DISCRIMINATION SOIL SALINIZATION DISTRIBUTION IN THE MIDDLE REGION OF HEIHE RIVER BASIN USING TM DATA

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ABSTRACT

A preliminary study has been conducted to test the effectiveness of the stepwise canonical discriminant approach to making spatial discrimination of salt-affected soil surfaces, using the Landsat TM data taken in the middle reaches of the Heihe River, China. We regard a saline area as being composed of salt-affected patches differ in degree and try to make discrimination of salt-affected soil surfaces by stepwise canonical discriminant approach. Five indices (*B*4, *Wetness*, SI, NDSI, Fe_2O_3) were selected as discriminating variables, and two canonical discriminant functions (y_1, y_2) were determined for the three groups using these five discriminating variables. When group centroids and individual cases were plotted on the plane determined by two canonical discriminant functions y_1 and y_2, the groups were quite distinct and their centroids were well separated. These results suggest that the stepwise canonical discriminant approach is promising for spatial discrimination of salt-affected soil surfaces.

Keywords**—**Stepwise Canonical discriminant approach, Heihe River, Landsat TM data, Soil salinization

1 INTRODUCTION

Soil salinity influences soil properties and cause land degradation and the reduction of productivity of agricultural areas. The development of effective salinity control practices requires an understanding of the causal relationship between soil and water salinization and salt formation and movement in the soil. Thus, the first step in establishing an innovation in the salinity control practices is to develop a means for assessing the degree of soil salinization and its spatial distribution easily and efficiently. Recently years, remote sensing had become an effective method in monitoring temporal and spatial changes in soil salinity. Usually, there have two methods to extract soil salinity information. One is by image processing, such as supervised or unsupervised classification[1] to obtain space distribution of soil salinity, but it needs a large number of measurement data. Another method is by incorporating the auxiliary variables such as soil salinity content, groundwater level and so on to study soil salinity distribution; however, the auxiliary variables can induce fragmentation of remote sensing image and limit classification accuracy[2]. In this study, we regard a saline area as being composed of salt-affected patches differ in degree and try to make discrimination of salt-affected soil surfaces by stepwise canonical discriminant approach using Landsat TM data.

2 MATERIALS AND METHOD

2.1 Study area and data

In the grasslands stretching around Linze, Gansu, the Lanzhou University Grassland Station and the Atmospheric

Weather Station (100°04′E, 39°15′N) is established. The study area was selected near the station (Fig.1). Climatic annual precipitation of study area is 145 mm, and annual maximum and minimum air temperature are 35.7 and -32.4, respectively. This study area is located in the middle reaches of the Heihe River, which comes from the Qilian Shan range and disappears into the Badain Jaran desert. Three 360×360 m test plots with various land surfaces, bare-soil area (strongly saline), reed area (wetland), and barley field (irrigated) were selected and delineated as shown in Fig.1.

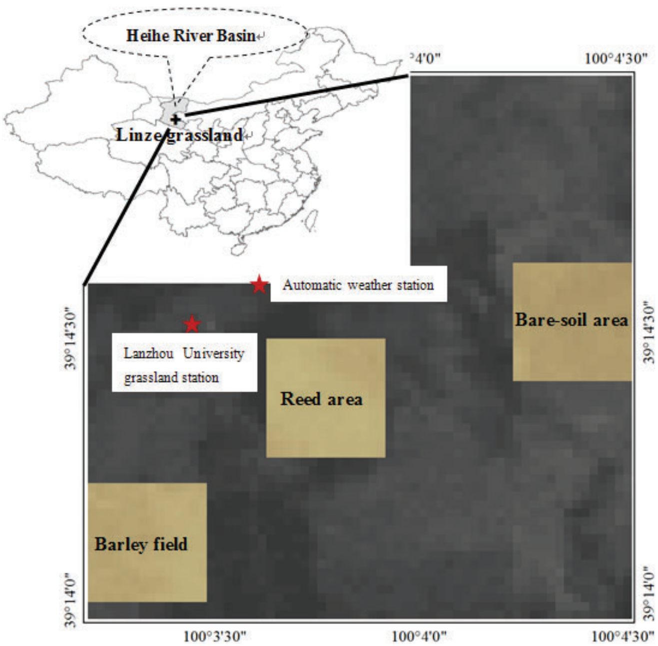

Fig.1 Study area and polygons defining three kinds of test plots (training areas)

The Landsat TM image obtained on Sep 23, 2007 was used in this study. The geometric correction was implemented so that its RMS accuracy was controlled within half a pixel. The resolution of resampled pixel was about 30 m. In atmospheric correction, the mid-latitude summer model was used as the atmospheric profile, and the rural mode of aerosol model was applied. By resampling, 157 pixel values were obtained in and around each test plot, which is called the group in the statistical analysis and hence 471 pixel values were used in this analysis.

2.2 Discriminating variables

We got five discriminating variables, that is, *B*4, *Wetness*, SI, NDSI, and Fe_2O_3 to extract salinization information.

(1) *B*4 denotes reflectance of the fourth band of TM data.

(2) *Wetness* is the third component of K-T transformation, namely tasseled-cap transformation, which is a special principal component analysis and can improve discriminant precision of salt-affected soil classification [3,4]. By K-T transformation, three feature variables can be produced. The first feature relates to soil reflectance, the second the amount of green vegetation, and the third (*Wetness*) the canopy and soil moisture.

(3&4) SI (Salinity index) and NDSI (normalized differential salinity index) can better reflect soil salinization[5]. The calculation formulas list in the following:

$$SI = \sqrt{B1 \times B3}$$

$$NDSI = (B3 - B4) / (B3 + B4)$$

(5) Fe_2O_3 is a weathering index. O_2 react with Fe^{2+} contained in original mineral forming Fe_2O_3. Under intensively weathering, Fe_2O_3 amount increase quickly, however, weathering also can cause soil salinization. In remote sensing application, the ratio of $B3/B1$ is used as substitute index for Fe_2O_3 [6].

2.3 Method

A kind of multivariate data analysis, stepwise canonical discrimination approach is applied to spatial discrimination of salt-affected soil surfaces. Based on discriminant analysis results, variables which can discriminate soil from different salinization degree clearly are introduced into the discriminant function, in contrast, those variables cannot discriminate saline soil well are deleted from discriminant function[7]. In this study, we used SPSS16.0 software to build the canonical discriminant function.

3 RESULTS AND ANALYSIS

Using 157 cases for each group and hence 471 cases in total, we retrieved two canonical discriminant functions. Table 1 shows their eigenvalues and measures of importance. The first canonical discriminant function (y_1) contains 70% of the total discriminating power in this system. Canonical correlation coefficient, which is a measure of the degree of relatedness between the groups and the function, are rather large. Thus, the two canonical discriminant functions are expected to be powerful discriminators.

Table 1 Eigenvalues and measures of importance

Canonical Discriminant Function	Eigenvalue	Relative Percentage (%)	Canonical Correlation Coefficient
y_1	4.851	70.0	0.911
y_2	2.080	30.0	0.822

Table 2 shows the standardized discriminant coefficients and within-groups structure coefficients. A structure coefficient, or a correlation coefficient between discriminating variable and a canonical discriminant function, tells us how closely the variable and the function are related. From these results it can be deduced that discriminating variables *B*4 and SI contribute mainly to y_1, while Wetness and Fe_2O_3 contribute mainly to y_2. This suggests that function y_1 reflects the “vegetation + salinity” conditions and function y_2 reflects the “soil + wetness” conditions in each pixel.

Table 2 Standardized discriminant function coefficients and within-groups structure coefficients

Discriminating Variable	Standardized Discriminant Function Coefficient		Within-groups Standardized Discriminant Structure Coefficient	
	y_1	y_2	y_1	y_2
*B*4	-0.931	1.191	**0.647**	0.586
Wetness	0.657	-0.548	0.144	**-0.612**
SI	3.833	-1.378	**0.632**	0.511
NDSI	-2.590	0.338	0.338	0.443
Fe_2O_3	0.210	0.483	-0.198	**0.640**

Figure 2 shows the two-function plot of group centroids and individual cases. The groups are quite distinct and their centroids are well separated. As ground-truth data, we have only measurements of EC_{SAT}[8] of the top soil layer (0-10cm)made at one site for each test plot on 29 June, 2011, which were 180 dS m^{-1} in “Bare-soil area”, 20 dS m^{-1} in “Reed area”, and 5 dS m^{-1} in “Barley field”. Furthermore, the TM images used in this study were obtained on Sep.23, 2007, when barley had been harvested. Thus, further study is needed to collect ground-truth data contemporaneously to validate the spectral signatures from the satellite images. However, it turns out that the power of the two functions y_1 and y_2 for discriminating salt-affected soil surfaces is promising, and y_1 seems to reflect the difference in vegetation-salinity conditions between test plots and y_2 the difference in soil-wetness conditions between them as judged from the within-groups structure coefficients above.

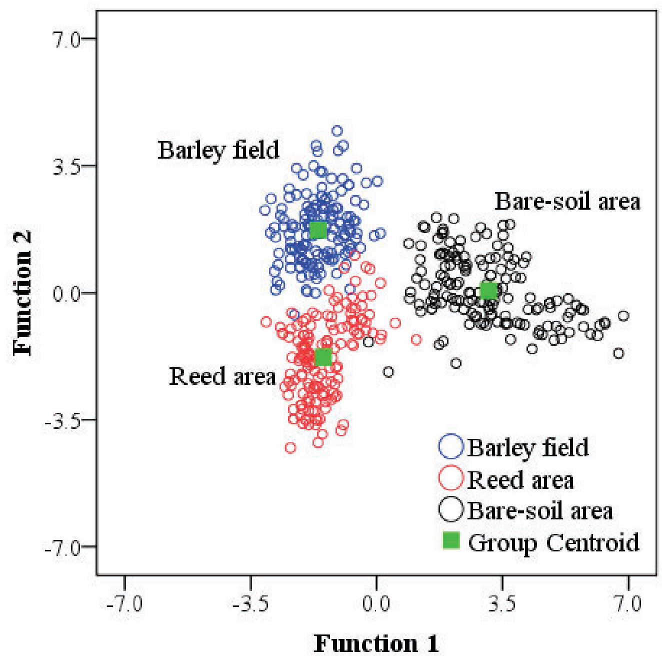

Fig.2 Two-function plot of group centroids and individual cases. Function 1 is y_1 and Function 2 is y_2.

4 CONCLUSIONS

A preliminary study has been conducted to test the effectiveness of the stepwise canonical discriminant approach to making spatial discrimination of salt-affected soil surfaces, using the Landsat TM data taken in the middle reaches of the Heihe River, China. We regard a saline area as being composed of salt-affected patches differ in degree and try to make discrimination of salt-affected soil surfaces by stepwise canonical discriminant approach. Three 360 test plots (groups) were selected as training areas. Five indices ($B4$, *Wetness*, SI, NDSI, Fe_2O_3) were selected as discriminating variables, and two canonical discriminant functions (y_1, y_2) were determined for the three groups using By stepwise canonical discriminant approach. When group centroids and individual cases were plotted on the plane determined by two canonical discriminant functions y_1 and y_2, the groups were quite distinct and their centroids were well separated. Results suggest that the canonical discriminant approach is promising for spatial discrimination of salt-affected soil surfaces; besides, further study is needed to validate the spectral signatures from the satellite images.

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