

Spatial distribution change of forest cover by climate change in Korea

*Byun, Jae-Gyun¹•**Lee, Woo-Kyun¹• Choi, Jung-Kee² • Lee, Young-Jin³•Chung, Dong-Jun⁴

¹Department of Environmental Science and Ecological Engineering, Korea University, Seoul, Korea

²Department of Forest Management, Kangwon National University, Kangwon, Korea

³Department of Forest Resources, Kongju National University, Chungnam, Korea

⁴National Forestry Cooperatives Federation, Daejeon, Korea

*worbs12@korea.ac.kr

**Corresponding Author : leewk@korea.ac.kr

Abstract

This study analyzed the impact of climatic and topographic factors on tree radial growth of *Pinus densiflora* and *Quercus* spp. forest in Korea. Annual tree growth can be affected by age, current size, density, competition, site environment, and climatic factors such as temperature, precipitation and humidity. To find the relationship between annual tree radial growth and climatic factors, we took core samples from individual trees and measured the tree radial width. We found the spatial differences in tree radial growth. There exists spatial relationship between topographic and climatic factors, and tree radial growth. Using this relationship, we predicted spatial distribution change of *Pinus densiflora* and *Quercus* spp. forest with Generalized Additive Model(GAM) analysis based on GIS.

Key words : climate change, *Pinus densiflora*, *Quercus* spp., growth response, spatial distribution, GIS

1. Introduction

The forest occupies 1/3 area of globe land and charges 2/3 photosynthesis of the earth(Korea forest service, 2007). The urban forest provides comfortable living space through absorbing carbon, air purification and temperature control (Kim et al., 2009). In Korea, the forest area covers 65% of total land which is approximately 637ha (Korea Forest Service, 2008a). The important impacts by climate change are on vegetation growth and spatial distribution change in forest area of the country. Korea Forest Service makes a plan to eliminate moisture competition through intense management of forest and reduce damages caused disasters like by harmful insect, landslide and forest fire. Korea Forest Service will try to make structural diversity of forest type and promote resistance and resilience on rapid environmental change to southern evergreen needleleaf forest for climate change adaptation (Korea Forest Service, 2009). Among several forest species, the red pine is one of the most important species as for timber and cultural values. Red pine accounts for around 27% of forest area through natural growth and afforestation. In addition, *Quercus* spp. such as *Quercus mongolica*, *Quercus variabilis* are the most widely distributed as self-sown plants in forest and receives much recognition as potential vegetation (Lim et al., 1995). The growth of individual tree is affected by age, density, site which is related with competition and topographic and climatic factors such as temperature, precipitation and humidity. In this study, we found impact relationship of each factors to red pine and *Quercus* spp. and based on it, we try to predict the spatial difference of the growth and possibility spatial distribution change due to climate change.

2. Material and Methods

2.1 Material

For the national forest inventory in 2007, we took core samples from individual trees and measured the tree radial width. We have got the DB of annual ring growth from central Korea. We used 1,042 *Pinus densiflora* and 2,170 *Quercus* spp. to analyze the relationship between tree radial growth and topographic and climatic factors. The general description of growth and climatic factors are presented in Table 1.

Table 1. General description of sample data

variables	<i>Pinus densiflora</i> (1,042 stems)				<i>Quercus</i> spp. (2,170 stems)			
	mean	min	max	SD	mean	min	max	SD
Growth(mm)	2.1	0.3	10.6	0.9	2.0	0.3	7.2	0.9
Age(year)	37.6	14.0	104.0	11.7	38.6	10.0	104.0	14.1
DBH(cm)	19.5	6.0	75.0	8.1	16.7	6.0	46.0	6.0
Height(m)	11.0	2.2	26.4	3.4	11.4	2.4	25.5	3.2
TWI*	3.0	1.0	27.6	1.6	2.9	0.9	27.6	1.8
Temperature(°C)	12.1	7.3	15.7	1.3	11.8	7.3	16.5	1.4
Precipitation(mm)	1198	993.0	1784	141.8	1222	993.0	1784	153.5
Humidity(%)	64.0	57.0	72.1	3.1	64.3	57.0	75.9	3.1

*TWI:Topographic wetness index (Ramus et al., 2007)

2.2 Method

The climatic data was interpolated by IDSW (Inverse Distance Squared Weighting) based on the observation data obtained from 75 weather stations in Korea (Choi et al., 2009). We created equation which is related to tree radial growth and tree age. We estimated the coefficient by using NLIN procedure SAS (SAS Institute, 1998) and we used SPATIAL STATS module of SPLUS to find spatial autocorrelation (Kaluzny et al. 1998). In this study, we assumed that tree radial growth depends on tree age and this equation is modeled as,

$$GR = \alpha_0 + \alpha_1 \cdot AGE^{\alpha_2} \quad (1)$$

We employed Standard Growth(SG) which is defined as radial growth of age 30(Eq 2).

$$SG = \alpha_0 + \alpha_1 \cdot 30^{\alpha_2} \quad (2)$$

We estimated standard growth based on age and radial growth (Eq 3).

$$SG = GR \cdot \left(\frac{30}{AGE} \right)^{\alpha_2} \quad (3)$$

We used GAM (Generalized Additive Models) to find relationship standard growth and TWI, temperature and precipitation (Eq 4).

$$\text{Standard Growth} = f(TWI, T, P) = \beta_0 + \beta_1 \cdot TWI + \beta_2 \cdot T + \beta_3 \cdot P \quad (4)$$

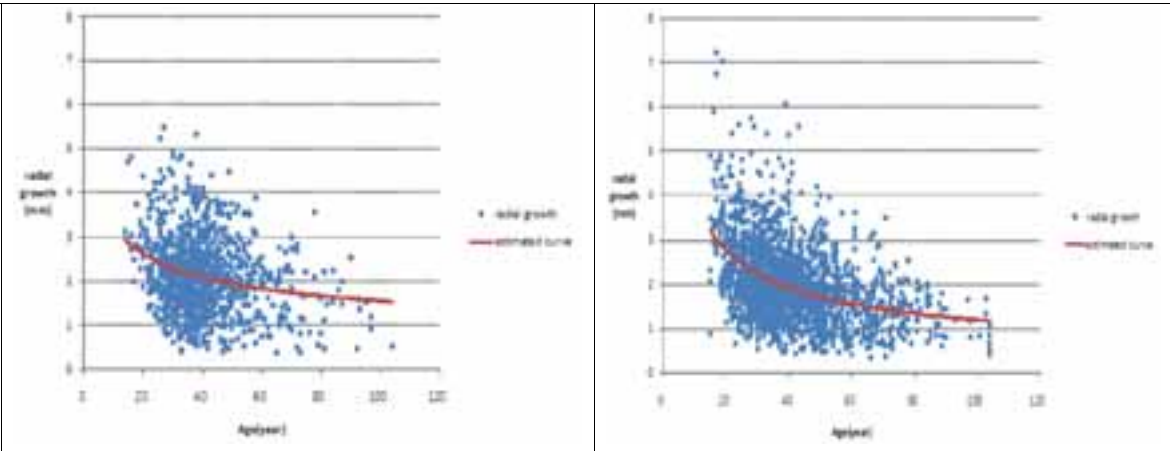
Generalized Additive Models provide a simple description of the data, summarizes the contribution of each predictor with a single coefficient and provides a simple method for predicting new observations (Hastie et al., 1990).

3. Results and Discussion

The coefficient was estimated using Gauss-Newton method of SAS NLIN and growth estimated curve was estimated using estimated coefficient (Eq 5,6).

$$Gr = 7.1016 - Age^{-0.0005} \quad (\text{pine}) \quad \text{-----} \quad (5)$$

$$Gr = 18.9385 - Age^{-0.0009} \quad (\text{oak}) \quad \text{-----} \quad (6)$$



1) *Pinus densiflora*

2) *Quercus* spp.

Figure 1. Radial growth cloud and estimated curve

From equation 2 and 3, we can make new standard growth equation as following.

$$SG_{Pinus} = Gr \cdot \left(\frac{TWI}{100} \right)^{0.00017} \quad SG_{Oak} = Gr \cdot \left(\frac{TWI}{100} \right)^{0.00042}$$

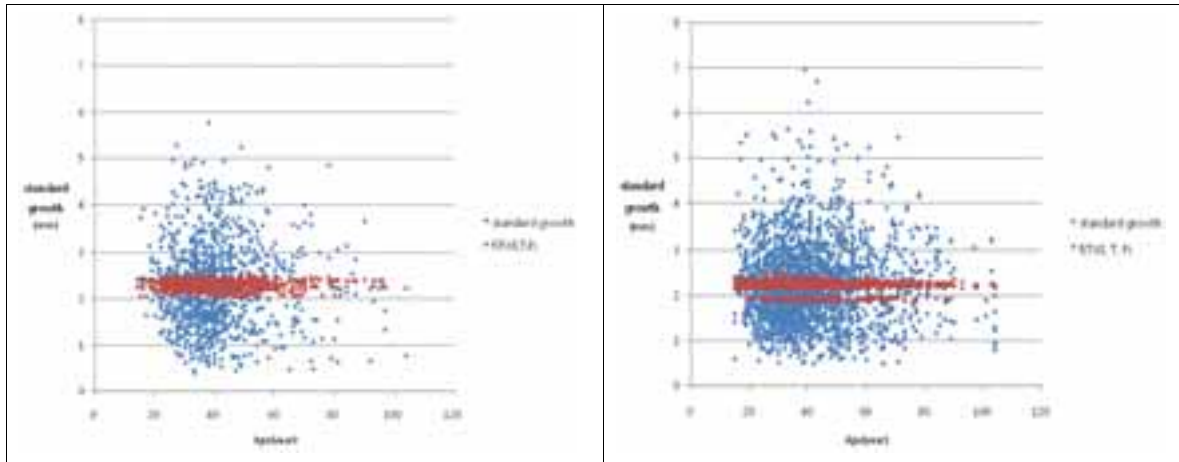
Table2 presented the relationship between standard growth and TWI, temperature, precipitation. It shows that increasing of temperature is negative effect on the growth of *Pinus densiflora*. On the other hand, it has positive effect on the growth of *Quercus* spp.

Table 2. Parameter estimation and related statistics for Generalized Additive Models

		coefficients	Std Error	t-value	pr > t
<i>Pinus densiflora</i>	TWI	0.01478	0.01555	0.9505	0.3422
	Temperature	-0.06113	0.02952	-2.0708	0.0386
	Precipitation	-0.0007839	0.0002566	-3.0547	0.0023
<i>Quercus</i>	TWI	0.01323	0.01015	1.3034	0.1926

spp.	Temperature	0.03563	0.01852	1.9239	0.0545
	Precipitation	-0.0004256	0.0001376	-3.0936	0.0020

In figure 2, most of TWI, temperature and precipitation cannot be fully explained by SG. It means that tree growth is mostly influenced by age, density and soil etc. Topographic and climatic factors have just additional effect on tree growth. So it's difficult to explain the standard growth just with climatic factors.

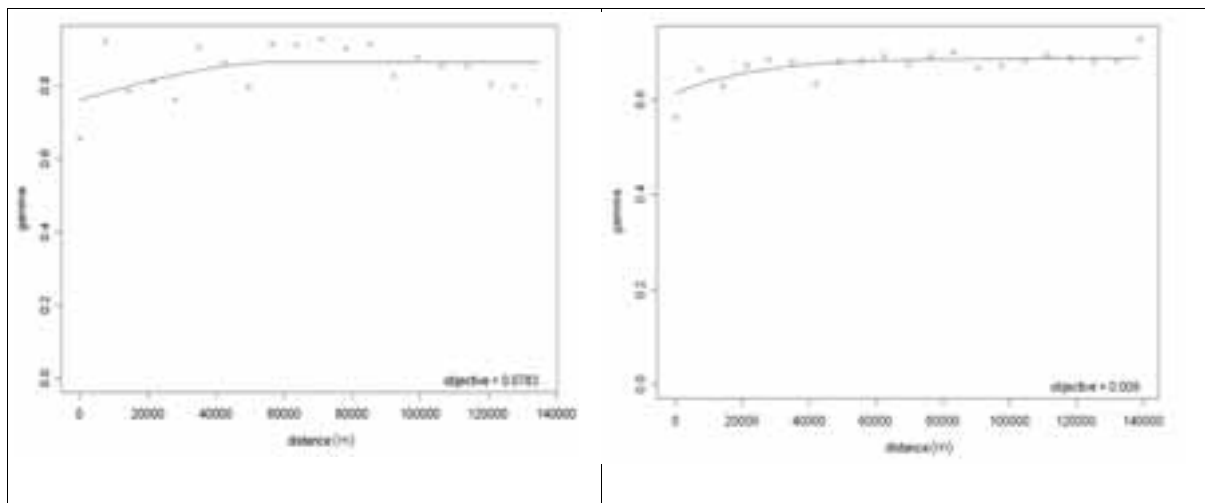


1) *Pinus densiflora*

2) *Quercus* spp.

Figure 2. Standard growth and estimation of standard growth using GAM (SG=f(TWI,T,P))

We used SPLUS for finding autocorrelation of standard growth at figure 3. In ranges of 60Km, *Pinus densiflora* have a little spatial autocorrelation, but *Quercus* spp. doesn't have any spatial autocorrelation. It means that *Pinus densiflora* have a regional variation of growth, but *Quercus* spp. doesn't have any spatial variation of growth.



1) *Pinus densiflora*

2) *Quercus* spp.

Figure 3. Variogram of standard growth

GAM analysis shows that *Pinus densiflora* are more vulnerable to increasing temperature. In case of rising temperature by 0.04 degree, lots of red pine could be replaced to *Quercus* spp. The changes of spatial distribution between *Pinus densiflora* and *Quercus* spp. are estimated by forest type map based on GIS with the

application of standard growth value, topography and climate factor formula. Table 3 shows the lag-time that is the period required of declining red pine. Red pine, which belongs to evergreen needleleaf forest, lag-time is 30 years. The expected vegetation distribution of figure 4 indicates the replacement of *Pinus densiflora* to *Quercus* spp.. *Pinus densiflora* will start to replace to *Quercus* spp. after 60 years and even 100 years almost *Pinus densiflora* will be replaced to *Quercus* spp..

Table 3. The lag time of different vegetation to climate change (unit : year) (Kirilenko et al., 1998)

Vegetation types	Mortality delay	Seed transition and burgeon	Establishment	Total times
Evergreen needleleaf forest	30	10	25	65
Evergreen broadleaf forest	40	5	5	50
Deciduous needleleaf forest	30	15	25	70
Deciduous broadleaf forest	40	10	30	80
Mixed forest	40/30	10	25/30	75/70



(a) Current



(b) After 60 years

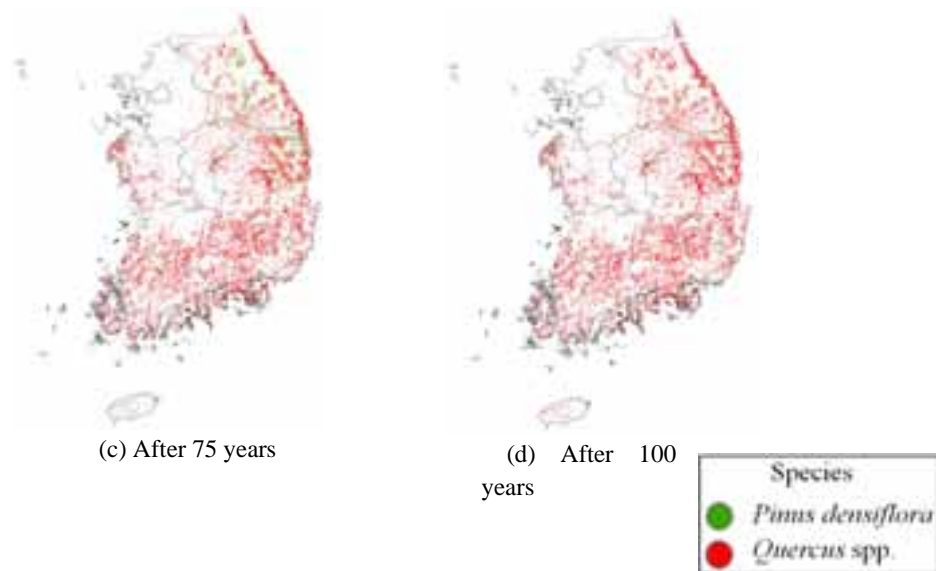


Figure 4. Spatial distribution change of forest over time in Korea

4. Acknowledgement

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