CORRELATION ANALYSIS BETWEEN FOREST VOLUME, ETM+ BANDS, AND HEIGHT ESTIMATED FROM C-BAND SRTM PRODUCT

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Forest stand height and volume are important indicators for management purpose as well as for the environmental analysis. Shuttle Radar Topography Mission (SRTM) is backscattered over forest canopy and DSM can be acquired from such scattering characteristic, while National Elevation Dataset (NED) provides bare earth elevation data. The difference between SRTM and NED is estimated as tree height, and it is correlated with forest parameters, it is correlated with forest parameters, including average DBH, Trees per acre, net BF per acre, and total Net MBF. Especially, among them, net Board Foot(BF) per acre is the index that well represents forest volume. The Project site was Douglas-fir dominating plantation area in the western Washington an the northern Oregon in the U.S. This study shows a relationship of high correlation between the forest parameters and the product from SRTM, NED, and ETM+.. This research performs multi regression analysis and regression tree algorithm, and can get more improved relationship between several parameters.

KEY WORDS: Forest stand, SRTM, NED, ETM+, Board Foot, Regression tree algorithm

1. INTRODUCTION

1.1 Overview

Forest cover is of great interest to a variety of scientific and land management applications, many of which require not only information on forest categories, but also tree canopy density. Also, tree height is an important and interesting forest indicator, but its usefulness is concentrated on a commercial purpose of private timber companies. Forest density can be meaningful indicator that informs how desertification is proceeded and how much forest is destructed by fire.

Although the importance of forest density index is well known, measuring it is not easy deal. Most forest researchers performed field survey measurement to estimate the density of entire timberland. However, field survey at a large area is time-consuming and inefficient. And, in any cases, it is impossible to access to deep timberland, because of the lack of proper transportation. So, it is appropriate to replace inefficient field survey measurement by remote sensing. Remote sensing can be defined as measuring ground, underground, and atmosphere without contact with objects, namely remote ways, including satellite, airplane, and photogrammetry. Remote sensing can be classified into two ways, by active sensors and by passive sensor. Passive sensor is well known for many people, and, in other words, optical sensor can be called. Major characteristic of passive sensor is to sense the backscattered light from surface, which is emitted by the sun. But, the disadvantage of passive sensor is that, without light and good weather condition, it is impossible to sense the ground surface. Active sensor can cover this disadvantage of passive sensor. It itself generates and transmits the waves, and receives backscattered signal. Thus, it is less influenced by the amount of light and weather condition.

In estimating forest density, applying each sensor, passive sensor and active sensor, is a good alternate to field surveying, but combining two sensors is more effective, owing to flexible availability and least noise effect. And combining related parameters enables to make rigid model. This study investigated the relationship between forest volume, especially Net Board Foot (NBF), SRTM-NED product, and ETM+ Bands.

1.2 Research Site

The research site is the western Oregon State, and many parts are covered by Douglas-fir species. Forest stands in inventory GIS data include several forest information, plantation year, species type, and canopy density.

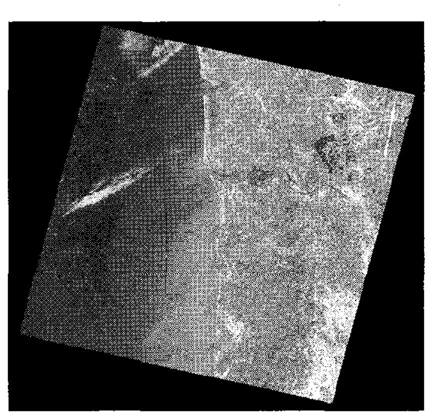

Figure 1. Research Site (Western Oregon)

1.3 Data Characteristic

Shuttle Radar Topography Mission (SRTM) used C-Band and X-Band, and U.S operated only C-Band. Many satellite systems, including ERS-1/2, Radarsat, and Envisat has acquired data using C-Band. Although X-Band is disturbed by many noises and much influenced by weather condition, C-Band enables to get better coherence than X-Band and less influenced by weather. And it is not easy to perform SAR interferometry using two SAR images, but many C-Band satellites have been applied to detect land displacement and subsidence using InSAR. In the early stage of SRTM, "Unfinished" data, SRTM version 1.0 has many voids, so they caused the distortion of topography and geographic error. Recently released, "Finished" data SRTM version 2.0 reduced many voids. USGS provides 1 arc sec SRTM, in U.S.A region, and 3 arc sec SRTM, in an international region on the website http://seamless.usgs.gov. Most countries have their own digital elevation model (DEM), but have not had the experience to have global-scale DEM.

Landsat 7, ETM+, was officially integrated into NASA's Earth Observing System in 1994. It was lauched on April 15, 1999, from Vandenburg Air Force Base, CA. into a Sun-synchronous orbit. Lansat has thre main objectives: The first one is to main data continuity by providing data that are consistent in terms of geometry, spatial resolution, calibration, coverage characteristics, and spectral characteristics with previous Landsat data. The Second one is to generate and periodically refresh a global archive of substantially cloud-free, sunlit landmass imagery. The third one is to contine to make Landsat-type data available to U.S. and international users at the cost of fulfilling user requests and to expand the use of such data for global change research and commercial purposes. Landsat utilizes 8 bands, which include visible wavelength (RGB), Infrared bands, and panchromatic band. (Table 1)

Table 1. ETM+ Bands

Band No.	Wavelength (μ m)
1	0.450~0.515
2	0.525~0.605
3	0.630~0.690
4	0.750~0.900
5	1.55~1.75
6	10.40~12.50
7	2.08~2.35
8 (panchromatic)	0.52~0.90

Each band has its unique characteristic to react to atmosphere, water, and forest. From such aspect, ETM+ can be used to discriminate land use type and vegetation healthiness.

2. ANALYZING THE RELATIONSHIP BETWEEN FOREST VOLUME, SRTM-NED, AND ETM+ BANDS

SRTM is backscatterd from canopy surface, and NED represents the bare earth elevation. The difference between SRTM and NED can be the estimated tree height. But, when considered its relationship deeper, forest density is also related with the subtraction of SRTM and NED. In spite of the same tree height, in case of low forest density, low SRTM-NED value will result in, and in case of high forest density, high SRTM-NED value will result in. Therefore, it is essential to consider the relationship between SRTM-NED and forest density.

2.1 Method

Inventory GIS data involves various forest information, including forest density, species type, plantation year, and area. It is created based on each forest stand. Both SRTM and NED can be downloadable from http://seamless.usgs.gov. Though the USGS website provides several resolutions of NED, in order to keep two images the same resolution, 1 arc sec (about 30m) resolution was obtained. The difference between SRTM and NED can be calculated by a simple operator (-). (Figure 2)

Figure 2. Differential Image of SRTM and NED (Oregon)

Matching with SRTM image and inventory GIS data is an important problem, because some mismatches can become error source. Inside buffering of inventory data, having the polygon type, is performed. This procedure has two advantages. The first one is to reduce the effect of SRTM horizontal accuracy, because 50m inside buffering enables to ignore the influence of horizontal accuracy. The second one is to decrease the boundary effect. Boundaries of each polygon can be influenced by pixel values around its boundary. Buffering eliminates the boundary effect. Through intersection with SRTM-NED and inventory GIS, mean pixel value corresponding to each polygon can be calculated.

ETM+ data can be obtained from http://glcf.umiacs.umd.edu, which provides various products, involving MODIS, AVHRR, and Landsat TM/ETM+. ETM+ image, Oregon, was acquired in July, 2001. ETM+ has 8 bands, but thermal Infrared and panchromatic band are less related with forest and vegetation, so ETM+ 6 Bands (1,2,3,4,5,7) was obtained from the website.

2.2 Results

To show the relationship between SRTM-NED, ETM+ Bands, and forest density, multi-regression analysis and regression tree analysis is performed. When searching the relationship between target parameter and independent parameters, multi-regression is a general solution. Following occam's razor, "simple is beautiful", considering many variables is not the best way, but can not be the worst way describing their relationship.

Table 2. Multi regression result

Variable	Value
Y intercept	39057.94
SRTM-NED	707.1999
ETM+ 1	676.3197
ETM+ 2	-2409.32
ETM+ 3	1921.168
ETM+ 4	-287.837
ETM+ 5	784.2184
ETM+ 7	-1631.55
R^2= 0.568 N=316	

Table 2 shows the result of multi regression between forest density (Net BF per Acre), SRTM-NED, and ETM Bands. The Determinant coefficient R^2 is about 0.57, which means a strong linear relationship between variables.

Classification tree algorithm is a feasible algorithm. Huang C. et al (2001) acquired good results performing regression tree algorithm in publication "A strategy for estimating tree canopy density using Landsat 7 ETM+ and high resolution images over large areas." In this study, using the same algorithm, proper analysis was derived. Regression tree generates a model with rules that describes the relationships between the independent and dependent parameters in the data set. The models for these small data sets required less than one second to complete, and using piecewise regression, it can be more powerful than a multivariate linear model because it allows variables to be weighted differently as condition changes.

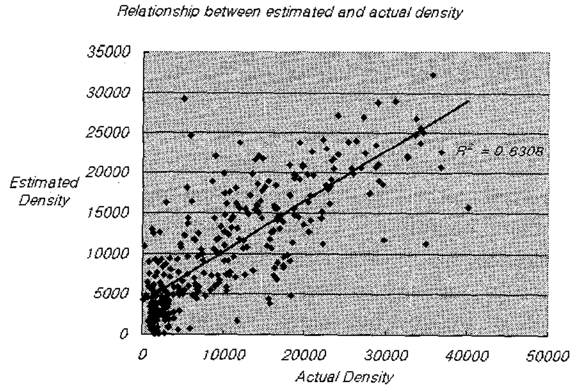

Figure 3. Regression tree result

In Figure 3, the determinant coefficient of estimated and actual density was 0.6308, which means that, when compared with multi linear regression, better estimation equation is generated by rule-based regression algorithm.

3. CONCLUSION

Remote sensing is useful method to estimate forest parameters, forest age, density, height, and volume. Especially, radar is less influenced by weather condition and, day and light. Also, optical sensor can supplement the disadvantage of radar remote sensing, noise effect and low object recognition, in spite of restricted use by weather. Combining optical sensor and active sensor can results in making reasonable model to estimate forest variables, like forest volume. This study found that forest volume can be estimated by using both SRTM and Landsat ETM+. Multi linear regression analysis show that there is a strong linear relationship between forest volume index (Net BF), SRTM-NED, and ETM+ bands. Also, by using some rules and conditions, rule-based regression tree enables to generate more improved linear model. There is not still sufficiently strong relationship, but, when additional images and subsequent conditions are considered, better linear model will be made.

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