ACCURACY IMPROVEMENT OF LOBLOLLY PINE INVENTORY DATA USING MULTI SENSOR DATASETS

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Timber inventory management includes to measure and update forest attributes, which is crucial information for private companies and public organizations in property assessment and environment monitoring. Field measurement would be accurate, but time-consuming and inefficient. For the reason, remote sensing technology has been an alternative to field measurement from an economic perspective. Among several sensors, LiDAR and Radar interferometry are known for their efficiency for forest monitoring because they are less influenced by weather and light conditions, and provide reasonably accurate vertical/horizontal measurement for a large area in a short period. For example, Shuttle Radar Topography Mission (SRTM) and National Elevation Dataset (NED) in the U.S. can provide tree height information and DSM. On the other hand, LiDAR DSM (the first return) and DEM (the last return) can also present tree height estimation. With respect to project site of loblolly pine plantation in Louisiana in the U.S., the accuracy of SRTM C-Band approach estimating tree height was assessed by the LiDAR approaches. In addition, SRTM X-Band and NED were also compared with the results. Plantation year in inventory GIS, which is directly related to forest age, is high correlated with the difference between SRTM C-Band and NED. As a byproduct, several stands of age mismatch could be recognized using an outlier detection algorithm, and optical satellite image (ETM+) were used to verify the mismatch. The findings of this study were (1) the confirmation of usefulness of the SRTM DSM for forest monitoring and (2) Multi-sensors- Radar, LiDAR, ETM+, MODIS can be used for accuracy improvement of forest inventory GIS altogether.

KEY WORDS: SRTM, LiDAR, ETM+, MODIS, Loblolly Pine, Inventory GIS

1. INTRODUCTION

1.1 Overview

Timber inventory management includes to measure and update forest attributes, which is crucial information for private companies and public organizations in property assessment and environment monitoring. Many timberlands are invested by individuals and private companies, and timberland owners periodically sell to liquidate their assets. Consequently, timberland transactions have become very active and their valuation is frequently requested prior to any price negotiation. For this reason, quality assurance and improvement of timber inventory databases in the forest industry has become more than ever. Field measurement would be accurate, but time-consuming and inefficient. For the reason, remote sensing technology could be the solution alternative to field survey. Specially, the method using radar is useful, because it is less influenced by the amount of light and weather condition and provides reasonably accurate measurement for a large area in a short period. Among SAR applications, SAR interferometry is very promising technology, which enables to generate DEM and detect a tiny land displacement. SAR inteferometry has potential in estimating tree height. In addition, optical sensors, like Landsat and SPOT, can improve the accuracy of SAR interferometric tree height estimation, by using several bands of RGB and infrared. In this study, quality improvement of timber inventory database will be investigated, using SAR and Landsat ETM+.

1.2 Project Site

The research site in this study is Louisiana State, many areas of which is commercially planted by forest companies and individual timberland owners. Dominant species in this area is loblolly pine, which grows up linearly, so its plantation year in forest inventory GIS has linear relationship with the height of loblolly pine.

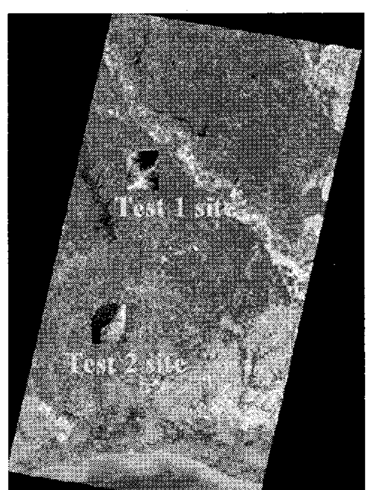

Figure 1. Project Site (Louisiana State) and Test sites

1.3 Data Characteristics

SRTM, cooperated with U.S. (NASA, NGA), Germany (DLR), and Italy (ASI), was the mission that acquired a global DEM that covers 80% area, using a single pass interferometry. SRTM C-Band (5.6cm), operated by U.S., and X-Band (3.1cm), operated by Germany and Italy, are acquired at the same time and has different characteristics. (Table. 1)

Table 1. Specification of C-Band and X-Band

Parameter	Band	
	X	C
Wavelength	5.6cm	3.1cm
Carrier frequency	5.3GHz	9.6GHz
Polarization	Dual	VV
System Swath	225km	50km

NED, provided by USGS, presents bare earth elevation that forest and building are removed. The data is made by aerial photogrammetry and field survey.

LiDAR is very effective method in generating DEM within cm horizontal/vertical accuracy, which can make DSM and DEM altogether using the first return and the last return. LiDAR data in Louisiana State is collected from 2000 to 2006, supported by FEMA, National Flood Insurance Program and the private insurance industry in the state. LiDAR systems being used in the Louisiana project are accurate to 15-30 cm RMSE. Specially, data used in this study is acquired in 2005.

Landsat ETM+ scene from April from 2000 covering project site is used. Panchromatic and Thermal infrared band is excluded in investigating the relationship band DN and plantation year.

MODIS NDVI covering entire north America was acquired in 2000 and reprojected as it has the same coordinate system.

2. ASSESSING THE ACCURACY OF SRTM C-BAND

For the purpose of assessing the accuracy of SRTM C-Band, test 1 and 2 site (Figure.1) is selected. Test 1 site has SRTM X-Band, C-Band, and NED, but no LiDAR data. Thus, the absolute SRTM C-Band elevation accuracy cannot be calculated, and the difference of phase center between X-Band and C-Band can be examined. Test 2 site has SRTM X-Band, C-Band, NED, and LiDAR data. Though other data were acquired in 2000 and LiDAR data is collected in 2005, LiDAR DSM elevation in forest area can be estimated from strong linear relationship (correlation coefficient: 0.90) between the tree height from LiDAR DEM and DSM and the plantation year in inventory GIS. As a consequence, the absolute vertical accuracy of SRTM C-Band could be assessed , assuming that LiDAR, having high vertical accuracy, is ground truth in forest and non-forest area.

2.1 Test 1 site

From different wavelength of SRTM C-Band and X-Band, its DEM shows very different characteristics.

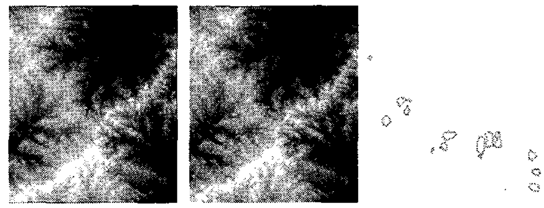

Figure 2. C-Band and X-Band of Test 1 site and Data void

Upper figure (figure 2) presents C-Band and X-Band of Test 1 site and data void of entire Louisiana area. C-Band has many data voids (the third image of figure 2), so much time for eliminating them was took. Though voids in SRTM v.2.0 are reduced, many voids still exist and they should be considered when processing SRTM C-Band, because they could be error sources. C-Band, having lower noise, shows smoother texture than X-Band, but X-Band illustrates more detailed information, like bridge and small stream, than C-Band.

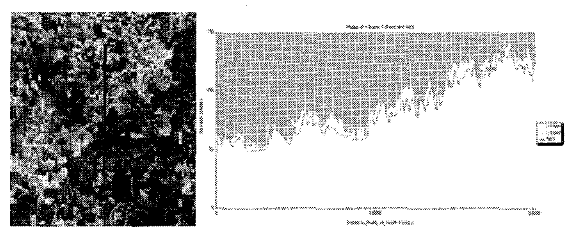

Figure 3. Test 1 Landsat image (ETM+) and Profile of A-A' line

When compared with X-Band, C-Band, and NED, by obtaining the profile of A-A' line, NED shows the lowest elevation, and X-Band had higher elevation than C-Band. The difference between X-Band and C-Band was about 1.034m, and the result means that X-Band penetrates canopy deeper than C-Band, but the depth is not great.

2.2 Test 2 site

In order to compare the elevation of X-Band, C-Band, NED, and LiDAR in forest area, in first, elevation in bare earth area was compared, assuming that the elevation from various products, has same elevation. The road surface could be bare earth, and 50 points above the surface were selected and their elevation were compared.

Table 2. Difference between LiDAR DEM and other products

	Elevation Difference
LiDAR DEM - LiDAR DSM	-0.12 m
LiDAR DEM - NED	-0.03 m
LiDAR DEM - C-Band	-6.71 m
LiDAR DEM - X-Band	-3.16 m

Assuming that LiDAR DEM is ground truth elevation, systematic vertical errors of C-Band and X-Band can be calibrated from the difference of several products. The calibration in bare earth can be applied to the results in forest region, though forest area and bare earth have a few different backscattering characteristics.

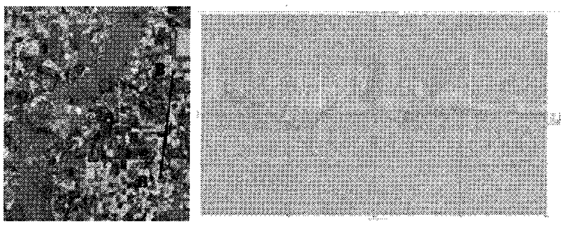

Figure 4. Test 2 Landsat image (ETM+) and Profile of B-B' line

LiDAR data in Test 2 is obtained in 2005, so canopy height in forest area in 2000 was calculated from linear relationship with plantation year and tree height. As a result, it is concluded that loblolly pine grows 2.557m for 5 years. When the elevation of LiDAR DSM in 2005 is corrected as much as the value, actual canopy elevation, assumed as ground truth, can be obtained in 2000. In figure 4, LiDAR DEM has the lowest elevation, and LiDAR DSM has the highest elevation. The varying trend of X-Band, C-Band, and LiDAR DSM is almost identical. From 400 points in forest area of test 2 site, the elevation of all products is obtained, calibrated, and compared with each other.

Table 3. Difference between LiDAR DSM, X and C-Band

	Difference
LiDAR DSM - X-Band	0.78 m
LiDAR DSM - C-Band	2.42 m
X-Band - C-Band	1.36 m

As shown in table 3, it is found that X-Band has small penetration depth (0.78m) and C-Band has a little bigger value (2.42m). This penetration depth means the position of phase center, that each wave is backscattered. And, though C-Band penetrates canopy layer a little, it has sufficient vertical accuracy in estimating canopy layer and tree height.

3. METHOD USING SRTM C-BAND AND NED

SRTM C-Band presents approximate canopy height, although it has about 2.42m penetration depth, and NED presents bare earth. So, the difference between C-Band and NED means the interferometric tree height.

3.1 Result

The both datasets of SRTM and NED has the same resolution (30m), and for analysis, two datasets were precisely aligned, while they were reprojected to have the same coordinate system (UTM 15, WGS84). The difference between C-Band and NED was compared with the plantation year of forest inventory GIS data.

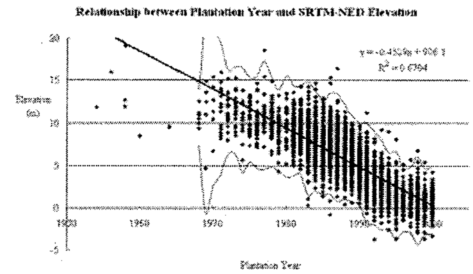

Figure 5. Relationship between plantation year and SRTM-NED elevation

In figure 5, the plantation year in 3500 datasets of forest inventory GIS data is high correlated with the difference between SRTM and NED. Its coefficient of determination, r^2, is 0.6704, and the value means that a strong linear relationship between SRTM-NED and plantation year exists.

3.2 Outlier removal

In figure 5, two thin lines represent the range of 3 standard deviation, and points outside its range can be considered as outliers. 27 of 3500 datasets were detected as outlier. Also, its type can be classified to 3 types of causes. These types could be acquired by the comparison with ETM + scene.

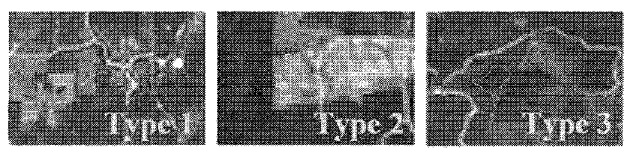

Figure 6. Type 1, 2,and 3 outlier

Type 1 outlier is made by the error of inventory GIS data, because it has incorrect plantation year. Type 2 outlier is made by the variance of SRTM elevation and noise, because it has great negative elevation. Type 3 outlier is generated by volume scattering, because it has much bigger height than actual one. When outliers are removed, there is stronger linear relationship between SRTM-NED and plantation year. ($r^2 \approx 0.69$)

4. METHOD USING ADDITIONAL OPTICAL SENSORS

Landsat ETM+ bands (Band 1, 2, 3, 4, 5, 7) are related with several forest parameters, like tree height, density, water content, and age. And Tassled Cap, NDVI, and Principal components from ETM+ and MODIS NDVI are very useful vegetation indices and they are also closely related with forest parameters. Using SRTM and indices from optical sensors, linear relationship between plantation year and estimated value could be improved.

4.1 Analysis using Multiple Linear Regression

Using 15 variables, related with forest age, obtained from SRTM C-Band, ETM+, and MODIS, which are SRTM-NED, ETM+ 1, 2, 3, 4, 5,and 7 bands, ETM+ NDVI, TC Brightness, TC Greeness, TC Wetness, PC 1, 2, and 3, and MODIS NDVI, single and multiple linear regression of plantation year and each variable were performed.

Table 4. Regression Analysis between variables and plantation year

Variable	R^2	Variable	R^2
SRTM-NED	0.69	ETM+ NDVI	0.19
ETM+ 1	0.28	TC Brightness	0.39
ETM+ 2	0.33	TC Greeness	0.23
ETM+ 3	0.29	TC Wetness	0.35
ETM+ 4	0.04	PC 1	0.37
ETM+ 5	0.36	PC 2	0.37
ETM+ 7	0.33	PC 3	0.25
MODIS NDVI	0.05	ALL	0.74
Stepwise Forward Regression Variables: SRTM-NED, ETM+ 1, 3, 5, ETM+ NDVI, TC Brightness, TC Wetness, PC 3 R^2: 0.73			

In Table 4, when using all variables, determinant coefficient was 0.74. And from stepwise forward regression, 8 of 15 variables were selected and its result was 0.73 (r^2).

4.2 Analysis using Regression Tree Algorithm

Regression tree algorithm is similar to the decision tree classifier in that it recursively splits training samples into subsets, two at each split. Instead of assigning class labels to the subsets, it develops a linear regression model for each of them. Each splitting is made such that the combined residual error of the models for the two subsets is substantially lower than the residual error of the single best linear model for the samples in the two subsets, and that the combined residual error of the split is the minimum of all possible splits. This algorithm has been applied to many remote sensing applications and its result was feasible.

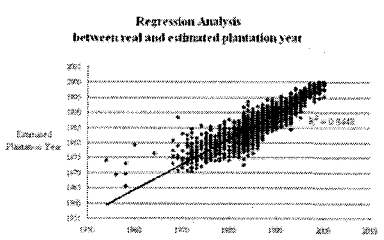

Figure 7. Relationship between real and estimated plantation year from regression tree algorithm

In figure 7, real and estimated plantation year from regression tree algorithm has a strong linearity and its determinant coefficient was 0.84. From this result, the estimation of plantation year using regression tree algorithm with various data inputs, SRTM and optical sensors, could be very effective and promising.

5. CONCLUSION

Information, related with forest, is very critical for private purpose and environmental aspects. Also, commercially managed timberland varies actively, while forest can be cut for a new plantation and its ownership can be changed. Although detecting such change is not easy job, by using remote sensing, much effort and time can be alleviated. SRTM C-Band has sufficient vertical accuracy in estimating tree height, and the plantation year and C-Band has a strong linear relationship. When the result from SRTM C-Band is supplemented by additional optical sensors, the relationship can be improved. In conclusion, using C-Band and more sensors is efficient and effective in updating and managing inventory GIS data.

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