Integration of remote sensing and GIS technology to evaluate grassland ecosystem health in north China

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Abstract. Grassland in north China faces serious ecological degradation in recent decades. Overgrazing and unsuitable farming over the grassland are believed to be the direct causes leading to such ecological disasters as sand and dust storms in north China. Objective of the study is to integrate remote sensing and GIS technology for evaluation of grassland environmental health in north China. Methodology used in the study includes ground observation, grassland database establishment, reclamation mapping, and remote sensing image interpretation. Our results indicate that grassland reclamation for agricultural farming is very serious in recent decade in north China. About 15% of grassland has been reclaimed into farmland in the transaction zone of north China in a short period from 1985 to 2000. Most reclaimed farmlands are not suitable for agricultural cropping. In both transaction and pasture zones the areas of unsuitable farmland account for above 20% of total farmland area. Desertification is also very serious in the grassland. 4 of the 6 provinces under study have over half of grassland areas suffering various levels of desertification. Percentage of grassland areas under intensive desertification to the total is high up to 57% in Gansu and over 30% in Inner Mongolia, Qinghai and Ningxia. We classified the grassland into 5 categories according to the degree of desertification. The results show that the categories with slight, moderate and complete desertification mainly concentrate in southern and central Inner Mongolia. This evaluation provides valuable assistances to policy proposals for local administration of farming and grazing activities in the region.

Keywords: grassland, ecosystem, overgrazing, unsuitable farming, desertification.

I. INTRODUCTION

The frequent happening of sand storms invading north China since mid-1990s has gained widely concerns from both domestic China and neighboring countries such as South Korea and Japan. It has been commonly agreed that the sand storms are the direct results of environmental deterioration and ecosystem degradation in the grassland of north China [1][2]. Overgrazing and unsuitable farming on the grassland are believed to be the direct causes leading to such ecological disasters as sand and dust storms in north China [3]. Consequently, grassland issues have become an important area of scientific investigation in China in recent years [4]. In order to provide information for anti-desertification and grassland administration in the region, several efforts have been on the way to understand the grassland ecosystem. And our researches at Chinese Academy of Agricultural Sciences (CAAS) represent a leading role to the grassland issues of north China [3][4]. The objective of this study is to present the results of our series studies on the issues. We intend to integrate remote sensing and GIS technology for evaluation of grassland environmental health in north China. The health of grassland ecosystem is defined as the status of environmental ecosystem in its evolution, which enables the evaluation of ecosystem through investigation of its key factors shaping the evolution.

II. METHODOLOGY

Methodology used in the study includes ground observation, mapping agricultural reclamation of grassland, remote sensing image interpretation and grassland database establishment.

A. Ground observation

For evaluation of grassland ecosystem health, a series of ground observations had been conducted with collaboration of 13 local Grassland Administration Stations during 2002-2003. Totally we observed 4500 samples on 14 patterns of grassland in North China for the observation. Information relating to grass density, height, dry weight, grass type, soil type, and so on have been collected in the field using square sampling method. For each sampling stop, at least 5 sampling squares are observed for field information collection. B. Mapping agricultural reclamation of grassland

Reclamation of grassland has been commonly viewed as an important factor leading to ecosystem degradation and environmental deterioration in north China. In order to evaluate grassland ecosystem health in our study region, we conducted the mapping of agricultural reclamation of grassland into cropping farmland in recent decade. This was mainly done through comparison of land use and land cover change of grassland and farmland between 1985 and 2000. Two types of maps were used for the mapping: land use/cover and vegetation. Both maps were with scale of 1: 1 million. GIS program ArcInfo was used as tool to compare the maps of the two periods for the mapping.
C. Remote sensing image interpretation

In order to compare the changes of land use/cover and vegetation for reclamation mapping, we need to have the maps of two periods: 1985 and 2000. The former is available but the later is not. Therefore, we have to produce the current land use/cover of our region. For this, MODIS images acquired in 2000 was used. The bands 1-2 of MODIS image with spatial resolution of 250m under nadir can meet the requirements of large-scale land cover mapping such as in our region. Landsat TM images are also used for detailed study of some important regions such as central Inner Mongolia where rural economic activities are characterized with mixture of agricultural cropping and pasture grazing. Besides, the grass cover rate is generated from NDVI computed from red and infrared bands of MODIS images.

D. Grassland database establishment

Together with the long-term observation data from the 13 local Grassland Administration Stations, a database on grassland ecological structures and functions has been established. This database has been integrated with available geospatial data of the region such as rainfall, sunshine hours, temperature, and soil types to map the current ecological status of the grassland and to evaluate the recent reclamation of grassland for agricultural farming.

III. RESULTS AND ANALYSIS

A. Grassland reclamation in north China

Grassland ecosystem in north China has been suffering from environmental degradation in recent decades, as a result of reclamation and overgrazing. Both are driven by population pressure under unreasonable administration. Table 1 lists the grassland reclamation since 1985 in north China. According to the traditional economic activities, the spatial distribution of grassland in north China can be divided into two zones. Transaction zone is characterized with a mixture of agricultural cropping and pasture grazing. The zone is composed of 341 counties and banners (local administrative region in China). Pasture zone is economically featured with mainly nomads in the past. Now the nomads have settled down for their grazing.

The transaction zone has a total territory of ~1875 thousand km², of which grassland accounts for 35.79%. During period between 1985 and 2000, about 797115 km² has been reclaimed into farmland for cropping. The reclamation activities have directly led to the sharp reduction of grassland in the zone. In 1985 there were about 768975 km² of grassland in the zone while the area decreased to 671860km² in 2000. The reclaimed grassland accounts for 14.45% of current total grassland area (table 1). Thus the grassland was with an annual reduction of ~1% during the period. Many newly reclaimed farmlands are not very suitable for agricultural cropping due to the many environmental constrains such as slope and water scarcity. Currently the zone has total farmland of ~355 thousand km² but 22.57% of them fall into the category of unsuitable for farming. The amount of unsuitable farmland in the zone is 64325 km², which is equal to 2/3 of the newly reclaimed grassland. This implied that most of the reclaimed farmlands changing from grassland are actually not suitable for cropping.

<table>
<thead>
<tr>
<th>Items</th>
<th>Transaction zone</th>
<th>Pasture zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of county</td>
<td>341</td>
<td>148</td>
</tr>
<tr>
<td>Total territory (km²)</td>
<td>1874837</td>
<td>2611186</td>
</tr>
<tr>
<td>Grassland (km²)</td>
<td>671860</td>
<td>1492970</td>
</tr>
<tr>
<td>Reclaimed grassland (km²)</td>
<td>97115</td>
<td>31719</td>
</tr>
<tr>
<td>Reclaimed as % of grassland</td>
<td>14.45</td>
<td>2.12</td>
</tr>
<tr>
<td>Farmland (km²)</td>
<td>354672</td>
<td>101149</td>
</tr>
<tr>
<td>Unsuitable farmland (km²)</td>
<td>64325</td>
<td>30333</td>
</tr>
<tr>
<td>Unsuitable as % of farmland</td>
<td>22.57</td>
<td>29.99</td>
</tr>
</tbody>
</table>

Situation in pasture zone is a little bit better in terms of reclamation of grassland. The zone has 148 counties with a total territory of ~2611 thousand km² (table 1). Since grassland is the main land use pattern in zone, the percentage of grassland is up to 57% in spite of vast territory occupied with unprolific desert and gobi (rock-particle desert). Due to much less population, reclamation of grassland in the zone is slightly fewer than that in the transaction zone. Table 1 indicates that totally 31719 km² of grassland have been reclaimed into farmland in the zone during the past 15 years, which accounts for 2.12% of its current grassland area. Though the percentage is low, the amount of reclamation is still a problem leading to environmental degradation in the zone. When comparing with unsuitable farmland, we can see that almost the newly reclaimed farmlands are unsuitable for agricultural cropping. The unsuitable farmland accounts for ~30% of total farmland in the zone. Large amount of unsuitable farmland can be attributed to the newly reclaimed grassland, because the unsuitable farmland is numerically equal to ~95% of newly reclaimed grassland in area.

The intensive reclamation of grassland into farmland has caused serious environmental degradation in north China, including on-going desertification and decrease of grass cover rate in the grassland. Several sand storms since mid-1990s has been widely viewed as the direct result of grassland ecosystem degradation in recent decades.

B. Desertification of grassland in north China

In addition to quantity decrease, quality declination also consists of environmental degradation in the grassland. Table 2 lists the desertification of grassland in the provinces of north China. According to environmental conditions, the grassland can be divided into two broad categories: under sustainable evolution and under desertification. As indicated in table 2, sustainable grassland accounts for less than 50% in 4 of the 6 provinces. This implied that desertification is very severe in the grassland of north China. Among the 6 provinces, only Hebei and Qinghai has sustainable grassland area exceeding the desertification area of the grassland. Ningxia has the lowest percentage of sustainable grassland, indicating that its above 86% of grassland are suffering various levels of desertification. Gansu and Shaanxi also have very low percentages of sustainable grassland (~40%), implying that their grasslands are also under extensive desertification.
Desertification of grassland can be classified into three levels according to their severities: slight, moderate and intensive. Grasslands under the level of slight desertification are defined as those starting the symptom of desertification. Moderate desertification means that an obvious process of desertification is on the way. And intensive desertification indicates the process to be almost completes. Table 2 indicates that Hebei and Shaanxi have the lowest percentage of grassland under moderate and intensive desertification. Gansu province has the most severe desertification due to its above 50% of grassland under category of intensive desertification. Inner Mongolia, Qinghai and Ningxia also have above 1/3 of grassland areas under intensive desertification. Since Inner Mongolia and Qinghai have the largest amount of grassland, their high percentages of grassland areas under intensive desertification demonstrate their severe grassland ecosystem degradation.

C. Grass cover rate in the grassland of north China

Grass cover rate can be used as an important indicator for evaluation of the healthy status of grassland ecosystem. When the rate is high, grass would be dense. This probably is due to the few disturbance of reasonable grazing. Figure 1 shows the spatial variation of current grass cover rate in the grassland of north China. In spite of high cover rate in most areas, we also notice that areas with low cover rate are vast. Spatially, the east Inner Mongolia and Qinghai has higher grass cover rate, indicating the generally health of grassland ecosystem in the regions. The west Inner Mongolia and Qinghai has the lowest grass cover rate, implying the health of their grassland ecosystems is the worst in comparison with other regions. Actually these two parts are mainly dominated with pattern of desert grassland, which has very low productivity and its ecosystem is very fragile in its natural conditions.

What needs to be concerned is the central Inner Mongolia where original grassland is very good. However, overgrazing in recent decades has led to sharp decrease of grass productivity. Consequently, grass cover rate in the region is experiencing gradually declination. Many areas in the region have above 40% grass cover rate, but now are less than 20%.

Our field observation also verifies that the phenomenon of grassland desertification is mainly observed in the region. Our study [3] indicates that the region is one of the intensive overgrazing areas in north China.

D. Spatial distribution of reclaimed grassland

As a giant agricultural country with over 1.3 billion of population on its only 9.6 million km² of total territory, China faces the challenges of providing sufficient food for its people on its way to modernization. The systemic release of rural farming labors has led to several reclamation surges in recent decades. Figure 2 shows the reclamation changes of grassland since 1980 in the whole China. As we can see, intensive reclamation of grassland mainly distributes in the transaction zone of north China. Southeastern Gansu province and northeastern Inner Mongolia have the concentative reclamation of grassland into farmland. The reclamation is also seen to be intensive in the central Inner Mongolia and eastern Qinghai (figure 2).
<400mm and lack of irrigation infrastructures. In 148 grazing counties ~31719 km² of grassland (accounting for 2.12% of total grassland area) had been reclaimed in recent decades and above 95% of these newly reclaimed farmland belongs to unsuitable farmland category according to our analysis. In 341 farming-grazing counties about 14.45% of grassland had been reclaimed and about 2/3 of the newly reclaimed farmland are not suitable for farming (table 1). Figure 3 indicates that the unsuitable farmlands are mainly concentrated in central Inner Mongolia, which is followed by Gansu (especially in its Hexi corridor region) and Ningxia.

**Figure 3. Spatial distribution of cultivated farmland in north China.**

**E. Grassland ecosystem health in north China**

Combining with MODIS image interpretation, we classify the grassland of north China into 5 patterns according to the degree of desertification. The results are shown in figure 4. Class 1 represents the area remaining its natural status without symptoms of desertification, class 2 prone to slight desertification, class 3 under moderate desertification, class 4 under strong desertification, and class 5 under complete desertification.

**Figure 4. Classification of grassland in north China**

Figure 4 indicates that the healthy grassland under class 1 is mainly distributed in northeast Inner Mongolia and southeast Qinghai, while the categories with slight, moderate and complete desertification (classes 2, 3, and 5) are mainly concentrated in southern and central Inner Mongolia especially Shelingola and Ykimholo regions. The areas under strong desertification are mainly in western Inner Mongolia and Qinghai. This evaluation of grassland ecosystem health will provides valuable assistances to policy proposals for local administration of farming and grazing activities in the region.

**IV. CONCLUSION**

Grassland ecosystem health has been evaluated in the study using integration of remote sensing and GIS technology. Focus is given to reclamation and unsuitable farming. In recent decade, grassland reclamation into agricultural farming is very serious in north China. About 15% of grassland had been reclaimed into farmland since 1985 in the transaction zone. Most of the newly reclaimed farmlands are not suitable for farming. In both transaction and pasture zones, the amount of unsuitable farmland areas accounts for above 20% of total farmland area. Such extensive reclamation has directly led to the ecological degradation of grassland in north China. Together with overgrazing, environmental deterioration and ecosystem degradation has become more and more severe in recent years. Spatially the dramatic change of ecosystem health can be seen in central Inner Mongolia where desertification can be classified as moderate to strong stages, in addition to intensive reclamation and unsuitable farmland. Understanding the spatial variation of grassland ecosystem and its change will be very helpful for planning any actions to slow down the process of continuous ecosystem degradation in the grassland.

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