Acta Ecologica Sinica 36 (2016) 269–274

Contents lists available at ScienceDirect

Acta Ecologica Sinica

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

Population structure and dynamics of *Abies spectabilis* at treeline ecotone of Barun Valley, Makalu Barun National Park, Nepal

Parveen Kumar Chhetri [a,*], Raju Bista [b], David M. Cairns [a]

[a] Department of Geography, Texas A&M University, College Station, TX, United States
[b] ForestAction Nepal, Lalitpur, Nepal

ARTICLE INFO

Article history:
Received 25 June 2015
Received in revised form 14 May 2016
Accepted 16 May 2016

Keywords:
Treeline ecotone
Population dynamics
Age structure
Recruitment pattern
Treeline advance

ABSTRACT

The population structure and dynamics of high altitude, long-lived treeline species can be utilized as an indicator for climate change. This study was conducted in the treeline ecotone of the Barun Valley, eastern Nepal in order to understand the population dynamics of *Abies spectabilis*. The *A. spectabilis* population showed the reverse J-shaped size and age distribution curves indicative of undisturbed old growth forest. The age structure is mostly dominated by the young individuals, however, their mortality was found to be very high. Positive relationships between recruitment and high temperatures during winter months (January, February and December) and one summer month (August) were discovered. No significant relationship was found between precipitation and climate of the region. If warming condition prevails in summer and winter seasons in the near future, then there is chance that more individuals will be established above the treeline area, triggering the treeline advance.

1. Introduction

Ongoing climate change will have a strong influence on vegetation communities, particularly on the transition zone communities such as the treeline ecotone. Treeline ecotone is the high altitude limit of forests and occurs between closed continuous forest below and the treeless alpine zone above. Low temperature is the most common limiting factor, affecting plant physiology such as photosynthesis, respiration, and seed germination in treeline ecotone [1]. Global warming can be expected to alleviate these constraints, provide chances for plants to invade bare areas, and improve growth of already established plants in severe environments. Therefore, population dynamics of treeline species, notably those of long-lived species can be utilized as an indicator of climate change, especially temperature change [2,3]. However, there is dearth of information on the population structure of treeline species from the Himalayan region.

One recent study has indicated that air temperature is increasing strongly in the eastern Himalaya (>0.02 °C/yr), and this trend is more distinct at higher elevations during the winter season [4]. There is a chance that the temperature increase will change the structure of the treeline ecotone by promoting the establishment of seedlings and saplings. The presence of seedlings and saplings above the treeline [5], their annual variation in abundance and distribution [6] are indicators of future changes in upper treeline stability and the potential for treeline advance. If the numbers of seedlings are fewer in the undergrowth, the death of existing trees will lower the treeline. If there exists a large number of seedlings that establish and grow well, the position of the treeline is maintained or a rise of the treeline may occur [7]. Therefore, research on establishment pattern of seedlings and saplings, their mortality, size and age structure, and important climatic variables controlling the recruitment pattern will clarify the processes of treeline fluctuation [8].

The Himalayan silver fir (*Abies spectabilis* (D. Don) Mirb.) is an important species in the sub-alpine conifer forest in the eastern Himalaya. It is a tall evergreen, pyramidal shape tree found between 2800 and 4000 m a.s.l. in the sub-alpine forest of Nepal [9] and is the main treeline species of Nepal. However, few studies have been carried out at the treeline of the Nepal Himalaya, and fewer have concentrated on population dynamics [10–13]. Therefore, this study was carried out in Barun Valley, Makalu Barun National Park, eastern Nepal Himalaya to understand the population dynamics of *A. spectabilis* within the treeline ecotone. In our earlier studies on the treeline ecotone of Barun Valley, we focused on the spatial pattern of recruitment (establishment pattern), quantified the treeline advance rate [12], analyzed tree-ring climate response and tree-ring width trend [14]. In this study, we have quantified the mortality rate based on life table and have determined important climatic variables that control the recruitment pattern based on climate recruitment response analysis.

2. Methodology

2.1. Study area

This study was conducted in the Barun Valley (27°44′N-27°47′N, 87°08′E-87°10′E) of the Makalu Barun National Park (MBNP), eastern

* Corresponding author.
E-mail address: parveenkchhetri@tamu.edu (P.K. Chhetri).

http://dx.doi.org/10.1016/j.chnaes.2016.05.003

Nepal (Fig. 1). Barun Valley lies within the subtropical Asian monsoon zone, characterized by a pronounced summer rainfall falling between June and September; more detailed information about the climate of this area is found in Chhetri and Cairns [14]. Due to minimum human activities, treelines of Barun Valley are undisturbed [12,14]. *A. spectabilis* is a dominant species of sub-alpine forest of Barun Valley and other associated species are *Betula utilis*, *Rhododendron hodgsonii*, *Rhododendron camplylocarpum*, *Rhododendron wightii*, *Acer campbelli*, and *Sorbus microphyllus*.

2.2. Plot establishment

A field investigation was carried out in October–November of 2010 and 2011. Seven plots in treeline ecotone were established: three plots each at south- and north-facing slopes (S1–S3, N1–N3), and one plot at east-facing slope (E) (Fig. 1). More information of the study plots is found in Chhetri and Cairns [12]. All the individuals of *A. spectabilis* within the plots were counted and classified into three height classes: trees (>2 m), saplings (0.5–2 m) and seedlings (<0.5 m) [15]. All the individuals of *A. spectabilis* within the plots were measured for morphometric features. Basal diameter and diameter at breast height (DBH, 1.37 m above ground level) of the trees were measured by a DBH tape. Height of the trees was measured by a clinometer, and the height of seedlings and saplings was measured by a wooden scale. Reproductive effort was classified as presence or absence of catkins or cones. Density, basal area, canopy coverage and stem internode measurement were also calculated for the trees, saplings and seedlings at each site.

2.3. Dendroecological procedure

The age of trees was determined by tree-ring core samples that were collected from the base of the trees using an increment borer. The age of seedlings and saplings was determined by counting the number of branch whorls and bud scars on the main stem [15,16]. This method can underestimate the true age [17], so 76 stem cross-sections were also collected to quantify the error. The cross-sections were also used for an age - height regression analysis to estimate the time needed for seedlings and saplings to reach approximate breast height [12,18]. This equation was used to remove the age error caused by coring height. Cross-sections were also collected using a hand saw for seedlings and saplings that could not be aged by branch whorls and for dead seedlings and saplings.

2.4. Population structure and static life table

Population structures for *A. spectabilis* were determined for aggregations of all plots on south, north and east-facing aspects. Individuals were classified into 5 cm DBH and 5 year age classes to determine population structure. Data from all plots, regardless of slope aspect, were pooled to create a static life-table of *A. spectabilis* population. Out of the total 1407 individuals that were sampled in the field, 1366 were used for the life table construction and the remaining were neglected due to age related issue. Age classes (10 year) were used for life table construction [3,19]. The life table is an important tool to estimate the future survival trends of the population and can be used to investigate individual survival status in each age class at a particular time [19]. Description of the life table components and calculation steps are presented in Table 2.

2.5. Population survivorship and mortality curves

On the basis of life table of *A. spectabilis* population, the survivorship and mortality curves were calculated [19]. The survivorship curve was drawn between the $ln\mathbf{l_x}$ (proportion of individuals surviving from the

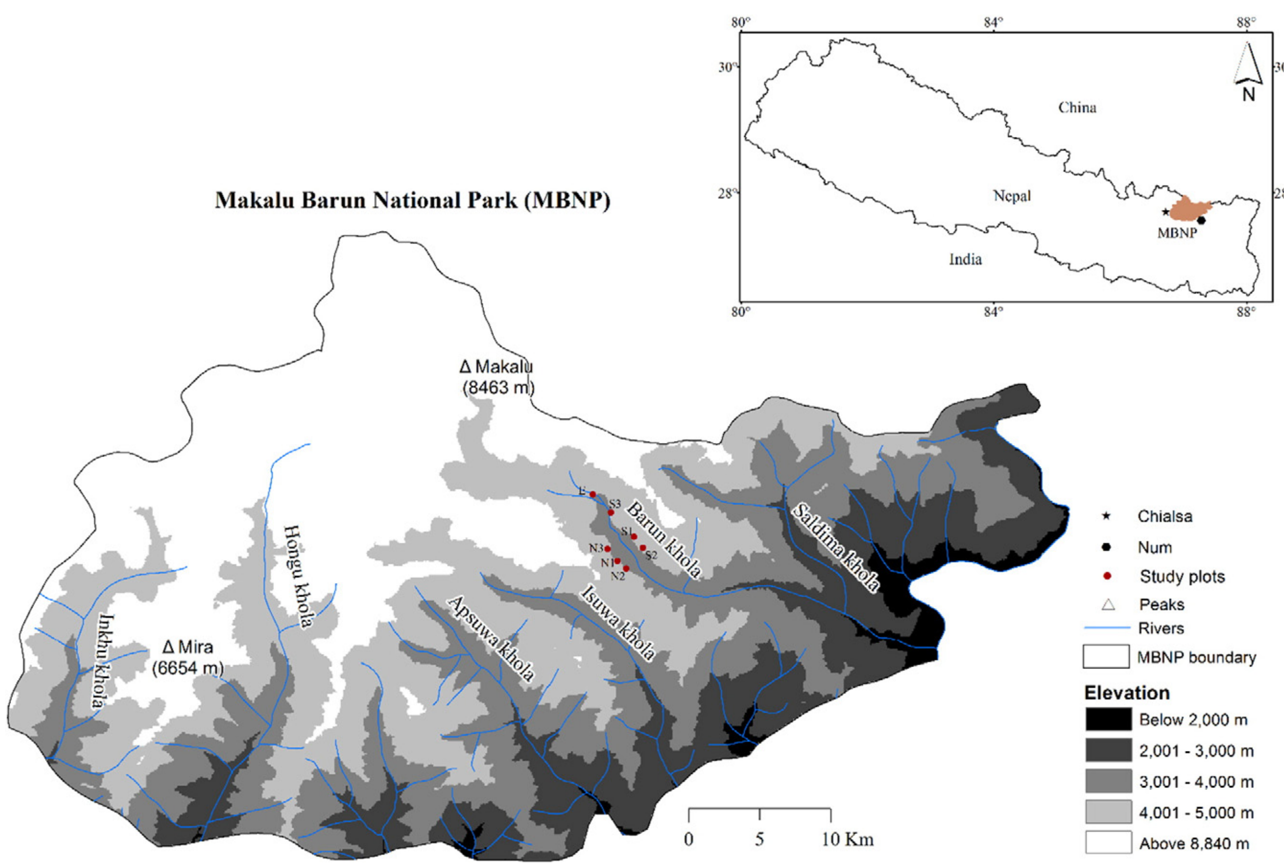

Fig. 1. Study area: Barun Valley, Makalu Barun National Park (MBNP), eastern Nepal. Inset map indicates location of MBNP, and Chialsa and Num meteorological stations.