Changes in stress within grassland ecosystems in the three counties of the source regions of the Yangtze and Yellow Rivers

YiPing FANG
1 Institute of Mountain Disaster & Environment, Chinese Academy of Sciences, Chengdu 610041, China; ypfang@imde.ac.cn

DaHe QIN
2 Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

YongJian DING
2 Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

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Changes in stress within grassland ecosystems in the three counties of the source regions of the Yangtze and Yellow Rivers

YiPing FANG1*, DaHe QIN2, YongJian DING2

1 Institute of Mountain Disaster & Environment, Chinese Academy of Sciences, Chengdu 610041, China;
2 Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China

Abstract: Based on a database of more than 40 years of second production process and energy flow records for Maduo, Qumalai and Yushu counties, a dynamic model of the stress within grassland ecosystems was established using a nonlinear regression method for this source regions of the Yangtze and Yellow Rivers. The results show that dynamic curves of stress within grassland ecosystems in the three counties were in the shape of an inverted “U” during the period 1965–2007. It also revealed that the variation in actual amount of livestock inventories reflected the general trends of the stress within the grassland ecosystems in the source regions, although there were many other factors for the increase or reduction in grassland ecosystem stress.

Keywords: the source regions of Yangtze and Yellow Rivers; the stress within grassland ecosystems; inverted “U” model; driver

1 Introduction

The stress within grassland ecosystems is the synthesis reflection of outside factors (including climate and vegetation changes and human disturbance) on the impact of the grassland ecosystem. In order to track the effects of the stress, much research has focused on grassland plant productivity (i.e. primary productivity) in terms of assessment of productivity of grassland (Huang et al., 2000; Wang et al., 2001; Han et al., 2003; Seaquist et al., 2003; Yao et al., 2004; Zhao et al., 2004; Jiang et al., 2006; Turner et al., 2006; Li et al., 2007; Chen et al., 2008; Prieto-Blanco et al., 2009; Wang et al., 2009), spatial distribution (Piao et al., 2004), influential factors (Li and Huang, 2005; Sun et al., 2005; Hao and Wu, 2006; Han et al., 2007; Zhao, 2007; Guo et al., 2008; Steinshamn and Thuen, 2008; Zhang et al., 2008; Wang and Fang, 2009), sustainable utilization (Shimodaa et al., 2009) as well as effect and adaptation of animal husbandry (An et al., 2001; Kabubo-Mariara, 2009). However, there was little research on the dynamic of grassland ecosystem stress. Understanding the stress change within grassland ecosystems and their drivers is essential to find some measures to enhance positive and minimize negative effects (MEAB, 2003). Recently, Feng et al. (2009) evaluated ecological stress caused by animal husbandry in the source regions of the Yangtze, Yellow and Lancang Rivers over the last 40 years, using an ecological stress-index defined as the ratio between realistic and theoretical carrying capacity of grassland.

There is still little research published on the stress process and drivers of grassland ecosystems, especially quantified stress based on the second production process of grassland ecosystems and energy flow in the Qinghai-Tibet Plateau. The objective of this paper is to reveal the long-term change of the stress within grassland ecosystems in the source regions of the Yangtze and Yellow Rivers, using second production process of grassland ecosystem and energy flow.
Yellow Rivers) are located at the east of the Qinghai-Tibet Plateau (Fig. 1). It is a typical region of alpine and plateau climate (Li et al., 2006), with mean altitude above 4,000 m, sensitivity to the changes of climate, diversified species of vegetation of high altitude localities (Li et al., 2007), and it is a very important component part of the cryosphere in China. This area contains the headwaters of the Yangtze and Yellow Rivers, with widely distributed wetlands, many lakes and developed river systems, glaciers and permafrost (Yang et al., 2004; Li et al., 2007). The Maduo, Qumalai and Yushu counties with different geographical conditions were chosen as a case study to approach the stress of grassland ecosystems among 12 counties of all the source regions in Qinghai Province (SBQP, 2008) (Table 1).

![Fig.1](source_regions_yangtze_yellow_rivers.png)  
**Fig.1** The location of the source regions of the Yangtze, Yellow River and three study areas

<table>
<thead>
<tr>
<th>Information</th>
<th>Maduo/Guoluo</th>
<th>Qumalai/Yushu</th>
<th>Yushu/Yushu</th>
<th>The source regions of the Yangtze and Yellow Rivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic location</td>
<td>33°50′–35°40′N</td>
<td>33°36′–35°40′N</td>
<td>32°41′–33°46′N</td>
<td>32°30′–35°40′N</td>
</tr>
<tr>
<td>Mean elevation (m)</td>
<td>&gt; 4,000</td>
<td>3,950 – 5,590</td>
<td>4,493</td>
<td>3,335 – 6,564</td>
</tr>
<tr>
<td>Climate feature</td>
<td>Semi-humid continental climate</td>
<td>Typical plateau-continental climate</td>
<td>Typical plateau-continental climate</td>
<td>Typical plateau-continental climate</td>
</tr>
<tr>
<td>Average temperature (°C)</td>
<td>−4.1</td>
<td>−3.3</td>
<td>2.9</td>
<td>−0.78</td>
</tr>
<tr>
<td>Average rainfall (mm)</td>
<td>326.3</td>
<td>380 – 470</td>
<td>487</td>
<td>459.4</td>
</tr>
<tr>
<td>Area (km²)</td>
<td>25,240</td>
<td>52,500</td>
<td>13,462</td>
<td>200,000</td>
</tr>
<tr>
<td>Population</td>
<td>14,000</td>
<td>27,000</td>
<td>91,000</td>
<td>470,000</td>
</tr>
<tr>
<td>Proportion of animal husbandry production value in regional GDP (%)</td>
<td>38.6</td>
<td>57.6</td>
<td>48.0</td>
<td>47.0</td>
</tr>
</tbody>
</table>

### 2.2 Methodology

In order to address the complexity of ecosystem stress-factor, the authors focused on the dynamic of grassland ecosystem stress based on the dimension of second production process. The consumption, reduction and livestock inventories are considered together to entirely mirror the energy flow and its direction in the second production process of grassland ecosystem. Therefore, the constructed model of grassland ecosystem stress may consist of the following parts:

\[
P_e = \sum_{k=1}^{k=n} H_k + \sum_{j=1}^{n} R_j + \sum_{m=1}^{m=n} P_m,
\]

where \( P_e \) is the stress on the grassland ecosystem; \( H_k \) is the reduced part of droppings, urine and carcasses of animals; \( H_k = (\text{yield of droppings} + \text{urine of inventories of cattle + horses + sheep}) \times \text{energy transformation constant} \), based on the structure of present livestock; \( R_j \) is the energy consumption in respiration of animal for cattle breeding production, and could be measured by using the difference between annual grass consumption of cattle or sheep and increasing amount of cattle body mass (Yang et al., 2008); \( P_m \) is the second productivity of animal husbandry, representative of yield of livestock products and livestock inventories on hand. The energy values of the elements in the formula are converted into unified units to make it easy to compare (Yang et al., 2008).

In grassland ecosystem, \( H_k \) is the incoming while \( R_j \) and \( P_m \) are outgoing elements, among which \( R_j \) is
transmitted in the form of heat energy to the surroundings and most of $P_m$ flows out of the ecosystem in the form of livestock products (Yang et al., 2008). Therefore, the $P_m$ could be divided as:

$$P_m = \sum A_i + \sum M_j + \sum N_k + \sum W_n,$$

where, $\sum A_i$ is the amount of livestock inventories at the end of year (J); $\sum M_j$ is the total yield of meat (J); $\sum N_k$ is the total yield of milk (J), and $\sum W_n$ is the total yield of wool (J).

2.3 Data collection

In this study, data on livestock inventories, livestock structure and product yield were collected from statistical yearbooks of Qinghai Province, Guoluo and Yushu Tibetan Autonomous Prefectures and relevant counties from 1965 to 2007.

3 Results

The result shows that the stress within the grassland ecosystems of Maduo, Qumalai and Yushu counties varies yearly as one-variable Cubic function (Figs. 2–4), and the confidence level for statistical test is above 95% on average. The correlation coefficients of regression functions are 0.628, 0.715 and 0.916 respectively for Maduo, Qumalai and Yushu.

The stress within grassland ecosystems in the three counties increased rapidly in the 1960s, and reached the peak in the late 1970s and early 1980s, and began to decrease since then. The curves indicate some increases in stress in Maduo and Qumalai after 2003, but not in Yushu county where stress appears to have continued to decrease.

Spatially, it shows the fastest speed of variation of grassland ecosystem stress in the south county Yushu, followed by north countries Qumalai and Maduo (Fig. 5). The maximum value of stress of grassland ecosystem in Yushu County is 2.59 and 1.59 times that of Maduo and Qumalai.

The dynamic models of grassland ecosystem stress are displayed as follows respectively based on nonlinear regression analysis:

**Maduo County:**

$$y_1 = 9E-05x_1^3 - 0.0072x_1^2 + 0.1619x_1 + 0.0813, \quad R_1^2 = 0.6288,$$

**Qumalai County:**

**Yushu County:**
Qumalai County: \[y_2 = 0.0002x_2^3 - 0.0161x_2^2 + 0.3278x_2 + 0.1379,\]
\[R_2^2 = 0.7157,\] (4)
Yushu County: \[y_3 = 1E-04x_3^3 - 0.0128x_3^2 + 0.3526x_3 + 0.5857,\]
\[R_3^2 = 0.9168,\] (5)

where, \(y_i\) is the grassland ecosystem stress \((1E+16J)\); \(x_j\) is the year series \((1965=1)\); \(R_m^2\) is the percentage of variability of the dependent variables explained by the regression equation, indicating the effect of fitting function.

The fitting curves of these three counties (Figs. 2–4) are all in the shape of inverted “U”, which means that the stress within the grassland ecosystems increases swiftly at first, then peaked, and subsequently decreased. As the functions (3)–(5) are derivable, and the point exists where the derivative is zero, satisfying the condition that the derivatives at both sides of the point are opposite (left: positive; right: negative), then a maximum value exists. The derivation provides the maximum values from derivation of grassland ecosystem stress were 1.30, 2.12 and 3.37 \((10^{16} J)\) in Maduo, Qumalai and Yushu respectively in the year of 1980, 1978 and 1981.

4 Discussion

The stress within grassland ecosystems is first highly related to the grazing animal. According to the almanac statistics, the number increased abruptly since 1960 and reached the peak in the late 1970s and early 1980s, and then it went down greatly. The change in livestock inventories display the shape of inverted “U’s”, the same as the change of stress within grassland ecosystems. On the other hand, the rate of domestic animals for sale and commodity in Maduo, Qumalai and Yushu in 2007 was 1.83, 1.18, and 3.07 times of that in 1985, respectively. It takes on the trend of increasing yield of livestock product and declining number of livestock inventories since 1985. In fact, the rate of reduction in livestock inventories is more rapid than the increase rate of livestock production yield, thus the trend in the stress within grassland ecosystems was down.

The inventories of breeding animals was closely related to the fast increase in population from the early 1950s to the end of the 20th century and people’s awareness of market economic reform since 1980. For example, the population in the source regions was 3.09 times in 2000 of that in 1953 (Wang et al., 2004; Sheng et al., 2007). The population increase led to the increase of livestock inventories from the 1960s to the end of the 1970s and the early 1980s in the collective economy, and the increase of their maximum benefit (Zhang et al., 2007) from commodities of animal products since the 1980s. The improvement in management techniques and awareness of herdsmen who were educated and trained by local governments has led to a reduction of stress within grassland ecosystems to a certain extent since the 1980s.

The role of climatic change on ecosystem stress is mainly due to the increase in annual average temperature since the 1960s (Hu et al., 2007) and the decrease of annual rainfall since 1980, especially a sharp decrease in summer and autumn (Hu et al., 2007). This led to climate change (Hu et al., 2007) restricting the growth of seasonal grassland biomass, and thus affecting the growth of livestock and actual stock-carrying capacity. These factors have had an increasing impact on the grassland ecosystem since 1980.

Some remarkable degradation of grassland spatially and temporally also increased the stress within grassland ecosystems since the mid 1970s (Liu et al., 2008), especially from 1986 to 2000. For example, it has revealed some decreases in the alpine areas of 15.82%, 5.15% and 24.36% in high coverage, alpine meadow and swamp meadow, and a 7.5% decline in the area of...
lake surfaces respectively (Wang et al., 2004). The trend of degradation was still significant from 2000 to 2007, despite the overall slowing of grassland degradation. For example, rodents have damaged one third of grasslands through eating and digging in the past two decades (Fig. 6). Spatially, it shows variation in different regions and vegetation belts (Liu et al., 2008). Much severer degradation occurred in the source region of the Yellow River than the Yangtze River, and a far higher rate of degradation in winter and spring than in summer (Zhang et al., 2006; Liu et al., 2008). Such degradation has exacerbated erosion in the world’s highest and largest wetland area, and has decreased carrying capacity of livestock, thus causing further increasing stress on grassland ecosystems.

Fig. 6  Rats are causing serious damage on the grassland in the regions

Since the household-based contract responsibility system was implemented in 1984, extensive farming has gradually converted into intensive farming and commodity production. This has brought about adjustments in the structure of livestock products, increasing the rate of commodity and market supply, and grassland protection, rational utilization of grassland, and the national project of returning grazing land to grassland since 2003. Some measures such as the rodent control project, grassland fencing and improved, sown grasslands have laid a good foundation for decreasing grassland stress and a sustainable livestock industry. The constitution and implementation of a series of policies and rules effectively restrained the situation of overgrazing in the source regions and has gradually reversed the trend of increasing stress within grassland ecosystems (Fig. 5).

There are many drivers influencing increased or reduced stress within grassland ecosystems. However, livestock inventories correlate closely with the level of stress within grassland ecosystems. The correlation coefficient is up to 0.85, that is, the former varies almost directly with the latter. Therefore, the variation in actual amount of livestock inventories in the source regions reflects the general trend in stress within grassland ecosystem there.

In addition, there appeared to be a time lag before the influence of human factors became apparent in the source regions. This was related to the implementation of the household-based contract of grazing land management, the project to return grazing land to grassland, the project to reduce livestock numbers, and an increasing rate of domestic animals and commodities for sale. Due to the above factors’ combined influence, the stress within grassland ecosystems in this region has been notably decreasing since the 1980s.

5 Conclusion

The annual change curves of stress within grassland ecosystems in Maduo, Qumalai and Yushu counties are all in the shape of inverted “U’s”, with maximum values respectively occurring in 1980, 1978 and 1981.

The livestock inventories are significantly correlated to the variation of stress within the grassland ecosystem (the correlation coefficient is up to 0.85) although there are many factors influencing increases or reductions in grassland ecosystem stress. Therefore, the variation in actual livestock inventories reflects the general trend of the stress within grassland ecosystems in the source regions.

Therefore, it is very necessary approach to improve livestock productivity while reducing overall livestock numbers in order to maintain the production and output of individual flocks and herds to enhance the well-being level while reducing grassland ecosystem stress.

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References


