

DYNAMICS OF SANDY DESERTIFICATION AND ITS DRIVING FORCES IN WESTERN JILIN PROVINCE

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ABSTRACT: By establishing the interpreting elements, and applying supervised classification, the sandy desertification was interpreted and the desertified land areas of the counties in the western Jilin Province in 1986 and in 2000 were obtained. Taking Tongyu and Qian'an as examples, the natural driving forces and man-made driving forces were analyzed. The paper comes the conclusions that the material sources and the warming and dry climate are the internal causes of potential land desertification; the irrational human activities, such as destroying forest and reclaiming the grassland, are the external causes of potential land desertification; while more rational human activities, such as planting trees and restoring grassland can reverse the land desertification. Furthermore, the countermeasures and suggestions for the development of agriculture and animal husbandry in the western Jilin Province are put forward.

KEY WORDS: sandy desertification; remote sensing; dynamics; driving forces; western Jilin Province

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Land desertification indicates that under the fragile environment of arid or semiarid regions, because of the excessive artificial economic activities, which destroyed the balance of ecosystem, the environment degenerates by characterizing with sand blown by wind in the regions where it was not desert before (WANG and ZHU, 2003). With the development of economy, human beings have been increasingly paying more attention to the environment. Gradually, the studies on land desertification in the ecotone between agriculture and animal husbandry in the northern China come to be more deeply, and be enriched, such as the study on the characteristics of organisms under desertification, the influence of desertification on organisms (LI and ZHOU, 2001; ZHAO and ZHAO, 2000; ZHAO *et al.*, 1999), the climatic characteristics of desertification area (ZHANG and LI, 2003; ZHU and LI, 2002), the carrying capacity of the desertified area (MAO *et al.*, 2000) and the prevention and control of desertification (SUN and WEI, 1997) etc.

RS technique is good at obtaining macroscopic information in time, and it is playing a more and more important role in monitoring and investigating resources and environment. With RS images, the dynam-

ic process of land desertification in the western Jilin Province was obtained, and natural and artificial driving forces of the dynamic process of land desertification were analyzed through taking Tongyu County and Qian'an County as examples. This work provide a foundation for the prevention and control of land desertification, and also offers a reference to the improvement of ecological environment and the economic development in Northeast China.

1 STUDY AREA

The western Jilin Province is located in the hinterland of Songnen Plain, ranging from 121°38' to 126°10' E and from 43°58' to 46°18' N, with a total area of 4.5×10⁶ ha. It is composed of counties of Baicheng, Taonan, Tongyu, Zhenlai, Da'an, Changlin, Qian'an, Qian Gorlos and Fuyu (Fig. 1). In the region, it is arid and windy in spring, and has obvious annual temperature difference. The average annual precipitation, descending from east to west, is from 500mm to 400, and the average annual evaporation changes from 1600mm to 2000mm, ascending from east to west. The average annual relative humidity is in the range of 40% – 65%,

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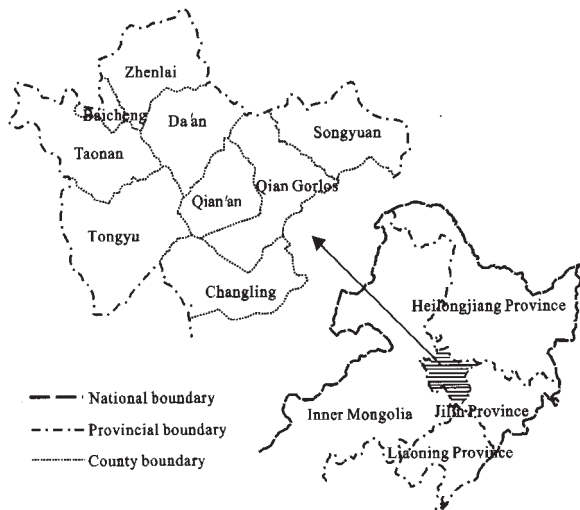


Fig.1 Sketch map of spatial distribution of the study area

declining from east to west. The annual average wind speed is more than 4m/s. The total annual radiation is $5.1 \times 10^{12} - 5.2 \times 10^{12} \text{J/m}^2$ and increases from east to west. The region is the transitional zone from semi-humid forest steppe to semi-arid steppe and desert. The major kinds of soil in this region are bland chernozem, chernozem, sandy soil, saline-alkaline soil and meadow soil. The main kinds of relief are floodplain, lower fluvial terrace, alluvial plain and fixed or semi-fixed dune. The altitude is changing from 110m to 160m, and the relative height is about 20m. The region is of transitional characteristics of typical factors of environment, such as vegetation, soil, land-use type and

climate etc. and it has been recognized as fragile ecological ectone and fragile climate region (QIU, 2003). Land desertification is the great menace to the ecological environment of this region. Based on the analysis of dynamic trend of land desertification in the western Jilin Province, the paper selects the counties of Tongyu and Qian'an as examples, where the land desertification has been reversed, to analyze the driving forces.

2 CLASSIFICATION OF DESERTIFICATION

With Landsat/TM images in September of 1986 and September of 2000 (from the receiving station of Chinese Academy of Sciences), by combining with field test and building standards of interpretation, the land desertification is interpreted by the method of supervised classification (each kind of land-use and its interpretation elements are shown in Table 1). The classification standards of land desertification degree are shown in Table 2.

3 RESULTS

3.1 Dynamics of Area of Desertified Land

According to the dynamic trend of the area of desertified land in all counties of the western Jilin Province, the area of desertified land in the western Jilin Province declined as a whole. Based on Table 3, it is concluded that the land desertification has been reversing as a whole. The area of desertified land decreased

Table 1 Surface features and their corresponding elements in the result map by supervised classification

Type ID	Type	Interpreting elements
1	Grassland	Green, fuzzy edge, high degree of vegetation coverage, in the shape of sheet, patch or strip
2	Forestland	Dark green, in the shape of patch, fuzzy edge, stereo(the hue is dark or light because of the effect of shadows of hill)
3	Cultivated land	Different colors for different crops and different times, in the shape of bigger rectangle
4	Residential area	Magenta, in the shape of lines, fuzzy patch edge
5	Lake and reservoir	Dark blue, in the shape of patch, smooth edge, different colors for the waters with different deepness and qualities
6	Saline-alkaline land	White or paleness, in the shape of patch, mostly attached to alkaline lake
7	Shelterbelt	Dark green, in the shape of line, mostly located around cultivated land
8	Slight-degree desertified land	Rosy color, in the shape of irregular patch
9	Middle-degree desertified land	Rosy color, usually being in sparse forest area, in the shape of irregular patch
10	High-degree desertified land	Amaranth, in the shape of irregular patch
11	Serious-degree desertified land	Paleness, in the shape of strip, usually being the relief of dune and sand ridge

Table 2 Evaluating indices of land desertification classes

Degree of desertification	Vegetation coverage (%)	Proportion of sandy land area(%)	Feature
Slight-degree desertified land	>60	<5	Quicksand sited on the sandy surface
Middle-degree desertified land	30-60	5-25	Patches of quicksand or dune with grass and shrub on sandy surface
High-degree desertified land	10-30	25-50	Patches of quicksand or interdistributing of dune, grass and shrub sandpile
Serious-degree desertified land	<10	>50	Concentrated, connected and intensively active dunes on sandy surface

Table 3 The desertified land area of each county in western Jilin Province

		Baicheng	Taonan	Tongyu	Zhenlai	Da'an	Changling	Qian'an	Qian Gorlos	Fuyu	Total
1986	Area of desertified land ($\times 10^3$ ha)	9.1	68.2	293.3	49.2	81.9	201.5	35.5	116.8	102.3	957.8
	Proportion in total desertified area (%)	0.95	7.12	30.62	5.14	85.5	21.04	3.71	12.19	10.68	100
2000	Area of desertified land ($\times 10^3$ ha)	4.5	76.1	214.1	58.7	78.0	209.3	34.7	105.2	77.5	858.1
	Proportion in total desertified area (%)	0.52	8.87	24.95	6.84	90.90	24.39	4.04	12.26	9.03	100

Note: The urban area of Songyuan is included in Fuyu County.

from 957.8×10^3 ha in 1986 to 858.1×10^3 ha in 2000, and the net decrease of 99.7×10^3 ha is about 10% of the total area of desertified land. The proportion in total desertified area of all counties except for Baicheng, Tongyu and Fuyu takes on ascending trend, and the increments are different.

3.2 Dynamic Change of Land Desertification

In order to make further analysis of the dynamics of land desertification, it is necessary to analyze the area change of land desertification in different degrees. The change of total area cannot clearly reflect the ecological environment change. From Table 4, it can be seen that the land area of slight-degree desertification is increasing in all counties except for Baicheng, but the area of middle-degree, high-degree, and serious-degree desertification is reduced in all counties except for Da'an and Taonan, which indicates that the potential desertification could not be neglected.

3.3 Speed of Change of Land Desertification

Here, we describe the dynamic change of land desertification by the method of describing the dynamic degree of land change.

$$SD = \frac{U_b - U_a}{U_a} \times \frac{1}{t} \times 100\% \quad (1)$$

Formula (1) can be used to describe the dynamic degree (ZHAO *et al.*, 2001), where SD is the dynamic degree of desertification land of some type in some place, which means the relative annual increase rate, U_a is the area of desertified land in the start year, U_b is the area of desertified land in the final year, t is the interval of years being measured.

The land desertification in the region takes on a reverse trend as a whole according to the formula (1) (Table 5). Dynamic degree of land desertification in every county is less than 1.39%, which is the annual increase rate of desertification in the ectone of agricul-

Table 4 Dynamics of the desertification degree of the western Jilin Province ($\times 10^3$ ha)

	1986				2000				Change			
	Slight degree	Middle degree	High degree	Serious degree	Slight degree	Middle degree	High degree	Serious degree	Slight degree	Middle degree	High degree	Serious degree
Baicheng	3.2	4.5	1.0	0.3	2.3	1.8	0.2	0.2	-0.9	-2.7	-0.8	-0.1
Taonan	26.2	31.9	8.4	1.6	39.8	30.7	3.8	1.7	13.6	-1.2	-4.6	0.1
Tongyu	92.6	153.7	26.4	20.6	113.3	80.8	11.7	8.3	20.7	-72.9	-14.7	-12.3
Zhenlai	18.0	22.6	4.7	3.8	30.4	22.2	2.8	3.3	12.4	-0.4	-1.9	-0.5
Da'an	30.9	37.8	9.1	4.1	44.2	22.0	6.4	5.4	13.3	-15.8	-2.7	1.3
Changling	40.7	134.7	15.0	11.1	112.0	78.4	12.3	6.6	71.3	-56.3	-2.7	-4.5
Qian'an	6.1	25.3	2.7	1.4	17.5	14.5	1.3	1.3	11.4	-10.8	-1.4	-0.1
Qian Gorlos	23.0	79.5	9.1	5.2	58.0	35.1	7.4	4.7	35.0	-44.4	-1.7	-0.5
Fuyu	1.2	92.0	4.2	4.9	37.7	33.6	1.9	4.4	26.5	-58.4	-2.3	-0.5

Table 5 Change speed and status of each level of desertified land

	Baicheng	Taonan	Tongyu	Zhenlai	Da'an	Changling	Qian'an	Qian Gorlos	Fuyu	Average
SD(%)	-3.36	0.77	-1.8	-1.29	-0.97	0.26	-0.15	-0.66	-1.6	-0.69
Desertification status	Reverse	Growing	Reverse	Reverse	Reverse	Growing	Reverse	Reverse	Reverse	Reverse

ture and animal husbandry in the northern China in the 1980s. If only considering the numeric variance, we can see that only the dynamic degrees of desertification in counties of Taonan and Changling are positive, indicating a growing trend.

Through further computation, we can see that, in recent 15 years, the variance rates of the areas of slight-degree desertified land are all positive values, and the absolute values of them are bigger than those of middle-, high- and serious-degree desertified land. The

values of dynamic degrees of slight-degree desertified land are between 0.1% and 146.67%, and the variance range is 145.67%; the values of dynamic degrees of middle-degree desertified land is between -4.23% and -0.12%, and the variance range is 4.11%; the values of dynamic degrees of high-degree desertified land is between -3.71% and -1.2%, and the range is 2.51%; serious-degree desertified land is between -2.33% and 2.12%, the range is 4.45%. It is indicated that the variance of slight-degree desertified land is obvious and its spatial difference is more remarkable.

4 DRIVING FORCES OF DESERTIFICATION

4.1 Natural Factors

4.1.1 Material factors

Songnen Plain is a diluvial plain that derived from fault basin formed in the Mesozoic era (ZHANG and LIN, 2000). There are 70–100m of loose sediment deposited at the west of Songnen Plain, and in the most deep place, it is as deep as 180m, which provides abundant sources of sand for desertification (LIN *et al.*, 1999).

4.1.2 Climatic factors

The wind in the region was very strong, according to the observed data from 1960 to 1990. Tongyu County has the strongest wind in this region, with an average wind speed of about 4.2m/s. The average wind speed of Qian'an is 3.6m/s. If the land desertification is regarded as a general natural disaster, the fragile ecological environment provided a potential condition for desertification when the climate becomes warmer and drier (AN *et al.*, 2002), the vegetation on the surface of earth becomes sparse, and the proportion of saline soil and sandy soil becomes relatively large. With the change of the natural conditions, the ecological environment takes on a trend of deterioration under the action of natural and artificial factors, and this is just reason why the development of middle-, high- and serious-degree desertification reversed, but the slight-degree desertification has grown, just as it is indicated by HA Si and DONG Guang-rong, the land desertification is a course of environmental degradation under the background of arid and windy climate (HA, 1994). The climate changes, especially the change of aridity and humidity, affect the formation and development of land desertification to a great extent (DONG, 1998).

4.2 Artificial Factors

There are two types of human activities influencing e-

cological environment, which are constructive activities and destructive activities respectively. For example, reasonable modes of land use, which are constructive activities, such as planting trees and grass can improve the ecological environment, but excessive cultivation, excessive deforestation and excessive herding, which are destructive activities, will destroy the ecological environment. According to the dynamics of desertification in counties of Tongyu and Qian'an, the ecological environment as a whole has improved, which shows that human beings have paid more and more attention to the ecological environment and that people have taken many ecological measures to improve environment, such as prohibiting herding, advocating alternate herding and planting grass and trees, which has brought about remarkable achievements, such as the reduction of the area of middle-, high- and serious-degree desertified land. From 1986 to 2000, the number of bigger livestock had decreased (Fig. 2a); the area of forest had increased (Fig. 2b). But we can also find that the reclamation on the grassland and forestland is still the most direct cause of land desertification because of augment of population (Fig.2c, d and e) and its pressure on cultivated land at the same time (although the statistical value of the forestland area takes on an increasing trend, the coexisting activities of planting and disafforestation, and reclamation on forestland have resulted in the revival of some fixed dunes and led to more intensive desertification). The result shows that the area of forestland is increasing (Fig.2b), but the area of grassland is decreasing (Fig.2e).

4.3 Synthetical Effect of Natural Factors and Artificial Factors

The vegetation is a protector for the soil. Sandy surface provides abundant sand sources for desertification. Human activities, such as excessive reclamation, excessive deforestation, have devastated the original vegetation and made the sandy surface exposed. Then the climate changes, such as warming climate, aridity and strong wind, have made the desertification intensive. Besides these, there are also feedback mechanism between human activities and evolution of ecological environment. The seasonal aridity in this region, called spring aridity, is an important factor to the fragility of regional ecological environment. Especially in April, there is no rain through the month, and the drought time is far more than the days during which the soil moisture has reached wilting point. Just in the period, the wind is strong and the temperature is increasing so that the quantity of evaporation is twice as much as the

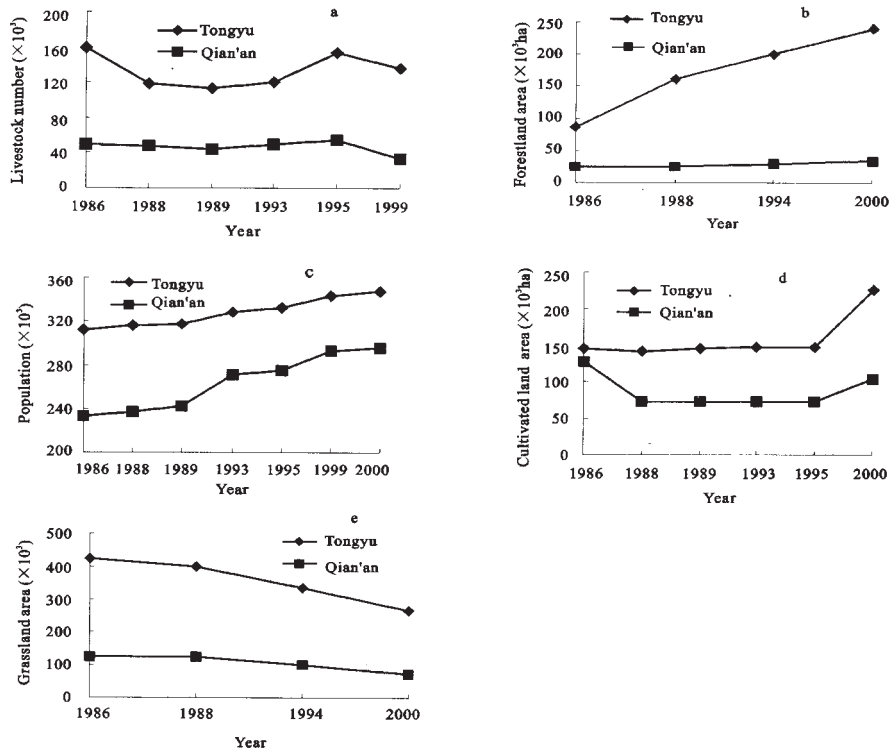


Fig. 2 Dynamic trends of population, livestock and areas of land use in Tongyu and Qian'an counties from 1986 to 2000

quantity of precipitation. Severe drought restricts the plants' growth. The fragility of ecological environment would not be exposed under the conditions of better vegetation on the surface of earth, however, if the excessive reclamation, herding and deforestation devastate the vegetation and then the surface of earth lose protection, the nutrient and moisture status of soil will intensively deteriorate under the fierce influences of wind and drought and then the area of vegetation decline since the vegetation could not intrude these places again, which made more intensive land desertification in reverse (ZHANG *et al.*, 2003). There are positive feedback mechanism between regional ecological environment and micro climatic environment, which means that worse underlying surface leads to bad micro climatic environment, and consequently bad micro climatic environment intensively affects the change of underlying surface conditions.

Hence, the synthetic influence of human activities and natural factors are the immanent causes of the potential land desertification in Qian'an and Tongyu counties.

5 PROPOSITIONS

According to the analysis mentioned above, it can

been seen that the warmer and drier climate, the strong wind, and the immanent fragility of the environment in the western Jilin Province resulted in the formation of potential land desertification. The reasonable land use modes, such as tree and grass planting and reducing quantity of herding will reverse the land desertification.

In order to improve the ecological environment and to release the harm brought to agriculture and pasturing by land desertification in the ectone of the western Jilin, two measurements should be adopted under the prerequisite of guaranteeing the economic income in the western Jilin and even in the whole northeastern China. On the one hand, it is to take improving measurements; on the other hand, it is to prohibit the activities of devastating ecological environment. The measurements in detail are as follows:

(1) To conduct ecological cure in northeastern ectone such as planting trees in suitable place for plant, planting grass in suitable place for herding, prohibiting pasturing and stopping cultivation in the land where the desertification is severe, restricting or stopping pasturing or adopting alternate pasturing in the land where the desertification is slight and altering the conventional feeding mode and adopting the mode of col-

lecting grass and forage to feed livestock.

(2) To prohibit the activities of reclaiming the grass land and the activities of opening up wilderness by devastating the forest and to reward the activities of grass and tree planting.

(3) To encourage emigration and to make certain the agricultural population, which can be sustained here according to the ecological capability of the ectone.

The measurements above would take effect, if they were synthetically used to cure the land desertification and improve the ecological environment in the ectone.

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