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Original research article

Effects of micro-topographies on stand structure and tree species diversity in an old-growth evergreen broad-leaved forest, southwestern Japan

Tran Van Do[a,b,c,*], Tamotsu Sato[b], Satoshi Saito[d], Osamu Kozan[a], Hiromi Yamagawa[e], Dai Nagamatsu[f], Naoyuki Nishimura[g], Tohru Manabe[h]

[a] *Center for Southeast Asian Studies, Kyoto University, Kyoto, Japan*
[b] *Department of Forest Vegetation, Forestry and Forest Products Research Institute, Tsukuba, Japan*
[c] *Silviculture Research Institute, Vietnamese Academy of Forest Sciences, Hanoi, Viet Nam*
[d] *Department of Plant Ecology, Forestry and Forest Products Research Institute, Tsukuba, Japan*
[e] *Kyushu Research Center, Forestry and Forest Products Research Institute, Kyushu, Japan*
[f] *Tottori University, Tottori City, Japan*
[g] *Gunma University, Maebashi City, Gunma, Japan*
[h] *Kitakyushu Museum of Natural History and Human History, Kyushu, Japan*

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ABSTRACT

Stand structure and species diversity were studied in correspondence with micro-topographies in an old-growth forest in southwestern Japan. The study was conducted in a 200 × 200 m^2 permanent plot, which were divided into 400 subplots using grids of 10 m × 10 m. Subplots were categorized to four micro-topographies as crest slope (CS), head hollow (HH), upper slope (US) and lower slope (LS), basing on slope of forest floor and plot position, and to two elevational zones as below 450 m and above 450 m. Tree censuses for all individuals with diameter at breast height (DBH) $\geqslant$ 5 cm were conducted in 2009 and 2013. The results indicated that CS had subplot means of living stems, dead stems, DBH, basal area (G), and basal area increment ($\triangle$G) significantly higher than that in LS. While, means of recruited stems and Shannon diversity index were significantly lower. Comparing between below and above 450 m elevational zones indicated the significantly higher parameters of stand structure and species diversity in above 450 m elevational zone. The differences of edaphic conditions led to difference of density of living stems, species density, DBH, G, and $\triangle$G among micro-topographies. Therefore, crest slope, upper slope, and higher elevational zones should be encouraged for the purposes of carbon accumulation and storage. While, the lower elevational zones should be used for the purposes of species diversity conservation.

1. Introduction

It is becoming increasingly apparent that plant communities change compositionally and structurally in response to biotic and abiotic factors. While, micro-topographies affect on edaphic conditions (e.g. fertility, depth, erosion, instability),

* Correspondence to: Center for Southeast Asian Studies, Kyoto University, 46 Shimoadachi-cho, Yoshida Sakyo-ku, Kyoto 606-8501, Japan. Tel.: +81 75 7539645.
E-mail addresses: dotran@cseas.kyoto-u.ac.jp, dotranvan@hotmail.com (T.V. Do).

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light anisotropy/availability, and biological attributes (e.g. biota, microorganism activities), leading to difference of tree's growth, crown asymmetry, and forest stand structure and diversity (Matelson et al., 1995; Clémentine et al., 1998; Clark et al., 1998; Gale, 2000; Robert, 2003; Tateno and Takeda, 2003). Therefore, micro-topography is a synthetic factor in governing stand structure and species diversity.

The regime of land surface disturbance in relation to micro-topographies has been noted as an important factor affecting stand structure and species diversity (Kikuchi and Miura, 1993; Sakai and Ohsawa, 1994; Nagamatsu et al., 2003). A relationship between vegetation characteristics and geomorphic processes was found, particularly at sites with frequent catastrophic disturbances such as land slides (Miles and Swanson, 1986; Van der Sman et al., 1993; Bellingham et al., 1996; Nakamura et al., 1997). Topographies have potential effects on species distribution, diversity, and growth through soil water availability and soil fertility (Becker et al., 1988; Silver et al., 1994; Homeier et al., 2010). Steep topography sites with high rainfall and strong typhoons mean that geomorphic processes are on occasion the critical factors determining vegetation patterns (Sakai and Ohsawa, 1993; Bellingham et al., 1996). Species richness, basal area increment, and stem density were higher in valleys than ridges in southern Ecuadorian Andes forests (Homeier et al., 2010). Enoki et al. (1996) concluded that tree species diversity was higher in lower slope than upper slope in secondary temperate forest, Japan. While, basal area was lower in lower slope than upper slope (Enoki et al., 1996).

Study on stand structure and species diversity may support us a better management strategy for each micro-topography within a climatic region. Therefore, the aims of this study were to examine changes of stand structure and species diversity and to generate the correlation of stand parameters among four micro-topographies basing on 4-year interval tree censuses of a 4-ha permanent plot in an old-growth evergreen broad-leaved forest, southwestern Japan.

2. Study site

The study was conducted in an old-growth evergreen broad-leaved forest, Aya town, southwestern Japan. Average annual rainfall and average annual temperature of study site were 2509 mm and 17.4 °C from 1981 to 2010 recorded data, respectively. The bedrock is Mesozoic shale and sandstone (Kumamoto Regional Forestry Office, 1963). A moderately moist Brown Forest soil type predominates. Climate including temperature and precipitation was known as ordinary conditions (Sato et al., 2010) and there were no strong typhoons hit the study site between 2009 and 2013, when tree censuses were conducted.

A square permanent 200×200 m^2 plot (Fig. 1) was established in 1989 for long-term ecological research. The plot locates on a steeply inclined north-northwestern slope (32°03′N, 131°12′E), expanding from 380 to 520 m above sea level. There are two gullies and a shallow valley without surface water in the plot. More details of the permanent 200×200 m^2 plot can be found at Sato et al. (1999).

3. Methods

3.1. Field surveys and data collection

Most studies of vegetation–geomorphology relationship have been based on topographic elements, such as ridges, slopes, and valleys (Harrison et al., 1989; Basnet, 1992; Ashton et al., 1995; Nagamatsu et al., 2003). Each micro-topography has a different geomorphic process, which refers to the interactions between erosion and deposition of soil materials by overland flow and mass movements. Therefore, slope degree and position are the main parameters used to classify micro-topographies (Harrison et al., 1989; Basnet, 1992; Ashton et al., 1995; Yamakura et al., 1995; Nagamatsu et al., 2003). The range of slope degree in each micro-topography is different site by site based on the difference of soil type, rainfall, and soil erosion level. In this study, micro-topography classification was inherited from Ohnuki et al. (1998), who classified the present study plot to four micro-topographies and found the significant difference of amount of soil erosion among micro-topographies. Crest slope (CS) has a gentle slope of approximate 0°–25°, locating in uppermost area of slopes. Upper slope (US) locates adjacent to CS and has slope of less than 32°. Head hollow (HH) including both head hollow and head wall is a concave slope of less than 42°. Lowe slope (LS) including both lower slope and flat foot slope has slope of less than 49° (Ohnuki et al., 1998). CS had lowest soil erosion, which equaled to 20% of that in HH. LS equaled 40% soil erosion in HH. US equaled 48% soil erosion in HH. The highest soil erosion belonged to HH.

A 200×200 m^2 permanent plot was divided into 400 subplots by using 10 m × 10 m grids (Fig. 1). Each subplot was classified to one of four micro-topographies. If a subplot locates in more than one micro-topography, it was classified to a micro-topography which has highest area ratio. For analyzing the effects of elevation on stand structure and species diversity, subplots were divided into two groups of above 450 m elevational zone and below 450 m elevational zone. The 4-ha plot expands from 380 to 520 m above sea level with a range of 140 m elevation. Contour 450 m was selected as it is the middle of plot, which divides plot to two equal elevation ranges of 70 m and more or less similar number of 100 m^2 plots for two elevational zones. In Septembers 2009 and 2013, tree censuses were conducted for all stems with diameter at breast height (DBH) ≥ 5 cm. All stems were identified to species, mapped, tagged, and measured for DBH. In addition, recruited and dead stems were recorded in 2013 census.