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Structure and regeneration dynamics of dominant tree species along altitudinal gradient in a dry valley slopes of the Bhutan Himalaya

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Abstract

The aim of our study was to characterize the structure and regeneration dynamics of dominant tree species along altitudinal gradient in dry valley slopes of the Bhutan Himalaya. In the typical dry valley slopes of west-central Bhutan, we analyzed forest stratification, tree crown projection, and population structure from lower dry valley bottom (1520 m a.s.l.) to upper humid ridge top (3370 m a.s.l.) across five major forest types: i.e. (1) dry pine forest with *Pinus roxburghii* as a dominant species; (2) mixed broad-leaved forest with *Quercus lanata* (evergreen), *Quercus griffithii*, (deciduous), and *Rhododendron arboreum* (evergreen) as major canopy species; (3) evergreen broad-leaved forest dominated by *Quercus semecarpifolia*, *Quercus glauca* and *Quercus oxyodon*; (4) cool conifer forest dominated by *Abies densa* and *Tsuga dumosa*; (5) cold conifer forest with *A. densa* and *Juniperus recurva* as dominants. In general, regeneration pattern of major dominant species shifted from inverse-J (lower altitudes), to sporadic (mid-altitudes), and to uni-modal type (upper altitudes) corresponding to three regeneration trends: (1) invasive at the lower, warm, dry forest under relatively strong human disturbances; (2) stable/balanced at the mid-altitude, in a relatively stable, mature moist evergreen broad-leaved forest with gap regeneration; and (3) poor/low regeneration at the upper, cool, humid conifer forest with a continuously cattle-grazed understory. Overall, regeneration patterns were balanced in all forest types, however care should be taken to prevent excessive exploitation of dry pine forest of lower valley bottom, and to control cattle grazing at higher altitudes. Our findings can be incorporated into management plans for sustainable management and conservation of mountain forests.

Keywords: Population structure; Disturbance regime; Environmental gradient; Bhutan

1. Introduction

The presence of typical dry valleys in the midst of humid eastern Himalaya including Bhutan, is a unique feature (Schweinfurth, 1957, 1992; Ohsawa, 1987; Eguchi, 1987, 1997) (Fig. 1A). In the Bhutan Himalaya, dry valleys are developed in the inner valleys from west to east along the major rivers mainly caused by strong and hot wind that ascends every afternoon from down stream along the dry river valley bottom leading to specific local dryness, which extends from south to north (Fig. 1B and C). This phenomenon leads to pronounced transition in floristic composition along the typical dry valley slopes, which starts from a warm, dry pine forest at the valley bottom at ca. 1000 m a.s.l. changes to moist mixed broad-leaved forest at the mid-altitudes of 2000–2800 m a.s.l., and ends with a cool, humid conifer forest at the ridge top at ca. 3500 m a.s.l. Coincidentally, major human settlements are located around the bottom of dry valleys, inhabitants of which use the nearby forests for extraction of timber, litter for cattle bedding, and firewood. Sites are also often used for cattle grazing, and thereby, forests become the principal source of their livelihood.

Although several studies have analyzed the altitudinal and latitudinal forest zones in relation to climate of the Himalayas and the surrounding mountains (Champion, 1936; Stainton, 1972; Saxena and Singh, 1984; Sargent, 1985; Ohsawa, 1987, 1992; Ohsawa et al., 1986; Singh and Singh, 1992; Singh et al., 1994; Tang and Ohsawa, 1997; Wangda and Ohsawa, 2006a,b), very little is known on the comparative ecology and regeneration dynamics of the forests along the typical dry valley slopes. Studies along the dry valley slopes are important because of steep environmental gradients leading

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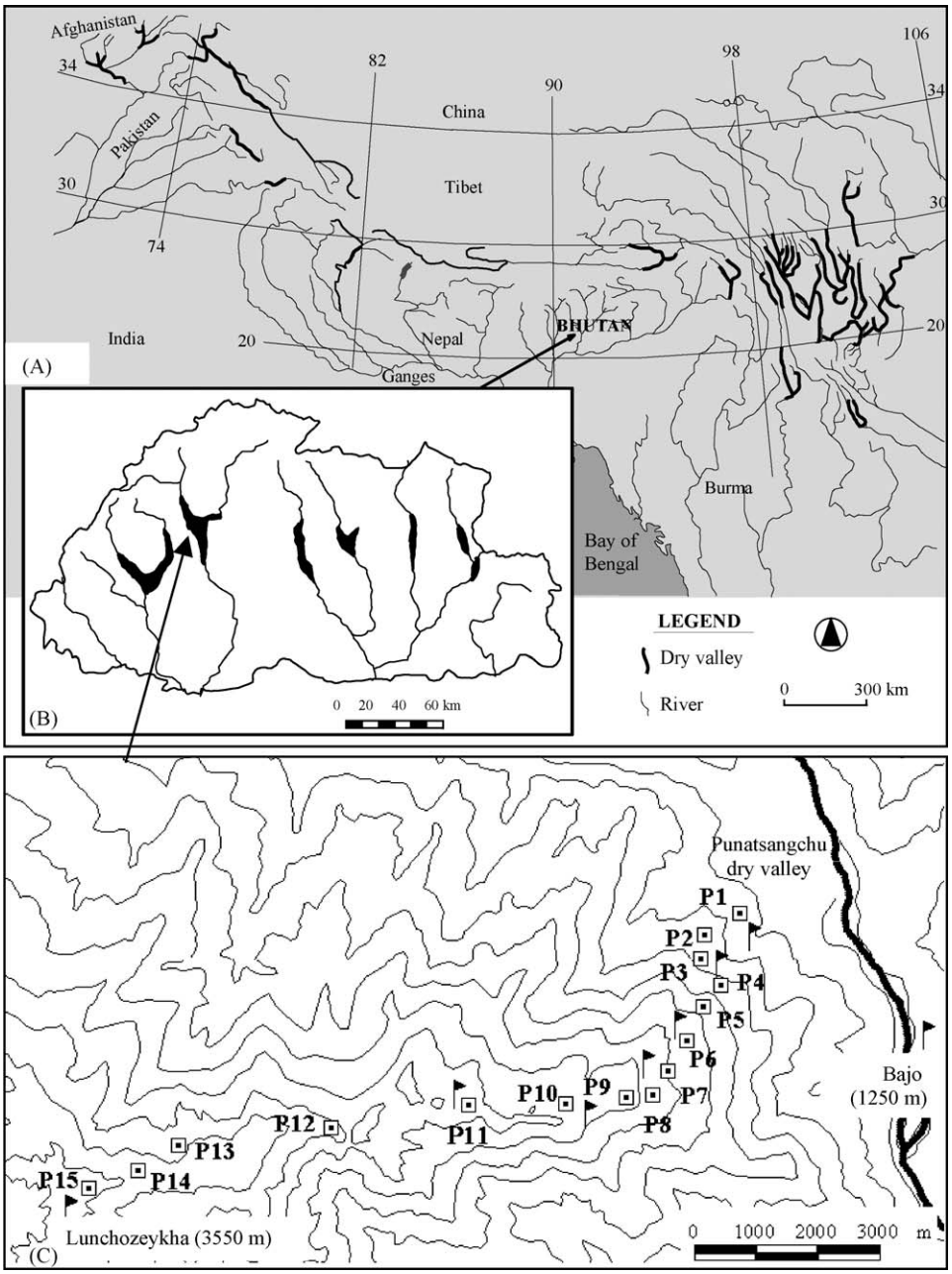

Fig. 1. Location map of the study area: (A) distribution of dry valleys in the Himalaya including Bhutan (based on Schweinfurth, 1992); (B) distribution of dry valleys in the Bhutan Himalaya (after Ohsawa, 1987) and; (C) topographical map (40 m interval) of the study area showing forest sampling plots (P1–P15) and climatic data loggers (flags) from the dry valley bottom at Bajo (1250 m a.s.l.) to Lunchozeykha (3550 m a.s.l.) on the ridge top.

to rapid change in forest types. Here we examine floristic composition, structural traits, and regeneration mechanisms of forests on the dry valley slopes. Our specific goal is to clarify regeneration dynamics of dominant trees based on their population structure, seedling/sapling densities and crown projection maps along altitudinal gradient of a typical dry valley. This type of ecological knowledge is fundamental for conservation and sustainable utilization, and linking complex altitudinal and climatic gradients with human activities may provide important information for the policy makers for drafting management plans of fragile mountain ecosystems.

2. Materials and methods

2.1. Study site

The present study was conducted in a typical dry valley along Punatsangchu (river), west-central Bhutan (Fig. 1B). Specifically, the forest sampling plots (P1–P15) were set up along the dry valley slopes facing to the east of Punatsangchu from Bajo (1250 m, 27°30′N, 89°52′E) at the valley bottom to Lunchozeykha (3550 m, 27°28′N, 89°45′E) at the ridge top (Fig. 1C).

Based on the Holdridge's life zone classification system (1967), the study area ranged from warm, dry sub-tropical type