PREDICTING POTENTIAL INVASION OF LANTANA CAMARA USING SPECIES DISTRIBUTION MODELLING IN THE PART OF CENTRAL HIMALAYA : CASE STUDY OF GARHWAL DIVISION OF UTTARAKHAND

Saurabh Purohit[1], Neelam Rawat[2], Govind Singh[2] and Durgesh Pant[2]

[1] Indian Institute of Remote Sensing , 4, Kalidas Road, Dehradun, India

Email: saurabhpurohit10@gmail.com

[2] Uttarakhand Space Application Centre, 93 Phase-II, Vasant Vihar, Dehradun, India

Email: neel2406@gmail.com, *gopi.negi78@gmail.com*, *durgesh.pant@gmail.com*

KEYWORDS: Invasion, Climate change, Lantana camara, MaxEnt Model, WorldClim, MODIS NDVI

ABSTRACT

The impact of climate change in climate impinges on various mechanisms and components of the earth ecosystem to the species level. The increasing atmospheric GHG concentrations change the various individual components of the system with a broad range of response with times. The combined effect of spatial and non-spatial climate and environmental variables of species interaction dynamics helps in assessing the potential consequences of climate change for plant invasion. The threat posed by invasive species to biodiversity may be exacerbated by climate change. *Lantana camara* L. (lantana) is a woody shrub that is highly invasive in many countries of the world. It has a profound economic and environmental impact worldwide. Knowledge of the likely potential distribution of this invasive species under current climate will be useful in planning better strategies to manage the invasion. Predicting potential geographic distribution of the species is important from species occurrence and management planning purpose. This study was carried out in Garhwal division of Uttarakhand State in India on potential distribution modeling for *Lantana camara* using MaxEnt model. The Worldclim bioclimatic variables, slope, elevation, MODIS NDVI and LULC data along with 168 spatially well-dispersed species occurrence points were used to predict the potential invasion distribution of *Lantana camara*. Jackknife test was used to evaluate the importance of the environmental variables for predictive modeling. Maxent model was accurate with a statistically significant AUC of 0.882 of test data. The approach could be promising in knowing the potential invasion of species and thus, can be an effective tool in its management and other appropriate planning. This will not only help in distribution but its extend of proliferation in global climate change scenario.

INTRODUCTION

Colonization of new areas by plants and animals is a naturally occurring process related with ecosystems (White et al., 2006). However, this process has been severely impacted by anthropogenic activities. In changing climatic scenario biological invasion is one of the most critical threat to biodiversity after habitat destruction, biodiversity loss and species extinction worldwide. Biological invasion has been homogenizing the world‟s flora and fauna (Hobbs 2000). Invasive species can have detrimental economic impacts on human enterprises such as fisheries, agriculture, grazing and forestry (Shackleton et al. 2007). The type of impacts range from reduction in native species richness and abundance (Woziwoda et al. 2014), to impacts on overall ecosystem diversity (Shanungu 2009), alteration in water regime (LeMaitre 2004), soil pathogenesis (Mangla and Callaway 2008), and increased risk of disturbances such as fire (D'Antonio and Vitousek 1992). Invasion is now internationally recognized as the single most serious threat to biodiversity after habitat destruction, with severe impact on ecosystem services (Convention on Biological Diversity 2009).

Lantana camara, also known as wild sage is the genus of verbenaceae family with 600 varieties existing worldwide. It is a thorny multi-stemmed, deciduous shrub with an average height of 2m (6ft). The shrub‟s taxonomic position is defined as belonging to the class of magnoliopsida, order lamiales, family verbenaceae and genus *Lantana* (GISIN, 2011). Stems are square in outline, covered with bristly hairs when green, often armed or with scattered small prickles. Lantana camara possesses a strong root system. The species has made itself indispensable in most parts of India. It is native species of South, Central America and the Caribbean islands (Baars, 2002), has its presence recorded even in Brazil, Florida, Jamaica, Mexico, and Trinidad. The diversity, broad geographic expansion and wide ecological tolerance are so large that the Invasive Species Specialist Group (ISSG) considers it among "100 of the World's Worst invaders" (Day et al., 2003). It was introduced in 1807 as an ornamental plant by the British in Calcutta Botanical Garden (Brandis, 1882; Aravind and Rao, 2001; Nanjappa et al., 2005; Bhagwat et al., 2012). It has its indiscriminate spread and presence in almost all regions of India including farm, pasture, fallow land and forest except the Thar Desert and its surroundings (Kannan et al., 2009; Aravind et al., 2010; Kimothy et al., 2010; Surampalli, 2010; Patel et al., 2011; Dobhal et al., 2011). Its success as a woody invasive species is attributed to its toxicity to potential herbivores, the presence of allelochemicals, its ability to produce proliferous flowering and seeding, its long range seed dispersal capabilities and its reproductive versatility. Large portion of forest in the Himalayan foothills covering Dudhwa, Corbett and Rajaji National Parks have been reported with high density of Lantana camara‟s presence (Sharma et al., 2005; Kimothi et al., 2010; Priyanka and Joshi, 2013).

Ground surveys have historically provided the main approach for identification, mapping and monitoring invasive species (Tan et al. 2012, Shah and Reshi 2014). Due to inaccessibility and time constraints remote sensing (RS) has become an increasingly popular approach for the mapping and monitoring of invasive species, with a diversity of sensors having varied temporal, spectral, radiometric and spatial resolution. Remote sensing alone cannot identify *Lantana camara* in closed canopy using remote sensing techniques. The use of GIS and ecosystem modeling techniques can present understorey spread of invasive species using risk maps (Price et al., 2007; Tuanmu et al., 2010; Taylor et al., 2012). These tools combined with eco-physiological analyses of key environmental variables have become indispensable in estimating current and potential spread of invasion and their drivers at landscape levels. Models predicting the potential geographic distribution of species are critical in knowing the species spread, conservation biology with a number of statistical models to simulate the spatial distribution of plant species invasive species, species diversity and impact of climate change (Ferrier, 2002; Peterson et al., 2003; Graham et al., 2006, Thomas et al., 2004). There are a variety of empirical approaches which are being widely used to map invasion distribution potential of invaders. A few of these approaches which uses species presence records are ecological niche modeling (Peterson and Vieglais, 2001; Hirzel et al., 2002;), envelope method (Bioclim) (Farber and Kadmon, 2003; Beaumont et al., 2005; Heikkinen et al., 2006; Araujo and Peterson, 2012), Generalized Additive model (GAM) (Guisan et al., 2002; Leathwick et al., 2002; Austin, 2007), logistic\ regression (Pearce and Ferrier, 2000; Cord and Boris, 2004; Chahouki and Chahouki, 2010), neural networks (Manel et al., 1999; Spitz and Lek, 1999; Manel et al., 2001; Moisen and Frescino, 2002) and regression trees (Death and Fabricius, 2000; Death, 2007).

Maximum entropy (Maxent) model is a species distribution model (SDM) originating from the statistical mechanics (Phillips et al., 2006, Jaynes, 1957). This environmental model used for predicting the potential distribution of species has several advantages;it simply require a set of known occurrences together with predictor variables such as topography, climate, soil, biogeography etc. that make use of both continuous and categorical data and incorporate the interactions between the variables (Priyanka and Joshi, 2013; Elith; 2011, Phillips and Dudik, 2008, Phillips et al., 2006).

MATERIALS AND METHODS Study Area

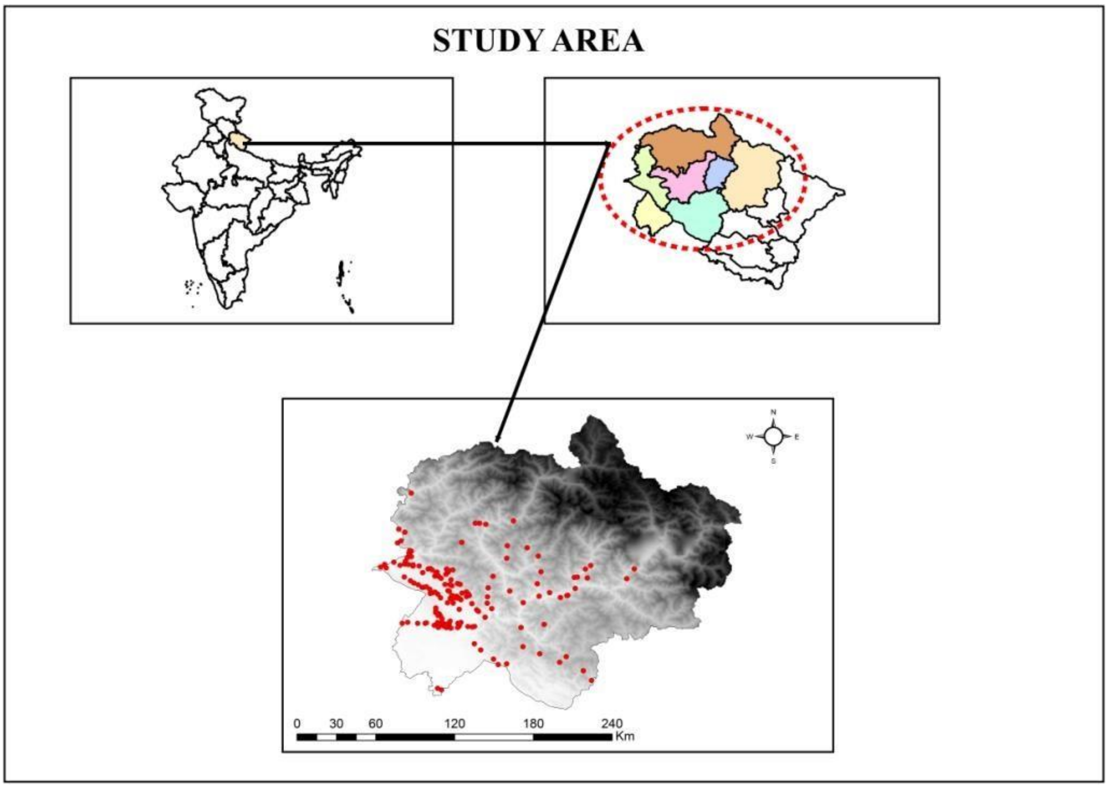

Figure 1 Study area along with occurrence points of *Lantana camara*

The Garhwal region of the Western Himalaya lies in northern India and includes seven districts of the state of Uttarakhand (namely Dehradun, Tehri Garhwal, Pauri Garhwal, Uttarkashi, Rudraprayag and Chamoli and Haridwar). It covers an area of 24,433 km^2 .To its east lies the Kumaon Himalayan region and to its west the state of Himachal Pradesh.Two of the most populous districts i.e. Dehradun and Haridwar lies in Garhwal resulting in surge of anthropogenic activities. Two important river systems drain this region; Yamuna, which flows along its western boundary(separating it from Himachal Pradesh) and the Ganges, which flows through the middle of Garhwal together with their tributaries. Vegetation types ranges from Tropical moist deciduous forest dominated with *Shorea robusta* species to alpine meadows above which is generally the snow line with sparse vegetation and rocks. Due to its biodiversity, Garhwal region has got number of protected areas prominently among them are part of Corbett and Rajaji Tiger Reserve. Nanda Devi Biosphere reserve which include valley of flowers national park is also situated here.

Species Occurrence Data

Base map was prepared using SoI toposheets and open soruce satellite data. A total of 195 occurrences of *Lantana camara* were recorded randomly in the study area using handheld Global Positioning System (GPS) receiver with ±5 m positional accuracy. During the post field data assessment, all point locations collected were overlaid on the fishnet mesh of 1x1 sq km. Certain grids having more than one point were identified and reduce to one point per grid. The selection of one location was based on nearness to the center of the grid under consideration. As a result, a total of 168 spatially unique points per grid were finally used in the data analysis and modeling.

Environmental Variables

A total of 34 environmental variables were used. Nineteen bioclimatic variables (Hijmans et al. 2005) with 30 arc second (˜1Km) spatial resolution were obtained from the WorldClim dataset (http://www.worldclim.com), and used to detect the most influential variables associated with the present distribution of *Lantana camara*. The Shuttle Radar Topography Mission (SRTM) with 1 arc second (˜30 m) spatial resolution was used to generate the slope, aspect and elevation data layers. MODIS NDVI product was used for NDVI and MODIS IGBP data was used for Land Use/Land Cover data. Pearson correlation test was conducted to remove the highly correlated variables and final fifteen layers were used to be used for Maxent modeling. These variables were stored in ASCII file format at 30 arc-seconds (~ 1.0 km) resolution. These datasets were finally checked for precise spatial matching as prerequisite for modeling tools. All ASCII files consisted of 247 rows, 309 columns, and 0.00833 cell size representing continuous data in ratio and interval scales of measurements and discrete data in nominal scale of measurements. Thirty percent of training sites were taken as test sites.

Model Version Used

MaxEnt Algorithm version 3.4.1 released in December 2016 (Phillips et al., 2006) was used for mapping the potential geographic distribution of *Lantana camara* in Garhwal division.

Results and Discussion Evaluation of MaxEnt Model Receiver Operating Characteristic (ROC) curve

A ROC plot is a plot of sensitivity and 1-specificity, with sensitivity representing how well the data correctly predicts presence, whereas specificity provides a measure of correctly predicted absences (Fielding and Bell, 1997). The ROC curve is generally used to evaluate the simulation accuracy of the model (Hanley and McNeil, 1982). The area below the ROC curve, i.e. the value of the area under the curve (AUC) indicates the predictive accuracy of the model. In the present study, the AUC of the constructed model based on the potential climatic factors affecting the distribution of *Lantana camara* was 0.927 and 0.882, for training and test data respectively. This AUC value indicated that the constructed model is applicable and had good predictive accuracy and therefore it was suitable for geographic distribution of *Lantana camara* in Garhwal division.

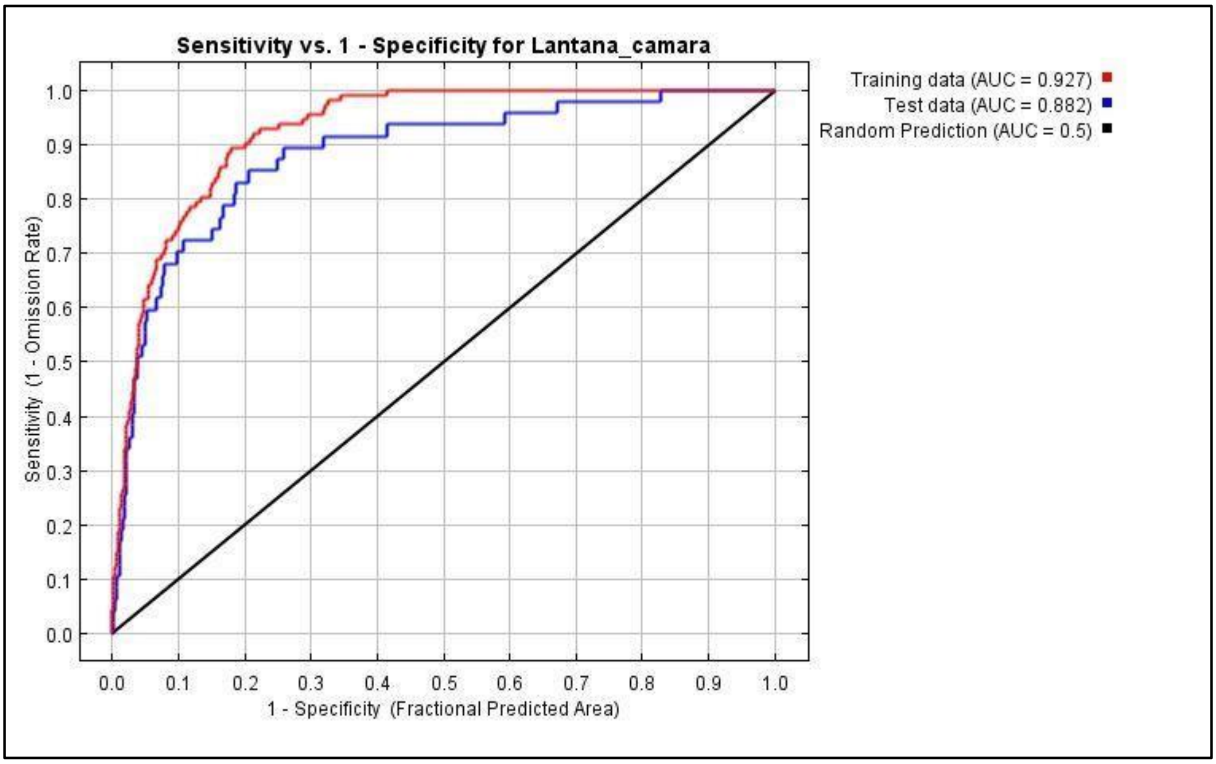

Figure 2 ROC curve of sensitivity versus specificity for *Lantana camara.*

Prediction modeling

For the prediction modeling, the maximum entropy (MaxEnt) model (Phillips et al. 2006) was chosen due to its better performance with small sample sizes as compare with other SDMs (Elith et al. 2006). The MaxEnt model uses presence-only data to predict species distribution based on the theory of maximum entropy (Phillips et al. 2006).The 70% of selected data used for training and the rest 30% for testing. The Area under the Receiving Operator Curve (AUC) was used to evaluate model"s goodness-of-fit and model with highest AUC value was considered as the best performer. The Jackknife procedure was used to assess the importance of the variables. The final potential species distribution map had a range of values from 0 to 1 which were regrouped in to five classes of potential habitats based on suitability viz., very high suitability (> 0.8), „High suitability" (0.6 to .8), „Good suitability" (0.4–0.6), „Moderate suitability (0.2–0.4). Least Suitability (<0.2).

Table 1 Environmental variables used in the study and their percentage contribution.

Variable	Description	Percent Contribution
Bio1	Annual mean temperature	7.7
Bio2	Mean diurnal range	1.5
Bio3	Isothermality	2.1
Bio4	Temperature seasonality	2.5
Bio5	Maximum temperature of warmest month	37.8
Bio6	Minimum temperature of coldest month	3.8
Bio12	Annual precipitation	7.1
Bio13	Precipitation of wettest period	3.8
Bio14	Precipitation of driest period	1.2
Bio15	Precipitation seasonality	13.9
SLO	Slope	2
LULC	Land use and land cover	0.8
ALT	Altitude	8.3
NDVI_sept		0.9
NDVI_oct		6.7

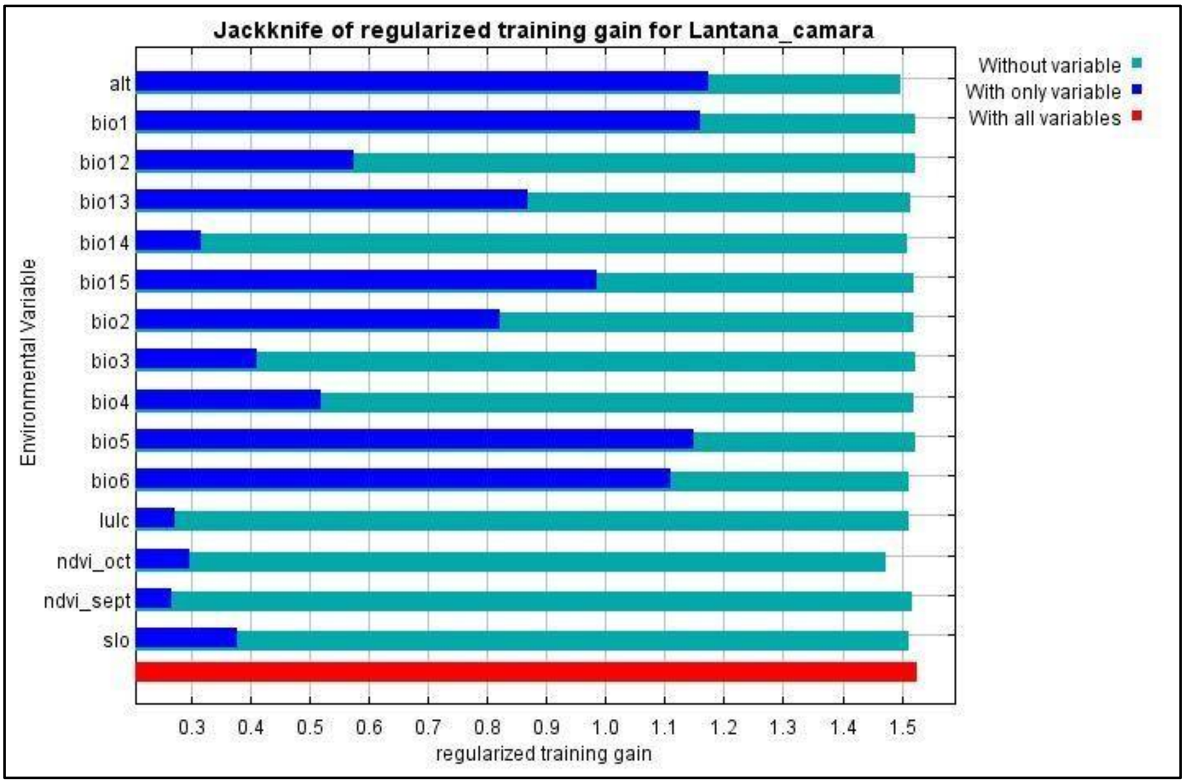

Figure 3 The Jackknife test for evaluating the relative importance of environmental variables for *Lantana camara* in Garhwal Division.

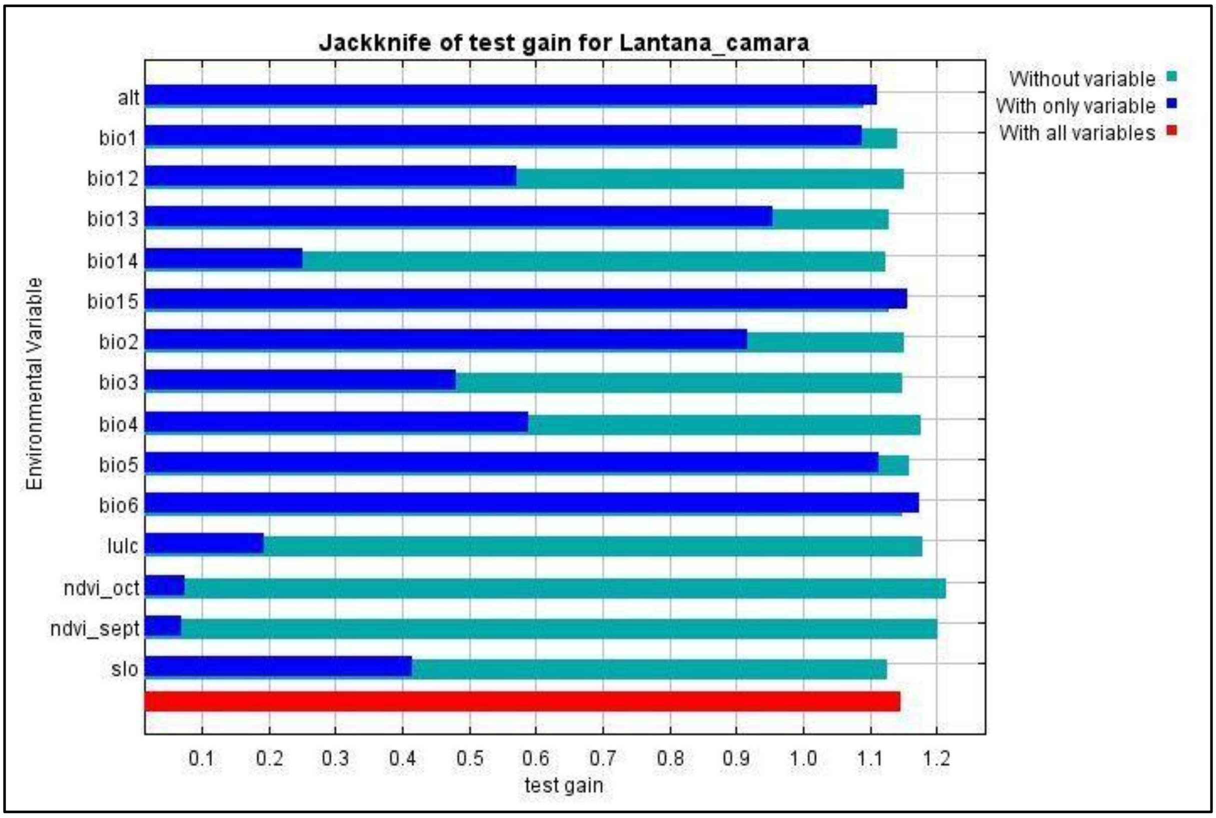

Figure 3. The Jackknife of test gain for *Lantana camara* in Garhwal Division.

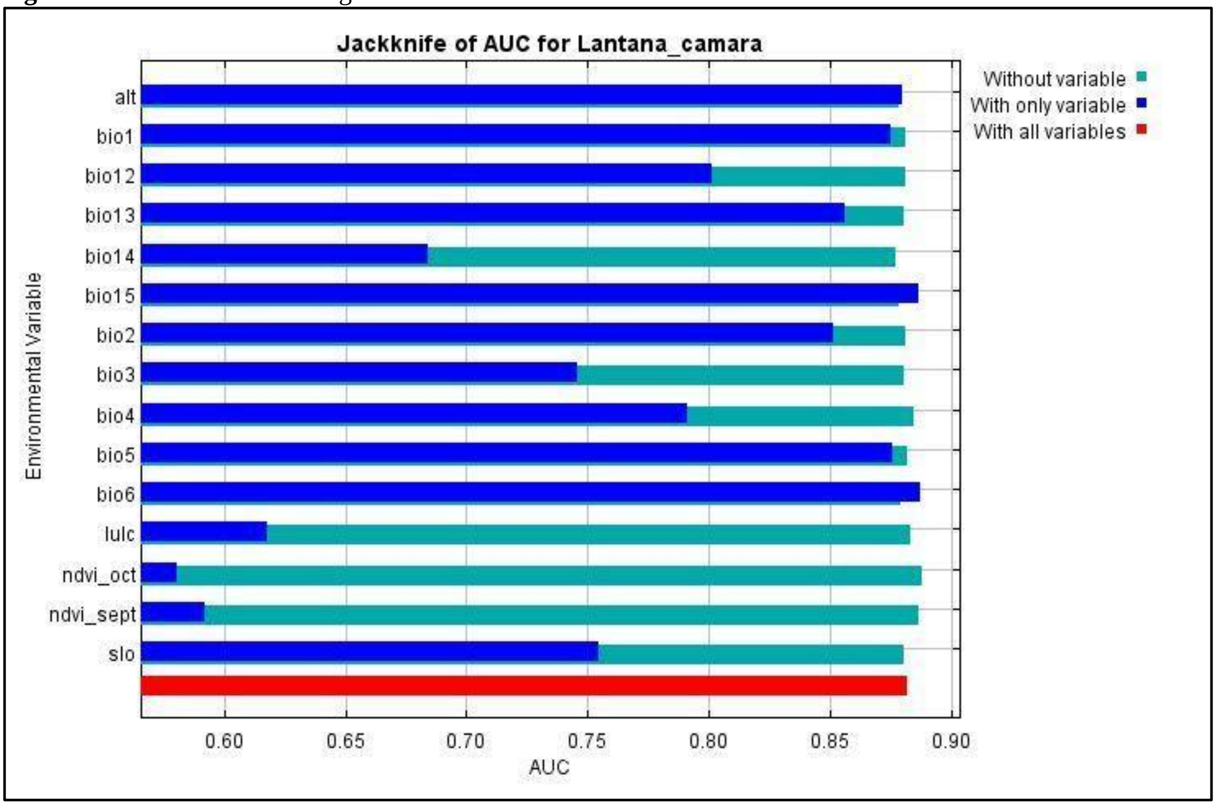

Figure 4 The Jackknife of AUC for *Lantana camara* in Garhwal Division.

(Note: "alt" is Altitude; "Bio1" is Annual mean temperature; "Bio12"is Annual precipitation; "Bio13" Precipitation of wettest period; "Bio14" is precipitation of coldest quarter; "Bio15" is Precipitation seasonality "Bio2" is Mean diurnal range (mean of monthly max. and min. temp.); "Bio3" is Isothermality; Bio4 is Temperature seasonality; Bio5 is Maximum temperature of warmest month; Bio6 is Minimum temperature of coldest month; “LULC” is land use/land cover map; ndvi_sept is NDVI for September; ndvi_oct is NDVI for October; “SLO” is slope.)

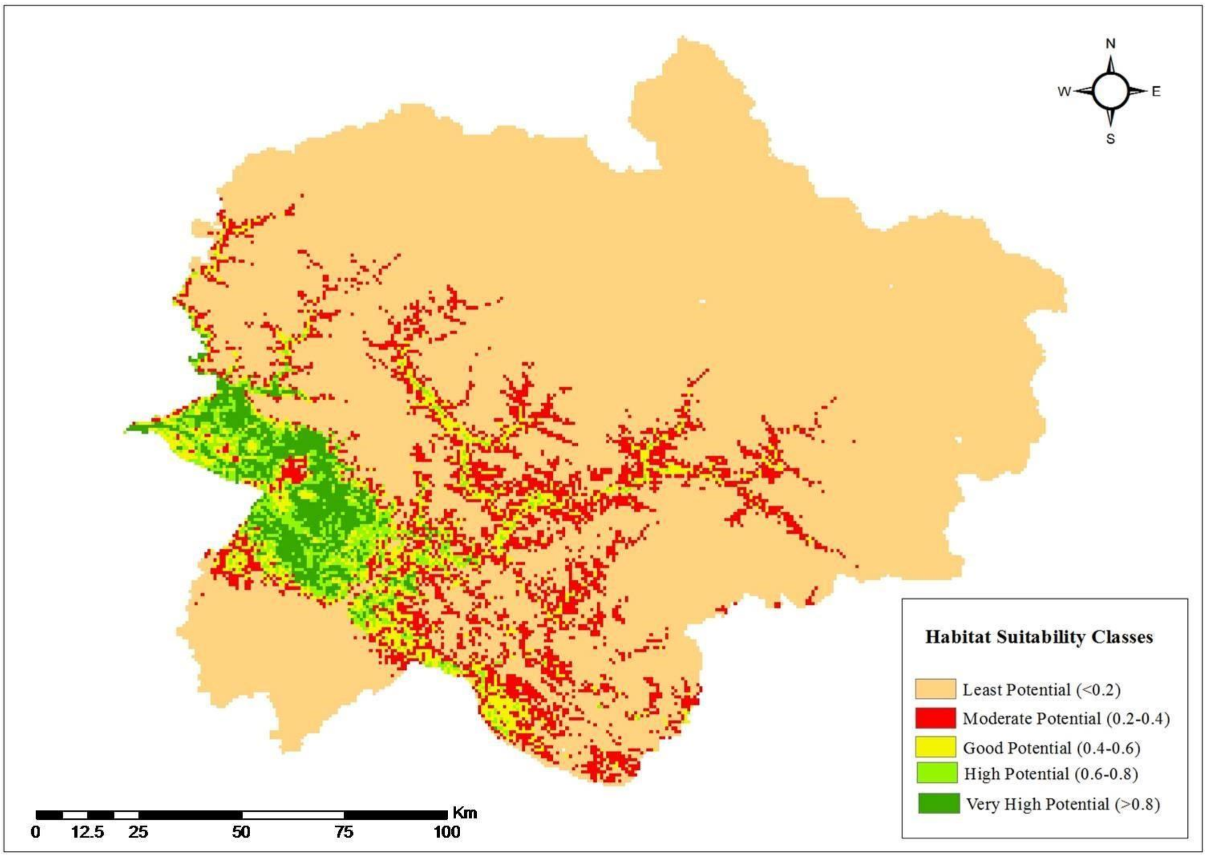

Figure 5 Predicted potential distribution of *Lantana camara* in Garhwal Division

Results showed that Dehradun valley and Rajaji Tiger Reserve has got very high and high habitat suitability of the *Lantana camara* . Portions of Pauri Garhwal and Corbett Tiger reserve have got good to high potential. Some areas in hilly regions of Tehri, Rudraprayag and Chamoli districts are also suitable for *Lantana camara* invasion.

Conclusion

The present study is in conformance with the various studies for modeling *Lantana camara* invasion potential as similar parameters were found to influence the distribution of *Lantana camara* in selected study region. Few new findings in relation expansion of the habitat suitability to the higher regions in the Himalaya were found. Future studies can relate the ingression of *Lantana camara* to climate change using different climatic scenarios.

Acknowledgements

Authors are highly grateful to the Uttarakhand Forest department for the permission to do the field work.

References

Araujo, M.B & Peterson, A.T., 2012. Uses and misuses of bioclimatic envelope modeling, Ecology, 93(7), pp. 1527–1539.

Austin, M., 2007. Species distribution models and ecological theory: A critical assessment and some possible new approaches Ecological Modelling, 200, pp. 1-19.

Beaumont, L.J., Hughes, L & Poulsen, M., 2005. Predicting species distributions: use of climatic parameters in Bioclim and its impact on predictions of species current and future distributions, Ecological Modelling, 186, pp. 250-269.

Bhagwat, S.A., Breman, E., Thekaekara, T., Thornton, TF & Willis, K.J., 2012. A Battle Lost? Report on Two Centuries of Invasion and Management of *Lantana camara L.* in Australia, India and South Africa, PLoS ONE, 7(3).

Chahouki, M.A.Z & Chahouki, A.Z., 2010. Predicting the distribution of plant species using logistic regression (Case study: Garizat rangelands of Yazd province), Desert, 15, pp. 151-158.

Chatanga, P., 2007. Impact of the Invasive Alien Species, *Lantana camara* (L.) on native vegetation in Northern Gonarezhou National Park, Zimbabwe, MSc. Thesis, University of Zimbabwe.

Convention on Biological Diversity (2009). Strategic Plan for Biodiversity 2011-2020 and the Aichi Targets. Convention on Biological Diversity, United Nations, Montreal, Quebec, Canada.

Cord, P.L & Boris, S., 2004. Predicting the species composition of *Nardus stricta* communities by logistic regression modelling, Journal of Vegetation Science, 15, pp. 623-634.

D'Antonio, C & Vitousek, P.M., 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics 23: pp. 63-87.

Day, M.D., Wiley, C.J., Playford, J & Zalucki, M.P., 2003. Lantana: current management status and future prospects. Australian Centre for International Agricultural Research Canberra, ACIAR Monograph, 102, pp 1-128.

Death, G., 2007. Boosted trees for ecological modeling and prediction. Ecology, 88(1), pp. 243-251.

Death, G & Fabricius, K.E., 2000. Classification and regression trees: a powerful yet simple technique for ecological data analysis. Ecology, 81(11), pp. 3178-3192.

Elith, J., Phillips, S.J., Hastie, T., Dudík, M., Chee, Y.E & Yates C.J., 2011. A statistical explanation of MaxEnt for ecologists. Diversity and distributions, 17(1), pp. 43-57.

Farber, O & Kadmon, R., 2003. Assessment of alternative approaches for bioclimatic modeling with special emphasis on the Mahalanobis distance. Ecological Modelling, 160, pp. 115-130.

Ferrier, S., Drielsma, M., Manion, G & Watson, G., 2002. Extended statistical approaches to modelling spatial pattern in biodiversity in northeast New South Wales. II. Community-level modelling. Biodiversity & Conservation, 11(12), 2309-2338.

Graham, I.D., Logan, J., Harrison, M.B., Straus, S.E., Tetroe, J., Caswell, W & Robinson, N., 2006. Lost in knowledge translation: time for a map? Journal of continuing education in the health professions, 26(1), pp. 13-24.

Guisan, A & Hofer, U., 2003. Predicting reptile distributions at the mesoscale: Relation to climate and topography. Journal of Biogegraphy (30) pp. 1233-1234.

Heikkinen, R.K., Luoto, M., Araujo, M.B., Virkkala, R., Thuiller, W & Sykes, M.T., 2006. Methods and uncertainties in bioclimatic envelope modelling under climate change. Progress in Physical Geography, 30(6), 1–27

Hirzel, A.H., Hausser, J., Chessel, D & Perrin, N., 2002. Ecological-niche factor analysis: how to compute habitatsuitability maps without absence data?, Ecology, 83(7), pp. 2027-2036.

Hobbs, R.J., 2000a. Land-use changes and invasions. Island Press, Covelo. pp. 55-64.

Huang, C & Asner, G.P., 2009. Applications of Remote Sensing to Alien Invasive Plant Studies. Sensors 9:pp. 4869-4889.

Jaynes, E.T., 1957. Information theory and statistical mechanics. Physical review, 106(4), 620.

Kimothi, M.M., Anitha, D., Vasistha, H.B., Soni, P & Chandola, S.K., 2010. Remote sensing to map the invasive weed, *Lantana camara* L. in forests, Tropical Ecology, 51(1), pp. 67-74.

Leathwick, J.R., Elith, J & Hastie, T., 2006. Comparative performance of generalized additive models and multivariate adaptive regression splines for statistical, Ecological Modelling, 199, pp. 188-196.

LeMaitre, D.C., 2004. Predicting invasive species impacts on hydrological processes: The consequences of plant physiology for landscape processes. Weed Technology 18:pp. 1408-1410.

Manel, S. Dias & Ormerod, J.M., 1999. Comparing discriminant analysis, neural networks and logistic regression for predicting species distributions: a case study with a Himalayan river bird, Ecological Modelling, 120, 337–347.

Manel, S., Williams, H.C & Ormerod, S.J., 2001. Evaluating presence–absence models in ecology: the need to account for prevalence. Journal of Applied Ecology, 38, pp. 921-931.

Mangla, S & Callaway, R.M., 2008. Exotic invasive plant accumulates native soil pathogens which inhibit native plants. Journal of Ecology 96:pp. 58-67.

Moisen, G.G & Frescino, T.S., 2002. Comparing five modelling techniques for predicting forest characteristics. Ecological Modelling, 157, pp. 209-225.

Nanjappa, H.V., Saravanane. P & Ramachandrappa., 2005. Biology and management of *Lantana camara* L. - a review, Agricultural Review, 26(4), pp. 272-280.

Pearce, J & Ferrier, S., 2000. An evaluation of alternative algorithms for fitting species distribution models using logistic regression, Ecological Modelling, 128, pp.127–147.

Peterson, G.D., Cumming, G.S & Carpenter, S.R., 2003. Scenario planning: a tool for conservation in an uncertain world. Conservation biology 17(2), pp. 358-366.

Peterson, A.T & Vieglais, D.A., 2001. Predicting Species Invasions Using Ecological Niche Modeling: New Approaches from Bioinformatics Attack a Pressing Problem, BioScience, 51 (5), pp. 363-371.

Phillips, S.J., Anderson, R.P & Schapire, R.E., 2006. Maximum entropy modeling of species geographic distributions. Ecological modelling, 190(3),pp. 231-259.

Phillips, S.J & Dudík, M., 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography, 31(2), pp.161-175.

Price, J.P., Gon, III S.M., Jacobi, J.D & Matsuwaki, D., 2007. Mapping Plant Species Ranges in the Hawaiian Islands: Developing a Methodology and Associated GIS layers, Hawaii Cooperative Studies Unit Technical Report HCSU-008.

Priyanka, N & Joshi, P., 2013. Effects of Climate Change on Invasion Potential Distribution of *Lantana camara*. Journal of Earth Science and Climate Change 4:164.

Shackleton, C.M., McGarry, D., Fourie, S., Gambiza, J., Shackleton, S.E & Fabricius, C., 2007. Assessing the effects of invasive alien species on rural livelihoods: case examples and a framework from South Africa. Human Ecology. 35, pp.113-127.

Shanungu, G.K., 2009. Management of the invasive *Mimosa pigra L*. in Lochinvar National Park, Zambia. Biodiversity 10, pp. 56-60.

Sodhi, N.S & Ehrlich, P.R., 2010. Conservation Biology for all. Oxford University Press, pp. 341.

Sharma, G.P & Raghubanshi, A.S., 2006. Tree population structure, regeneration and expected future composition at different levels of *Lantana camara L.* invasion in the Vindhyan tropical dry deciduous forest of India, Lyonia, 11(1), pp.27-39.

Shah, M.A & Reshi, Z.A., 2014. Characterization of alien aquatic flora of Kashmir Himalaya: implications for invasion management. Tropical Ecology 55:pp.143-157.

Spitz, F & Lek, S., 1999. Environment impact prediction using neural network modelling. An example of wildlife damage. Journal of Applied Ecology, 36, pp.317-326.

Tan, D.T., Thu, P.Q & Dell, B., 2012. Invasive Plant Species in the National Parks of Vietnam. Forests 3, pp.9971016.

Taylor, S., Kumar. L., Reid, N & Kriticos, D.J., 2012. Climate Change and the Potential Distribution of an Invasive Shrub, *Lantana camara L*, PLoS ONE, 7(4), pp 1-14.

Thomas, C.D., Cameron, A., Green, R.E., Bakkenes, M., Beaumont, L.J., Collingham, Y.C & Hughes, L., 2004. Extinction risk from climate change. Nature, 427(6970), pp.145-148.

Tuanmu, M.N., Viña, A., Bearer, S., Xu, W., Ouyang, Z., Zhang, H & Liu, J., 2010. Mapping understory vegetation using phenological characteristics derived from remotely sensed data. Remote Sensing of Environment, 114, 1833–1844.

White, E.M., Wilson, J.C & Clarke, A.R., 2006. Biotic indirect effects: a neglected concept in invasion biology. Diversity and Distributions. 12, pp. 443- 455.

Woziwoda, B.D.Kopec & Witkowski, J., 2014. The negative impact of intentionally introduced *Quercus rubra L.* on a forest community. Acta Societatis Botanicorum Poloniae 83, pp.39-49.