Global Ecology and Conservation 1 (2014) 2–12

Contents lists available at ScienceDirect

Global Ecology and Conservation

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

Original research article

Separation of the bioclimatic spaces of Himalayan tree rhododendron species predicted by ensemble suitability models

Sailesh Ranjitkar[a,b], Roeland Kindt[c], Nani Maiya Sujakhu[a,d], Robbie Hart[e], Wen Guo[a,d], Xuefei Yang[a,*], Krishna Kumar Shrestha[f], Jianchu Xu[a,b,**], Eike Luedeling[c]

[a] Key Laboratory of Plant Diversity and Biogeography of East Asia, Kunming Institute of Botany, Kunming 650204, China
[b] World Agroforestry Centre East and Central Asia, Kunming 650204, China
[c] World Agroforestry Centre, United Nations Avenue, Gigiri, 30677, Nairobi, 00100, Kenya
[d] University of Chinese Academy of Sciences, Kunming, China
[e] Missouri Botanical Garden, 4344 Shaw Blvd., St. Louis, MO 63110, USA
[f] Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal

ARTICLE INFO

Article history:
Received 1 April 2014
Received in revised form 3 July 2014
Accepted 4 July 2014
Available online 23 July 2014

Keywords:
Rhododendron arboreum
Distribution
BiodiversityR
Consensus method
Ensemble model
Hindukush–Himalaya–Hengduan Mountain

ABSTRACT

The tree rhododendrons include the most widely distributed Himalayan Rhododendron species belonging to the subsection Arborea. Distributions of two members of this subspecies were modelled using bioclimatic data for current conditions (1950–2000). A subset of the least correlated bioclimatic variables was used for ecological niche modelling (ENM). We used an ENM ensemble method in the BiodiversityR R-package to map the suitable climatic space for tree rhododendrons based on 217 point location records. Ensemble bioclimatic models for tree rhododendrons had high predictive power with bioclimatic variables, which also separated the climatic spaces for the two species. Tree rhododendrons were found occurring in a wide range of climate and the distributional limits were associated with isothermality, temperature ranges, temperature of the wettest quarter, and precipitation of the warmest quarter of the year. The most suitable climatic space for tree rhododendrons was predicted to be in western Yunnan, China, with suitability declining towards the west and east. Its occurrence in a wide range of climatic settings with highly dissected habitats speaks to the adaptive capacity of the species, which might open up future options for their conservation planning in regions where they are listed as threatened.

1. Introduction

Since habitat suitability of plants and animals is strongly determined by climate (Marino et al., 2011; Pearson and Dawson, 2003), niche models, driven by climate variables, have emerged as primary tools for projecting climate change impacts on species ranges (Elith et al., 2006; Hijmans and Graham, 2006; Hill et al., 2012). Species are assumed to occur within a certain climatic space determined by the climatic needs of the species (Trivedi et al., 2008). Climate envelope models characterize

* Corresponding author. Tel.: +86 871 65223909.
** Corresponding author at: World Agroforestry Centre East and Central Asia, Kunming 650204, China. Tel.: +86 871 65223355.
E-mail addresses: yangxuefei@mail.kib.ac.cn (X. Yang), J.C.Xu@cgiar.org (J. Xu).

http://dx.doi.org/10.1016/j.gecco.2014.07.001

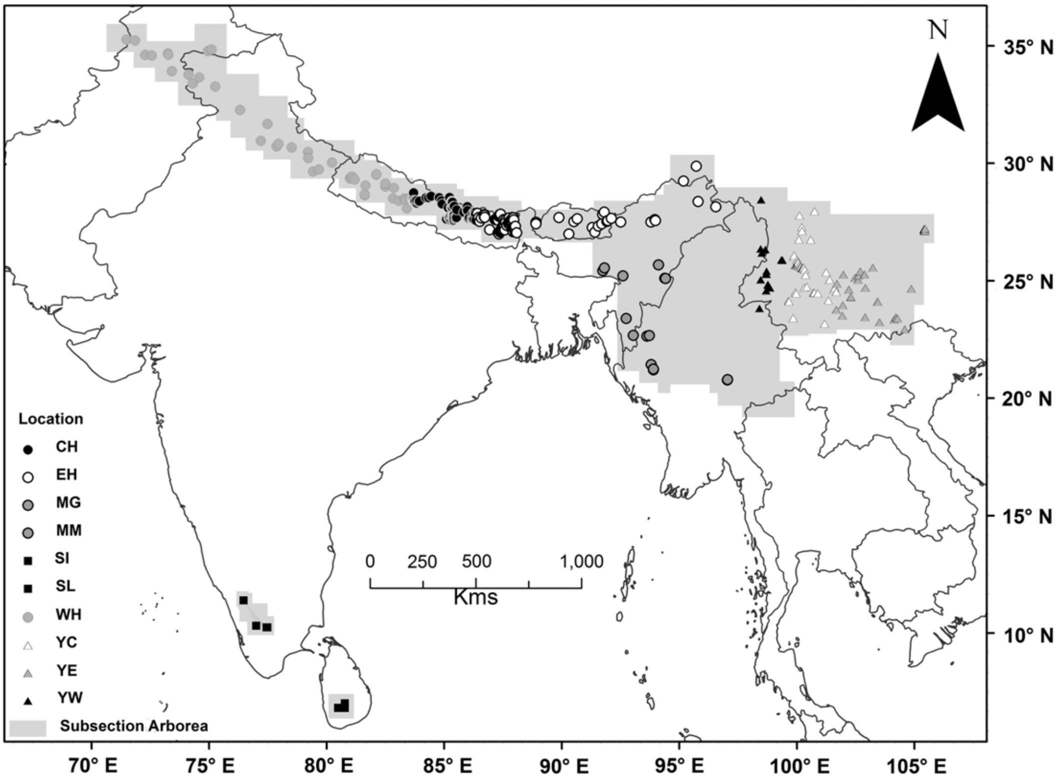

Fig. 1. Distribution range of the subsection Arborea (section Ponticum and genus *Rhododendron*) in the Himalayas and the Hengduan Mountains, Southeast and South Asia. The inset shows the altitudinal distribution of *Rhododendron arboreum* (*R. arb*) and *R. delavayi* (*R. del*); Locations were obtained from herbarium collections of tree rhododendron specimens. *R. delavayi* was described in West Yunnan (YW), Central Yunnan (YC) and East Yunnan (YE); *R. arboreum* was described in the remaining locations [Central Himalayas—CH, Eastern Himalayas—EH, Meghalaya—MG, Northeast India and adjoining hills of Myanmar—MM, South India—SI, Sri Lanka—SL, and Western Himalayas—WH].

these climatic needs (Bakkenes et al., 2002; Trivedi et al., 2008), and classify locations on the map according to climatic suitability for the species. Climate envelope approaches are rooted in ecological niche theory (Grinnell, 1917; Guisan and Thuiller, 2005; Hutchinson, 1957), and they are increasingly being applied in ecological and evolutionary research (Austin, 2007; Elith and Leathwick, 2009; Sagarin et al., 2006), as well as for studies in the fields of biogeography and biological conservation (Araújo et al., 2004; makowsky et al., 2010). Understanding the ecological needs of keystone species, such as rhododendrons (Singh et al., 2009) in the Himalayas, is of critical importance for ecosystem conservation.

Among *Rhododendron*, the subsection Arborea of the section Ponticum and the subgenus Hymenanthes (Chamberlain, 1982) contains only a few species. Two species in this subsection, *Rhododendron lanigerum* Tagg and *R. niveum* J.D. Hooker, are endangered/threatened (Fang et al., 2005) species with small distributional ranges, and they are not included in the present work due to insufficient data. Some literature (sensu Fang et al., 2005) divided the remainder of the subsection Arborea into two species, *R. arboreum* Smith and *R. delavayi* Franchet, while some includes *delavayi* as one of the sub-species of *R. arboreum* (sensu Chamberlain, 1982). Five lower taxa of *R. arboreum* have been listed, three from the Himalayas (including subsp *delavayi*) and two from tropical highlands (Giriraj et al., 2008; Long, 1991; Press et al., 2000; Sekar, 2010). Because of the wide distributional range and the complex infra-generic taxonomy, we summarily refer to this taxonomic group as "tree rhododendrons", where appropriate in this paper. Tree rhododendrons occur in Southern China, Myanmar, India, Bhutan, Nepal, and Northern Pakistan (*R. arboreum* subsp *arboreum* and *R. arboreum* subsp *cinnamomeum*) at elevations between approximately 1000 and 3800 masl (Fig. 1) (Chamberlain et al., 1996; Fang et al., 2005; Long, 1991; Press et al., 2000; Sekar, 2010). In addition, isolated populations, possibly representing remnant vegetation from glacial periods of the Pleistocene (Burkill, 1924; Giriraj et al., 2008), exist in mountainous regions of South India (*R. arboreum* subsp *nilagiricum*) and Sri Lanka (*R. arboreum* subsp *zeylanicum*).

Tree rhododendrons are an important component of Himalayan ecosystems. They fulfil multiple functions within ecosystems throughout the mountain range. They grow in a wide range of habitats, including steep areas of high rainfall and acidic soils, and so help to stabilize slopes and maintain watershed functions (Cox, 1990; Gibbs et al., 2011). This widely-distributed species likely plays a major role in sustaining a wide-range of insect and bird pollinator populations due to its profuse flowering and nectar provision from early spring to early summer (Ranjitkar et al., 2013; Singh et al., 2009). Tree rhododendrons also serve as very important habitat components for several endangered species, including the red panda *Ailurus fulgens* (Dorji et al., 2011), the Himalayan musk deer *Moschus chrysogaster*, the Asian black bear *Ursus thibetanus* (Rai et al., 2012), and the cheer pheasant *Catreus wallichii* (Jolli et al., 2012).