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Estimate Site Index Equations for *Pinus densiflora* Based on Soil Factors in Gyeonggi Province

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ABSTRACT : Site index is the essential tool for forest management to estimate the productivity of forest land Generally, site index equation is developed and used by relationship between stand age and dominant tree heights. However, there is a limit to use the site index equation in the application of variable ages, environmental influence, and estimation of site index for unstocked land. Therefore, it was attempted to develop a new site index equations based on various environmental factors including site and topographical variables. This study was conducted to develop regional site index equations based on the relationship between site index and soil factors for *Pinus densiflora*. Environmental factors that obtained from GIS application, were selected by stepwise-regression. Site index Equation was estimated by multiple regression from selected factors. Four environmental factors were selected in the final site index equations by stepwise regression. It was observed that coefficients of determination for site index equations were ranged from 0.34 which seem to be relatively low but good enough for estimation of forest stand productivity. The site index equations developed in this study were also verified to be useful by three evaluation statistics such as model's estimation bias, model's precision and mean square error type of measure.

Keywords : Site index, Forest management, *Pinus densiflora*, Stepwise regression

INTRODUCTION

Nowadays, improving forest productivity is very important task to meet the wood demand. The forest productivity has a close relationship not only with economic returns, but also environmental friendly restoration within forest ecosystem. Moreover, accurate and reliable evaluation of site quality for selected species and the availability of timber yield information are vital for the assessment of reforestation project.

Site index is the essential tool for forest management to estimate the productivity of forest land. Generally, site index equation is developed and used by relationship between stand age and dominant tree heights. However, there is a limit to use the site index equation in the application of variable ages, environmental influence, and estimation of site index for unstocked land. Therefore, it was attempted to develop a new site index equations based on various environmental factors including site, soil and topographical variables.

Generally, soil and environmental indicator is tremendous impact on wood growth. Therefore, analysis of theses reciprocal action carries on important meaning for forest productivity (Kim, 1991).

This study was conducted to develop site index equations based on the relationship between site index and

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environmental factors for *Pinus densiflora*.

MATERIAL AND METHOD

Study site is Gyeonggi province inclusive of the Seoul Metropolis and Incheon metropolitan city (Figure 1). Total forest area of study site is 585,738 ha and softwood forest is 35% (Korea Forest Service).

Fig. 1. Study site.

Site indices basis on 30 years were estimated by the cumulative NFI data (National Forest Inventory 2006~2007).

Site Indices were estimated using site index estimation in Table 1 and used for analyzing the relationship to topographical and environmental factors. Site index estimate model were based on Chapman-Richards model that was approved flexibility for site index estimation. This model has 3 parameters in itself.

Soil map data is comprised of 28 topological indicators and informal inventory data. The influence topographical factors and soil profiles on site index for *Pinus densiflora* were evaluated by multiple regression analysis (Belsley et. al., 1980; Myers, 1986; Judge et. al., 1988). All topological factors were obtained in the form of code numbers (Table 2) and randomly divided 7:3 ratios for verification (Table 3).

For development equations by multiple regression

Table 1. Site index estimate model and Parameter estimation

Model	Spices	Parameter estimation	
		b	*c*
Chapman-Richards model $SI = H_D\left[\frac{1-e^{-bt_i}}{1-e^{bt_j}}\right]^c$ (SI = site index, H_D = dominant tree heights, t_i = age of stand, t_j = the base age (30), b, c = parameter estimation)	*Pinus densiflora*	0.0483	1.4360

Table 2. Topological factors for multiple regression.

Variables	Variable Name	Variables	Variable Name
SI	Site Index at Base Age 30 Years	X_{14}	Effective Soil Depth
X_1	Elevation	X_{15}	Soil Depth in Horizon A
X_2	Slope	X_{16}	Soil Depth in Horizon B
X_3	Configuration of the Ground	X_{17}	Organic matter in Horizon A
X_4	Aspect	X_{18}	Organic matter in Horizon B
X_5	Parent Rock.	X_{19}	Soil texture in Horizon A
X_6	Soil Drainage	X_{20}	Soil texture in Horizon B
X_7	Sedimentary Style	X_{21}	Contained Stone in Horizon A
X_8	Soil Erosion	X_{22}	Contained Stone in Horizon B
X_9	Shape of Slope	X_{23}	Soil dryness and wetness in Horizon A
X_{10}	Outcrop of Rock	X_{24}	Soil dryness and wetness in Horizon B
X_{11}	Ratio of Valley to Hill	X_{25}	Soil Consistency in Horizon B
X_{12}	Out crop of Weathering Efflorescence	X_{26}	Soil Consistency in Horizon B
X_{13}	Weathering Efflorescence		

models, researching verified data required a supplementary budget. The solution of these difficulties is randomly data divide.

The site index equations developed in this study were also verified by three evaluation statistics such as model's estimation bias (MD), precision of model (SDD) and mean square error type of measure (SED) (Shin, 1990; Arabatzis and Burdhart, 1992).

The estimated equation which developed from fit data has been verified in test data. If the verification was available for estimation, re-estimate equation using total data. Finally, site index distribution map was prepared by GIS application.

Table 3. Data summary of the fit and test data sets used in this study.

Species	Total	Fit Data	Test Data
Pinus densiflora	160	116	44

Table 4. Evaluation statistics in this study.

Class	MD	SDD	SED
Expression	$\sum_{i=1}^{n} \frac{e_i}{n}$	$\sqrt{V_e}$	$\sqrt{V_e - MD^2}$

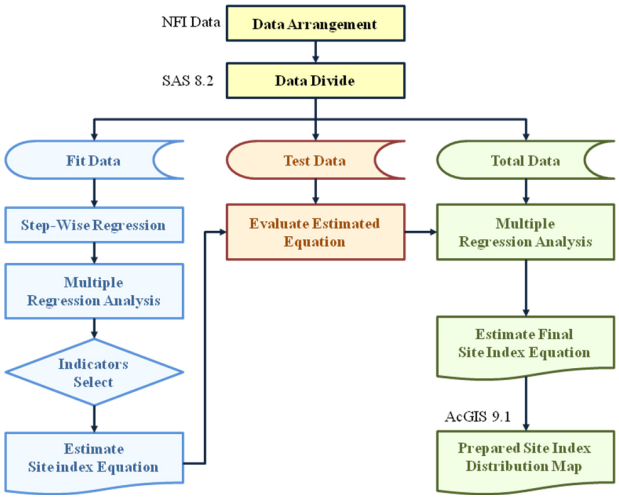


Fig. 2. Flowchart in this study.

RESULT AND DISCUSSION

Four environmental factors such as were selected in fit data (Table 5). Internal correlate indicators were excluded from step-wise regression and each indicator was distributed by GIS technique. Distribution map is grid format.

It was observed that coefficients of determination for site index equations were 0.35 which seem to be relatively low but good enough for estimation of forest stand productivity (Table 6).

According to evaluation statistics, the site index equation was good enough for site index estimation (Table 6).

Finally, estimated site index equation is Table 8 and coefficients of determination for site index equations were 0.34 which seem to be relatively low but good enough for estimation of forest stand productivity.

The result of estimated site index map via ArcGIS map calculator is Figure 3. Map calculator is GIS tool of

Table 5. Selected soil factors by multiple regression and distribution map

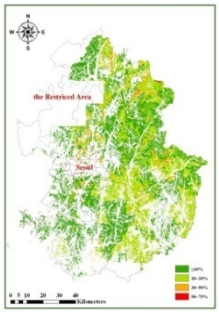
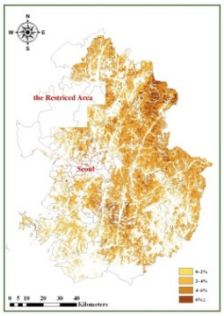
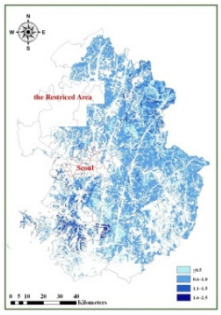
Variables	X_{10}	X_{17}	X_{21}	X_{25}
Variable Name	Outcrop of Rock	Organic matter in Horizon A	Contained Stone In Horizon A	Soil Consistency in Horizon B
Distribution Map				

Table 6. Estimated site index equation in this study

Data	Equation	R^2
Fit Data	$SI = 5.44+1.96\ X_{17}+1.24\ X_{10}-2.67\ X_{25}+1.96\ X_{21}$	0.35

Table 7. Evaluation statistics for estimated site index equation

Species	n	MD	SDD	SED
Pinus densiflora	44	-0.54	2.19	2.23

Table 8. Estimated site index equation in this study

Data	Equation	R^2
Total Data	$SI = 5.16+1.81\ X_{17}+1.29\ X_{10}-2.28\ X_{25}+1.72\ X_{21}$	0.34

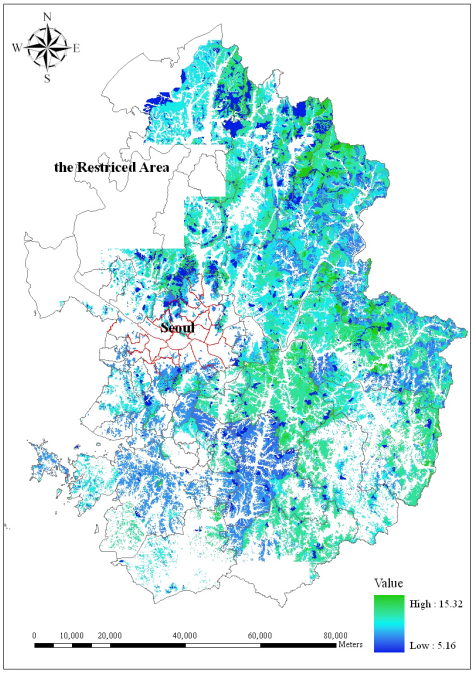


Fig. 3. Illustrate of site index distribution by estimated equation.

ArcGIS that was frequently used for interporation

It is that expected the results obtained in this study could estimate not only regional site index equation by species but also provide information for forest management.

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