Relationship Between Vegetation Coverage and Rural Settlements and Anti-desertification Strategies in Horqin Left Back Banner, Inner Mongolia, China

Jian Zhou[1,2,3], Fengrong Zhang[1,2,3], Yan Xu[1,2,3](✉), Yang Gao[1,2,3], and Xiaoyu Zhao[1,2,3]

[1] College of Resources and Environmental Sciences, China Agricultural University, No. 2 Yuanmingyuan West Road, Haidian, Beijing 100193, China
jzhou2287@163.com, {frzhang,xuyancau}@cau.edu.cn, gaoyang123@gmail.com, zhaoxiaoyu1992@sina.com

[2] Key Laboratory for Agricultural Land Quality, Monitoring and Control, The Ministry of Land and Resources, Beijing 100193, China

[3] Research Center of Land Use and Management, China Agricultural University, Beijing 100193, China

Abstract. This paper investigated the relationship between vegetation coverage and rural settlements in Horqin Left Back Banner. There are 4 spatial patterns about the relationship between vegetation coverage and rural settlements, including high region-low region, high region-low region-high region, high region-low region-high region-low region, and high region. Around rural settlements, land is used as cultivated land and vegetation coverage is high. The overlap effect of overgrazing and extensive cultivation creates the first low region of vegetation coverage. With increasing distance from rural settlements, human disturbance to vegetation growth decreases, vegetation coverage increases, and the high region appears again. The second low region of vegetation coverage is caused by the overgrazing of another rural settlement. At the border region of 2 adjacent villages, 3 different conditions are presented with the vegetation coverage and rural settlements. In the first condition, vegetation coverage is low and is located at the intersection of both low regions of the 2 rural settlements. In the second condition, the vegetation coverage is high and is located at the intersection of both high regions of the 2 rural settlements. In the third condition, vegetation coverage is low and is located at the intersection of both low regions of the 2 rural settlements. According to the changing patterns and reasons for such patterns, we present strategies for anti-desertification, including banning grazing, stopping extensive cultivation, promoting optimal choice of sand-fixation plant, and clarifying land property rights.

Keywords: Vegetation coverage · NDVI · Rural settlements · Anti-desertification · Horqin Left Back Banner (HLBB)

D. Li and Z. Li (Eds.): CCTA 2015, Part I, IFIP AICT 478, pp. 125–142, 2016.
DOI: 10.1007/978-3-319-48357-3_13

1 Introduction

Desertification, defined in the Convention to Combat Desertification and Drought in 1994 as "land degradation in arid, semiarid and dry sub-humid areas resulting from various factors including climatic variability and human activities," will most likely become the greatest threat to humanity in the future because it diminishes the Earth's capacity to support human beings with the steady increase in global population [1]. Desertification is one of the most serious environmental and socioeconomic problems [2, 3]. Thus, many anti-desertification efforts have been made, including determination of the underlying mechanisms of desertification [4–7], risk assessment of desertification [8, 9], monitoring of desertification development [10–13], and investigating the effectiveness of anti-desertification projects [14–16]. China is one of the world's most desertification countries [17–19]. The desertified land in China occupies approximately 13 % of the country's total surface area and is a major source of Asian dust [20]. To address this problem, the Chinese government has launched several projects to fight desertification, such as "Three-North Shelterbelt Project" in 1978, "Grain for Green Project" in 1999, and "Beijing and Tianjin Sandstorm Source Controlling Project" in 2000. Because of these projects, the desertified land has been diminished and environment has become better in China, as well as in Horqin Sandy Land [14].

For desertification mechanism, the following is the general consensus: natural characteristics and human activities were the driving factors of desertification. However, at different locations and different periods, the main driving force of desertification is diversity. For instance, some researchers have proposed that desertification was caused by climate change in the Mu Su Sandy Land and Otindag Sandy Land and their adjacent regions, and this hypothesis was supported by archaeological evidence [21–23], whereas others have argued that human activities were the causes [24, 25]. Meanwhile, previous studies explored the effect of single or multiple factors of human activities on desertification [22, 23]. Otherwise, rural settlement is the place where all human activities occur. The patterns of vegetation coverage around rural settlements are also not clear. So, it is significant to study the relationship from the micro view of rural settlement and from the comprehensive view of taking rural settlement as the place of human activities gathering, between rural settlement and desertification. Vegetation coverage can indicate desertification risk and is an important indicator of the fixation of sand dunes and the restoration of soil fertility. So understanding the patterns of rural settlements and vegetation coverage can offer scientific support for anti-desertification efforts. The following can be determined: the critical potential desertification area, how desertification spreads in area, and what strategies can be adopted to enhance the effects of anti-desertification methods.

As mentioned above, the aims of this study are the following: (I) investigate vegetation coverage patterns (desertification risk degree) around one rural settlement and between 2 adjacent rural settlements, (II) analyze the driving forces of the difference of vegetation coverage in different regions, (III) put forward strategies to anti-desertification by increasing vegetation coverage.

2 Study Area and Study Transect

2.1 Study Area

Horqin Left Back Banner (HLBB) is a county covered 11481 km^2 in Inner Mongolia and located in northern China with a geo-location from 121°30′E–123°42′E and 42°40′N–43°42′N (Fig. 1). HLBB lies in the agro-pastoral fragile ecotone, being a part of Horqin Sandy Land which is the first sandy land in area in China. Being a typical temperate continental climate type, its average annual temperature is 5.3 °C–5.9 °C. Average annual precipitation is 415 mm and is concentrated in June to August, accounting for 70 % of average annual precipitation. The average annual rainfall reduces from east to west and from south to north. Average annual evaporation is 3.9–4.5 times the average annual rainfall. Average annual wind speed is between 3.5 m/s–4.5 m/s and high-speed windy days are concentrated in winter and spring. Generally, the average number of windy days with a speed of >5 m/s (causing sand blowing) reaches 40 in one year. The landform in HLBB includes undulating sand dune, flat sand land, dune slack, and plain. Geomorphic characteristics are connections of fixed-sand dune, semi-fixed sand dune, and moving sand dune and the alternative distribution of undulating sand land and marshy land. Sand dunes are mainly distributed in the north, south, and west of HLBB. The plain is located in the east. Aeolian sandy soil is the main soil type which takes up 68.9 % in all area of HLBB. In general, the physical features of HLBB create conditions for the formation and development of desertification.

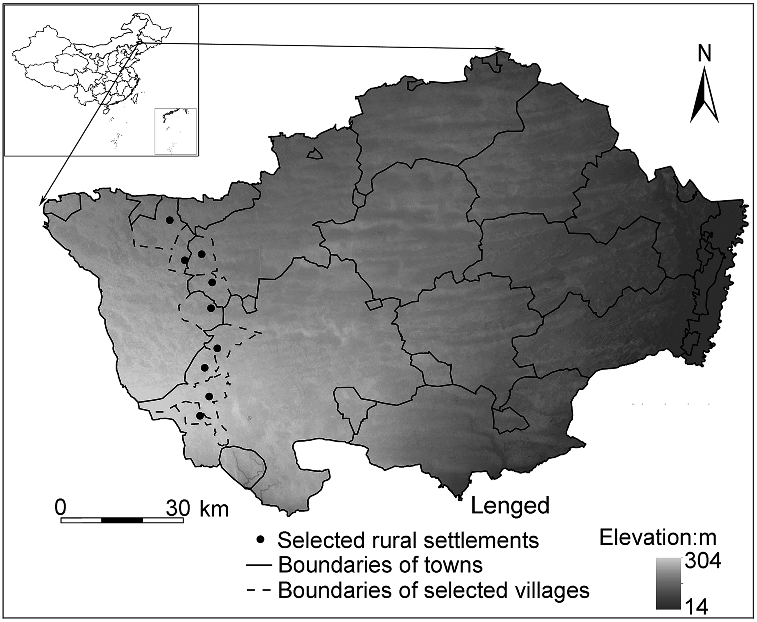


Fig. 1. The location of HLBB and the selected rural settlements

Being an agro-pastoral ecotone, the main animals raised in HLBB are sheep and cattle. Maize is the staple planting crop, and the cropping system is one harvest a year. In 2013, the population was 4.05×10^5, and population density was $35/km^2$. The numbers of sheep and cattle were 4.678×10^5 and 4.013×10^5, respectively. The maize planting area was 1.61×10^5 hm^2 accounting for 86 % in all sown area.

2.2 Study Transect

A total of 262 villages are in HLBB, and analyzing the relationship between vegetation coverage and rural settlement for each village would be difficult. Belt transect method was employed. A belt from north to south, which contains 9 villages (Fig. 1), was chosen. In the belt transect, precipitation ranges from 280 mm in the north to 360 mm in the south. The study transect is located in the sand dune distribution zone, which is vulnerable to land desertification. Elevation drops from 280 m to 40 m. Elevation of HLBB changes from 304 m to 14 m. Agriculture and animal husbandry coexist in the transect area. Cropping system is one harvest a year, and the crop is mainly maize. Thus, the study transect can represent the whole study area in natural conditions and production mode. Villages in the belt transect include Bayantala Gacha (BYTLGC), Momai Gacha (MMGC), Bianjie Gacha (BJGC), Baixingtu Gacha (BXTGC), Genggei Gacha (GGGC), Wuguan Gacha (WGGC), Wudantala Gacha (WDTLGC), Hailasitai Gacha (HLSTGC), and Xinaili Gacha (XALGC) from north to south. Gacha as an administrative unit is equal to village.

3 Materials and Methods

3.1 Materials

Vegetation grows well in August because rainfall is rich in June to August [26]. Thus, one Landsat-8 imagery, acquisition time 30-08-2014, path 120 and row 030, cloud cover 0 %, resolution 30 m, was obtained from USGS (http://glovis.usgs.gov/). Vegetation coverage was presented by calculating vegetation index. Village boundary and rural settlements were extracted from land use database for 2012 (1:10000) which was formed through land use change survey on the base of the Second Land Use Survey of China completed in 2009. In addition, we conducted twice field surveys in HLBB from 09-07-2014 to 19-07-2014 and from 08-10-2014 to 15-10-2014 to investigate the plantation, desertification, vegetation, water, and living conditions. Some questionnaires on the above mentioned aspects were created.

In this paper, NDVI was chosen as the vegetation index to reflect vegetation coverage and was calculated with the software of ENVI. Before calculating NDVI, radiometric calibration and atmospheric correction were made by ENVI. Then, geometric registration was conducted between reflectance imagery and land use map, and the registration accuracy was 0.205 pixels. The polygon layer of 9 rural settlements for 9 villages was converted into gravity center point layer to analyze the spatially changing patterns between the vegetation coverage and rural settlements with the help of geographic information system software (ArcGIS 10.0).

3.2 Methods

3.2.1 Vegetation Index

Desertification is closely related to vegetation coverage. Low level vegetation coverage indicates high risk of desertification, especially in sandy land areas. NDVI is a significant measure that reflects vegetation coverage [27, 28] and was calculated as Formula 1 [29, 30]. The higher NDVI value, the better the vegetation coverage.

$$NDVI = (RED - NIR)/(RED + NIR) \tag{1}$$

RED represents reflectance of red band and *NIR* represents reflectance of near-infrared band.

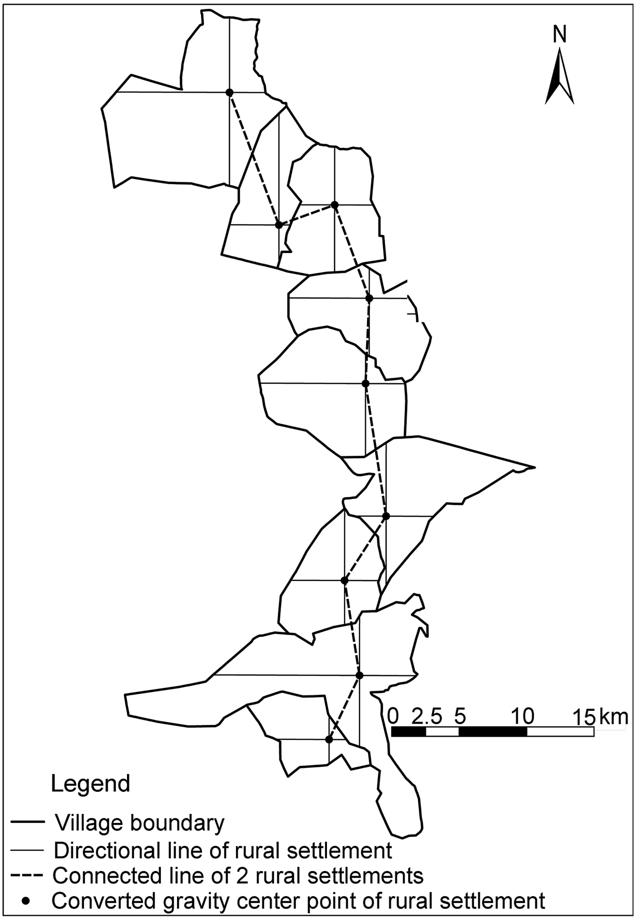


Fig. 2. Directional line of each rural settlement and connected line of 2 adjacent rural settlements

3.2.2 Vegetation Coverage Changing Patterns Around One Rural Settlement and Between 2 Adjacent Rural Settlements

To analyze vegetation coverage changing patterns around one rural settlement and between 2 adjacent rural settlements, four directional lines (east, west, south, and north) were made. These lines started from gravity center points of rural settlements and ended at village boundaries by ArcGIS 10.0. Then, buffering was made for two sides of each line, and the buffering distance was 300 m with the help of ArcGIS 10.0; 300 m is equal to the length of 10 grids. At last, starting from intersection point of the line and the boundary of rural settlement polygon to village boundary, a NDVI value was obtained by averaging NDVI values of 10 grids every 30 m. In this way, vegetation coverage changing condition was obtained in the 4 directions (Fig. 2). The vegetation coverage of 4 directions represents vegetation coverage condition around one rural settlement.

One line was made to connect 2 adjacent rural settlements, and the buffering distance for 2 sides of each line was 300 m (Fig. 2). Starting from the intersection point of connected line and the boundary of one rural settlement polygon and ending at the intersection point of connected line and the boundary of the other rural settlement polygon, the averaged NDVI was calculated every 30 m to determine vegetation coverage condition between 2 rural settlements.

4 Results and Discussions

4.1 Vegetation Coverage Changing Patterns Around One Rural Settlement

In terms of NDVI changing trend in each direction, 4 changing patterns of NDVI were obtained, as follows: high region-low region, high region-low region-high region, high region-low region-high region-low region, and high region.

Sixteen directions of 9 rural settlements had the NDVI changing pattern of high region-low region, as follows: BYTLGC-E, MMGC-S, MMGC-W, BJGC-S, BJGC-W, BXTGC-N, BXTGC-S, BXTGC-W, GGGC-N, WGGC-S, WGGC-E, WDTLGC-N, WDTLGC-E, HLSTGC-N, HLSTGC-E, and XALGC-E (Table 1). Mean NDVI values of 16 high regions changed from 0.58 to 0.81, and mean NDVI values of 16 low regions changed from 0.26 to 0.48. The maximum ratio of average NDVI value of high region to that of low region was 3.12 in XALGC-E, and the minimum ratio was 1.46 in BXTGC-N. In general, mean NDVI value of high regions was twice higher than that of low regions. Lengths of high regions varied from 330 m to 3510 m, and the average length was 1721.25 m. Lengths of low regions changed from 360 m to 3510 m. The average length was 1638.75 m (Table 5).

Eleven directions of 8 rural settlements had the NDVI changing pattern of high region-low region-high region, as follows: BYTLGC-N, BYTLGC-S, BJGC-N, BXTGC-E, GGGC-S, WGGC-W, WDTLGC-S, WDTLGC-W, HLSTGC-S, XALGC-N, and XALGC-W (Table 2). NDVI values of the first high regions varied from 0.49 to 0.86, and average NDVI value of the first high regions was 0.68. NDVI values of the second high regions changed from 0.33 to 0.93, and average NDVI value

Table 1. NDVI changing pattern of high region-low region

Village name and direction	Starting distance/m	Ending distance/m	Average NDVI
BYTLGC-E	0	1050	0.70
	1080	2250	0.41
MMGC-S	0	1830	0.73
	1860	2730	0.30
MMGC-W	0	2190	0.79
	2220	3450	0.47
BJGC-S	0	2880	0.58
	2910	4890	0.29
BJGC-W	0	750	0.70
	780	2190	0.36
BXTGC-N	0	750	0.70
	780	2100	0.48
BXTGC-S	0	330	0.68
	360	4200	0.38
BXTGC-W	0	1140	0.69
	1170	5880	0.34
GGGC-N	0	810	0.59
	840	1740	0.32
WGGC-S	0	3210	0.78
	3240	5070	0.35
WGGC-E	0	3030	0.76
	3060	3360	0.45
WDTLGC-N	0	3510	0.63
	3540	5130	0.33
WDTLGC-E	0	600	0.73
	630	2130	0.35
HLSTGC-N	0	2100	0.63
	2130	4170	0.35
HLSTGC-E	0	2760	0.79
	2790	3750	0.35
XALGC-E	0	600	0.81
	630	1200	0.26

Notes: XXX-X, XXX represents rural settlement name and X represents one direction among east, west, south and north.

of the second high regions was 0.64. NDVI values of low regions changed from 0.26 to 0.71, and average NDVI value of low regions was 0.44. The maximum, average, and minimum ratios of average NDVI value of the first high regions to that of low regions were 2.23, 1.55, and 1.11, respectively. The maximum, average, and minimum ratio of average NDVI value of the second high regions to that of low regions were 2.50, 1.45, and 1.10, respectively. Lengths of the first high regions varied from 480 m to 1590 m, and the average length was 913.64 m. Starting distances of low regions away from the

Table 2. NDVI changing pattern of high region-low region-high region

Village name and direction	Starting distance/m	Ending distance/m	Average NDVI
BYTLGC-N	0	630	0.59
	660	3510	0.40
	3540	5400	0.60
BYTLGC-S	0	870	0.49
	900	4290	0.30
	4320	6600	0.33
BJGC-N	0	1380	0.54
	1410	3630	0.27
	3660	4080	0.47
BXTGC-E	0	480	0.66
	510	3270	0.36
	3300	3390	0.47
GGGC-S	0	990	0.83
	1020	2940	0.42
	2970	5070	0.57
WGGC-W	0	690	0.79
	720	1860	0.71
	1890	2190	0.93
WDTLGC-S	0	1590	0.86
	1620	2670	0.58
	2700	2970	0.84
WDTLGC-W	0	600	0.67
	630	2580	0.55
	2610	3600	0.74
HLSTGC-S	0	1170	0.66
	1200	4350	0.36
	4380	5040	0.56
XALGC-N	0	750	0.78
	780	1110	0.62
	1140	1440	0.86
XALGC-W	0	900	0.58
	930	3270	0.26
	3300	3780	0.65

boundary of rural settlement varied from 510 m to 1620 m. The average starting distance away from the boundary of rural settlement was 943.64 m. Ending distances of low regions away from the boundary of rural settlement ranged from 1110 m to 4350 m. The average distance away from the boundary of rural settlement was 3043.64 m. The average length of low regions was 2100 m. Starting distances of the second high regions away from the boundary of rural settlement varied from 1140 to 6490 m. The average length of the second high regions was 886.36 m (Table 5).

Table 3. NDVI changing pattern of high region-low region-high region-low region

Village name and direction	Starting distance/m	Ending distance/m	Average NDVI
BYTLGC-W	0	330	0.54
	360	3480	0.38
	3510	4800	0.74
	4830	7920	0.42
MMGC-N	0	510	0.74
	540	3990	0.43
	4020	4500	0.73
	4530	8100	0.35
BJGC-E	0	870	0.59
	900	1980	0.30
	2010	2430	0.70
	2460	2700	0.32
WGGC-N	0	870	0.68
	900	2880	0.36
	2910	4620	0.71
	4650	5340	0.45
HLSTGC-W	0	660	0.69
	690	2490	0.36
	2520	6870	0.65
	6900	10410	0.27

Five directions of 5 rural settlements had the NDVI changing pattern of high region-low region-high region-low region, including BYTLGC-W, MMGC-N, BJGC-E, WGGC-N, and HLSTGC-W (Table 3). NDVI ranges of the first high regions, the first low regions, the second high regions, and the second low regions were 0.54 to 0.74, 0.30 to 0.43, 0.65 to 0.74, and 0.27 to 0.45, respectively. The average NDVI values of the first high regions, the first low regions, the second high regions, and the second low regions were 0.65, 0.37, 0.71, and 0.36, respectively. Average length of the first high regions was 648 m. The average starting distance and average ending distance away from the boundary of rural settlement of the first low regions were 678 and 2964 m. The average length of the first low regions was 2286 m. The average starting distance and average ending distance away from the boundary of rural settlement of the second high regions were 2994 and 4644 m. The average length of the second high

Table 4. NDVI changing pattern of high region

Village name and direction	Starting distance/m	Ending distance/m	Average NDVI
MMGC-E	0	660	0.68
GGGC-E	0	2580	0.85
XALGC-S	0	1440	0.90

regions was 1650 m. The average starting distance away from the boundary of rural settlement of the second low regions was 4674 m and the average length of the second low regions was 2220 m (Table 5).

Another NDVI changing pattern for 3 directions of 3 rural settlements was high region, including MMGC-E, GGGC-E, and XALGC-S (Table 4). Average NDVI values of 3 directions were 0.68, 0.85, and 0.90 respectively. Lengths of 3 directions were 660, 2580, and 1440 m.

Generally, the location selection of rural settlement give preference to the place that is rich in water and is fertile in soil resource. So, around one rural settlement, land is exploited into cultivated land and used for food supply and economic income. Furthermore, according to our field research, to keep the sustainable use of the relatively

Table 5. NDVI value and distance of each region

Changing pattern	Region	NDVI			Average distance/m		Length/m
		Max	Min	Average	Starting	Ending	
High region-low region	High region	0.81	0.58	0.71	0	1721.25	1721.25
	Low region	0.48	0.26	0.36	1751.25	3390.00	1638.75
High region-low region-high region	The first high region	0.86	0.49	0.68	0	913.64	913.64
	Low region	0.71	0.26	0.44	943.64	3043.64	2100.00
	The second high region	0.93	0.33	0.64	3073.64	3960.00	886.36
High region-low region-high region-low region	The firs high region	0.74	0.54	0.65	0	648.00	648.00
	The first low region	0.43	0.30	0.37	678.00	2964.00	2286.00
	The second high region	0.74	0.65	0.71	2994.00	4644.00	1650.00
	The second low region	0.45	0.27	0.36	4674.00	6894.00	2220.00
High region	High region	0.90	0.68	0.81	0	1560.00	1560.00

fertile cultivated land, farmers take conservation tillage (for example, crop straw stubble and no-tillage) to fertilize soil and reduce soil wind erosion under windy and less rainfall circumstance. Crops planted in the cultivated land around rural settlements grow well, and NDVI value is high. HLBB is a coexistence zone of farming and grazing and is a vast territory with sparse population. This zone had a population density of 35/km^2 in 2013. Outside cultivated land around rural settlements, the main land use type is grassland. Compared to the limited population, the area of grassland is vast. In case of drought years, the farmers adopt extensive cultivation to get grain. In this way, many grasslands are exploited and planted. However, the exploited land is abandoned in the next few years due to quick decrease in soil fertility after land use. According to the report of grassland resource survey in HLBB, all grassland may be exploited, planted, and abandoned within 8 years. This land use mode destroys land vegetation, and land becomes vulnerable to desertification. At the same time, grazing economy is a significant part of the family income for farmers, which can contribute >50 % of the total family income. Although banning grazing is conducted during 1 May to 1 June every year in HLBB, overgrazing still exists during other times in this zone according to our surveys. Overgrazing and extensive cultivation is devastating to the growth of vegetation. Thus, the NDVI changing pattern of high region-low region is formed, and the low region of NDVI is vulnerable to desertification.

On the basis of NDVI changing pattern of high region-low region, NDVI value increased with increasing distance from rural settlements, thereby indicating that vegetation coverage is improving. Average distance from the starting point of the second high region of high region-low region-high region to the boundary of rural settlement was 3073.64 m. According to our field survey, grazing distance is also about 3000 m. Furthermore, with increasing distance from rural settlement, farmers will not attempt cultivation. Thus, cultivation declines until no cultivation occurs. This finding demonstrated that vegetation coverage can improve in a manner similar to the vegetation coverage of cultivated land around rural settlements if vegetation could grow without disturbance from overgrazing and extensive cultivation in HLBB. The NDVI changing pattern of high region-low region-high region is formed. Relevant literatures and data showed that water consumption of grass is less than 300 mm, and some shrubs consume less than or about 300 mm of water; for example, *Haloxylon ammodendron* and *Caragana microphylla* [31, 32]. The average annual rainfall of HLBB was 328.5 mm during the vegetation growth period. Natural rainfall satisfies the water demands of grass and some shrubs in a large portion of HLBB. Thus, grass and shrub plants rather than trees should be chosen, and overgrazing and extensive cultivation should be forbidden in anti-desertification strategies in HLBB. Thus, shrub and grass can grow well, and vegetation coverage can be high.

Another changing pattern of NDVI was high region-low region-high region-low region. The average distance from starting point of the second low region to the boundary of rural settlement was 4674 m, which was the farthest away from rural settlement and was near the other rural settlement. This changing pattern can be explained in the section on "vegetation coverage between rural settlements."

For MMGC-E, GGGC-E, and XALGC-S, NDVI changing patterns were high region only. Lengths of high regions were 660 and 1440 m for MMGC-E and XALGC-S, respectively. Lengths of the 2 high regions are short relatively, and land is used for cultivation. For GGGC-E, a river passes through from west to east. Water resource is relatively rich, and land is used for cultivation. So, NDVI values are high in the 3 directions. As to GGGC-W, several small scale rural settlements exist along the river, which can affect land use. Thus, no obvious change in trend of NDVI was observed (Fig. 3).

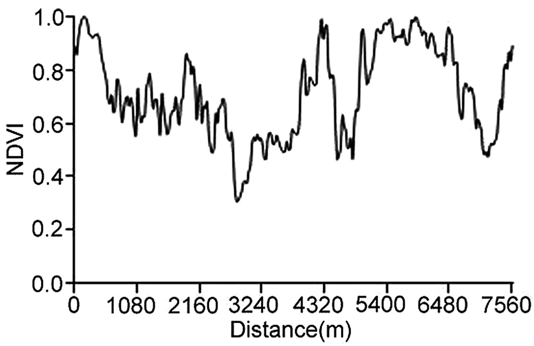
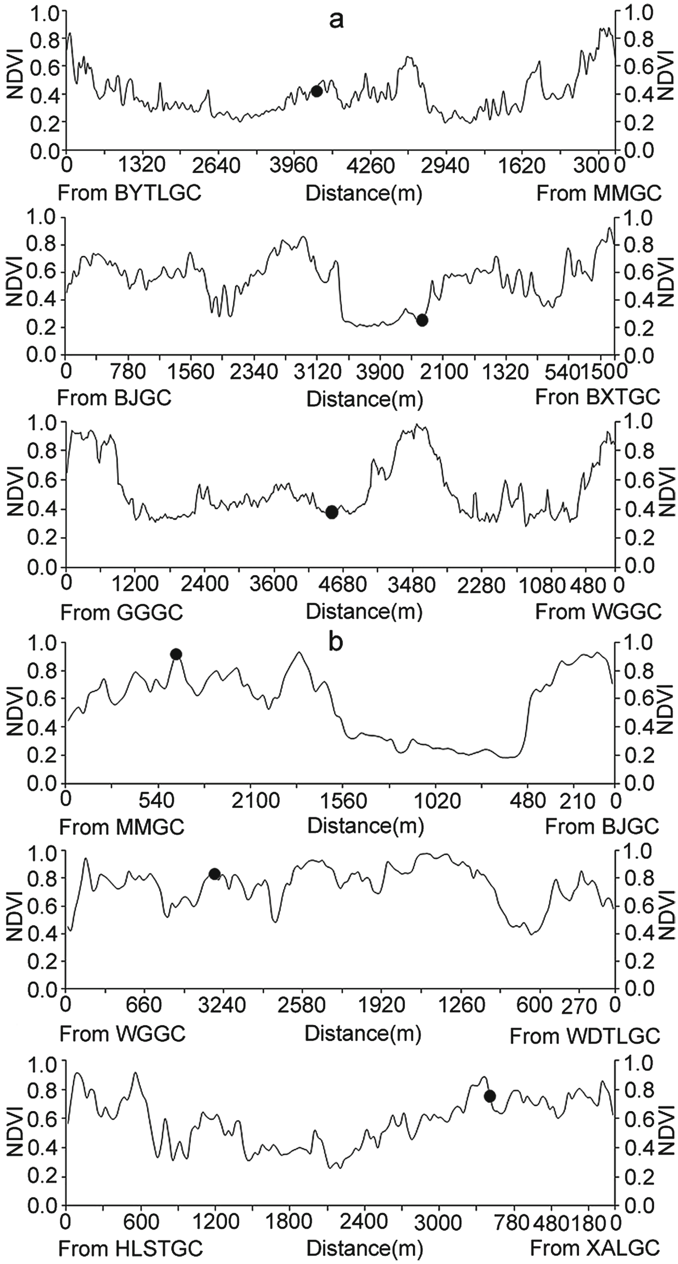


Fig. 3. NDVI changing condition of GGGC-W

In all, a high region of NDVI existed near rural settlements, in which land does not easily undergo desertification. Desertification does not occur easily because land near rural settlements is used for cultivation and is tilled year after year. Outside of cultivated land near rural settlement was a low region of NDVI that comprises mainly grassland. Because overgrazing and extensive cultivation, both of which destroy vegetation growth, coexist in this region, vegetation coverage is poor, and the land is vulnerable to desertification. With increasing distance from rural settlement, a high region of NDVI appears which indicates that vegetation coverage is improving. This phenomenon is mainly due to the decline of effect of human disturbance on vegetation growth, and rainfall can meet the water demand of shrubs and grass. If human disturbance to vegetation growth can be stopped, restoration of vegetation can succeed. As to the second low region of high region-low region-high region-low region, an explanation is given in the section on “vegetation coverage between rural settlements.”

4.2 Vegetation Coverage Between Rural Settlements

For vegetation coverage at the border region of 2 adjacent villages, 3 conditions for 8 connected lines existed according to NDVI changing trend along each connected line. First, vegetation coverage at junction area of 2 adjacent villages was at the intersection of low region of one rural settlement and low region of the other rural settlement, including: BYTLGC-MMGC, BJGC-BXTGC, and GGGC-WGGC (Fig. 4a). Second, vegetation coverage at junction area of 2 adjacent villages was at the intersection of high region of one rural settlement and high region of the other rural settlement, including MMGC-BJGC, WGGC-WDTLGC, and HLSTGC-XALGC (Fig. 4b). Third,



Note: Dot in the curve means the juncture of village boundary and connected line of 2 adjacent rural settlements; a represents the first condition and b represnts the second conditon.

Fig. 4. NDVI changing trend between 2 adjacent rural settlements for the first condition and the second condition

vegetation coverage at junction area of 2 adjacent villages was at the intersection of low region of one rural settlement and low region of the other rural settlement, including BXTGC-GGGC and WDTLGC-HLSTGC (Fig. 5). The difference between the first and third conditions was the NDVI changing pattern of rural settlement.

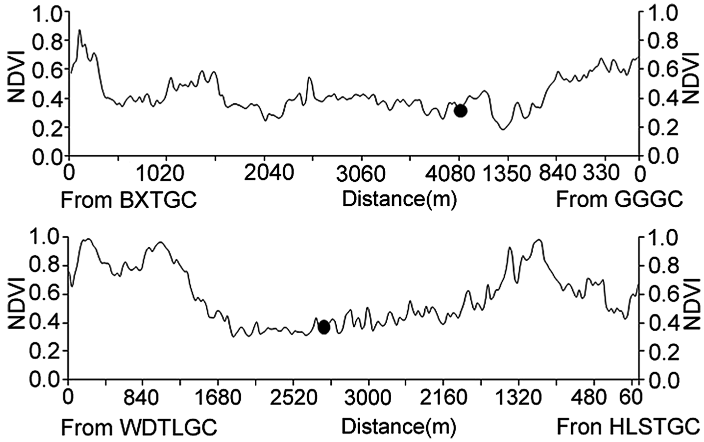


Fig. 5. NDVI changing trend between 2 adjacent rural settlements for the third condition

In the first condition, NDVI changing pattern of one rural settlement was high region-low region, and NDVI changing pattern of the other rural settlement was high region-low region-high region-low region. For the rural settlements with NDVI changing pattern of high region-low region-high region-low region, the second low region does not result from the extensive cultivation and overgrazing itself, but rather from the overgrazing of the other rural settlement. This phenomenon can be demonstrated by distances from the juncture of village boundary and connected line of 2 adjacent rural settlements to 2 rural settlements. The distance from the juncture to BYTL, which had the NDVI changing pattern of high region-low region, was 4350 m. Distance from the juncture to MMGC, which had the NDVI changing pattern of high region-low region-high region-low region, was 5160 m. The distance from the juncture to BXTGC, which had the NDVI changing pattern of high region-low region, was 2340 m. The distance from the juncture to BJGC, which had NDVI changing pattern of high region-low region-high region-low region, was 4410 m. The distance from the juncture to GGGC, which had the NDVI changing pattern of high region-low region, was 4590 m. The distance from the juncture to MMGC, which had NDVI changing pattern of high region-low region-high region-low region, was 4890 m. Human disturbance from rural settlements with the NDVI changing pattern of high region-low region is the reason for the formation of the second low region of high region-low region-high region-low region. According to our field surveys, junction area is closer to the rural settlements, which have NDVI changing pattern of high region-low region. Overgrazing at the second low region mainly comes from the closer rural settlements. At the same time, overgrazing from the farther rural settlements is vanished.

In the second condition, vegetation coverage at junction area of 2 villages was at the intersection of high region of one rural settlement and high region of the other rural settlement. One rural settlement had the NDVI changing pattern of high region-low region-high region, whereas the other had the pattern of high region. Distance from the juncture to MMGC, WGGC, and XALGC, which had NDVI changing pattern of high region, were 630, 1230, and 960 m. Distances from the juncture to BJGC, WDTLGC, and HLSTGC, which had NDVI changing pattern of high region-low region-high region, were 2520, 3300, and 3390 m, respectively. Because distance from the juncture to rural settlements with NDVI changing pattern of high region-low region-high region is farther, human disturbances to the junction zone decreases. At the same time, distance from the juncture to rural settlements with NDVI changing pattern of high region is nearer, and land is used for cultivation. Thus, the vegetation coverage at the junction area improves.

In the third condition, vegetation coverage at junction area of 2 villages was at the intersection of low region of one rural settlement and low region of the other rural settlement. Both rural settlements had the NDVI changing pattern of high region-low region. NDVI at the junction area is much smaller than that of the high region. These results are due to the overgrazing and extensive cultivation from 2 rural settlements. Land in the junction area is more vulnerable to desertification.

5 Conclusions

Four NDVI changing patterns existed around rural settlements, as follows: high region-low region, high region-low region-high region, high region-low region-high region-low region, and high region. Due to natural conditions, for example water and soil, land is used as cultivated land around rural settlements, and vegetation coverage improves. Outside of high region around rural settlements is a low region of NDVI because of the overlapping effects of overgrazing and extensive cultivation; thus, the area is vulnerable to desertification. With the increase of distance far away from rural settlements, human disturbance decreases, vegetation coverage improves, and the high region of NDVI appears again. For the second low region of NDVI of high region-low region-high region-low region, it comes from the overgrazing of another rural settlement.

There were 3 conditions of vegetation coverage at the border region of 2 adjacent villages. First, vegetation coverage at junction area of 2 adjacent villages was at the intersection of low region of one rural settlement and low region of the other rural settlement. One rural settlement had NDVI changing pattern of high region-low region, and the other rural settlement had NDVI changing pattern of high region-low region-high region-low region. The second low region of high region-low region-high region-low region for one rural settlement results from the other rural settlement's overgrazing. Second, vegetation coverage at junction area of 2 adjacent villages was at the intersection of high region of one rural settlement and high region of another rural settlement. One rural settlement had NDVI changing pattern of high region-low region-high region and the other rural settlement had NDVI changing pattern of high region. Third, vegetation coverage at junction area of 2 adjacent villages was at the intersection of low region of one rural settlement and low region of the other rural settlement. Both rural settlements had NDVI changing pattern of high region-low region. The overlap effect of overgrazing and extensive cultivation from 2 rural settlements makes the NDVI at junction area much smaller.

6 Strategies for Anti-desertification

Vegetation coverage condition is closely related to land desertification. Outskirt of cultivated land around rural settlements is the emphasis area of anti-desertification because the vegetation coverage is poor and overgrazing and extensive cultivation are severe in this area. Banning grazing and stopping extensive cultivation should be done to protect vegetation growth and to further promote anti-desertification.

At the same time, far away from rural settlements, another high region of NDVI appears again, indicating that vegetation can grow well in the study area when no human disturbance affects vegetation growth. Integrating with the natural condition of the study area, grasses and shrubs rather than trees should be chosen for anti-desertification. Thus, vegetation can show improved growth, and anti-desertification efforts can succeed further.

The formation of the second low region of NDVI for high region-low region-high region-low region comes from overgrazing of another rural settlement. NDVI value at junction area of 2 adjacent villages, which had the NDVI changing pattern of high region-low region, is much lower. Unclear grassland poverty makes the misuse land resource at the junction area. So, clarification of land property right can affect the rational use of grassland and can help in anti-desertification.

Differences exist among rural settlements in terms of population and number of livestock. Length is different for the same region in the different NDVI changing patterns. So, the determination of emphasis zone range for anti-desertification should be combined with the specific situation of rural settlements.

Acknowledgment. We would like to recognize the National Science Foundation of China (grant 4127111) and the Special Scientific Research of the Ministry of Land and Resource (grant 201411009) for the support of related data and yield survey. We are grateful to the Inner Mongolia Land Surveying and Planning Institute and Inner Mongolia Land Consolidation Institute for support.

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