Future scenario projections of livestock carrying status of grassland ecosystem in Kazakhstan

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Abstract

As a country dominated by animal husbandry, the livestock carrying status in Kazakhstan has a prolonged impact on grassland degradation and restoration, and thus on the supply of grassland ecosystem services. Here we predict future conditions of livestock carrying status by modeling change in potential forage supply and consumption from 2020 to 2030, using three alternative scenarios following Representative Concentration Pathways, specifically SSP2 (RCP4.5, MESSAGE), SSP1 (RCP2.6, IMAGE) and SSP3 (RCP7.0, AIM), namely BAU, TSS and SSS respectively. Our future scenarios suggested that from 2020 to 2030, the forage consumption in central and southern regions of Kazakhstan is predicted to increase rapidly, while forage supply will decrease in these regions, especially the northern parts. The livestock carrying status in the southern regions tends to be overloaded to different degrees especially under the SSS and BAU scenarios, whereas the other areas hold surplus status. Our study could serve as a scientific basis for enhancing grassland management and achieving the target of the Sustainable Development Goals 2030.

Introduction

Kazakhstan has vast natural grassland and animal husbandry has been the priority of the government. However, the grassland in Kazakhstan is suffering from ongoing degradation due to climate change, policy factors and intensive grazing (Xin et al. 2019). Monitoring the forage supply by grassland and demand by livestock, further assessing the grassland carrying status is of great importance for sustainable grassland management, since it provides a scientific basis to maintain reasonable livestock carrying capacity, adjust the balance between supply and demand, and optimize grazing strategies to quickly respond to grassland changes (Huang et al. 2020). In the coming decades, the grazing system will continue to bear great pressure (Sun et al. 2020). On the one hand, climate change will affect grassland phenology and growth, therefore posing a threat to ecosystem functions. On the other hand, the rapid growth of the population would boost the demand for animal husbandry and thus lay a heavier burden on the grassland ecosystem (Bardgett et al. 2021). To mitigate and respond to these threats, it is necessary to identify areas that are affected and threatened greatly. However, few studies have been conducted to assess the changes in grassland productivity under climate change and their impacts on livestock carrying status. Therefore, we intend to predict the potential dynamics of grassland supply capacity in Kazakhstan by 2030 and carry out research on the early warning of livestock carrying capacity and propose harmonious adaptation strategies for halting grassland degradation and facilitating sustainable management.

Methods

We adopted the Carnegie-Ames-Stanford Approach (CASA) model (Potter et al. 1993; Field et al. 1995) to estimate the net primary productivity of vegetation (NPP) of grassland. Specifically, we used the precipitation, air temperature and incoming photosynthetically active radiation data from CIMP6 dataset (https://pcmdi.llnl.gov/CMIP6/), and land use data (https://data.pnnl.gov/group/nodes/dataset/13192) from 2000 to 2030 as the model input to obtain the NPP, which represent the productivity of grasslands. Then we used root:shoot ratios (Mokany, Raison and Prokushkin 2006) to calculate the aboveground biomass and further calculated the grassland forage supply (SNPP) according to the proportion of available forage (Milchunas and Lauenroth 1993). The FAO projections of future herd size in each country and the projected distribution of population density (Gao, 2020) by 2030 were used to quantify forage consumption (CNPP). Finally, we obtained the livestock carrying index (LCI) (Zhang et al. 2014) by comparing the forage consumption with the forage supply (CNPP/SNPP). The LCI is an indicator which measured the relationships between the grassland supply and livestock consumption, with the value>1 indicating that the demand exceeding the local supply, and vice versa. We further divided the LCI into six levels, including rich and

surplus (<0.6), surplus (0.6-0.8), balance (0.8-1.0), critical overload (1.0-1.2), overload (1.2-1.4) and severe overload (>1.4).

Results and Discussion

Livestock carrying status in Kazakhstan by 2030

From 2020 to 2030, under the three future scenarios, the forage supply in southern regions of Kazakhstan shows a rapid decrease, especially in Mangghystau and South Kazakhstan, with a decreasing trend of more than 5%. The forage supply in the northern regions indicates increase trend, and the growth rate in West Kazakhstan and Qostanay exceeds 4%. The TSS scenario shows the most rapid increasing rate in grassland supply. Regarding forage consumption by livestocks, all the Kazakhstan's regions show increasing trend in various degrees. Specifically, the central and southern areas exhibit a relatively higher increase, especially under the SSS scenario.

By 2030, under the three future scenarios (Figure 1), the livestock carrying status in southern regions of Kazakhstan is predicted to be seriously overloaded, especially Mangghystau with a severe overload status. Central and northern regions exhibit surplus status in different degrees, among which West Kazakhstan shows rich and surplus status. The average LCI of Kazakhstan under the TSS, SSS and BAU scenario increased by 2%, 3% and 5% from 2020 to 2030, respectively. Specifically, under the TSS scenario, the carrying status of South Kazakhstan is not as serious as the other two scenarios, and northeast regions tend to show more surplus status. Under the SSS scenario, the carrying status of regions especially the northern ones appear to be more overloaded compared with the BAU scenario, with an overload or severe overload status. These probably due to the increasing of the cultivated land areas in south Kazakhstan especially under the SSS scenario, and decresing grassland areas caused by degradation and desertification (Wen et al. 2019).

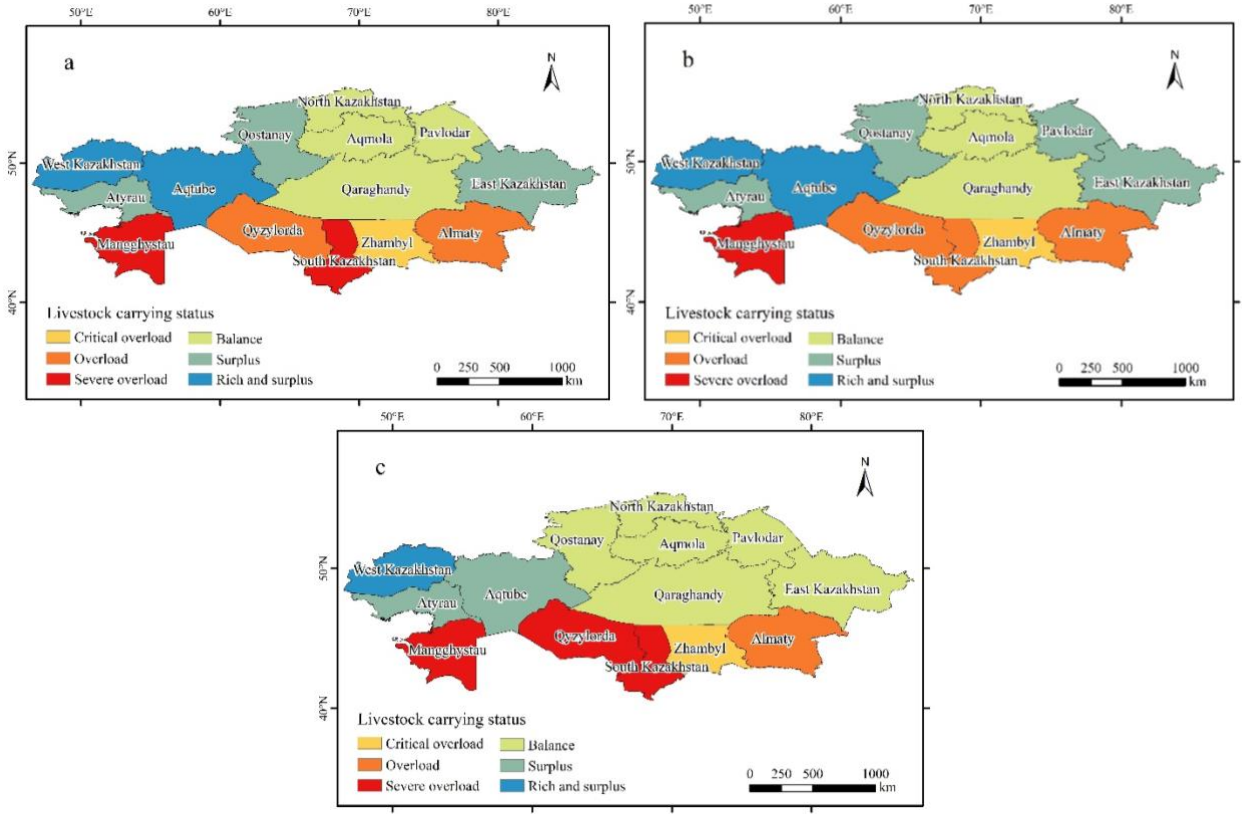

Figure 1. Livestock carrying capacity in Kazakhstan's regions by 2030 under three future scenarios: (a) BAU scenario; (b) TSS scenario; (c)SSS scenario.

Strategies for sustainable management of grassland

From the perspective of supply, by 2030, the supply capacity of grassland ecosystems in northern Kazakhstan will increase, while the southern regions exhibit a rapid decrease. It is necessary to enhance grassland management, increase carbon sequestrations and mitigate the impact of climate change (Bardgett et al. 2021). For the central and southern parts of Kazakhstan where grasslands are widely distributed, it is essential to control further desertification through sand prevention and desertification control, implement measures such as livestock reduction and balance between grass and livestock, and enhance the restoration of

natural grasslands.

From the perspective of consumption, the livestock's demand for forage in Kazakhstan showed a continuous increasing trend. Kazakhstan should take this change into full consideration when carrying out structural adjustments. Moreover, increasing supports from the government such as seasonal rotational policies, is required for animal husbandry to vigorously improve its production. Appropriately increasing exchanges and cooperation with other countries and controling the cropland expansion is required to increase the imports of livestock products to meet the residents' needs for a balanced diet, and release the livestock carrying pressure in southern Kazakhstan.

Conclusions

Despite the limitation of the CASA model due to its reliance on the future climate and land use/cover data with some uncertainties, our findings provide a useful knowledge base to identify the regions with the greatest carrying potential and pressure, thus helping to consider diverse strategies to enhance grassland productivity and adaptation to drastic climate change. Given that grassland provides a series of ecosystem services for human beings, the prediction of supply-consumption relationships of other ecosystem services of grassland needs to be further discussed in the future.

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