Forest Ecology and Management 336 (2015) 183–193

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

The impacts of thinning on the fruiting of saprophytic fungi in *Cryptomeria japonica* plantations in central Taiwan

Wan-Rou Lin [a], Pi-Han Wang [a,*], Ming-Chieh Chen [b], Yau-Lun Kuo [c], Po-Neng Chiang [d], Ming-Kuang Wang [d]

[a] Department of Life Sciences, Tunghai University, No. 1727, Sec. 4, Taiwan Boulevard, Taichung 40704, Taiwan
[b] School of Forestry and Resource Conservation, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei 10617, Taiwan
[c] Department of Forestry, National Pingtung University of Science and Technology, No. 1, Shuefu Road, Neipu, Pingtung 91201, Taiwan
[d] Department of Agricultural Chemistry, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei 10617, Taiwan

ARTICLE INFO

Article history:
Received 14 August 2014
Received in revised form 16 October 2014
Accepted 23 October 2014
Available online 11 November 2014

Keywords:
Biodiversity
Cryptomeria japonica
Forest management
Plantation
Selective thinning
Taiwan

ABSTRACT

Forest thinning is an important method for managing forests, changing forest structure, biological diversity and community. This study examined forest thinning effects on macrofungal diversity and the environmental factors affecting fruiting and community structure. Field surveys were conducted from 2006 to 2010 in 35-year-old *Cryptomeria japonica* plantations in central Taiwan. Thinning was completed in October 2007 and included control, 25% thinning, and 50% thinning treatments. Each treatment had four replications. Forest thinning and time affected macrofungal species richness observed but not abundance. Thinning influenced macrofungal community compositions; however, the difference between the two thinning intensities was not significant. The macrofungal community showed significant differences between communities of eastern and northern aspect. A redundancy analysis indicated that macrofungal communities in the *C. japonica* plantations were significantly affected by relative humidity, light, canopy cover, soil water content, soil temperature, soil pH value and soil texture. The fruiting of a dominant coral fungal species, *Scytinopogon* sp., was affected by thinning and light. The fruiting bodies of this species decreased in the 25% thinning plots and disappeared in 50% thinning plots in the first two years post-thinning, but were recorded in the third year post-thinning. After thinning, macrofungal species richness observed decreased, the community changed, and changes were associated with environmental conditions. Forest thinning decreased observable macrofungal diversity and changed the community structure, and these changes were associated with environmental variation after thinning.

1. Introduction

Species diversity is increasingly considered a key function of the ecosystem (Scherer-Lorenzen et al., 2005). In recent decades, biodiversity conservation has been increasingly considered when conducting forest management operations (Bengtsson et al., 2000; Lindenmayer and Franklin, 2002). Thinning, a common forest management technique, improves the growth of the remaining trees and enhances forest regeneration (Grant et al., 2007). Thinning is nevertheless a disturbance to organisms in forest ecosystems and affects biodiversity and ecosystem function (Bengtsson et al., 2000). Studies regarding the impact of silvicultural systems on diversity and community have recently grown in number (e.g. Bonet et al., 2012; Luoma et al., 2004; Pilz et al., 2006; Seiwa et al., 2012; Teste et al., 2012; Yamashita et al., 2014). There has been lots of attention paid to soil arthropods and bacteria, and most of these studies focus on forests in the temperate zone (Luoma et al., 2004; Meyer et al., 2005; Pilz et al., 2006).

Fungi, a major component of biodiversity, are essential for decomposition, nutrient cycling (Chapin et al., 2002; Tate, 1995) and nutrient transport (Delvasto et al., 2006; Tortora et al., 2007) in the forest ecosystem. High fungal diversity is essential to support the stability and resilience of the forest ecosystem (Perry et al., 1989). Factors influencing the fungal community included vegetation (Ferris et al., 2000), environmental factors (Tedersoo et al., 2011), climate changes (Kauserud et al., 2008) and disturbance (Bonet et al., 2012; Luoma et al., 2004; Seiwa et al., 2012; Teste et al., 2012). Fungal species with different environmental tolerances shift in abundance in response to changing environments.

Studies on the response of the macrofungal community to thinning in tropical areas were few (Brown et al., 2006; Lin et al., 2011),

* Corresponding author. Tel.: +886 4 23592026; fax: +886 4 23590296.
E-mail address: phwang@thu.edu.tw (P.-H. Wang).

http://dx.doi.org/10.1016/j.foreco.2014.10.022
0378-1127/

and most of the studies in tropical area (eg., Lin et al., 2011) fell short of the link of changing environments and macrofungal community. Thus, knowledge regarding the effects of disturbances on macrofungal diversity and community are important for evaluating the stability and resilience of a forest ecosystem.

There were about 45,000 ha of *Cryptomeria japonica* plantations in mountainous regions (Taiwan Forestry Bureau 1995) in Taiwan. This tree species was introduced from Japan in 1896 and was cultivated extensively for economic uses in 1911. The plantation forest in Taiwan entered the maturation stage. However, timbers of this tree species are no longer popular in Taiwan because of high cost and low economic values. Due to these reasons, a new management strategy to incorporate the needs of ecosystem functioning, recreation, conservation and educational purposes is developed. In order to provide science-based knowledge to developing a reasonable strategy, the large scale project to investigate the effect of different thinning practices in communities and ecosystem functions was conducted.

Macrofungi are major components of global biodiversity and control the rates of key ecosystem processes. Understanding how macrofungi respond to the disturbance caused by forest thinning is important for developing forest management strategies and biodiversity conservation. This study investigated the thinning effects on macrofungal diversity and community and identified environmental factors affecting fruiting by investigating the phenology, diversity, and abundance of macrofungi. In this context, there were three principle questions to answer. First, what is the effect of thinning on fungal diversity and community structure in the plantations? Second, what environmental factors affect the macrofungal community after thinning? Third, what are the dominant species and the thinning effect on their fruiting pattern? Potential indicator species for recovery of the environments from forest thinning were also investigated.

2. Materials and methods

2.1. Study site

The study site is located in Zen-Len area, Nantou County in central Taiwan. The site ranges from 23°28′N to 23°55′ latitude and from 120°48′E to 121°09′E longitude. Elevation ranges from 1300 to 1500 m. Average annual air temperature and rainfall recorded from nearby Sun Moon Lake Weather Station (23°53′N, 120°54′E) were 15.78 °C and 2628 mm, respectively. Most rainfall at this site occurs during the summer, from June to September. Some rainfall also occurs during the spring, from March to May; there is no obvious dry season. The natural vegetation in this area was clear-cut about 35 years previous to the start of the study and replanted with Japanese cedar, *C. japonica* (L.f.) D. Don. Two hundred and twenty-two species were classified to understory trees and shrubs, including 55 species of ferns, 138 species of dicotyledon and 27 species of monocotyledon. The dominant species are *Elatostemma lineolatum majus* and *Diplazium dilataum* (Hsieh, 2010).

2.2. Experimental design

Twelve 1-ha permanent plots (100 × 100 m) with northern and eastern aspects were established (Fig. 1a) for long-term monitoring of biodiversity dynamics. Plot 1 to 5 and plot 12 had an easterly aspect while plots 6 to 11 had a northerly aspect. The twelve plots were divided into three treatments of four plots, and each plot was randomly assigned a treatment of control, a 25% or a 50% thinning treatment (Fig. 1a). Each plot was divided into one hundred 10 × 10 m grids, using a theodolite. Thinning treatments consisted of tree removal in alternating quadrats as indicated in Fig. 1b. In treatment plots with 25% thinning, trees in one 10-m quadrat with each 20-m quadrat were cut, while in 50% thinning plots, trees in two 10-m quadrats with each 20-m quadrat were thinned (Fig. 1b). Thinning was performed during June to September of 2007. Average numbers of residual trees per plot (post-thinning) were 956 (control), 693 (25% thinning) and 476 (50% thinning) (I-Fan Sun, personal communication, September 23, 2009). The basal area in the control, 25% thinning and 50% thinning treatment before thinning was 58, 50.1 and 55.3 m^2/ha (Wang et al., 2010). After thinning, the basal area in the control, 25% thinning and 50% thinning treatment was 58, 43.1 and 24.9 m^2/ha (Wang et al., 2010). Only logged trunks with diameters >20 cm were removed from thinned plots for economic uses. Leaves, branches, and smaller trunks that were produced by thinning were left in the plots. To serve as a control for forest type, sampling plots were also established near the plantations in a natural broadleaf forest dominated by Lauraceae and Fagaceae.

2.3. Collection, identification and documentation of macrofungal species

In order to investigate macrofungal diversity and community in the plots, six 10-m diameter circular subplots were established in each plot (Fig. 1c). Mature fruiting bodies in the subplots and on the transect line between the subplots were investigated from August 2006 to October 2010 once every two months during the fruiting season (March to October). Macro-morphological features of fresh sporocarps, such as size, shape and color, the substrates they grew and their ecology were noted (Lodge and Cantrell, 1995). Morphological descriptions were compiled for each species to establish their identities. Sporocarp numbers, fruiting seasons and locations were also recorded. Voucher specimens of each species were photographed *in situ* and then collected. The macrofungi were dried at 40 °C for 1 or 2 days and preserved at the Department of Life Sciences, Tunghai University, Taiwan. Some collections were deposited in National Museum of Natural Science. To identify specimens, literatures including Chang et al. (2000), Chou and Chang (2005), Chou (2010), Corner (1950), Laessoe (1999), Ryvarden (1991), Tzean et al. (2010) were consulted.

2.4. Monitoring of environmental factors

The environmental factors in each study site plot, including temperature, water content, soil texture and pH, and temperature, relative humidity and light in the forest, were measured to identify the factors that influenced the differences in the macrofungal community. Hourly soil temperature was detected by T-type Thermocouple-type sensor (Omega Engineering Ltd., Stamford, USA) at soil depths of 10 and 20 cm. Soil water content was detected by a Soil Water Capacitance Probe (Sentek Pty Ltd., Stepney, SA, Australia) at depths of 10 and 20 cm and data were recorded every 15 min. A soil:water ratio of 1:5 was used for the measurement of soil pH. Air-dried soils (<2 mm) were suspended in distilled water and dispersed by ultrasonication for 10 min. Dispersed soils were separated into clay, silt and sand fractions by sedimentation and centrifugation for the soil texture analysis (Jackson, 1979; Gee and Bauder, 1986). Air temperature and relative humidity in the forest were monitored by data loggers (HOBO Pro Series data logger, Onset, Bourne, MA). The data logger was placed at a height of 1.5 m and data were recorded every 5 min. Incident, light photosynthetically active radiation (PAR) was measured and recorded at 5 min intervals at a height of 1.5 m with a quantum light sensor (LI-COR LI190SB-L Quantum Sensor, Lincoln, Nebraska, USA). We used the percentage of unthinned area to represent percent canopy cover. For example, the percentage canopy cover of the control