Spatiotemporal distribution pattern of soil temperature in forest gap in Pinus koraiensis-dominated broadleaved mixed forest in Xiao Xing’an Mountains, China

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Abstract

By using regular grid and transect methods, plot and sub-plots were established in the forest gap of Pinus koraiensis-dominated broadleaved mixed forests in Xiao Xing’an Mountains, China. The surfacial, maximum and minimum temperature (T_s, T_max, and T_min), and the temperature at 5, 10, 15, and 20cm soil depths were measured from May to September 2006 to illustrate their spatiotemporal distribution patterns. The results showed that high-value regions of daily T_s were not at the gap center, but at north-western and eastern sides of the gap, with an asymmetric distribution. Their mean difference between daily T_max and T_min was bigger in the trees early and late growth periods, but relatively smaller in fast growth period. As for daily and monthly mean soil temperatures over soil depths, a bimodal behavior was observed in east-west direction. Daily and monthly mean temperature exhibited no apparent and single peak behavior in north-south direction, except in May, respectively.

Key Words

Pinus koraiensis-dominated broadleaved mixed forest, forest gaps, soil temperature, distribution pattern.

Introduction

Forest gaps exist widely in forest ecosystems, are in an important phase of forest cycle regeneration. Environmental heterogeneity caused by gap formation, its impact on species distribution, population dynamics and species diversity in forest gaps, and its important roles in forest succession, regeneration and growth have been widely concerned (Poulson and Platt 1989; Beckage et al. 2000; Fownes and Harrington 2004; Pedersen and Howard 2004; Diaci et al. 2005). Microclimatic difference between and within canopy gaps (De Freitas and Enright 1995), light index and its application in Sweden (Dai 1996), microclimate (Carlson and Groot 1997), states of partially microclimatic factors after gap formation and soil moisture response (Canham et al. 1990; Gray et al. 2002; Clinton 2003; Raymond et al. 2006) were systematically performed. Over the past decade, our researches on forest gaps gradually increased in China (Zang RG et al. 1999), but so far, those on microclimate in gaps have been not yet fully developed, particularly on spatiotemporal distribution patterns of soil temperature after gap formation is still rare. Only a fewer researchers investigated the microclimate in gaps, their researches mainly dealt with light, spatiotemporal distributions of air and soil temperature (Zang RG et al. 1999; Zhang YP et al. 2001)) as well as other microclimatic factors (Liu WJ et al. 2000a; Zhang YP et al. 2002, 2003; Zhu JJ et al. 2007), and microclimatic difference (Liu WJ et al. 2000b). However, studies on spatiotemporal distribution of soil temperature are still scarce (Zhang YP et al. 2001; Zhu JJ et al. 2007). In vast temperate regions, studies on the changes in soil temperature after gap formation are even rarer (Li Y et al. 2007; Zhu JJ et al. 2007). Therefore, measurement plot and sub-plots were established, spatiotemporal distribution pattern of soil temperature in this forest gap was analyzed in order to provide basic data for researches on environmental heterogeneity and regeneration in canopy gaps, sustainable ecosystem management.

Materials and methods

Study site and experimental design

Investigations were performed from May to September 2006 in a gap created naturally in Pinus koraiensis-dominated broadleaved mixed forests in Xiao Xing’an Mountains, in Liangshui National Nature Reserve (47°06′49″–47°16′10″N, 128°47′8″–128°57′19″E) of Northeast Forestry University, in Dailing District, Yichun City, Heilongjiang Province, China. For a more in-depth description of this Reserve, see Duan et al. (Duan et al. 2009). The study site is located in broad-leaved Pinus koraiensis forests at an elevation of 420 m, with negative slope, a slope grade of 10–15°, a northern aspect. The plot area was 20 m×20 m. Canopy gap was irregularly shaped with about 200 m² area, naturally created by multiple gap-makers at unknown time in the past. The reason for gap formation is more complicated, such as breakdown, snag, and tree-fallen. Tree species surrounding the gap boundary are mainly Pinus koraiensis and Betula costata with their average...
height of 17.5 m. For the details of this site, see Duan et al. (Duan et al. 2009). Measurements done from May to September 2006 in this study area included surfacial, maximum and minimum temperature in a grid design (Figure 1), and the temperature at 5, 10, 15, and 20 cm soil depths along two perpendicular transects (Figure 2).

Figure 1. Locations of measurement plots of \( T_s \), \( T_{\text{max}} \) and \( T_{\text{min}} \). The black line indicates the approximate contour of the gap.

Figure 2. Locations of measurement plots of soil temperature at 5, 10, 15, and 20 cm soil depth. The black line indicates the approximate contour of the gap.

Soil temperature measurements

41 locations of measurement sub-plots were selected in the forest gap and around its edge by using regular grid and transect methods, surfacial, maximum and minimum thermometer were placed at each location (Figure 1). Other 13 locations of measurement sub-plots were located at gap center (GC), gap edge (GE), expanded gap edge (EG), understory (US) along two transects running North-South and West-East directions through gap center. Bended tube thermometers were installed in each location to measure the temperature at 5, 10, 15, and 20 cm soil depths (Figure 2). Measurement was done from 6:00h to 18:00h for 6-10 days monthly, time interval was 2 hours.

Data processing

Soil temperature, which was not directly measured in other locations in the gap, was assessed by estimation of spatially local Kriging interpolation from geographical statistics (Wang SP et al. 2003). SPSS 11.5 and GS+For Windows 3.11 softwares were used for basically and spatially statistical analysis on the data, respectively. SURFER 7.0 software (Golden Software 1999) was used for estimation of spatially local Kriging interpolation and further mapping of soil temperature.

Results

Spatiotemporal distribution pattern of soil temperature in forest gap

Daily spatial distribution pattern of soil surface temperature in forest gap

Daily spatial distribution pattern of \( T_s \) in forest gap in July was set as an example (Figure 3). In general, within a day, the high-value region of \( T_s \) happened with the sequence of northwestern, northern and eastern sides of the gap, \( T_{\text{max}} \) within the high-value region was 27.0 °C (14:00h) > 25.0 °C (12:00h) > 23.0 °C (10:00h) > 22.0 °C (16:00h).

Monthly spatial distribution pattern of soil surface temperature in forest gap

For the distribution of \( T_s \), all high-value regions in months appeared in eastern side of the gap, but their \( T_{\text{max}} \) was different, relatively higher from June to August; the secondary high-value regions occurred in northwestern side of the gap every month, but their gradients were all smaller. All high-value regions of \( T_s \) were not in the central gap, but in eastern and northwestern side of the gap, their distribution was asymmetric (Figure 4).

Spatiotemporal distribution pattern of difference between daily \( T_{\text{max}} \) and \( T_{\text{min}} \) in forest gap

In the early growing season (May), the diurnal range of \( T_s \) was bigger, reached 21.0 °C in northwestern side of the gap (Figure 5). That was smaller from June to August than that in May, there was a decreasing tendency; while in the late growing season, it was larger in September than in August. Comparatively higher mean difference between daily \( T_{\text{max}} \) and \( T_{\text{min}} \) in our study area was all located in northwestern and eastern side of the gap.
Soil temperature along different directions in forest gap

The diurnal variation in soil temperature along different directions

A bimodal behavior of soil temperature at all locations was observed in east-west direction (Figure 6), their bimodal values were respectively located in expanded gap edge in western side and in canopy gap edge in eastern side; An unapparent single peak behavior at all locations was found in north-south direction, the positions of their bimodal values changed weakly over time and shifted between in canopy gap edge in northern side and in the center of gap, but in general, the soil temperature in northern side was larger than that in southern side. By contrast, it was comparatively smaller under understory. The magnitude of change in soil temperature at 5 cm depth was the highest (2~7 °C) in daytime, the lowest at 20 cm depth (0~2 °C).

The monthly variation in soil temperature along different directions

Generally, a bimodal behavior was observed in east-west direction every month (Figure 7), bimodal values occurred in gap edge in eastern side and in expanded gap edge in western side, respectively, bimodal value in the eastern side was larger than that in western side. Monthly mean soil temperatures except in May in north-south direction exhibited an unapparent single peak behavior, bimodal value appeared in the central gap and in expanded gap edge in northern side over time, and meanwhile soil temperature in northern side was slightly higher than that in southern side.

Conclusion

For the high-value regions of $T_s$ in the gap, there was apparent diurnal variation, with the sequence of north-western, northern and eastern sides of the gap, those were all located in north-western and eastern side with
an asymmetric distribution every month; Mean difference between daily $T_{\text{max}}-T_{\text{min}}$ was larger in the tree’s early and late growth periods, but relatively smaller in fast growth period. Comparatively higher diurnal range was all in north-eastern and eastern side of the gap; As for daily and monthly mean soil temperatures at 5, 10, 15, and 20 cm depths, a bimodal behavior was observed in east-west direction, daily bimodal values were respectively located in expanded gap edge in western side and canopy gap edge in eastern side, monthly bimodal values occurred in gap edge in eastern side and expanded gap edge in western side, respectively; Daily and monthly mean temperature exhibited no apparent and single peak behavior in north-south direction, except in May, respectively.

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