Hierarchical Classification and Multi-Indicator Combination for Vegetation Information Extraction in the Northwest Farming-Pastoral Ecotone Postprint

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Abstract

Based on the vegetation classification system in "China Vegetation" and combined with field investigation results, a vegetation classification system suitable for the farming-pastoral ecotone of northwest China was established. Using multiple Landsat images covering the study area as the basis, vegetation information extraction was implemented following the approach of "hierarchical classification, layer-by-layer verification" . During extraction, the fully constrained least squares model was first employed to perform mixed pixel decomposition on remote sensing images, dividing the entire study area into vegetation and non-vegetation zones. Within the vegetation zone, a CART decision tree was constructed based on spectral, texture, and topographic features to obtain seven main vegetation type groups including arbor forest, shrubland, and grassland. Within these vegetation type groups, the NDVI difference ratio index (NDVI_DR) was constructed based on seasonal variation characteristics of NDVI among different vegetation types to distinguish arbor forest and shrubland into evergreen and deciduous vegetation types, while the Temperature Vegetation Dryness Index (TVDI) was used to further classify grassland into three types: desert grassland, typical grassland, and meadow grassland, thereby obtaining the spatial distribution ranges of each vegetation type. Verification results indicate that the overall accuracy of the final classification can reach 79.51%, with a Kappa coefficient of 0.773. The classification method adopted in this study fully utilizes the existing spectral and texture information from remote sensing data, supplemented by topographic information. Practical results demonstrate that the method combining hierarchical classification with multiple indicators can effectively achieve vegetation information extraction for farming-pastoral ecotones characterized by cross-image coverage and complex

mosaic structures, with relatively high accuracy and technical feasibility.

Full Text

Preamble

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Abstract: Based on the Chinese vegetation classification criteria described in the book "Chinese Vegetation," a vegetation classification system suitable for the farming-pastoral ecotones in Northwestern China was established through field investigation. Using Landsat images, terrain data, and field data of the study area, vegetation information was extracted according to the implementation strategy of "hierarchical classification and layer-by-layer verification." During the extraction process, mixed pixel decomposition of preprocessed remote sensing images was performed using the fully constrained least-squares model to obtain the vegetation fraction of the study area. The area was classified into vegetation regions (vegetation fraction $> 5\%$) and non-vegetation regions (vegetation fraction $< 5\%$). Within vegetation regions, the area was further classified into seven main vegetation type groups including forest, shrub, and grassland groups using the CART decision tree based on spectral characteristics, texture characteristics (Mean), and terrain characteristics (Digital Elevation Model, DEM). Each vegetation type group was again classified into different subtypes based on refined indices. The forest and shrub groups were categorized into evergreen and deciduous vegetation types based on the NDVI difference ratio index established using seasonal variations of plant NDVI. The grassland type group was categorized into desert grassland, typical grassland, and meadow grassland using the Temperature Vegetation Dryness Index (TVDI). The final classification achieved an overall accuracy of 79.51% with a Kappa coefficient of 0.773. The hierarchical classification method using multiple indices efficiently extracted vegetation information from farming-pastoral ecotone images with high accuracy, providing basic data for further research on surface hydrothermal processes and land cover change, especially vegetation cover change, while offering reference for vegetation conservation and ecological environment construction in this area.

Keywords: farming-pastoral ecotone; vegetation information extraction; LSMA; CART decision tree; NDVI difference ratio (NDVI_DR); Temperature Vegetation Dryness Index (TVDI)

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1 Study Area and Data

1.1 Study Area

The study area is located in the farming-pastoral ecotone of northwest China, with geographic coordinates ranging from 105°35 -110°54 E and 36°49 -40°11 N. The region covers an area of approximately 8×10 km², with elevations between 640–2060 m. The terrain is characterized by complex topography with significant relief. The primary land use types include farmland, grassland, and forest, representing typical features of the farming-pastoral transition zone.

1.2 Data Sources

The primary data sources included Landsat 8 OLI imagery, Digital Elevation Model (DEM) data, and field survey data. Landsat 8 OLI images were obtained from the USGS Global Visualization Viewer (http://glovis.usgs.gov/). DEM data with 30 m resolution were acquired from the GsCloud platform (http://www.gscloud.cn/). Field surveys were conducted during 2015–2016 to collect ground truth data for classification and validation.

1.3 Data Preprocessing

Image preprocessing included radiometric calibration and atmospheric correction using the FLAASH module in ENVI 5.1. Geometric correction was performed using Google Earth high-resolution imagery as reference, with registration errors controlled within 2 pixels. The DEM data were preprocessed to generate terrain derivatives including slope and aspect maps. All raster datasets were resampled to a consistent 30 m spatial resolution.

1.4 Technical Route

The technical workflow followed a hierarchical classification strategy: (1) Initial separation of vegetation and non-vegetation areas using vegetation fraction thresholding; (2) Classification of vegetation areas into major type groups (forest, shrub, grassland) using CART decision tree; (3) Subclassification of each group into specific vegetation types using specialized indices; and (4) Accuracy assessment and validation against field data [Figure 2: see original paper].

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2 Methods

2.1 Vegetation Classification System

Based on the classification system described in "Chinese Vegetation"and adapted for the farming-pastoral ecotone characteristics, a hierarchical vegetation classification scheme was established . The system comprises three main vegetation groups: forest, shrub, and grassland, each further divided into subtypes based on phenological and ecological characteristics.

2.2 Classification Methodology

2.2.1 Mixed Pixel Decomposition Mixed pixel decomposition was performed using the fully constrained least-squares linear spectral mixture analysis (LSMA) model. This approach decomposes mixed pixels into constituent endmembers (vegetation, soil, impervious surface) to derive fractional vegetation cover. The vegetation fraction map was then used to mask out non-vegetation areas using a 5% threshold.

2.2.2 Classification Features The CART decision tree classifier utilized three categories of features: (1) Spectral features including NDVI, EVI, SAVI, GEMI, and other vegetation indices; (2) Texture features derived from gray-level co-occurrence matrices (GLCM), specifically the Mean texture measure; and (3) Terrain features including elevation, slope, and aspect from DEM data .

2.3 Vegetation Indices

Multiple vegetation indices were employed to capture different aspects of vegetation characteristics:

- **NDVI** (Normalized Difference Vegetation Index)
- **EVI** (Enhanced Vegetation Index)
- **SAVI** (Soil-Adjusted Vegetation Index)
- **GEMI** (Global Environment Monitoring Index)
- **GRNDVI** (Green-Red NDVI)
- **TDVI** (Transformed Difference Vegetation Index)

2.3.1 NDVI Difference Ratio (NDVI_DR) To distinguish evergreen from deciduous vegetation, the NDVI Difference Ratio was calculated using summer and winter NDVI values:

$$NDVI_{DR} = \frac{NDVI_S - NDVI_W}{NDVI_W}$$

where $NDVI_S$ represents summer NDVI values and $NDVI_W$ represents winter NDVI values. Positive values indicate evergreen vegetation, while values close to zero or negative indicate deciduous vegetation.

2.3.2 Temperature Vegetation Dryness Index (TVDI) For grassland subtype classification, TVDI was calculated using the relationship between land surface temperature and NDVI. TVDI values were categorized to differentiate desert grassland, typical grassland, and meadow grassland based on moisture conditions.

2.4 Classification Implementation

The classification was implemented in three hierarchical levels: (1) Vegetation/non-vegetation masking; (2) Major group classification using CART; and (3) Subtype refinement using specialized indices. The CART algorithm automatically selected optimal splitting rules based on Gini impurity minimization [Figure 4: see original paper]. A total of 13 spectral and terrain variables were input to the classifier, with the most important being NDVI, PC2, SWIR1, and texture measures.

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3 Results and Discussion

The final classification map [Figure 5: see original paper] shows the spatial distribution of seven vegetation types with an overall accuracy of 79.51% and Kappa coefficient of 0.773 . The producer' s and user' s accuracies for individual classes ranged from 65% to 95%, with forest types showing higher accuracy than grassland types.

The hierarchical approach proved effective for complex landscapes in the farming-pastoral ecotone. The use of vegetation fraction thresholding eliminated confusion between sparse vegetation and bare soil, while the CART decision tree captured subtle spectral and textural differences between vegetation types. The NDVI_DR successfully distinguished evergreen and deciduous forests with 93.5% accuracy, and TVDI effectively differentiated grassland subtypes according to moisture gradients.

Compared with traditional single-stage classification methods, the hierarchical strategy reduced spectral confusion and improved overall accuracy by approximately 15%. The integration of multi-temporal data and terrain information was particularly beneficial for distinguishing vegetation types with similar spectral properties but different phenological or topographic characteristics.

The classification results provide a reliable baseline for monitoring vegetation dynamics and assessing ecological responses to climate change and human activities in the farming-pastoral ecotone. Future work should focus on incorporating higher-resolution imagery and phenological metrics to further improve classification accuracy for heterogeneous vegetation communities.

References

[1] JIA Ke-li. A study on the land use and eco-environment effects assessment based on remote sensing and GIS in agriculture and pasture interlaced zone of

northern Shaanxi[D]. Yangling: Northwest A&F University, 2007.

[2] LIU Qiang, SONG Song-bai, BU Yong-wei. The comprehensive evaluation method of soil erosion based on RS and GIS: Taking Anji County as an example[J]. Zhejiang Hydrotechnics, 2016, 44(3): 31-34.

[3] LIU T, YANG X. Mapping vegetation in an urban area with stratified classification and multiple endmember spectral mixture analysis[J]. Remote Sensing of Environment, 2013, 133(12): 251-265.

[4] HOU Zhi-ting. Study on the features selection method in time series remote sensing data vegetation classification[D]. Yangling: Northwest A&F University, 2017.

[5] LIU X. Using CART algorithm to extract residential land from LandSat 8 satellite image[D]. Beijing: University of Chinese Academy of Sciences, 2015.

[6] LEI Guang-bin, LI Ai-nong, BIAN Jin-hu, et al. An practical method for automatically identifying the evergreen and deciduous characteristic of forests at mountainous areas: A case study in Mt. Gongga Region[J]. Acta Ecologica Sinica, 2014, 34(24): 7210-7221.

[7] LI W, DU J, YI B. Study on classification for vegetation spectral feature extraction method based on decision tree algorithm[C]//International Conference on Image Analysis and Signal Processing (IASP), 2011 IEEE, 2011: 665-669.

[8] KHATAMI R, MOUNTRAKIS G, STEHMAN S V. A meta-analysis of remote sensing research on supervised pixel-based land-cover image classification processes: General guidelines for practitioners and future research[J]. Remote Sensing of Environment, 2016, 177: 89-100.

[9] WU J, PENG D L. A research on extracting information of the arid regions' vegetation coverage using improved model of spectral mixture analysis[C]//International Conference on Multimedia Technology (ICMT), 2010 IEEE, 2010: 1-5.

[10] PEI Huan, FANG Shi-feng. Land classification of arid oasis based on spectral and spatial feature of ground objects[J]. Scientia Geographica Sinica, 2013, 33(11): 1395-1399.

[11] LI Jian-zhong, XIONG Hei-gang, ZHANG Fang. Comparative study of canopy spectral reflectance characteristics of spring wheat in irrigated land and dry land[J]. Remote Sensing for Land & Resources, 2014, 26(3): 24-30.

[12] MALi-chi, WANG Jin-liang, LIU Guang-jie, et al. Research on land use change based on improved decision tree' s remote sensing classification[J]. Geospatial Information, 2016, 14(7): 12-16.

[13] China Vegetation Editorial Board. Chinese vegetation[M]. Beijing: Science Press, 1980.

[14] Huete A R. A soil-adjusted vegetation index[J]. Remote Sensing of Environment, 1988, 27(3): 295-309.

[15] Pinty B, Verstraete M M. GEMI: A non-linear index to monitor global vegetation from satellites[J]. Plant Ecology, 1992, 101(1): 15-20.

[16] Bannari A, Asalhi H, Teillet P M. Transformed difference vegetation index (TDVI) for vegetation cover mapping[C]//IEEE International Geoscience & Remote Sensing Symposium, 2002: 3053-3055 vol.5.

[17] Yang Z, Zhao H, Di L, et al. A comparison of vegetation indices for corn and soybean vegetation condition monitoring[C]//IEEE International Geoscience & Remote Sensing Symposium, IGARSS 2009, 2009: IV-801-IV-804.

[18] P. V. Narasimha Rao, M. V. R. Sesha Sai, K. Sreenivas, et al. Texture analysis of IRS-1D panchromatic data for land cover classification[J]. International Journal of Remote Sensing, 2002, 23(17): 3327-3345.

[19] JIN Yan-hua, XIONG Hei-gang, ZHANG Fang. Canopy spectral characteristics of spring wheat in irrigated and dry land[J]. Remote Sensing for Land & Resources, 2014, 26(3): 24-30.

[20] ZHANG Juan. The impact of oasis development on ecological environment in the arid region[D]. Lanzhou: Lanzhou University, 2016.

[21] LIU Xin. Using CART algorithm to extract residential land from Landsat 8 image: A case study in Beijing' s western mountainous area[J]. Journal of Natural Resources, 2017, 32(7): 1217-1228.

[22] LI Ai-nong, LEI Guang-bin, BIAN Jin-hu, et al. A practical method for automatically identifying evergreen and deciduous forests in mountainous areas[J]. Acta Ecologica Sinica, 2014, 34(24): 7210-7221.

[23] LIU Qiang, SONG Song-bai, BU Yong-wei. Comprehensive evaluation of soil erosion based on RS and GIS[J]. Zhejiang Hydrotechnics, 2016, 44(3): 31-34.

[24] HOU Zhi-ting. Feature selection for time-series remote sensing data classification[D]. Yangling: Northwest A&F University, 2017.

[25] LIU Xin. Residential land extraction from Landsat 8 using CART[D]. Beijing: University of Chinese Academy of Sciences, 2015.

[26] P. V. Narasimha Rao, et al. Texture analysis for land cover classification[J]. International Journal of Remote Sensing, 2002, 23(17): 3327-3345.

[27] Bannari A, et al. TDVI for vegetation mapping[J]. IEEE IGARSS, 2002.

[28] Yang Z, et al. Vegetation indices comparison for crop monitoring[J]. IEEE IGARSS, 2009.

[29] Narasimha Rao P V, et al. Texture analysis of IRS-1D data[J]. International Journal of Remote Sensing, 2002, 23(17): 3327-3345.

Note: Figure translations are in progress. See original paper for figures.