Mapping the vertical distribution of vegetation and typical plant community of Wuyi Mountain Reserve with remote sensing images

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Abstract. Wuyi Mountain Reserve is the only reserve area for world biosphere, cultural and natural heritage of China. Mapping vegetation type by general remote sensing technology in mountainous area is known to be a very difficult work. Studying bio-diversity by remote sensing technology in Wuyi mountain has not been done before. This paper addresses methods for mapping vertical distribution of vegetation and typical plant community of Wuyi Mountain Reserve Area with remote sensing images. Wuyi mountain digital elevation model (DEM) with vertical vegetation zonation was mapped with SPOT 5 remote sensing image and DEM data, which made multidimensional visualization of vertical zonation on the base of mapping vegetation types. Knowledge rules for extracting rarely typical plant community was established according to published paper and field sample. Typical plant communities such as Tsuga chinensis and Pinus taiwanensis are mapped using merged SPOT 5 satelites image and DEM data. The result provides basic information for further studying forest scene diversity. However, in order to get more reliable result, there still has a demand for higher resolution remote sensing images (e.g. QuickBird), large scale DEM data and more detailed field data.

Keywords: Wuyi mountain nature reserve area; SPOT 5; remote sensing; plant community, vertical zonation

1 Introduction

In 1999, WuYiShan city became one of the world nature and culture Heritage site. It has such honorable names as follows: the world natural and culture heritage site; the State key scenic area and State key nature Reserve; the National Tourist Resort Area; the State First Rate Air Harbour, the world' Human & Biosphere Preserve.

Located in the western part of the WuYiShan the Wuyi Mountain natural reserve has largest and most representative semitropical original forest ecosystem in China. It was praised by the bio-scientists both at home and abroard as "the world of insects", "the world biological bank", "the paradise of the birds", "the kingdom of snakes".

Investigation on bio-diversity in Wuyi Mountain was mainly going by the means of field investigation. In the past decades, plenty of information and observation data has been collected. Lan (2003) analyzed plant community diversity in Wuyi mountain reserve area with community samples. Feng(2004) has studied species diversity and Spatial patterns about Pinus taiwanensis. Qian(2007) has studied bio-diversity of Tsuga chinensis.

As for the other parts of the world, mapping vegetation types by general remote sensing technology in mountainous area is a difficult task and bio-diversity studies by remote sensing technology in the Wuyi mountain were not tried yet. This paper addresses method for mapping vertical distribution of vegetation and typical plant community in Wuyi Mountain Reserve Area with remote sensing images. The vertical vegetation zonation was realized using SPOT 5 remote sensing images and DEM data.. Knowledge rules for extracting rarely typical plant community was established according to published papers and field samples. Typical plant communities such as Tsuga chinensis and Pinus taiwanensis are mapped using merged SPOT 5 satelite images and DEM data. The result provides basis information for further studying forest scene diversity.

2 Study area and database

2.1 Study area

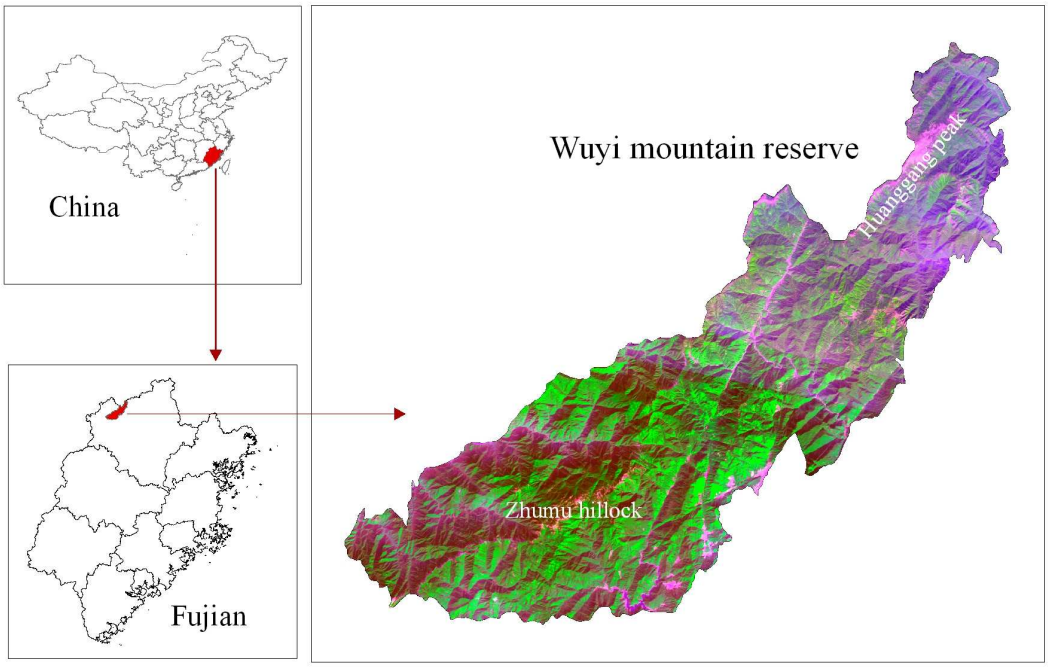


Fig.1. Location of the Study area

Wuyi Mountain is the only reserve area for world biosphere, cultural and natural heritage of China. It is located between latitude 27°33′-27°54′ N and longitude 117°27′-117°51′E, in the Southeast of China (See figure 1). Total area cover approximately 56500 hectares. It has the largest and most completely preserved sub-tropical forest ecosystems in southeast of China. The climate is characterized as semi-tropic monsoon type. The relative high peaks in the northeast part form a natural barrier and produce a kind of micro-climate, characterized by low temperatures, large precipitations, high humidity, long fog days and significant changes in vertical distribution of species.
The Reserve preserves primitive forests with an area of over 20,000 hectares. Its vegetation types mainly include evergreen broadleaved forest, mixed coniferous and broad-leaved forest, evergreen and deciduous broadleaved mixed forest, coniferous forest, shrubs and bamboo forest. There are nearly 4,000 plant species in the reserve, 19 of which such as ginkgo, Chinese hemlock, Chinese tulip, China cypress and ornament plants are under the first-grade state protection. In addition, there are dozens of rare or local special plant species.

2.2 Database

Data source in this investigation are the following:

- SPOT 5 cloud-free images, acquired on October 16, 2004 (cover up part of the study area) and on February 1, 2005 (cover down part of the study area),
- digital elevation model (DEM) with scale 1:50000,
- forest maps
- field data about typical plant community obtained by the Global Positioning System (GPS).

3 Methodology

We can establish the flow for mapping vertical distribution of vegetation and typical plant community with remote sensing images, see figure 2. Softwares used in this study are ERDAS9.0 and ARCGIS9.0.

3.1 Extract vertical distribution knowledge of vegetation

Wuyi Mountain Nature Reserve lies in the main part of Wuyi mountain range, with an average elevation of over 1,200 meters. The main peak, Huanggangshan peak, reaches 2,158 meters above sea level. It is the highest peak of the all not only in Wuyi mountain range, but also in the entire southeastern area of the Chinese mainland. Wuyi mountain range has great disparity of altitude. For instance, in an area of 556.7 square kilometers, the highest point tops 2,158 meters while the lowest is only 300 meters above sea level.
Because of the great difference between altitude (1700 meters), vegetation differs with altitude and shows a vertical zonation. There are subtropical evergreen broadleaved forest, mixed coniferous and broad-leaved forest, coniferous forest, middle mountain dwarf forest, Middle mountain top meadow, in turn from down to top in Wuyi mountain reserve.

Subtropical evergreen broadleaved forest
Subtropical evergreen broadleaved forest is a kind of vegetation type in the center subtropical monsoon zone in China. It is also basic vegetation type at the bottom of vertical zonation in Wuyi mountain. There is a large area subtropical evergreen broadleaved forest from elevation 350 meters to 1100 meters.

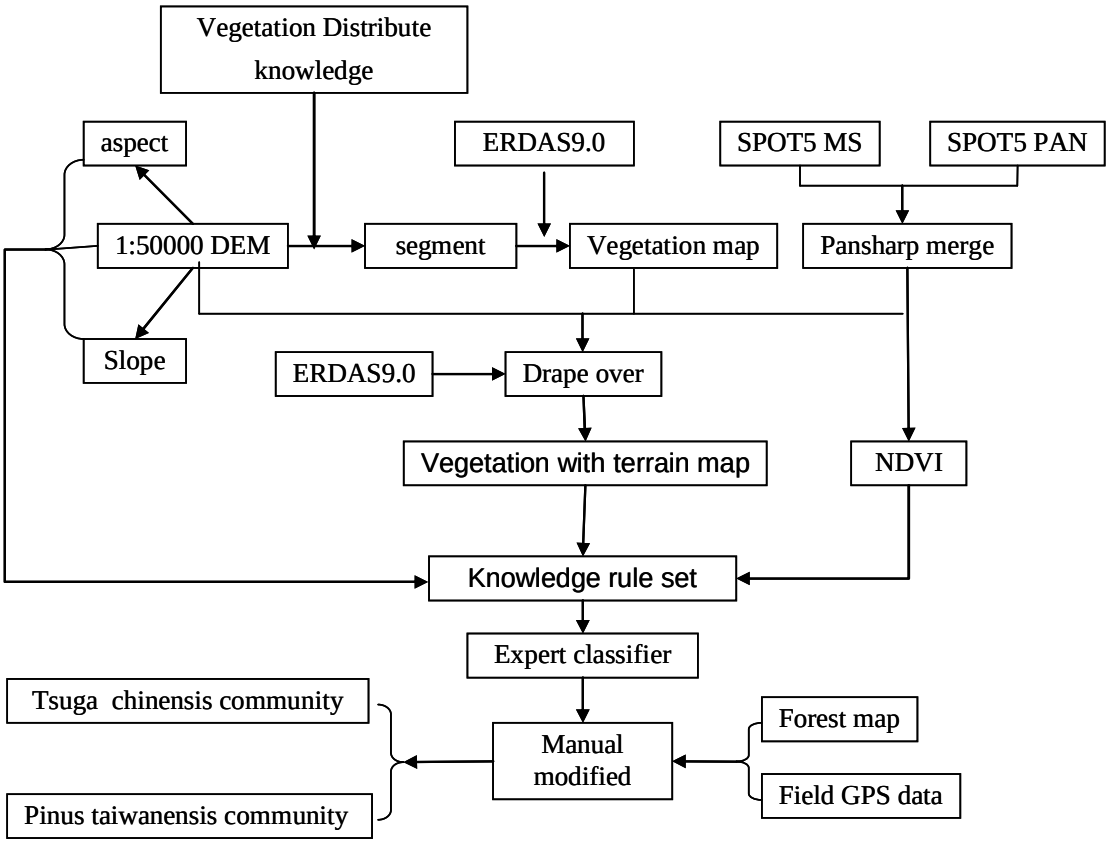


Fig. 2. Flow for Mapping Vertical distribution of vegetation and typical plant community with remote sensing images

Mixed coniferous and broadleaved forest
Mixed coniferous and broadleaved forest stand from 1100 to 1500 meters elevation. It is a transitional forest type.
Coniferous forest

Coniferous forest stand from 1500 to 1800 meters. The biocoenoses is mainly composed of Pinus taiwanensis, Tsuga chinensis and Cryptomeria.

Middle mountain dwarf forest
Middle mountain dwarf forest cover areas with elevation from 1700 to 1970 meters. Middle mountain dwarf forest is a kind of special community derived from subtropical evergreen broad-leaved forest which degraded under the special eco-environment like high altitude. The forest exists in high elevation zone. There is the thinner soil, steeper slope and stronger wind, perennial humidity with low temperature.

Middle mountain top meadow
Middle mountain top meadow lies from 1900 to 2158 meters. The forest zone is mainly composed of gramineousness and sedge with some short Pinus taiwanensis and shrub.

3.2 Mapping digital elevation model with vertical vegetation zonation

The following information gather knowledge rules based on literature review. The information primary comes from observation and field study work. The knowledge rules were implemented in the model as follow:

IF elevation>350m AND elevation <1100m THEN Subtropical evergreen broadleaved forest
IF elevation >1100m AND elevation<1500 THEN Mixed coniferous and broadleaved forest
IF elevation>1500 AND elevation < 1800 THEN coniferous forest
IF elevation>1700 AND elevation<1970 THEN Middle mountain dwarf forest
IF elevation>1900 THEN Middle mountain top meadow

Digital elevation model with vertical vegetation zonation can be made according to the following steps:

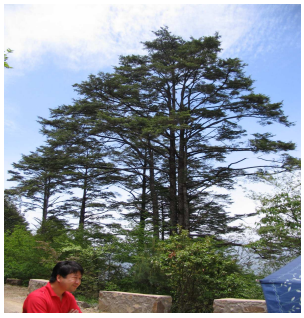
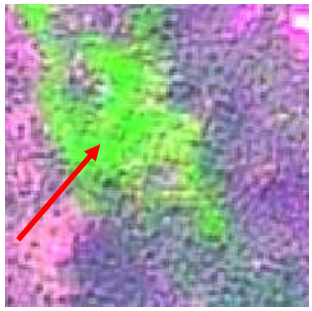
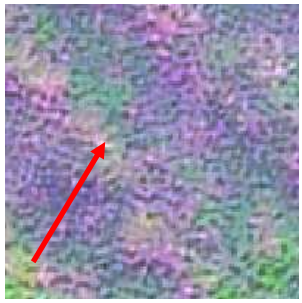
- elevation data at the scale of 1:50000 (DEM) is segmented separately according to the knowledge rule above with ArcGIS desktop or ERDAS software; the result was transformed into vector format.
- SPOT 5 image of study area created by merging 2.5×2.5m panchromatic with 10×10m multi-spectral data using so-called pansharp method.
- Merged SPOT 5 image was draped over 25×25m digital elevation model (DEM) with virtual GIS module in ERDAS9.0 .The result will be used for the background of vegetation zonation
- Add vegetation zonation data with vector format and set color semi-transparent
- Add title and legend. Then map for digital elevation model with vertical vegetation zonation was created (see Figure 3).

3.3 Mapping typical plant community based on remote sensing image

Plant community structure is complicated because it is composed of many species. The object community to be extracted is sparse in space and the scale of individual plant is lesser than the spatial resolution of remote sensing image. Consequently it is very difficult to extract rare plant community from the high resolution remote sensing images like SPOT 5.
Typical plant community mapping such as Tsuga chinensis and Pinus taiwanensis was tried using merged SPOT 5 remote sensing image and DEM data.

Knowledge rules of typical plant community
A preliminary work is necessary before processing remote sensing image and DEM data. NDVI was created from Merged SPOT 5 image. NDVI was calculated using the SPOT scaled band near infrared and red reflectance data: NDVI = (near infrared-red) / (near infrared+red). Topographic data was calculated from 50,000 DEM data of Bureau of Surveying and Mapping of Fujian province using ArcGIS software. Slope and aspect were derived from DEM. NDVI, elevation, slope and aspect are main factors to extract rarely typical plant community. Knowledge rules about rarely typical plant communities were acquired from former paper.
Interpretation features for Tsuga chinensis and Pinus taiwanensis should be established based on merged SPOT 5 remote sensing image, DEM, GPS survey points and forest map (see Table 1).

Table 1. Interpretation features for Tsuga chinensis and Pinus taiwanensis community

community	Interpretation Features	Field photos	Spot color image
Tsuga chinensis	Light green Smooth hue forming larger patch coarse texture		
Pinus taiwanensis	bottle green Smaller patch Higher elevation		

Extract Tsuga chinensis community

Tsuga chinensis is a key protected species in Fujian province, which exists in the mountain forest in the south of Changjiang river (Qiu,1994).There is an important area of Tsuga chinensis in the Wuyi mountain nature reserve area. According to published paper, their distribution can be wide (from 700 to 2000 meters), but most of the individuals are located in place with elevation from 1650 to 1900m which lies in the southeast and northwest slope of Huanggang peak (Zheng, 2003). Additionally, most of Tsuga chinensis are located under slope of 25 to 35 degrees.

According to field GPS samples and characteristics of vegetation in the reserve area,,the NDVI of vegetation coverage is generally more than 0.6, which NDVI has been normalized to the range [-1 ,1]. Slope knowledge for Tsuga chinensis is ascertained as 15°-38°because of its higher elevation. So knowledge rules for mapping Tsuga chinensis was built based on analysis above as follows:

IF NDVI > 0.6 and 15 < slope < 38 and 1650 < elevation < 1900 Then Tsuga chinensis

Tsuga chinensis was extracted automatically based on the knowledge rules above with expert classifier module in software ERDAS 9.0.

Extract Pinus taiwanensis community

Pinus taiwanensis is a particularly interesting community, which most exists the southeast of China (Hong, 1997, Bi, 2001). It is know that Pinus taiwanensis grows at the higher elevation. There is a significant dominance when elevation is above 1550 meters with shade and semi-shade slope. Moreover, Pinus taiwanensis grows in a wide range of slopes (Song, 2005). So, slope knowledge for Pinus taiwanensis we ascertained is about 20°-38°.

We can establish knowledge rules according to published paper and analysis above as follows:

IF NDVI > 0.6 and 20 < slope < 38 and Aspect < 90 or aspect > 270 and 1500 < elevation < 2100 and Tsuga chinensis false THEN Pinus taiwanensis

Pinus taiwanensis community was extracted automatically based on the knowledge rules above with expert classifier module in software ERDAS 9.0.

Accuracy assessment

Because of the few field samples, the result from expert classification can only be validated with vegetation map provided by the Wuyishan Nature Reserve bureau. The classification identified eight

spots with Tsuga chinensis communities out of the sixteen figured on the vegetation map. Pinus taiwanensis community area covers 157 hectares on the vegetation map but only 89 hectares were classified with our method (about 57 percent). A manual modification is necessary for improving the accuracy from the automatic classification.

Manual modification of the result from expert classification
The result from knowledge rules was modified using a manual method according to the information from the vegetation map.
The final thematic map was draped over DEM in ArcGIS 9.0 and became spatial distribution map of Tsuga chinensis and Pinus taiwanensis community in Wuyi mountain reserve (see figure 4).

4 Result

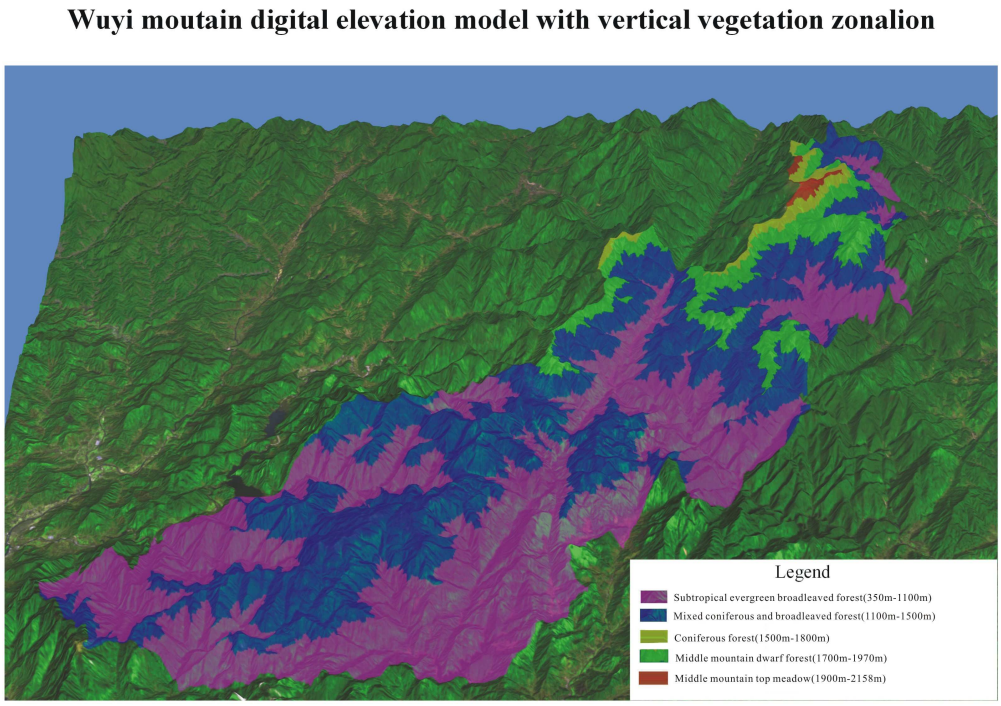


Fig. 3. Wuyi mountain digital elevation model with vertical vegetation zonation

- With three-dimensional map for vegetation it is possible to appreciate terrain information and distribution of vegetation vertically and horizontally. The map has a better visual value and is better readable than general two dimensional' ones. This method, is more appropriated to show the vertical distribution of vegetation.
- Because of rigid thresholds and uncertain knowledge rules, the result from expert classification shows that most of Tsuga chinensis was extracted. On the one hand, There are still some communities that we know from forest map and field data that are missing. On the other hand, some false information were also extracted. These mistakes were corrected through manual method.
- The area of Tsuga chinensis that resulted from interpretation is about 730 hectares. It shows Tsuga chinensis mainly exists in two sites in space: one is near Huanggang peak, the other one is near Zhumu hillock. Further, Tsuga chinensis distributes like a strip from northeast to southwest in a narrow elevation range.
- The area of Pinus taiwanensis that resulted from interpretation is about 89 hectares. Pinus taiwanensis mainly exists in the southeast slope of Huanggang peak and northwest of Xingcun village, scattered in other zones.

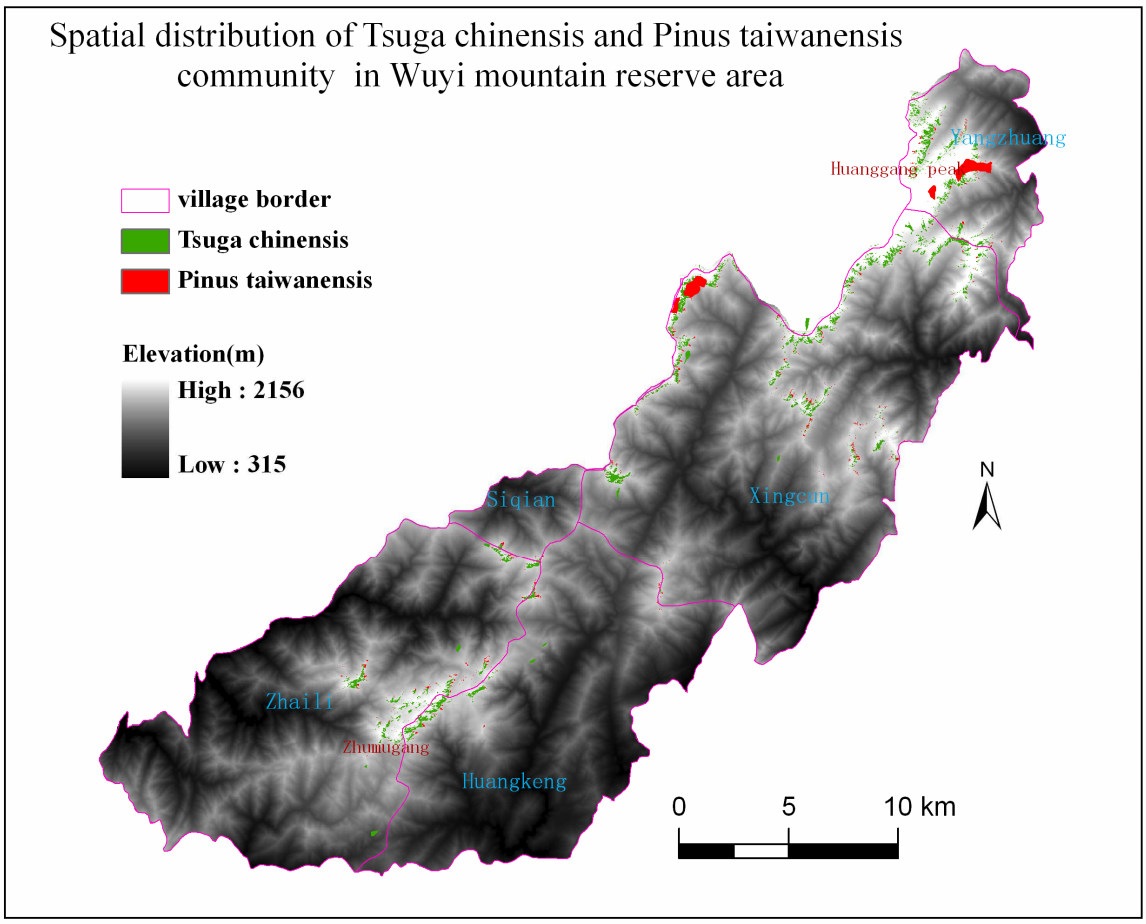


Fig. 4.Spatial distribution of Tsuga chinensis and Pinus taiwanensis community in Wuyi mountain reserve

5 Discussion and Conclusion

- Three-dimensional map for vegetation with terrain information has a better visual impact and are better readable than classic maps. Vertical distribution of vegetation can be exhibited better with this method.
- The area of Tsuga chinensis resulting from interpretation is about 730 hectares. It shows Tsuga chinensis mainly exists in two sites in space: one is near Huanggang peak and the other is near Zhumu hillock. Further, Tsuga chinensis distributes like a strip from northeast to southwest in a narrow elevation range. The area of Pinus taiwanensis derived from interpretation is about 89 hectares. Pinus taiwanensis mainly exists the southeast slope of Huanggang peak and northwest of Xingcun village. It is scattered in other zones.
- Community are composed of many species and their structure is complicated. Object community to be identified is sparse in space and the scale of individual plant is lesser than the spatial resolution of remote sensing image like SPOT 5. It is very difficult to extract rare plant community from high resolution remote sensing images. Consequently, the result only shows primary information of community.
- Because this study is limited by the resolution of remote sensing image, of DEM and few field GPS survey, the result only shows coarse distribution information for Tsuga chinensis and Pinus taiwanensis. Main distribution characteristic of Tsuga chinensis and Pinus taiwanensis can be embodied. In order to get more reliable result, higher resolution remote sensing images, large scale DEM data and more detailed field data would be preferable. Fox example, QuickBird remote sensing image with 0.61 meter spatial resolution may be used for extracting tree crown of typical plant, which is significant to get more exact result.

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