ANALYSIS OF TIME-SERIES MODIS 250M VEGETATION INDEX DATA FOR VEGETATION CLASSIFIATION IN THE WENQUAN AREA OVER THE QINGHAI-TIBET PLATEAU

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ABSTRACT

A multi-temporal analysis and statistical analysis were applied to examine vegetation index (VI) based vegetation separability based on investigation data from 99 vegetation plots sampled in 2009 and corresponding 10-year time-series of MODIS EVI and NDVI data of these plots in the Wenquan area, a transition area between permafrost and seasonally frozen soil on the eastern Qinghai-Tibet plateau. The analyses of multi-temporal VI dataset show similar phenological characteristics of all vegetation types during the entire growth season, while they have distinguishable VI values at different periods, namely germination, maturity and senescence periods. Spectral separability between every two vegetation types identified by the Jeffries–Matusita distance statistic is not significant in the growing season, indicating the vegetation classes of this study area not spectrally separable. High intra-class variability of each vegetation type is the primary cause of low separability in different growth periods.

Index Terms**—**Spectral analysis, vegetation, time domain analysis

1. INTRODUCTION

Under the influence of climate and surrounding environment, vegetation usually has clear phenological characteristics, which can be discovered by time series data derived with remote sensing methods. Remote sensed time series data offer a reliable data source to monitor and assess vegetation variations. A number of literatures [1-5] reported successful land cover classification studies at either local or global scale by using time series AVHRR data. However, the coarse spatial resolution of AVHRR data, generally 1 km or 8 km, constraints it being used in a comprehensive vegetation investigation.

The time-series MODIS 250m vegetation index (VI) datasets present some advantages over the AVHRR VI datasets including higher spatial and temporal resolutions and no charge to users, the latter might be particularly important for the work in a large study area, for example, for a vegetation investigation of the Qinghai-Tibet plateau (QTP) with an area of over 2.5 million sq km. Existing studies show that the MODIS 250m data are suitable for large scale vegetation classification mapping [6-9] with various methods developed. However, its applicability and methodology of MODIS 250m VI data for vegetation classification purpose to the Qinghai-Tibet plateau remain unclear. The purpose of this study is to investigate the applicability of the multi-temporal MODIS EVI and NDVI datasets at the 250m spatial resolution to vegetation classification in a transition area between permafrost and seasonally frozen soil known as the Wenquan area over the Qinghai-Tibet plateau. A multi-temporal analysis and statistical analysis against 10-year MODIS VI data and field investigation data from 99 plots were then conducted for this purpose.

2. STUDY AREA

The Wenquan area is located in the southeastern part of the Qinghai-Tibet plateau. Administratively, it extends across four counties, Xinghai, Maduo, Maqin and Dulan of the Qinghai province, western China (Fig.1.b). Elevations in the study area range from 3430 to 5300m above sea level, with an average of 4327m. Two high and steep mountain ranges, the Ela Mountains and Jiangluling Mountains, are situated in the study area, and are in northwest-southeast direction. The Qing-Kang road traverses through the area in a northeast-southwest direction. There are two basins, the Wenquan basin and the Kuha basin, with lower elevations and flat terrains (Fig.1.a). Nearby meteorological Huashixia station reports average annual temperature of -3.2 ℃ and annual precipitation of up to 500-600mm in this area. According to the field investigation in 2009, the area is dominated by three vegetation types, i.e., alpine grassland, alpine meadow, and alpine swamp meadow, plus a small portion of alpine shrub.

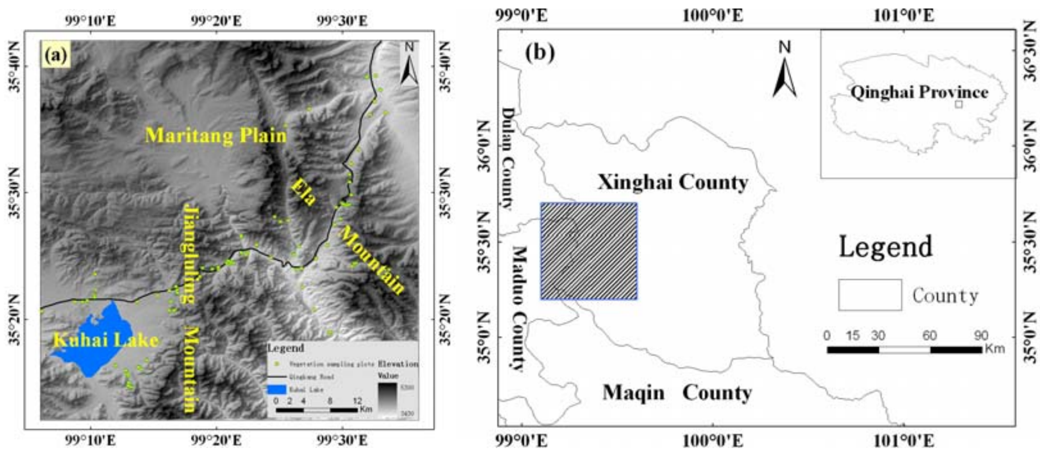

Fig.1 The terrain (a) and location (b) map of the study area.

3. DATA AND METHOD

3.1. Field investigation

A comprehensive vegetation investigation in the Wenquan area was carried out September 12 through October 7, 2009. In order to validate MODIS VI data which represent an average condition of a 250m×250m cell, single plots were specifically selected in those sites that a simple vegetation type dominates. We set up a total of 99 vegetation transects in the area. Each vegetation transect is 50m long and extends along topographic gradients. 5 to 10 quadrats, each with a size of 1m by 1m, were randomly selected with an interval of 5 to 10m. Vegetation type, community structure, species, coverage, and average plant height were recorded for each quadrat. Their geographic coordinates was logged with a GPS receiver. The location of each transect was set to be the center location of all quadrats sampled along this transect. Among the total 99 transects, 49 are with alpine meadow, 30 with alpine grassland, 16 with alpine meadow marsh, and 4 with alpine shrub (see green dots on the Fig .1.a).

3.2. Remote sensing data

In this study, MODIS VI datasets (MOD13Q1) were acquired from the NASA WIST website. There are totally 223 16-day composite MODIS VI data for a 10-year period from March 5, 2000 to October 31, 2009. For the ease of use, both EVI and NDVI data were projected into the WGS84 lat/lon reference system from their original sinusoidal projection and also converted to TIFF format form original HDF format.

3.3. Method

Prior to a multi-temporal analysis, the Harmonic Analysis of Time Series(HANTS)approach was used to reconstruct the VI time series data. HANTS helps to reveal the inherent cyclical nature of the internal curves and measure vegetation dynamics quantitatively. To eliminate unnecessary impacts of potential noisy factors on the VI values, the actual VI data in the grid cells corresponding to the 99 sample plots take an average of VI values in 3 × 3 grid cells surrounding where the sample plot is located. An IDL computerized program was specifically developed to extract 10-year VI data of those sites from MODIS VI images. Ten years of VI data for same vegetation type (i.e. alpine grassland, alpine meadow, alpine swamp meadow, and alpine shrub) were then averaged to create multi-temporal VI profile for each vegetation type. Those profiles were visually assessed in comparison with vegetation growth calendars to determine phonological behavior of each vegetation type through the time-series VI data.

The Jeffries–Matusita (JM) distance statistic was then used to verify the inter-class separability between vegetation types based on the time-series VI data [10]. The JM distance between a pair of classes was given by

$$JM(c_j, c_k) = \int_x [\sqrt{P(x|C_j)} - \sqrt{P(x|C_k)}]^2 d_x \quad (1)$$

where x denotes a span of VI time-series values, c_j and c_k denote two vegetation classes, and P is conditional probability. With an assumption of normal distribution, Eq. (1) can be reduced to

$$JM = 2(1 - e^{-B}) \quad (2)$$

where

$$B = \frac{1}{8} D^2 + \frac{1}{2} \ln\left(\left| \frac{\sum_j + \sum_k}{2} \right| / \sqrt{\left|\sum_j\right| \left|\sum_k\right|} \right) \quad (3)$$

$$D^2 = (\mu_j - \mu_k)^T \left(\frac{\sum_j + \sum_k}{2}\right)^{-1} (\mu_j - \mu_k) \quad (4)$$

where μ_j and μ_k correspond to expected VI values of two classes, and Σ_j and Σ_k are unbiased estimates for the class-specific covariance matrices. The JM distance, ranging from 0 to 2, with 2 being mostly separable, provides a general measure of separability between two classes based on the average distance between their class density functions.

The above mentioned analyses are based on average VI data which will not fully represent intra-class variability. A range analysis was therefore used to analyze the intra-class variability of all vegetation types to evaluate impact on the inter-class separability.

4. RESULTS AND ANALYSES

4.1. Multi-temporal VI profiles and vegetation phenology

The multi-temporal averaged VI profiles of major vegetation types in the study area were presented in Fig.2. Similar phenological characteristics during the entire growth season of all vegetation types are observed. For all vegetation types, photosynthetic activity obviously starts in late May and early June as EVI and NDVI see rapid increases on around May 24 and June 9. VI values reach their peaks in the mid-summer (i.e. August 12). Senescence phases of all vegetations occur in late October as we see rapid EVI and NDVI decreases in around October 15 and October 31.

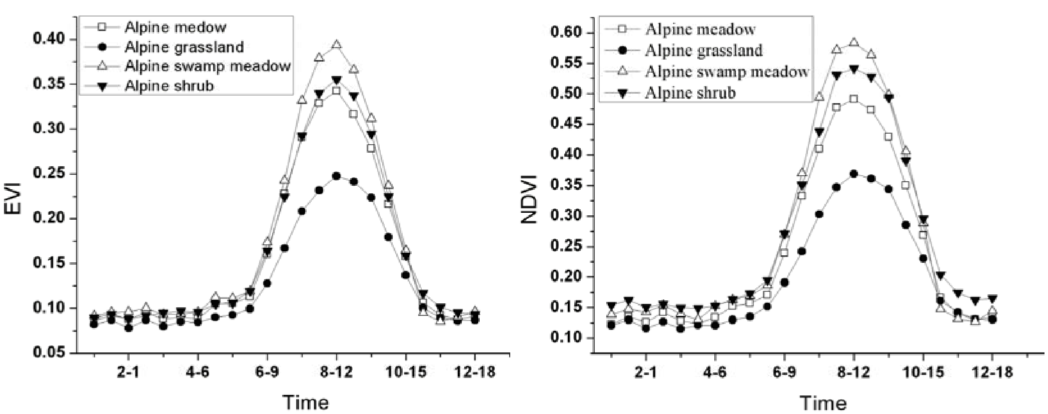

Fig.2. Multi-temporal averaged VI profiles (EVI and NDVI) of the major vegetation types.

4.2. JM distance statistic

The VI profiles shown in Fig.2 suggest major vegetation types may have separability at certain points in growing season, especially in the maturity period. However, these profiles only represent region-level class averages; vegetation can have considerable intra-class variability due to variations in environmental conditions. Using NDVI data as an example, the JM distance was calculated for maturity periods of the four vegetation types (Table.1).

Table1. Pair-wise JM distances between vegetation types at the maturity periods

Vegetation types	Alpine shrub	Alpine meadow	Alpine grassland	Alpine swamp meadow
Alpine shrub	-	0.50	0.55	0.44
Alpine meadow	0.50	-	0.55	0.45
Alpine grassland	0.55	0.55	-	0.93
Alpine swamp meadow	0.44	0.45	0.93	-

As shown in Table 1, alpine swamp meadow and alpine grassland are mostly separable with a JM distance of 0.93, while alpine shrub and alpine swamp meadow the worst with a JM distance of 0.44. However, all JM distances in the Table 1 remain small, indicating low spectral separability in the maturity periods between all classes. Their similar calendars and high intra-class variability may lead to VI signal overlapping and contribute to their low separability.

4.3. Range analysis

In order to much more clearly explain intra-class separability, a range analysis was conducted. Taking NDVI data as an example, as shown in Fig.3, different curves represent NDVI profiles from different sample plots and the vertical lines indicate the variance of NDVI at given time points. For each vegetation type, greater variance of VI profiles is observed in the growth season, and smaller variance in dormancy periods. A maximum variance of VI is observed at the maturity time. Even though averaged NDVI profiles of different vegetation types differ from each other (Fig.2), the realistic NDVI distributions remain overlapped so that we cannot rely on averaged NDVI for classification. For example, in the maturity period, NDVIs of alpine meadow range from 0.15 to 0.70 with an average NDVI of 0.47; NDVIs of alpine grassland range from 0.18 to 0.57 with an average of 0.35. Given a NDVI of 0.50 at the maturity period at a location with unknown vegetation type, it is hard to determine its vegetation type as this NDVI actually falls within all the four types, whereas according to averaged values (Fig.2) it might be of alpine meadow. The implication suggested in Fig.3 is a classification approach taking advantage of probability distribution instead of using averaged value should be developed.

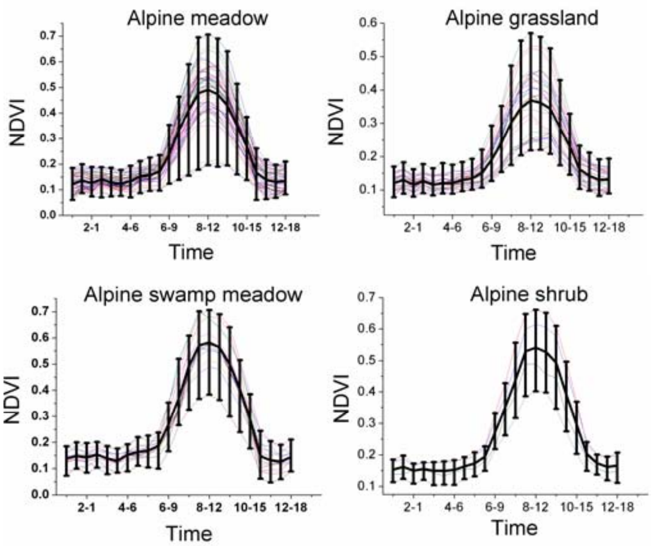

Fig.3 Range analyses with NDVI data of the four vegetation types.

5. CONCLUSIONS

By analyzing the 250 m MODIS VI datasets together with field investigation data, similar phenological characteristics in the entire growth seasons of all vegetation types are observed in the Wenquan area. However, different vegetation types present distinguished characteristics in terms of averaged VI values at different periods. Spectral separability between every two types identified by the JM distance is found not good in the growing season, indicating all vegetation classes in the study area are not spectrally separable. The high intra-class variability may lead to low separability at different composite periods. Following range analysis confirms the high intra-class variability which makes the traditional vegetation classification approach using averaged VIs inapplicable in this study area. It suggests a classification approach taking advantage of VI probability distribution instead of using averaged VI should be developed. This is our next work where VI distribution characteristics as well as terrain factors such as aspect, slope and elevation, etc will be taken into account.

6. ACKNOWLEDGEMENTS

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