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Detecting forest landscape boundary between Mountain Birch and evergreen coniferous forest in the northern slope of Changbai Mountain

CHANG Yu[1], BU Ren-cang[1], HU Yuan-man[1], XU Chong- gang[1], WANG Qing-li[2]

(1. Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang 110016, China. E-mail: lndscp@iae.ac.cn; 2. Shenyang Branch, CAS)

Abstract: Boundaries between different forest types in Changbai Mountain Eastern China are results from complex interactions between forest ecosystems, topography, and geomorphology. Detecting and quantifying the transitional zones are highly important since high environmental heterogeneity and biodiversity are often found within these zones. In this study, we used GIS and multivariate statistics techniques (PCA and MSWA) to analyze data from Landsat TM satellite imageries and quantitatively determined the positions and widths of the landscape boundary between mountain birch and evergreen coniferous forests in the northern slope of Changbai Mountain. The results showed that the widths of the landscape boundary ranges from 30—50m while using the MSWA or/and PC method. Such detected widths are consistent with field transect data that suggests a 50m transitional zone width. The results further suggest that TM data can be used in combination with GIS and statistical techniques in determining forest landscape boundaries; MSWA is more reliable than PCA, while PCA can also be used to determine the landscape boundary when transects are properly located.

Keywords: Changbai Mountain; forest landscape boundary; PCA & MSWA

Introduction

Landscape boundaries, or transitional zones/ecotones among different landscapes, have often been ignored or reduced to lines on a map when ecologists studied. However landscape boundaries are inherent features of landscapes and play important roles in ecosystems dynamics. For an example, high biodiversity is often found in landscape boundaries (Karv, 1999; Juge, 1997; Gottfried, 1998). In addition, changes of their location can be used as an indicator of climatic changes (Kupfer, 1996). For these reasons, landscape boundaries have recently become a focus of investigations in landscape ecology (Gosz, 1993; Fortin, 1996) and global climatic changes (Taylor, 1995; Hessl, 1997a; Mast, 1998; Malanson, 1997). As interest in landscape boundaries increases, there is increased need for formal methods to detect them (Fortin, 1994; 1995). But it is difficult to quantitatively detect landscape boundaries due to their complexity. Landscape boundaries are the results from complex interactions between ecosystems, topography, and geomorphology. In this paper, we use GIS, RS, GPS and multivariate statistics methods (PCA and MSWA) combined with field investigation to quantitatively determine the position and width of boundary between mountain birch and evergreen coniferous forest in the northern slope of Changbai Mountain to (1) provide a case study; (2) present a kind of method in detecting landscape boundary; and (3) test the feasibility of using TM image to determine landscape boundary.

1 Data source and process

The data derived from the field investigation (length of transect is 510m and width 2m) in Changbai Mountain in August 2000. They were rendered in terms of "sample plot × species", and transformed into a matrix according to the importance value of species in each sample plot. Size of the matrix is 102 by 100.

The TM image on sep. 4th 1997 (7 bands). We first selected 49 control points from topographic maps, getting the coordinates of Gaussian Krieg Projection, and then used the RS image processing software (Ermaper 5.5) to calibrate. Second, the coordinates on transect, which was got by GPS, were transformed into Transverse Mercarto Projection coordinates. Thus, the transect data could be matched with the image data. Finally, the image traverse data on transect, namely the TM data of seven bands, were extracted by Ermapper. Because of the relationships between the data of seven bands, we used PCA (principal component analysis) to minimize the dimension. By this way, two principal components were got for further analysis.

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2 Methods

The transect data and RS data were analyzed by MSWA (Moving Split-window Analysis) and PCA respectively.

MSWA, a classical method of one dimension value analysis, was first used by Whittaker (Whittaker, 1960) to analyze the distribution of vegetation by moisture and slope. Later, it was applied to the classification of soil (Webster, 1973; 1978). It was also the most effective method to analyze landscape boundary. The usage of this method is as follows:

First, put two windows on the even-interval samples (the number of samples among one of the windows equals to the other), and compare the dissimilarity of the samples in the two half windows; second, move the window backward by a sample until all the samples on the transect are used.

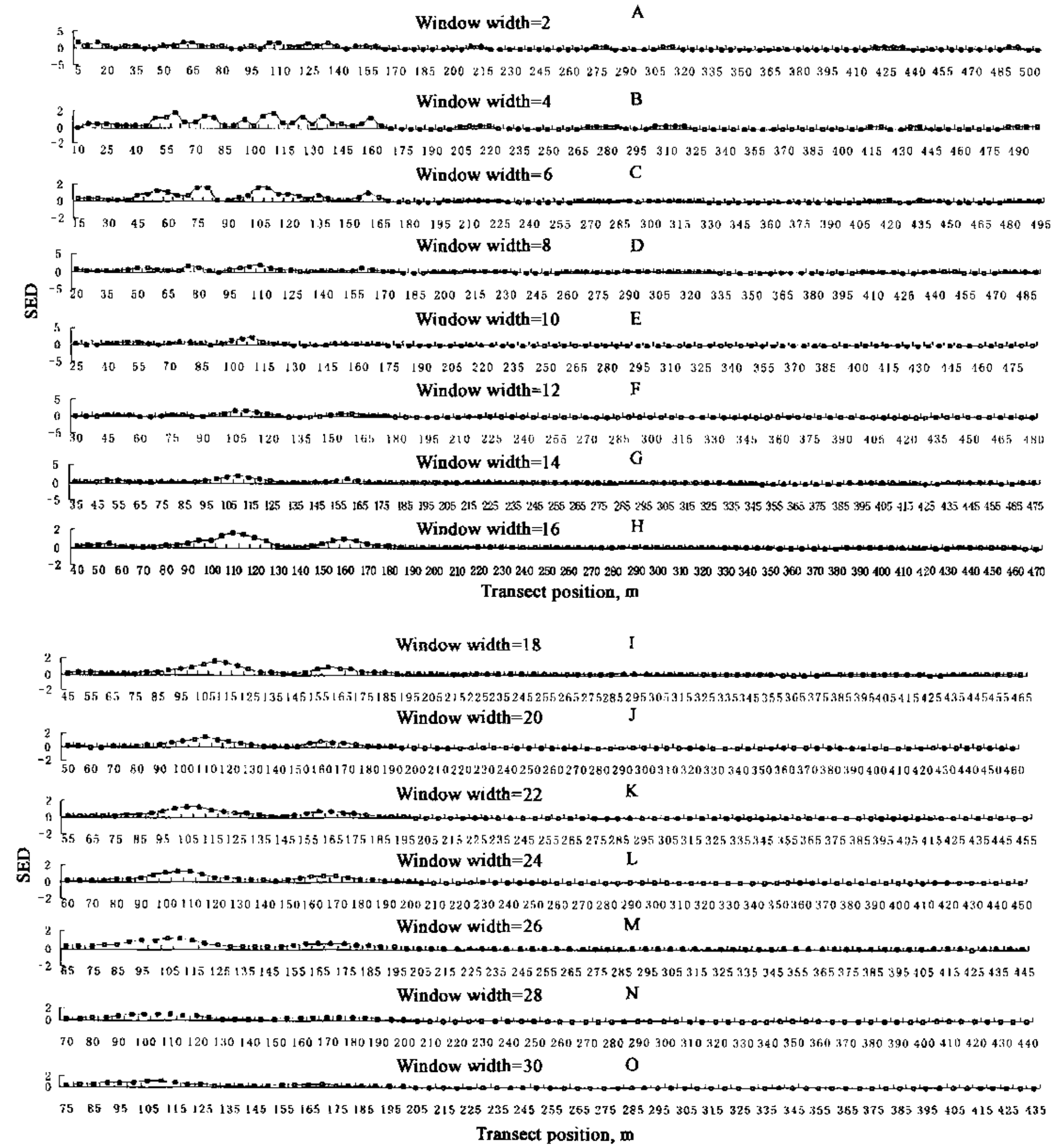

Fig. 1 *Betula ermanii*/evergreen coniferous forest boundary determination by moving split-windows method with transect data. From A to O, the window's width is from 2 to 30 respectively

There are a lot of methods to calculate the dissimilarity. Because the results got by SED (Square euclidean distance) were compatible with field observation(Wierenga, 1987), it is the most commonly used method. The formula of this index is as follows:

$$SED_n = \sum_{i=1}^{m} (\bar{x}_{iaw} - x_{ibw})^2,$$

where n represents the midpoint of the two half-windows or the stop point of the window, a and b represent the two half-windows respectively, w denotes the width of the window, while m stands for the variable numbers of each sample plot(Brunt, 1990; Turner, 1991).

According to the graph plotted by SED as ordinate and the position of transect as abscissa in Cartesian coordinates, we can determine the condition of landscape boundary by the change of the slope. Higher and narrower peaks denote abrupt landscape boundary, while lower and wider peaks denotes gradual landscape boundary.

3 Results

3.1 Moving-split-window analysis

3.1.1 Transect data

The width of each window is assigned 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28 and 30 respectively. We calculated the dissimilarity between the two half-windows, and then plotted the graph by SED as ordinate and transect position as abscissa (Fig.1).

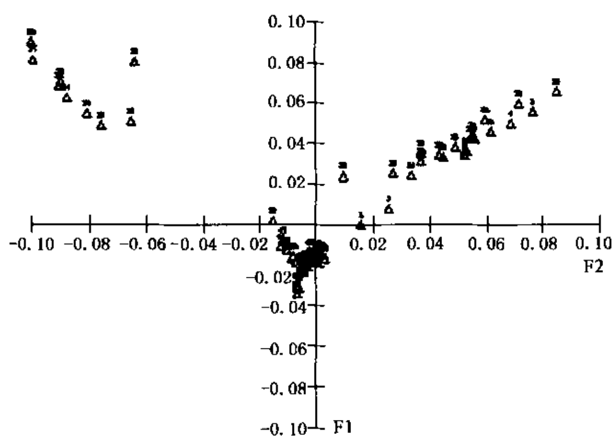

Fig 2 Ordination of sample plots along the transect by PCA

The figure shows that: when the width of window reaches 14, the change of the graph tends to be stable. Combined with the outcome of field investigation and PCA (Fig.2), we conclude that the boundary between mountain birch and evergreen coniferous forest falls in between the two peaks, from 110m to 160m. That is to say that the width of boundary is 50m.

When the window width is less than 14, due to the effect of difference between plant communities in ecosystem, the peaks on landscape boundary is not very obvious. Thus, the spatial scale in studying the boundary between mountain birch and evergreen coniferous forest in northern slope of Changbai Mountain should be greater than 35m.

3.1.2 RS data

Extracting the 7 bands data on the TM image in 1997 on the transect. Result by MSWA (Fig.3) shows that when the window width equals to 6, there is a relatively obvious peak on the curve where the boundary between the mountain birch and evergreen coniferous forest lies. We can also conclude that the width is about 2-pixel width(60m) which proximately equals to the result of field investigation. From above, we can draw a conclusion that the remote sensing technology can be used to determine the landscape boundary.

3.2 Principal component analysis(PCA)

3.2.1 Transect data

The importance value data on the boundary between mountain birch and evergreen coniferous forest are processed by PCA, the six most important principal components are shown in Table 1. We use the first two components to draw scatter map of the sample plots(Fig.2).

According to Fig. 2, the sample plots can be easily divided into three groups. Group 1 includes sample plots 1—22; group 2 includes sample plots 23—32(excluding sample plot 28); group 3 includes sample plots 33—102. Group 1 belongs to mountain birch. Group 2 belongs to boundary between mountain birch and evergreen coniferous forest. Group 3 belongs to evergreen coniferous forest. The ordination utterly corresponds with the field observation. According to this, we conclude that the position of the boundary between mountain birch and evergreen coniferous forest lies in between 110m and 160m on transect. That means the width of the boundary between mountain birch and evergreen coniferous forest is 50m.

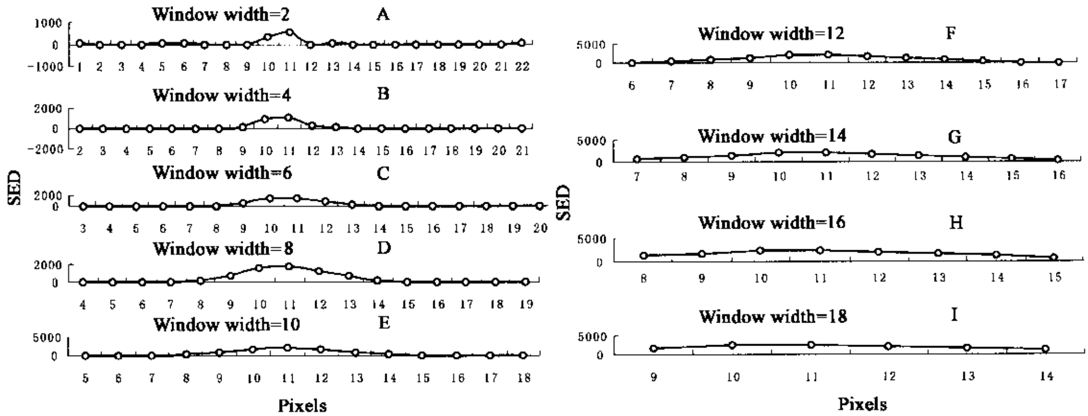

Fig.3 *Betula ermanii*/evergreen coniferous forest boundary determination by moving split-windows method with remote sensed data. From A to I, the window's width is from 2 to 18 respectively

3.2.2 RS data

The transect coordinates got by GPS is adjusted through projection transform to match the TM image coordinates which has been geometrically corrected. Then using RS image processing software, we extract the RS data of seven bands on transect. By PCA, we get the first two components.

Table 1 Eigenvalues, percentage and cumulative percentage of transect data in the boundary between *Betula ermanii* and evergreen coniferous forest

Principal component	F1	F2	F3	F4	F5	F6
Eigenvalues	0.114	0.099	0.032	0.020	0.015	0.012
Percentage	30.168	26.271	80572	5.308	3.973	3.286
Cumulative percentage	30.168	56.439	65.011	70.318	74.291	77.577

The ordination of the pixels of the first two principal components is shown in Fig.4. According to the figure, all pixels can be divided into 3 groups. The group on the left belongs to evergreen coniferous forest; the group on the right belongs to mountain birch, while the middle group belongs to the boundary between the above two. From this, we can initially conclude that the width of boundary between mountain birch and evergreen coniferous forest is 30m. The result is lower than that from transect data.

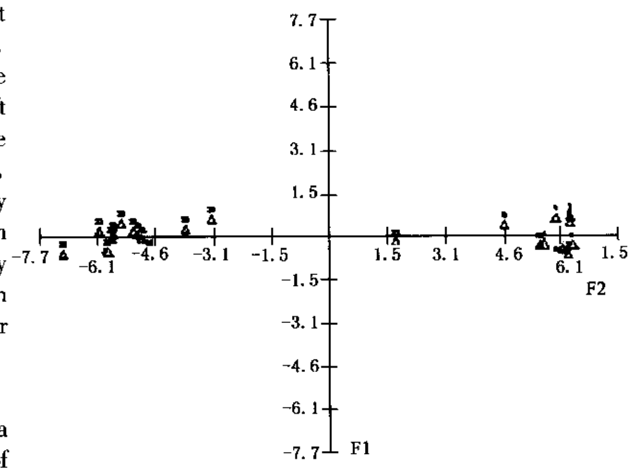

Fig.4 Ordination of pixels along transect line by PCA

4 Conclusions

The respective analysis of transects data and RS data by MSWA shows that the width of the boundary between mountain birch and evergreen coniferous forest is 50m by transect data, 60m by RS data. The results of PCA shows that the width is 50m by transect data, and 30m by RS data.

The results got from transect data and RS data by MSWA are on the whole compatible with each other, which demonstrate the feasibility of the application of RS data in the determination of the landscape boundary width. In contrast with PCA, MSWA is more reliable.

PCA can also be used to quantitatively determine the width of landscape boundary when transect lines are properly located, but the results got from RS data is relatively lower.

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