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Distribution of some obnoxious weeds in north-western Ghats of India

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ABSTRACT

Flora and fauna of Western Ghats, a biodiversity hot spot are under major threat due to various factors. Invasion of exotic species has been considered as one of the major threat in the area. In the present study, potential distribution of three obnoxious weeds, *viz. Chromolaena odorata*, *Lantana camara* and *Parthenium hysterophorus* was modeled using 32 environmental variables and MAXENT modeller. These three species showed distinct potential distribution patterns with only slight overlap between *C. odorata* and *L. camara,* and between *L. camara* and *P. hysterophorus.* Overlap of the former pair was seen mostly along the wet western slopes of Western Ghats, and latter along the eastern, rain shade dry areas. The environmental variables that contributed to the model showed that it was basically precipitation and temperature seasonality that defined their distribution. It was interpreted that the weeds might have adapted to different sets of environmental conditions throughout their distributional range; and hence, the variables operating in the study area contributing to the model may not be useful in predicting their presence elsewhere. It is concluded that to understand the full adaptability of these weeds, environmental variables can be studied at local levels and the results compiled for larger areas to get the full spectrum.

Key words: *Chromolaena odorata,* Ecology amplitude, *Lantana camara, Parthenium hysterophorus*

Invasive species are considered among the greatest threats to native biological diversity and functioning of natural ecosystems. Bioinvasion is homogenizing the worlds flora and fauna (McKinney and Lockwood 1999, Baiser and Lockwood 2011), altering the biogeochemical cycles (Strayer *et al.* 2006) and is recognized as a primary cause of global biodiversity loss (Czech and Krausman 1997, Wilcove *et al.* 1998) and species extinction (di Castri 1989). Millenium Ecosystem Assessment (2003) considered climate change along with invasive species as the most pervasive forms of ecosystem disturbance. Foxcroft *et al.* (2009) gained insight into broad patterns of invasion in Southern Kruger National Park and found that at that scale invasion was over-estimated, though it was useful for determining current and potential species distribution over a wider land scale. As the understanding of geographic range is considered as an ecological challenge, important tools such as bioclimatic models, ecological niche models and species distribution models have been used in the study of their geographic range (Jeschke and Strayer 2008).

Usefulness of bioclimatic models has been well established in inferring the full geographic range when distributional information available is scanty (Walther *et al.* 2005, Pearson *et al.* 2007). In spite of proven values of applying models for the distribution of weeds, only a small percentage have used models as predictive tool (Freckleton and Stephens 2009). Wang and Wang (2006) applied ecological niche models to predict potential invasion areas of *Ageratina adenophora* in China by indicating favourable and less favourable areas. Mandle *et al.* (2010) developed ecological niche models for both the native and introduced ranges using MAXENT and used them to explore the question of expansion in greater detail. In the present study, an attempt has been made to understand the potential distribution of three obnoxious weeds, *viz. Chromolaena odorata*, *Lantana camara* and *Parthenium hysterophorus* using BIOCLIM data and MAXENT model.

MATERIALS AND METHODS

Western Ghats is a hill range that runs north to south for about 1600 km parallel to the west coast of India. Along with Sri Lanka, it forms one of the 34 biodiversity hotspots. It is divided into northern, central and southern Western Ghats. The study area is north-western Ghats but is restricted to the state of Goa and north-western Karnataka and south-western Maharashtra. The area extends from Deccan plateau in the east to the west coast through the mountains of Western Ghats. The sampling area was between 73.7°-74.9° E and 14.9°-16.7° N (Fig. 1).

Field trips were carried out from June 2007 to May 2011 to record the distribution of populations of three weeds, *viz. C. odorata*, *L. camara* and *P. hysterophorus*

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using GARMIN GPS 12. Total 104 occurrences were recorded for *C. odorata*, 48 for *L. camara* and 20 for *P. hysterophorus*. Additional distributional data points for *L. camara* (4 points) and *P. hysterophorus* (6 points) were collected from outside the study area and incorporated for analysis to test the effectiveness of local versus additional data in prediction of potential distribution of weeds.

MAXENT software (version 3.3.3e) was used for modeling environmental variables at 30 arc-seconds resolution (~1 km) were downloaded from WorldClim (http://www.worldclim.org). One altitude layer, 12 monthly precipitation layers and the following 19 bioclim variables were used in the study: BIO1 [annual mean temperature], BIO2 [mean diurnal range (mean of monthly (max temp - min temp))], BIO3 [isothermality (BIO2/BIO7) (*100)], BIO4 [temperature seasonality (standard deviation *100)], BIO5 [max temperature of warmest month], BIO6 [min temperature of coldest month], BIO7 [temperature annual range (BIO5-BIO6)], BIO8 [mean temperature of wettest quarter], BIO9 [mean temperature of driest quarter], BIO10 [mean temperature of warmest quarter], BIO11 [mean temperature of coldest quarter], BIO12 [annual precipitation], BIO13 [precipitation of wettest month], BIO14 [precipitation of driest month], BIO15 [precipitation seasonality (coefficient of variation)], BIO16 [precipitation of wettest quarter], BIO17 [precipitation of driest quarter], BIO18 [precipitation of warmest quarter], BIO19 [precipitation of coldest quarter]. MAXENT model was run using random seed with random test percentage of 30. Five replicates with replicated run type as Bootstrap and 500 as maximum iterations were used for the model. Output format was set as cumulative and output file type saved as asc. Coordinates collected from the field using GPS for the presence of weeds was used as sample file. Percent contribution and permutation importance of each variable and map generated for minimum prediction (to avoid over estimation) were considered for interpretation. Potential areas predicted by the model were checked for their presence to validate the prediction. The potential distribution of invasive species has been modeled based on several modelling software (Chejara *et al.* 2010).

RESULTS AND DISCUSSION

In the present study, we predicted the potential distribution of three invasive weeds, *viz. C. odorata*, *L. camara* and *P. hysterophorus* based on actual presence data of populations in the field and building models using MAXENT.

Chromolaena odorata

Potential distribution of *C. odorata* on large scale has been attempted by McFadyen and Skarratt (1996) and Kriticos *et al.* (2005) using CLIMEX. Based on earlier data and compilation the distribution of *C. odorata* has been shown all along the Western Ghats (McFadyen 2003, Kriticos *et al.* 2005, Muniappan *et al.* 2005). In the present study distribution data has been collected from a small segment of Western Ghats and using BIOCLIM layers and MAXENT potential distribution has been modelled. The results showed that its potential distribution starts from coastal areas and extends up to the hilly regions of Western Ghats in Goa and in border areas of Karnataka and Maharashtra states; the potential distribution is predicted only to the hilly areas towards north and south (Fig. 2). As its presence has been well documented throughout the Western Ghats, the model was not able to predict its presence for a larger area based on local data. Even the maximum distribution (not shown here) as predicted by the model increased its potential distribution only marginally.

The skewed distribution towards the coast in Goa can be attributed to the hilly undulating terrain that extends almost to the coast of Goa with good rainfall and vegetation. As *C. odorata* is known to have preferences for humid and wet conditions that is provided by monsoon with longer days (Zachariades *et al.* 2009), thus explaining its distribution towards the western side of Western Ghats. This is reflected in the model as nearly 90% of the prediction is contributed by three parameters, *viz.* precipitation in the month of January, May and July (Table 1). In January, the precipitation is only through dew, and July is the heaviest rainfall month in the region. In addition, permutation importance of various layers showed that BIO4 is 61.1% followed by precipitation in January and driest months (22.3 and 9.3%), respectively. However, the rainfall requirement seemed to be different in different geographical regions (Zachariades *et al.* 2009), which suggested that the model used here may not be fitting elsewhere.

Lantana camara

This is considered as a weed of international significance due to its impact on agriculture, forestry and biodiversity (Sharma *et al.* 2005). The potential distribution of *L. camara* in study area is predicted along the hilly areas (Fig. 3). The environmental variables that contributed to the model are basically precipitation in the months of January, May and July as in the case of *C. odorata*. Apart from precipitation of various months, altitude seems to be contributing substantially. The permutation importance is basically provided by three layers of data, *viz.* BIO14 (precipitation of driest month), followed by precipitation in January and BIO4 (Table 1). These variables

Table 1. WorldClim environment variables that define the potential distribution of three obnoxious weeds in Western Ghats

Variable	Percent contribution	Permutation importance
Chromolaena odorata		
Prec1	41.3	22.3
Prec7	27.7	1.7
Prec5	21.6	0.3
Bio19	2.5	0.1
Prec12	2.2	0.6
Bio4	1.3	61.1
Bio14	0.4	9.3
Lantana camara		
Prec1	39	18.8
Prec7	21	0.4
Prec5	14	0.5
Prec11	8	0.5
Prec2	6.6	0
Alt	2.5	0
Bio19	2.4	0.1
Prec12	1.5	0.6
Bio14	1.3	54.1
Bio17	1.2	3.2
Prec4	1.2	0.1
Bio4	0.1	18.3
Lantana camara (with additional distribution data incorporated from outside study area)		
Prec1	30.5	2.2
Prec7	27.1	1.4
Prec11	10.5	0
Bio14	8.8	56.4
Alt	7.6	0
Prec2	5.1	0.1
Prec4	3.2	0
Bio19	2.5	0
Prec12	1.9	1
Bio4	0.3	34.4
Parthenium hysterophorus		
Bio4	27.8	29
Prec1	26.9	17.2
Prec3	8.2	0.4
Bio2	7.4	0
Prec9	6.5	0
Prec6	6.1	1.3
Prec5	4.3	0
Prec7	2.1	0.5
Bio14	2.1	29.6
Bio19	1.3	0.7
Prec12	1.2	0.6
Bio17	1.1	12.2
Parthenium hysterophorus (with additional distribution data incorporated from outside study area)		
Bio4	42.2	36.7
Prec1	19.1	23.4
Bio14	7.1	12.5
Bio2	5	1
Prec3	4.3	1.3
Prec2	2.9	3.6
Bio8	2.4	0
Prec7	2.2	0
Bio1	2	0
Prec6	1.8	1.2
Bio13	1.6	0.4
Bio16	1.6	0
Bio6	1.4	1.2
Prec12	1.4	1.2
Bio19	1.3	0
Bio12	0.3	6.5

were generally in agreement with some of those used by Li (2011) while predicting potential distribution of *L. camara* in China.

Additional four data points collected from outside the study area did not alter the potential distribution significantly (Fig. 4). However, precipitation in the month of May (Prec 5) has not contributed to the model as compared to the data from study area alone. Permutation importance has changed substantially in favour of BIO4 while reducing that of Prec1 (Table 1). The model could not predict its distribution in larger area, as in the case of *C. odorata.* It is adapted to grow in wide climatic conditions (Day *et al.* 2003), hence it was not the same climatic factors that were contributing to its distribution in different areas, thus rendering the model only locally applicable.

Parthenium hysterophorus

The resulting image showed that its distribution along the coastal area was almost nil and most of its potential distribution was shown on the eastern side of Western Ghats (Fig. 5). Twelve environmental variables contributed 1% or more to the model of which BIO4 and precipitation in January contributed 54.7% to the model. Permutation importance to the model was provided by BIO14 in addition to BIO4, Prec1 and BIO17 (Table 1).

The prediction extends the potential distribution towards east into drier areas and substantially into north and south with the addition of six data points from outside the study area (Fig. 6). Dhileepan and Senaratne (2009) earlier documented 495 recorded sites for this species in India and used CLIMEX to develop a model in which heat stress and temperature have rendered high value to the model. High Eco-climatic Index (EI) values have been predicted for the Deccan plateau and east coast. McConnachie *et al.* (2011) in their study concluded that modeled distribution in South Asia was in agreement with the available distribution data. Comparison of environmental variables that contributed to them showed that BIO4 was the major factor followed by precipitation in January and of driest month. The same factors, especially the former one in the form of heat stress and temperature have been identified by Dhileepan and Senaratne (2009).

Within the study area, slight overlapping in distribution was predicted between *C. odorata* and *L. camara* at one side and *L. camara* and *P. hysterophorus* on the other side, but not between *C. odorata* and *P. hysterophorus.* In the cases of *L. camara* and *P. hysterophorus*, the distribution was not predicted along the western coastal regions.

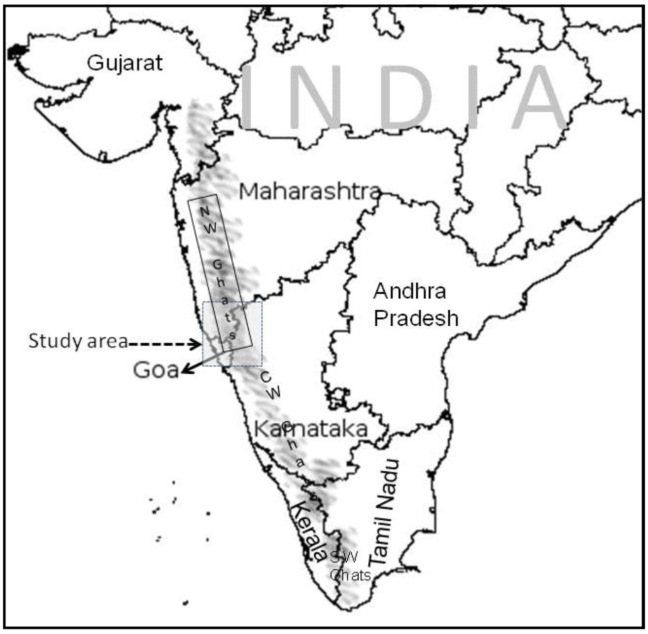

Fig. 1. Map of peninsular India showing the study area

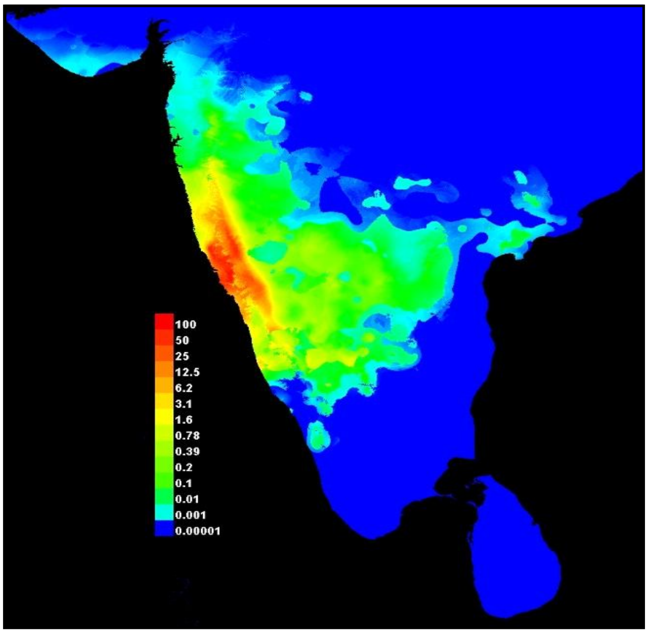

Fig. 2. Potential distribution of *Chromolaena odorata* predicted using MAXENT and distributional data from study area

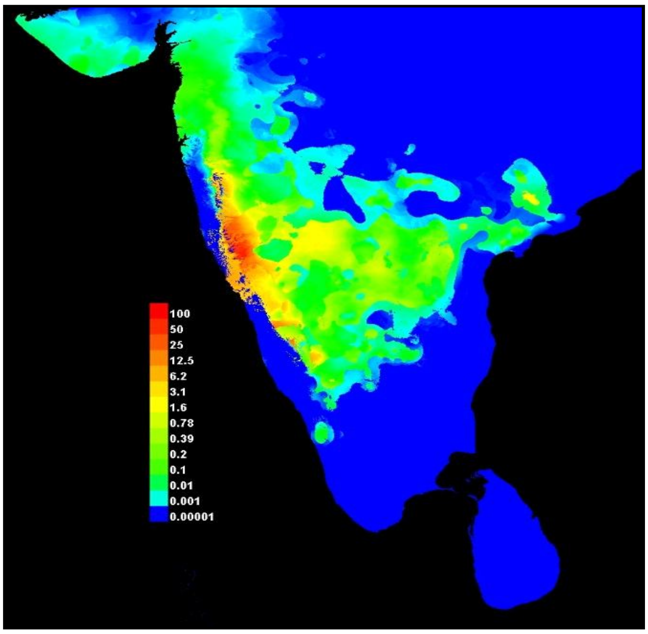

Fig. 3. Potential distribution of *Lantana camara* predicted using MAXENT and distributional data from study area

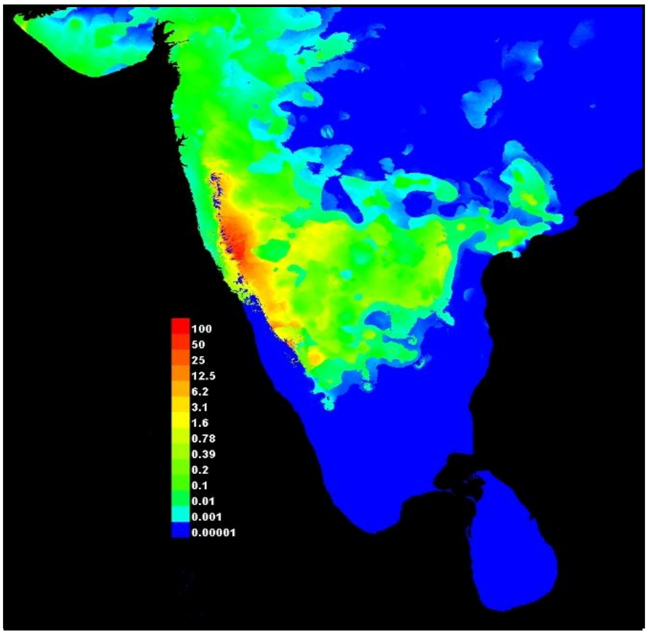

Fig. 4. Potential distribution of *Lantana camara* predicted using MAXENT and distributional data from study area as well as from outside study area

In all the above three cases, distribution was not predicted for south-western Ghats or the areas east of it wherein their distribution is documented. This proved that local data may not be useful to predict the weeds even in the same phyto-geographical zone as these weeds are well adapted to different environmental conditions. Hence, it was safe to work for smaller geographical areas and compile the data to understand the environmental variables that contribute to their presence in different areas.

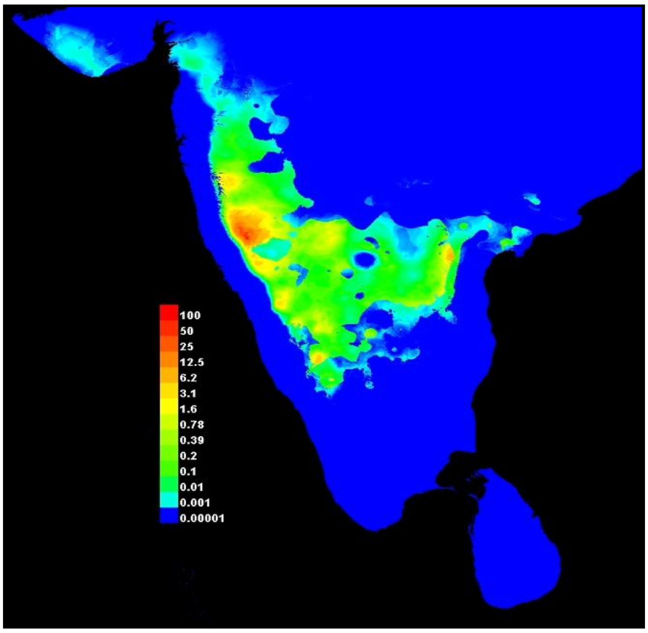

Fig. 5. Potential distribution of *Parthenium hysterophorus* predicted using MAXENT and distributional data from study area

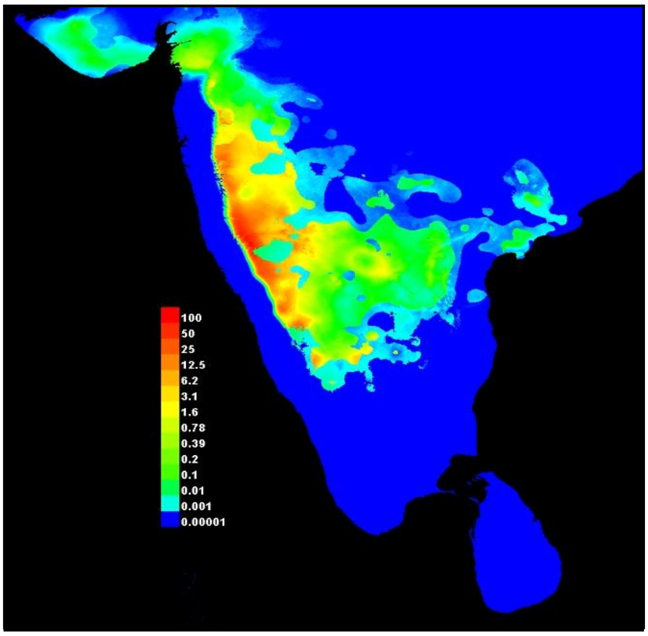

Fig. 6. Potential distribution of *Parthenium hysterophorus* predicted using MAXENT and distributional data from study area as well as from outside study area

In the present study, potential distribution has been predicted for these weeds. It was concluded that a) the ecological requirement was distinct for each of these weeds and hence distribution overlap was seen only to lesser extent, and b) the weeds probably have adapted to different environmental variables even within the same phytogeographical region and hence local distributional data cannot predict their potential distribution far beyond the local area. To understand adaptations of any weed to different environmental conditions, studying large areas by dividing them into smaller units will help.

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REFERENCES

Baiser B. and Lockwood JL. 2011. The relationship between functional and taxonomic homogenization. *Global Ecology and Biogeography* **20:** 134–144.

Chejara VK, Kriticos DJ, Kristiansen P, Sindel BM, Whalley RDB and Nadolny C. 2010. The current and future potential geographical distribution of *Hyparrhenia hirta*. *Weed Research* **50:** 174–184.

Czech B and Krausman PR. 1997. Distribution and Causation of Species Endangerment in the United States *Science* **277:** 1116.

Day MD, Wiley CJ, Playford J and Zalucki MP. 2003. *Lantana*: current management status and future prospects, pp. 1-128. In: *ACIAR Monograph No. **102***: Australian Centre for International Agricultural Research, Canberra.

Dhileepan K. and Senaratne KADW. 2009. How widespread is *Parthenium hysterophorus* and its biological control agent *Zygogramma bicolorata* in South Asia? *Weed Research* **49:** 557–562.

di Castri F. 1989. History of biological invasions with special emphasis on the old world, pp. 1-30. *In*: *Biological Invasions: a Global Perspective* (Eds. Drake JA, Mooney HA, di Castri F, Groves RH, Kruger FJ, Rejmánek M and Williamson M.). John Wiley & Sons, New York.

Foxcroft LC, Richardson DM, Rouget M and MacFadyen S. 2009. Patterns of alien plant distribution at multiple spatial scales in a large national park: implications for ecology, management and monitoring. *Diversity and Distribution* **15:** 367–378.

Freckleton RP and Stephens PA. 2009. Predictive models of weed population dynamics. *Weed Research* **49**: 225–232.

Jeschke JM and Strayer DL. 2008. Usefulness of bioclimatic models for studying climate change and invasive cpecies. *Annals of the New York Academy of Sciences* **1134**: 1–24.

Kriticos DJ, Yonow T and McFadyen RE. 2005. The potential distribution of Chromolaena odorata *(Siam weed) in relation to climate*. Weed Research *45: 246-254.*

Li XR. 2011. Quantitative risk analysis and prediction of potential distribution areas of common Lantana (*Lantana camara*) in China. *Computational Ecology and Software* **1**(1): 60-65.

Mandle L, Warren DL, Hoffmann MH, Peterson AT, Schmitt J, von Wettberg EJ. 2010. Conclusions about niche expansion in introduced *Impatiens walleriana* populations depend on method of analysis. *PLoS ONE* **5**(12): e15297.

McConnachie AJ, Strathie LW, Mersie W, Gebrehiwot L, Zewdie K, Abdurehim A, Abrha B, Arya T, Asaregew F, Assefa F, Gebre-Tsadik R, Nigatu L, Tadesse B and Tana T. 2011. Current and potential geographical distribution of the invasive plant *Parthenium hysterophorus* (Asteraceae) in eastern and southern Africa. *Weed Research* **51**(1): 71-84.

McFadyen RC. 2003. *Chromolaena* in Southeast Asia and the Pacific, pp. 130-134. *In*:. *Agriculture: New Directions for a New Nation – East Timor (Timor-Leste)* (Eds. da Costa H, Piggin C, da Cruz CJ and Fox JJ Eds.).

McFadyen RE and Skarratt B. 1996. Potential distribution of *Chromolaena odorata* (Siam weed) in Australia, Africa and Oceania. *Agriculture, Ecosystems and Environment* **59**: 89–96.

McKinney ML and Lockwood JS. 1999. Biotic homogenization: a few winners replacing many losers in the next mass extinction. *Trends in Ecology and Evolution* **14:** 450–453.

Millennium Ecosystem Assessment. 2003. *Ecosystems and Human Well-being: A Framework for Assessment*. Island Press: Washington, DC.

Muniappan R, Reddy GVP and Lai P. 2005. Distribution and biological control of *Chromolaena odorata*, pp. 223-233. *In*: *Invasive Plants: Ecological and Agricultural Aspects*. Inderjit (Ed.). Birkhäuser Verlag, Switzerland.

Pearson RG, Raxworthy CJ, Nakamura M and Pe-terson AT. 2007. Predicting species' distributions from small numbers of occurrence records: A test case using cryptic geckos in Madagascar. *Journal of Biogeography*. **34:** 102- 117.

Sharma GP, Raghubanshi AS and Singh JS. 2005. *Lantana* invasion: an overview. *Weed Biology and Management* **5:** 157-165.

Strayer DL, Eviner VT, Jeschke JM and Pace ML. 2006. Understanding the long-term effects of species invasions. *Trends in Ecology and Evolution* **21**(11): 645-651.

Walther G, Berger S and Sykes MT. 2005. An ecological 'footprint' of climate change. *Proceedings of Royal Society B* **272**: 1427-1432.

Wang R and Wang Y. 2006. Invasion dynamics and potential spread of the invasive alien plant species *Ageratina adenophora* (Asteraceae) in China. *Diversity and Distribution* **12**: 397–408.

Wilcove DS, Rothstein D, Dubow J, Phillips A and Losos E. 1998. Quantifying threats to imperiled species in the United States. *BioScience* **48**(8): 607-615.

Zachariades C, Day M, Muniappan R and Reddy GVP. 2009. *Chromolaena odorata* (L.) King and Robinson (Asteraceae), pp.130-162. In: *Biological control of Tropical Weeds using Arthropods*. (Eds. Muniappan R, Reddy GVP and Raman A.) Cambridge University Press.