PREPARATION OF CARBON DIOXIDE ABSORPTION MAP USING KOMPSAT-2 IMAGERY

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ABSTRACT: The objective of this study is to produce the CO_2 (carbon dioxide) absorption map using KOMPSAT-2 imagery. For estimating the amount of CO_2 absorption, the stand biomass of forest was estimated with the total weight, which was the sum of individual tree weight. Individual tree volumes could be estimated by the crown width extracted from KOMPSAT-2 imagery. In particular, the carbon conversion index and the ratio of the CO_2 molecular weight to the C atomic weight, reported in the IPCC (Intergovernmental Panel on Climate Change) guideline, was used to convert the stand biomass into the amount of CO_2 absorption. Thereafter, the KOMPSAT-2 imagery was classified with the SBC (segment based classification) method in order to quantify CO_2 absorption by tree species. As a result, the map of CO_2 absorption was produced and the amount of CO_2 absorption was estimated by tree species.

KEY WORDS: KOMPSAT-2, SBC, carbon dioxide absorption map, IPCC

1. INTRODUCTION

To respond global climate changes, international nations had founded IPCC and had adopted UNFCCC (United Nations Framework Convention on Climate Change). It is the Kyoto protocol - carrying legal binding force to developed countries - that UNFCCC selected for mandatory reduction of green house gas emissions. In this protocol, “Carbon Sink” is provided as one of the additional, ancillary processes to reduce green house gases. Kim et al.(2007) mentioned that the forest is major carbon sink and converts carbon dioxide to carbon in biomass and in soil during the photosynthesis processes of vegetation. By following IPCC GPG (Good Practice Guidance), building statistics of green house gases is necessary for certification of entire amount of carbon, which the forest absorbed and converted. In Korea, KFRI (Korea Forest Research Institute) leads related researches and projects for constructing statistical database (Lee et al., 2004; Seo et al., 2006; Lee, 2007), and KFS (Korea Forest Service) works on many projects for expending carbon sinks, such as “ten-year-plan for carbon sink (2005)”.

There have been many studies about estimating the amount of green house gas emission and absorption, which forms the basis of reliable green house gas statistics based on IPCC GPC; estimates of biomass and carbon absorption of stand (Seo et al., 2005), estimates of carbon emissions by biomass burning and land-use change (Dong et al., 2003), assessing carbon dynamics in agriculture using remote sensing (Daughtry et al., 2002), and monitoring terrestrial carbon cycle using remote sensing data (Calvet et al., 2004; Smith et al., 2008).

In previous studies using satellite imagery, biomass and carbon sinks are mainly estimated by classification of vegetation and soil in wide area using low-resolution images; MODIS, SPOT-VEGETATION, or NOAA-AVHRR (Ranson et al., 2007). However, estimated values from low-resolution images are less reliable than those from high-resolution images, because it is difficult to obtain precise information by using low-resolution images. Although recent studies have applied high-resolution images, such as IKONOS and Quickbird, on estimating biomass and carbon storage (Thenkabail et al., 2004), these are limited to the estimation of carbon storage of individual vegetations. Therefore, carbon storage estimation for various tree species is required to acquire more precise data, and for this estimation, detailed vegetation distribution map is essential. There are many studies about techniques, which classify the stand into tree species by satellite imagery or digital aerial photograph, to produce precise vegetation distribution map (Jun et al., 2003; Kim et al., 2007), including PBC (Pixel Based Classification), and SBC and so on. PBC is a traditional method of image classification, using maximum likelihood method. However, due to ‘salt-and-pepper’ effect, it is not appropriate that producing vegetation distribution map applies this classification method with high-resolution images (Chung et al., 2001; Cho et al., 2002; Kim et al., 2007). SBC can compensate this weak point of PBC by producing segments (Van der Sande et al., 2003; Kim, 2007).

In this study, it will present a procedure which calculates the amount of carbon dioxide absorption for individual species, after classifying tree species in the forest area by SBC using KOMPSAT-2 imagery. Then, it can establish the basis of future CO_2 absorption map.

2. MATERIALS AND METHODS

2.1 Study area and Materials

The study area was selected between top 4152368, left 380415 and bottom 4149277, right 383689, covering an area of 1,012ha; the corresponding portion of the IKONOS imagery is shown in Figure 1. The study area was representative of a rural landscape, comprised mostly of forest land, with a few agricultural and residential areas. This area well represents the forest cover types and topography of central Korea. Oak and other deciduous species evenly dominated the entire area, as typically found in central Korea, with some planted coniferous stands of Korean pine, Japanese larch and pitch pine distributed at relatively lower elevations.

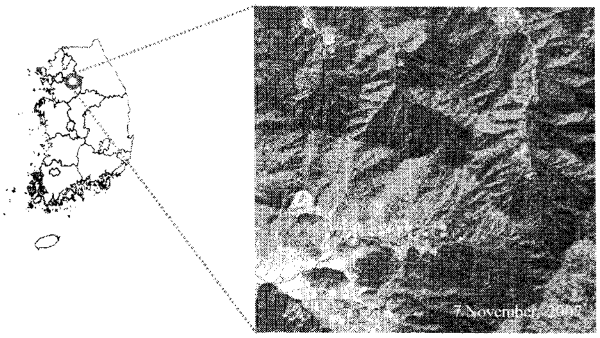

Figure 1. The study area with the pan-sharpened KOMPSAT-2 imagery

A multispectral KOMPSAT-2 imagery, acquired on 7 November 2007, of a 15 km x 15 km area in the central Korea, was used classify tree species for mapping the capacity of carbon dioxide absorption. The KOMPSAT-2 imagery was composed of 4 spectral bands with 4 m spatial resolution and 1 panchromatic band with 1 m spatial resolution. A panchromatic band and 4 multispectral bands were fused through IHS transformation with a 4-3-2 band combination for RGB color. A fused pan-sharpened imagery was used for classification.

2.2 Methods

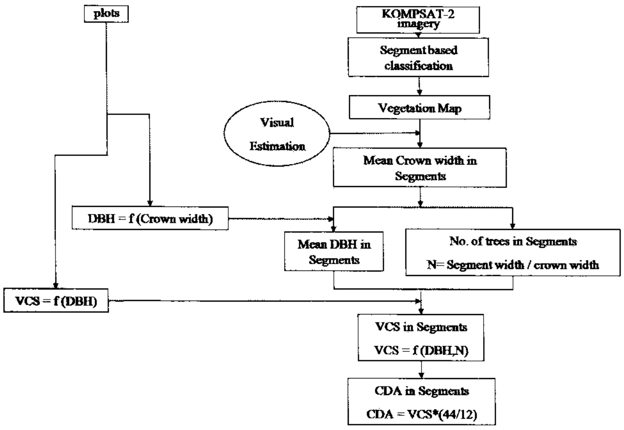

Figure 2. Study process

This Study followed a certain process in figure 2. Firstly, after segmentation of KOMPSAT-2 imagery, it took SBC method for preparing forest cover map. Also, CDA (carbon dioxide absorption) was calculated by regression function of DBH (diameter at breast height) and CW (crown width) estimated from field survey, and by VCS (vegetation carbon storage) equation.

2.2.1 Segmentation of Imagery: Segments, which are called image objects split into zoned partial areas of differing characteristics (Definiens, 2006). For generating such segments, we segmented a KOMPSAT-2 imagery using Definiens Professional 5.0 (Definiens Imaging, 2002). The Definiens Professional 5 uses a region-growing segmentation approach, where the segment size is first determined with a scale parameter measuring the maximum possible homogeneity (Definiens, 2006). The homogeneity criteria were set up using color and shape parameters, which define the total relative homogeneity of the resulting image objects. The shape criterion was composed of two parameters; smoothness and compactness. In this study, the optimal values for generating a segmented image were employed from previous study (Kim, 2007) as shown in Table 1.

Table 1. Parameters used for image segmentation

Level	Scale parameter	Heterogeneity	
		Color	Shape
1	90	0.9	0.1
2	160	0.9	0.1
3	200	0.9	0.1

2.2.2 Classification of Segmented Image: The KOMPSAT-2 image was first classified using a conventional PBC with a maximum likelihood classifier. These results were used for comparison with those obtained from the SBC. A SBC method, with the majority principle, was used. In this approach, the pixels of each class classified by the PBC method were counted, with a class occupying the majority of a segment assigned to the entire segment.

2.2.3 Classification of Segmented Image: The DBH is needed to compute the amount of CDA. Even though the CW of individual trees can be delineated with the naked eye, the DBH can not be extract from the satellite imagery. In this study, therefore, the field measurement for the CW and DBH was conducted, and then we performed the regression analysis to create $DBH = f(CW)$ by tree species. Thereby, DBHs of individual trees in forest stands could be extracted from imagery since the CW could be estimated from the KOMPSAT-2 imagery. The computation of CDA was based on the segment, and sample plots, circle-shaped, (r: 10m) by tree species were set up in the segments of each tree species. And then the number of individual trees was counted in sample plots (approximately 314m^2), thereby, the number of individual trees in each segment by tree species could be estimated.

The dry stem weight including the bark (W) is required for biomass estimation of individual trees. The W of an individual tree could be calculated with the equation 1(KFRI, 1998), and the DBH could be extracted through the regression function as using the crown width delineated from high resolution satellite imageries. Parameters such as a, b and c were generated by a previous study in KFRI. We used the parameter values by tree species.

$$W = a + bD + cD^2 \qquad (1)$$

where W (kg) = The dry stem weight including the bark
D (cm) = the DBH
a, b, c = coefficients (Table 2).

Table 2. Coefficient values by tree species

Species	Parameter		
	a	b	c
Pinus rigida	12.1740	-3.2861	0.3635
Pinus koraiensis	30.1793	-5.8218	0.4319
Larix leptolepis	1.4253	-1.9804	0.4001
Quercus acutissima	-3.6617	-0.5153	0.3512

Biomass (B) which can be computed with the W and Biomass Expansion Factor (BEF) is necessary to calculate the amount of VCS as shown in equation 2 and 3 (KFRI, 1998). We used BEF values which were estimated by KFRI (1998). However, the BEF values were generated as only two tree categories, coniferous and deciduous trees. Therefore, we applied the same value (1.6512 on Coniferous tree) to *Pinus rigida*, *Pinus koraiensis* and *Larix leptolepis*. In the case of *Quercus acutissima*, 1.7202 was used for the BEF on deciduous trees.

$$B = W \times BEF \qquad (2)$$

When VCSs were computed with Biomass, we used 0.5 as the carbon converstion index by IPCC.

$$VCS = B \times 0.5 \qquad (3)$$

Finally, CDA could be estimated with VCSs which were generated from the amount of biomass. For calculating the CDA, the conversion ratio (44/12) which is the value to convert the amount of carbon (C) into the amount of carbon dioxide, was employed from KFRI research.

$$CDA = VCS \times (44/12) \qquad (4)$$

Eventually, the CDA can be represented with only one variable, DBH, by equation 1, 2, 3 and 4 as shown in equation 5. With such result, we could calculate a CDA an individual tree and estimate total CDA as multiplying the number of individual trees in each segment.

$$CDA = BEF(a + bD + cD^2) \times 55/30 \qquad (5)$$

3. RESULTS

3.1 Generation of Segments

As a result of segmentation with Level 1, 2 and 3 respectively, the Level 2 (scale parameter 160, color 0.9, shape 0.1) showed the best result. Attempts with otherwise case like Level 2 and 3 led the KOMPSAT-2 imagery to an over-segments and under-segment. Therefore, we employed the SBC and the Level 2 to generate segments on which the computation of the CDA was based.

3.2 Classification of Segmented image

When the vegetation was classified into 5 classes through the SBC method, for verifying the result of classification, an error matrix was produced (Congalton et al., 1983) (Table 3). As a result of cross tabulation, the overall accuracy was 70%.

Table 3. Error matrix of SBC using KOMPSAT-2 imagery

Class	Producer's Accuracy (%)	User's Accuracy (%)
Pinus rigida	71	50
Pinus koraiensis	100	60
Larix leptolepis	57	80
Quercus app.	60	90
non-forest area	87	70

3.3 Estimation of the Amount of CO_2 Absorption

To estimate DBH from KOMPSAT-2 imagery, regression analysis was performed with field-derived DBHs and CW. As a result, regression functions were created by tree species as shown in Table 4. The coefficients of determination (R^2) by tree species was 0.59 for *Pinus rigida*, 0.70 for *Pinus koraiensis*, 0.55 for *Larix leptolepis* and 0.52 for *Quercus* spp..

Table 4. Regression functions and accuracy by tree species

Tree species	Regression function	Coefficient of determination (R^2)
Pinus rigida	$4.066\ln(x) + 10.35$	0.59
Pinus koraiensis	$8.077\ln(x) - 2.986$	0.70
Larix leptolepis	$7.028\ln(x) - 1.734$	0.55
Quercus spp	$5.978\ln(x) - 2.307$	0.52

Eventually, the total CDA by tree species was estimated with the number of individual trees and estimated DBHs in equations of Table 4. As a result, total CDAs were 13,850 ton for *Pinus rigida*, 6,486 ton for *Pinus koraiensis*, 67,044 ton for *Larix leptolepis* and 47,206 ton for *Quercus* spp. (Figure 3).

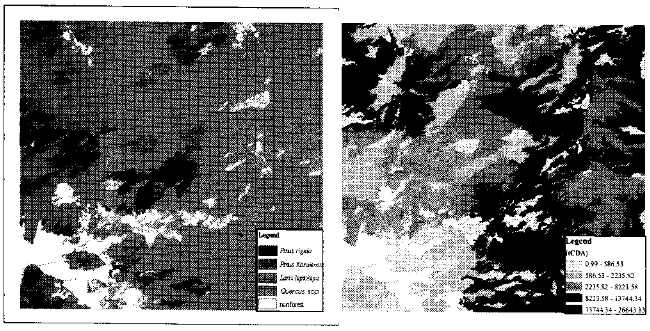

Figure 3. Vegetation distribution map (left) and CDA distribution map (right)

4. CONCLUSIONS

In this study, the amount of the CDA by tree species was computed as KOMPSAT-2 imagery segmented. Firstly, segments were generated from KOMPSAT-2 imagery through the SBC method. Subsequently, we investigated DBHs and CWs in the field for creating regression functions between DBHs and CWs. Thereby, the DBH could be extracted from KOMPSAT-2 imagery. Eventually, the total CDA could be calculated with the DBH extracted from KOMPSAT-2 and the BEF analyzed by some previous researches of KFRI. As a result, the total CDA was computed as 134,587 ton and CDAs by tree species were 6,486 ton for *Pinus rigida*, 6,486 ton for *Pinus koraiensis*, 67,044 ton for *Larix leptolepis* and 47,206 ton for *Quercus* spp..

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6. CONCLUSIONS

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