

A Monitoring Method of Desertification in Naiman, Inner Mongolia, China

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Abstract

Naiman Qi is located in the east edge of Horqin desert and recently affected by desertification. The desertification has progressed by overgrazing and overcutting and fixed sand dunes began to move again in this area. In this study, we intended to develop a monitoring method of desertification using Landsat data in order to understand how the desertification has progressed. We could define the desertified area using land use classification and following three indexes; vegetation $[(TM4-TM3) / (TM4+TM3)]$, structure $[(TM5-TM1) / (TM5+TM1)]$, and redness $[(TM3-TM1) / (TM3+TM1)]$. And we obtained yearly changes by superimposing desertified areas identified from data of different year.

1. Introduction

The term "desertification" in its technical sense has a broader meaning than simply describing the phenomenon occurring in peripheral areas of deserts. Therefore, "desertification" has been redefined in Agenda 21 as "land degradation in arid, semi-arid and dry subhumid areas resulting from various factors, including climatic variations and human activities". The term "desertification" is clearly used now to refer not only surrounding deserts, but also major food producing areas into semi-arid and subhumid areas.

Even in East Asia, where there is little arid area, we can see that the new definition brings this problem closer to home. In particular, in Eastern China, which contains 50% of the land and over 90% of the population of that country, climatic conditions are changing from the semi-arid regions in the north to the subtropical, subhumid areas in the south. Zhu et al.¹⁾ estimated that

desertification in China was induced by water and wind erosion, affecting 1.483 million km², about 15% of the land area of China.

The purpose of this study is to develop a monitoring method of desertification using Landsat data in order to understand how desertification has progressed.

2. Some characteristics of desertification in Naiman

Naiman is located about 400km NE of Beijing (Fig.1).

This semi-arid region has an annual average rainfall of 372mm and annual average temperature of 6.4°C.

Lacustrine sediments in the Quaternary are the main surface layer deposits in this region, and widely distributed sand dunes, formed in an earlier dry period, have fixed and become covered by soil and vegetation with humidifying of climate. On fixed sand dunes and in the lowlands between dunes, field crops are grown, especially corn and sorghum. In addition, the grasslands in northeastern Naiman have been extensively developed.

Desertification has been caused by the destruction of natural vegetation and about 1-2 m of topsoil, and begins with the movement of unconsolidated sand. In this region, a strong wind of 5m/s (18km/h) often blows the sand in the spring. Landsat images have shown wave-like patterns on the ground surface facing the dominant wind direction, with widely-distributed sand dunes extending from west to east. The movement of sand is inversely related to particle size, i.e., the smaller the sand particle the greater the movement, and annual dune movement of 5 m/yr has been observed. Furthermore, in the grassland we can confirm points where the sand has been expanding in elliptical patterns around ponds. At present, measures have been put into effect to stop the movement of sand, and there are places in peripheral areas where vegetation has invaded.



Fig.1 The study area

3. Extracting methods by land use classification

When we extract desertified areas using Landsat Data, the most precise method is to define the desertified areas and land use types based on existing maps and field survey.

So, we examined land use classification in a test area of Naiman using land use units of the desertification map of Naiman Qi. Those units contain active dune, grassland, cropland, forest, wetland, village and water body.

First, in the test area we established about five typical points of each unit where have not changed since the map published. Second, we checked reflectances of the every points using Landsat data observed on different five times from May to September in 1992. Figure 2 shows a example of the result. Some characteristics are summarized as follows. Active dune has the highest reflectance as compared with other units through bands and times. In contrast, water body has the lowest one on both 4th and 5th bands, which belong to near infrared region, through bands and times. And so, active dune and water body are easily distinguished from other units using only one datum by above reasons. In the case of other units we could divide those units using two data of late May and late July. Because cropland and grassland have poor vegetation and forest area is already covered with green leaves in late May. And cropland has higher density of vegetation than

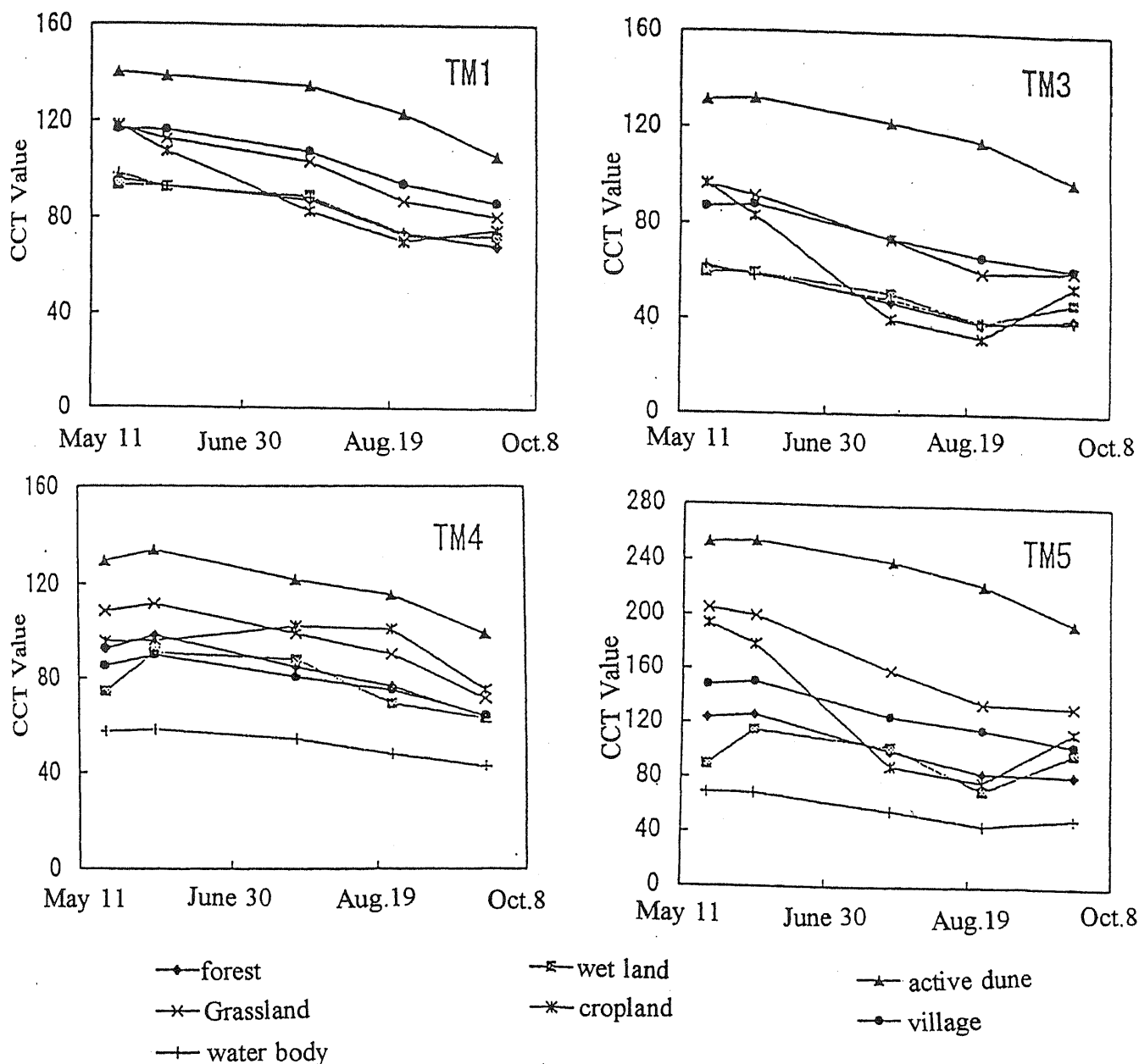


Fig.2 Seasonal changes in spectral reflectance of each land cover/land use type

grassland in late July. These phenomena show difficulty to divide into cropland, forest and grass land by only one image. However we could solve this problem by using different two images which observed on spring and summer. Because in late May cropland and grass land are almost bare before seeding and trees are covered in fresh green, in late July and August cropland and grass land are covered in green and cropland has a higher density than grass land. This changes reflect a value of red band which is 3rd band in TM and has high reflectance against the photosynthetic pigment chlorophyll.

In this study, we used five bands data of Landsat TM for classifying land use as shown below; 3rd band of May 20th and 1st, 3rd, 4th and 5th bands of July 23rd. We took the places where we checked the reflection of each land use type for training areas and classified those types with supervised classification. And we had a high probability in the classification (Table 1). Each unit

was discriminated from the other units with more than 80 % of probability. Especially, cropland and grassland were discriminated with 95% of probability. As mentioned above, we confirmed this method was useful for land use classification. If we can annually classify the land use in the same area and compare the results, we will be able to get desertification trends as well as reclamation and abundant of cropland and clearing and plantation of trees.

Table 1 Verification of land cover/land use classification with maximum likelihood method

	active dune	grassland	cropland	forest	Wetland	village	Water body
active dune	96.87	1.25	0.00	0.00	0.00	0.00	0.00
grassland	0.29	94.71	0.29	1.14	0.86	1.29	0.00
cropland	0.00	2.82	94.86	0.91	0.00	0.00	0.00
forest	0.00	4.51	0.00	80.56	12.85	1.04	0.00
wetland	0.00	2.50	0.00	6.75	81.25	2.50	5.75
village	0.00	0.54	0.18	2.06	8.04	86.03	0.00
water body	0.00	0.00	0.00	0.61	2.74	0.00	95.43

4. An extracting method by land cover changes

The classification method of land use is effective in monitoring desertification, but there is no guarantee that Landsat data are provided for it every year. So, we examined a method to define the desertified area by only one image and proposed following three indexes.

First, a vegetation index was used to identify unvegetated regions.

For LANDSAT TM data $(TM4-TM3) / (TM4+TM3)$

For LANDSAT MSS data $(MSS7-MSS5) / (MSS7+MSS5)$

Low values of this index represented unvegetated areas. Comparisons were made with composite images to derive the threshold, then unvegetated areas were identified. And, to consider seasonal fluctuations in vegetation, we used autumn and spring data and common areas were identified.

Second, water bodies and man-made structures such as settlements, which were included in the unvegetated regions, had to be removed. For that purpose, the ratio $(TM5-TM1) / (TM5+TM1)$ was obtained. Since bare land in this band ratio was higher than water bodies and man-made structures, it was possible to separate the two. Therefore, the index derived from this ratio was named the structure index. Since there was no MSS sensor corresponding to TM 5, old data were masked by water bodies and man-made structures derived from the new images. Third, using the redness index $(TM3-TM1) / (TM3+TM1)$ which reflects the amount of oxidized iron contained in the ground, desert areas were identified by the ground color in each region. Finally, desertified areas identified from data of different year were superimposed to obtain yearly changes.

Next, we verified a application of this method in a test area, a 30 km square area was selected as the test area, and was analyzed for desertification patterns in the last 10 years. Desertifying regions have low vegetation indexes. White colored areas showing the soil colors of this areas were identified, the results from analysis of old and new images were superimposed to clarify the changes(Fig.3).

The spatial proportions of the test area undergoing desertification were roughly 40%. And the area of reclaimed land and the area of newly desertifying land were roughly 12% in the districts. This fact indicated that the spatial extent of desertification is almost constant in the last 10 years.

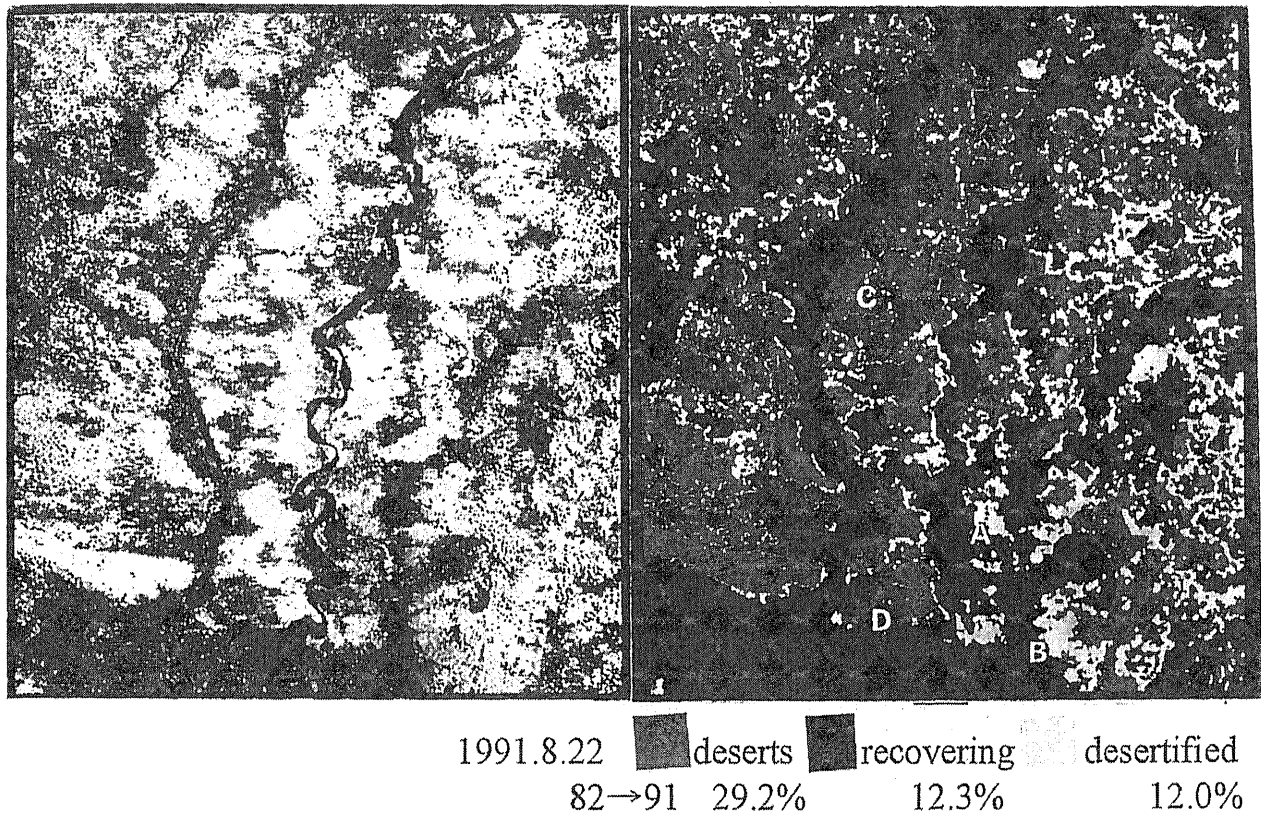


Fig.3 Composite photo of Landsat TM(left) and recent trend of desertification in Naiman, Inner Mongolian Autonomous Region

Especially the areas around the settlements and around the N-S running road and railway in the eastern part of the town showed some recovery from 1982-91, in contrast to outlying areas, where desertification continued. These facts show that desertification does not proceed unilaterally regardless of the state of degradation; rather, thanks to some sort of measures implemented when relatively easy to do so, the progress of desertification could be restrained.

Furthermore, we verified the results of the analysis by ground truth. Here, we introduce following three sites.

"A" point ($42^{\circ} 49' 56''\text{N}$, $120^{\circ} 45' 15''\text{E}$), situated on about 10km of fixed sand dunes in eastern Naiman (A in Fig.3), is an area which Landsat data analysis showed to be desertifying from 1982-1991. According to a desertification map compiled by the Chinese Academy of Science, cropland that had been cultivated by the dry farming method was classified as abandoned farmland in 1958 and as shrubland in 1974, and shrublands of willow were seen in the area. There was no trace of cultivation on the forest floor, just a scant covering of grass, and sand dunes had begun to encroach on some parts of the area. This condition corresponded well with the results of the image processing.

"B" point ($42^{\circ} 49' 8''\text{N}$, $120^{\circ} 47' 33''\text{E}$) located about 8km SSE of "A" point (Fig.3), was also judged to have been desertifying from 1982-91. According to the desertification map, this area was classified as grassland in both 1958 and 1974, but a comparison of the two years shows a vast reduction in spatial extent and a transformation into semi-solid sand dunes. A field study revealed scant traces of cultivation in depressions, but the ground was nearly covered by sand, and the sand dunes had begun to move again.

"C" Point(42° 51' 2"N, 120° 42' 11"E) differs from the two previous sites in that it was determined to be land that was reclaimed from the desert in 1982-91. This is an area of sand dunes about 5km east of Naiman (Fig.3). The desertification map showed the surrounding area to be one of moving and semi-moving sand in 1958; by 1974, the central area had become a moving sand area, with the surrounding area consisting of solidified sand dunes. In the composite Landsat images from 1991, this area clearly differs from the white color of the moving sand dunes, leading us to assume that vegetation in the area has recovered. Moreover, the topography of the area consists of small patches of undulating moving dunes (maximum size 7-8m), but most of the ground surface has vegetation cover such as grasses of the *Artemisia* family and young willows and other scrub. The sand dunes have also been observed to be solidifying. This is the result of a prohibition on grazing enacted about 5 years previous. In addition to naturally recovering grasses, poplar groves have also been planted in part of the area.

5. Concluding remarks

Desertification in Naiman was characterized by reactivating of fixed sand dunes. In this study, we proposed a monitoring method of desertification using Landsat data in order to understand how desertification has progressed.

At first, we developed a monitoring method of land use change by supervised classification. This method needs data of two different times in the same year, but shows how land use changed in each pixel. We did no more than show the high possibility of application in this study. In near future, we want to show a result using this methods, if we will be able to get the data of different years in this area. Second, we investigated a monitoring method of land cover changes by following three indexes; natural vegetation, structures, and soil redness. These indexes were very effective to understand the conditions and trends of desertification. We confirmed that no significant changes in spatial extent of desertification were seen in the test district. Land management around major settlements, roads, railway lines, etc., was relatively meticulous and desert land was being reclaimed. Conversely, in outlying regions new desert land was appearing. As described above, we could understand the conditions and trends of desertification through this method.

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7. References

Zhu, Zhenda et al (1992): China: Desertification Mapping and Desert Reclamation. Form "World Atlas of Desertification," UNEP. pp.46- 49.