Ecological Niche-Based Species Distribution Modelling

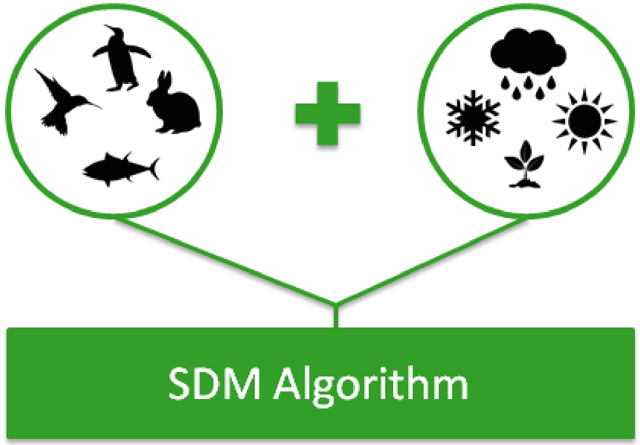
Dr. Hitendra Padalia
Head, Forestry and Ecology Department
hitendra@iirs.gov.in

Approaches to Habitat or Environmental Suitability Assessment

- **Habitat Suitability Index (HSI):**
  - An HSI is a numerical index that represents the capacity of a given habitat to support a selected species;
  - These models are based on hypothesized species-habitat relationships rather than statements of proven cause and effect relationships.

- **Mechanistic SDMs**
  - Predict suitable environments using a species' physiological limitations in their tolerance to environmental conditions;
  - Do not incorporate known occurrence records;
  - Difficult to use due to required knowledge of species.

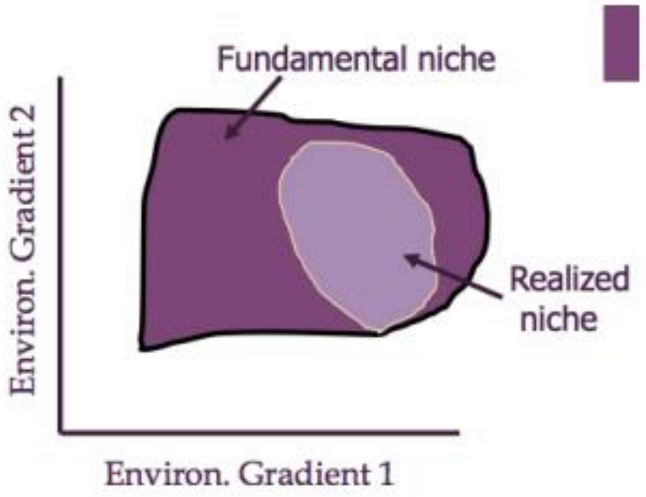
- **Correlative SDMs**
  - Aim to estimate environmental conditions suitable for a species using known distributions;
  - Correlate known occurrence records with various abiotic and biotic factors.



Definition & Type of Ecological Niches

Hutchinson defined ecological niche as:

- n-dimensional hyper-volume. n-equates the number of environmental factors;
- Full range of conditions and resources where an organism can live without interference is its fundamental niche.
- Realized niche includes interactions such as competition that may restrict environments where a species may live.



The relation between environmental gradients under ecological niche

Why a Ecological Niche based Correlative SDM)?

- Traditionally, only species locations are available. Available data is generally sparse. Do not tell where else species may occur.
- SDM predict likely areas of occurrence of species.
- Can also predict likely impacts of natural or anthropogenic disturbance on species.
- Species survey planning of RET species
- Reserve design and configuration
- Sites suitability for re-introduction

Assumptions in Ecological Niche Modelling

"Ecological niche models are based on the relationship between the species locations and their environmental covariates or predictors."

- ✓ Over evolutionary time, species would be selected to adapt to a set of environmental variables, characteristic of its ecological niche.
- ✓ Species ecological niche should not change with changing environmental conditions ("**Niche conservatism**")

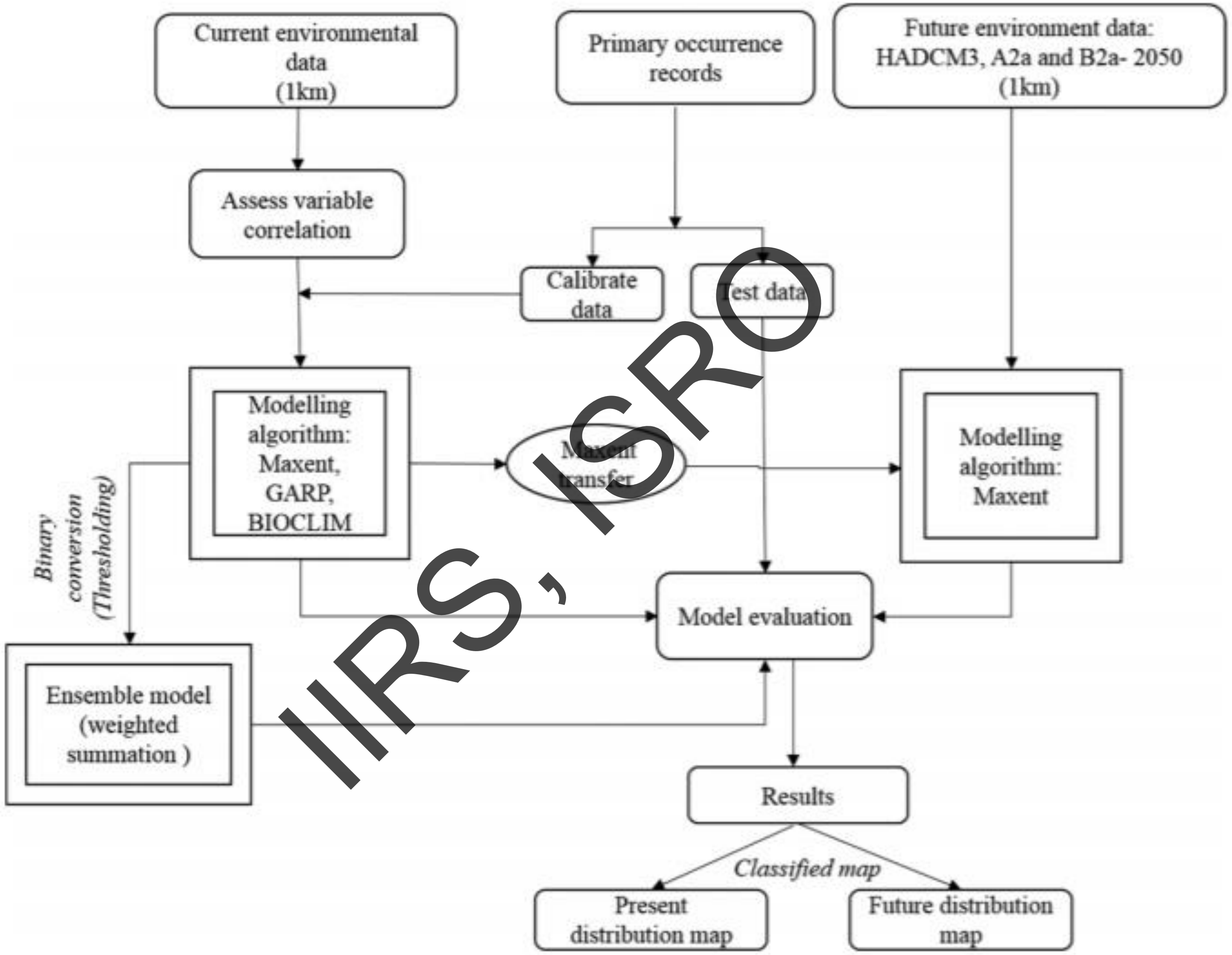
Ecological Niche Modelling Algorithms

- Logistic Regression (Presence/ Absence data)
- Genetic Algorithm for Rule Set Production (GARP) (Presence data)
- MaxEnt (Maximum Entropy) (Presence data)

Ecological Niche Modelling Software

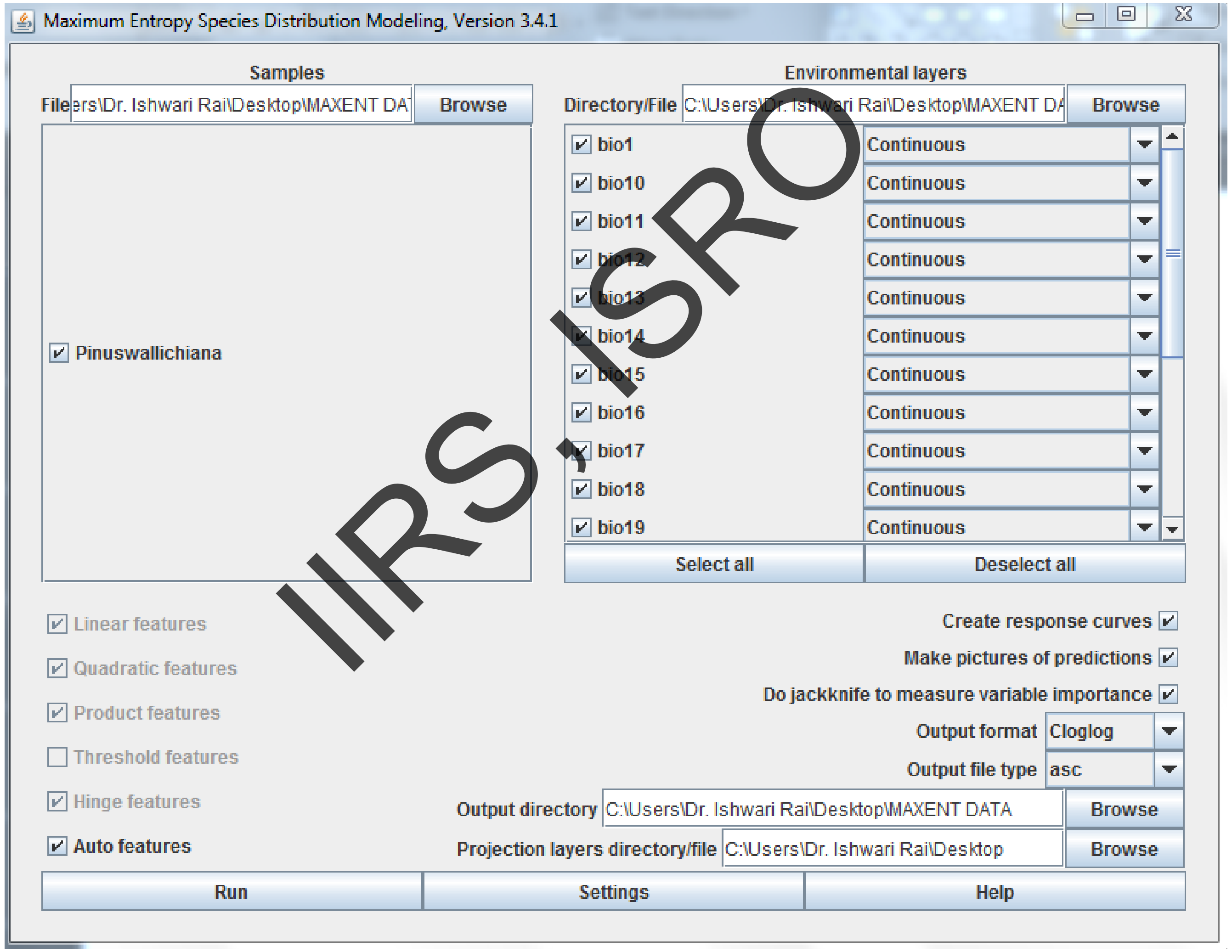
- DIVA-GIS is useful in preparation of bioclimatic variables
- MaxEnt uses presence only data and performs well when there are few presence records available.
- ModEco implements various SDM algorithms.
- SPACES is an online Environmental niche modeling platform

General Methodology

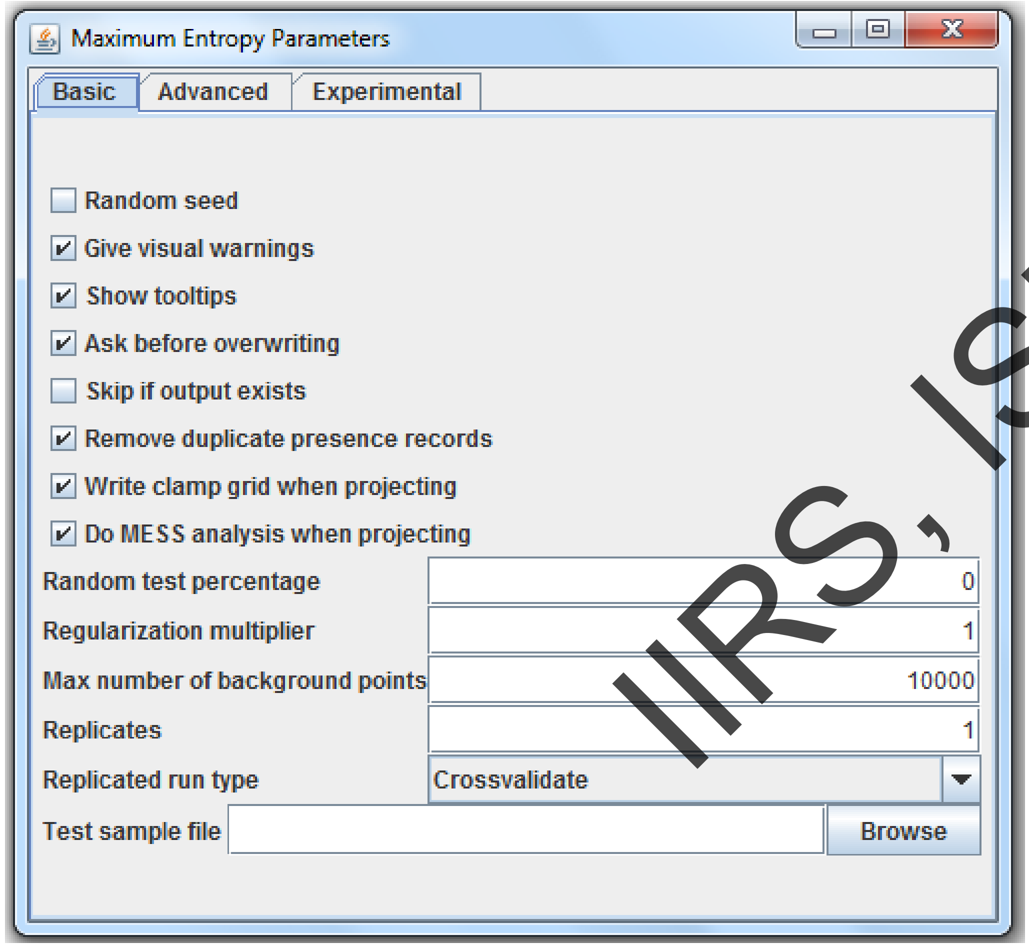


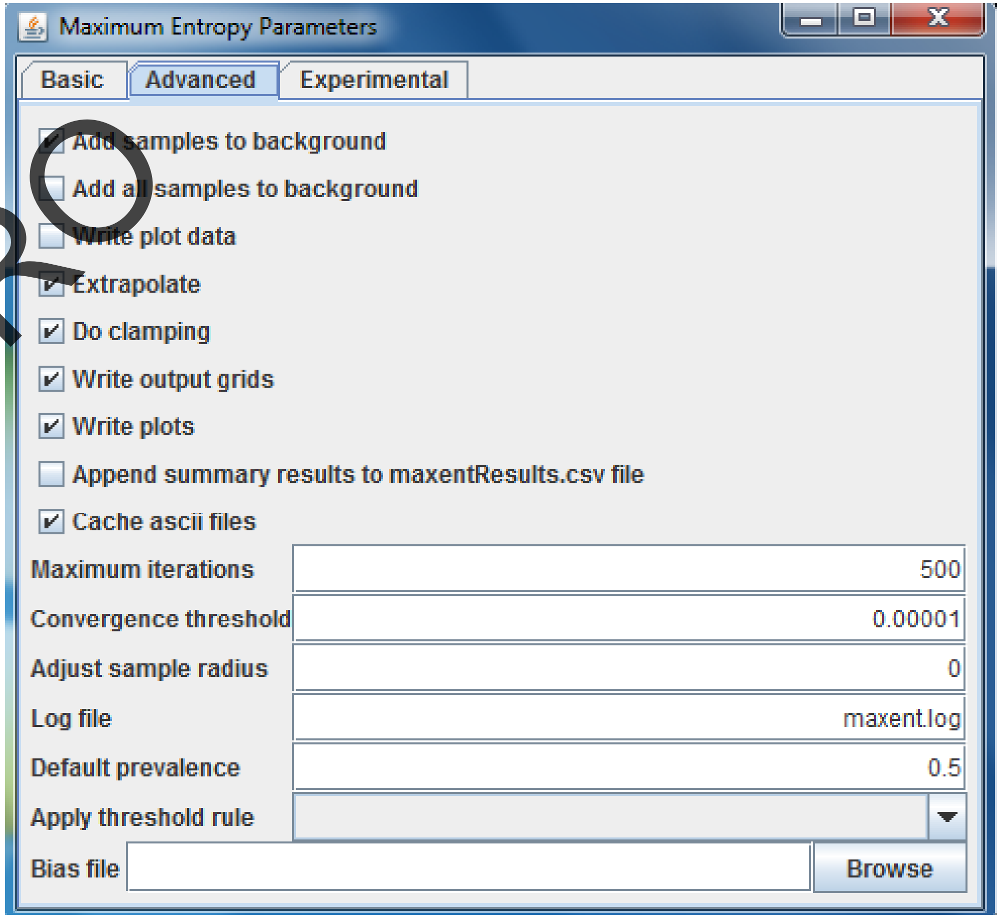
[Mapping invasion potential using ensemble modelling. A case study on Yushania maling in the Darjeeling Himalayas](), V Srivastava, VC Griess, H Padalia - Ecological Modelling, 2018

The MaxEnt approach is used to estimate probability of distribution of target species by analyzing the probability distribution of maximum entropy (Phillips et al., 2006).



http://www.cs.princeton.edu.


Maximum Entropy Parameters
Basic
Advanced
Experimental
Random seed
Give visual warnings
Show tooltips
Ask before overwriting
Skip if output exists
Remove duplicate presence records
Write clamp grid when projecting
Do MESS analysis when projecting
Random test percentage
0
Regularization multiplier
1
Max number of background points
10000
Replicates
1
Replicated run type
Crossvalidate
Test sample file
Browse


Maximum Entropy Parameters
Basic
Advanced
Experimental
Add samples to background
Add all samples to background
Write plot data
Extrapolate
Do clamping
Write output grids
Write plots
Append summary results to maxentResults.csv file
Cache ascii files
Maximum iterations
500
Convergence threshold
0.00001
Adjust sample radius
0
Log file
maxent.log
Default prevalence
0.5
Apply threshold rule
Bias file
Browse

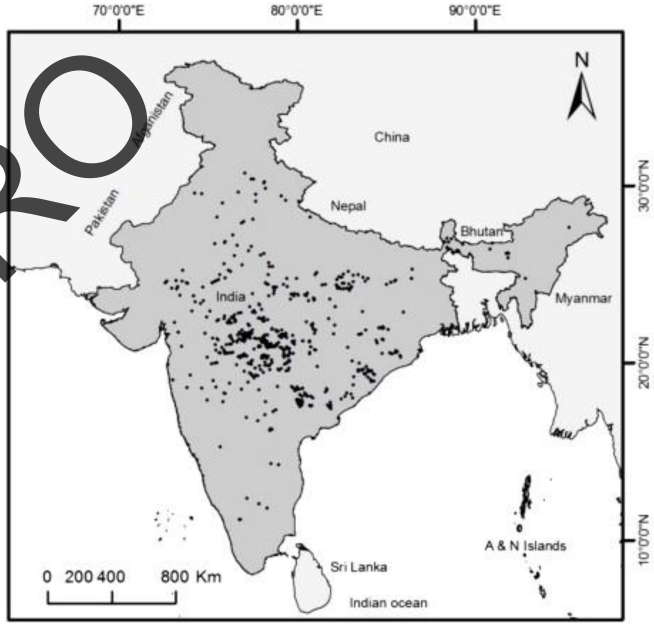
Case study: Predicting Bushmint's Invasion Range in India

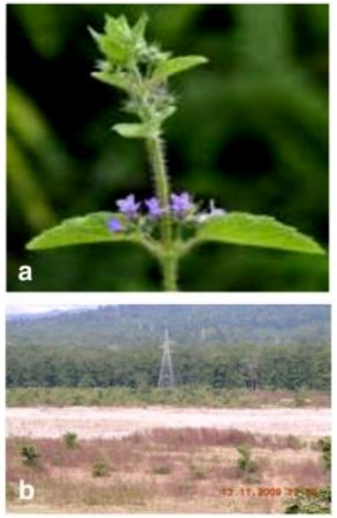
Multicollinearity

Table A.2
Multi-collinearity test by using cross-correlations (Pearson correlation coefficients, r) among environmental variables.

Variables	Bio1	Bio2	Bio3	Bio4	Bio5	Bio6	Bio7	Bio8	Bio9	Bio10	Bio11	Bio12	Bio13	Bio14	Bio15	Bio16	Bio17	Bio18	Bio19	LULC	ELE	SLO	ASP
Bio1	1																						
Bio2	≈1	1																					
Bio3	.94	.94	1																				
Bio4	.98	.98	.90	1																			
Bio5	≈1	≈1	.94	.98	1																		
Bio6	≈1	.99	.94	.97	≈1	1																	
Bio7	≈1	≈1	.93	.99	≈1	.99	1																
Bio8	≈1	≈1	.93	.99	≈1	≈1	≈1	1															
Bio9	.82	.83	.80	.84	.83	.82	.83	.83	1														
Bio10	≈1	≈1	.93	.99	≈1	.99	≈1	1	.83	1													
Bio11	≈1	≈1	.94	.97	≈1	.99	≈1	≈1	.81	≈1	1												
Bio12	−.69	−.69	−.62	−.73	−.70	−.69	−.70	−.70	−.64	−.70	−.70	1											
Bio13	−.51	−.51	−.44	−.56	−.52	−.51	−.52	−.52	−.44	−.51	−.50	.95	1										
Bio14	−.53	−.54	−.50	−.62	−.54	−.53	−.55	−.55	−.70	−.55	−.50	.78	.64	1									
Bio15	.45	.45	.51	.42	−.45	.48	.44	.45	.58	.44	.45	−.14	.11	−.46	1								
Bio16	−.63	−.63	−.55	−.68	−.64	−.63	−.64	−.64	−.57	−.64	−.61	.99	.97	.73	.98	1							
Bio17	−.74	−.75	−.73	−.78	−.75	−.75	−.75	−.75	−.77	−.74	−.72	.88	.74	.88	−.53	.81	1						
Bio18	−.74	−.74	−.68	−.78	−.75	−.74	−.75	−.75	−.70	−.74	−.72	.99	.90	.78	−.18	.97	.88	1					
Bio19	−.72	−.74	−.72	−.67	−.73	−.73	−.73	−.71	−.63	−.71	−.72	.78	.67	.59	−.49	.70	.85	.77	1				
LULC	−.66	−.66	−.66	−.66	−.66	−.66	−.66	−.66	−.63	−.66	−.66	.65	.65	.64	−.66	.65	.64	.64	.65	1			
ELE	−1	≈−1	≈−1	≈−1	≈−1	≈−1	≈−1	≈−1	−.99	≈−1	≈−1	.97	.97	.94	−.99	.97	.94	.96	.96	.66	1		
SLO	−.46	−.46	−.52	−.49	−.47	−.40	−.48	−.46	−.41	−.47	−.44	.61	.59	.62	−.53	.60	.64	.63	.62	.28	.46	1	
ASP	−.84	−.84	−.85	−.85	−.84	−.83	−.84	−.84	−.82	−.84	−.84	.85	.85	.84	−.85	.85	.84	.85	.85	.60	.84	.47	1

Note: If two variables had $r \ge \pm 0.8$, only one of them was selected in the same model. Correlations were significant at $\alpha = 0.05$ (calculated by statistic software, SPSS 16.0).





Bushmint in India (black dots depict presence locations, field photographs:
(a) Bushmint in flowering during September and
(b) monothickets of bushmint (in light violet color) along the river course during December in Dun valley).

Presence data:
463 presence points in a total of 16,518 biodiversity plots (2002 to 2007). 67 records of bushmint were compiled from the independent surveys (2007 to 2011).

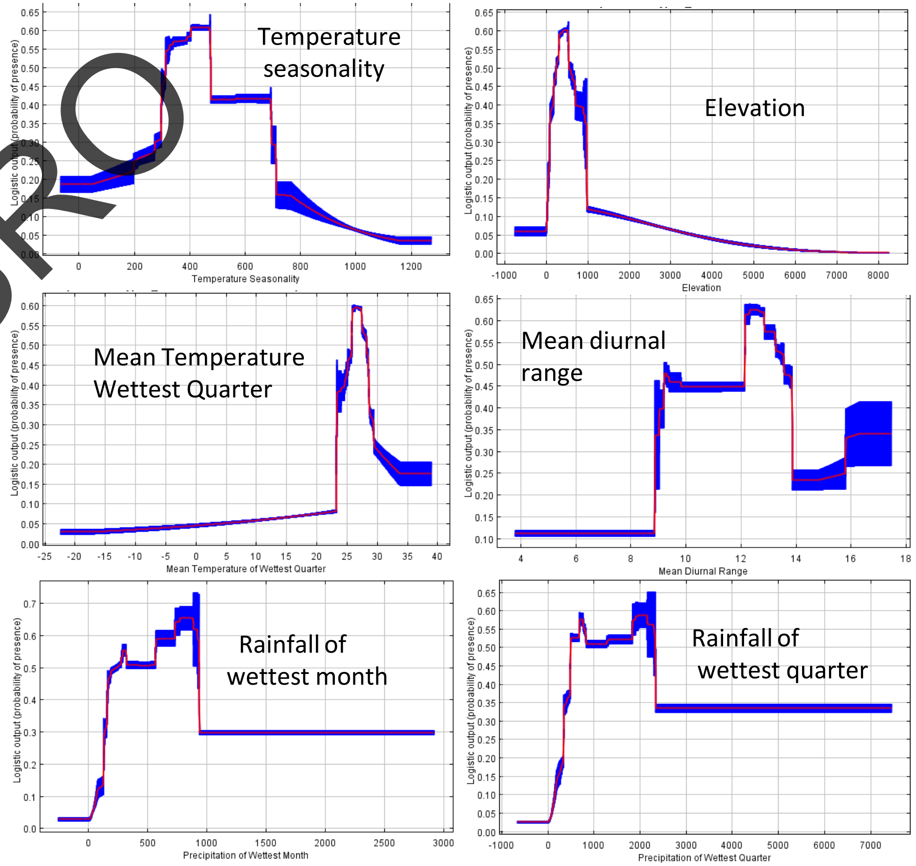
Environmental data layers

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

Code	Environmental variables	Unit	% Contribution
Bio1	Annual mean temperature	°C	
Bio2	Mean diurnal range (mean of monthly max. and min. temp.)	°C	
Bio3	**Isothermality** ((Bio2/Bio7) × 100)	–	72.2
Bio4	Temperature seasonality (standard deviation × 100)	C of V	
Bio5	Maximum temperature of warmest month	°C	
Bio6	Minimum temperature of coldest month	°C	
Bio7	Temperature annual range (Bio5–Bio6)	°C	
Bio8	Mean temperature of wettest quarter	°C	
Bio9	**Mean temperature of driest quarter**	°C	0.7
Bio10	Mean temperature of warmest quarter	°C	
Bio11	Mean temperature of coldest quarter	°C	
Bio12	**Annual precipitation**	mm	1.3
Bio13	Precipitation of wettest period	mm	
Bio14	**Precipitation of driest period**	mm	1.3
Bio15	**Precipitation seasonality (CV)**	C of V	1.0
Bio16	Precipitation of wettest quarter	mm	
Bio17	Precipitation of driest quarter	mm	
Bio18	Precipitation of warmest quarter	mm	
Bio19	**Precipitation of coldest quarter**	mm	0.8
LULC	**Land use and land cover**	15 types	21.9
ELE	Elevation	m	
SLO	**Slope**	°	0.8
ASP	Aspect	°	

Note: The highlighted variables, selected through multi-collinearity test, were used in modeling.

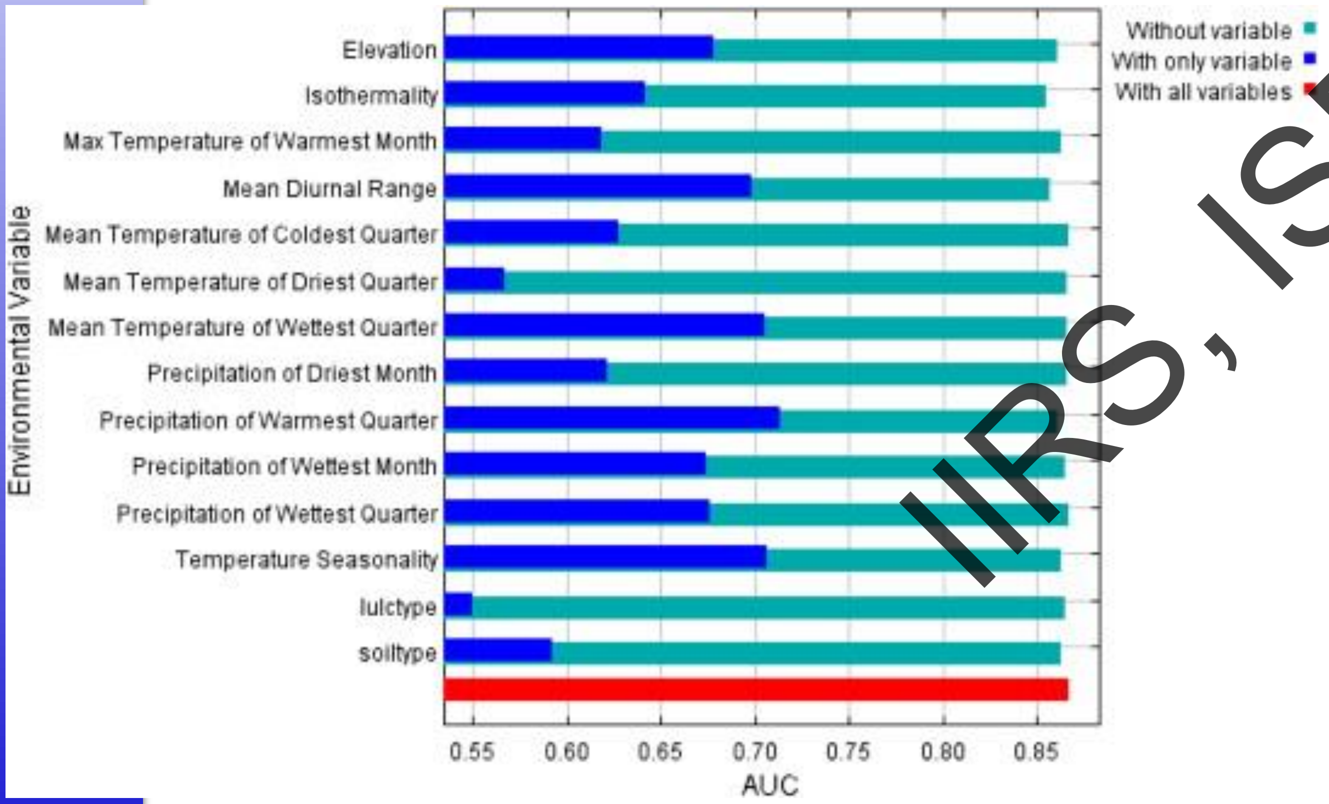
Response of Bushmint towards key environmental variables



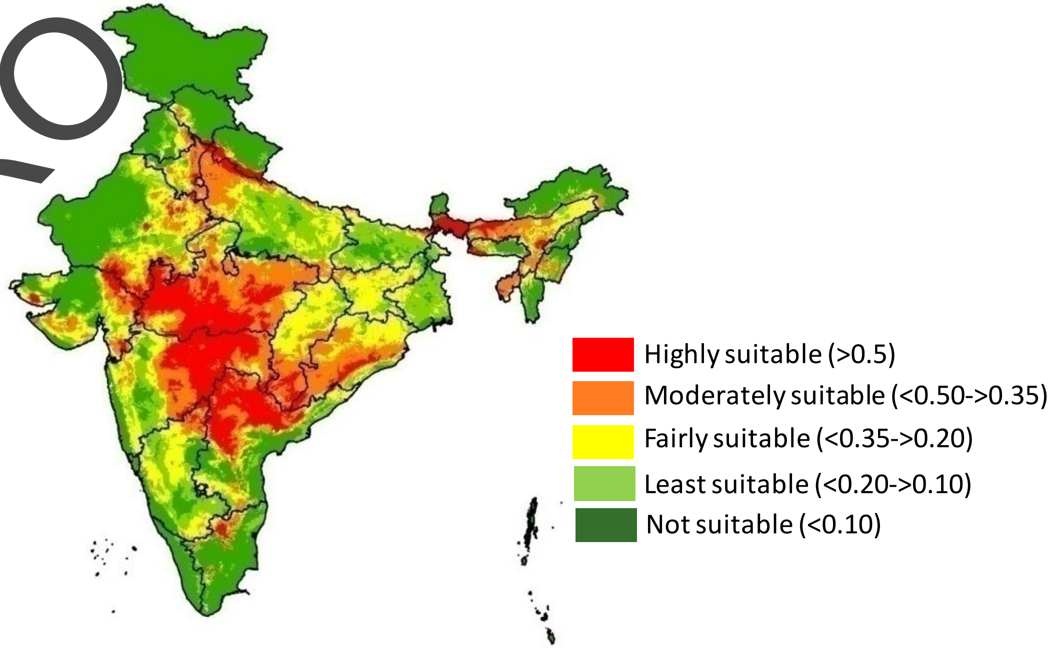
Mean response and ±1 SD calculated over 10 replicates.

Case study: Predicting Bushmint's Invasion Range in India

AUC Test Gain for different variables

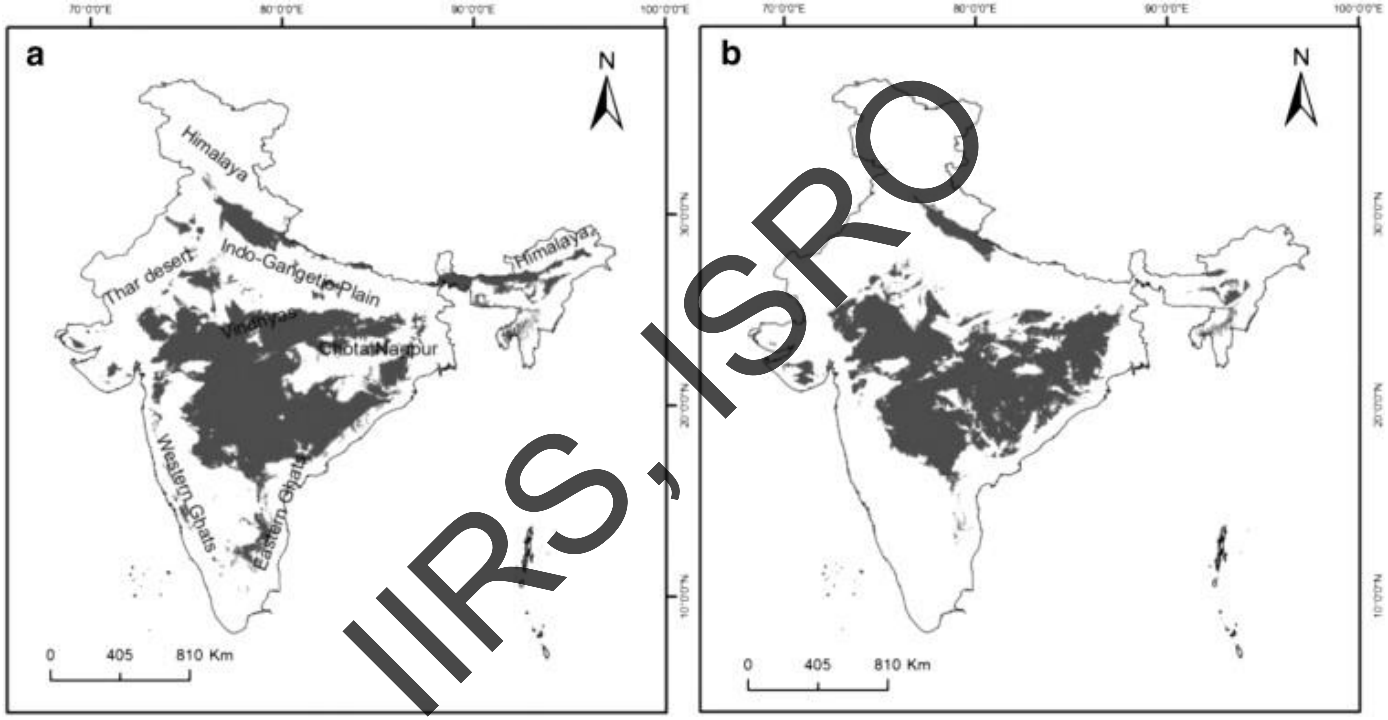


Jackknife test for AUC



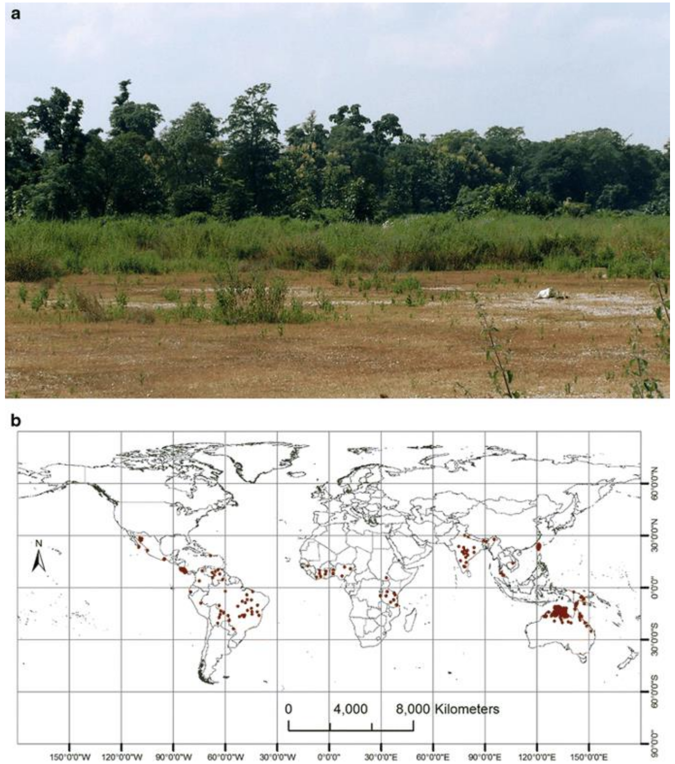
MaxEnt based probability distribution map of bushmint (Hyptis suaveolens) over India.

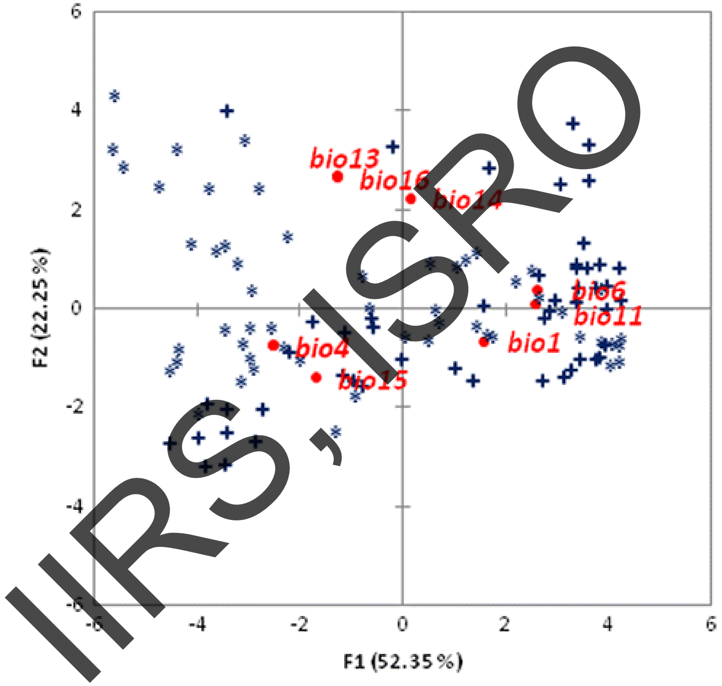
Comparison of MaxEnt and GARP Outputs

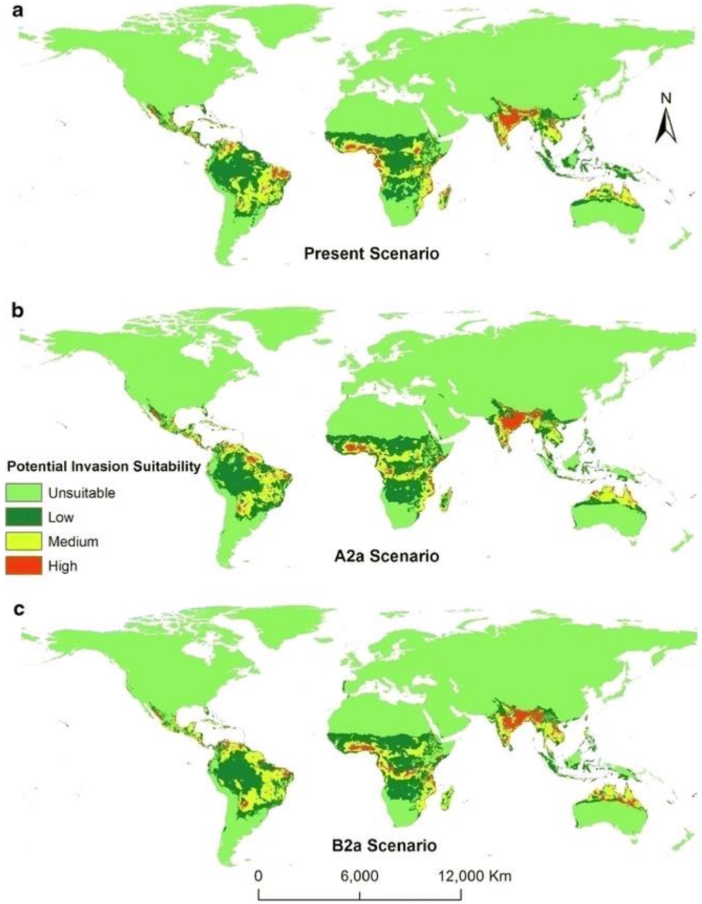


GARP had a relatively lower area under curve (AUC) score (AUC: 0.75), suggesting its lower ability in discriminating the suitable/unsuitable sites. MaxEnt performed better with an AUC value of 0.86.

Modeling potential invasion range of alien invasive species, *Hyptis suaveolens* (L.) Poit. in India: Comparison of MaxEnt and GARP (2014) Ecological Informatics,36-43
Hitendra Padalia, VivekSrivastava, S.P.S.Kushwaha Volume 22,







Plot of PC-1 and PC-2 scores of climatic profile of native and invaded sites of bushmint. The *plus* and *star symbol* in the plot represents bushmint's occurrence records from native and invaded populations respectively.

How climate change might influence the potential distribution of weed, bushmint (Hyptis suaveolens)? Hitendra Padalia, Vivek Srivastava & S. P. S. Kushwaha (2015) Environmental Monitoring and Assessment, 187, 2010

Considerations in Ecological Niche Modelling

1) All sampling data are incomplete and potentially biased;
   - Location data errors
   - Sampling prevalence and sample size
   - Spatial extent and background selection

2) No single model works best for all species, in all areas, at all spatial scales, and over time; and
   - No two models are the same
   - Species characteristics matter
   - Evaluation and calibration

Jarnevich et al., Ecological Informatics

Considerations in Ecological Niche Modelling

3) Predictor variables must capture distribution constraints
- Multi-collinearity
- Missing a key environmental layer

4) The results of species distribution models should be treated like a hypothesis to be tested and validated with additional sampling and modeling in an iterative process.
- Model interpretation
- Creating “yes/no” maps with thresholds

New trends in Ecological Niche based SDM

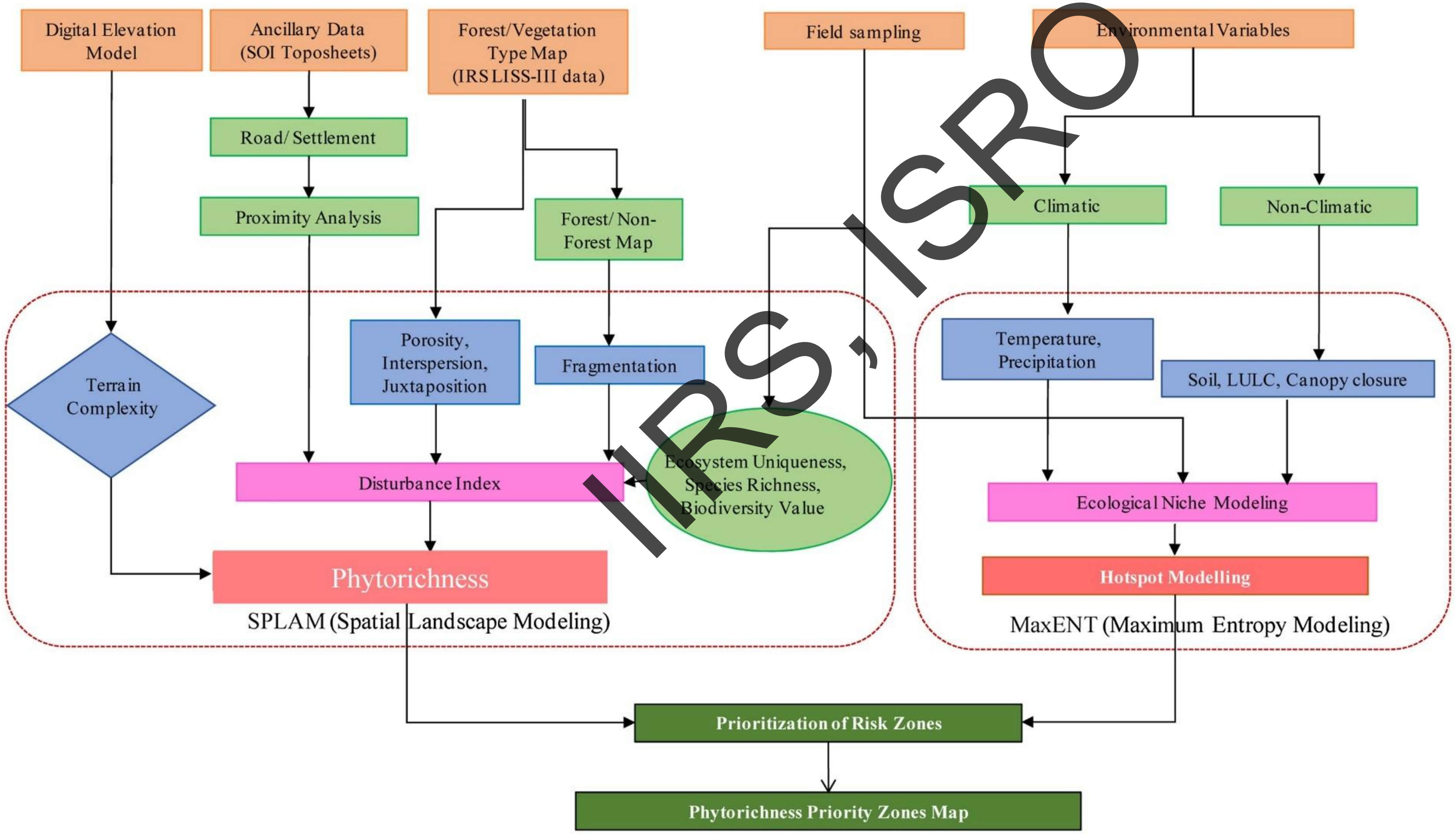
- Phylogeography and population dynamics of an endemic oak (*Quercus fabri* Hance) in subtropical China revealed by **molecular data and ecological niche modeling;**

- Evidence of **ecological niche shift** in Rhododendron ponticum (L.) in Britain: Hybridization as a possible cause of rapid niche expansion;

- Is there a correlation between **abundance and environmental suitability** derived from ecological niche modelling? A meta-analysis;

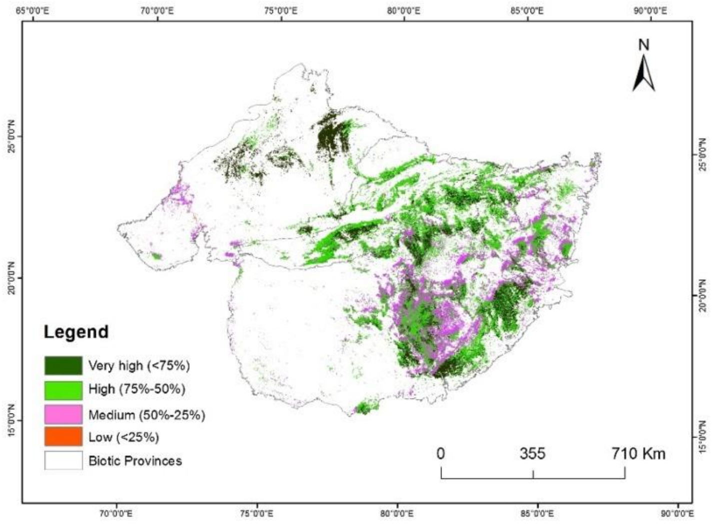
- Spatial modelling of **congruence of native biodiversity and potential hotspots of forest invasive species** (FIS) in central Indian landscape

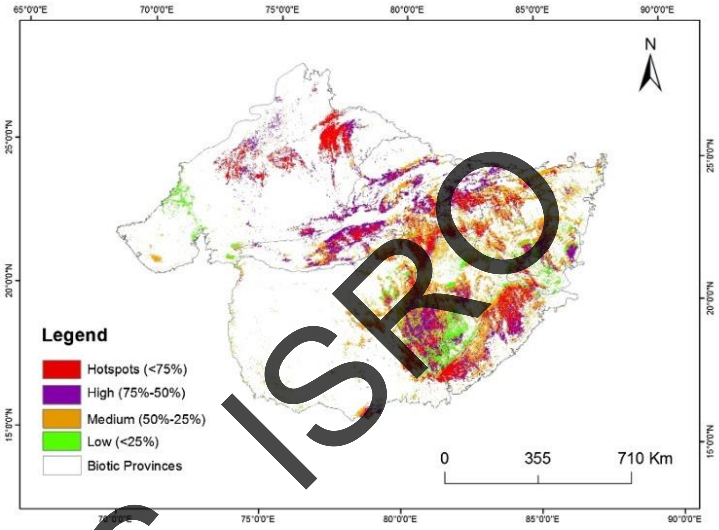
Spatial modelling of congruence of native biodiversity and potential hotspots of forest invasive species (FIS) in central Indian landscape

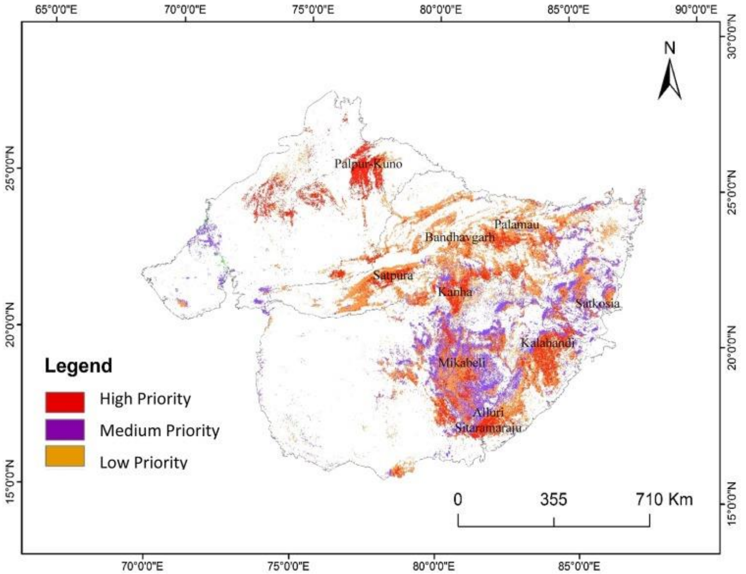


111 Forest Invasive Species (FIS) Invading Central Indian landscape were considered.

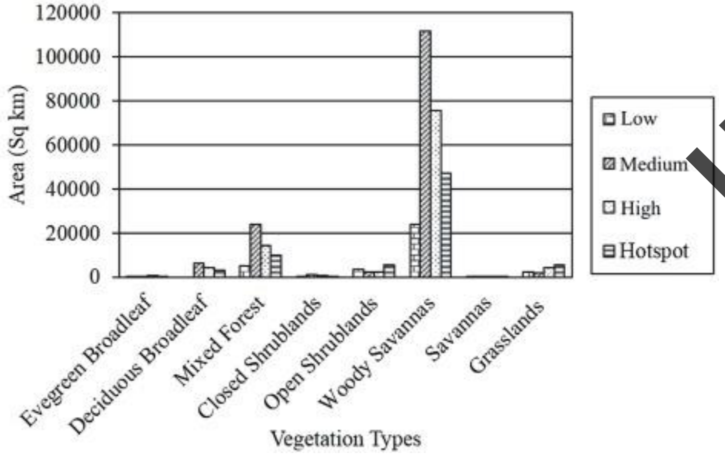
Spatial modelling of congruence of native biodiversity and potential hotspots of forest invasive species (FIS) in central Indian landscape

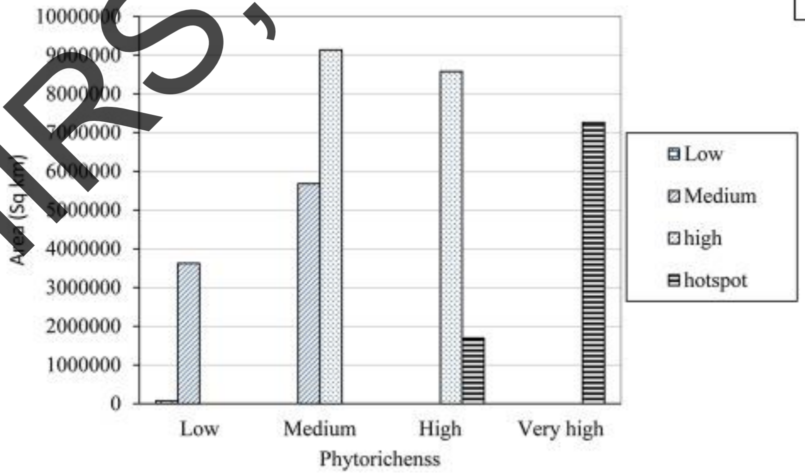






Priority zones for phytorichness conservation.

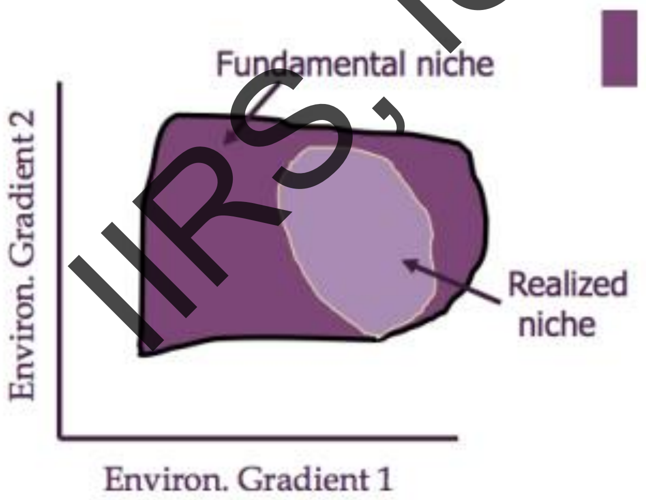




Spatial modelling of congruence of native biodiversity and potential hotspots of forest invasive species (FIS) in central Indian landscape (2017) Hitendra Padalia & Utsav Bahuguna, J. for Nature Conservation,36, 29-37

Constraints in Ecological Niche Based SDM

- ENM does not include biotic interactions (competition), dispersal and lag effects(e.g. invasive species).
- Extrapolation violates several statistical and ecological assumptions.



The relation between environmental gradients under ecological niche

Thank You

Contact Details of the Faculty:

Email- hitendra@iirs.gov.in
Tel-0135-2524170