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Stability of alpine timberline ecotone on Taibai Mountain, China*

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Abstract—Landscape boundaries are always indicated by the vegetation boundaries. As an ecotone between closed forest and treeline, alpine timberline may respond to global climate changes sensitively. The stability of timberline and treeline depend not only on climate change, but also on the interaction of both sides of the ecosystems. Three natural boundaries existing in the timberline transitional zone are recognized: (1) timberline (upper limit of closed forest zone); (2) treeline (upper limit of tree islands zone); (3) tree-species line (upper limit of individual tree growth). Paleobotanical and sedimentary evidences suggest that there were several times of climate fluctuation during the Holocene period in this area. The timberline of Taibai Mountain must have moved for four times on the millennium scale. Being a stochastic oscillation boundary, treeline appears in a semi-stable condition on the century scale. The tree-species line is even more unstable, which appears in an unstable status on the decades scale. The comparison of the stability within several landscape boundaries, shed light on the sensibility of these communities to various perturbation and environmental heterogeneity, i.e., herb community is the most sensitive one, which is followed by shrubs, and forest is the most stable one. Trees and shrubs can adapt to rocky and poor soils. On the contrary, alpine herbs are able to adapt to wetter and cooler soils. Finally, under a scenario of a temperature of 1.5—4.5℃ increase, the present timberline will be relatively stable but treeline and tree-species line will move upward.

Keywords: landscape boundaries, stability, alpine timberline.

1 Introduction

Taibai Mountain, which extends from 33°49′31″ to 34°08′11″N and from 107°41′23″ to 107°51′40″E, is the highest peak of Qinling Range. It is also an important boundary between subtropical and temperate zones in China. The present timberline of Taibai Mountain situates at 3400m and 3300m altitude on the south and north slopes respectively. The maximum glaciation occurred between 2800m and 3000m altitude in the Late Glacial Period (Shi, 1989). Thus, the altitude of present timberline is about 400m higher than most of the lower boundaries of glaciation. Being an ecotone between closed forest and treeline, alpine timberline may be sensitive to global climate changes. This may be one of the reasons why ecologists are paying more and more attention to it recently.

We have observed the timberline and treeline on Taibai Mountain for more than two years, in an attempt to explain their dynamics on landscape scales.

2 Determination of landscape boundaries

It is well known that the landscape boundaries are often indicated by vegetation boundaries. Based on TWINAPAN classification and DCA ordination, 153 plant plots are divided into 5 community types as the following (Fig.1): (1) closed forest (mainly consists of *Larix chinensis*); (2) subalpine shrub; (3) subalpine shrub-meadow; (4) marsh meadow; (5) alpine meadow.

Landscape boundaries are often demarcated by biodiversity index, which vary along with the elevation gradient. There are three peak values on the curve of relationship between Whittaker Index and altitude (Fig.2). As a result, three natural boundaries existing in the timberline transitional zone are recognized: (1) timberline (upper limit of closed forest zone); (2) treeline (upper limit of tree island zone); (3) tree species line (upper limit of individual tree growth).

The sharpness of these three boundaries are quite different, as the upper limit of closed forest zone appears very sharply, which is situated at about 3400m altitude; and that of tree island zone

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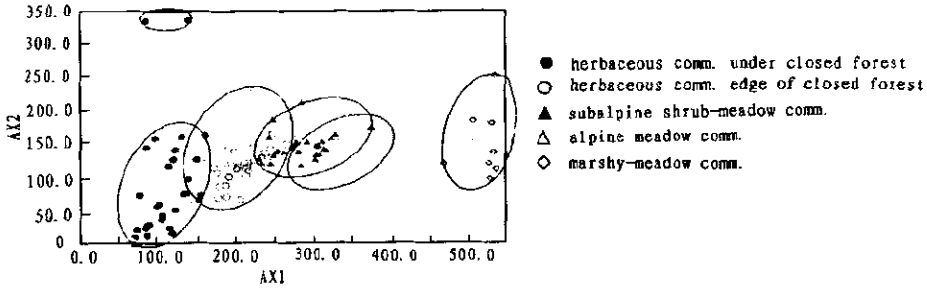

Fig.1 The DCA ordination result

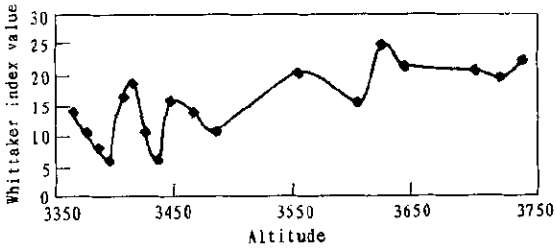

Fig.2 The relationship between Whittaker Index value and altitude

appears gradually, forming a line by forest patchs, which can extend to an altitude of 3500m; the upper limit of tree species line is obscure, which is close to 3600m altitude.

3 Events of timberline ecotone dynamics

The stability of timberline depends much on past climate than on that of present. According to the curve showing the relationship between present trees' age and the altitude, the timberline of south slope of Taibai Mountain seems to maintain its stability on century scale, from late 16th century to late 19th century (Fig.3). These trees may have established during the optimum period for a few hundred years (Tong, 1996).

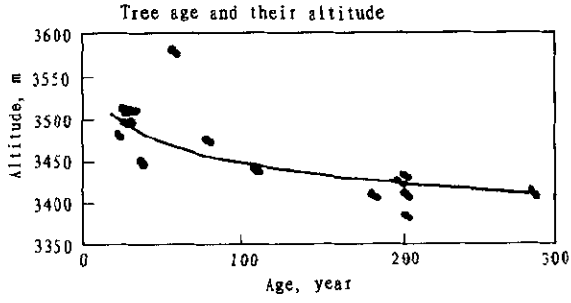

Fig.3 Relationship between trees' age and altitudes

Trees near the treeline have established since early this century, but old trees are seen rarely here.

The uppermost site of tree growth is 3710m altitude, and there is only a 25-year-old tree living there.

4 Factors influencing the stability of timberline and treeline

There are various factors to influence landscape boundaries, such as time scale of climate change, topography and surface characters, functional types of dominate species and their interaction, as well as disturbance intention. We just emphasis on three points as the following.

4.1 Time scale of climate changes

Climate change may occur on different time scales. Paleobotanical remains and sedimentary evidences suggest that there were seven times of climate fluctuation during the Holocene in this area. And the timberline of Taibai Mountain must have moved upward and downward alternately

for 4 times on the millennium scale (Tian, 1990).

On the century scale, the favorable climate takes a gradual turn. Six times temperature fluctuations have taken place since 11th century. Temperature raised in 1030, 1220 and 1820, but dropped during period of 1070—1140, 1420—1460 and 1840—1920. The timberline may extend upward slightly during the past few hundred years. But the treeline fluctuates well along with climate change. And tree islands patches also displays their dynamics; in the mean time, the composition of communities also change (Tong, 1996).

On present decade scale, climate fluctuates less than in the past period, which can be reflected in Fig. 4 by tree-rings fluctuations. The comparison between relative tree-ring width variation and the temperature fluctuation show that the two correspond well or the latter lags a little. For with the growth of trees, the upper limit of tree species will be, of course, disturbed by current climate. And the seedling establishment by conifers above tree limit is occurring on a basis more than occasional one (Daly, 1985).

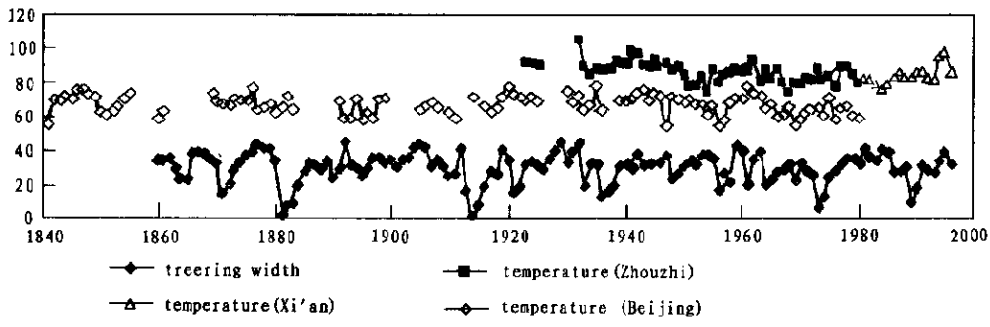

Fig. 4 Comparison between the tree-ring width and the temperature in the past 138a

4.2 Topography and surface character

As is well known, alpine zone has obvious remains of glaciation, such as horn peak, "U" shaped valley, and periglacial, such as rocky slope, stone sea and so on. The rocky surface can delay the soil formation and keep vegetation in its primary stage of succession for a fairly long time. Larch is a pioneer tree species occupying the stone sea or stone river areas frequently, but, in contrast, herbs grow in areas with fine soil. Since environmental heterogeneity may influence the landscape structure strongly, thus the timberline ecotone appears mosaic and zigzag shapes.

4.3 Functional types and their interaction

According to whether the species use the shared resources in the same way, or respond to the disturbance by the same mechanism, the species can be grouped into different functional groups. We use multivariate analysis method to cluster the species appearing in the area according to a set of characters. The result shows that plants with different life forms and different functional groups in high elevation have different ecological amplitudes, so these species may show different responding types to climate change, and different capability to adapt to the environment and to compete with other species. On the other hand, the ordination result also shows the relationship between different ecological species groups and their environment. The soil temperature will drop in higher altitude, while the moisture condition may change to favorable ones under the same basis. Ax_1 axis in DCA ordination shows that the response sensitivity of different functional groups to soil temperatures decrease with the increase of elevation (Fig. 1). As a result, some herb species such as *Deschampsia caspitosa*, *Coluria purdomii*, *Aster flacidus*, *Polygonum sphaerostachyum*, *Kobresia graminifolia* etc. can grow well in cold marsh-meadow or alpine meadow. That is to say, the alpine meadow due to their suitability for cold conditions grow in high elevation while

some species of alpine meadow, sub-alpine meadow, meadow of edge forest and herbs under forest occur in lower elevation as they are suitable for relative warmth.

Some dominant shrubs on alpine zone can also show an increasing gradient tolerability with the increase altitude. Therefore the shrubs there can be divided into two groups: the alpine shrubs and sub-alpine shrubs. The former ones are characterized by stolon, and can survive in the environment with strong winds, very low temperature and snow cover, they are mainly consists of the following species: *Salix cupularis*, *Rhododendron capitatum*, *Spiraea alpina* and so on. On the other hand, the latter ones are characterized by their straight-form stems, and thus grow in parts with relative lower elevation. For example, *Lonicera hispida* and *Potentilla glabra* can not tolerate very harsh condition, and thus they grow in sub-alpine zone.

Furthermore, different kind of functional group species can display different characteristics when adapting to water or moisture content. Herbs can make the best utilization of the water inside upper soil layer, while trees usually use water in deep layers. It is found on alpine and sub-alpine of Taibai Mountain that there is water flowing under stone sea or stone river, and perhaps this can explain why *Larix chinensis* trees are distributed in rocky places.

As far as the community is concerned, closed *Larix chinensis* forest and sub-alpine shrubs are all relatively stable, but the open sub-alpine shrubs can not adapt themselves to shady environment under forest. The *Larix chinensis* seedlings have to compete with dense shrubs but have little chance to succeed, and thus are distributed in rocky areas. As with the characteristic of apical dominance, *Larix chinensis* trees can not tolerate the strong-winded, low-temperature and snow-covered environment, so they show a stolon life-form in order to adapt to such harshy environment (Korner, 1998).

5 Conclusion

Ultimately, global climate change will cause the shifts of landscape boundaries on regional scale, but the process is very slow, probably will take a few hundred years.

On landscape scale, vegetation boundary's oscillation depends not only on climatic conditions, but also on the habitat conditions and the correlation between habitat and communities.

Under a scenario of a 1.5—4.5℃ temperature increase, the present timberline will be relatively stable but treeline and tree-species line will move upward.

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