Journal of Arid Environments 121 (2015) 112–123

Contents lists available at ScienceDirect

Journal of Arid Environments

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

Facing north or south: Does slope aspect impact forest stand characteristics and soil properties in a semiarid trans-Himalayan valley?

Inger Elisabeth Måren [a, *], Sikha Karki [a, b], Chanda Prajapati [a, b], Ram Kailash Yadav [b], Bharat Babu Shrestha [b]

[a] The University of Bergen, Department of Geography, Fosswinckelsgate 6, 5007, Bergen, Norway
[b] Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, PO Box 5275, Nepal

ARTICLE INFO

Article history:
Received 19 December 2014
Received in revised form
9 May 2015
Accepted 1 June 2015
Available online 24 June 2015

Keywords:
Manang valley
Arid region
Carbon storage
Forest use
Land use change
Soil nutrients

ABSTRACT

An understanding of the differences in vegetation and soil characteristics between slope aspects in high altitude semiarid environments is fundamentally important for efficient management of these semi-natural systems; however, few studies have quantified these differences. Here, we analyzed forest stand characteristics, carbon stocks and soil properties of north- and south-facing slopes in a trans-Himalayan semiarid valley. *Pinus wallichiana* was the dominant and *Juniperus indica* the co-dominant species in both aspects, whereas *Betula utilis* and *Abies spectabilis* were only recorded in north-facing forests. *Pinus* regenerated in both aspects, whereas *Juniperus* did not. Carbon stocks did not differ between aspects; 33 t/ha in north-facing and 31 t/ha in south-facing forests. Similarly, soil properties did not vary between slope aspects, expect for potassium (highest in south-facing slopes). These results suggest that topographic factors affect mountain forests through their direct influence on radiation and moisture, but that human disturbance also plays a significant role affecting vegetation and soil characteristics in a semiarid environment. These natural and anthropogenic factors may play in harmony or in discord with each other. Here, the aridity of the region, parent material and land use history led to less pronounced differences between slope aspects, than commonly found in moister habitats.

1. Introduction

Mountain forests, occupying 23% of the Earth's forest cover (Price et al., 2011), is home to about 12% of the global human population (FAO, 2002). Consequently, sustainable management and conservation of mountain environments and their unique biological diversity are pertinent for maintaining the livelihoods of mountain communities. Forest diversity, composition and regeneration are affected by factors like climate, topography, aspect, inclination of slope soil type and land use. Differences in insolation period and intensity change with aspect, thereby forming a range of microclimates in multifaceted landscapes (Holland and Steyn, 1975). Several studies conclude that the variation between two contrasting aspects is the result of the differences in solar radiation received, e.g. in North America (Cantlon, 1953), the Middle East (Kutiel and Lavee, 1999), Australia (Kirkpatrick et al., 1988), in east Africa (Vetaas, 1992), the Himalaya (Ghimire et al., 2010; Paudel and Vetaas, 2014), and even within the same elevation (Shank and Noorie, 1950). Cantlon (1953) and Pook and Moore (1966) revealed that opposing slopes vary in their microclimate; light intensity, soil and air temperature, humidity, soil moisture and evaporation, and duration of growing periods, and that these differences are closely associated with differences in vegetation composition and structure. In general, for the northern hemisphere, south-facing slopes receive more sunlight and become more xeric and warmer, supporting drought-resistant vegetation and less conducive for tree growth, while north-facing slopes retain moisture and are cold and humid, supporting moisture-loving plants.

The trans-Himalayan region of central Asia is known for

* Corresponding author.
E-mail addresses: inger.maaren@geog.uib.no (I.E. Måren), sikhakarki@gmail.com (S. Karki), chanda_prajapati@hotmail.com (C. Prajapati), rkp.yadav@cdbtu.edu.np (R.K. Yadav), bb.shrestha@cdbtu.edu.np (B.B. Shrestha).

http://dx.doi.org/10.1016/j.jaridenv.2015.06.004

harboring permanent human settlements in cold arid environments at high elevations, typically ranging from 3000 to 4800 masl, as well as being home for many endangered plant and animal species. The region exhibits complex topographical structure, high intensity of solar radiation, high degree of seasonality, extreme weather conditions, low precipitation and low productivity (Miehe et al., 2001), but the influence of slope aspect on forest stand characteristics and soil physico-chemical properties in the semiarid inner valleys of the Himalaya are still lacking. The understanding of aspect is important for forest management and planning because of its influence on growth and forest productivity. Many studies have estimated high productivity potential, and hence high carbon sequestration potential, for temperate mid-elevation, community managed broad-leaved forests in the Himalaya (Chhetri, 1999), but little work has been carried out in high-altitude forests. In the Himalayan agro-ecological system, forests in the agricultural matrix landscape provide biomass based ecosystem services to the subsistence farmers (Måren and Vetaas, 2007; Måren et al., 2013). In Nepal, the majority of people; more than 80%, heavily depend on agriculture for their subsistence, and the study area of Manang is no exception; here people rely on agriculture and livestock rearing for subsistence survival. The farming system comprises a typical high altitude Himalayan system with valley cultivation and animal husbandry (Chaudhary et al., 2007); where *Pinus wallichiana* A. B. Jacks. (Himalayan Blue Pine) forests provide firewood, construction materials, edible plants and traditional medicine, and conifer needles mixed with manure provide natural fertilizer, a fundamental nutrient input to the agriculture. This interrelationship between forest and agriculture is age old and analyzing forest stand characteristics can inform land management; both agricultural and forested. In order to assess the relevance of slope aspect for forest stand characteristics, we analyzed vegetation parameters and soil chemical properties of northern and southern slopes under traditional land use regimes in the high altitude semiarid Manang Valley of Nepal. Our objectives were to answer: 1) is there a significant difference in tree species richness, structure and regeneration between slope aspects? 2) is there a significant difference in above ground tree biomass and carbon stocks between forests on northern and southern slopes?, 3) does soil chemical properties vary between slope aspects?, and 4) can pine needle color be linked to soil chemical properties?

2. Material and methods

2.1. Study area

The Manang district, Nepal, is located between latitudes 28° 27′ to 28° 54′ N and longitudes 83° 49′ to 84° 34′ E, with an elevation gradient from 1880 to 8136 m above sea level (Fig. 1). It borders China to the north, Lamjung and Gorkha districts to the east, Myagdi and Mustang districts to the west, and Kaski and Lamjung districts to the south. The U-shaped Manang Valley is glacially formed and surrounded by high mountains; the Annapurna range to the south, Choya and Himlung to the north, Manasalu to the east and Muktinath and Damodar to the west, and positioned in the rain shadow of the trans-Himalayan region. More than two thirds of the surface area is occupied by high mountains and dominated by land under snow or glaciers; Manang district covers an area of 2246 km^2, of which 66% is mountains and rocks, 8% cultivated area, 5% pasture, 9% forest, and 9% shrub land (DDPoN, 2012). The parent material of Manang contains quartzites with layers of hematite, slates and limestone with clays and marl (Hagen, 1969). Manang has semiarid cold, desert-like conditions, resembling that of the Tibetan plateau, and receives little of the monsoon rain from the southeast and the southwest as it lies north of the massive Annapurna range (Aase and Vetaas, 2007). Most of the rainfall occurs from June to September and snowfall is common in winter (November to March). Average annual precipitation is 279 mm (2008–2012) at Manang Bhot (3420 masl), the nearest meteorological station to the west, with maximum monthly rainfall in July (61 mm) and no rainfall in December (Department of Hydrology and Metrology). Average maximum temperature at Jomsom to the east (2744 masl, temperature data not available at Manang Bhot) is 22.8 °C for July and average minimum is −2 °C for January.

The great variation in climatic conditions in Manang district gives rise to a variety of vegetation types, ranging from subtropical, temperate, xerophyllous to alpine vegetation, and the district hosts a wide range of flora and fauna divided into three board ecological-cultural zones; 1) *Nar-Phoo*; mostly located above timberline with steppe communities of mainly *Juniperus indica* Bertol., *Berberis* L.-, *Rosa* Lindl.- and *Lonicera* Mill.-species, 2) *Nyeshang* (Upper Manang) with *Pinus wallichiana* forests with the upper belt of *Betula utilis* D.

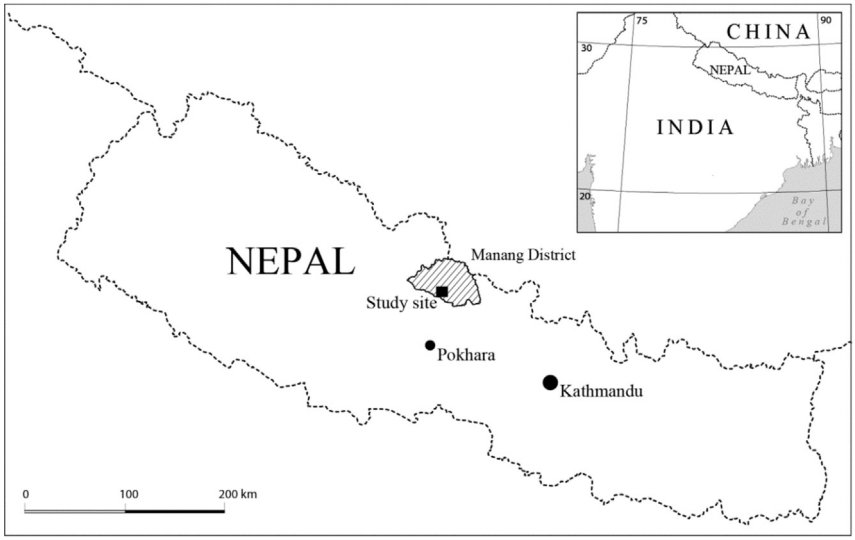

Fig. 1. Map of Nepal showing the study site in the Manang valley located within the Manang district.