Postprint: Extraction of Historical Spatial Distribution of Spruce Forests in the Tianshan Mountains Based on 3S Technology

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Abstract

Employing remote sensing techniques in conjunction with historical remote sensing imagery data, this study utilizes Tianshan spruce (Picea schrenkiana var. tianschanica) forest habitat characteristics as fixed factors, combined with vegetation index analysis, terrain factor analysis, principal component analysis, and object-oriented decision tree classification methods to extract historical spatial distribution information of Tianshan spruce forests, thereby supporting the evaluation of implementation benefits for natural forest resource protection projects in contexts of missing historical data. Research demonstrates: With age characteristics of Tianshan spruce forests serving as fixed factors, and current-year high spatial resolution remote sensing imagery together with forest resource inventory data as baseline information, historical spatial distribution information of Tianshan spruce forests can be effectively extracted from historical remote sensing imagery through object-oriented classification methods, achieving an extraction accuracy of 93.3%; Among vegetation index factors, NDVI exhibits the strongest indicative performance for Tianshan spruce forests, with the optimal NDVI value range for Tianshan spruce forest extraction determined as [0.35, 0.8];

Terrain factors and principal component analysis methods can substantially compress redundant image information, enhancing both the accuracy of spruce forest information extraction and computational efficiency. Collectively, leveraging historical remote sensing imagery combined with habitat characteristics of Tianshan spruce forests enables effective extraction of historical spatial distribution information of spruce forests, providing data support for forest resource management decision-making and climate change adaptation in data-scarce scenarios.

Full Text

3S-Based Extraction of Historical Spatial Distribution of *Picea schrenkiana* var. *tianschanica* in the Tianshan Mountains

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Abstract

The spatial distribution information of *Picea schrenkiana* var. *tianschanica* in the Tianshan Mountains during historical periods was extracted using remote sensing methods. This approach integrated vegetation indices, topographic factors, principal component analysis, decision tree classification, and habitat characteristics of *P. schrenkiana* in the study area, combined with historical remote sensing image data. The purpose was to provide support for benefit evaluation of natural forest resources protection projects under conditions of missing historical data. Results showed that: (1) The historical spatial distribution information of *P. schrenkiana* in the Tianshan Mountains could be extracted from remote sensing images by setting forest stand age as a fixed factor and using present high-resolution remote sensing images and forest management inventory data as background information. The accuracy of information extraction for *P. schrenkiana* in the study area could reach as high as 93.3%, demonstrating that remote sensing images can be effectively used to extract spatial distribution information of *P. schrenkiana* in the Tianshan Mountains. (2) Among vegetation index factors, *P. schrenkiana* in the Tianshan Mountains showed the most sensitive response to NDVI, with the optimal NDVI range for extracting information being [0.35, 0.8]. (3) Topographic factors and principal component analysis methods could greatly compress redundant image information, which improved both the accuracy of information extraction for *P. schrenkiana* forest and the processing speed. Overall, the spatial distribution information of *P. schrenkiana* forest in historical periods can be well extracted by using historical remote sensing images combined with habitat characteristics of *P. schrenkiana* forest in the Tianshan Mountains, thereby providing data support for formulating forest resource management measures and responding to climate change in data-scarce contexts.

Keywords: historical remote sensing image; decision tree classification; *Picea schrenkiana* var. *tianschanica*; spatial distribution; Fukang Forest Farm

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2 Materials and Methods

2.1 Data Sources

The study utilized multiple data sources including Landsat TM5 imagery (30m resolution, 1994), high-resolution remote sensing imagery (0.8m resolution, 2016), Digital Elevation Model (DEM) data, forest management inventory data (2016), and field survey data. The study area covered elevations ranging from 1500m to 2700m.

2.2 Methodology

The methodology combined vegetation indices, topographic factors, and principal component analysis with decision tree classification to extract historical distribution information.

Vegetation Indices Calculation: Three vegetation indices were calculated from the remote sensing data:

1. Ratio Vegetation Index (RVI):

$$RVI = \frac{\rho_{red}}{\rho_{nir}}$$

2. Normalized Difference Vegetation Index (NDVI):

$$NDVI = \frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \rho_{red}}$$

3. Enhanced Vegetation Index (EVI):

$$EVI = G \times \left[\frac{\rho_{nir} - \rho_{red}}{\rho_{nir} + \lambda_1 \rho_{red} + \lambda_2 \rho_{blue} + L}\right]$$

Where ρ_{red}, ρ_{nir}, and ρ_{blue} represent surface reflectance in the red, near-infrared, and blue bands respectively; and G, λ_1, λ_2, and L are coefficients with values of 2.5, 6.0, 7.5, and 1.0 respectively.

Decision Tree Classification: A decision tree classifier was developed based on the habitat characteristics of *P. schrenkiana*. The classification rules incorporated: - Elevation range: 1500–2800m - Slope range: 5°–50° - Aspect range: 225°–360° - NDVI threshold range: [0.35, 0.8]

Principal Component Analysis: PCA was applied to reduce data redundancy and improve computational efficiency in image processing.

[Figure 1: see original paper]

3 Results

3.1 Classification Accuracy

The overall accuracy of historical spatial distribution extraction reached 93.3%, with a Kappa coefficient of 0.89, indicating high classification reliability.

3.2 Vegetation Index Response Analysis

Among the vegetation indices analyzed, NDVI demonstrated the strongest response to *P. schrenkiana* distribution. The optimal NDVI range for identifying *P. schrenkiana* stands was [0.35, 0.8], which provided the highest discrimination accuracy.

3.3 Topographic Factor Influence

Topographic factors significantly influenced the distribution patterns of *P. schrenkiana*: - Elevation: 90.75% of *P. schrenkiana* stands occurred between 1000–2200m - Slope: 94.34% were distributed on slopes ranging from -1° to 32° - Aspect: 98.11% occurred on aspects between -23° to 3° (representing specific directional orientations)

[Figure 4: see original paper]

3.4 Principal Component Analysis Results

PCA effectively compressed redundant spectral information, which not only improved classification accuracy but also enhanced computational processing speed, making it particularly suitable for large-area historical remote sensing data analysis.

[Figure 5: see original paper]

4 Discussion

The integration of historical remote sensing imagery with species-specific habitat characteristics provides a robust methodological framework for reconstructing past forest distributions. This approach is particularly valuable in regions with limited historical ground survey data. The high accuracy achieved (93.3%) demonstrates that remote sensing-based retrospective analysis can effectively support forest resource management decision-making and climate change adaptation strategies. The method’ s efficiency in processing large datasets while maintaining accuracy makes it applicable for broader regional studies of forest dynamics in mountainous ecosystems.

References

[1] Editorial Committee of Xinjiang Forest. *Xinjiang Forest* [M]. Beijing: China Forestry Publishing House, 1989.

[2] Li Jiangui, Pan Cunde, Peng Shikui, et al. Demography and survival analysis of *Picea schrenkiana* [J]. *Journal of Beijing Forestry University*, 2001, 23(1): 84-86.

[3] Fan Jing. Nutrient and Water-holding Characteristics of Litter of *Picea schrenkiana* var. *Tiancanica* Forest in the Tianshan Mountains [D]. Hefei: Anhui Agricultural University, 2013.

[7] Li Minghui, He Fenghua, Liu Yun, et al. Spatial distribution pattern of tree individuals in the Schrenk spruce forest, Northwest China [J]. *Acta Ecologica Sinica*, 2005, 25(5): 1000-1006.

[18] Chen Li, Lin Hui. Vegetation information extraction based on K-T transform and principal component transform [J]. *Journal of Central South University of Forestry & Technology*, 2014, 34(6): 81-84.

[19] Song Lu. The Study on Growth and Physiological Characteristics of Main Species in *Picea* [D]. Lanzhou: Gansu Agricultural University, 2015.

[22] Zhang Yutao, Li Jimei, Chang Shunli. Spatial distribution pattern of *Picea schrenkiana* var. *tianschanica* population and its relationships with topographic factors in middle part of Tianshan Mountain [J]. *Chinese Journal of Applied Ecology*, 2011, 22(11): 2799-2806.

[23] Zhao Yingshi. *Principles and Methods of Remote Sensing Application: 2nd* [M]. Beijing: Science Press, 2013: 174-175.

[24] Zhu GL, Liu YB, Ju WM, et al. Evaluation of topographic effects on four commonly used vegetation indices [J]. *Journal of Remote Sensing Technology and Application*, 2014, 29(5): 744-751.

[28] McIver DK, Friedl MA. Using prior probabilities in decision-tree classification of remotely sensed data [J]. *Remote Sensing of Environment*, 2002, 81: 253-261.

[32] Yan Enping. Study on Extraction of Based-leaved forest Information Based on Medium and High Spatial Resolution Remote Sensing Image [D]. Changsha: Central South University of Forestry and Technology, 2011.

[33] Liu Weiguang, Pan Jie. A hyperspectral assessment model for leaf chlorophyll content of *Pinus massoniana* based on neural network [J]. *Chinese Journal of Applied Ecology*, 2017, 28(4): 1128-1136.

[34] Han Tingting, Xi Xiaohuan, Wang Cheng, et al. Study on forest classification in Yunnan based on decision tree algorithm [J]. *Remote Sensing Technology and Application*, 2014, 29(5): 744-751.

[35] Ding Chengfeng, Zhang Huifang, Gao Yaqi, et al. 3S-Based Extraction of Spatial Distribution of *Picea schrenkiana* var. *tianschanica* in History in the Tianshan Mountains [J]. *Journal of Arid Land Resources and Environment*, 2016, 30(9): 190-195.