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THE DYNAMIC MONITORING OF HORQIN SAND LAND USING REMOTE SENSING

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ABSTRACT: Horqin Sand Land is regarded as the typical region for studying the problem of desertification. The integration of 3S(GIS, GPS and RS) techniques offer a most helpful method to study and monitor the dynamics of desertification. Based on the data derived from 3 periods′ multitemporal Landsat TM imagery of the 1990s, the regional land use and dynamics of desertification in Horqin Sand Land were studied. The main results revealed that: 1) as long as the general change tendency was concerned, the desertification of Horqin Sand Land would continue to spread; 2) there was a gradual decrease in the area of both moving sand dunes and semi-stabilized ones, which meant that fruitful progress had been made to control the desertification during the 1990s; 3) as a result of unreasonable cultivation, the total area of stabilized sand dunes and grassland in the middle and western region decreased obviously. It suggested that the increasing damage caused by human was leading to the hazard of further desertification. So in the future, it is necessary to take more effective measures to control the spread of desertification and restore the degraded ecosystems for the purpose of optimizing the global eco-environment in Horqin Sand Land.

KEY WORDS: Horqin Sand Land; desertification; remote sensing; dynamic monitoring

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1 INTRODUCTION

Remote sensing monitoring is a frequently employed approach of studying the problems of desertification. The development of remote sensing technique as well as its marriage to GIS and GPS, namely the integration of 3S technique, create a technical means to trace the evolving dynamics of desertification over a specified period so as to offer some insights to local decision-making departments to intensify or improve the current measures for controlling potential desertification in the future. In the second phase of RS technique application, priority should be given to dynamic monitoring instead of static monitoring and to quantitative investigation other than to qualitative explanation(CHEN, 1991).

Horqin Sand Land, combined with Mu Us Desert, Hulun Buir Sand Land and Otingdag Sand Land, are identified as the four greatest sand lands in semi-arid transitional zone between agriculture region and pastrure area in northern China. Because of its continuous desertification tendency, Horqin Sand Land is regarded as the typical region for studying the problem of desertification. In the recent twenty years, many scholars have employed RS technique to study Horqin Sand Land, ranging from the formative mechanism and developmental process to evolution tendency (ZHU and LIU, 1981; ZHANG and WANG, 1999; PEI *et al*., 1997; ZHAO *et al*., 1998a, 1998b; XU and ZHAO, 2000). However, detailed case studies on the desertification problems based on land-use types had been absolutely rare. Therefore, the authors classified the satellite images of three periods of the early, mid to late 1990s into different land-use types respectively, and then analyzed the dynamics of land use through the 1990s.

2 METHODS

2.1 The Study Area

Horqin Sand Land is located in the western part of

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northeastern China (42°41′ to 45°15′N, 118°35′ to 123°30′E), with an area of 51 700km^2 (WU, 2001). The study areas in this paper include: 1) the typical desertification region in the middle and western Horqin Sand Land, covering two banners administered by Chifeng City and two banners administered by Tongliao City; 2) the typical desertification region in the eastern Horqin Sand Land, involving four banners administered by Tongliao City.

2.2 Data Source

The satellite data used in the study was denoted in Table 1.

Table 1 Satellite data used in the study

Region	Scene no.	Data source type	Date
Eastern region	120/30	Photographic image	1994-09-09
		Digital data	1999-06-22
Middle and western region	121/30	Photographic image	1991-08-22
		Photographic image	1994-09-15
		Digital data	1999-09-13
	122/30	Photographic image	1990-06-23
		Photographic image	1994-09-15
		Digital image	1999-09-01

2.3 Identification of Rules for Land-Use Classification

In the process of desertification monitoring, it is necessary to define a set of representative and pragmatic criteria to differentiate land-use types (WANG *et al.*, 1998). The authors grouped all the land types according to characteristics of desertification, which can be further divided into stabilized sand dune, semi-stabilized sand dune and mobile sand dune. Other parts of the Horqin Sand Land in the satellite imagery were classified as cultivated land, built-up land (residential land), open water, grassland and forest. The rule for land-use type classification was indicated in Table 2.

2.4 Geometric Correction of Satellite Image

2.4.1 Geometric correction of TM digital images in 1999

Approximately 30 GCPs (Ground Control Points) in every scene were located in contour maps (1: 100 000) as well as digital images at the same time. Using ARC/INFO software, the GCPs in contour maps were input as label points of vector coverages into computer. As a result of transformation, the projection coordinates of GCPs in Beijing 1954 Gauss Kruger coordinate system were determined, based on which the images were corrected geometrically with PCI 6.2 and RMS error less than 1.0.

2.4.2 Geometric correction of TM photographic images in 1990 and 1994

Ascribing to the same extent of photographic images and digital images, the GCPs labelled in digital images were located correspondingly in photographic images. The boundaries of all patches in images were facsimiled to transparent paper so as to form the polygon maps including GCPs to which visual interpretation was applied. Supported by ARC/INFO, the graphics were input into computer by quantified to form vector coverages, while the GCPs were input as TICs. Finally the coverages were transformed to Beijing 1954 Gauss Kruger coordinate system with RMS error less than 1.0.

2.5 Classification of Satellite Images

The satellite data of 1990, 1994 and 1999 were recorded in different media (Table 1), so different classification methods were employed. While classification aided by computer was applied to the digital images of 1999, the photographic images of 1990 and 1994 were classified with visua l interpretation.

Table 2 Land-use types in Horqin Sandy Land and their characters

Land-use type	Physical character
Stabilized sand dune	Characterized by sandification; vegetation coverage higher than 40% vegetation cover including forest, bush or grass
Semi-stabilized sand dune	Characterized by sandification; vegetation coverage ranging from 20% to 40%; vegetation cover including sparse forest, bush or grass
Mobile sand dune	Characterized by sandification; vegetation coverage lower than 20%; possible vegetation including some kinds of sand-fixing pioneer plants
Cultivated land	Cultivated land in reserve and tentative cultivated tract
Built-up land	Cities, towns or villages
Open water	Puddles, reservoirs or rivers
Forest	No sandification; dominated by dense trees
Grassland	No sandification; covered by grass or shrub

2.5.1 Classification aided by computer for 1999 TM digital images

It is well known that Landsat TM data have seven layers, each of which provides different information of the ground surface. In order to accelerate the process of data handling, the authors employed relativity analysis to deduct some of layers that contributed little information to the study. As a result, TM6 was cut out in the study because as a thermo-infrared channel, it is in low resolution and can only indicate the surface temperature of the earth.

Since three scenes of images of 1999 were made in different seasons, the same land-use types were represented by different image character. It could decrease the accuracy of classification. So the authors investigated the typical areas of different land-use types in Horqin Sand Land whose spatial information were recorded by GPS(Fig. 1). These areas were located and trained in three scenes of images. Then the authors created the models for different land-use types. With the help of supervised classification, the images of 1999 were classified into land-use types with the average accuracy of 79.49%, 88.24%, 78.5% and general accuracy of 64.33%, 87.33% and 81.54% for scene 120/30, 121/30 and 122/30 respectively. According to ground survey data and satellite imagery, some errors induced by supervised classification were corrected.

Classified raster-based images were transferred into vector coverages, which could be operated by GIS software (ARC/INFO and ARCVIEW), in order that the classified result could be used for spatial analysis as well as maps display and output.

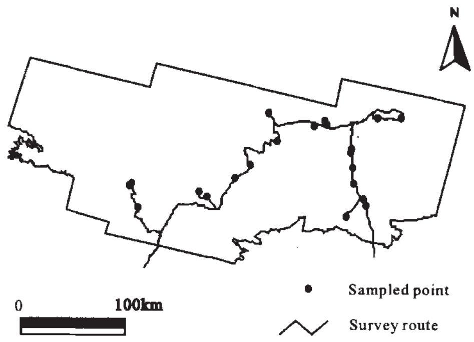


Fig. 1 Ground survey route and sampled point distribution in Horqin Sand Land

2.5.2 Visual interpretation of 1990 and 1994 TM photographic images

In order to solve the problems caused by seasonal difference in different scenes of satellite images, the authors referred to the existed land-use cartographies as interpretation symbols for different land-use types in RGB(red, green, blue) pseudo-color satellite photographs of September and June respectively (Table 3). Then the authors performed classification and input the results into computer to form polygon coverages.

2.6 Field Validation

In July 2000, we sampled 22 typical areas coupling with land-use types classified in satellite image of ground survey(Fig. 1). The sampling points involved different land-use types, such as mobile sand dune, stabilized sand dune, forest, cultivated land, grassland and open water.

Table 3 Main character of land-use types in satellite image for interpretation

Land-use types	Image character (September)	Image character(June)
Cultivated land	Red or cyan in color, regular texture, mostly in the form of rectangles surrounded by shelterbelt	Cyan in color, regular texture, mostly in the form of rectangles surrounded by shelterbelt
Built-up land	Bluish gray in color, with disordered texture decorated by dark red and gray spots	Bluish gray in color, with disordered texture decorated by dark red and gray spots
Open water	Blue, bluish black or light blue in color	Blue, bluish black or light blue in color
Forest	Red or pink in color, without dune generated texture	Dark red in color, without dune generated texture
Grassland	Dark green and smooth, without sand dune generated texture	Brown, without sand dune generated texture
Stabilized sand dune	Pink or dark green in color, with an obviously dune generated texture	Pink or dark green in color, with an obviously dune generated texture
Semi-stabilized sand dune	Gray in color, with an obviously white or gray dune generated texture	Gray in color, with an obviously white or gray dune generated texture
Mobile sand dune	White in color, with a texture generated from wave shape dune	White in color, with a texture generated from wave shape dune

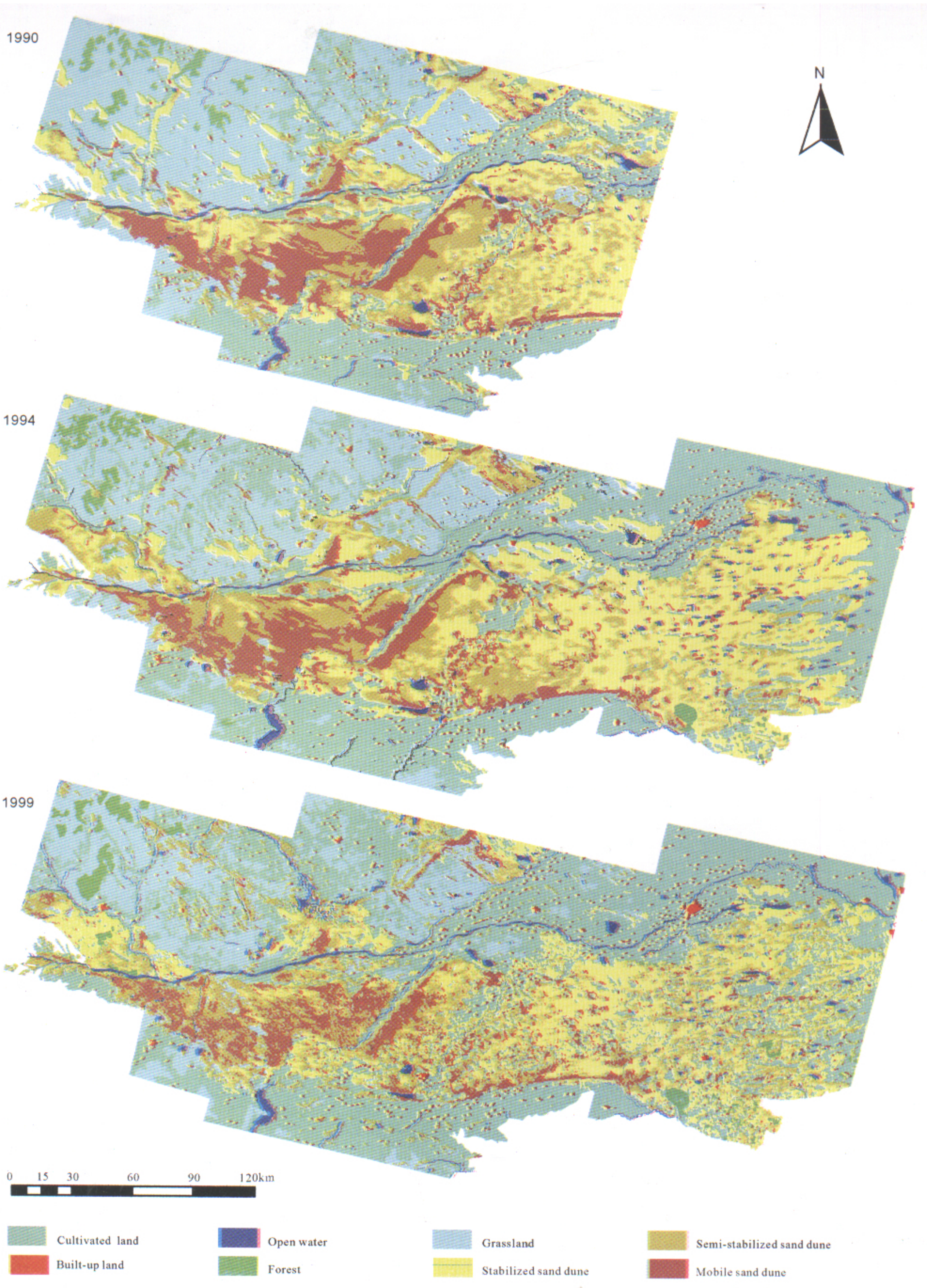
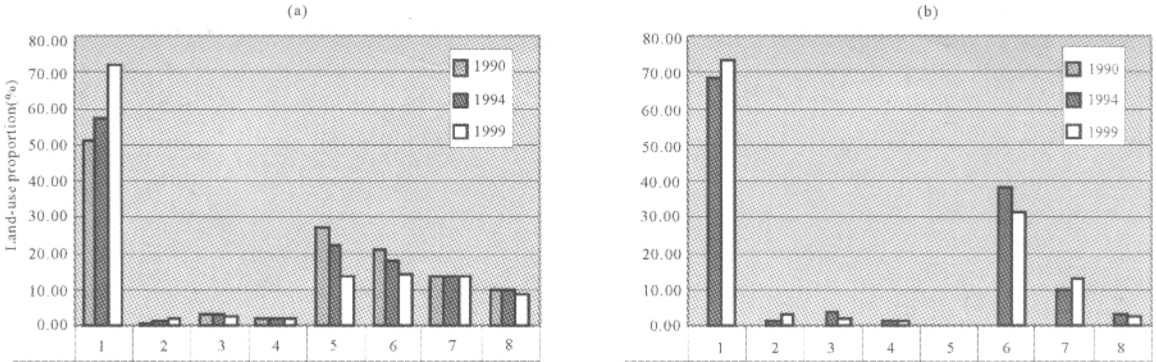


Fig. 2 Land use of Horqin Sand Land in 1990, 1994 and 1999



	1	2	3	4	5	6	7	8
1990	50.8	0.64	2.50	1.38	26.6	20.7	13.0	9.93
1994	57.0	0.89	2.80	1.89	22.1	17.4	13.6	9.90
1999	71.6	1.47	2.34	1.42	13.0	14.0	13.3	8.41

	1	2	3	4	5	6	7	8
1990	--	--	--	--	--	--	--	--
1994	68.5	0.96	3.25	1.11	0.10	38.6	9.69	2.50
1999	72.9	2.97	1.44	1.36	0.11	31.0	12.6	2.24

1—cultivated land; 2—built up land; 3—open water; 4—forest; 5—grassland; 6—stabilized sand dune; 7—semi-stabilized sand dune; 8—mobile sand dune

Fig. 3 The dynamic change of land use in middle and western region(a) and eastern region(b)

3 RESULTS AND CONCLUSION

The results of satellite image classification were demonstrated in Fig. 2. By performing spatial analysis using GIS software, the total area of individual land-use type and its proportion in eastern region or the middle and western region were computed respectively(Fig. 3).

It can be concluded as follows: 1) as long as the general change tendency was concerned, the desertification of Horqin Sand Land would continue to spread; 2) there was gradual decrease in the area of both mobile sand dunes and semi-mobile ones, which meant productive progress had been made in the control of desertification during the 1990s; 3) the total area of the stabilized sand dunes decreased significantly, some have degraded into semi-stabilized sand dunes, while some was cultivated for agriculture. It indicated that human disturbance was aggravating; 4) as for grassland, the difference in the dynamics of recent ten years occurred between the eastern region and the middle and western region. The total area of the former kept in approximately constant value while the latter showed an obvious shrinking tendency; 5) the land area settled by peasants and herdsmen tended to increase, especially in the case of an increase of 210% in the total area of residence in the six years from 1994 to 1999 in the eastern region; 6) in the middle and western region, the forest was mainly distributed in the mountainous area, with a little change; meanwhile, the forest in the eastern region increased 23% from 1994 to 1999; 7) compared with approximately unchanged area of open water in the middle and western Horqin Sand Land, the open water area in eastern region decreased 56% in the 6 years from 1994 to 1999.

4 DISCUSSION

Through the observations of ground survey, it is found that the data derived from satellite images are generally comparable. The area of cultivated land in reality had a deviation from the statistic value based on the results of satellite image classification. The reason that the stabilized sand dunes and the seedling forest which were cultivated for crop should not be ascribed to cultivated land. However, they were interpreted as cultivated land in the process of satellite imagery classification. According to the statistical data made by the local government, the lands stated above took up 20% to 30% of total cultivated land.

In addition to ground survey, the authors also interviewed the related local government departments and got gleaned some first-hand materials about desertification in Horqin Sand Land. Therefore, the authors inferred that natural factors, such as global warming and precipitation reduction, were certainly responsible for the variation of land cover in Horqin Sand Land. But it was human behavior that governed the region's land-use dynamics, both in positive tendency and negative tendency. On the one hand, the desertification controlling engineering should be credited with decreasing the area of mobile sand dunes in the past years. For example, in the southeastern Horqin Sand Land, the shelterbelts became mature along the West Liao River in recent years. It effectively transformed part of sand dunes to forest cover and succeeded in holding up the spread of sand dunes and leading the ecological conditions to a promising state. On the other hand, the excessive reclamation on the stabilized sand dunes turned these lands into semi-stabilized ones. Meanwhile, overgrazing had degraded large area of grassland soil to sandy soil or alkali-saline soil.

In general, attributing to many years′ endeavor, the eco-environment had been improved to some extent in Horqin Sand Land. Nevertheless, local government should be alert in the spread of sandy soil in the future because the risk of potential desertification had not been eradicated yet.

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