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Original Research Article

Composition, diversity and distribution of woody species in relation to vertical stratification of a tropical wet evergreen forest in Bangladesh

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ABSTRACT

The composition, diversity and spatial distribution pattern of woody species were analyzed along the vertical profile of a tropical wet evergreen forest in Bangladesh. The forest stand consisted of five vertical strata. The species composition was moderately similar among the strata, while the highest degree of similarity was between fourth and bottom strata. *Bursera serrata* Wall. ex Colebr. was the most dominant species, and may be typically climax species together with *Microcos paniculata* L. ex W & A. and *Maesa ramentaca* (Roxb). A. DC in terms of their high importance values. Species–area relationships depict compositional instability of the present forest, because expected maximum numbers of species (165) were four times higher than the recorded numbers of species (40) for the total stand. Smaller species richness in the upper strata was compensated by greater species evenness (Pielou's index J'), resulting in almost constant Shannon's index H' across the strata. It indicates each stratum may have the same role in maintaining high woody species diversity. The rate of equality of individuals among the different species decreased with increasing species richness due to decrease of J' from the top stratum downward. The distribution pattern of the entire stand was greatly influenced by the aggregated distribution of the majority of the juveniles those mainly appeared in the bottom stratum. However, vertical strata shared a mixed distribution pattern of random and aggregate which followed from the upper strata to downward. This type of distribution pattern for stratified stand is probably consistent in tropical forests.

1. Introduction

Biodiversity and species diversity are widely used terms in ecology and natural resource management (Hurlbert, 1971; Kaennel, 1998; Schulze and Mooney, 1994; Do et al., 2015). Biodiversity is a key issue in nature conservation (Wilson, 1988), and species diversity is an important component of biodiversity (Itô, 1997). Tree species diversity is fundamental to overall forest biodiversity, because trees provide resources and habitats for almost all other forest species. In addition, structural diversity measured as variation across a vertical stand profile also appears to be a good ecological indicator of the conservation of woody species diversity (Koop, 1989; Neumann and Starlinger, 2001). Hozumi (1975) proposed a mathematical model for analyzing the vertical stratification of forest stands (M–w diagram), and Feroz et al. (2006) developed an objective method for distinguishing boundaries among strata in the M–w diagram. Using this methodology, they found

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that subtropical evergreen broadleaf forests in the southern part of Japan and China consisted of four or five strata (Hozumi, 1975; Feroz et al., 2006, 2009; Min et al., 2010). Species diversity and development of vertical stratification both increase along the latitudinal thermal gradient from higher latitudes to the tropics (Hozumi, 1975; Yamakura, 1987; Kira, 1991; Ohsawa, 1995; Kimmins, 2004). In addition, the degree of vertical stratification is an important factor for maintaining higher woody species diversity (Feroz et al., 2006, 2008), because a particular layer's species could contribute high species diversity for an entire stand. For instance, conservation of small trees in the lower layers, especially the bottom layer, is indispensible for sound maintenance of evergreen broadleaf forests in the southern part of Japan (Feroz et al., 2006).

The topography of Bangladesh is mostly low and flat. The floodplain and terraces account for about 88% of the land area, whereas hills occupy only 12% (FAO, 1988). The Chittagong Hill Tracts (CHTs) region is the major hill range of the country located in the southeast bordering India and Myanmar. It covers only 10% of the total land area of the country, but possess country's one-third of the flowering plant species. Phyto-geographically, Chittagong and CHTs show an admixture of Indo-Chinese floristic elements. The forests of this region may be broadly classified into tropical wet evergreen, semi evergreen and deciduous types. Commercial tree plantations, illegal logging, dam mega-projects, and forced displacement are responsible for the accelerated destruction of the valuable ecosystems and biodiversity of this region. Rubber, teak and eucalyptus plantations for export have provoked negative ecological effects and convert the forests into degraded forest land. Nevertheless, natural patches still exist in some places of the tropical wet evergreen forest in Kaptai National Park, CHTs. These patches would be precious in view of floral diversity for the conservation of the whole forest biodiversity. Thus, they offer unique opportunities for observing the floristic composition, woody species diversity and structural aspect of tropical forest.

Most vegetation surveys of the natural forest in Kaptai National Park, CHTs focused only on understory (Uddin and Hassan, 2012; Feroz et al., 2014). Therefore, canopy woody species, including saplings, were omitted. However, the upper vegetation stratum, which is influenced by the understory woody species (through the modification of resource availability, e.g. light, water, and soil nutrients) (Barbier et al., 2008), is also a very important component of forest species composition, diversity, and structure. Moreover, there is no study in Bangladesh forest that reports the vertical stratification and its effect on floristic composition, woody species diversity and spatial distribution pattern of trees. Therefore, the aims of this study were (1) to distinguish vertical stratification of the forest, and (2) to quantify composition, diversity and spatial distribution of woody species on the basis of vertical stratification.

2. Materials and methods

2.1. Study site and sampling

The study was conducted in a tropical wet evergreen forest, located at Kaptai National Park (22°29.99′ N and 92° 10.722′ E) in Chittagong Hill Tracts of Bangladesh (Fig. 1). This area belongs to Kaptai forest range under the management of Rangamati south forest division. The forest is also known as Rampahar reserve forest declared in 1875 (Anonymous, 1960). It is a secondary forest with mature stand (Fig. 2). An operation of clear-cutting in this region has been done approximately 80 years ago. The canopy in this forest is evergreen with dense coverage. Subsoil is yellowish brown to strong brown and strongly structured. Loamy soil developed on consolidated or semi consolidated siltstone, sandstone and clayey on shale's. Soil on the high hill is excessively drained and less than 1 m depth. The soil pH range lies between 4.5 and 6.0. The country has a sub-tropical monsoon climate with a distinct dry season. Although there are six seasons in a year, three seasons viz. winter, summer and monsoon are prominent. In the winter (November–February) the temperature varies from 5° to 23 °C, in the summer (March–June) the maximum temperature shoots up to 40 °C while monsoon starts in July and persists until October (FAO, 1988). The mean monthly minimum temperature and the mean monthly maximum temperature are respectively 24.3 ± 0.3 (SE) °C in December and 34.8 ± 0.5 (SE) °C in May. Mean annual temperature was 29.6 ± 0.4 (SE) °C. The warmth index was 295.2 ± 1.2 (SE) °C month, which was >240 °C month of the tropical region defined by Kira (1977). The mean annual rainfall is 2535 ± 125 (SE) mm. The mean annual humidity is about 80%. Most of the evaporation is concentrated in the dry season. The average annual evaporation is about 500 mm. The maximum wind velocity recorded is 96.54 km/h (FAO, 1988).

A sample plot was established in the middle portion of the mountain in CHTs as a representative stand of the forest, and had an area of 1600 m^2 (40 × 40 m) which was divided into 64 quadrats of equal size (5 × 5 m) (Fig. 2). The plot is relatively small, but is sufficiently large for the analysis of forest stratification by the method of Hozumi (1975); the preceding studies have used sample area of 400–1225 m^2 (Hozumi, 1975; Feroz et al., 2008; Min et al., 2010; Feroz et al., 2015). The altitude of the plot, which faced to the South with a slope of 31.2°, was 253 m above sea level. All woody plants (tree height $H > 0.10$ m) present in the study plot were identified and recorded to species by local name with the help of experienced personnel of Bangladesh Forest Department. Image plates were prepared for voucher specimens that could not be identified in situ. Every such specimen was tagged and given a unique identification code. Later local named species and voucher specimens were confirmed to identify up to species level using available literature (e.g. Das and Alam, 2001; Khan et al., 2001; Dey, 2006; Ahmed et al., 2009) and matching with the collections preserved in the Bangladesh National Herbarium as well as with the images available in the website. The measurements obtained for the area were: tree height (H) and stem diameter at a height of one-tenth of tree height ($D_{0.1H}$). Multi-stemmed individuals were measured separately and treated as separate trees.