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Spatial Surveillance of Invasion by Alien Species in a Heterogeneous Ecological Landscape

Ugyen Thinley, College of Natural Resources, Royal University of Bhutan, Thimphu, Bhutan
https://orcid.org/0000-0002-6629-9565

Poramate Banterng, Khon Kaen University, Khon Kaen, Thailand

Roengsak Katawatin, Khon Kaen University, Khon Kaen, Thailand

Santimaitree Gonkhamdee, Khon Kaen University, Khon Kaen, Thailand

ABSTRACT

This article is an attempt to assess the invasion risk from the most noxious alien plant species using the GPS recorded locations and environmental variables. The invasion risk was modelled by combining the three ecological niche modelling algorithms- DesktopGARP, Openmodeller DesktopGARP and Maxent after validating their accuracies. The accuracies ranged from moderate to good in all the algorithms, for all six species. The result showed Ageratina adenophora and Ageratum conyzoides as highly invasive species both in terms of area coverage and the ecological tolerance range of the study site. It was also indicative that, irrespective of the species, agricultural lands are most susceptible to invasion among all other types of land uses in the study area.

KEYWORDS

AUC, Ecological Niche Modelling, GARP, Invasion Risk, Maxent

INTRODUCTION

Globalization in trade routes, markets and products using modern technologies drive the spread of invasive alien species (IAS), whose introduction does, or is likely to, cause economic or environmental harm or direct harm to human health through intentional or accidental introductions (Meyerson & Mooney, 2007). As such, biological invasion has become a global problem, subjecting many countries to huge losses in their economy through negative impacts on crops, animal and human health, and the loss of biodiversity. A loss of over US$ 40 billion annually in the United States of America is accounted for by crop losses and in controlling of invasive species (Pimentel, Lach, Zuniga, & Morrison, 2000). Likewise, an estimated total of US$ 29.47 billion annual agricultural damage in Southeast Asia were attributed to non-indigenous weeds, pests and pathogens (Nghiem et al., 2013). In some European countries, 10-20% of patients are accounted for pollen allergy caused by common ragweed leading to hay fever, rhinoconjunctivitis and asthma-like symptoms (Scalera, Genovesi, Essl, & Rabitsch, 2012).

Some of the detrimental effects on biodiversity include competitive exclusion of native species through modification of habitat and facilitating subsequent invasions (Simberloff & Von Holle, 1999). Such processes lead to disruptions of ecosystem services such as disturbing water flow regime by increasing evaporation rates, reducing stream flow and dilution capacity in case of South Africa

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(Chamier, Schachtschneider, Le Maitre, Ashton, & Van Wilgen, 2012; D'Antonio & Vitousek, 1992). *Ageratina adenophora, Ageratum conyzoides, Chromolaena odorata, Lantana camara, Mikania micrantha* and *Parthenium hysterophus* were long recognized as IAS in South and Southeast Asia (Pallewatta, Reaser, & Gutierrez, 2003) and recently as global IAS by the Centre for Agriculture and Bioscience International (2018). In China, some of these species were found fast spreading, from lowlands to mountains causing extirpation of native local plants, death of animals (by *A. adenophora*) resulting in serious economic losses to agriculture, forestry and livestock and severe damage of ecology (Wan et al., 2010; Yan, Zhenyu, Gregg, & Dianmo, 2001). In India some of the species such as *P. hysterophorus*, were found to be noxious, allergenic and poisonous to humans and animals, while others were found to reduce crop yield, cause loss of native biodiversity and prevention of forest regeneration (Singh, 2005).

Impacts of invasion would mean a worse scenario in the case of Bhutan, given its inhospitable geographical terrain (Ohsawa, 1987, 1991), holding only about 3% as arable land (Gaden, Choden, & Tshomo, 2015) with high vulnerability to climate change (International Center for Integrated Mountain Development, 2009). Although the Bhutan quarantine act clearly states that Bhutan shall prevent introduction of pests and control the widespread of those already present, since mid-960s, the import of invasive plants either as ornamental or alternative food has become popular. Between 1997 and 2000 some 60 plant species were introduced (Weiss et al., 2004). As such, Weiss et al. (2004) recommend that a risk assessment of introduced plants for their invasion potential is essential.

To date, in Bhutan, there are no scientific investigations and assessments conducted on the ecology of IAS. More importantly there is no scientific evidence on the distribution patterns of such species (National Biodiversity Center, 2014), thereby exacerbating the problem in systematic planning with proper strategies to monitor and control the IAS in the country (Pallewatta et al., 2003). Out of 46 vascular invasive plant species in the country, 11 were recognized as IAS (Royal Government of Bhutan, 2012; National Biodiversity Center, 2009, 2014). Cognizant of this emerging issue, building baseline information on some of the most important invasive species using cost-efficient modelling techniques is imperative. This study, as such, deals with ecological niche modelling (ENM) featuring 6 pantropical plant species *A. adenophora*, A. conyzoides, *C. odorata*, *L. camara*, *M. micrantha* and *P. hysterophus*), recorded in Bhutan and recognized as the most noxious IAS by the Centre for Agriculture and Bioscience International (2018). Pictographic species details about their origin, biology, socio-economic and environmental impacts are in the supplementary material (S1).

ENM is a tool for predicting potential geographic distribution of a species on a landscape by analyzing the relationships between a species' geographical location data and environmental variables (Anderson, Lew, & Peterson, 2003; Peterson & Vieglais, 2001; Soberon & Peterson, 2005). The ENM approach in predicting potential distributions is increasingly used in mapping the risk of invasion (Fan et al., 2018; Turbelin, Malamud, & Francis, 2017; West, Kumar, Brown, Stohlgren, & Bromberg, 2016). In this study, Desktop GARP (DKGARP), Open Modeler Desktop GARP with best subset implementation (OM DKGARP) and Maximum Entropy (Maxent) with the research hypothesis that, invasiveness of alien species varies with respect to environmental covariates. The objectives were to 1) map invasion risk through ensemble modelling, 2) compare ecological range tolerances between the species and 3) assess the susceptibility of ecoregions to potential invasion.

MATERIALS AND METHODS

The study was conducted in Bhutan (Figure 1), located in the southern slopes of the Himalaya between 26.45°N and 28.10°N, and 88.45°E and 92.10°E, with the altitudes ranging from 100 m in the south bordering India to 7500 m, bordering Tibet (Ohsawa, 1987). The country covers an area of 38,394 km^2 (National Biodiversity Center, 2009) with only little over 700,000 people (National Statistical Bureau, 2011). The country presents a highly heterogeneous ecological landscape comprising Tropical, Subtropical, Warm Temperate, Cool Temperate, Cold Temperate and Artic/Alpine zones (Ohsawa, 1987).