ROH 2018/Jan.

Science Journal of Graduate School of Rakuno Gakuen University

Research of One Health

journal homepage:http://gra.rakuno.ac.jp/roh.html

Population changes behind grassland degradation in Horqin region of Inner Mongolia, China

Yintai Na[1,2], Buho Hoshino[1)*], Shin'ya Kawamura[1)], Tsedevdorj Serod [3)]

[1)] Rakuno Gakuen University, 582, Bunkyodai-Midorimachi, Ebetsu, Hokkaido 069-8501, Japan
[2)] College of Resources and Environment Economy, Inner Mongolia University of Finance and Economics, No.185, North two ring road, Hohhot 010070, Inner Mongolia, China
[3)] Department of Geography, Mongolian National University of Education,14, Baga toiruu, Ulaanbaatar, 210648, Mongolia

***Corresponding Author: Buho Hoshino**

(Tel/Fax: +81-011-388-4913, E-mail: aosier@rakuno.ac.jp.)

Abstract

High immigration and fertility rates in Inner Mongolia, China, have led to a large-scale transformation of grassland into farmland. Also, overgrazing resulted in the reduction in grazing land, and hence grassland degradation. Such disappearance of grasslands has been most apparently seen in Horqin region of Inner Mongolia. This paper used technologies of remote sensing and geographic information systems to reveal the impacts of population changes on grassland degradation in Horqin, and underlying history and policy-related explanation, to make a quantitative study on the relationship between both. Results showed that the fast growth rate was observed prior to 1981, primarily due to the policies encouraging immigration and population growth. When these policies were terminated in 1981, the growth rate began to slow down. The linear trend coefficients of the population density indicated uneven population growth over time in each banner/county regarding the time series, with R^2 from 96.8% of the linear trend equations significantly different ($p<0.05$). Spatial features of population density varied across banners, as the immigrant population was affected by factors such as distance from farming areas, agricultural conditions and changes, urbanization, and mineral resource development. Correlations between the percentage of degradation areas and population density in two typical areas were 0.905（p=0.035）and 0.503（p=0.387）.

Keywords: Grassland degradation; Immigration; Population change; Inner Mongolia; Horqin

1 Introduction

Human population, natural resources, environment, and their combined interactions, have become the greatest problem on Earth. This is especially a problem in developing countries in Asia and Africa（Carr et al., 2009; Feng et al., 2014）[1][2].

Studies on grassland degradation in most developing countries indicate that climate variability and overgrazing are two main causes of grassland degradation（Belsky, 1992; Mabbutt, 1984; Suttie et al.,2005）[3][4][5], and great achievements have been made in researches on the present grassland degradation as a result of climate changes and overgrazing in the Horqin region. Man et al., (2000)[6] and Zhao et al., (2000)[7] discussed the impact of climate changes on the grassland degradation in Horqin; Lv et al., (2016)[8] and Zhao et al., (2008)[9] analyzed the relationship among the climate change , grazing intensity and grassland vegetation community; Wulan et al.,（2002）[10], NA et al.,（2008, 2010）[11][12]discussed the grassland degradation from the view of changes revealed from historical farming archives; Su et al.,（2003）[13],Sun et al.,（2015）[14], Liu et al.,（2000）[15]studied the impact of grazing on the grassland soil degradation; Wang et al.,（2004）[16]quantified the relationship among the soil water content, vegetation coverage and wind erosion rate, Chang et al.,（2003）[17]analyzed the relationship among the degradation and cultivated land and grazing capacity by the regression equation.

However, some findings contradict the viewpoint that climate changes and overgrazing are blamed for the grassland degradation（Petz et al., 2014[18]; Bagan et al., 2010[19]; Kim and Keane, 2015[20]; Sylvester et al., 2016[21]）. Though the relationships between population and environment have been highly concerned（Lakhan, 2015[22]; Low and Heinen, 1993[23]）, the quantitative and empirical study between population and grassland are still inadequate. Due to the complexity of the constant administrative adjustment, the severe lack of data on human population changes and previous environmental monitoring in the Horqin region, most studies can only focus on the impact of overgrazing on grassland degradation within the recent 30 years. An insufficient amount of researches focus on medium-term and long-term studies (50-300 years) on the relationship between human population and grassland degradation, especially the studies based on the impact of policies. This is because the different combination of time and location studies may lead to the different conclusion in terms of the causes for the grassland degradation.

Therefore, this paper used technologies of remote sensing and geographic information systems to reveal the impacts of population changes on Grassland degradation in Horqin, and underlying history and policy-related explanation, to make a quantitative study on the relationship between both. As a result, some proposals can be provided scientifically for the “Grazing prohibition” policy implemented in Inner Mongolia.

2 Study area

In Mongolia, “*Horqin*” means “*a man with bows and arrows*” and refers to the nomads distributed from the banks of the West Liaohe River and the Nen River（Huturong, 2010）[24].

Over time, Horqin has evolved from a tribal name into the current geographical term, and the famous Horqin grassland in the beginning of the 20th century has changed into the current “Horqin sand” after a century, which is moreover a synonym for sandy land that covers an area of approximate 52,300 km^2（Wulan et al., 2002; NA et al., 2008）[10] [11], but remains similar to the range of the region in which the former Horqin Mongolians lived (Fig. 1). This region is of the temperate continental monsoon climate, with an average precipitation of up to 300-500*mm* and an average annual wind speed of 3.0-4.4m/s.

As it is shown in Fig. 1, the study region covers the banners of Tongliao City, including Horqin Left Back Banner, Horqin Left Middle Banner, Naiman Banner, Hure Banner, Jarud Banner, Kailu County, Horqin District, and Ho Lin Gol City, as well as Ar Khorchin Banner of Chifeng City and Horqin Right Middle Banner of Hinggan League.

3 Materials and Methods

3.1 Materials

The main population data source (1947-2011) is adopted from *the Census Data Collection of the Inner Mongolia Autonomous Region* in the year 1953, 1964, 1982, and 2000, *the Endeavor of Inner Mongolia* (1947-1989), *the Inner Mongolia Autonomous Region Statistical Yearbook* (1990-2012) and the website of Inner Mongolia Autonomous Region Bureau of Statistics (www.nmgtj.gov.cn).

Remote sensing satellite data of five scenes were obtained when it is cloudless, covering the typical areas during the growing season (http://earthexplorer.usgs.gov/) and then they are geographically referenced, radiometrically calibrated and subseted in the ENVI5.1 software (Exelis Visual Information Solutions, USA, 2014).The detailed information is listed in Table 1.

3.2 Research Method

Normalized Difference Vegetation Index（NDVI）

The NDVI is usually used to characterize the vegetation coverage (Tucker, 1979)[25], and the calculation equation is as follows:

$$\mathbf{NDVI} = \frac{\rho_{NIR}-\rho_{RED}}{\rho_{NIR}+\rho_{RED}} \qquad (1)$$

Here, NDVI is the vegetation index, ρ_{NIR} is the reflectance of near-infrared band , ρ_{Red} is the reflectance of red band.

Linear trend model

The linear trend model was used in this study for the trend analysis of population density growth for each 10-year with the slope of linear trend after regression analysis. The slope of linear trend is calculated based on Eq. (2):

$$\theta_{slope} = \frac{n\times\sum_{i=1}^{n} i\times PD_i-(\sum_{i=1}^{n} i)(\sum_{i=1}^{n} PD_i)}{n\times\sum_{i=1}^{n} i^2-(\sum_{i=1}^{n} i)^2} \qquad (2)$$

Here, θ_{slope} is the slope of linear trend, PD_i is the population density for the year i, n is 10.

Correlation Analysis

The Pearson's correlation coefficient (Lee Rodgers and Nicewander, 1988) [26] was used to check the correlations between the percentage of degradation area and population density, which is calculated based on Eq. (3):

$$r_{xy} = \frac{N\sum x_i y_i-\sum x_i \sum y_i}{\sqrt{N\sum x_i^2-(\sum x_i)^2}\sqrt{N\sum y_i^2-(\sum y_i)^2}} \qquad (3)$$

where, N is the sample number, x and y represent the percentage of degradation area and population density for the sample i, r_{xy} indicates the correlation between them. Possible correlations range from +1 to -1. The larger the absolute value of r is, the stronger their correlation is. A zero correlation indicates that there is no relationship between the two variables.

4 Result and Analysis

4.1 The Temporal Change of Population Density

It is shown that the population density of Horqin exhibited a significant linear increase from 1947 to 2011 (Table. 2), and that the total population density increased from 10 to 42 people/km^2, which represented a four-fold growth increase compared to that in 1947, and remained a rather high growth rate.

The population densities of Horqin district, Ho Lin Gol City, Kailu County, Naiman Banner and Horqin Left Middle Banner all increased to more than 6 people/km^2 during each 10-year period, whereas those of the remaining banners were all less than 5 people/km^2 for each 10-year period. After 1976, the population growth rate of Ho Lin Gol City was the highest in each 10-year period at 40 people/km^2 due to the development of mineral resource exploring, followed by Horqin District and Kailu County, which were the main destinations of immigrants and had average 10-year population growth rates of 33 people/km^2 and 11 people/km^2 respectively, representing a rather large variation.

It can be seen from Table. 3 that the trend coefficient for 1947-1956 was 0.47. The ones for 1957-1966 and 1967-1976 were 0.77 and 0.71 respectively, which were 5.6 times and 5.2 times of the one for 1997-2011 (0.14). And the trend coefficients for 1977-1986 and 1987-1996 were 0.57 and 0.41 respectively.

The trend coefficient of each county could reflect the difference of population growth speed . The population growth rate of Horqin District was the fastest from 1947 to 1956, with trend coefficients of 3.61. It is followed by Horqin Left Back Banner, Kailu County, Hure Banner and Naiman Banner, with the trend coefficients of 0.67, 0.62, 0.56 and 0.42 respectively. The trend coefficients of the other banners were all less than 0.37.

During the period 1957-1966, the population growth rates of most banners reached the peaks, and the trend coefficients of the population growth rates of Horqin District, Kailu County and Korqin Left Middle Banner were 5.62, 2.15 and 1.01 respectively. In contrast, the population growth rates of Khorqin Left Back Banner and Hure Banner in the southern area of the region slowed compared with those of the previous decade, with trend coefficients of 0.56 and 0.47 respectively.

From 1967 to 1976, the population growth rates in most regions significantly decreased, especially those of Horqin District and Kailu County, where the proportion of farming and the level of urbanization were high (trend coefficients of 3.23 and 1.72 respectively). In contrast, Horqin Left Back Banner, Hure Banner, Naiman Banner and Horqin Right Middle Banner all reached their respective peaks of population growth rates (0.74, 0.59, 0.97 and 0.29 respectively).

During the next two decades (1977-1986 and 1987-1996), the population growth rates in most banners slowed down, among which the decrements in the population growth rates of Horqin Left Back Banner, Hure Banner and Naiman Banner were the largest, and those in Ar Khorchin Banner and Jarud Banner were much lower.

From 1997 to 2011, all banners reached its lowest growth rate, with the exception of Ho Lin Gol City which had a trend coefficient of 2.69, and the trend coefficients of all the remaining county were lower than 1.0. Horqin Left Middle Banner, Ar Khorchin Banner and Horqin District showed the highest decrements with the trend coefficient of 0.02, 0.03 and 0.48 respectively, and with decreases of 97%, 83% and 82% respectively.

The variability of the slope in the population density linear trend better demonstrated the temporal differences on population growth of each Banner and County from 1947 to 2011, and it was found that R^2 Statistics from 96.8% of the linear trend equations had significant differences ($P<0.05$), compared with the critical value table of the linear correlation coefficient r. (See Table 4).

4.2 The Spatial Change of Population Density

Fig. 2 shows the spatial distribution characteristics of population density in the study area for every 10 years since 1947. First of all, it was sparsely populated with the range of 1-15 people/km^2 in most parts of the study region in 1947. The population densities gradually decreased from the farming areas in the middle of the Horqin to the farming-pastoral areas and the pastoral areas in the hinterland of the Horqin region, which is particularly reflected in Fig. 2 a.

Secondly, compared with the population density maps in 1947, it was found that the growth rates of population density in Ar Khorchin Banner, Horqin Right Middle Banner and Jarud Banner was slower. Horqin Left Back Banner and Hure Banner had faster growth rates than the above three banners because they were closer to the agricultural regions in distance and the early stages of immigration were limited by the natural environmental conditions (Fig. 2 b and Table3).

Thirdly, it is shown from the population density maps in 1967 (Fig. 2 c) and 1977 (Fig. 2 d) that the population distribution no longer exhibited denseness or sparseness depending on the distance from farming areas by 1957, when the immigrant population reached a certain scale and settled down. However, favorable farming conditions had become the first choice. In this trend, the population flow moved from the sandy grassland areas like Horqin Left Back Banner and Hure Banner to the fertile Khorqin District and Kailu County and then advanced to the surrounding leveled areas such as Horqin Left Middle Banner and Naiman Banner.

Fourth, population distribution of the study area shows new features in 1987 and 2007 (Figs. 2e, 2f, 2g and Table3). Because the grassland resources that could be developed into new farmland became increasingly scarcer with the advance of reclamation in the study region, the areas of earlier agricultural development, such as Naiman Banner, Hure Banner and Horqin Left Middle Banner, showed serious grassland degradation, and immigrants mainly moved from the south to the north in the Horqin region, the sparsely populated and vast areas, such as Horqin Right Middle Banner, Jarud Banner, and Ar Khorchin Banner, and so on（Wulan et al., 2007）[27].

4.3 The policy and reason analysis behind the population change

Shortly after the founding of the People's Republic of China, a number of population and reclamation policies were formulated and implemented in Inner Mongolia according to the national conditions at that time (Table 5). These policies exerted direct or indirect effects on the population size and production patterns and thus profoundly affected the ecological environment of the grassland.

Population growth reached the peaks during the periods of 1957 to 1966 and 1967 to 1976, which was related to the implementation of the population policy “the more people there are, the more powerful they are” from 1949 to the end of the 1960s and the “Immigration to Inner Mongolia” policy from 1954 to 1960, and 88% of immigrants among them migrated into the region during 1954-1960 (Hu and Zhang, 1986; Song et al., 1987)[28][29].

During this period, no large scale immigration occurred from 1977 to 1986, however, population immigrants from the other provinces continued until the implementation of the policy “No large scale immigration to the Inner Mongolia” in 1981(Yu, 2006) [30], and the population growth rate began to decline obviously after the enforcement of the family planning policy.

In addition to the causes mentioned above, the reasons for the uneven population growth in the time series lie in the following facts: As the center of politics and culture, Horqin District experienced unusually rapid populaiton growth with its higher urbanization, but the growth rates significantly decreased from 1967 to 1976（Table 3）. In contrast, Horqin Left Back Banner, Hure Banner, Naiman Banner and Horqin Right Middle Banner all reached their respective peak of population growth rates due to the special period of China’s “Cultural Revolution” (1967-1976), when a large number of immigrants (including the educated youth) from inland China transferred to rural and pastoral areas (Zhao and Zhen 2000)[31]. With the restoration of production and culture since 1977, large population swarmed into cities, and thus the population in Horqin District boomed.

4.4 The impacts of population change on the grassland

This paper selected the Shao Gen County of Ar Khorchin Banner and Bagaborihe Sum of Naiman Banner as the typical areas (Fig. 4), and defined the degradation area where the NDVI value is less than the Mongolian plateau threshold value of 0.1 (Liu et al., 2010; Li, 2007)[32][33]. And according to the statistics, the population density in the corresponding banner is analyzed (Fig. 5). The correlation coefficient between the population density of Ar Khorchin Banner and the percentage of degradation areas of Shao Gen county's grassland is 0.905(p=0.035), and the correlation coefficient between the population density of Naiman Banner and the percentage of degradation areas of Bagaborihe grassland is 0.503(p=0.387), both belong to positive correlation, which implied that the grassland degradation became increasingly serious with the growth of population density.

According to Table 5 and Table 6, with the increasing of population density, Grassland degradation has also gradually become serious. The closeness between the population density of Ar Khorchin Banner and the degradation of Shogen is even more pronounced. Correlation analysis shows, the correlation coefficient between degradation area proportion and population density is higher in region where Grassland degradation started late. Probably because of Naiman Banner is located near to inland farmland and agriculturalization started earlier, large area of grassland had already been desertified as shown in the image of year 1977.

With the population increasing, the need for agricultural resource including land, fresh water etc. is becoming the main pressure for our society. The land, forest, and grassland are over used in order to satisfy to human's requirement, which leading the grassland degradation (Curran et al., 2004) [34].

Several studies indicate that increased population is responsible for the worse ecological environment of grassland in Inner Mongolia. In 1994, John et al. (1994) suggested that less rainfall, increased population, large scale graze make the grassland bear great pressure (John et al., 1994) [35]. The similar theory was raised by Bi et al. (2016), large number of immigrants in Inner Mongolia were encouraged to conduct agricultural activity, followed with grassland reclaim, finally, leading to degradation as well as the impaired ecological environment (Bi et al., 2016) [36]. According to Aorenqi, lifestyle change from nomadism to settlement, unreasonable fencing, and farming pattern contribute to the Inner

Mongolia grassland regeneration as well. With noticeable, nomadism to settlement and agricultural farm is accessory to population increased(Ao et al. 2005) [37].

Both Mongolia and Inner Mongolia of China share the main area of the Mongolian grasslands. Mongolia represents the traditional animal husbandry country. The number of population and livestock of Mongolia is growing rapidly in the past half century. Although overgrazed, the Mongolia's grassland still maintains a good condition on some level. In contrast, degradation in Inner Mongolia of China is becoming more and more seriously, which was driven mainly by increased population (Hoshino et al., 2009) [38].

In 1990s In the begining of the 90's, the Prairie overload of grassland in China was estimated around 84%, by using this detail as base plan, and considering the fact of human population growth, at the peak of human population on 20th century, even though the population of nomatic people grow as the average of whole country population at 30%.Based on the annual 2% increasement in income by nomatic people, which obtained from farming or herding, grassland would be suffer from overload pressure to 300% (Hou et al., 2001) [39]. In instance, due to overherding in grassland and Grassland degradation issues in future, greater speed and magnitude of hearding labour force transfer (immigration or premises transfer) will be demand.

5 Discussion

Grassland degradation is mainly influenced by both natural and human factors. The decrease of precipitation and the increase of the temperature are the most basic natural factors affecting the grassland degradation, but during the past over 60 years, there were no significant changes in climate conditions such as precipitation and temperature in the area (Zhang et al. 2012) (Bao et al. 2008)[40][41]. Therefore, human activities are identified as the main driving factor in modern grassland degradation in the region, which is the same as the research conclusions drawn by Wang et al. (2004)[16] and Dong (2001)[42].

During the past 100 years, the main production mode in the region is the farming with low degree of mechanization, and the population is the most fundamental driving force of the extension of cultivated land and the agriculture development. Therefore, it can be concluded that the grassland degradation in this region basically resulted from the immigration and the population explosion caused by high growth rate, which is the same as the views held by Ci and Liu (2000)[43], Wulan and Wulan et al., (2002, 2007), Wang et al. (2004) and Dong (2001).

Li (2014)[44], Liu (2010)[32], Li(2007) [33] and other researchers found that the period from 1970s to 1990s witnessed the all-scale degradation of Inner Mongolia grassland, and the situation has been improved since the beginning of the 21st century due to a series of ecological projects such as " Returning cultivated land to forests and grassland " and "grazing prohibition " policy implemented by Inner Mongolia to control the grassland degradation (Hao 2011)[45], (Zhou 2012)[46]. This phenomenon can also be confirmed by Figure 4 and the data of typical degradation areas. Besides, grazing, agricultural mechanization degree and level of economic development and population growth have lagging influences on the grassland. These factors as well as the comprehensive and local factors and differences of dominant factors make the relationship between grassland degradation and the population more complex and multivariate, thereby increasing the difficulty of the research. Throughout the modern history of grassland degradation in the region, the grassland degradation usually happened when large population immigrated and dug up grassland during the Republic of China (1912-1949) and after the foundation of PRC. However, insufficient data can be found to prove the relationship between the population and the grassland degradation of large areas, so this study attempts to reveal this quantitative relationship.

6 Conclusions

The total population density of the study region increased from 10 to 42 people/km^2 from 1947—2011 and exhibited a significant trend of linear increase.

Population density change of each banner was uneven in time series. The variability of the slope in the population density linear trend better demonstrated the temporal differences on population growth of each Banner and County from 1947 to 2011, and the R^2 Statistics from 96.8% of the linear trend equations had significant differences (p<0.05).

The spatial distance from farming areas, the regional natural environmental conditions and their changes, as well as the processes of urbanization and mineral resource development have resulted in the changes of the spatial distribution features of the Horqin population. Overall, the spatial distribution of population density was higher in the central region than that in the other regions; additionally, the population density in the southern region was higher than that of the northern region.

Immigration and immigrant fertility were the biggest "contributors" to population growth in this region. The rapid growth driven by immigration policies and encouragement for a high birth rate significantly slowed down after 1981, indicating that the immigration and family planning policies enforced by the government played important roles in the Inner Mongolian.

Correlation analysis between the ratio of degradation area and the population density was 0.905（p=0.035）in Ar Khorchin Banner and 0.503（p=0.387）in Naiman Banner, indicating that the increase of population density aggravated the degree of grassland degradation, and its impact was greater in the early period than the late stage of grassland degradation.

Acknowledgments This research has been supported by the National Natural Science Foundation of China（No.61661045 and No.41561009）.

References

1.Carr D L, Lopez A C, Bilsborrow R E, 2009. The population, agriculture, and environment nexus in Latin America: country-level evidence from the latter half of the twentieth century. Population and Environment, 30(6): 222-246.

2.Feng Z M, Yang Y Z, You Z, 2014. Research on the suitability of population distribution at the county level in China. Acta Geographica Sinica, 69(6): 723-737.

3.Belsky A J, 1992. Effects of grazing, competition, disturbance and fire on species composition and diversity in grassland communities. Journal of Vegetation Science, 3(2): 187-200.

4.Mabbutt J A, 1984. A new global assessment of the status and trends of desertification. Environmental Conservation, 11(02): 103-113.

5.Suttie J M, Reynolds S G, Batello C, 2005. *Grasslands of the world.* Plant production and protection series no. 34, Rome: Food and Agriculture Organization of the United Nations (FAO).

6. Man Z M, Ge Q S, Zhang P Y, 2000. Case studies on the impact of climatic changes on the farming-pastoral transitional zone in historical period. Geographical research, 19(2): 141-147. (in Chinese)

7. Zhao H L, Zhang T H, Cui J Y et al., 2000. Effect of

Climatic Changes on Environment and Agriculture in the Past 40 Years in Interlaced Agro-pasturing Areas of North China- A Case Study in Horqin Sand Land. *Journal of desert research*, *20* (SL): 2-7. (in Chinese)

8. Lv P, Zuo X A, Zhang J, et al., 2016. Effect of Grazing Intensity on Vegetation in Sandy Grassland of in Horqin. *Journal of desert research*, *36*(1): 34-39. (in Chinese)
9. Zhao H L, Okuro T, Li Y L, et al., 2008. Effects of human activities and climate changes on plant diversity in Horqin sandy grassland, Inner Mongolia. *Acta Prataculturae Sinica*, *17*(5):1-8. (in Chinese)
10. Wulan T Y, 2002. The development agricultural of and changes of land use in Horqin in the 20th Century. Journal of natural resources, 17(2): 157-161. (in Chinese)
11. NA Y T, 2008. Research on Horqin Sand Desertification Evaluation at the Beginning of 21st Century based on 3S Technologues(D).Inner Mongolia Normal University. (in Chinese)
12. NA Y T, Wulan T Y, Qin F Y, 2010. Dynamic Monitoring of Land Desertification in Horqin Lef t Wing Rear Banner,Journal of Inner Mongolia Normal University (Natural Science Edition). 39:612-616. (in Chinese)
13. Su Y Z, Zhao H L, 2003. Influences of Grazing and Exclosure on Carbon Sequestration in Degraded Sandy Grassland, Inner Mongolia, North China. Chinese. Journal of Environmental Science, 24(4): 23-28. (in Chinese)
14. Sun D C, Li Y L, Zhao X Y et al., 2015. Effects of Grazing and Enclosure on Soil Respiration Rate in Horqin Sandy Grassland. Journal of desert research, 35 (6): 1620-1627. (in Chinese)
15. Liu X M, Guan H B, Liu Y J, 2000. Study on soil animal diversity under grazing in horqin sandy pasture, InnerMongolia. Journal of Desert Research, 20:29-32. (in Chinese)
16. Wang T, WU W, ZHAO H L et al., 2004. Analyses on Driving Factors to Sandy Desertification Process in Horqin Region, China. Journal of Desert Research. 24:519-528. (in Chinese)
17. Chang X L, Lu C X, Gao Y B, 2003. Impacts of human economic activities on wind and sand environment in Kerqin sandy land. Resources Science, 25(5): 78-83. (in Chinese)
18. Petz K, Alkemade R, Bakkenes M, et al., 2014. Mapping and modelling trade-offs and synergies between grazing intensity and ecosystem services in rangelands using global-scale datasets and models. Global Environmental Change, 29: 223-234.
19. Bagan H, Takeuchi W, Kinoshita T et al., 2010. Land cover classification and change analysis in the Horqin Sandy Land from 1975 to 2007. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 3(2): 168-177.
20. Kim J H, Cho J, Keane T D, 2015. Political fragmentation and land use changes in the Interior Plains. Population and Environment, 37(1): 63-82.
21. Sylvester K M, Gutmann M P, Brown D G, 2016. At the margins: agriculture, subsidies and the shifting fate of North America’s native grassland. Population and environment, 37(3): 362-390.
22. Lakhan G R, 2015. Population and Environment Relationship: An Empirical Review with Respect to Pakistan. Population and Environment, 6(5):117-123
23. Low B S, Heinen J T, 1993. Population, resources, and environment: implications of human behavioral ecology for conservation. Population & Environment, 15(1): 7-41.
24. Huturong A, 2010. Three hundred years Ahlu Horqin (p. 7). Hohhot: Inner Mongolia People Publisher (In Mongolia).
25. Tucker C J, 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote sensing of Environment, 8(2): 127-150.
26. Lee Rodgers J, Nicewander W A, 1988. Thirteen ways to look at the correlation coefficient. The American Statistician, 42(1): 59-66.
27. Wulan T Y, Wu D, NA Y T, 2007. The population change in Horqin in the 20th Century. Acta Geographica Sinica, 62(4): 418-426. (in Chinese)

28.Hu H Y, Zhang S Y, 1986. Population and Geography of China (p. 152, 253). Shanghai: East China Normal University Press.(in Chinese)

29.Song N G, et al. (1987). Population of China (Inner Mongolia Part) (p. 164). Beijing: China Financial & Economic Publishing House. (in Chinese)

30.Yu X, 2006. The migration of population and regional economic growth analysis in north-east after the establishment of the country. Population Journal, 157(3): 29-34. (in Chinese)

31. Zhao M, Zhen J H, 2000. Research on Problems of Population and Grain in Inner Mongolia. Human Geography, 15(5): 68-71. (in Chinese)

32.Liu T H, Wu X H, Dong Y P, 2010. Analysis on vegetation coverage of grassland desertification based on TM image. Journal of Arid Land Resources and Environment, 2(2): 141-144. (in Chinese)

33. Li J H, 2007. Research on Desertification Assessmentin Naiman Kerqin Based on Remote Sensing (p. 64). Harbin: North-East Forestry University. (in Chinese)

34.Curran SR, Sherbinin A. 2004. Completing the Picture: The Challenges of Bringing “Consumption” into the Population–Environment Equation. Population and Environment, 26, 107-131

35.John WL, Gregory JW, Liu YM. 1994. Population Constraints on the Development of Pastoral Areas in China. Rural Economy in China, 55-61. (in Chinese)

36.Bi LG, Du SF. 2016. Impact of Population Migration on Grassland Animal Husbandry and Changes in Ecological Environment. Frontier, 100-104. (in Chinese)

37.Ao RQ, Da LT. 2005. Research on sustainable development of grassland pastoral areas. Inner Mongolia University of Finance and Economics, 26-29. (in Chinese)

38.Hoshino B. 2009. A comparative study of pasture degradation of Inner Mongolian fenced and unfenced land based on remotely sensed data.

39.Hou DM. 2001. Grassland governance should clearly implement the "effective unloading population ecological pressure" of the basic principles of Science and Technology Review, 12-14.(in Chinese)

40. Zhang M J, Chun X, Liang A et al.,2012. Climate changes in Horqin Sandy Land in recent 60 years. Journal of Arid Land Resources and Environment, 26: 8-16. (in Chinese)

41.Bao H H, BAO Y, Tya W, 2008. Characteristics of Drought/Flood Spatial and Temporal Distribution in Horqin Sandy Land During the Last 300 Years. Journal of Arid Land Resources and Environment, 22:100-107. (in Chinese)

42.Dong Y X, 2001. Quantitative Identification of Driving Factors of Contemporary Sandy Desertification in Semi-arid Zone in China. Journal of desert research, 04:97-102. (in Chinese)

43.Ci L J, Liu Y P, 2000. Driving Action of Population Increase on Desertification. Journal of Arid Land Resources and Environment, 1: 28-33. (in Chinese)

44.Li J Y, 2014. Spatio-temporal Variations and its Driving Factors of the Grassland Sandy Desertification in the Horqin Sand Land Based on Remote Sensing (p. 62). Beijing: Chinese Academy of Agricultural Sciences Dissertation. (in Chinese)

45.Hao H G, Tuya W, 2011. Evaluation on Results of Grain for Green Project in Horqin Sandy Land. *Soils*, 43:818-834. (in Chinese)

46.Zhou D C, Zhao S Q, Zhu C, 2012. The Impact of the Grain for Green Project on the Land Use/Cover Change in the Northern Farming-pastoral Ecotone, China. *Scientia* Geographica Sinica, 32:442-449. (in Chinese)

Table 1 Detailed Information of Remote Sensing Data

Time	Path/Row	Band Information	Satellite/Sensor	Resolution
1977/7/4	131/30	MSS5(0.55)/MSS6(0.66)/MSS8(0.89)	Landsat2/MSS	57m
1985/9/6	121/30	TM2(0.56)/TM3(0.66)/TM4(0.83)	Landsat5/TM	30m
1992/7/7	121/30	MSS1(0.55)/MSS2(0.65)/MSS4(0.89)	Landsat5/MSS	60m
2009/6/20	121/30	TM2(0.56)/TM3(0.66)/TM4(0.83)	Landsat5/TM	30m
2014/7/4	121/30	ETM2(0.56)/ETM3(0.66)/ETM4(0.83)	Landsat8/ETM^{+}	30m

Table 2. Population density of 1947-2007 with 10-year interval

Location / Year	AKB	HRMB	HB	KC	HLBB	HLMB	NB	JB	HLGC	HD	TA
1947	6	4	14	26	10	18	18	1		47	10
1957	9	6	18	32	16	23	23	4		86	16
1967	13	8	23	52	22	32	31	8		139	23
1977	16	11	29	68	28	42	40	12	2	170	30
1987	18	13	33	77	32	49	47	14	65	205	35
1997	20	15	36	84	34	56	51	17	104	235	39
2007	21	16	38	88	35	56	54	18	130	260	42
Average	2	2	4	10	4	6	6	3	41	35	5

Note: the unit is person/km^2 .TA(Total Average)

Table 3. The slope of linear trend

Year	AKB	HRMB	HB	KC	HLB	HLM	NB	JB	HLGC	HD	TA
1947-1956	0.32	0.12	0.56	0.62	0.67	0.38	0.42	0.22		3.61	0.47
1957-1966	0.39	0.26	0.47	2.15	0.56	1.01	0.76	0.42		5.62	0.77
1967-1976	0.38	0.29	0.59	1.72	0.74	1.00	0.97	0.37		3.23	0.71
1977-1986	0.21	0.27	0.49	0.95	0.41	0.73	0.70	0.28	6.03	3.50	0.57
1987-1996	0.19	0.18	0.26	0.66	0.13	0.68	0.39	0.26	4.09	2.71	0.41
1997-2006	0.03	0.11	0.09	0.37	0.13	0.02	0.25	0.09	2.69	0.48	0.14

As it is shown in Table1, Table2, Table3, Ar Khorchin Banner(AKB), Horqin Right Middle Banner(HRMB), Hure Banner(HB), Kailu County(KC), Horqin Left Back Banner(HLBB), Horqin Left Middle Banner(HLMB), Naiman Banner(NB), Jarud Banner(JB), Ho Lin Gol City(HLGC), Horqin District(HD), and TA(Total Average).

Table 4 Population density linear trend coefficients of the study region and each county or banner from 1947-2011

Year	1947-1956		1957-1966		1967-1976		1977-1986		1987-1996		1997-2011	
Banner	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2	Slope	R^2
Arhorqin Banner	0.32	0.98*	0.39	0.97*	0.38	0.99*	0.21	0.96*	0.19	0.94*	0.03	0.63*
Horqin Right Middle	0.12	0.90*	0.26	0.95*	0.29	0.99*	0.27	0.99*	0.18	0.97*	0.11	0.84*
Hure Banner	0.56	0.56*	0.47	0.94*	0.59	0.98*	0.50	0.99*	0.26	0.96*	0.09	0.64*
Kailu Banner	0.62	0.81*	2.15	0.98*	1.72	0.99*	0.96	0.99*	0.66	0.99*	0.37	0.89*
Horqin Left Back Banner	0.67	0.96*	0.56	0.94*	0.74	0.99*	0.41	0.97*	0.13	0.86*	0.13	0.88*
Horqin Left Middle	0.38	0.80*	1.01	0.97*	1.00	0.99*	0.73	0.99*	0.68	0.98*	0.02	0.01
Naiman Banner	0.42	0.70*	0.76	0.98*	0.97	0.99*	0.70	0.99*	0.39	0.96*	0.25	0.95*
Jarud Banner	0.22	0.96*	0.42	0.96*	0.37	0.99*	0.28	0.99*	0.26	0.98*	0.09	0.87*
Ho Lin Gol							6.03	0.98*	4.09	0.96*	2.69	0.98*
Horqin district	3.61	0.95*	5.62	0.98*	3.28	0.99*	3.50	0.99*	2.71	0.98*	0.48	0.06
Total	0.47	0.98*	0.77	0.99*	0.71	0.99*	0.57	0.99*	0.41	0.99*	0.14	0.75*

*indicates significant difference at the level of（$p < 0.05$, n=10）

Table 5 Summary of population and reclamation policies implemented in Inner Mongolia during 1949-2014

Time	Policy
1949-1957	Land reclamation policy, reward reclamation, husbandry dominant while developing agriculture
1954-1960	Immigration to Inner Mongolia policy
1966-1976	Herdsmen do not rely on others for crop production; Educated youth support frontier construction
1959-1961	Producing grain in the wilderness through vigorous land reclamation and prioritizing grain crop production
1949-end of 1960s	The more people there are, the more powerful they are
1980s	Development of reserved cultivitable land resources
1981 to present	The family planning policy
2000-present	Returning cultivated land to forests and grassland
2014- present	Implementing the second-child policy for some eligible families

Table 6 Degradation and population density in typical areas

Area	Shao Gen County of Ar Khorchin Banner			Bagaborihe Sum of Naiman Banner		
Year	PD	DA	Percentage （%）	PD	DA	Percentage （%）
1977	16	42.06	8.2	40	208.64	62.8
1985	18	57.28	11.1	46	249.96	75.2
1992	19	417.64	80.9	50	291.11	87.6
2009	21	435.35	84.4	54	252.81	76.1
2014	21	363.72	70.5	55	242.34	73

PD: Population density, DA: Degradation area, Percentage（%）: Percentage of degradation areas

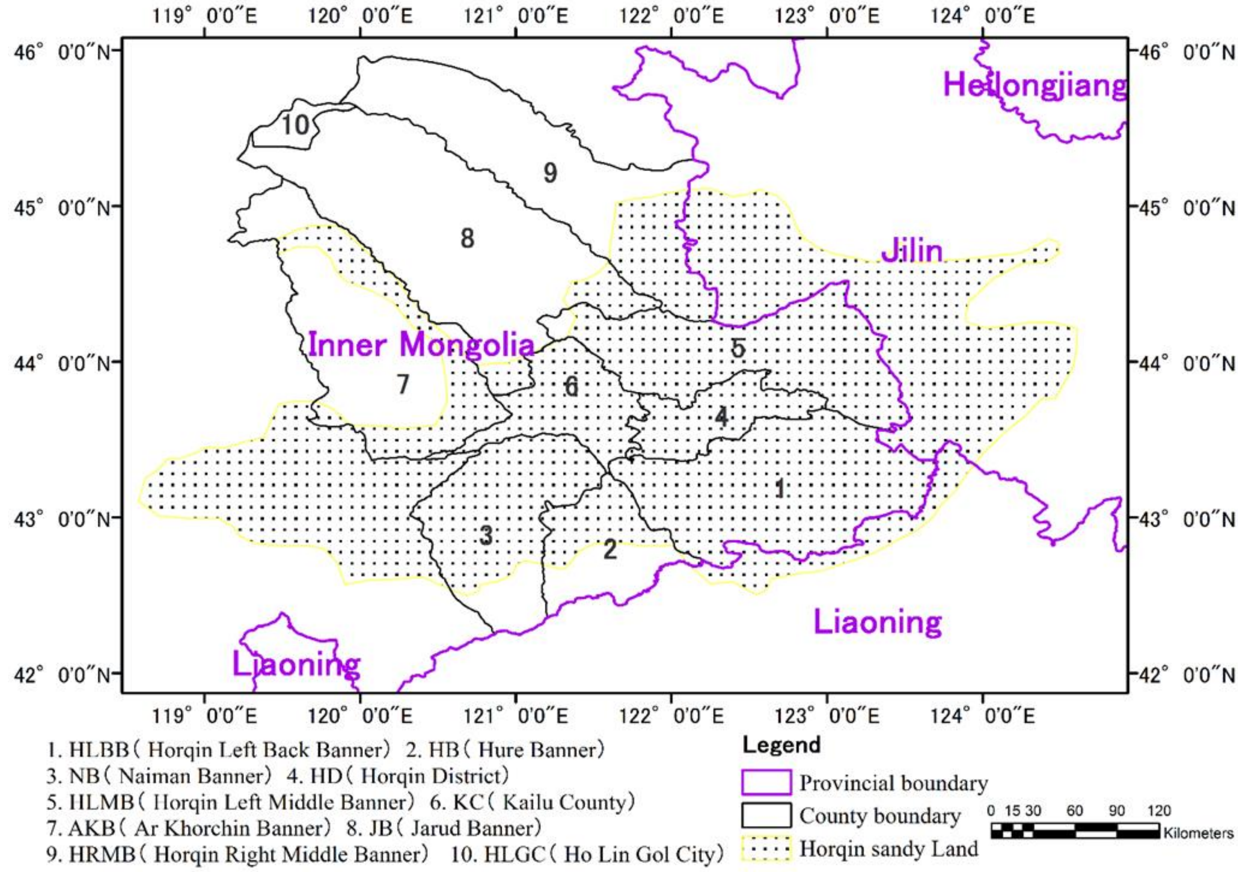

Fig.1 Location map of the study area

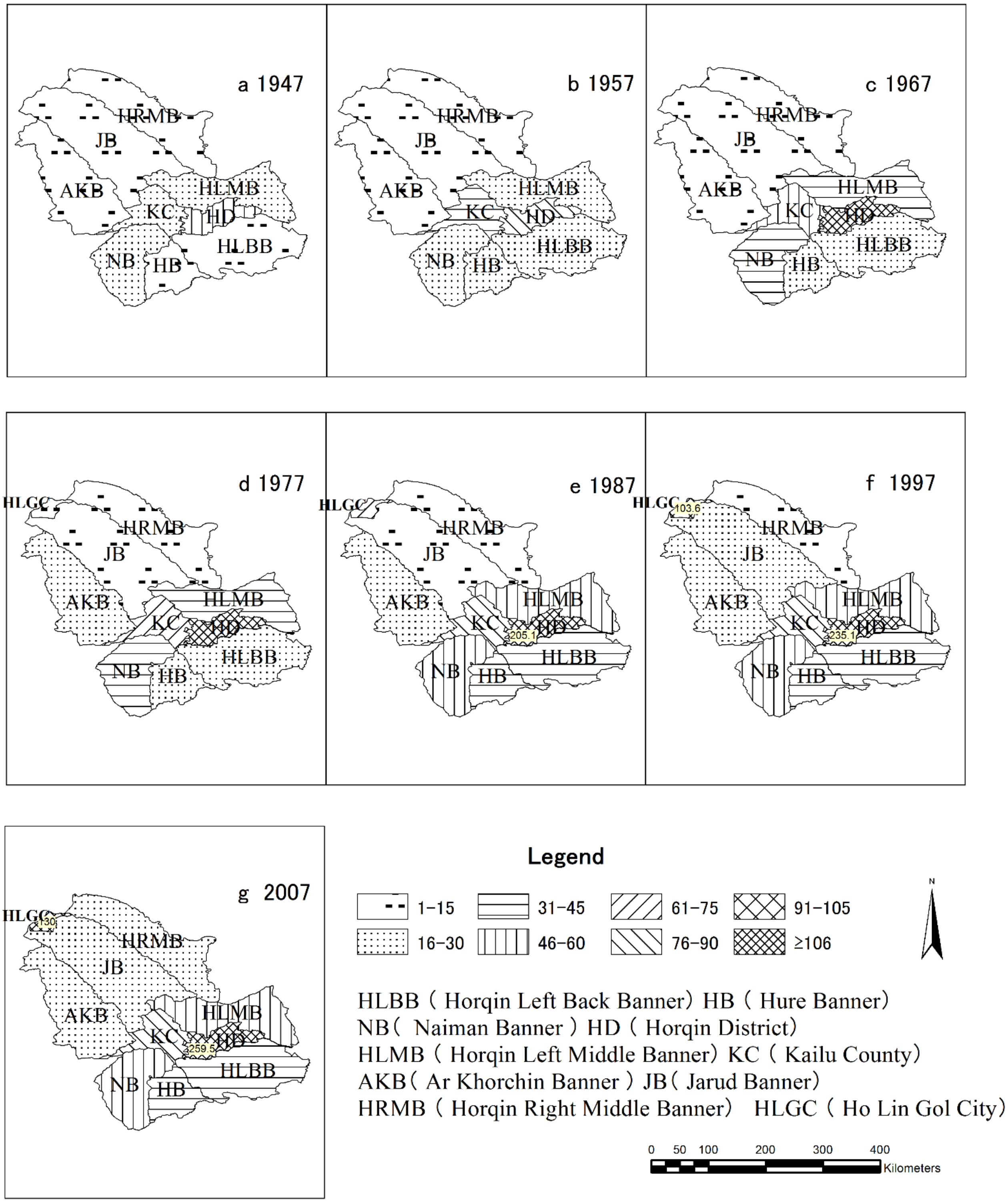

Fig. 2 **S**patial distribution of population density (persons/km^2) changes in Horqin from 1947 to 2007

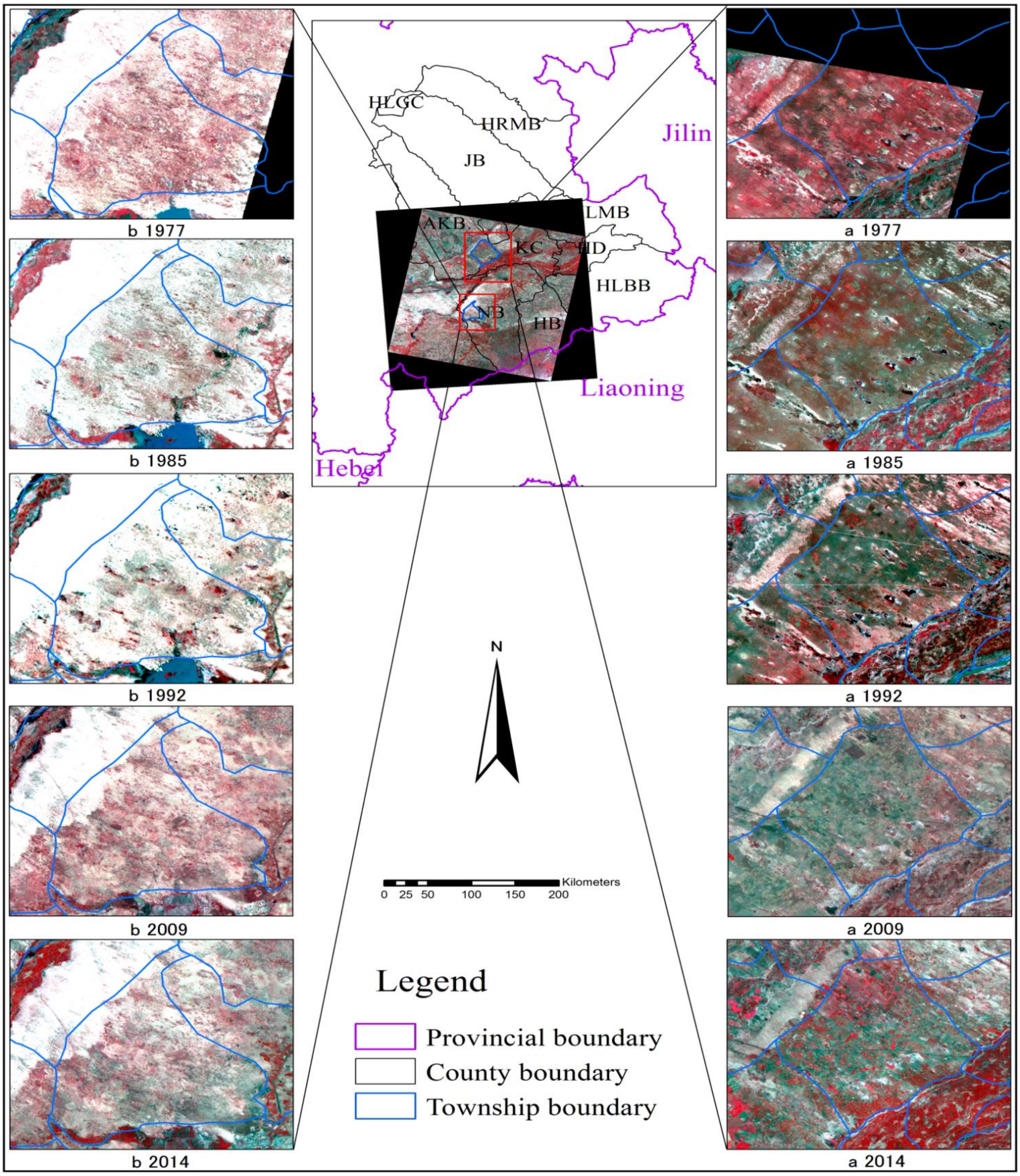

Fig. 3 Standard false-color composite satellite images of Shaogen County of Ar Khorchin Banner (a) and Bagaborihe Sum of Naiman Banner (b) in 1977, 1985, 1992, 2009 and 2014

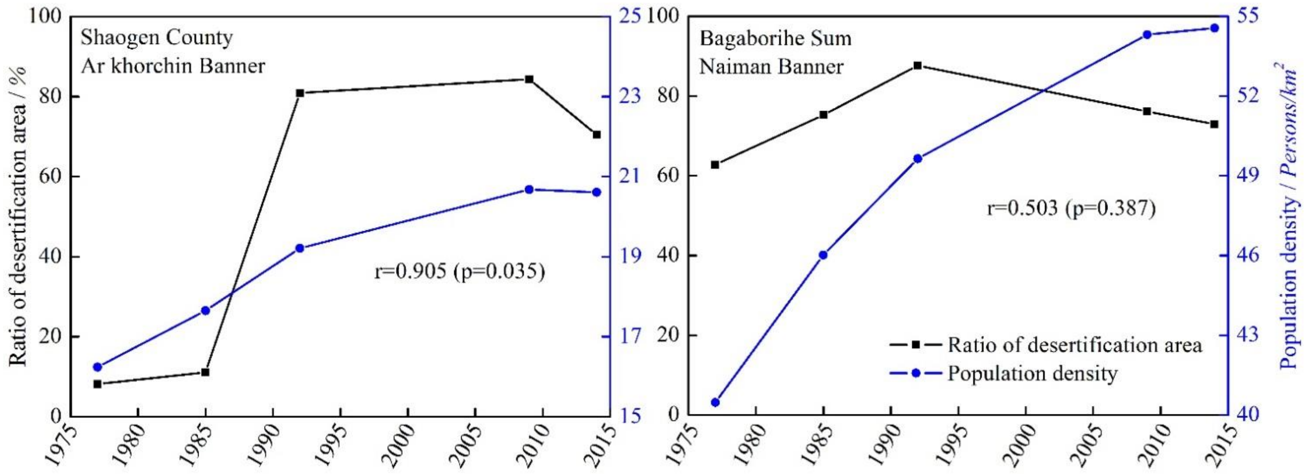

Fig. 4 Dynamic change of the population density and the percentage of degradation area in Shaogen County of Ar Khorchin Banner and Bagaborihe Sum of Naiman Banner