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Applied research of landscape ecology in desertification monitoring and assessment

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Abstract: A preliminary research on landscape ecology in desertification monitoring and assessment was reported. Also, this paper laid stress on the study of landscape diversity, dominance, evenness and Markov Matrix model and their respective landscape ecological meanings in the desertification monitoring and assessment. Concurrently, it took Shazhuyu Experimental Area, Qinghai Province as a specific case study.

Key words: landscape ecology; desertification; monitoring and assessment; Shazhuyu Experimental Area

Introduction

Desertification is an important common concerning issue in international community. China has a large area of desertified land and is one of the countries suffered serious damage by desertification in the world. The total area of desert and the desertified land of the whole country is about 2.622 million km^2, accounting for 27.3% of the land areas' total. The economical losses caused by the desertification is quite huge. The areas of sanification only is every year expanding at the area of 2460 km^2 and the situation is becoming more acute.

In order to timely and accurately keep up with the status and changes of desertification in the whole country, it had on the basis of the Academy of Forest Inventory and Planning under the State Forestry Administration established the China National Desertification Monitoring Center for a purpose of systematically desertification monitoring of the whole country. Since the desertification monitoring is a new task, the technology and the methods of desertification monitoring and assessment are still in the process of studying and probing stage at home and abroad. This paper through some specific case studies elucidates the preliminary applied results of the landscape ecology in desertification monitoring and assessment.

1 Desertification monitoring and its classification of landscape elements

1.1 Conception of desertification

In accordance with the definition of the "united nations convention to combat desertification", "desertification" means land degradation phenomenon and process in arid, semi-arid and dry sub-humid areas (the humid index between 0.05—0.65) resulting from various factors, including climatic variations and human activities (CCICCD, 1994).

Climatic variation causes the change of structure and function from non-desertification ecological system to the desertification ones. However, except for the background of climatic variation, the irrational human activities are further increased the negative impact. Thus, the transformation from non-desertification system to desertification system and the light degree of desertification to more grave state has been accelerated. Especially, in the agro-pasture crisscross areas with a fragile eco-environment and human disturbance, the trends of desertification is becoming more accurate.

Currently, in the national macro-monitoring of the desertification, three aspects are involved: the land use type, the type and degree of desertification. The land use type is a base of desertification monitoring and assessment. Only making clear the status and the trends of desertification for different land use type, then the preparation of a targeted prevention and control

measures for combating desertification is possible.

1.2 Classification of landscape elements in desertification monitoring and assessment

Based on the requirements of desertification monitoring and assessment and concurrently refer to the present national classification criterion of land use, the classification of landscape elements has the following three forms: (1) In response to the requirements of national macro-monitoring and assessment for desertification, landscape elements are divided into 6 types of first-grade classification system: the arable land, grassland, forestland, waters, the land for urban and rural industrial and communication purposes and non-reclaimed land and so on. (2) In response to the requirements of regional monitoring and assessment for desertification, the landscape elements classification is based on the first-grade classification system, the second-grade classification system is derived, for instance, the arable land can further be divided into paddy fields, irrigated land and non irrigated farmland and so on. (3) In response to the requirements of the monitoring spots for desertification. Based on the second-grade classification system, the landscape elements can be continually divided, for example, adding some restricted factors of geomorphology, soil texture, soil type and plant community and so on.

Actually, even in a same land use type we can always see different types and different degrees of the desertified plots, different types and degrees of desertified land always display in different spots with different sized on the remote sensing images. It is therefore coinciding with the implication of landscape elements (patch). Thus, from this point, any different desertified land may be regarded as an independent landscape element.

2 Assessment indexes and methods of landscape ecology in desertification monitoring and assessment

One of the objectives of desertification monitoring and assessment is to keep abreast of the dynamic change and trend of desertified land. As the change of desertified land can be regard as the change of landscape patterns in landscape ecology, some assessment indexes and methods of landscape ecology for monitoring and assessment of dynamic change of desertified land are also valuable.

2.1 Assessment indexes

2.1.1 Diversity index

Diversity index, indicated by the Shnnon-Weaner index, reflects the diversity of the landscape types, with the following formula:

$$H = -\sum_{i=1}^{S} P_i \log_2 P_i ,$$

where H is the diversity index; P_i the percentage of landscape element i; S the number of landscape element.

The variation of diversity index, when used in desertification monitoring and assessment, indicates the trend of the landscape change. Studies show that where there is a bigger percentage of desertified land (over 50%), the smaller diversity index which indicates the reduced heterogeneity of the landscape, resulting in a decrease in its ecological functions, and its trend to turn into desert as an example of the western China. Meanwhile, when the percentage of desertified land is smaller (less than 50%), the increase of the diversity index, with the exception of impacts effected by other landscape types, indicates the extension of desertified land, contributing to the degeneration of the whole landscape. A case in point is the eastern part of China.

2.1.2 Dominance index

Dominance is used to measure the dominant percentage of one or several landscape type(s) in the landscape, with the formula as below (O'neill, 1988):

$$D = H_{max} + \sum_{i=1}^{S} P_i \log_2 P_i ,$$

where D is the dominance index; P_i the percentage of landscape element i; S the number of landscape element.

H_{max} in the above formula refers to the maximum value of diversity index of the landscape when there exists the equal percentage of each landscape element.

The change of the dominance index, when used in desertification monitoring and assessment, indicates the dominant percentage of desertified land in the whole landscape as well as its influence upon the formation and change of the landscape patterns. Studies show that where there is a bigger percentage of desertified land (over 50%), the increase of dominance index is the indication of the dominant role of desertified land in the whole landscape, resulting in the worsening trend of the landscape patterns. For instance, the western part of China. To increase oasis area by planting trees and grass would reduce the dominance of deserts and to curb its development. Where smaller percentage of desertified land (less than 50%), the decrease of dominance index indicates the increasingly stronger influence of desertified land upon the whole landscape and the reduced landscape ecological functions. Take, for example, the eastern part of China.

2.1.3 Evenness index

The evenness index is used to describe the distribution of various landscape types in the landscape, with the formula below (Rome, 1982):

$E = H/H_{max}$; E is the evenness index; H the revised Simpson index; $H = -\log_2\left[\sum_{i=1}^{S}(Pi)^2\right]$, H_{max} the maximum diversity index of landscape; $H_{max} = \log_2 S$.

The change of evenness index, when used in desertification monitoring and assessment, indicates the variable distribution percentage of desertified land and its trend in the whole landscape pattern. Studies show that if there is a bigger percentage of desertified land (over 50%), the evenness index drops, which shows the lower evenness of landscape pattern distribution and the increasing dominance of desertified land, resulting in the transfer of the whole landscape to desert. Just as the western part of China. On the contrary, in the area where the percentage of the desertified land is smaller (less than 50%), the increased evenness index, with the exception of influence by other landscape patterns, indicates the trend of even landscape distribution and the increase of percentage of desertified land. For example, in the eastern part of China.

2.2 Assessment methods

Various analytic methods of landscape ecology can be applied in desertification monitoring and assessment, such as comprehensive analysis of assessment values from different indexes of landscape ecology or Markov Matrix model of ecology.

Markov Matrix model plays an important role in analysis of dynamic change of desertified land. Contrasting aerial photos and satellite images in different historical periods, with the application of Markov Matrix model, we can not only enable to better understand the interchange between different degrees of desertified land (Sun, 1991), but between the desertified land and other landscape elements (such as arable land, grassland, forest land etc.), from which their change rates can be obtained. All these results are vital in combating desertification.

3 Case study

3.1 General situation

The study area, located in Shazhuyu District of Gonghe Basin, Qinghai Province in China (99°45′—100°30′E, 36°03′—36°40′N), is one of the main desertified areas in Qinghai Province. The district has an total area of 2181.12 km^2 and the elevation range is from 2871 to 3870m. The annual precipitation averages 246.3 mm and the annual evapotranspiration 1776.7 mm. The

average fresh gale days are 50.6 (up to 97 days) each year with the wind speed 2.7 m/s (maximum speed 40 m/s) and the main wind direction is west and northwest. The frost-free period averages 91 days.

The area has a temperate arid climate with an average annual temperature of 2.4℃, characteristic of dry and cold weather as well as strong wind. The soil is rich in sand and owing to long-term irrational land use, the desertified land is widely distributed in this area, mainly distributed in the river valley of Shazhuyu River, especially on the south bank. The area affected by desertified land is 127480.2 hm^2 covering 58.45 per cent of the total area. The main dune types are crescent dune and its chain with the height of 3—18m and the annual moving speed at 7—81m.

3.2 Types of landscape elements

There are 8 types of landscape element in the study area: (1) farmland; (2) forestland; (3) grassland; (4) residential area; (5) waters; (6) moving sand dune; (7) semi-fixed sand dune; (8) fixed sand dune.

3.3 Study methods

Based on a TM image of the study area at a scale of 1:100000 in 1994 with a topographic map of Shazhuyu District at a scale of 1: 100000 and the remote sensing interpret technique, the map of distribution of landscape element types in the study area in 1994 has been drawn. The map of distribution of landscape element types in the study area in 1958 has been drawn by referring the topographic map of Shazhuyu District at a scale of 1:100000 in 1958. On the basis of the above distribution maps, each patch area on the maps was surveyed and calculated two times using the electronic planimeter, and the results average in the error range. The area of each landscape element type in 1958 and 1994 was calculated (Table 1).

Table 1 Number, area and percentage of landscape elements in Shazhuyu District

Landscape element	1994			1958		
	Number	Area, hm^2	Percentage	Number	Area, hm^2	Percentage
Farmland	10	9880.0	4.53	10	3717.3	1.70
Forest	10	3684.3	1.69	6	3326.8	1.53
Grassland	23	122466.3	56.15	23	165348.4	75.81
Residential area	13	1029.7	0.47	15	664.3	0.30
Waters	4	1510.2	0.69	8	1281.0	0.59
Moving sand dune	12	41374.4	18.97	23	23749.1	10.89
Semi-fixed sand dune	4	15432.3	7.08	2	3126.5	1.43
Fixed sand dune	11	22734.8	10.42	3	16898.6	7.75
Total	87	218112.0		90	218112.0	
Average		2507.0			2423.5	

3.4 Results and discussion

3.4.1 Diversity

The diversity index of the whole landscape in the study area increased from 1.29 to 1.92 in 1958 to 1994 (Table 2), which indicates that the heterogeneity of landscape elements increased and the percentage difference among different landscape elements decreased. Table 1 shows that except the grassland, the area of other landscape elements increased, especially desertified land. This indicates that diversity gives the trend of desertified land change in a certain sense.

Table 2 The diversity, dominance and evenness in Shazhuyu District

Index	year	
	1958	1994
Diversity of the whole landscape	1.29	1.92
Diversity of desertified land	1.28	1.47
Dominance of the whole landscape	1.71	1.09
Dominance of desertidied land	0.30	0.12
Evenness of the whole landscape	0.25	0.48
Evenness of desertified land	0.73	0.86

The diversity index of desertified land increased from 1.28 to 1.47 in 1958 to 1994 (Table 2), which shows the decreased percentage difference

between moving sand dune, semi-fixed sand dune and fixed sand dune (Table 2) and the trend of their change. The percentage and the area of moving sand dune and semi-fixed sand dune increased fast, while that of fixed sand dune increased slowly.

3.4.2 Dominance

The dominance index of the whole landscape in the study area decreased from 1.71 to 1.09 in 1958 to 1994 (Table 2), which indicates that the ability of the landscape element dominant in the whole landscape decreased and the influence of other landscape elements on the whole landscape increased . From Table 1 we can find that in 1958 the grassland was dominant in the whole landscape and in 1994 the non-beneficial influence of desertified land is increasing with its extended area, but the influence is not beneficial. If the decertified land continuously increased, the whole landscape would degenerate and turn into desert in the end. The dominance here can be used as indication for monitoring the change of regional desertified land.

The dominance index of desertified land decreased from 0.30 to 0.12 in 1958 to 1994 (Table 2), which indicates that the influence of moving sand dune, semi-fixed sand dune and fixed sand dune on the whole landscape has changed. It can be found from Table 1 that the increased area of fixed sand dune is quite small, but those of semi-fixed sand dune and moving sand dune are quite large. The results show that the influence of moving sand dune and semi-fixed sand dune are becoming increased and that the whole landscape has the desertification trend.

3.4.3 Evenness

The evenness index of the whole landscape in the study area increased from 0.25 to 0.48 in 1958 to 1994 (Table 2), which shows that the whole landscape is even. The influence of landscape elements having weak control of the whole landscape is increasing and the influence of those having strong control is decreasing. We can see from Table 1 that from 1958 to 1994 the effect of the grassland is decreasing and the influence of other landscape elements is increasing, especially decertified land. The result is consistent with the analyses of both the diversity and the dominance.

The evenness index of desertified land increased from 0.73 to 0.86 in 1958 to 1994 (Table 2). The results indicate that the influence of semi-fixed sand dune on the whole landscape is increasing and that of fixed sand is decreasing. The result is also consistent with the analyses of the diversity and the dominance.

3.4.4 Analysis of the change of landscape spatial patterns

The change among the different landscape elements in the study area from 1958 to 1994 are given in Table 3 and Table 4, which shows that a great change has taken place in the past 36 years in the landscape spatial patterns, especially in the grassland. The total area of the grassland which turned into other landscape elements is 42882.1 hm^2, of which, 6162.7 hm^2 is reclaimed as farmland with the average annual change rate of 171.2 hm^2 turned into forestland with the annual average area of 9.9 hm^2. Meanwhile 365.4 hm^2 is used as residential area and 229.2 hm^2 is used as reservoir. 21940.9 hm^2 has degenerated into moving sand dune with the average annual change rate of 609.5 hm^2. 13826.4 hm^2 turned into semi-fixed sand dune with the average annual change rate of 384.1 hm^2. Attention should be paid to the fact that the area of the grassland turning into moving sand dune and semi-fixed sand dune is 35767.3 hm^2 covering 21.63 per cent of grassland area in 1958. It indicates that the whole landscape trend to turn into desert. There are several many causes for the above mentioned change. Natural factor is one of them and the damage by the local residents on the grassland is the major causes, such as overgrazing, over cutting, irrational digging and so on. If effective protection measures are not implemented, the structure and the function of the whole landscape will further degenerate or lose finally.

Table 3 Transition matrix of the area of landscape elements in Shazhuyu District from 1958 to 1994, hm²

1958 \ 1994	Farmland	Forest land	Grassland	Residential area	Waters	Moving sand dune	Semi-fixed sand dune	Fixed sand dune
Farmland	3717.3							
Forestland		3326.8						
Grassland	6162.7	357.5	122466.3	365.4	229.2	21940.9	13826.4	
Residential area				664.3				
Waters					1281.0			
Moving sand dune						17912.9		5836.2
Semi-fixed sand dune						1520.6	1605.9	
Fixed sand dune								16898.6

Table 4 Transition matrix of landscape elements in Shazhuyu District from 1958 to 1994, %

1958 \ 1994	Farmland	Forest land	Grassland	Residential area	Waters	Moving sand dune	Semi-fixed sand dune	Fixed sand dune
Farmland	100							
Forestland		100						
Grassland	3.73	0.22	74.06	0.22	0.14	13.27	8.36	
Residential area				100				
Waters					100			
Moving sand dune						75.43		24.57
Semi-fixed sand dune						48.64	51.36	
Fixed sand dune								100

The change of desertified land shows that the moving sand dune of 5836.2 hm² has turned into fixed sand dune through harnessing and the average annual change rate is 162.2 hm². The area of semi-fixed sand dune which turned into moving sand dune is 1520.6 hm² and the annual area averages 42.2 hm². The result indicates that part of the whole landscape is turning better. However, as there is larger area of grassland turned into moving sand dune, the whole landscape trend to desert. Which shows that it is feasible to improve the function of the landscape through combating desertification in the part of landscape, but if the whole landscape is not protected and rationally used from ecological angle, the ecological problems will not be solved completely.

4 Conclusion

Conclusions drawn based on the above-mentioned analyses are as follows: (1) Landscape element and land use type as a base of desertification monitoring and assessment, are an ecosystem in ecology. So we can learn and apply the experiences and the technology concerning the land use in landscape ecology to the desertification monitoring and assessment. (2) The assessment indexes and the study methods of the change of landscape spatial patterns, such as diversity, dominance, evenness and Morkov Matrix model etc., can be employed evaluation of the dynamic change of the whole landscape and the desertified land. (3) The results of the indexes and the study methods application in the study area show that they can be used as indication for analysis of the trend of the whole landscape and the desertified land.

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