G-1.2.1 Assessment of the Human Effect on Desertification and Land Degradation

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Abstract

1) Desertification in eastern China was characterized by reactivation of fixed sand dunes at Naiman, surface erosion of the topsoil at Lanxi, and severe gully erosion resulting in badlands at Yuanmou.

2) No significant changes in areal extent of desertification were seen in any of the analyzed regions of Naiman, Lanxi, and Yuanmou. Land management around major settlements, roads, railway lines, etc., in all these regions was relatively meticulous and desert land was being reclaimed. However, in outlying regions new desert land was appearing, making it difficult to say that suitable land management was being practiced.

3) Indexes for natural vegetation, structures, and soil redness were used to give us an understanding of the conditions of desertification, and, combined with the results of past and present analyses, were very effective.

4) We evaluated the processes of desertification in Yuanmou Province, where gully erosion is prominent.

Key Words Desertification, Remote Sensing, Eastern China, Active Dune

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 (1992) 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 clarify the characteristics of disetification areas and to understand how desertification has progressed over the last 10-20 years in some model areas of diffrent types of desertification using Landsat data.

2. Some characteristics of desertification in Eastern China

Some characteristics of desertification are mentioned as follows.

Desertification by wind erosion occurs in arid and semi-arid regions where the surface layer is consisted of sand. Areas where desertification is already pronounced are mainly seen in the lower reaches of inland rivers west of 105° E latitude and in areas surrounding oases. Such regions account for 2/3 of the desertifying regions in northern

China. A typical landscape consists of moving sands and gravels caused by overgrazing, overcultivation, and cutting of natural vegetation, and sand dunes which are reactivating. This has been occurring for the past 100 years. In addition, similar phenomenon are also observed in semi-arid and subhumid regions where sand deposits form the upper ground surface layer, such as northeast plains, the middle reaches of the Changjiang (Yangtze) River, and the coastal plain.

Water erosion mainly affects the middle reaches of the Huanghe (Yellow) River in loess region, mountainous areas of southwestern China, and hilly areas in the northeast. The major landscapes are consisted of 1) ridge and badland areas formed by water erosion in semi-arid and subhumid loess plateau, 2) badlands in humid areas where runoff has affected granite and laterite landscape, 3) rocky desert-like landscape in limestone areas of the mountain regions, and 4) gravel desert-like landscape in humid areas where debris flows in mountainous regions have led to the blanketing of valley floors with sand and gravel.

In this study, we selected below three model areas(Fig.1). First was Naiman area in the Inner Mongolia Autonomous Region as a region typifying desertification caused by wind erosion. Second was Lanxi in Zhejiang Province, as an example of surface erosion by running water. Third was Yuanmou in Yunnan Province, as an example of severe gully erosin resulting in badlands.

(1) Naiman (Inner Mongolia Autonomous Region)

Naiman is located about 400km NE of Beijing . This semi-arid region has an annual average rainfall of 372mm and annual average temperature of 6.4 ℃. 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 humidifing of climite. 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 1-2m 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 around 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 5m/yr has been observed. Furthermore, in the grassland sections 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. However, in some areas the dune sand is being collected as material for bricks, encouraging desertification.

(2) Lanxi (Zhejiang Province)

Lanxi, about 300km west of Shanghai, is located in the northeastern section of a long basin which runs east to west. The climate is subtropical monsoon climate, with annual precipitation of 1,360mm, half of which falls in April, May, and June. Autumn is a dry period, and the annual evapotranspiration rate of 1,493mm is somewhat higher than the annual precipitation. The topography within this basin is roughly divided into alluvial plain and hilly areas, with desertification progressing in most of the latter. The soils of the hilly areas are red soils of the Quaternary. Originally, the ground surface consisted of a top layer of about 2-3m of red soils underlain by 7-8m of "tiger stripe" clayey sediment layers containing 2 gravel layers.

Desertification in this region is caused by the cutting of forested slopes for cultivation. After the land has been denuded, rainfall erodes the surface layer, and the red soils are washed away. For this reason, the density of rilles and gullies in desertified hills is relatively low, and convex slopes have been preserved. This type of landscape, which has been called the "red desert," can be seen on a much larger scale in Nanchang, 200km to the west. LANDSAT images show distinctive areas of bare, red ground surface. The area has been abused several times in the past, even, it is said, 200–300 years ago. However, it is believed that most of the serious desertification has occurred within the past 30 years.

Vegetation experiments on denuded land have shown that bamboo forests, tea plantations, etc., reduce erosion is nearly zero, and efforts are being made to preserve the land.

(3) Yuanmou (Yunnan Province)

Yuanmou, about 200km NW of Kunming, is located in the bottom of a long, narrow basin which runs north to south. Its elevation is 1,250–1,350m m.s.l. Due to the influence of the foehn which comes over the Transverse Mountains, annual precipitation is only 613mm while annual evapotranspiration is 3,847.8mm, making this a very dry place. The mountains surrounding this basin are still undergoing upheaval. The valley floor itself is not necessarily flat, and there is a mixture of valleys and the hilly uplands that they dissect. Desertification is progressing in the uplands, where the dry, red, porous soil becomes soft and susceptible to landslides when suddenly saturated with a large amount of water. The ratio of vegetation cover is less than 20%. Flash floods coming immediately after the dry season cause considerable gully erosion, and a badlands landscape is forming. Even LANDSAT images indicate that a meshed pattern of gullies is encroaching on the uplands. The shrublands and forests in the mountains on the eastern fringe of the basin provide a stark contrast to the grazing lands in the western mountains.

In the remaining flat surface of uplands, irrigated sugar cane fields spread out, but in the surrounding areas gully erosion is progressing, apparently having reached a depth of 7–8 m over the past 30 years. Furthermore, in some places gullies are regressing at a rate of 6 m/yr, causing damage to sugar cane fields. Severe erosion has continued over the past several years. Thirty years ago, flooding occurred two or three times every ten years, howeverrecently, about 2–3 floods apparently have been occurring every ten years.

3. Methods for Understanding Desertification Processes

Using LANDSAT data, we identified desertifying regions by the following methods:

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

For LANDSAT TM data (TM 4 - TM 3) / (TM 4 + TM 3)

For LANDSAT MSS data (MSS 7 - MSS 5) / (MSS 7 + 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 non-vegetated regions, had to be removed. For that purpose, the ratio

(TM 5 - TM 1) / (TM 5 + TM 1)

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 band 5, old data were masked by water bodies and man-made structures derived from the new images.

Third, using the redness index (TM 3 - TM 1) / (TM 3 + TM 1) 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.

4. Recent trends of desertification

30 km square sections, one for each the three study areas, were selected as model districts, and were analyzed for desertification patterns over the last 10–20 years using methods mentioned above. Desertifying regions have low vegetation indexes. Areas showing the soil colors of the respective areas (white for Naiman, red for Lanxi and

Yuanmou) were identified, the results from analysis of old and new images were superimposed to clarify the changes.

The areal proportions of the three model districts undergoing desertification were, respectively, roughly 40% in Naiman, 3% in Lanxi, and 15% in Yuanmou. However, the area of reclaimed land and the area of newly desertifying land were roughly the same in all districts, indicating that the areal extent of desertification in all three districts is almost constant.

We show the example of Naiman in Fig.2.

In Naiman, 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. This trend was also evident in the other two regions. For example, in Yuanmou from 1976–92, the trend of land reclamation around the town and desertification in outer areas was clearly manifested. The same kind of result was also obtained from Lanxi for 1973–92.

The above results 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.

3. Ground truth of the state of desertification

Ground truth was conducted in Naiman to verify the results of the analysis.

(1) "A" point (420 49 56"N, 1200 45 15"E)

This site, situated on about 10km of fixed sand dunes in eastern Naiman (Fig.1A), is an area which LANDSAT data analysis showed to be desertifying from 1982–1991. According to a desertification process map compiled by the Chinese Academy of Science2,3), 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 LANDSAT data analysis. Moreover, on the surfaces of what were believed to be the original encroaching dunes were patches of shami (Gramineae) and nothing else, indicating that the sand had been moving within the past several years. The presence of strong winds which can easily move the sand was evidenced by the fact that all the willows comprising the shrubland were leaning in the same direction and that their root systems were exposed on the ground.

A possible reason for desertification was thought to be overgrazing, as evidenced by personal interviews and scattered livestock droppings found during a field survey.

(2)"B" point(420 49 8"N, 1200 47 33"E)

This site, located about 8km SSE of "A" point, was also judged to have been desertifying from 1982–91. According to the desertification process map, this area was classified as grassland in both 1958 and 1974, but a comparison of the two years shows a vast reduction in areal 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.

According to personal interviews, this had been a grassland containing some willow. However, the willows were cut to make room for grazing, which were raised at a density of one head per 20 hectares. Overgrazing resulted in the onset of desertification. Afterward, an attempt was made to grow wheat in the depressions, but there was little hope for a worthwhile harvest, as only about 25kg/ha was reaped from the best area, considerably less than the 350kg/ha harvested in surrounding areas which have not been subject to desertification.

(3)"C" Point(420 51 2"N, 1200 42 11"E)

This site 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. The desertification process 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 photos 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 Artemesia 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. Moreover, cultivation has also begun in limited areas, with crops including not only wheat but Chinese cabbages, carrots, watermelons, and corn, providing a yearly net income of about 4000 yuan for some of the more prosperous farmers. Groundwater is used for cultivation and is brought up from a depth of about 20m.

The resulting ground truth for these three sites roughly corresponds to the results of the analysis.

5. Evaluation of desertification processes

(1) Regions of gully erosion

As it has become possible to gain a spatial understanding of desertifying regions, we must now evaluate the processes of desertification. For this purpose, we have attempted to evaluate Yuanmou Province, an area typified by badlands caused by gully erosion.

Gullies are trenches with steeply sloping walls. Because gullies are prone to cast shadows by the sunlight during the LANDSAT observation period, they were identified by these shadows.

Since the LANDSAT observation period was about 9:30 a.m., sunlight came from a southeasterly direction. Therefore, filter processing was used to identify shadows cast by the light coming from the south and from the east.

Next, after giving these data sets binary values, further filter processing was conducted; only shadows with a minimum of 3 continuous pixels (90m) in all directions were kept. Then these binary images were processed using the Ultimage program on a Macintosh computer.

However, all the lineaments so derived may not always indicate gullies, since the shadows of roadside trees and structures may also be included. Therefore, using the results of land cover classification, we masked forests, cultivated lands and bush, and left only the sections of bare land and grassland. This became our gully density map.

Finally, we took the 3 X 3 pixels of the evaluated sites, and, based on the pixel of the lineaments, evaluated the degree of land degradation as follows:

None	Light	Moderate	Heavy	Severe
0	1–2	3	4	5–9

As a result, we found that there is a large area of mountainous slopes in the west used as grasslands which are not prone to gully erosion due to the brown color. On the other hand, in the hilly sections on the floor of the basin are only scattered, narrow areas of brown, indicating that a meshed pattern of gullies is developing. This is in accordance with data obtained from field studies and existing topographic maps.

6. Conclusion

1) Desertification in eastern China was characterized by reactivation of fixed sand dunes at Naiman, surface erosion of the topsoil at Lanxi, and severe gully erosion resulting in badlands at Yuanmou.

2) No significant changes in areal extent of desertification were seen in any of the analyzed regions of Naiman, Lanxi, and Yuanmou. Land management around major settlements, roads, railway lines, etc., in all these regions was relatively meticulous and desert land was being reclaimed. However, in outlying regions new desert land was

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Reference

Kadomura, Hiroshi (1991): Research Problems Associated with Observation of Land Degradation. Study funded by a grant from the FY 1990 General Fund for Scientific Research (A) 63302068 Research Report "Comparative Studies of Land Degradation Observation"; Tokyo Metropolitan University, pp.5–32.

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

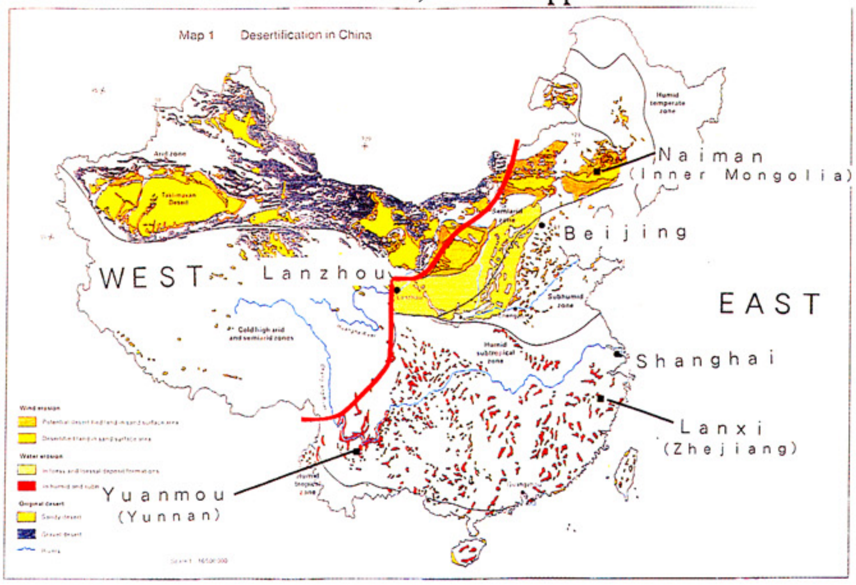

Fig.1 Desertification Map in China and Study areas (modified from Zhu et al. 1992)

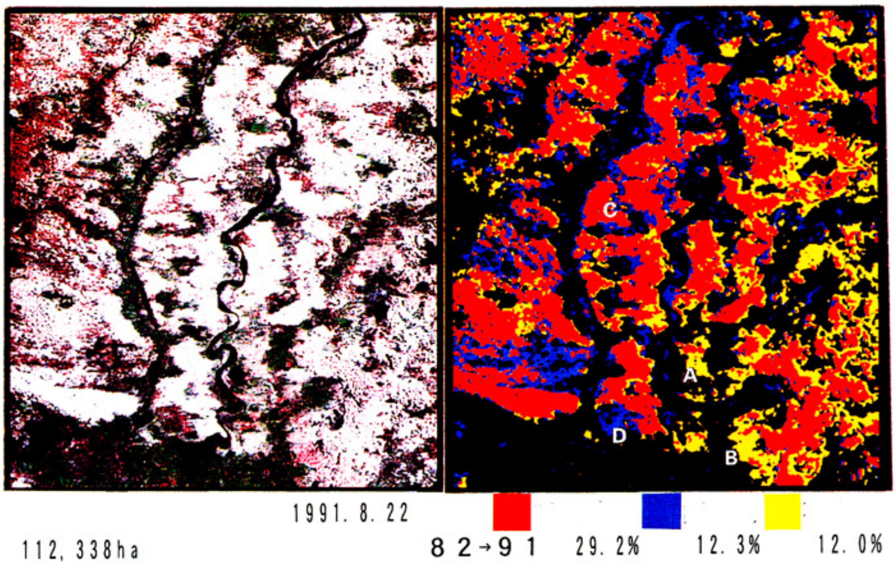

Fig.2 Recent Trend of Desertificaton in Naiman (1982 → 1991)
red:desert area
blue:recovered area
Yellow:desertified area