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Analysis of ecological carrying capacity based on the ecosystem function threshold — A case study of grassland in Inner Mongolia

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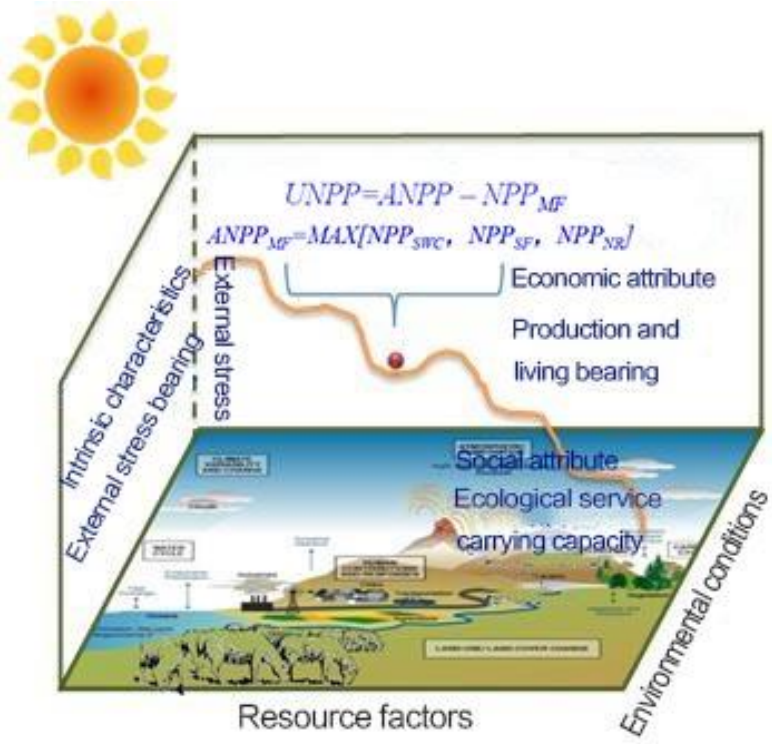
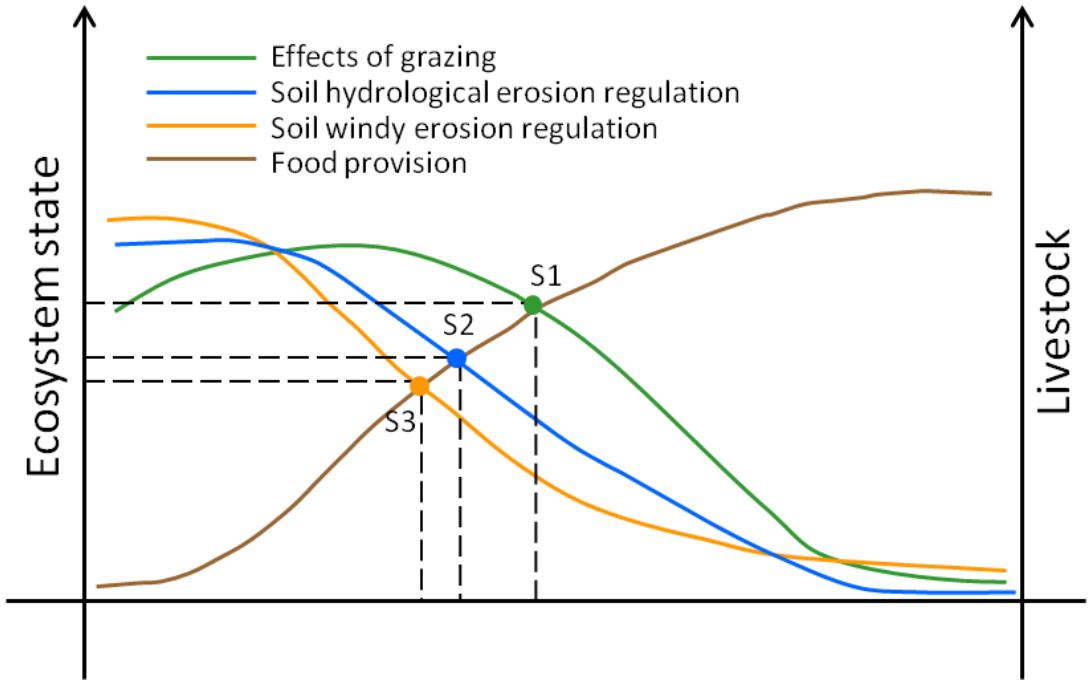
1. Introduction

- **Background:**
- Noticeable changes in ecological function have emerged in grasslands due to intense warming climate and human disturbance. The carrying capacity in grassland ecosystems was threatened by ecological degradation.
- There is an urgent need to establish a framework to quantitatively evaluate the carrying capacity of grassland ecosystems.
- **Goal and contributions:**
- Identify the threshold of maintenance of grassland ecosystem function.
- Evaluate the ecological carrying capacity of Inner Mongolia

2. Gist





Ecological carrying capacity calculation based on ecosystem function

The complexity and openness of ecosystem determine the characteristics of multi-dimensional, multi-scale and cascade correlation of ecological carrying capacity. There are many complex coupling and feedback relationships among different ecological carrying capacity.

3. Evaluation index of ecological carrying capacity

Ecological function

- **Environmental sustainability**

  ·soil and water conservation of (SWC)
  ·wind break and sand fixation (SF)

- **natural reproduction (NR)**

The ecological carrying capacity of ecologically fragile areas refers to the capacity of the population and the total amount of economic activities that resources and environment can support in a certain area within a certain period of time under the condition of ensuring a good ecological environment.

NPP

Ecological carrying capacity

- **Grazing capacity**

$$UNPP = ANPP - NPP_{MF}$$

$$ANPP_{MF} = MAX[NPP_{SWC}, NPP_{SF}, NPP_{NR}]$$

3.1 Quantity of soil erosion per unit area

$$A = R \cdot K \cdot L \cdot S \cdot C_w \cdot P$$

$$C_w = {}^{A}\!/_{(R \cdot K \cdot LS \cdot P)}$$

Where, A is the amount of soil erosion (t/hm^2 · A); R is the rainfall erosivity factor (MJ·mm/hm^2·h·a); K is the soil erodibility factor (t·hm^2·h/hm^2·MJ·mm); LS is the terrain factor; *Cw* is vegetation cover factor.

Identify the change threshold of soil and water conservation function in fragile ecosystems

3.2 Quantity of wind erosion per unit area

$$S_L = \frac{2 \cdot z}{S^2} Q_{MAX} \cdot e^{-(z/s)^2}$$

$$S = 151.71 \cdot (WF \times EF \times SCF \times K' \times C)^{-0.3711}$$

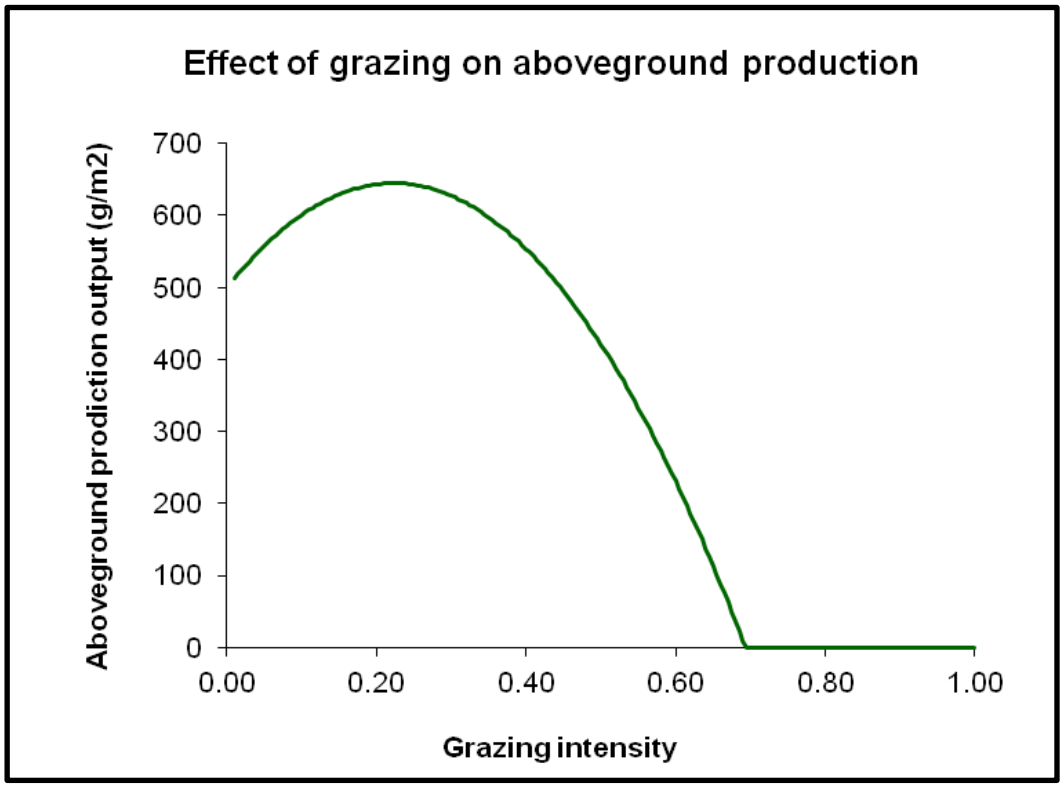
$$Q_{MAX} = 109.8 \cdot [WF \times EF \times SCF \times K' \times C]$$

$$C = e^{a_i (SC)}$$

Where, S_L is the actual amount of soil erosion, and *Qmax* is the maximum amount of transfer; *Z* is the maximum wind erosion distance, and *WF* is the climatic erosion factor. *EF* is soil erosion factor; *SCF* is soil crust factor; *K'* is the surface roughness factor; *C* is the vegetation cover factor. *SC* is vegetation coverage; a_i is the coefficient of different types of vegetation.

3.3 Quantity of natural reproduction

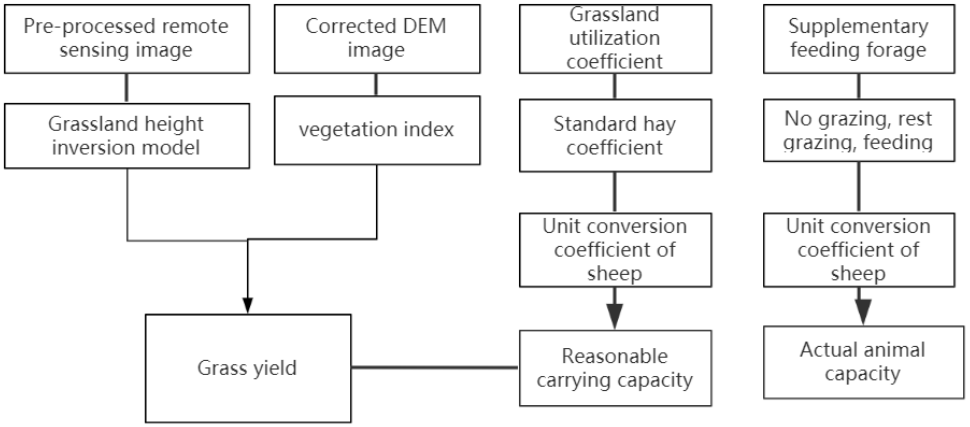
$$NPP_{NR}=NPP\ (1-ANPP_{ava}\%)$$



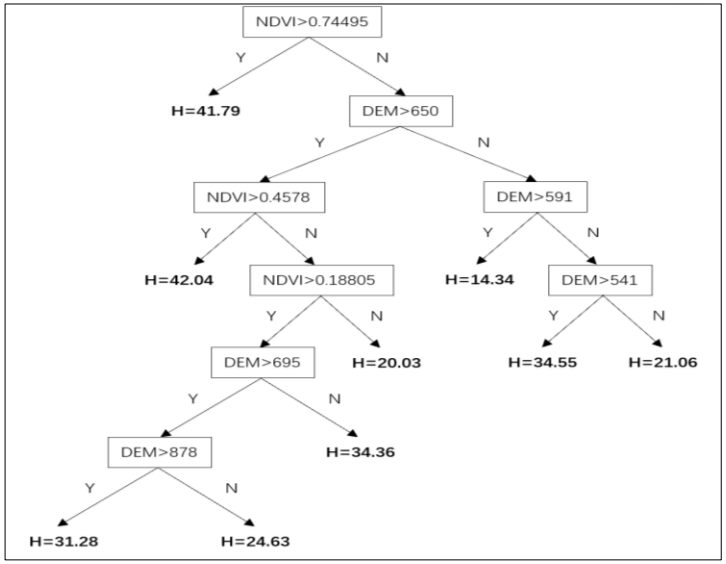
Relationship between grazing intensity and natural regeneration threshold of grassland

4. Method

4.1 Evaluation of NPP of natural grassland in Inner Mongolia



Grassland biomass inversion



Grassland height inversion model

$$G = -451.075NDVI^2 + 508.652NDVI + 4.572H - 85.068$$
$$(R^2 = 0.653, P < 0.001)$$
$$ANPP = 1.092G$$

4.2 Calculation of the grassland grazing capacity

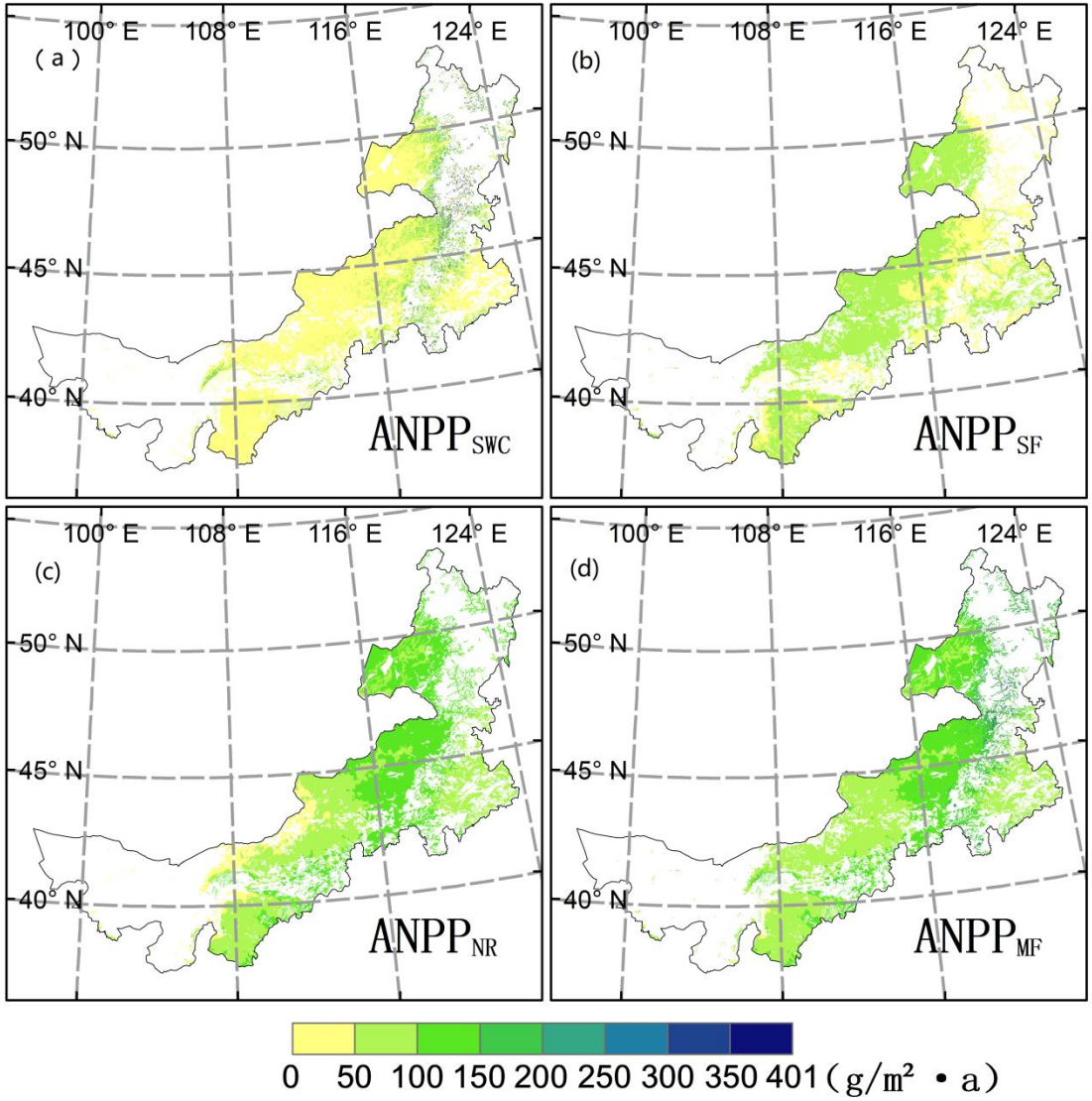
- **Calculation of the ecological grazing capacity :**

- $CC = (ANPP - ANPP_{MF}) \times \mathrm{CCSH} \div [\mathrm{DIOSU} \times (1 - \mathrm{MC}) \times 365]$
- $\mathrm{SCC} = \sum \mathrm{CC} \times \gamma^2$

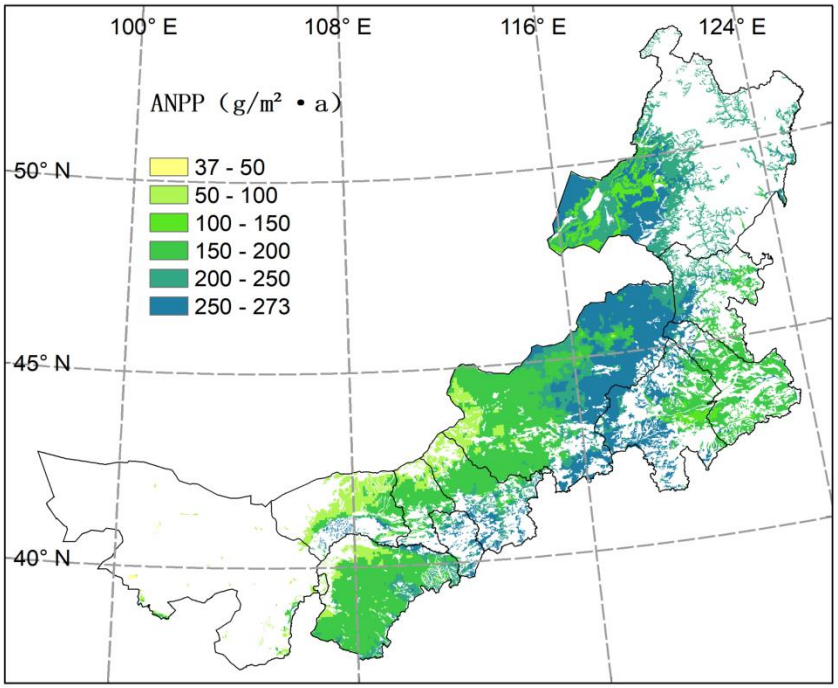
- **Calculation of the economical grazing capacity:**

- $\mathrm{SSR} = \sum [N_{ei} \times \frac{D_e}{365} + (N_{mi} - N_{ei}) \times \frac{D_m}{365}] \times \varepsilon_i$

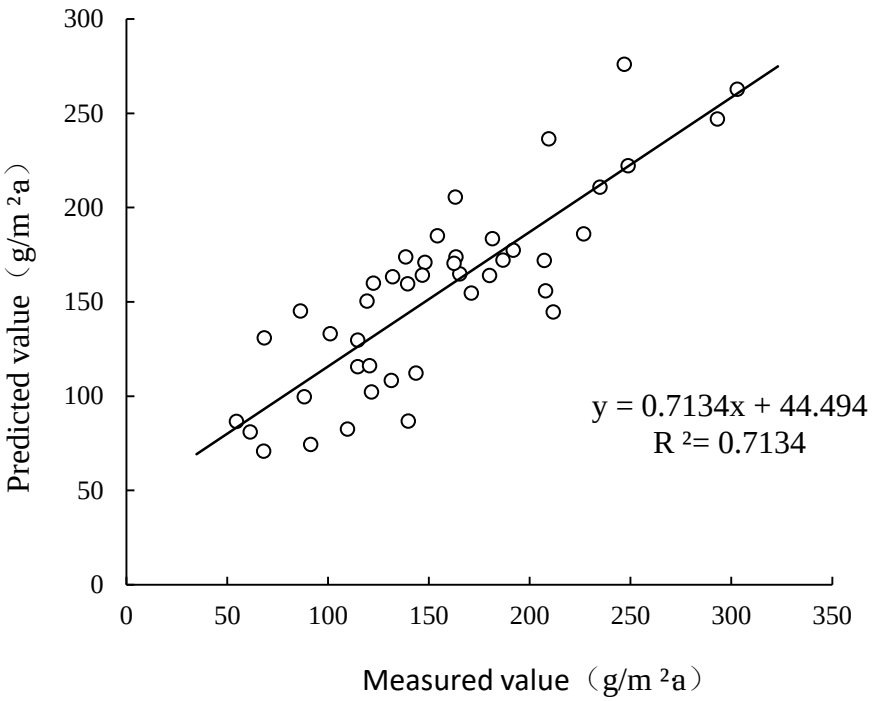
5. Result



The spatial distribution of ANPP needed to maintain ecological service function of grassland in Inner Mongolia

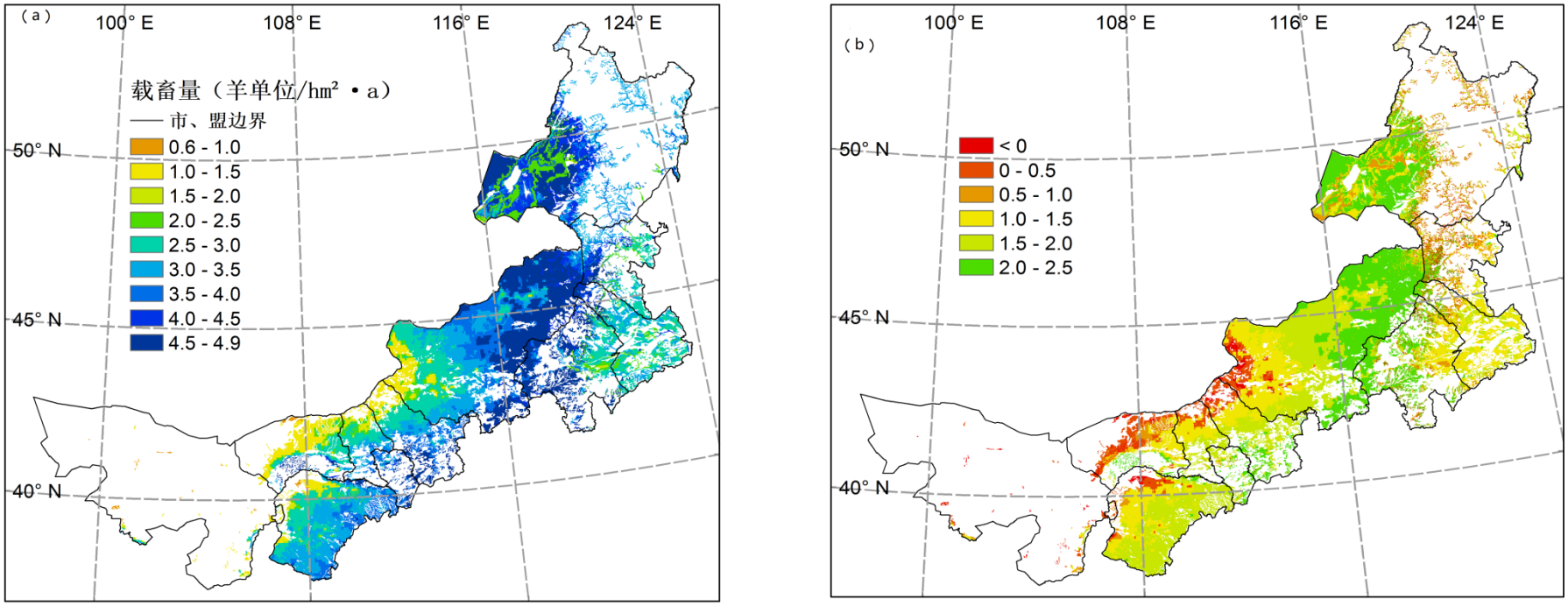


Spatial distribution of ANPP of grassland



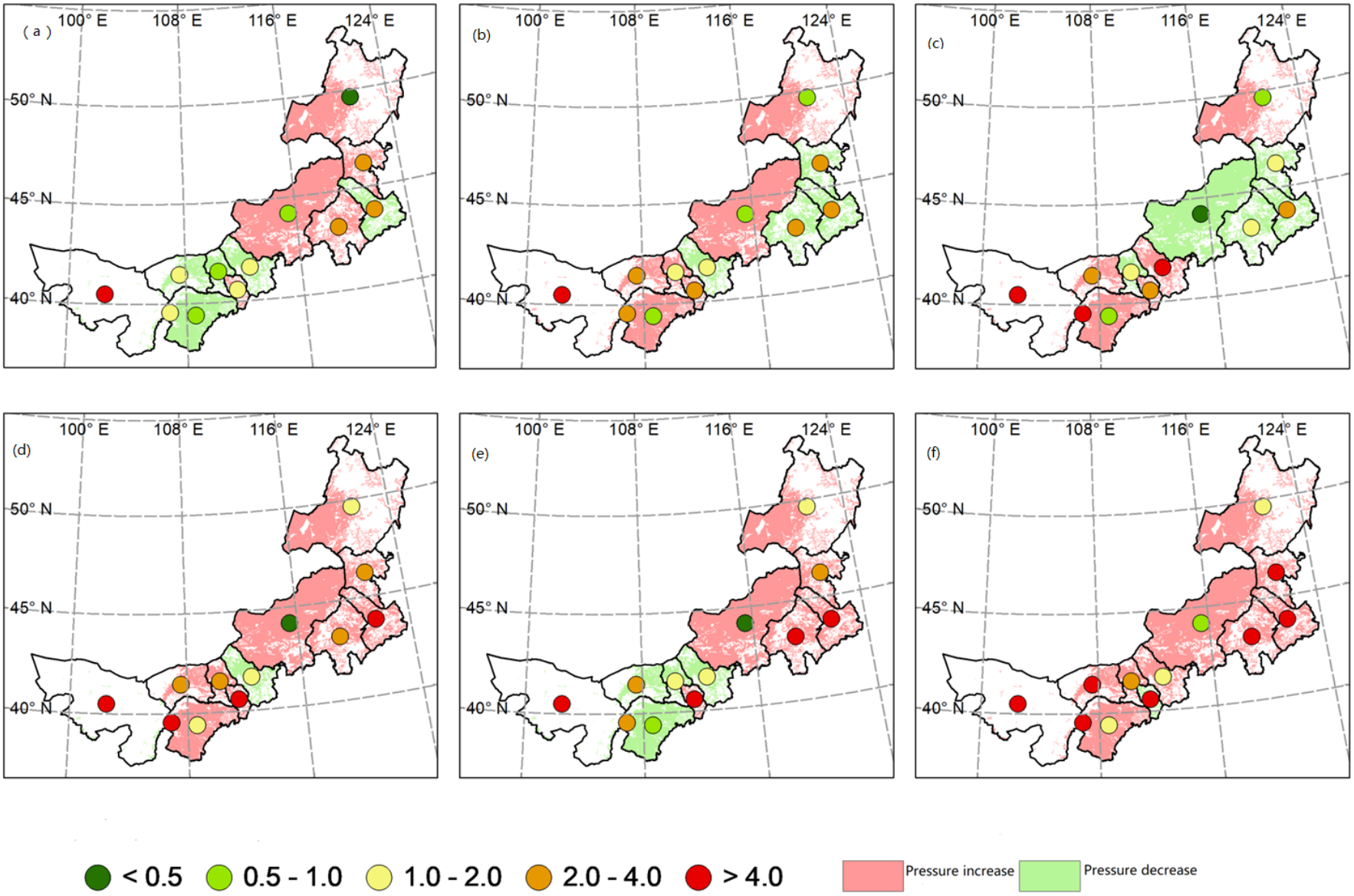
Verification ANPP model of grassland

The average grassland ANPP in Inner Mongolia showed a trend of decline from northeast to southwest. The grassland ecosystem gradually transferred from meadow grassland to desert grassland, and ANPP also showed an obvious trend of decline.

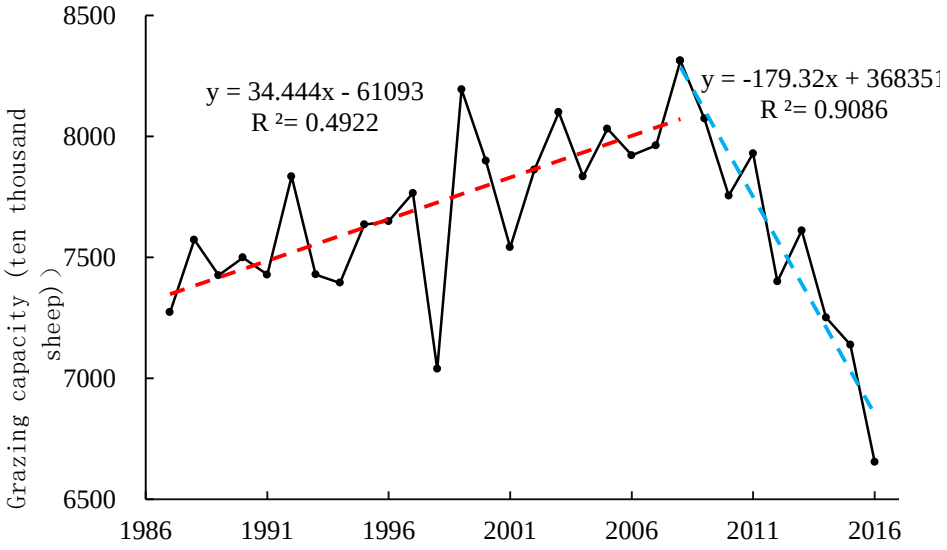


Evaluation of economic grazing capacity (a) and ecological grazing capacity (b) of Inner Mongolia grassland

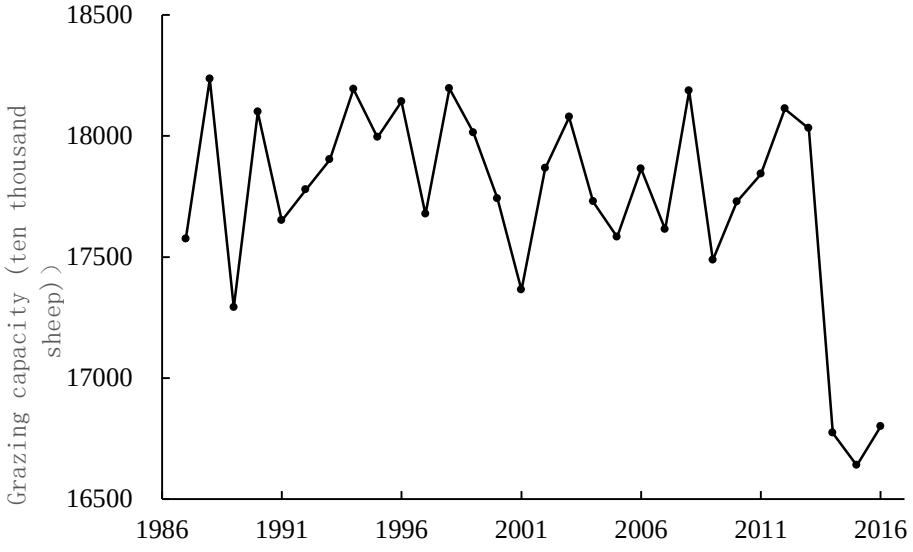
- When we ignore the ecological environment and natural renewal function, the average economic livestock carrying capacity is 3.42 sheep units/hm ² a, and the total livestock carrying capacity is 145,548,200 sheep units.
- Under the condition of maintaining ecological environment and natural renewal, the average ecological carrying capacity is 1.56 sheep units /hm ² a, and the total carrying capacity is 79.3364 million sheep units.



Grassland bearing state of Inner Mongolia administrative regions in 1991(a), 1996(b), 2001(c), 2006(d), 2011(e) and 2016(f)



Change of ecological grazing capacity in Inner Mongolia from 1986 to 2016



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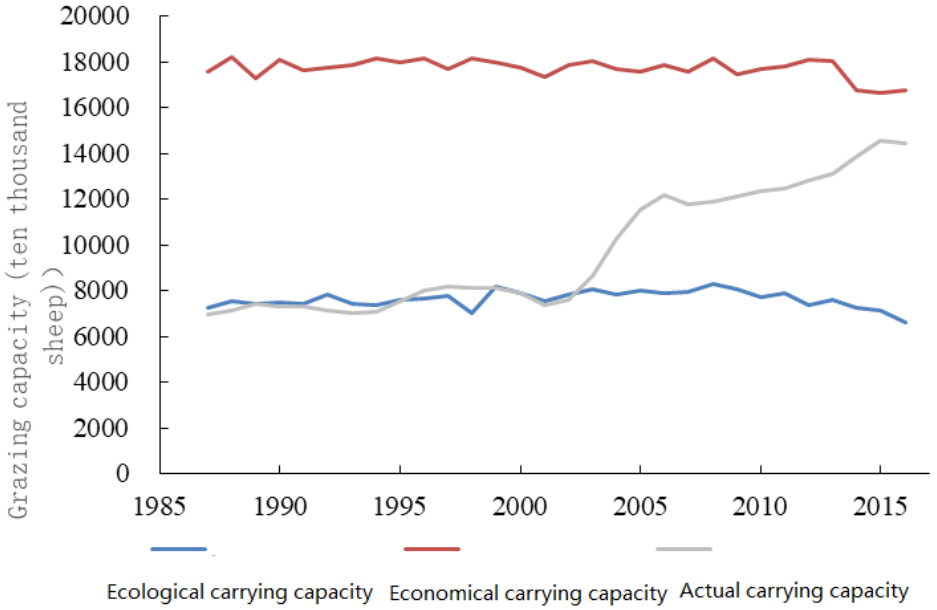

The change of carrying capacity of Inner Mongolia in 1985-2016

The reasonable carrying capacity of grassland should be the sustainable carrying capacity between ecological carrying capacity and economic carrying capacity, which can obtain the best economic benefits.

5. Summary

- The range of ANPP used to maintain ecosystem services in Inner Mongolia is between 38-400 g/m^2 • a, and the spatial distribution is decreasing from northeast to southwest.
- From the perspective of spatial distribution, the bearing capacity of grassland in the eastern part of Inner Mongolia is strong, while that of grassland in the western part is serious. In recent years, regions with weak ecological carrying capacity, such as Wuhai, Alashan and Xing 'an league. It can be explained that the more backward the economic development of the regions with poor ecological environment is, the seriously overloaded grassland ecosystem will make the local economic evelpment in an unsustainable state thus resulting in unbalanced regional development.

6. Disscussion

- There is a significant difference between measuring the ecological carrying capacity from the ecological perspective and the calculation results of the traditional methods. In the future, indexes of environmental maintenance function, such as diversity maintenance and carbon sequestration, can be selected to evaluate the bearing capacity according to the actual ecological conditions of the region.

- The setting of environmental maintenance function threshold still needs to be further improved.

Thanks for your attention!