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Original Research Article

Maxent modeling for predicting impacts of climate change on the potential distribution of *Thuja sutchuenensis* Franch., an extremely endangered conifer from southwestern China

Aili Qin [a,c,1], Bo Liu [b,c,1], Quanshui Guo [a,*], Rainer W. Bussmann [d], Fanqiang Ma [a], Zunji Jian [e], Gexi Xu [e], Shunxiang Pei [e]

[a] *Research Institute of Forestry Ecology, Environment and Protection, Chinese Academy of Forestry, Beijing, China*
[b] *College of Life and Environmental Science, Minzu University of China, Beijing, China*
[c] *Institute of Botany, Chinese Academy of Science, Beijing, China*
[d] *William L. Brown Center, Missouri Botanical Garden, St. Louis, USA*
[e] *Experimental center of Forestry in North China, Chinese Academy of Forestry, Beijing, China*

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ABSTRACT

Objectives
Detailed and reliable information about the spatial distribution of species provides important information for species conservation management, especially in the case of rare species of conservation interest. We aimed to study the consequences of climate change on geographical distributions of the tertiary rare tree species *Thuja sutchuenensis* Franch. (Cupressaceae) to provide reference for conservation management of this species, including priority area selection for introduction and cultivation of the species. We expect that this approach could be promising in predicting the potential distribution of other rare tree species, and as such can be an effective tool in rare tree species restoration and conservation planning, especially species with narrow distribution or raw presence-only occurrence data.

Methods
107 records covering the whole distribution range of *T. sutchuenensis* in the Daba Mountains were obtained during a 3-year field survey. The principle of maximum entropy (Maxent) was used to model the species' potential distribution area under paleoclimate, current and future climate background.

Results
The Maxent model was highly accurate with a statistically significant AUC value of 0.998, which is higher than 0.5 of a null model; The location of the potential distribution for the last interglacial period is in southeastern China, with the largest optimal habitat area being only 1666 km^2. In other periods, the central location of the potential distribution is accordant with the real present distribution, but the model's predicted optimal habitat area is outside the current distribution.

Conclusions
Our findings can be applied in various ways such as the identification of additional localities where *T. sutchuenensis* may already exist, but has not yet been detected; the

* Corresponding author.
E-mail address: guoqs@caf.ac.cn (Q. Guo).
[1] These authors contributed equally to this work.

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recognition of localities where it is likely to spread to; the priority selection area for introduction and cultivation and the conservation management of such rare tree species.

1. Introduction

Climate change is projected to alter species' natural distribution and drive biodiversity loss in forest ecosystems (Millennium Ecosystem Assessment, 2005). To mitigate the effects of climate change on forest ecosystems, we can effectively target conservation strategies by modeling species distributions to identify areas where sensitive species exist or likely exist. To effectively model species distributions, detailed and reliable information about the spatial distribution of species is needed. However, occurrence data tend to be very scarce for the vast majority of species, especially in the cases of rare species where such information is either non-existent or very poor (Newbold, 2010; Marcer et al., 2013).

Species Distribution Models (SDMs) are commonly used to predict the geographic range of a species given presence-only occurrence data and environmental variables assumed to influence its distribution (Raxworthy et al., 2003; Anderson and Martinez-Meyer, 2004; Franklin and Miller, 2009; Thorn et al., 2009; Elith and Leathwick, 2009; Peterson et al., 2011; Wilson et al., 2011). Of many species distribution model algorithm methods, Maxent (Maximum Entropy, Phillips, 2004) has proved powerful when modeling rare species with narrow ranges and available scarce presence-only occurrence data (Phillips et al., 2006; Elith et al., 2006; Pearson et al., 2007; Wisz et al., 2008; Rebelo and Jones, 2010; Elith et al., 2011; Sardà-Palomera et al., 2012; Garcia et al., 2013; Marcer et al., 2013). A number of studies have been conducted on the distribution of tree species, but most of them predict potential distribution areas under current climate conditions instead of taking the paleoclimatic background into account (Ma et al., 2014). This makes it difficult to clearly assess the changes of a species' distribution area in the past, present and future climate fluctuations. In addition, few studies focus on tree species with very narrow distribution areas and less presence-only occurrence data.

Thuja sutchuenensis Franch. (Cupressaceae) is a rare evergreen forest tree, naturally distributed in the Daba Mountains range in northwestern Chongqing Municipality and eastern Sichuan Province, China. This species was once listed as extinct in the wild by IUCN-SSC, until it was rediscovered in 1999 (Farjon and Page, 1999; Xiang et al., 2002). Previous studies suggested that *T. sutchuenensis* originated in the middle to late Tertiary (Peng and Wang, 2008; Cui et al., 2015). It experienced huge geological and climatic fluctuations in the late Tertiary and Quaternary. Currently the living individuals of this species are distributed in subtropical evergreen broadleaf forest, with mountain cinnamon or brown soil on limestone soil type. This area has an annual average temperature 6°-10°, an exposure of 1000–1200 h per year, frost-free days 150–200 d, average Annual Precipitation 1200–1400 mm.

For understanding its possible reaction to climate change it is crucial to model the area it previously occupied; i.e. range map and size under different climate background, including the middle to late Tertiary, Quaternary, now and future.

In the present study, we used Maxent to model the distribution of this ancient species in China. We aimed to use species distribution models (SDMs) to identify additional localities where *T. sutchuenensis* may already exist but remains undocumented or where it could potentially exist, ultimately providing targeted conservation strategies for this critically endangered species.

2. Materials and methods

2.1. Study area

The rare tertiary-relic tree, *T. sutchuenensis* Franch, is distributed between 108.5°E–109.25°E and 31.5°N–31.83°N in the Daba Mountains of southwestern China.

Our study area include major mountain chains of China, east to Changbai Mountain, west to the Tianshan, south to the Hengduan Mountains, and north to Greater Khingan range.

2.2. Species occurrence data collection

The occurrence locations of *T. sutchuenensis* in the Daba Mountains were collected during a 3-year field survey across southwestern China. We recorded and geo-referenced all natural populations and isolated individuals of *T. sutchuenensis*, totaling 107 records in the Daba Mountains, resulting in a detailed distribution map (Fig. 1).

2.3. Environmental variables

Temperature, rainfall, geographical barriers and other ecological factors, such as underlying geological formations, influence species distributions (Kaeslin et al., 2012). To determine which environmental variables most influence the distribution of *T. sutchuenensis*, we included in our model 19 bioclimatic variables (Hijmans et al., 2005) and one biophysical