Analysis of Correlation between Canopy Cover and Vegetation Indices

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Abstract

A canopy cover is geospatial information attributes that are commonly used in forestry and observation equipment allocation. However, it is extremely difficult to measure canopy cover ratio of all tree regions in the field, and tree's leaves are continuously changed by season and climate. Hence, a remote sensing technique that makes it possible to obtain forestry information on broad areas within a short period of time has been considered. This study has attempted to investigate the reliability of the results obtained from canopy cover based on the vegetation index of mid-resolution images by performing regression analysis between Landsat Normalized Difference Vegetation Index (NDVI), which has a relatively broad image acquisition area, LAI and DMT and reference data for canopy cover extracted from high-resolution images. It shows that the relationship of canopy cover and NDVI is higher than that of canopy cover and LAI, DMT. The DMT is needed improving the accuracy and updating more frequently. It is also found that the pixel-based canopy cover extraction approach provides better correlation results than the segment-based approach.

Keywords: *NDVI, LAI, DMT, Canopy Cover, Landsat, Regression*

1. Introduction

The determination of the attributes of tree information by area is closely related with the development of the density measure of the canopy cover, which effects military viewshed analysis, as well as with the forecast of tree growth and production of crops. [1] In urban areas as well, it is necessary to consider the seasonal effects of canopy cover in certain areas for the installation of monitoring equipment such as CCTV cameras and practical performance analysis. The Line of Sight (LOS)-oriented conventional studies have mostly focused on investigating the effect of altitude on LOS analysis, which is a matter of how to make the geographical form look like a real surface. In other words, these studies have focused on its effect on the results of LOS analysis. [2][3] The density measure of canopy cover, however, is very difficult to assess in all forests. Because of seasonal and climatic influences, it is difficult to reflect them as the result of the LOS analysis. In a study by Bang *et al*. (2010), the Density Measure % of Tree/Canopy Cover (DMT) of Vector Interim Terrain Data (VITD), a military digital terrain map, was used. [4] This has limitations in realizing actual visual probability without reflecting the latest canopy cover, which continuously changes.

The effect of vegetation distribution and density in a broad region on seasonal LOS analysis can vary, and it can be easily changed for the users' purposes. Therefore, the effects of NDVI-based tree cover could be considered. [5] Because the calculation of the actual density measure of tree cover in a broad area would be burdensome in terms of time and money, therefore, it is common to calculate correlations between vegetation indices and terrestrial data through remote sensing. To verify the increase in density measure of the canopy cover over years, many studies have come up with Landsat MSS and TM-based density measures of canopy cover and linear NDVI formula. [6-9] Li *et al*. (2012) used Landsat ETM+ to map the aquatic vegetation distribution on a large scale in Honglu lake-China. [10] Because NDVI represents vegetation viability, if the viability drops, the density measure of the canopy cover decreases even though leaves are still found. [11] In the case of LOS analysis, the density of leaves distributed from the canopy top to the ground as well as the canopy surface is influential. Therefore, the Leaf Area Index (LAI) would be more practical. Stewart *et al*. (2007) examined correlations between canopy cover and LAI and proved high correlations between the density measure of tree cover and LAI [12].

Despite the advantage of remote sensing techniques, the acquisition of spectral reflection energy on the ground on a cloudy or rainy day is not possible. Hence, it is not easy to get images in summer when woods are thick and lush. It is necessary to develop and make use of a formula between high-resolution images in summer and low and mid-resolution images that cover a broad area. This study has attempted to examine the possibility of enhancing reliability with the results from canopy cover based on low and mid-resolution images after analyzing correlations between typical low and mid-resolution Landsat NDVI, LAI and DMT with the reference data of canopy cover extracted from high-resolution images.

2. Data Preparation

2.1 Study Area

Two areas in South Korea were chosen for this study. Both Yeoncheon (Site I) and Cheolwon (Site II) are situated in the Demilitarized Zone (DMZ). Yeoncheon ($70km^2$) is comprised of farmland, watershed, urban area, grassland and forest while Cheolwon ($64km^2$) consists of farmland, watershed, urban area and forest. Both sites are restricted areas to which the general public is not allowed access.

2.2 Necessary Data Preparation

To get altitude data (DSM), SRTM DTED level-2, which was installed at 30-meter intervals in the test area, was used. A topographic effect correction was performed to support the generality of the results. Two high-resolution images (QuickBird satellite image and SPO-5 satellite image) were prepared. Low and mid-resolution images (experimental data extracted from main vegetation indices), which are called 'Landsat TM images', were prepared. The QuickBird images cover Area I while the SPOT-5 images cover Area II. Some brief information on these images is as follows:

Table 1 Data description

Digital Source	Location Coverage	Acquisition time	Spatial resolution	Spectral resolution	Data type
Landsat TM	Site 1, Site 2	June, 2004	30m	7 Bands	Raster
QuickBird	Site 1	August, 2004	2.8m	4 Bands	Raster
SPOT-5	Site 2	October, 2005	10m	4 Bands	Raster
VITD	Site 1, Site 2	-	-	-	Vector

3. Methodology

A canopy cover map can be made using high-resolution images. Because the areas covered by the images are narrow, it takes a lot of money to make a government-unit canopy cover map, and it is not easy to acquire images in the same period. It may be possible to make a canopy cover map using mid-resolution images, but there is a high possibility of producing an incorrect canopy cover map due to low spatial resolution. Therefore, this study has tried to make a more accurate, cost-efficient canopy cover map that reflects present conditions, which can be substituted for the prior DMT data using high- and mid-resolution images based on remote sensing vegetation indices.

The test method is divided into three steps. First, NDVI and LAI (vegetation indices) are generated from Landsat image. In addition, the DMT of the VITD to which attributes are allocated by vector polygon is rasterized. Second, a canopy cover map is generated from SPOT5 and QuickBird high-resolution satellite images. Lastly, correlations between a canopy cover map, which is made based on high-resolution satellite images and medium resolution NDVI, LAI and DMT, are computed, and their application is analyzed.

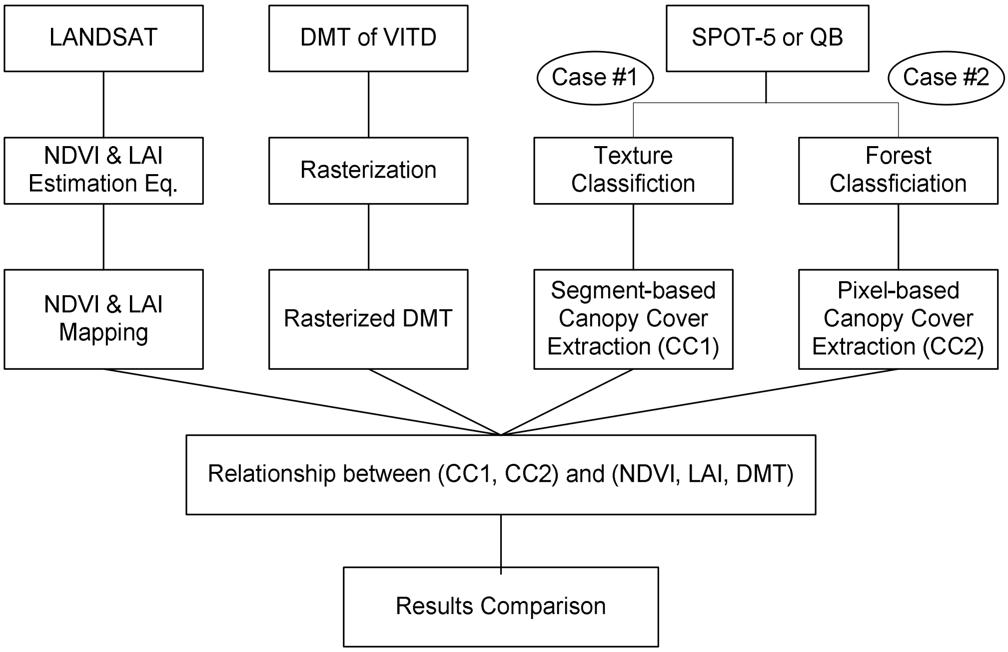


Figure 1. The flow chart of the experiment

3.1 Generation of Landsat Vegetation Indices

The Normalized Difference Vegetation Index (NDVI) is the most popular vegetation indices. NDVI is calculated on a per-pixel basis as the normalized difference between the red and near infrared bands from an image. In case of using Landsat TM image, NDVI is calculated by using the following equation [13][14]:

$$\mathrm{NDVI} = \frac{\rho_{TM4} - \rho_{TM3}}{\rho_{TM4} + \rho_{TM3}} \quad (1)$$

To calculate LAI using Landsat TM images, a Reduced Simple Ratio (RSR) was computed by pixel unit as shown in the equation below. LAI was then generated using a regression analysis formula suggested by Schiffman et al. (2008) [15].

$$RSR = \frac{\rho_{TM4}}{\rho_{TM3}} * \frac{\rho_{TM5\,Max} - \rho_{TM5}}{\rho_{TM5\,Max} - \rho_{TM5\,Min}} \quad (2)$$

$$LAI = 0.6789 \times RSR - 0.001 \quad (3)$$

3.2 Canopy Cover Ratio Method using High-resolution Satellite Imagery

In case #1, using high-resolution satellite images, MLC-based classification was conducted under the following categories: urban area, watershed, farmland, grassland and forest. After selecting forest only, the related parts were separated and selected in near infrared. Watershed segmentation was then performed in the separated images, then canopy ratio computation was carried out. [16] After calculating the number of forest pixels by segment, the density measure of the canopy cover by segment was obtained.

$$CCR_i = \frac{FA_i}{SA_i} \times 100 \quad (4)$$

where i is the segment number, CCR_i the canopy cover ratio of the i^{th} segment, FA_i the forest area in the i^{th} segment, and SA_i the whole area of the i^{th} segment.

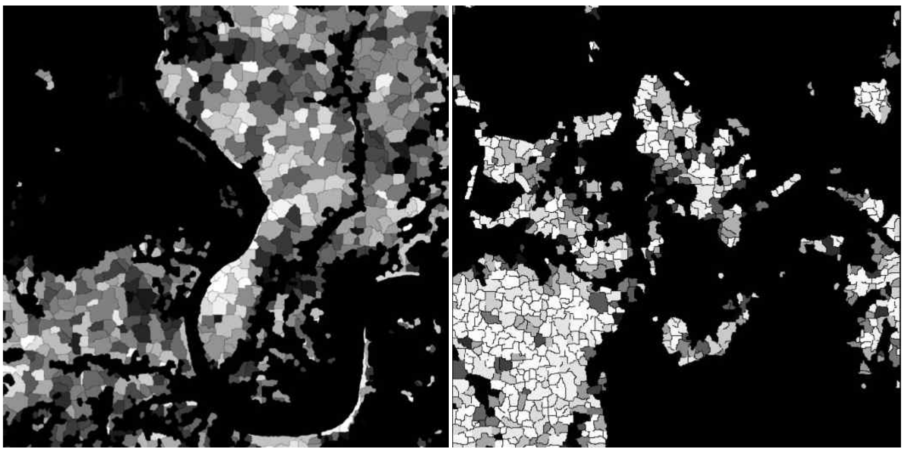
In case #2, the high-resolution satellite images were classified into 5 classes. The forest area was then extracted based on the classification result. After that, canopy cover was simply computed as the number of forest pixels in a Landsat ground resolution (30x30m).

3.3 Computation of regression Landsat Vegetation Indices with Canopy Cover map

The density measure of the canopy cover obtained by segment using high-resolution satellite images has been re-sampled to match the Landsat spatial resolution. Then, a pixel-to-pixel comparison was performed. Without a separate extraction from the forest area, the areas with positive NDVI only were targeted to minimize errors that could occur in barren and artificial structures. Ideally, the density measure of the canopy cover on all mid-resolution areas can be calculated based on a correlation formula between the density measure of the canopy cover from the regression analysis and vegetation indices.

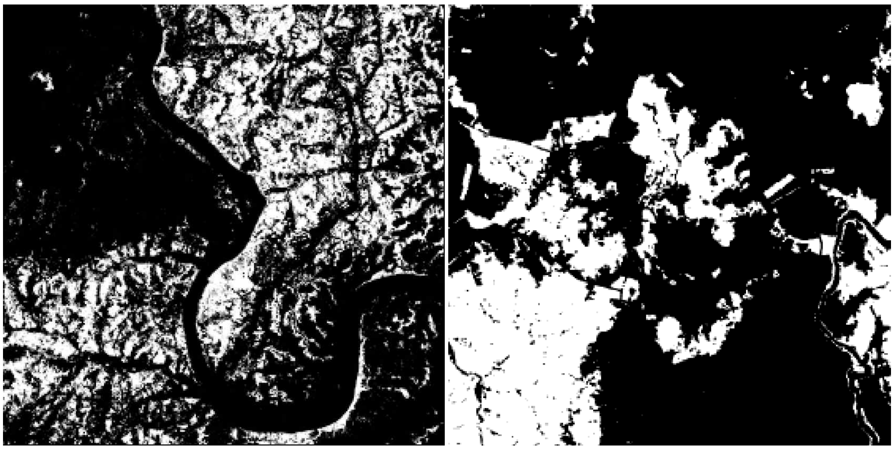
4. Experimental results and analysis

In this research we used 2 canopy cover map on 2 sites of study area. Using the method that was mentioned above, canopy cover map of site #1 was generated from the QuickBird image, and canopy cover map of site #2 was generated from the Spot 5 image. The Canopy cover maps of case #1 and case #2 were shown in Fig. 2 and Fig. 3.



(a) (b)

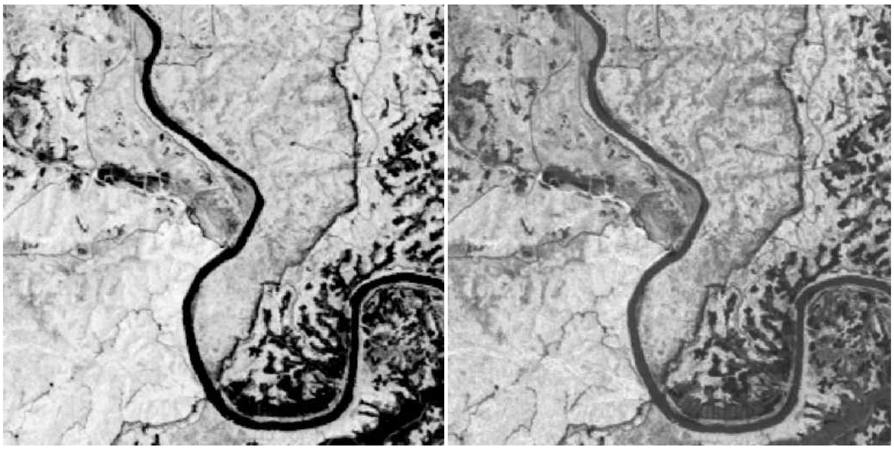
Figure 2. Canopy cover map of case #1: (a) Site #1 (b) Site #2



(a) (b)

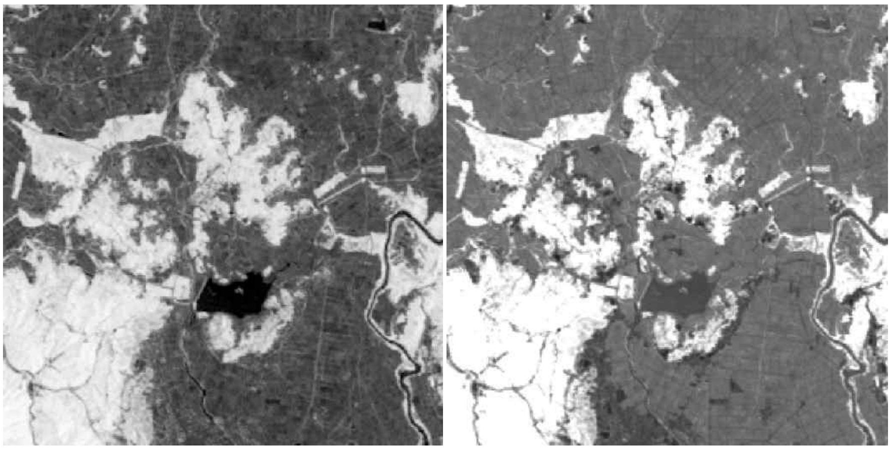
Figure 3. Canopy cover map of case #2: (a) Site #1 (b) Site #2

To compute NDVI and LAI the software ENVI was first used to transform Landsat DN value into reflectance. Then this reflectance data was used to calculate NDVI by using ENVI. This data was also used to calculate RSR as the Eq. 2 and then LAI was computed as the Eq. 3 by using spatial modeler in ERDAS. The results of NDVI and LAI computation were shown in Fig. 4 and Fig. 5.



(a) (b)

Figure 4. NDVI and LAI of site #1: (a) NDVI (b) LAI



(a) (b)

Figure 5. NDVI and LAI of site #2: (a) NDVI (b) LAI

In this research the canopy cover maps were generated by two methods as mention above. In case #1 the respective spatial resolution of two canopy cover maps are 2.8m and 10m. However, the NDVI and LAI which were derived from Landsat TM5 image have resolution of 30m. Therefore, canopy cover maps were re-sampled to match the resolution of NDVI and LAI image, after re-sampling all images have the resolution of 30m. Then the linear regression analysis was performed to evaluate the relationship between canopy cover and NDVI, LAI, DMT by using Matlab. The correlation coefficients and linear equations were shown in Tab. 2 and Tab. 3, respectively.

To reduce the impact of topographic on the NDVI and LAI computing, the topographic correction was carried out on Landsat image using ERDAS. Then the linear regression analysis was performed. However, the result is not better than the case in which the topographic correction was not performed. The maximum correlation coefficient is only 0.42.

In case #2, the canopy cover maps were generated as the number of 3x3m and 10x10m forest pixels in a 30x30m pixel. The correlation coefficients and linear equations for this case were also shown in Tab. 2 and Tab. 3.

Table 2. Correlation coefficient of CC and NDVI, LAI, DMT

	Canopy cover					
	Site #1			Site #2		
	NDVI	LAI	DMT	NDVI	LAI	DMT
Case #1	0.2045	0.2752	0.2435	0.4208	0.4344	0.1203
Case #2	0.2678	0.3947	0.2358	0.6292	0.5802	0.1914

Table 3. Linear equation of CC and NDVI, LAI, DMT

		Canopy cover		
		NDVI	LAI	DMT
Site #1	Case #1	y = 54x + 20.4	y = 9.292x + 28.43	y = 0.1625 + 46.67
	Case #2	y = 129.1x - 28.78	y = 25.11x - 17.99	y = 0.3127x + 38.1
Site #2	Case #1	y = 48.2x + 62.97	y = 6.468x + 75.24	y = 0.05491x + 89.53
	Case #2	y = 13.66x - 0.3775	y = 1.74x + 3.343	y = 0.01792x + 6.895

In case #1, the correlation coefficient (R) of canopy cover and LAI is highest in both sites. The R of canopy cover and NDVI is lowest in site #1, but in site #2 the minimum R is of canopy cover and DMT. However, there is only a mild relationship between canopy cover and NDVI, LAI in site #2. The relationship between canopy cover and DMT is lowest in both sites, maximum R is only 0.2435.

In case #2, the R of canopy cover and LAI is highest in site #1. But in site #2 the maximum R is of canopy cover and NDVI, and the R of canopy cover and NDVI, LAI is also higher than that of site #1. The R of canopy cover and DMT is lowest in both sites, maximum R is only 0.2358. In this case the correlation coefficient of canopy cover and NDVI, LAI are also higher than the case #1.

In site #2 the canopy cover map was generated from QuickBird image which has resolution of 2.8m, whereas in site #1 the canopy cover map was generated from Spot-5 image with resolution of 10m. But the R of canopy cover and NDVI, LAI, DMT of site #2 is higher than that of site #1.

5. Conclusions and future work

The regression results shown that the relationship of NDVI and canopy cover is strongest, and that of DMT and canopy cover is weakest. However, there is only a moderate relationship between Canopy cover and NDVI, LAI in site #2; and there is only a little relationship between Canopy cover and DMT. In site #1 only a little relationship between canopy cover and NDVI, LAI, DMT was found. It is also shown that the relationship between canopy cover and NDVI is higher than that of canopy cover and LAI. And the topographic correction does not improve the results of NDVI, LAI computation.

The relationship of canopy cover and NDVI, LAI, DMT is higher in case #2, in which the canopy cover was generated as the number of forest pixels in a 30x30m pixel. It shows that 2nd method of canopy cover extraction which was mentioned above is better than 1st method.

The canopy cover map in site #1 was generated from a very high resolution image, whereas in site #2 the canopy cover map was generated from a lower resolution image. But the relationship between canopy cover and NDVI, LAI in site #2 is higher than in site #1. This shows that using moderate high resolution satellite imagery for generating canopy cover map is more efficient than using very high resolution satellite imagery. Using seasonal images, we can make seasonal canopy cover map for LOS (Line of Sight) Analysis.

As mentioned above there is only a little relationship between canopy cover map and DMT in both sites, the maximum of correlation coefficient of canopy cover and DMT is only 0.2435. Therefore, DMT doesn't show the real canopy cover information, besides it is necessary to improve the accuracy of the DMT, and it also needs updating the DMT more frequently.

In this research three satellite images were used, these three images were acquired at different times. One was acquired in June 2004, another was acquired in August 2004, and the other was acquired in October 2005. The changes in the study sites during this period might affect on the accuracy of regression analysis. Therefore, in the future it is necessary to use the images which are acquired at the same time or at least in the same season in a year to evaluate the real relationship of canopy cover and NDVI, LAI, DMT.

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References

[1] Bach, H., Mauser, W., "Multisensoral Approach for the Determination of Plant Parameters of Corn", Proceedings of the IGARSS´95 Symposium, Firenze, IEEE, pp. 960-962, 1995.
[2] De Floriani, L., Magillo, P., "Multiresolution mesh Representation: Models and Structures", in Tutorials on Multiresolution in Geometric Modelling, pp. 363-418, 2002.
[3] De Floriani, L., Magillo, P., "Algorithms for Visibility Computation on Terrains: A Survey", Environmental and Planning B: Planning and Design 2003, vol. 30, no. 5, pp. 709-728, 2003.

[4] Bang, S.N., Heo, J., Han, S.H., Sohn, H.G., "Infiltration Route Analysis Using Thermal Observation Devices (TOD) and Optimization Techniques in a GIS Environment", Sensors, vol. 10, no. 1, pp. 342-360, 2010.
[5] Tomko, M., Trautwein, F., Purves, R.S., "Identification of Practically Visible Spatial Objects in Natural Environments", Advances in GIScience: 12th AGILE International Conference Proceeding, June 5th, Hannover, Germany, pp. 1-23, 2009.
[6] Larsson, H., "Acacia canopy cover changes in Rawashda forest reserve, Kassala Province, Eastern Sudan, using linear regression NDVI models", International journal of remote sensing, Vol.23, No.2, pp.335-339, 2002.
[7] Hellde"n, U., and Olsson, L., "Fuelwood assessment of the Kassala Province", The Democratic Republic of The Sudan. Remote Sensing Laboratory of Physical Geography, University of Lund, Sweden. Ref. FAO contract no. TF/SUD/033/-1/NET/ FOOD, p.27, 1989.
[8] Carreiras Joao M.B., Pereira Jose M.C., Pereira Joao S., 2006, "Estimation of tree canopy cover in evergreen oak woodlands using remote sensing", Forest Ecology and Management, vol. 223, issues. 1-3, pp. 45-53, 2006.
[9] Yang J., Zhang H., Yuan X., Zhang X., Chen H., Dong J., Wang Y., Zhang X., Assessment of Ecosystem Service Value Change Based on Land Use and Cover Change: A Case Study of Tianjin Binhai New Area, China, Advances in information Sciences and Service Sciences(AISS), vol. 4, no. 18, pp. 435-442, 2012
[10] Li, F., Li, C., Xiao, B., Mao, X., "Combination of Multiple Classifiers for Mapping Aquatic Vegetation Using Satellite Imagery", Journal of Convergence Information Technology, vol. 7, no. 19, pp. 546-553, 2012.
[11] Zheng, G., Moskal, L.M., Retrieving Leaf Area Index (LAI) Using Remote Sensing: Theories, Methods and Sensors, Sensors, vol. 9, pp. 2719-2745, 2009.
[12] Stewart, A.M., Edmisten, K.L., Wells, R., Collins, G.D., Measuring Canopy Coverage with Digital Imaging, Communications in Soil Science and Plant Analysis, vol. 38, issue 7-8, pp. 895-902, 2007.
[13] Hardisky, M.A., Klemas, V. and Smart, M., "The influence of Soil Salinity, Growth Form, and Leaf Moisture on the Spectral Radiance of Spartina Alterniflora Canopies", Photogrammetric Engineering and Remote Sensing, vol. 49, pp. 77-83, 1983.
[14] Jensen, J.R., "Remote Sensing of the Environment-An Earth Resource Perspective", Prentice Hall, pp.361-363, 2007.
[15] Schiffman, B., Basson, G., Lue, E., Ottman, D., Hawk, A., Ghosh, M., Melton, F., Schmidt, C., Skiles, J.W, "Estimation of Leaf Area Index (LAI) through the acquisition of ground truth data in Yosemite national park", ASPRS 2008 Annual Conference, Portland, Oregon, April 28 - May 2, 2008.
[16] Chang A., Eo Y., Kim S., Kim Y., Kim Y., Canopy-cover thematic-map generation for Military Map products using remote sensing data in inaccessible areas, Landscape and Ecological Engineering, vol. 7, pp. 263–274, 2011.