alpine steppe is higher than alpine meadow. The 'carpet' grassland of alpine meadows comprises mainly of *Kobresia* species (*Kobresia pygmaea* and *K. humilis*) with a very low plant height (< 5 cm). Alpine meadows are rich in plant species, with up to 30 species per m^2. Severe grazing of alpine meadow results in vegetation cover of a uniformly short plant height comprised primarily of *Kobresia*. In summer this takes on the appearance of a large green grassland carpet.

The huge alpine meadow in the Yellow River Source Zone is a unique natural landscape and an important grassland resource. Typical alpine meadows are found on the slopes of mountains and fluvial fans, and on river terraces within an elevation range of 3200-4800 m asl. Alpine meadow results from long-term grazing of the dominant *Kobresia* species on the plateau (Figure 2 c, d; Li, 2012). It is characterized by enrichment of mainly living root biomass. It is referred to as a golf-course-like "carpet" that is dominated by *Kobresia* species with a very low plant height (< 5 cm) (Miehe *et al.*, 2008). The root turf in alpine meadow plays a key role for the C cycling and C storage in this ecosystem (Ingrisch *et al*., 2015), but the alpine meadow ecosystem is a weak C sink during the growing season (Peng *et al.*, 2015). Meadow grassland is a very important resource for animal husbandry. Under heavy grazing without damage by small mammals, alpine meadow is grazed to uniformly short plants around 2 cm high. When 'traditional' grazing is practiced, alpine meadow is full of annual, palatable species that grow during summer, harbouring a high level of edible biomass that is able to support a reasonable density of grazing animals (Miehe *et al.*, 2008, 2009; Li, 2012; Li *et al.*, 2012).

Shown in Figure 3 is a typical catenal arrangement of hillslope and vegetation associations on a south-facing slope in the Yellow River Source Zone. The catena in Nanqi Village, Henan County (34°51′N, 101°28′E) has an altitude of 3580m. The river channel is comprised of angular-subangular gravels, reflecting a colluvial rather than an alluvial origin. Flow is generated both from runoff and groundwater stores. The adjacent floodplain surface is comprised of swampy meadow (wetland). It is dominated by cold-tolerant species such as *Kobresia tibetica*. Rising onto the terrace surface, *Carex moocroftii* and *Kobresia tibetica* start to appear with distance and elevation from the river channel (slope angle of 7°). This area of the terrace - 1 is drier than the floodplain, but it is still swampy meadow (wetland). Because of their proximity to the river, these areas of floodplain and terrace - 1 have high soil moisture. As a result, plants grow well, with the inter-twining root network supporting significant resistance to soil erosion. Slope angle increases to 5° on the terrace surface (terrace - 2), the margins of which are characterized by bare ground that reflects severe degradation. Given the relatively low soil moisture and the influence of water erosion and rodent activity, surface soils of some parts of the terrace -2 are relatively loose, with small patches of bare earth. The dominant species in this area include *Kobresia pygmaea* and *Stipa aliena*, associated with *Elymus nutans* etc. On the steeper hillslope itself (slope of 24°), the dominant species include *Kobresia pygmaea* and *Kobresia humulis*. The terrace area distributed with *Kobresia pygmaea* in Figure 3 is a favourite habitat for small mammals because of its mostly warm and dry conditions. It can also lead to Heitutan formation (i.e. a severely degraded alpine meadow) easily after small mammals' outbreak.

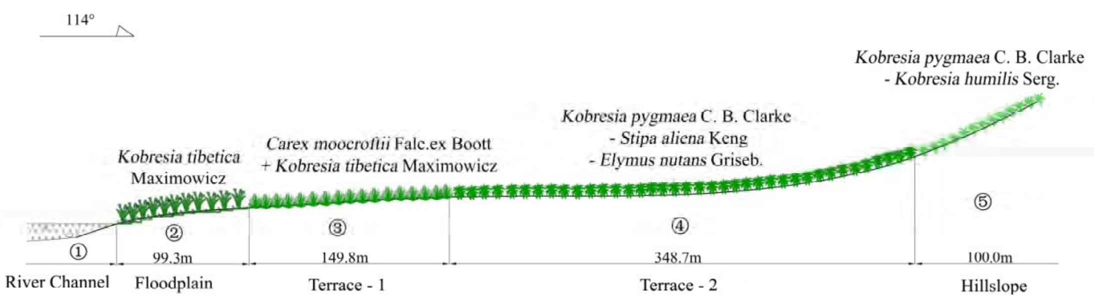

Fig. 3. Catenal section on a south-facing slope in the Yellow River Source Zone, from Nanqi Village, Henan County (Courtesy: Hu Xiasong and his research group).

A typical catenal arrangement of hillslope and vegetation associations on a north-facing slope is shown in Figure 4. Shrubs dominate the lower hillslopes. *Kobresia* meadows occur at higher and drier locations, and certain cushion plants (*Arenaria musciformis* and *Androsace tapete*). *Kobresia humilis* and various grasses and forbs are widely distributed along valley floors. The shrub *Potentilla fruticosa*, along with shrubby Salix species, are located on northern hillslopes. The marsh vegetation consists primarily of *Kobresia tibetica* and *Pedicularis longiflora*. *Kobresia pygmaea* meadows are mainly distributed on upper hillslopes. The piedmont areas distributed with *Kobresia humilis* in Figure 4 are good favourable habitats for small mammals' activities due to their warm and dry places. Some degradation with soil erosion can be found in this area. Soil types correspond to different formations of alpine meadow, transitioning down-profile from alpine meadow soil through mountain meadow soil to chestnut soil, and finally to marsh soils on the valley floor (Figure 4).

The project of Qinghai Ecological Protection and Construction in Sanjiangyuan - Phase II was officially launched in December, 2013 (NDRC, 2014). Alongside environmental protection, this project entails improving grassland and people's livelihoods and achieving coordinated economic, social and cultural development. According to this plan, from 2013 to 2022 China will invest 16 billion RMB (US$2.6 billion) to protect Sanjiangyuan (NDRC, 2014). Of these investments, nearly 8 billion RMB will be spent on ecological (re)construction in the Yellow River Source Zone. According to the protection plan, the restoration areas have been enlarged to 35% of the total area of Sanjiangyuan (Figure 1, NDRC, 2014), an increase from 15% prior to 2013. An additional area of 31,300 km^2 in the Yellow River Source Zone has been added since December, 2013. With the accomplishments of Phase I, which invested 7.5 billion RMB from 2004 to 2012, vegetation coverage in the protected area was significantly improved, and the area of wetlands has expanded, and conservation of water and soil resources has been conspicuously strengthened. Cai *et al.*

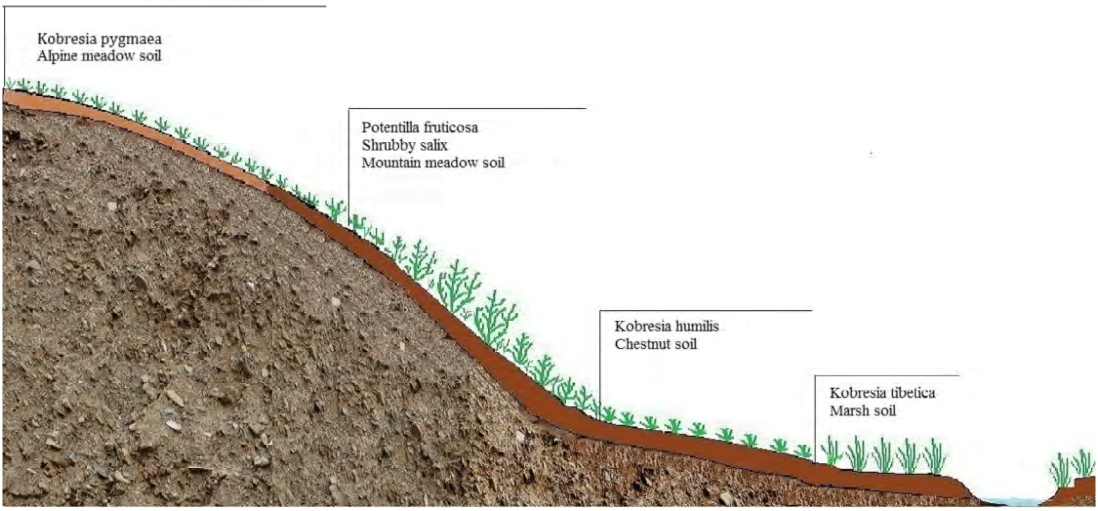

Fig. 4. Altitudinal and horizontal distribution of *Kobresia* meadow on a north-facing slope (Courtesy: Qiao Youming, Qinghai University for this figure).

(2015) indicated that ecological protection and restoration projects on the plateau have mitigated the grassland degradation and even reversed the degradation in some areas, using SPOT NDVI-based residual trend as an indicator. In addition, the production condition and livelihood of farmers and herdsmen were improved (NDRC, 2014). Further work is required to address underlying causes of rangeland degradation in the region.

Desertification of alpine steppe and Heitutan formation of alpine meadows

Grassland degradation not only directly affects the livelihood of pastoralists relying on these ecosystems, but also has indirect effects associated with climatic, hydrologic and socio-economic changes (Harris, 2010; Harris *et al.*, 2015). Alpine steppe is more vulnerable to degradation due to its location in the arid environment and low biomass. This kind of degradation can induce severe environmental consequences, such as desertification (Figure 5 a, b).

Alpine meadows in the Yellow River Source Zone have been seriously degraded by long-term over-grazing, small mammal outbreaks and soil erosion, in conjunction with climate change. In extreme instances, they have resulted in the formation of “Heitutan” grassland (Figure 6). The formation of Heitutan in the Yellow River Source Zone threatens the ecological integrity of the region, and negatively impacts upon local people’s livelihood and economic development. In schematic terms, the process of extreme Heitutan formation follows a pathway of: increasing grazing disturbance ′! triggering high frequency of small mammal outbreak ′! increasing burrow abundance of small mammals ′! soil erosion ′! emergence of largely eroded (bare) ground ′! Heitutan (Li *et al.*, 2013,a and b). Unsustainably high grazing levels underlie this vicious cycle. The exact role of small mammals remains unclear (Arthur *et al.*, 2007), but is probably context-dependent (beneficial to the grassland ecosystem where there is an appropriate stocking rate but, under overgrazing, it becomes deleterious).

Grassland protection in the Yellow River Source Zone

Simulation modelling by Li (2012) assessed the conditions under which the long-

a) severe degradation   b) Extreme degradation

Fig. 5. Various stages and states of desertification of alpine steppe. (a) severe degradation; (b) extreme degradation (photos: Li Xilai).

a) b)

Fig. 6. Various stages of Heitutan formation in the Sanjiangyuan region. (A) severely degraded with small mammal outbreaks and severe soil erosion extending across 40% of alpine meadow; (B) extremely degraded with less than 10% of usable alpine meadow (photos: Li Xilai).

term sustainable use of grasslands in the Yellow River Source Zone can occur. The outcomes of this modelling suggest that plant community dynamics in alpine meadow at the grazing intensity of 40-60% are sustainable, while also fostering local economic development, as they promote an abundance of sedges and grasses. The grassland degradation also resulted in significant carbon emissions, but the restoration to its healthy status can improve carbon mitigation potential (Huang *et al*., 2014). Severe/extreme degradation occurs when the capacity of self-restoration of the grassland ecosystem is exceeded over an extended period (Zhou *et al*., 2008). In this case, human intervention in the form of artificial seeding of native grass species is needed to improve soil fertility for desertified bare ground. Although some germinated inedible plants may not be edible to the stock, they can help to restore the degraded ecosystem. If extremely degraded rangeland is caused by small mammals, two methods are available to control their population: ecological and biological. Ecological measures are designed to restore the food chain and to increase the population of small mammals' predators. This sustainable control measure has the advantage of no residual environmental impact, but it suffers from a long delay before tangible benefits can be reaped. By comparison, biological control using botulinum toxin baits is much more effective without polluting the environment and secondary poisoning. Such baits do not impose any risk to rodent preyers, and can be widely adopted. These human intervention measures facilitate the self-recovery of degraded ecosystem by promoting the restoration of the wildlife food chain.

Conclusions

The Qinghai-Tibet Plateau is a vast geographic area and contains a diverse array of landforms, climates and ecosystem types. Given the variability in the inherent sensitivity of rangelands in differing areas, and the differing histories and intensities of human activities in different areas, there are marked differences in the extent of rangeland degradation. While climate change entails transitions to new assemblages of species, abiotic attributes such as soil and water conditions may not necessarily be subject to significant alteration in the short-medium term. However, human-induced changes brought about by land use intensification (overgrazing) induce transitions through moderate, severe and extreme states that may prove to be more difficult to be restored. Grazing alters the soil environment and nutrients that in turn affect the rangeland community biomass (above- and below-ground). Strong disturbance (overgrazing and small mammals' outbreaks) to rangeland communities may substitute other plants as the dominant species. Different measures are required to rehabilitate rangelands that have been degraded via different mechanisms. Reduction in grazing intensity and control of small mammals' outbreaks are required to rehabilitate reversibly degraded rangelands. However, targeted human intervention in the forms of selective planting of grasses and artificial seeding, in conjunction with ecological and biological control of the plateau rodent population is recommended to rehabilitate severely degraded rangelands. Further research work on impacts and benefits of small mammals to grassland ecosystem is required to address underlying causes of rangeland degradation in the region.

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