Climate Risk Management 19 (2018) 94–105

Contents lists available at ScienceDirect

Climate Risk Management

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

Predicting climate change impacts on the distribution of the threatened *Garcinia indica* in the Western Ghats, India

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ARTICLE INFO

Keywords:
Garcinia indica
Maximum entropy modelling
Western Ghats
Medicinal plants
Climate change

ABSTRACT

In recent years, climate change has become a major threat and has been widely documented in the geographic distribution of many plant species. However, the impacts of climate change on the distribution of ecologically vulnerable medicinal species remain largely unknown. The identification of a suitable habitat for a species under climate change scenario is a significant step towards the mitigation of biodiversity decline. The study, therefore, aims to predict the impact of current, and future climatic scenarios on the distribution of the threatened *Garcinia indica* across the northern Western Ghats using Maximum Entropy (MaxEnt) modelling. The future projections were made for the year 2050 and 2070 with all Representative Concentration Pathways (RCPs) scenario (2.6, 4.5, 6.0, and 8.5) using 56 species occurrence data, and 19 bioclimatic predictors from the BCC-CSM1.1 model of the Intergovernmental Panel for Climate Change's (IPCC) 5th assessment. The bioclimatic variables were minimised to a smaller number of variables after a multicollinearity test, and their contributions were assessed using jackknife test. The AUC value of 0.956 ± 0.023 indicates that the model performs with excellent accuracy. The study identified that temperature seasonality (39.5 ± 3.1%), isothermality (19.2 ± 1.6%), and annual precipitation (12.7 ± 1.7%) would be the major influencing variables in the current and future distribution. The model predicted 10.50% (19318.7 sq. km) of the study area as moderately to very highly suitable, while 82.60% (151904 sq. km) of the study area was identified as 'unsuitable' or 'very low suitable'. Our predictions of Climate change impact on habitat suitability suggest that there will be a drastic reduction in the suitability by 5.29% and 5.69% under RCP 8.5 for 2050 and 2070, respectively.

Objective and Significance: Primary objective of this study is to identify the potential distribution of medicinally and ecologically important but threatened *Garcinia indica* species in the northern Western Ghats on the basis of species occurrence data and nineteen bioclimatic predictors. Using MaxEnt modelling, current and future species distribution and suitability has been predicted using the BCC-CSM1.1 and four RCP scenarios of 2.6, 4.5, 6.0, and 8.5. The results also signify the bioclimatic variables contribution to the species distribution in northern Western Ghats.

Finally, the results signify that the model might be an efficient tool for biodiversity protection, ecosystem management, and species re-habitation planning under future climate change scenarios.

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https://doi.org/10.1016/j.crm.2017.11.002
Received 11 June 2017; Received in revised form 17 November 2017; Accepted 18 November 2017
Available online 23 November 2017
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1. Introduction

Anthropogenic influence on the world's climate is very clear and has become more evident in recent decades. The greenhouse gases (GHGs) are the primary agents responsible for the climate change, the recent emission rates of which are at the highest level in the recorded history (Lindner et al., 2010). According to theIPCC (2013), over the last century, the global temperature rose by 0.078 °C (Hansen et al., 2010), and is projected to rise by 0.3–4.8 °C by 2090–2099 (Priti et al., 2016). Recent changes in climatic condition have had significant impacts on human and natural systems. However, changing climatic condition can alter the function and structure of a forest by changing the intensity, frequency, timing, and duration of the fire, introduced species, pathogen and insect outbreaks, landslides, drought, hurricanes, ice storms, and wind storms (Dale et al., 2001). Increasing temperatures and variability of rainfall patterns can have significant impacts on the potential distribution of species range shifts, and some species' potential habitat will be predicted to disappear totally (Malcolm et al., 2006; Coetzee et al., 2009; Anderegg et al., 2015). There is a scientific consensus today that the species are shifting and declining much faster than in the past due to drastic changes in climatic conditions (Chen et al., 2011; Dobrowski et al., 2013). If the trends and intensity of current climate are not abated, significant and irreversible impacts on the natural environment are certain (Hamann and Wang, 2006). According to the Millennium Ecosystem Assessment (2005), up to 50%⁎⁎ of the world's biodiversity is already vulnerable to extinction. Therefore, predicting and measuring the accurate potential distribution of species under climate change as well as anthropogenic changes is important to undertake the urgent and effective conservation action (Dawson et al., 2011).

South Asia is likely to experience the warming above the global mean (Krishna Kumar et al., 2006; Christensen and Coauthors, 2007). Tropical cyclones, summer rainfall, and the frequency of intense rainfall are all expected to rise in South Asia (Krishna Kumar et al., 2006; Christensen and Coauthors, 2007). The projections from Hadley Centre Regional Model (HadRM2) show future rises in extreme daily maximum and minimum temperatures over the South Asian region due to the higher concentration of greenhouse gas (IPCC, 2007). This projected rise is 2 °C to 4 °C under the IS92a Scenario of IPCC in both maximum and minimum temperatures by the mid-21 th century (Krishna Kumar et al., 2006). In India, the tendency of the warming to be more prominent in winter which is also a noticeable feature of the observed trends of temperature (Rupa Kumar et al., 2003). These changing climatic conditions are shaping the future growth of forest habitats. Additionally, Western Ghat is one of the rich biodiversity regions of India. The region is also internationally recognised as a site of significant global importance for comprising areas of very high physical, aesthetic and cultural values. A large section of the Western Ghats forest area has been declined due to climate change, and increase of agricultural land for rubber, oil palm, tea, and coffee, and livestock grazing (Chandran et al., 2010; Chethana and Ganesh, 2013). More specifically, increasing temperature and variability of rainfall pattern can have significant impacts on the potential distribution, range shifts of a number of species as well as an overall decline in the suitable habitats in the Western Ghats's (Priti et al., 2016). Additionally, the deficit rainfall pattern of the Western Ghats may reduce the total forest cover area (Ramachandran et al., 2017).

Garcinia indica, a plant of the *Clusiaceae* family (also known *mangosteen*) is a fruit-bearing species that has cultural, pharmaceutical, culinary, and industrial significance (Mathew et al., 2001). The tree was first discovered in western India (https://www.organicfacts.net/health-benefits/fruit/garcinia-indica.html), especially in Maharashtra (Vidhate and Singhal, 2013) and is abundantly found in wastelands, riversides, and forest lands. However, it is indigenous species in India and found in Maharashtra and Goa of the Western Ghats region. The fruit can be consumed directly for an extensive variety of health benefits (Swami et al., 2014; Mathew et al., 2001). The pulp of the fruit skin is termed as 'kokum,' used in curries as a souring condiment. The prepared drink from fruits is used to release relative sunstroke in summer. The oil of the seeds is generally used for preparing an Ayurvedic medicine (known as 'Red Mango') that treating the skin diseases (Vidhate and Singal, 2013). However, the most significant health benefits of the tree species are relieving pain, eliminating inflammation, reducing allergic reactions, boosting the immune system, protecting the skin, optimising digestion, preventing chronic diseases, and treating heat strokes, gas, dysentery, and diarrhoea (Mathew et al., 2001). The tree products (Kokum) are even exported, adding to the nation's foreign reserve. India maintains a global monopoly in kokum production (Kshirsagar, 2008). In the Western Ghats, very few studies have been attempted yet for the distribution of medicinally significant species (Chandran et al., 2010; Priti et al., 2016), but the distribution of *Garcinia indica* under future climate change is the first attempt for restoration and reintroduction.

Species distribution models (SDMs) are empirical tools in ecology, biogeography, natural resource management, ecosystem management, and biodiversity conservation that represent the potential population distribution, on the basis of different environmental variables where it is obvious to occur (GuilleraArroita et al., 2015; Elith et al., 2006; Elith and Leathwick, 2009; Franklin, 2013). However, SDMs not only describe the environmental necessities of the population but are also able to predict its potential distribution with time and space in unsampled areas and future climatic conditions (Elith et al., 2006; Peterson, 2007). Among various SDMs, Maxent is highly regarded because it computes the probability distribution of a species with the help of maximum entropy rules (the greatest uniform distribution) and statistical mechanics (Phillip et al., 2004; Jaynes, 1957; Elith et al., 2006). The model has various advantages; it needs only environmental information and species occurrences data (Elith et al., 2011). It is also able to generate complex feedback to the used data, and inherent features avoid the model from overfitting (Wisz et al., 2008; Phillips and Dudik, 2008). Therefore, MaxEnt is most important for modelling the suitability distribution of limited occurrence data or rare species. Even, the predictions may be modelled using a very few sample occurrence (Wisz et al., 2008; Hernandez et al., 2008). The model result was also found to be less susceptible to sample size and highest performing amongst 12 species distribution modelling (Elith et al., 2006; Hernandez et al., 2008). Therefore, in the last few decades, Maxent modelling have been used to identify the changes in species diversity, to predict species range shifts, to assess potential threat to current and future climate change, and to identify reserve designs and evaluating conservation priorities (Franklin, 2009; Peterson et al., 2002; Duckett et al., 2013; Gallagher et al., 2013).

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