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RESEARCH PAPER

Estimation of forest-ecosystem site index using remote-sensed data

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Abstract: The estimation of site index and site quality forms the fundamental theory and basic tools in forest-ecosystem management and silviculture practice. The study on the spatial pattern and temporal dynamics of site index and site quality of forest ecosystem still lacks technological advancement. It is a novel approach for estimating forest productivity in large areas using satellite remote-sensed data. The site-index spatial distribution pattern of spruce (*Picea asperata*) forest in Songpan-Zhengjiangguan watershed, northwestern Sichuan Province, China, was described using the remote-sensing vegetation index application and the established inverse models. The application potential of the methodology in broad regions and forests using the accuracy assessment was evaluated. The results show that the site index of the spruce forest is in linear correlation with the remote-sensed vegetation indices (normalized difference vegetation index (NDVI) and soil adjust NDVI (TNDVI)), as well as with these inverse models with high accuracy. This study demonstrated that this approach can be used in similar estimation of different forest ecosystems.

Key Words: Forest ecosystem; spruce; site index; remote-sensed vegetation index; inverse model

1 Introduction

Site is the habitat for suitable forest growth and is composed of climate, geology, topography, soil, hydrology, vegetation and other biological factors[1−5]. The class of the site is usually represented by site index[6,7]. Many schools have been developed in the last couple of decades, for example, France-Swiss land school, Britain-American school, Finland school, and Russian School, as the evaluation of site index and site quality forms the fundamental theory and method in forest management and silviculture[3,8,9]. At present, based on the modern mathematics and computer technology, the quantitative analysis of site classification has become the major approach[10−14]. The site index table is one of the major components[5,7,10,15].

Although the quantitative analysis of site index is very important and useful, the application of the site index is still difficult[3,5,7], as high labor is consumed in sampling data collection, and permanent plots are not available for most forest ecosystems. There still lacks the knowledge with regard to site-area coupling and the analysis for spatial-temporal pattern and change in forest-ecosystem site[7,10,16].

Satellite remote sensing is the appropriate approach for studying the productivity, the age, the spatial pattern of forest ecosystems in large area[17,20]. Many scientists have focused on studying the vegetation characteristics of dynamics, and the relationship between the remote-sensing vegetation index and leaf area index (LAI), vegetation coverage, biomass, and PAR since the 1970's[18−21]. Based on the remote-sensing technology, the most popular remote-sensing vegetation index is the normal difference vegetation index (NDVI)[19,21]. NDVI has been widely applied in the estimation of LAI[21−23], net primary productivity (NPP)[20], and other indicators. The broad use of remote-sensing vegetation index will help improve the understanding of the forest production, and will also aid in the optimal operation of the silviculture and management of forest

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ecosystems. Unfortunately, this field still lacks research because of the limitation in theory, technology, and methodology.

Spruce forests are broadly distributed in the world, especially in northern hemisphere. Spruce (*Picea asperata)* is a specific species dominant in China. Its distribution region is in upper Minjiang valley, large and small Jinchuan watersheds of Sichuan, southwestern Shaanxi, Bailongjiang and Zhaohe watersheds, and eastern Gansu. The distribution region belongs to the water protection forests, and is the habitat for many kinds of important wildlife, e.g. Giant Panda. Spruce is the key silviculture species in the region because of its rapid growth and good wood quality and also because of its capability in resisting drought pressure and cold. This species has contributed to the protection of the natural forests and the reforestation in Sichuan province[26,29]. Several researches have been conducted, and data have been collected regarding the forest ecosystem dominated by spruce[4,24−28], which formed the basis of this research.

In this study, the results with regard to the spruce-dominant forest-ecosystem site-index spatial distribution pattern have been reported based on the landsat satellite remote-sensing imagery, the inverse models of remote sensing have been established, the accuracy of site index estimation has been assessed and the application potential in broad areas of forest ecosystems has been analyzed.

2 Method

2.1 Study area

The study area is located in Zhengjiangguan watershed of upper Minjiang in Songpan county of Northwest Sichuan (Fig.1). There are two geo-forms in the study area: alpine gorges and plateau hill (elevation greater than 3400 m, see DEM of Fig.2)[4,26,29]. The dominant vegetation is the dark conifer forest, which is composed mainly of spruce and fir trees (Fig.3)[17].

2.2 Investigation of site quality and calculation of site index

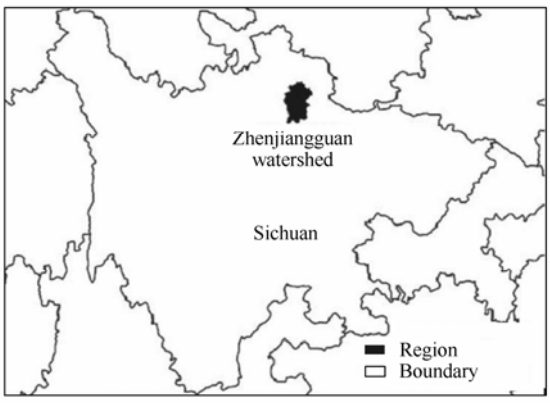

Fig. 1 The study area in Sichuan Province of China

The standard technology was used to sample the forest sites, and the sampled area covered 3–5 percentage of the study area. The sampled plot was 1200 m^2 (Fig.1)[25−27,30], and the sampled trees were about 300 individuals in total.

The investigation of the sampled plot included the physical habitat, mean breast height diameter, mean tree height, mean age, volume, dominant tree age and height, and litter. To evaluate the site quality, the mean height of dominant trees usually correlated with traits of the habitat, e.g., topography, soil and other climate variables, which was used to establish the models of potential habitat production[3,10]. The site index was calculated using mean height of five dominant trees in this study[28]. In this study, the orbital curve of the site index reflected the change in the dominant tree height with age[7,28]. Multiple models were designed and evaluated by comparing the fitting effectiveness, it was found that the Richard growth equation was the best among the models since its correlation

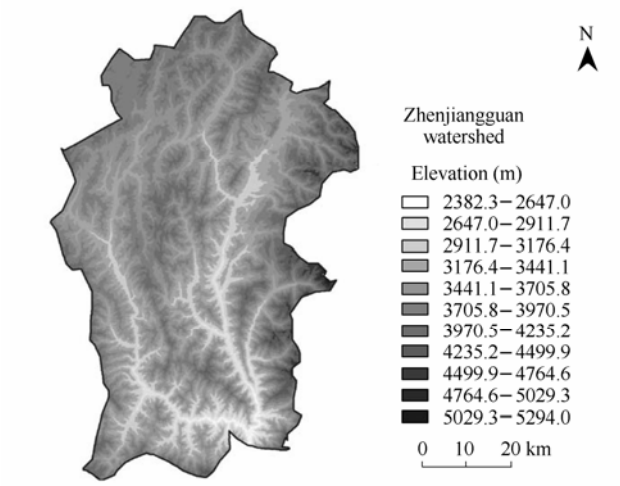

Fig. 2 The topography (DEM) of study area

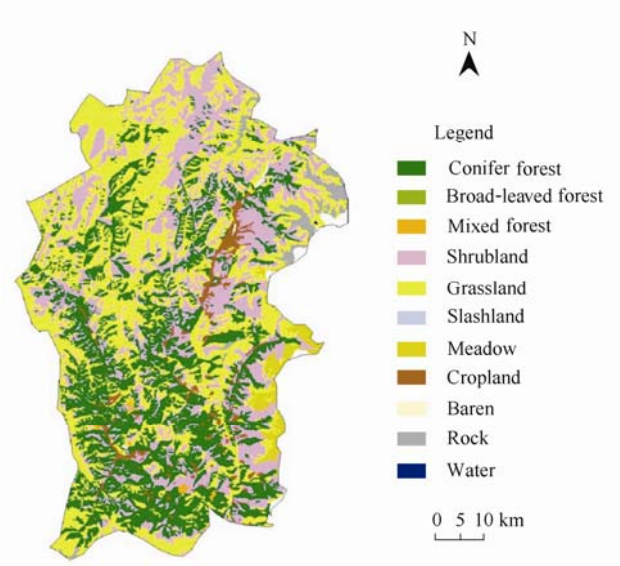

Fig. 3 The vegetation of study area