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Variations of plant life form diversity along the Northeast China Transect and its direct gradient analysis

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Abstract: Plant life form diversity and its direct gradient analysis on a larger scale climate change gradient were tested, based on the data from Northeast China Transect platform. The results showed that the species numbers, life form richness and life form diversity were relative higher at the eastern forests and the ecotone between typical vegetation, while those on the meadow grasslands and typical steppes were lower. Although plant life forms can reflect the climate variations, life form diversity is not consistent with the major global gradient along the NECT.
Keywords: northeast China transect; plant life form diversity; ecotone; gradient analysis

Introduction

Life form has been used extensively as a major means to compare vegetation types (Li, 1978; Jiang 1994), community structures (Wang, 1996), response of vegetation to climate change (Jiang, 1998; Guo, 1999). Some have tested the responses of plant life form to grassland deterioration (Wang, 1998). However, none has looked at the variations of plant life form along the terrestrial transects and its direct gradient analysis.

The Northeast China Transect (NECT), identified as a mid-latitude semi-terrestrial transect by the global change and terrestrial ecosystems (GCTE), runs in parallel to 43°30′N, ranging from 42° to 46°N and from 111° to 131°E (Zhang, 1997; Ni, 2000). The studies on the plant life form have been conducted at a numbers of vegetation types within and in the vicinity of the NECT, including forest at Changbai mountains (Jiang, 1998; Guo, 1999), meadow grassland (Li, 1978; Wang, 1998), forest at north China (Jiang, 1994; Guo, 1999). However, none has tested the variations of plant life form along the Northeast China Transect and its response to large-scale climate change. The objectives of the study were to investigate the variations of plant life form and its response to climate change along the NECT. This study is highly relevant to a better understanding of the global climate changes and geographic influences on plant life form.

1 Material and methods

1.1 Study sites

The NECT runs in parallel to 43°30′N, ranging from 42° to 46°N and 111° to 131°E in northeast China, about 1600 km in length and 300 km in width (Zhang, 1997). Due to the steep gradients of precipitation and elevation from the west to the east, vegetation vary gradually from desert grasslands and typical steppes in the west to temperature conifer-broadleaf mixed forests, deciduous broadleaf forests, and shrubs and woods in the east, with meadow grasslands in the middle (Zhang, 1997; Ni, 2000). The temperature conifer-broadleaf mixed forests, deciduous broadleaf forests, and shrubs and woods have dark-brown forest soil. Most of the meadow grasslands have dark brown soil, saline meadow soil and chestnut, while those of the typical steppes and desert grasslands have chernozem, chestnut and sandy loam in the west. The elevation gradient long the NECT was also steep, ranging from 140m in the middle to 1000m in

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the east and 1700m in the west(Ni, 2000).

1.2 Climate

The main determinants of the climate in northeastern China are the Mongolian anticyclone and moist Pacific air mass. In winter, the northeastern China is dominated by an intense Mongolian anticyclone (Domros, 1988). The steep pressure gradient between this high and the Aleutian low-pressure system produces a strong westerly flow of cold, dry continental air, at the surface, over northeast China. As the anticyclone breaks down in spring, the region comes increasingly under the influence of moist Pacific air mass, reaching a climax in the summer monsoon, which lasts two months. As the summer draws to the end, the low pressure area over the Indo-Pakistan subcontinent disappears with the development of the Mongolian anticyclone. The mean annual air temperature ranges from 1.4℃ to 5.9℃, varying from -21℃ in January to 23℃ in July.

Moisture gradient is very steep, with annual precipitation varying from 100—300 mm in the west to 600—1000 mm in the east along the NECT. Precipitation is not distributed evenly over growing season, of which 70% falls between June and August in this region. A more detail description of the climate of northeastern China and NECT may be found in Ripley *et al*. (Ripley, 1996) and Ni and Zhang(Ni, 2000).

1.3 Methods

The experiment was conducted in 1997 and 2000 along the NECT. 29 typical vegetation were selected for sample plots. The sampling area of each quadrat is 20m × 30m for forests, 2m × 2m for shrub woodlands and 1m × 1m for grasslands, with 6—10 replicates for each typical vegetation. The numbers of species and life form types at each quadrat were recorded. Plant life form is classed into macrophanerophyte (M), nanophanerophyte(N), chamaephyte(Ch), hemicrryptophyte(H), geophyte(G), therophyte(Th), based on Raunkiaer(Jiang, 1998) and Li(Li, 1979). The locations and elevations of each sampling area were measured by using GPS (Magellen™ Systems Corporation). Climate data were taken from the Climate Database of Laboratory of Quantitative Vegetation Ecology, Institute of Botany, Chinese Academy of Sciences, and some from the local weather stations throughout the NECT.

1.4 Data analysis

Plant life form richness(R) was calculated using Margalef's (1958) index:

$$R = \frac{S-1}{\ln N}, \tag{1}$$

where N is the number of species in the sampling area and S is the number of plant life form types.

Plant life form diversity(H) was calculated using the Shannon-Wiener index(Wang, 1997):

$$H = -\sum_{i=1}^{S} p_i \cdot \ln p_i, \tag{2}$$

where p_i is proportion of all species in the sampling area that belong to life form i, and s is the number of life form types.

Regressions of diversity parameters, e.g. species numbers, life form richness(R), diversity(H), against longitude or climate data, e.g. monthly and annual precipitation, monthly average and annual temperature, aridity index, elevation, were performed using Excel for Windows 98, in order to explain the spatial variations of plant life form along the NECT.

2 Results

2.1 Species numbers and life form types

Species numbers varied remarked from the east to the west along the NECT(Fig. 1). Eastern forests (128—131°) and the ecotone between farming region and typical steppe(115—117°) have the highest species numbers, while the meadow grasslands have the lowest, which is only about 1/3 of the former.

However, the species numbers at ecotone between the eastern forests and farming region (124—126°) were relatively lower, which is about 60% of the eastern forest. Species numbers at typical steppes and desert grasslands(111—114°) were relatively higher than those at meadow grasslands, even these regions were driest along the NECT.

The variations of life form categories were significant along the NECT (Fig. 2), due to the steep climate gradient. Hemicrryptophyte has the highest averaging percentage(48.48%), which can be as high as 70% at the meadow grasslands, followed by chamaephyte (19.01%), geophyte (17.11%), nanophanerophyte (6.51%), therophyte (5.02%) and macrophanerophyte (3.80%). Macrophanerophyta was mainly occurred at the eastern end of the NECT, while the nanophanerophyte was distributed at the two ends of the NECT. The percentage of the therophyte was relative lower, even human disturbances were intense the along the NECT.

Eastern forest regions have highest number of life form types, averaging 5.14 types, followed by typical steppes and desert grasslands (4.5). However, the meadow grasslands in the middle of the NECT have the lowest number of life form types (3.3), which is about 64% of those at the forest regions(Fig.3). The regressions of species number and the numbers of life form types against climatic variability(e. g. precipitation, temperature, aridity index) and geographic changes(e. g. longitude, elevation) were not significant, but that between the numbers of life form types and species numbers was significantly(Fig.3).

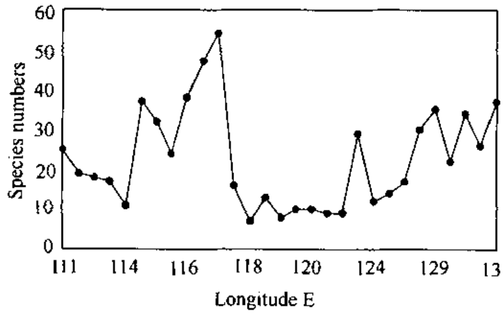

Fig.1 The variations of species number of the sampling sites along the NECT

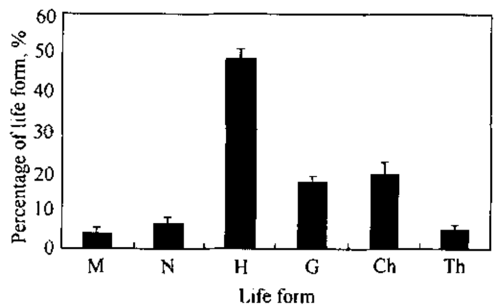

Fig.2 The average percentage of plant life form types along the NECT
M = macrophanerophyte; N = nanophanerophyte; H = hemicrryptophyte; G = geophyte; Ch = chamaephyte; Th = therophyte

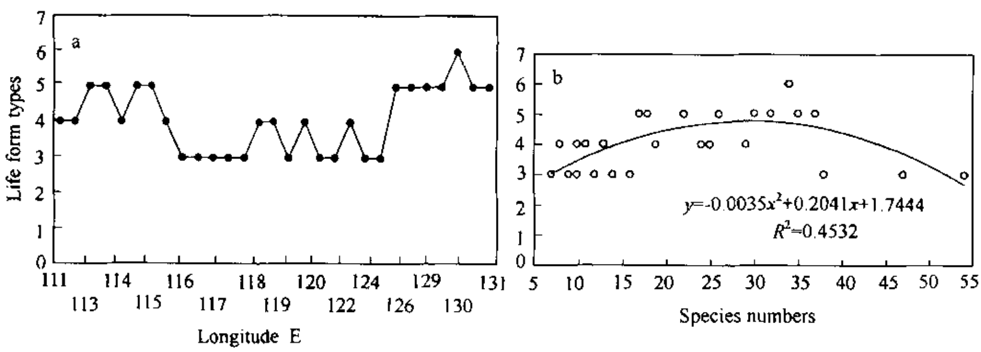

Fig.3 The variations of plant life form types along the NECT(a) and its relations with species numbers(b)

2.2 Life form diversity

Plant life form richness (R) varied significant along the NECT, due to geographic and climatic changes(Fig.4). The region between typical steppe and Kerqin Desert(119°) has the highest R (1.44), followed by 113 site(1.42), 126° site(1.41) and 130° site(1.38). The typical steppes and meadow grasslands have the lowest R (0.52 and 0.82), which are about 36% and 57% of the highest. Plant life form richness was statistically significant related with elevation along the NECT, varying as model:

$$R = 0.000006A^2 + 0.0014A + 0.79 \ (P < 0.05,\ n = 29), \quad (3)$$

where R is the plant life form richness, A is the elevation(m above sea level).

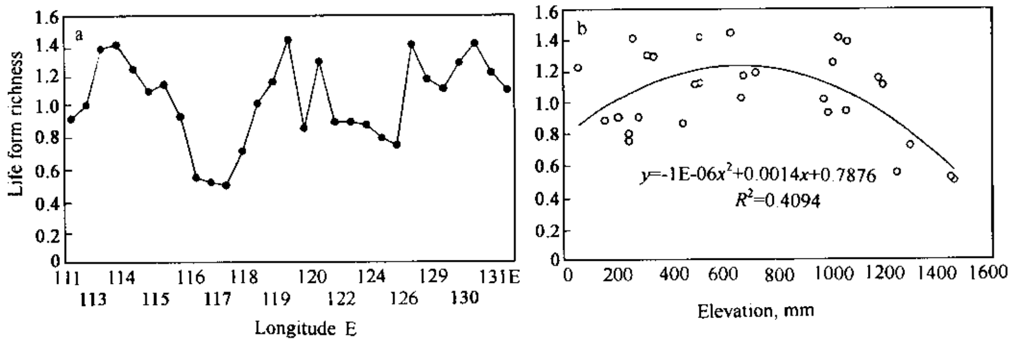

Fig.4 The variations of life form richness along the NECT(a) and its relations with site elevations(m, a.s.l)(b)

Like that of life form richness, plant life form diversity(H) varied considerably with the climatic and geographic changes along the NECT. The site at eastern forests(130°) have the highest life form diversity (1.54), while the typical steppe site(117°) have the lowest H(0.60), which is only about 2/5 of the highest(Fig.5). The life form diversities of ecotones of typical steppes-desert grasslands(113—115°), typical steppes——Kerqin Deserts(119—120°), meadow grasslands—eastern forests (126—128°), are also relative higher. Life form diversities at the two ends of NECT were significantly higher than those at the middle grasslands. Life form diversities were significantly related with longitude and first half year precipitation(Fig.5).

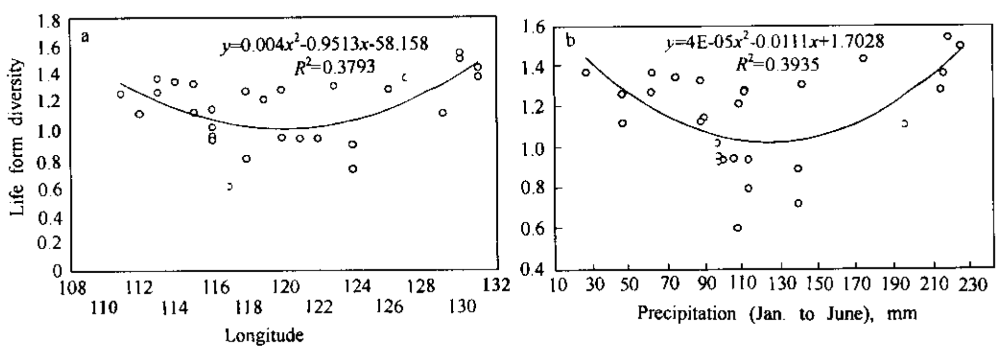

Fig.5 The variations of life form diversity along the NECT(a) and its relations with the first precipitation(b)

3 Discussion

Climate and geography changes are known to affect plant distribution and plant life form through the variable of precipitation and temperature(Li, 1979; Jiang, 1998; Guo, 1999). But the parameters of species numbers and life form diversity along the NECT are not always consistent with changes of climate and geography. Species numbers and life form diversity vary as nonlinearity models, even the precipitation decrease from the east to the west along the NECT. High species numbers and life form types at forest regions in the eastern end of the NECT are mainly due to the high moisture(Jiang, 1998; Guo, 1999). The annual precipitation in the eastern mountain forestry region is more than 1000 mm, while that in the western desert grasslands is no more than 200 mm(Zhang, 1997; Ni, 2000). Higher species numbers and life form types at the ecotones are mainly due to the species crisscross distribution of adjacent typical vegetation, e. g. typical steppe——Kerqin Desert (117 – 118°). Well developed rhizome systems and root of the dominant grasses at meadow grasslands, e. g. *Leymus chinensis* and *Stipa spp*, limit the other species distribution and establishment and result in lower species numbers and life form types at this regions(Li, 1978).

The variations of species diversity along the NECT are also not consistent with climate changes, even the moisture gradient is steep. But life form richness is significantly related with elevation(Fig.4). This indicates numbers of life form types decrease with the increasing of elevation at eastern mountains and western high Inner Mongolian Plateau. Low life form richness at meadow grasslands and topical steppes are mainly due to the limiting of hemicrryptophyte plants, e.g. rhizome grasses(Li, 1978). Hemicrryptophyta was the dominant life form type at the meadow grassland and typical steppe, which is about 60 % of the total species numbers(Li, 1979; Wang, 1996). Less life form types result in low life form diversity and evenness at those grassland regions. Ecotone regions, however, have relative high life form richness and diversities, this is may be explained by species crisscross distribution of adjacent typical vegetation. The relative high life form diversities at western NECT is mainly due to some shrub species distribution at the desert grasslands. Although life form can reflect the climate changes, life form diversity is not always consistent with the major global gradient (moisture) along the NECT.

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