



Modeling stand-level mortality based on maximum stem number and seasonal temperature



Moonil Kim^{a,b}, Woo-Kyun Lee^{a,*}, Go-Mee Choi^c, Cholho Song^a, Chul-Hee Lim^a, Jooyeon Moon^a, Dongfan Piao^a, Florian Kraxner^b, Anatoly Shvidenko^b, Nicklas Forsell^b

^a Division of Environmental Science and Ecological Engineering, Korea University, Seoul 136-713, Republic of Korea

^b Ecosystems Services and Management Program, International Institute for Applied Systems Analysis, Schlossplatz 1, A-2361 Laxenburg, Austria

^c Korea Forest Inventory Center, National Forestry Cooperative Federation, Seoul 138-880, Republic of Korea

ARTICLE INFO

Article history:

Received 10 August 2016

Received in revised form 30 November 2016

Accepted 1 December 2016

Available online 22 December 2016

Keywords:

Maximum stem number

Temperate forest

Tree mortality

National forest inventory

Temperature

Self-thinning

ABSTRACT

Mortality is a key process in forest stand dynamics. However, tree mortality is not well understood, particularly in relation to climatic factors. The objectives of this study were to: (i) determine the patterns of maximum stem number per ha (MSN) over dominant tree height from 5-year remeasurements of the permanent sample plots for temperate forests [Red pine (*Pinus densiflora*), Japanese larch (*Larix kaempferi*), Korean pine (*Pinus koraiensis*), Chinese cork oak (*Quercus variabilis*), and Mongolian oak (*Quercus mongolica*)] using Sterba's theory and Korean National Forest Inventory (NFI) data, (ii) develop a stand-level mortality (self-thinning) model using the MSN curve, and (iii) assess the impact of temperature on tree mortality in semi-variogram and linear regression models. The MSN curve represents the upper boundary of observed stem numbers per ha. The developed mortality model with our results showed a high degree of reliability ($R^2 = 0.55\text{--}0.81$) and no obvious dependencies or patterns in residuals. However, spatial autocorrelation was detected from residuals of coniferous species (Red pine, Japanese larch and Korean pine), but not for oak species (Chinese cork oak and Mongolian oak). Based on the linear regression analysis of residuals, we found that the mortality of coniferous forests tended to increase with the rising seasonal temperature. This is more evident during winter and spring months. Conversely, oak mortality did not significantly vary with increasing temperature. These findings indicate that enhanced tree mortality due to rising temperatures in response to climate change is possible, especially in coniferous forests, and is expected to contribute to forest management decisions.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Tree mortality is key process in stand dynamics and a highly complicated process. It is affected by a variety of environmental, physiological, pathological, and entomological factors, as well as random events. Generally, tree death results from complex interactions among multiple factors and is often a gradual process, although it can sometimes be abrupt (Waring and Schlesinger, 1987). Some factors weaken trees, while others directly cause tree death (Manion, 1981). Due to the complexity of the mortality process and uncertainty in the timing of tree death, mortality remains one of the least understood components of growth and yield estimation (Hamilton, 1986).

Although tree mortality is complicated, some generalities exist. There are two basic structures of mortality algorithms, determinis-

tic and stochastic, and there are six types of mortality algorithms, including gap-type, statistically fitted, carbon-based, abiotic/age, competitive, and progressive-stress algorithms (Hawkes, 2000). The degree of competition especially influences the likelihood of survival of each individual tree (Dobbertin and Biging, 1998). Unless trees are grown in an open environment, they always experience some competition from their neighbors, depending on stand density and the size and location of the neighboring trees. Trees compete for limited physical space and resources, such as a light, water, and soil nutrients. Some trees are outcompeted and subsequently die. Therefore, variables that describe this competition are essential for mortality modeling. Most mortality algorithms are empirical-based (statistical fitted), while others are process-based (Hawkes, 2000).

The mortality models have also generally been classified as two groups, tree- and stand-level models (Landsberg and Sands, 2011). Tree-level models had relatively complex algorithms and more uses for modeling the dynamics of uneven-sized stands than

* Corresponding author.

E-mail address: leewk@korea.ac.kr (W.-K. Lee).

stand-level models (Groot et al., 2004; Vanclay, 1994). Stand-level models have helped to forecast of forest resource conditions, as growth and yield in terms of volume, changes in order to obtain relevant information for sound decision making (Landsberg and Sands, 2011).

However, most models do not sufficiently meet the requirements of large-scale forestry scenarios applied to country or country-wide analyses on the property level. Some models are based on locally relevant, or insufficiently representative data, while others are adapted to certain treatments (e.g., only unthinned stands), and some account for only one or a few tree species of interest. For nation-wide analyses, the data should reflect the full range of variability with respect to treatments, sites, forest structure, and tree species. The use of data from a National Forest Inventory (NFI) with permanent sample plots is probably the best way to meet these requirements. For example, Monserud and Sterba (1999) developed a tree mortality model for Austrian forest species based on the Austrian NFI data.

Tree mortality is a natural ecological process (Franklin et al., 1987); however, drought- and heat-induced mortality, including associated infestation-related forest die-off, is often a selective force that differentially affects tree species and rapidly alters the size, age, and spatial structure of forests. Growing evidence suggests that many forests could be increasingly vulnerable to climate- and infestation-induced tree-mortality events (Allen et al., 2010; Hember et al., 2016). The significant interaction between climate and tree mortality for 11 common species, mainly pine and oak species, in Mediterranean regions was reported (Ruiz-Benito et al., 2013). Increased mortality are also associated with climate condition among many temperate tree species pine and fir species in central Turkey (Semerci et al., 2008), *Pinus tabulaeformis* in east-central China (Wang et al., 2007), *Abies koreana* in South Korea (Lim et al., 2008). Investigation into the physiological mechanisms through which dry and hot climatic conditions drive tree death and forest die-off represent a rapidly growing research area (McDowell et al., 2008; Sala et al., 2010), but the impact of forest die-off remains less well studied. Climate-induced forest mortality seems to be an emerging global phenomenon, yet there is very rare synthesis of the ecological, societal, and climatological consequences of dying forests at present.

The main goals of this study were to develop a model to simulate stand-level mortality (self-thinning) for temperate forests in South Korea and to evaluate the effect of the climate factor, in terms of temperature, on tree mortality. To achieve these objectives, permanent sample plots recorded by the Korean National Forest Inventory (NFI), Sterba's theory, semi-variogram analysis, and residual analysis were applied. The model is suitable both for even-aged as well as uneven-aged conditions.

2. Materials and methods

2.1. Description of South Korea forest and National Forest Inventory

South Korea forests occupy ~64% (6,450,438 ha) of total land area in the country. Evergreen needleleaf (mainly *Pinus densiflora*), deciduous broadleaf (mainly *Quercus* spp.), and mixed forests took up approximately 40.5%, 27%, and 29.3% of total forest area in 2015, respectively. South Korea's forest have been intensively managed and stocking volume has increased from 8.2 m³ ha⁻¹ in 1954 to 142.2 m³ ha⁻¹ in 2014 (Korea Forest Service, 2015). Currently, 69.5% of South Korean forests are less than 40 years old.

We used remeasurements from permanent plots of the Korean NFI for mortality and survival data (Korea Forest Service, 2015). A systematic 4-km grid of permanent plots covering South Korea was established in 2006–2010 (Korea Forest Research Institute, 2011). Each year, 20% of grid locations were sampled in a manner that the whole of South Korea was covered by the inventory each year. Each location was then remeasured from 2011 to 2015, exactly 5 years after the establishment. The total inventory comprises 4200 clusters, consisting of 16,800 permanent plots. Four circular sample plots were located at the intersection of each 4 × 4-km grid line. Each sample plot (31.6-m radius) covered 0.16 ha. Forest characteristics (tree species, age, and height), diameter at breast height (dbh), number of trees with a diameter greater than 6 cm, and topographical factors (coordinates, elevation, slope, and aspect) were measured at all sites. Tree species identification of plots was determined according to basal area of the dominant species. If basal area of red pine occupied more than 75% in a plot, the plot was considered a “red pine” stand.

Stand-mortality of each plot was recorded during each measurement. Each tree in the permanent plot had a unique number and was checked to determine the vital status (e.g., live or dead). Through this process, the stand mortality in each plot was estimated. In addition, the vital status of each individual tree was recorded, with mortality from natural causes distinguished from normal harvesting and thinning. Therefore, some data showing natural (disease and insect pests, wind damage, landslide) or artificial (forest fires, illegal activities, land cover change) disturbances in the plots during 2006–2015 were not considered in this study.

In this study, we used the Korean NFI remeasured data and evaluated the status of more than 1484 permanent plots of the five main temperate tree species in South Korea (Table 1), which include red pine (*Pinus densiflora*), Japanese larch (*Larix kaempferi*), Korean pine (*Pinus koraiensis*), Chinese cork oak (*Quercus variabilis*), and Mongolian oak (*Quercus mongolica*). These tree species form large forests in most of the mountainous areas of South Korea, occupying approximately 37%, 5%, 4%, 5%, and 11%, respectively,

Table 1
General description of the variables used in the mortality model according to species.

Data	Variables	<i>Pinus densiflora</i> (636)		<i>Larix kaempferi</i> (113)		<i>Pinus koraiensis</i> (120)		<i>Quercus variabilis</i> (308)		<i>Quercus mongolica</i> (306)	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
5th NFI (2006–2010)	Age (year)	33.8	8.7	30.5	6.8	28.2	7.7	38.5	10.7	34.9	8.6
	DBH (cm)	15.7	4.6	17.6	4.6	17.7	5.9	15.3	4.0	15.4	3.6
	Height (m)	10.6	2.7	14.2	3.2	11.8	3.3	11.3	2.1	11.7	2.5
	Ho (m)	12.6	3.3	17.2	4.3	13.4	4.3	13.5	3.1	13.2	2.7
	Stand density (n/ha)	1668.3	743.6	997.9	418.8	1119.4	569.1	1510.6	635.8	1482.6	604.1
	Elevation (m)	321.6	194.0	450.3	225.3	340.5	199.2	364.0	174.2	598.7	293.6
6th NFI (2011–2015)	Age (year)	38.8	–	35.5	–	33.2	–	43.5	–	39.9	–
	DBH (cm)	17.5	5.1	20.8	5.5	20.5	7.2	17.0	5.2	17.2	4.5
	Height (m)	11.8	2.8	18.0	3.4	13.8	3.8	12.3	2.9	13.0	3.2
	Ho (m)	13.4	3.4	20.1	4.4	15.6	3.8	15.0	3.3	14.4	3.2
	Stand density (n/ha)	1431.5	633.6	745.9	378.7	831.0	455.7	1196.0	552.3	1319.0	564.3

Download English Version:

<https://daneshyari.com/en/article/4759592>

Download Persian Version:

<https://daneshyari.com/article/4759592>

[Daneshyari.com](https://daneshyari.com)