Up-scaling vegetation carbon storage of *Pinus densiflora* stands from plot to watershed

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Abstract

This study suggested a process for up-scaling spatial distribution map of carbon storage in *Pinus densiflora* stands from plot to landscape level in Korea. Carbon storage in forest stands was divided into vegetation carbon storage (VCS) and soil carbon storage (SCS). Through plot based experiment, it was proven that the VCS has close relationship with tree size and the SCS with tree age and stand density. Using these relationships of plot level experiment, estimation functions of VCS were derived with influencing factors of DBH (diameter of breast height). Current carbon storage distribution of *Pinus densiflora* stands in landscape and regional level could be estimated from spatial distribution map of *Pinus densiflora* stands which was prepared using high resolution satellite imagery of Quickbird.

1. Introduction

Use of carbon sink is recommended as one of additional and subsidiary methods to reduce greenhouse gas in Kyoto protocol. There are many works for expanding carbon sink and preparing statistical data mainly promoted by Korea Forest Research Institute and '10-year plan for carbon sink (2005)' by Korean Forest Service.

Forest is important carbon sink where CO_2 is converted into carbon and stored into soil. Carbon storage of forest is estimated by the sum of vegetation carbon storage and soil carbon storage. It is needed to use spatial distribution of carbon storage for planning of forest management and growing effect of forest as carbon sink.

Pinus densiflora, which is a native tree species of Korea, mainly occupies forest area of South

Korea. Therefore, it is important to estimate vegetation carbon storage distribution of *Pinus densiflora* stands for predicting carbon storage of Korean forest. This study suggested method of estimating vegetation carbon storage by watersheds using spatial distribution of *Pinus densiflora* extracted from satellite imagery.

2. Materials and Methods

2.1. Study site

Study area is located in Pocheon-si, Geonggi-do and covers around 1,828 ha (Fig. 1a). About 76% of this area is forest and 78% has altitude of 100~400m, 90% located at slope below 30°.

(a) (b)

Fig. 1. Study site (a) and Quickbird satellite imagery (b)

2.2. Data and software

‘ERDAS IMAGINE 9.1’ and ‘Definiense Professional 5.0’ were used to classify and segment Quickbird satellite imagery (Fig. 1b), acquired in April 2005, having 0.6m spatial resolution. Extraction of *Pinus densiflora* from classified imagery and analysis of distribution of crown diameter ‘ArcMAP 9.0’ was performed with ‘ArcMAP 9.1’

2.3. Methods

This study was performed as shown in Fig. 2.

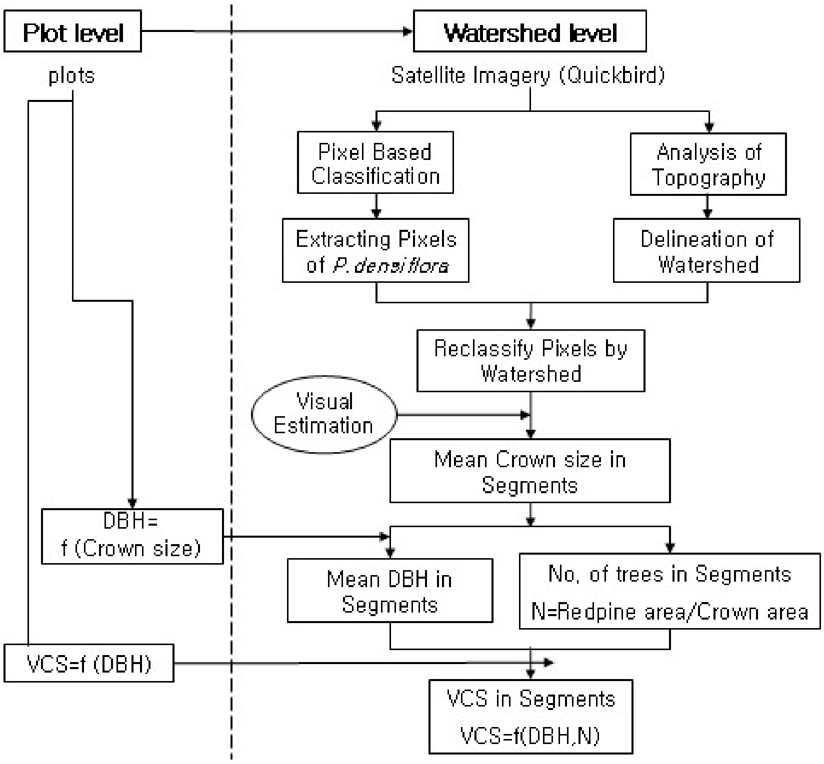


Fig. 2. Flow chart for estimating VCS in watershed level

2.3.1. Measurement of diameter at breast height and crown

Diameter at breast height and crown width by 59 trees of *Pinus densiflora* were measured in 2 sample plots of which radius were 10m and 15m. And then, relationship between diameter at breast height and crown width was derived.

2.3.2. Estimation of Pinus densiflora distribution and diameter at breast height

Satellite imagery was classified into '*Pinus densiflora*/ other coniferous/ hard wood/ others'. Study area segmented by watershed and distribution map of *Pinus densiflora* were used to calculate density of *Pinus densiflora* stands. Mean diameter of crown width was estimated by visual interpretation on satellite imagery. Through relationship between diameter at breast height and crown width, mean diameter at breast height was estimated. The number of *Pinus densiflora* in each watershed was derived by using projected crown area calculated with crown width.

2.3.3. Up-scaling to landscape level

The relationship between diameter at breast height and vegetation carbon storage (Eq. 3) was derived through regression function to estimate biomass for *Pinus densiflora* stands (Park. and Kim., 1989; Park. and Lee., 1990) (Eq. 1) and biomass-carbon storage conversion function (Eq.

2). Conversion coefficient was suggested by Intergovernmental panel for climate change (IPCC).

$$\log W = 2.523 + 1.99 * \log DBH \quad (1)$$

W = biomass of tree (gC/tree)

DBH = diameter at breast height (cm)

$$VCS\ (gC/tree) = W\ (gC/tree) * 0.5 \quad (2)$$

VCS = vegetation carbon storage

0.5 = conversion coefficient was suggested by IPCC

Eq. 3 is function derived from Eq. 1 and Eq. 2 for calculating VCS from DBH

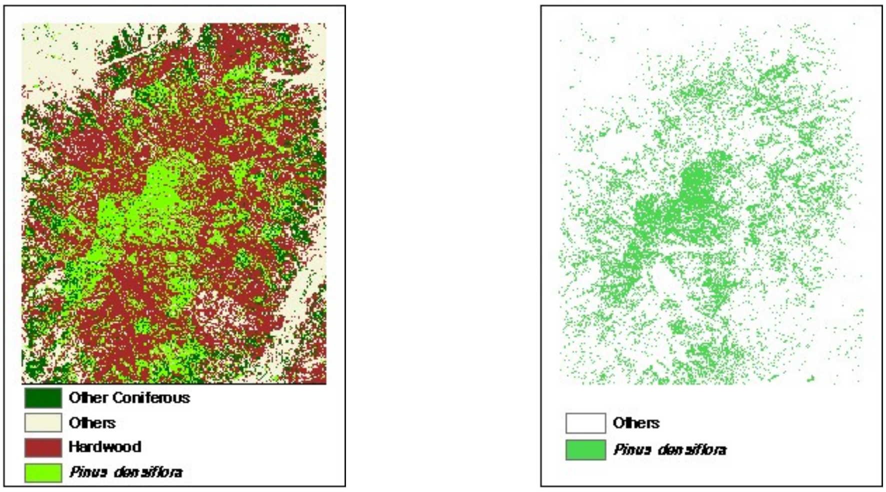
$$VCS\ (gC/tree) = 166.71 * DBH\ (cm)^{1.99} \quad (3)$$

VCS of tree was obtained from relationship between DBH and VCS. And then VCS was estimated by multiplying number of *Pinus densiflora* in each watershed by VCS.

3. Results and Discussion

3.1. Extracted Pinus densiflora stands

Approximately 26% of total area was extracted as *Pinus densiflora* stands (Fig. 3b) from imagery classified into 4 forest types (Fig. 3a). Table. 1 is error matrix, showing accuracy of classification. Overall classification accuracy and kappa value were 75% and 0.67 respectively.



(a) (b)

Fig. 3. Forest types(a) and Spatial distribution of *Pinus densiflora* stand(b)

Table. 1. Error matrix of supervised classification of Quickbird imagery

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy(%)	Users Accuracy(%)
PD	7	5	5	71	100
C	3	5	3	100	60
H	5	5	3	60	60
O	5	5	4	80	80
Total	20	20	15		

PD=*Pinus densiflora*, C=Other Coniferous, H=Hardwood, O=Others

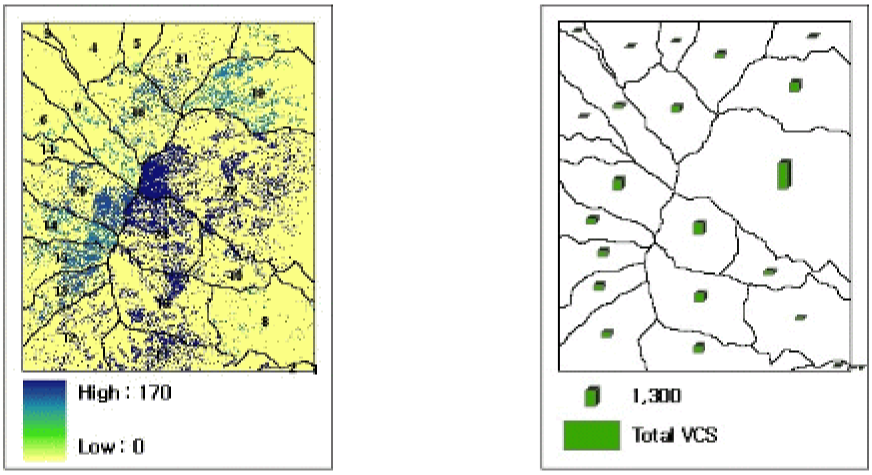
3.2. Watershed Segmentation

As a result of segmenting watershed, there were 22 watersheds and each area was 0.1 ~ 340.0 ha (Table. 2, Fig. 4a).

Table. 2. Pinus densiflora area, mean crown area, DBH, number of Pinus densiflora for each watershed

Watershed	Area (m^2)	Area ofPinus densiflora(m^2)	MeanCrown Diameter(m)	MeanCrown Area(m^2)	Number of Pinus densiflora	Mean DBH (cm)
1	978	0	0	0	0	0
2	58,646	587	6	32	18	25
3	115,448	2,309	6	30	76	24
4	599,498	5,995	6	28	212	23
5	258,966	10,359	6	24	436	22
6	417,658	20,883	6	27	764	23
7	483,602	29,016	6	29	993	24
8	1,300,000	52,000	6	30	1,722	24
9	1,000,000	90,000	6	28	3,183	23
10	653,554	91,498	7	40	2,311	27
11	937,974	131,316	7	36	3,616	26
12	979,702	137,158	8	45	3,023	28
13	508,087	152,426	7	35	4,323	26
14	767,584	168,869	6	30	5,593	24
15	553,251	171,508	6	32	5,331	25

16	902,538	180,508	7	33	5,440	25
17	880,131	228,834	8	49	4,668	29
18	1,200,000	288,000	8	55	5,197	31
19	1,400,000	294,000	6	29	10,060	24
20	938,737	319,171	7	35	9,053	26
21	900,756	405,340	9	62	6,516	32
22	3,400,000	884,000	8	45	19,487	28



(a) (b)

Fig. 4. Spatial distribution of mean VCS (a) and total VCS in watersheds (b)

3.3. Density of Pinus densiflora stands and mean crown width by watershed

Mean crown width of *Pinus densiflora* stands interpreted visually on satellite imagery was 3.0 ~ 6.4m. The number of *Pinus densiflora* in each watershed was calculated as dividing area of *Pinus densiflora* with mean crown area derived from crown width (Table. 2).

3.4. Estimation of DBH from diameter of crown

Relationship between crown width and DBH (Eq. 4) was generated with crown width and DBH of 59 trees measured in the field and the coefficient of determination was 0.8.

$$D = 4.7507 + 3.1175 * C \quad (4)$$

D = DBH (cm)

C = diameter of crown (m)

3.5. Distribution map of VCS

Mean VCS of trees (Fig. 4a) and the total amount of VCS (Fig. 4b) in each watershed were estimated by Eq. 3 with mean DBH and number of *Pinus densiflora* in each watershed.

4. Conclusion

This study was performed to estimate carbon storage of watershed using Geographical information system (GIS) and remote sensing.

Using data and model of previous researches, the accuracy was low and verification was not performed. Additionally, it could not be considered that conversion coefficient, suggested by IPCC, was suitable well for Korean forest.

Research and verification for DBH and carbon storage as well as development of conversion coefficient by tree species for Korea forest are needed to improve these limitations.

It is necessary to estimate not VCS distribution but also soil carbon storage for making forest effect clear and to use for reducing green house gas.

5. Acknowledgment

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