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Determining bioclimatic space of Himalayan alder for agroforestry systems in Nepal

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ABSTRACT

Himalayan alder species are proven to be very useful in traditional as well as contemporary agroforestry practice. These nitrogen-fixing trees are also useful in the land restoration. Therefore, understanding the distribution of Himalayan alder and the potential zone for plantation is meaningful in the agroforestry sector. Suitable climatic zones of *Alnus* spp. were modelled in MaxEnt software using a subset of least correlated bioclimatic variables for current conditions (1950–2000), topographic variables (DEM derived) and Landuse Landcover (LULC) data. We generated several models and selected the best model against random models using ANOVA and t-test. The environmental variables that best explained the current distribution of the species were identified and used to project into the future. For future projections, ensemble scenarios of climate change projection derived from the results of 19 Earth System Models (ESM) were used. Our model revealed that the most favorable conditions for *Alnus nepalensis* are in central Nepal in the moist north-west facing slope, whereas for *Alnus nitida* they are in western Nepal. The major climatic factor that contributes to *Alnus* species distribution in Nepal appears to be precipitation during the warmest quarter for *A. nepalensis* and precipitation during the driest quarter for *A. nitida*. Future projections revealed changes in the probability distribution of these species, as well as where they need conservation and where they can be planted. Also, our model predicts that the distribution of *Alnus* spp. in hilly regions will remain unchanged, and therefore may represent sites that can be used to revitalize traditional agroforestry systems and extract source material for land restoration.

1. Introduction

The importance of carbon sequestration increases when there is a sufficient number of trees to absorb the emitted carbon (McCarl and Callaway, 1993). Absorption of carbon is only possible when nitrogen binds phytomass with assimilated carbon during photosynthesis. Fixation of atmospheric nitrogen is essential so that it is readily available to trees (Galloway et al., 2004). The genus *Alnus*, belong to the birch family host species from the symbiotic endophytic genus *Frankia* (Khan et al., 2007). The symbiont *Frankia* uses carbohydrates from alder trees to convert atmospheric N_2 into reactive nitrogen, a nitrate form directly available to plants growing in the soil (Myrold and Huss-Dannel, 1994). *Alnus* species host nitrogen-fixing bacteria; therefore, they are ecologically important in nitrogen fixation. *Alnus* are pioneer species that establish in eroded and exposed soils, which in the course of time improve land health. Alders are vigorous and fast-growing, even in acidic soil and damaged sites such as burned areas and mining sites, further adding to their importance as the species of choice in forest restoration programs.

Alnus spp., specifically *A. nepalensis*, have commonly been used in traditional agroforestry systems as shade, fodder, fuelwood and

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timber. Traditional agroforestry systems are unique in hilly regions of Nepal and adjoining Himalayan countries (Sharma et al., 2007). Previous research has revealed that this species is an excellent choice for soil restoration and sloping land management. *Alnus* plantation with cardamom (Sharma et al., 2002), tea (Mortimer et al., 2015), and mandarin oranges (Chhetri and Gauchan, 2008) represent a few examples of the importance of *Alnus* in the agroforestry system. Such mixed plantation is beneficial to commercial crops.

Agroforestry systems are examples of the ecological aid and economic viability for people compared to rainfed agriculture (Sharma et al., 2007). Therefore, it is crucial to discover suitable areas for important tree species such as *Alnus* for agroforestry planning (Ranjitkar et al., 2016). Understanding and identifying potential growing areas will provide insight for the intercropping of commercial plant species that are essential for the livelihood of smallholder farmers. Alder species are planted throughout the hilly region and distributed throughout the Himalayas. It is essential to accurately discern how climatic factors determine the distribution probability of different *Alnus* species to recommend right species at the appropriate bioclimatic zone. Also, bioclimatic zone identification can identify suitable spaces where these species can be grown alternative to each other. In this study, we aim to describe the habitat suitability of the alder using species distribution modelling (SDM) methods. Specifically, we determine the best model for distribution probability and habitat suitability of focal species. We use that model to identify the climatic variables critical for occurrence of *Alnus* species. Finally, we determine the areas for plantations of two *Alnus* spp. in Nepal for appropriate agroforestry practice.

2. Materials and methods

2.1. Focal species

Two species of *Alnus* are reported in Nepal: *Alnus nepalensis* D. Don and *Alnus nitida* (Spach) Endl. *A. nepalensis* is the eastern Himalayan component distributed from northwest India through the Himalayas to Guangxi, Guizhou, Sichuan in China in the east, to Thailand, Vietnam, and Laos in the south (Shaw et al., 2014a). *A. nitida* is a native to the western Himalayas distributed from Afghanistan and Pakistan to northwestern India and western Nepal (Shaw et al., 2014b). In Nepal, *A. nitida* is somewhat rare and still requires careful investigation in the western part of the country. The species is known to occur in pure forest stands in the upper Karnali river valley in western Nepal (Fig. 1). It grows well in moist sandy soils, whereas *A. nepalensis* grows throughout hilly regions, in a wide range of soil including freshly exposed landslide, as well as degraded and disturbed sites. Encroachment, forest degradation, over-exploitation for fuel-wood and timber collection are known threats to *A. nepalensis* trees growing in the Nepal. Biological threats to *A. nepalensis* include the stem borers *Batocera* spp., an aphid *Eutfichosiphym alnifoliae* pest of economic importance, and a parasitic plant infestation (O'Neill and Rana, 2016). Biological threats have yet to be identified for *A. nitida*; however, forest degradation and habitat fragmentation are known to threaten the species.

2.2. Species data

We used herbarium specimen data (from 1968 to 2012) and field surveys (Appendix A4) to compile the location of occurrence for the focal species. Specifically, herbarium specimen data were gathered directly at the National Herbarium and Plant Laboratory (KATH) and Tribhuvan University Central Herbarium (TUCH) (Appendix A1 and A5). In addition, specimen data were gathered online from University of Tokyo (TI) (Appendix A2) and the Royal Botanical Garden at Edinburgh (RBGE) (Appendix A3 and A6). Present geographical locations of the species were confirmed through "ground truthing" in several places, where rapid field surveys, communication with community forest members, forest officers and residents were useful. All the geo-referenced recorded points were used to check spatial autocorrelation of the species distribution using binary presence/absence data. We selected random background points within an area of 50 km radius from the point of occurrence for each focal species in order to examine *Moran's I* for

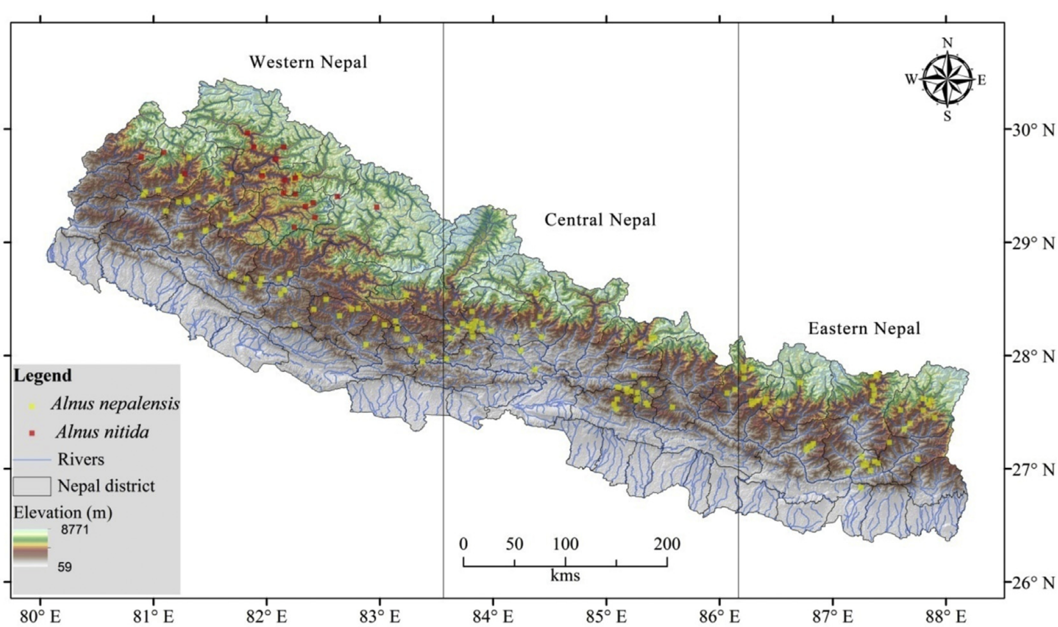

Fig. 1. Himalayan alder records from different parts of Nepal. Vertical lines represent tentative division of eastern (east to 86.3°), central and western (west to 83°) Nepal based on phytogeography (Stearn, 1960).

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