SPATIOTEMPORAL ANALYSIS OF LAND COVER CHANGE AND POPULATION DYNAMICS IN HORQIN SANDY LAND, CHINA

Yun Du (1), Hasi Bagan (1), Xuan Xie (1), Chaoming Chen (1)

[1]School of Environmental and Geographical Sciences, Shanghai Normal University, Shanghai, 200234, China
Email: 1000459348@smail.shnu.edu.cn; hasibagan@staff.shnu.edu.cn;
1000480061@smail.shnu.edu.cn; 1000480060@smail.shnu.edu.cn

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ABSTRACT: With the deepening impact of human activities on climate and land cover, the global ecological environment is undergoing rapid and extensive changes, so it is essential to explore the relationship between population change and land cover change. In this study, we used the multi-temporal Landsat images of 2000 and 2019 to evaluate the land cover change of Horqin sandy land in the past 20 years by using the classification method of random forest classification (RF). and analyzed the relationship between the change of land cover and population by statistical method. First of all, we selected training samples and testing samples based on the free Landsat data, and then classified the images by using the random forest classification to obtain the land cover maps of 2000 and 2019. Secondly, in order to carry out quantitative research, we set up 300m × 300m grid cells in the study area. Finally, the correlation between land cover maps and population data was analyzed by statistical method. The results show that: during the 20 years, the area of cropland, grassland, sandy land and built-up increased, while the area of woodland, bare soil and water decreased. It is worth noting that the area of built-up increased by 2.75%, which was mainly reflected in the spatial concentration and the urban scale expansion. From 2000 to 2019， the area of cropland increased most rapidly with the proportion of 7.31%, and the area of bare soil decreased most rapidly with the proportion of 10.8%. The most concerned land cover class of Horqin sandy land which is part of arid and semi-arid area is the sand, which increased from 7.2% in 2000 to 8.58% in 2019, and the water, which decreased from 21.27% in 2000 to 20.58% in 2019. Among these classes, cropland and built-up have strong positive correlation with population change. This implies that population growth is probably leading to further increases in the area of cropland and built-up. Based on the analysis of temporal and spatial changes of land cover classification in Horqin sandy land, this study further explores the relationship between such variations and population growth. Therefore, this study will provide basic data and decision-making reference for future ecological environment improvement in Horqin Region.

1. INTRODUCTION

Horqin sandy land is located in the fragile area of ecological environment in northern China, which is one of the hot spots in the research of ecological environment change in China. It is mainly formed by blowing sand wind and accumulating on the spot, and has experienced many times of sand dune activation, desert expansion, sand dune fixation and desert contraction in the historical period (Qiu, 1989).

At the beginning of the 21st century, the expansion of irrigation-based desertification control scale and the increase of irrigated farmland area led to the increase of water consumption, aggravation of desertification problem and decline of biomass (Zhao et al., 2009). Therefore, the problem of desertification control has attracted the attention of many scholars (Zhao et al., 2002; Zhao et al.,2009; Ge et al., 2010).

In recent years, due to the rapid increase of population and unreasonable land use patterns such as over cultivation and overgrazing, the region has become one of the most serious desertification crisis areas in China (Gao et al., 2000). Land desertification poses a serious threat to the environment, economy and society of the region (Zhu, 1991; Gao et al., 2019). Previous studies have shown that land use pattern and intensity are the main factors affecting the development or reversal of desertification (Cao et al., 2004; Qian et al., 2014). Therefore, the research of land use/land cover change characteristics in Horqin sandy land is of great significance for exploring the development trend of land desertification and effective governance. It is also of great importance to guarantee the ecological security of northern China. Many scholars had studied the characteristics of land use/land cover change in this area, but there are few relevant studies in the last 20 years.

Nowadays, Landsat series satellite data with its continuous, open, mature, free unique advantages, is a great data source for land cover change research (Wang et al., 2014; Bagan et al., 2020). In addition to data, selecting a good classification method is the key component for the classification process. Previous studies had shown that the random forest classification method has higher classification accuracy and is more sensitive to noise than other classification methods (Adam et al.,2014; Zhu et al., 2016).

Therefore, based on Landsat data, this study used random forest classification method to evaluate the dynamic change characteristics of land cover in Horqin Sandy Land in recent 20 years.

2. METHODOLOGY

2.1 Study Area

Horqin Sandy land is located in the west of the northeast Plain of China, at the intersection of the southern Part of the Great Xingan mountains and the northeastern foothills of the Yanshan Mountains. In terms of administrative division, it spans Chifeng City, Tongliao City and Xing'an League in Inner Mongolia. This region has a temperate continental monsoon climate, with dry, cold, and windy winter and hot and rainy summer. The average annual temperature is 5.8~6.4 ℃, and 70%~80% of the precipitation is concentrated from July to September, with annual precipitation of about 300~450mm (Cao et al., 2004).

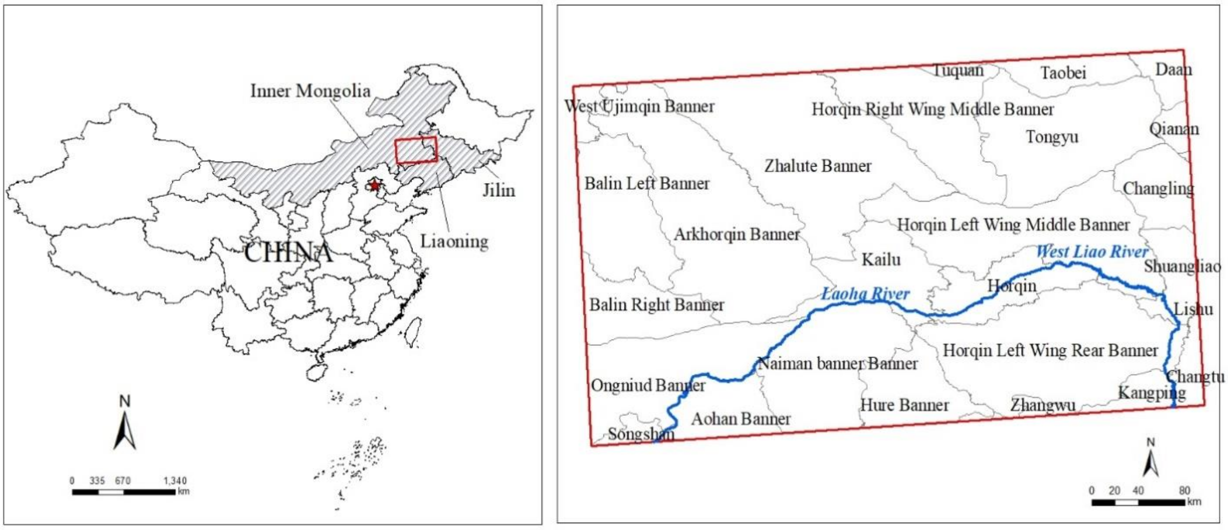

Figure 1. The location of study area

2.2 Satellite Data and Population Data

We acquired multidate Landsat Thematic Mapper (TM) and Operational Land Imager (OLI) Level-1TP data for the study area for 2000, 2002, 2017 and 2019 from the US Geological Survey (USGS) (http://glovis.usgs.gov/ and https://earthexplorer.usgs.gov/) (Table 1). The multidate image segmentation can reduce the error caused by using land-cover images independently classified from separate remote sensing images (Duveiller et al., 2008).

As can be seen from the table 1, we selected July, August and September, which is mainly due to the vigorous growth of vegetation in these three months. In addition, due to the influence of cloud cover, there is no suitable Landsat image for land cover classification in the study area in 2000 and 2019. We use the image of adjacent years to supplement the image for land cover classification.

Table 1. Summary of Landsat data used in this study

Date acquired	Path/row	Sensor	Spatial resolution	Year
20000731	119/029	Landsat 5 TM	30 m	
20000731	119/030	Landsat 5 TM	30 m	
20020914	120/028	Landsat 5 TM	30 m	
20020914	120/029	Landsat 5 TM	30 m	
20020914	120/030	Landsat 5 TM	30 m	2000
20000915	121/029	Landsat 5 TM	30 m	
20000814	121/030	Landsat 5 TM	30 m	
20000906	122/029	Landsat 5 TM	30 m	
20000906	122/030	Landsat 5 TM	30 m	
20190704	119/029	Landsat 8 OLI	30 m	
20190704	119/030	Landsat 8 OLI	30 m	
20170721	120/028	Landsat 8 OLI	30 m	
20170721	120/029	Landsat 8 OLI	30 m	
20170721	120/030	Landsat 8 OLI	30 m	2019
20190904	121/029	Landsat 8 OLI	30 m	
20190920	121/030	Landsat 8 OLI	30 m	
20190911	122/029	Landsat 8 OLI	30 m	
20190921	122/030	Landsat 8 OLI	30 m	

We conducted field campaigns in Horqin sandy land in August 2019. Based on this investigation, we obtained the ground reference sites, and defined 7 land-cover classes: cropland, grassland, woodland, built-up, water, bare soil and sandy. To ensure spatial separation and data correlation, we divided these sites into training and validation data (Table 2).

Table 2. Pixel counts by land-cover class

Class	2000		2019	
	Training	Validation	Training	Validation
Cropland	4795	1026	9336	1380
Grassland	4390	1153	3979	1012
Woodland	3054	1033	3225	1069
Sand	3773	1027	6336	1006
Bare soil	6077	1083	8558	1039
Built-up	4125	1058	4591	1037
Water	3413	1067	6562	1055
Total	29627	7447	42587	7598

The population data of 2000 and 2019 was acquired from the Worldpop website (https://www.worldpop.org). The units are number of people per pixel with country totals adjusted to match the corresponding official United Nations population estimates that have been prepared by the Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat (2019 Revision of World Population Prospects). The mapping approach is Random Forest-based dasymetric redistribution.

2.3 Random Forest Classification

The data and classification methods of land cover classification are the main factors affecting the classification accuracy. Random forest classification is an ensemble classification method that evolves from the bagging method proposed by Breiman (Breiman, 2001). Compared with the traditional classification methods, Random forest classification has some key advantages including non-parametric nature, high classification accuracy, and capability to determine variable importance (Rodriguez-Galiano, 2012).

2.4 Grid Cells

Grid-cell processing was used in this study to investigate the patterns of land cover changes and correlations between these changes in and population. The grid-cell approach represents a good compromise between necessary detail and computational feasibility (Bagan & Yamagata, 2012; Li et al., 2018). we created nets of grid cells at scales of 300 × 300 m covering the entire study area. The grid cells enabled us to calculate the proportion of each land-cover class and evaluate the spatial-temporal changes in land-cover categories to allow a much easier statistical comparison of the land-cover changes with population density changes.

3. RESULTS

3.1 Classification Accuracy

We established confusion matrixes to compare the test data and classification results, to obtain the overall accuracy of 2000 and 2019 are 85.94% and 79.96%. As it shown on figure 2, compared with other land cover class, the producer's accuracies of sand and water are higher. However, the woodland class in 2019 has lower producer's accuracy. This were possibly since cropland, grassland and woodland have similar spectral characteristics, woodland is easy to be confused with cropland and grassland.

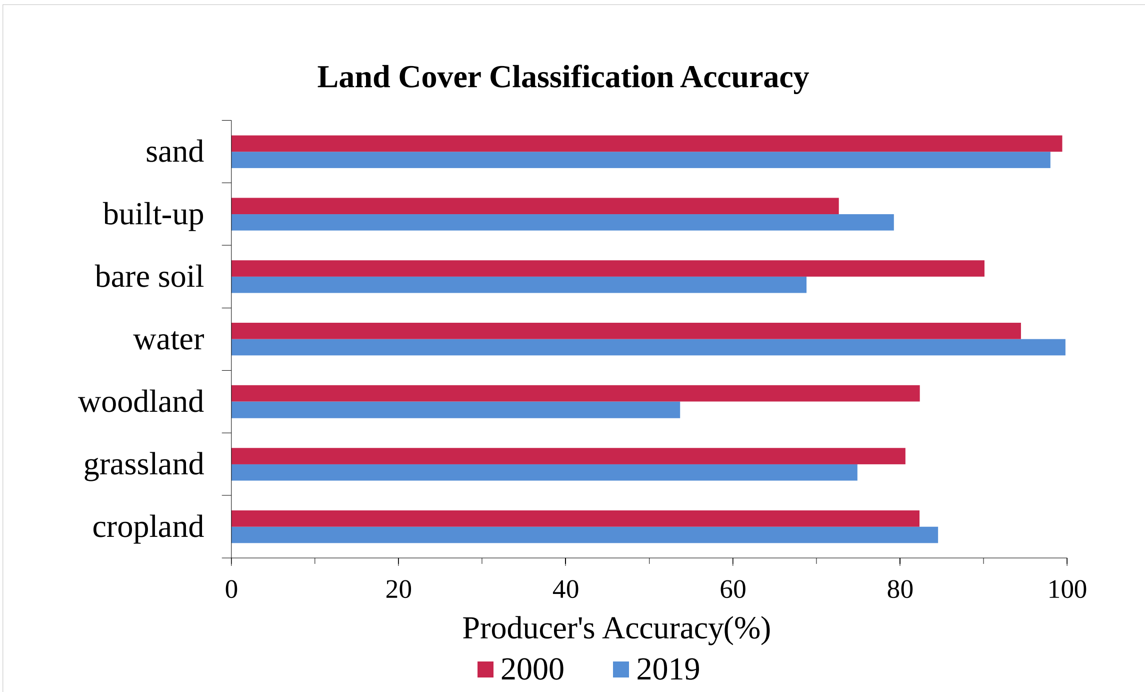

Figure 2. Land cover classification accuracies (%) for 2000 and 2019

3.2 Land Cover Change

We obtained land-cover classification maps for 2000 and 2019 by using the random forest classification (Figure 3) and calculated the percentage of area occupied for each class (Figure 4).

As shown in figure 3, from 2000 to 2019, the area of cropland, grassland, sandy land and built-up increased, while the area of woodland, bare soil and water decreased. It is worth noting that the area of built-up increased by 2.75%, which was mainly reflected in the spatial concentration and the urban scale expansion.

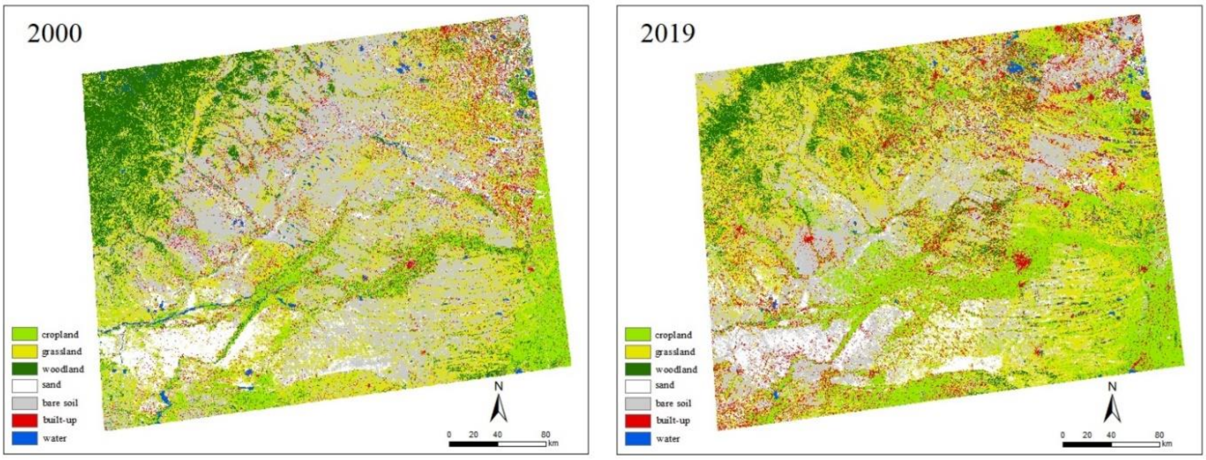

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Fig 3. Land-cover map in 2000 and 2019

As shown in figure 4, during the 20 years, cropland and bare soil had changed significantly. Cropland had nearly doubled from 9.57% in 2000 to 16.7% in 2019. Bare soil decreased from 28.3% in 2000 to 17.5% in 2019, which was nearly one-third of the original. Sandy land and water, land cover classes of most concerned in the arid and semi-arid area, increased by 1.38% and decreased by 0.69%.

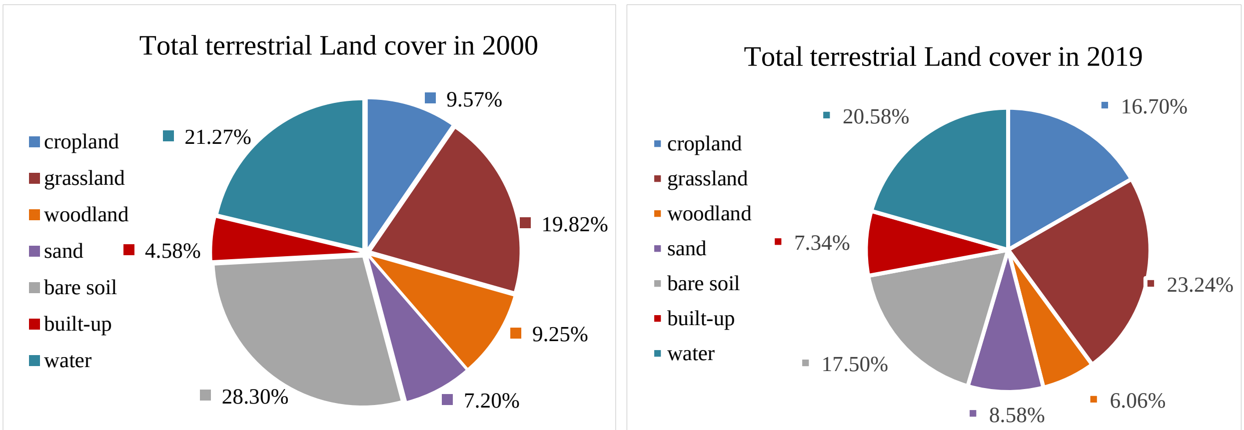

Figure 4. Proportion of each land cover classes in 2000 and 2019

3.3 Relationship Between Land-cover Classes and Population

We calculated the percentage changes in each class at the 300 m scale for 2000-2019. The built-up change has a significant positive correlation with the population density change. However, there are areas with poor correlation caused by sparse population density in some industrial regions. In addition, there is a strong correlation between cropland change and population.

4. CONCLUSION AND DISCUSSION

The research shows that the area of cropland and sandy land is further expanded, and the water area is reduced, which may be closely related to the population growth in this region since the 21st century. There is a high correlation between population growth and changes of cropland and construction land. It can be inferred that population growth promotes the expansion of urban and cultivated land. On the one hand, the increase of cropland ensures food security, on the other hand, it puts pressure on the ecological environment. Meanwhile, our field investigation has found that a new pattern of agriculture called desert rice has emerged in recent years. Its emergence may lead to the overuse of groundwater deep in the desert, thus further accelerating the expansion of sandy land. Therefore, to make the cause and mechanism of land cover change clearer, we will combine the temperature and precipitation data to conduct a more in-depth quantitative study of land cover change and driving factors in this region.

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