The Relationship between NDVI and Terrain Factors
--A Case Study of Chongqing

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Abstract

Normalized difference vegetation index (NDVI) has been widely used for qualitative and quantitative estimation of vegetation cover and growth activity. Understanding the relationship between NDVI and terrain attributes is of critical importance for protecting environmental and natural resources. A total 36 images of SPOT-VGTS10 with a spatial resolution of 1 km of 2007 were used to investigate the relationship between NDVI and topography in Chongqing. Three terrain attributes, namely, aspect, slope and altitude, were derived from a digital elevation model (DEM). According to its topographical characteristics, Chongqing was classified into four areas, namely, Northeastern Chongqing, Southern Chongqing, Central Chongqing and Western Chongqing. The results showed that topography had strong influence on the distribution and growth of vegetation in the study area. The values of NDVI varied from 0.5 to 0.8 for northeastern Chongqing, from 0.15 to 0.6 for western Chongqing, from 0.5 to 0.65 for central Chongqing, and from 0.4 to 0.8 for southern part of Chongqing. The values of NDVI increased with altitude in the four regions, especially in low altitude areas. The vegetation mostly occupied on 0-25 degree, north-facing and south-facing slopes for northeastern Chongqing, on 0-9 degree, east-facing and west-facing slopes for western Chongqing, on slope of 0-15 degree for central Chongqing, and on 0-20 degree, east-facing and west-facing slopes for southern Chongqing, respectively.

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1. Introduction

As one important component of terrestrial ecosystem, vegetation not only plays an important role in the energy flow and material circulation of ecosystem, but also is the important resources of human social economic activities. Vegetation is influenced by climate, topography and human activities, at the same time it also create adapting and feedback effects for climate and human activities.

Normalized difference vegetation index (NDVI) has been widely used for qualitative and quantitative estimation of vegetation cover and growth activity. Studies have shown that climatic factors, such as precipitation and temperature, are the major indicators for the growth and development of plants \[^{[1-4]}\]. Additionally, several studies reported that terrain factors including elevation, aspect and slope have effects on the distribution and growth of vegetation. Walsh, et al. (2001) studied multi-scale statistical correlation analysis on terrain attribute and NDVI, which showed that the correlation of slope and elevation etc terrain attribute and NDVI is different in various scales \[^{[5]}\]. On the basis of using GIS technique to extract terrain statistical data, Chen et al. (2006) analyzed the mutual relations of vegetation distribution and terrain factors in northwestern of Sichuan LongMen mountain by using relative analysis and factors analysis methods \[^{[6]}\]. The results show that the vegetation distribution and terrain factors were significant associated in their study area.

Chongqing, located in the heart of the Three Gorges reservoir area, is well known by the complicated topography and fragile ecosystem. Understanding the relationship between NDVI and terrain attributes is of critical importance for protecting environmental and natural resources in Chongqing.

2. Materials and methods

2.1. Site description

Chongqing is located in the southwestern part of China \(105°17'-110°11'E, 28°10'-32°13' N\) with an area of \(8.24 \times 106\) ha (Fig.1). The topography of the area is hilly and mountainous with a range of altitude of 100-2796.8 m. The climate is moderate sub-tropic with an annual precipitation of 1200 mm and average annual temperature of 18°C and total sunshine hours of 1000-1200 hours (http://www.cq.gov.cn/cqgk/zrdl/). According to the topographical characteristics and production distribute of crops in Chongqing, it was artificially divided into four areas, namely, Northeastern Chongqing, Southern Chongqing, Central Chongqing and Western Chongqing (http://www.cqates.com/fjlist.asp).

According to the digital elevation model (DEM) of Chongqing, northeastern area is the highest with altitude mainly ranging from 421 to 2505 m, followed by southern part with altitude from 400 to 1500 m, central Chongqing with altitude from 150 to 950 m, and western Chongqing with altitude from 200 to 900 m.

2.2. Data collection and process

Digital maps of topography at a scale of 1:100000 were provided by government agencies. A digital elevation model (DEM) was produced using ArcInfo (ESRI, 1999). The terrain attributes (aspect, slope and altitude) were derived from the DEM. A total 36 images of SPOT-VGTS10 with a spatial resolution of 1 km of 2007 were used to extract normalized difference vegetation index (NDVI).

The projection and coordinates of SPOT-VGT were defined as Lat/Lon and WGS1984, respectively, and were transformed using ENVI. Values of NDVI were calculated as follows.
\[ NDVI = 0.004 \times DN - 0.1 \tag{1} \]

where DN was the value of the SPOT-VGT products.

Pearson correlation coefficients were employed to investigate the relationships between NDVI and topographical variables.

3. Results and Discussion

3.1. Relationship between NDVI and elevation

The relationships between NDVI and altitude for different regions of Chongqing were given in Figure 2. It is clearly that the values of NDVI increased with altitude in the studied regions, especially in low altitude areas. Values of NDVI increased rapidly within the range of altitude of 500-1000 m in northeastern part of Chongqing, within 200-300 m in western part of Chongqing, within 150-300 m in central part of Chongqing, and within 400-600 m and 1100-1300 m in southern part of Chongqing. The results indicated that altitude has significant influence on the distribution of the vegetation in Chongqing.
3.2 Relationship between NDVI and slope

No significant relationship was found between NDVI and slope in the four regions of Chongqing (Fig. 3). However, the distribution of the values NDVI exhibited different distribution patterns in the four regions. For northeastern part of Chongqing, the values of NDVI mostly ranged from 0.5 to 0.8 and occupied on slope of 0-25 degree. For western part of Chongqing, the values of NDVI varied between 0.15 and 0.6 and mostly concentrated on slope of 0-9 degree. For central part of Chongqing, the values of NDVI mostly ranged from 0.5 to 0.65 and occupied on slope of 0-15 degree. For southern part of Chongqing, the values of NDVI mostly varied between 0.4 and 0.8 and occupied on slope of 0-20 degree.
3.3. Relationship between NDVI and aspect

No significant relationship was found between NDVI and terrain aspect in the four regions of Chongqing (Fig.4). However, the distribution of the values NDVI exhibited different distribution patterns along terrain aspects in the four regions. For the northeastern part of Chongqing, the values of NDVI were mostly concentrated at north-facing and south-facing slopes. For western and southern parts of Chongqing, the values of NDVI were mostly concentrated at east-facing and west-facing slopes. However, for the central part of Chongqing, the values of NDVI were almost consisence among the terrain slopes.

![Graphs showing the relationship between NDVI and slope in different regions of Chongqing](image-url)
Fig. 4 Relationship between NDVI and aspect in different regions of Chongqing.

Table 1 Correlation coefficients between NDVI and terrain factors

| Sampling Regions  | Factors | NDVI | Elevation | Slope | Aspect |
|-------------------|---------|------|-----------|-------|--------|
| Northeaster Chongqing | NDVI   | 1    |           |       |        |
|                   | Elevation | 0.4149 | 1         |       |        |
|                   | Slope     | 0.0983 | 0.0463    | 1     |        |
|                   | Aspect    | 0.0004 | 0.0446    | 0.0004 | 1     |
| Central Chongqing | NDVI   | 1    |           |       |        |
|                   | Elevation | 0.2479 | 1         |       |        |
|                   | Slope     | 0.0469 | 0.1248    | 1     |        |
|                   | Aspect    | 0.0013 | 0.0345    | 0.0102 | 1     |
| Western Chongqing | NDVI   | 1    |           |       |        |
|                   | Elevation | 0.2713 | 1         |       |        |
|                   | Slope     | 0.0271 | 0.1565    | 1     |        |
|                   | Aspect    | 0.0005 | 0.0218    | 0.0112 | 1     |
| Southern Chongqing | NDVI   | 1    |           |       |        |
|                   | Elevation | 0.3905 | 1         |       |        |
|                   | Slope     | 0.0019 | 0.0176    | 1     |        |
|                   | Aspect    | 0.0637 | 0.1058    | 0.0002 | 1     |
3.4. Correlation coefficients between NDVI and terrain factors

Correlation between NDVI and the selected terrain attributes for each region of Chongqing was also investigated and the coefficients were listed in Table 1. The results were consistency with the scatter plots (Fig.2-4). Elevation showed significant correlation with NDVI for the four regions while no significant relationships was found between NDVI and slope and between NDVI and aspect in the study area. The rank of correlation coefficients between NDVI and elevation was in the order of northeastern Chongqing > southern Chongqing > western Chongqing > central Chongqing, indicating the effect of topography on the distribution and growth of vegetation in the study area.

4. Conclusion

Understanding the relationship between NDVI and terrain attributes is of critical importance for protecting environmental and natural resources. This paper analyzed the relationship between NDVI and terrain factors (elevation, slope, and aspect) for different physiographic regions of Chongqing using SPOT-VGT images of 2007. The results showed that topography had strong influence on the distribution and growth of vegetation in the study area.

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