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Changes of Climate-Vegetation Ecosystem in Loess Plateau of China

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Abstract

The change of terrestrial ecosystem spatial distribution driven by climatic change is one of important factors leading to soil erosion in Loess Plateau. The quantitative analysis of climate change impacting on vegetation ecosystem will afford the efficient data to support the implement of reasonability ecological restoration project. HLZ ecosystem model is employed to simulate the changes of climate-vegetation ecosystem in Loess Plateau during the periods from 1964 to 1974 (C1), from 1975 to 1985 (C2), from 1986 to 1996 (C3), and from 1997 to 2007(C4) on spatial resolution of 1km×1km. Combining the elevation data, the results show that there are 15 types of climate-vegetation ecosystem in which the cool temperate steppe, cool temperate moist forest and warm temperate are the major climate-vegetation types which respectively occupied the 82.73%, 83.19%, 82.86% during the periods from C1 to C4, and 79.77% of the sum area of Loess Plateau. The most types of moist climate-vegetation ecosystems have decreased since C1 period, especially the area of nival area, alpine wet tundra and alpine rain tundra have rapidly decreased during the four periods. Furthermore, the average distribution elevation of all climate-vegetation ecosystems distribution are on the increase except warm temperate thorn steppe, especially the average distribution elevation of alpine rain tundra, boreal wet forest, cool temperate scrub and warm temperate dry forest have continuously increased during the four periods.

Keywords: Climate-vegetation ecosystem; Spatial distribution; Changes; Loess Plateau of China

1. Introduction

Climate change, as a part of global change, entails changes increases in mean temperature and distribution of precipitation [1]. The change of temperature and precipitation can alter the spatial-

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temporal distribution of energy, water and nutrients, increase natural disturbances, alter natural processes, modify ecosystem structure and functioning, and change the distribution pattern of plant [2-3]. Reserch about the climate change how to impact on the vegetation and how to classify the vegetation type on the basis of the distribution pattern of temperature and precipitation had been made by different earth surface scientists since early 1880s [4, 5]. Especially, the holdridge life zone (HLZ) model can be used to simulate the distribution of climate-vegetation ecosystem (termed life zones) by using meteorological data. It has been widely accepted in projecting impacts of climate change on vegetation distributions [6-11]. The Loess Plateau of China, located at 100º54′-114º43′E and 33º43′-41º16′N, is the most serious soil erosion regions and one of the most climate-vegetation sensitive regions with complex regional difference of vegetation spatial distribution in China, in which mean annual temperature is 3.6–14.3℃ and mean annual precipitation is 150-750 mm. The change of terrestrial ecosystem spatial distribution driven by climatic change is one of important factors leading to soil erosion in Loess Plateau of China. In this paper, spatial pattern of climate-vegetation ecosystems in the Loess Plateau of China and its changes in the four decades of C1, C2, C3, and C4 are analyzed on the basis of digital elevation model of Loess plateau by operating HLZ model on meteorological data from 110 weather stations that are scattered over Loess plateau.

2. Methods

HLZ classification divides the world into over 38 life zones in terms of annual mean biotemperature (MAB), average total annual precipitation (TAP), and potential evapotranspiration ratio (PER) logarithmically. Biotemperature is defined as the mean of unit-period temperatures with a substitution of zero for all unit-period values below 0℃ and above 30℃ [12]. Evapotranspiration is the total amount of water that is returned directly to the atmosphere in the form of vapor through the combined processes of evaporation and transpiration. Potential evapotranspiration is the amount of water that would be transpired under constantly optimal conditions of soil moisture and plant cover. The potential evapotranspiration ratio is the ratio of mean annual potential evapotranspiration to average total annual precipitation, which provides an index of biological humidity conditions. In other words, MAB, MAP and PER at site (x, y) and in the t'th year have the following formulation:

$$MAB(x,y,t)=\frac{1}{365}\sum_{j=1}^{365}TEM(j,x,y,t) \tag{1}$$

$$MAP(x,y,t)=\sum_{j=1}^{365}P(j,x,y,t) \tag{2}$$

$$PER(x,y,t)=\frac{58.93MAB(x,y,t)}{MAP(x,y,t)} \tag{3}$$

Where $TEM(j,x,y,t)$ is the value summing the hourly temperature above 0℃ and below30℃ on the *j'th* day and dividing by 24; $P(j,x,y,t)$ is the mean of precipitation on the *j'th* day.

Suppose

$$M_{tem}(x,y,t)=\log_2 MAB(x,y,t) \tag{4}$$

$$M_{pre}(x,y,t) = \log_2 MAP(x,y,t) \quad (5)$$

$$M_{per}(x,y,t) = \log_2 PER(x,y,t) \quad (6)$$

$$d_i(x,y,t) = \sqrt{\left(M_{tem}(x,y,t) - M_{tem_{i0}}\right)^2 + \left(M_{pre}(x,y,t) - M_{pre_{i0}}\right)^2 + \left(M_{per}(x,y,t) - M_{per_{i0}}\right)^2} \quad (7)$$

Where $M_{tem_{i0}}$, $M_{pre_{i0}}$ and $M_{per_{i0}}$ are standards of MAB logarithm, TAP logarithm and PER logarithm at the central point of the *i'th* life zone in the hexagonal system of HLZs. When $d_k(x,y,t) = \min_i \{d_i(x,y,t)\}$, the site (x,y) is classified into the k'th life zone.

3. Results

3.1 HLZ ecosystem spatial distribution pattern

Based on climate data and HLZ ecosystem model, the changes of climate-vegetation ecosystem in Loess Plateau are simulated. The simulated result shows that there are 15 types of climate-vegetation ecosystem in Loess Plateau and just in the Qilian Mountains, located in southwestern Loess Plateau, 9 types appear. From C1 to C4, there are significant regional differences of climate-vegetation geographic distribution pattern in Loess Plateau of China. The Fig.1 and Table.1 shows the cool temperate steppe, cool temperate moist forest and warm temperate are the major climate-vegetation types which respectively occupied 82.73%, 83.19%, 82.86%.Alpine wet tundra and rain tundra mainly distribute in high elevation region above 3000m; Boreal dry scrub with small area is distributed in the fringe area of boreal moist forest which is border on Inner Mongolia Plateau. Desert major distributes in the northwest of Loess Plateau of China.

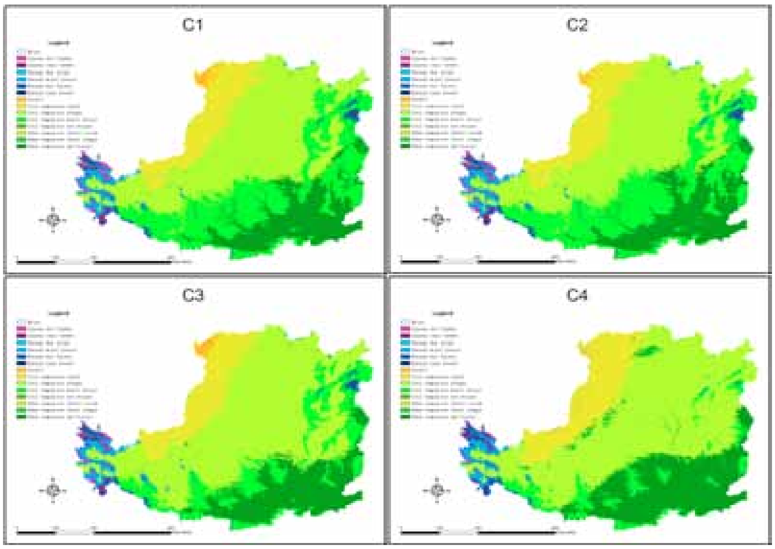

Fig. 1. Spatial distribution of HLZ ecosystem in Loess Plateau of China from C1 to C4

3.2 Change trend of HLZ ecosystem

The Table 1 shows that the nival, alpine and boreal climate-vegetation area has decreased and the warm temperate climate-vegetation area have increased during the periods from C1 to C4. According the each HLZ ecosystem type area during the four periods, the transfer matrix and Kappa coefficients are calculated between C1 to C4 which show the conversion phenomena of the HLZ ecosystem always takes place in transition region of different types. During the four periods, the Kappa coefficients of C1-C2 is 0.8726，C2-C3 is 0.7619，and C3-C4 is 0.7224 has decreased continuously, which indicates the change level of every HLZ ecosystem type is increasing.

Table1. Each type area of HLZ Ecosystem in Loess Plateau of China from C1 to C4 (Unit: Square km)

HLZ ecosystem type	C1	C2	C3	C4
Nival	2475	2565	2225	1242
Alpine moist tundra	3659	3572	3020	1583
Alpine rain tundra	2834	3140	2903	2538
Boreal dry scrub	186	30	119	0
Boreal moist forest	15989	17474	16914	14122
Boreal wet forest	8958	9078	8650	7106
Boreal rain forest	25	44	3	0
Desert	4079	1416	3536	156
Cool temperate scrub	70144	67761	69291	83342
Cool temperate steppe	257352	259618	320401	318981
Cool temperate moist forest	170933	168330	100624	50496
Cool temperate wet forest	244	507	27	38
Warm temperate desert scrub	11	172	729	7160
Warm temperate thorn steppe	102	67	470	10068
Warm temperate dry forest	92564	95781	100643	132723

3.3 HLZ ecosystem vertical distribution pattern

HLZ ecosystem vertical distribution pattern (table 2) can be calculated in terms of DEM data and HLZ Ecosystem spatial distribution data during the periods from C1 to C4, which shows that the average elevation of nival, alpine, and boreal distribution have continuously increased. The average elevation increasing rate (17.7m per decade) of the boreal wet forest is the fastest, the alpine rain tundra is the second fast (6.3m per decade), and other alpine and boreal HLZ ecosystem types is relative slow (about 3.0m per decade).

Table 2 Vertical distribution pattern of HLZ ecosystem in Loess Plateau of China (Unit: meter)

HLZ ecosystem type	C1	C2	C3	C4
Nival	4087.480	4080.600	4111.640	4216.770
Alpine moist tundra	3597.490	3580.920	3642.720	3745.260
Alpine rain tundra	3607.390	3613.350	3655.880	3858.370
Boreal dry scrub	2632.050	2606.200	2644.220	
Boreal moist forest	2910.890	2833.290	2887.720	3032.190
Boreal wet forest	2649.620	2677.960	2801.730	3357.110
Boreal rain forest	3192.640	3164.110	3365.670	
Desert	1050.440	1055.040	1048.810	1065.050
Cool temperate scrub	1290.620	1293.880	1317.820	1358.350
Cool temperate steppe	1424.120	1426.230	1410.530	1442.840
Cool temperate moist forest	1509.610	1498.760	1599.700	1822.980
Cool temperate wet forest	2231.340	2191.960	2330.150	2561.610
Warm temperate desert scrub	1057.910	1042.030	1053.330	1117.180
Warm temperate thorn steppe	1349.430	1350.100	1349.200	1197.880
Warm temperate dry forest	684.575	689.243	737.383	861.279

4. Discussion

Results from operating HLZ ecosystem model and the elevation of vertical distribution spatial statistic show that the number of average elevation decreasing HLZ ecosystem types gradually decreased: from C1 to C2, the number is 8; from C2 to C3, the number is 3; and from C3 to C4, only warm temperate thorn steppe's average elevation decreased. Such changing trend indicated that vertical distribution boundaries of climate-vegetation types in Loess Plateau of China moved in the direction of high altitude. Furthermore, those Climate-vegetation types with decreasing area and increasing elevation, such as nival and alpine wet tundra, shrunk in the direction of high altitude, while Climate-vegetation types with increasing area and increasing elevation, such as warm temperate dry forest, replaced types adapted to more cool biotemperature and extended to high altitude region. By integrated analyzing upper bound and lower bound of each HLZ ecosystem, we can find the vertical distribution changing trend and area changing trend of every type are coherent. That is to say, in most cases, if one type's area shrink, its' vertical distribution range will also shrink. These analysis results indicate the quantitative analysis of climate change impacting on vegetation ecosystem will afford the efficient data to support the implement of reasonability ecological restoration project.

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