Evaluating the effects of positioning errors on the accuracy of species distribution models using synthetic data

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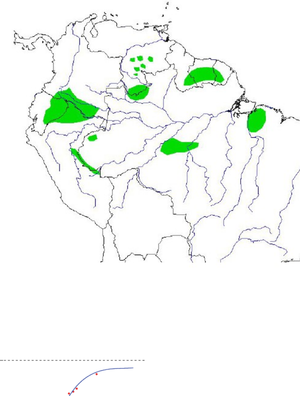
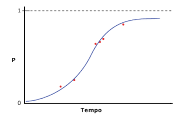
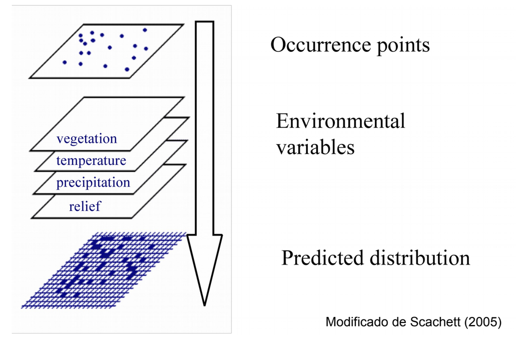
Introduction

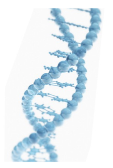
Biogeography is the science that attempts to document and understand the spatial patterns of biodiversity, studying the present and the past distributions of organisms.

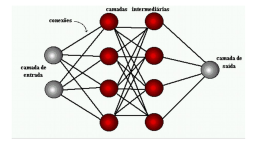


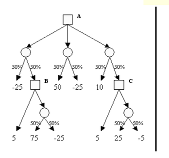
Species distribution models (SDM) estimates fundamental niche for a certain specie identifying and quantifying relationships between occurrence field data and environmental variables, through statistical, mathematical and data mining methods.









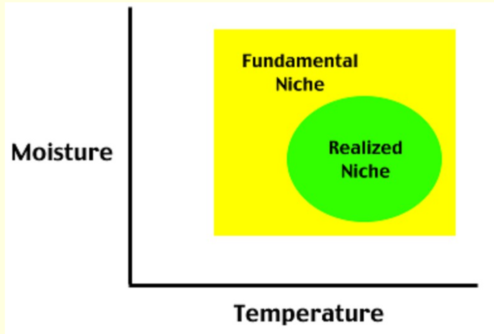


Niche concept

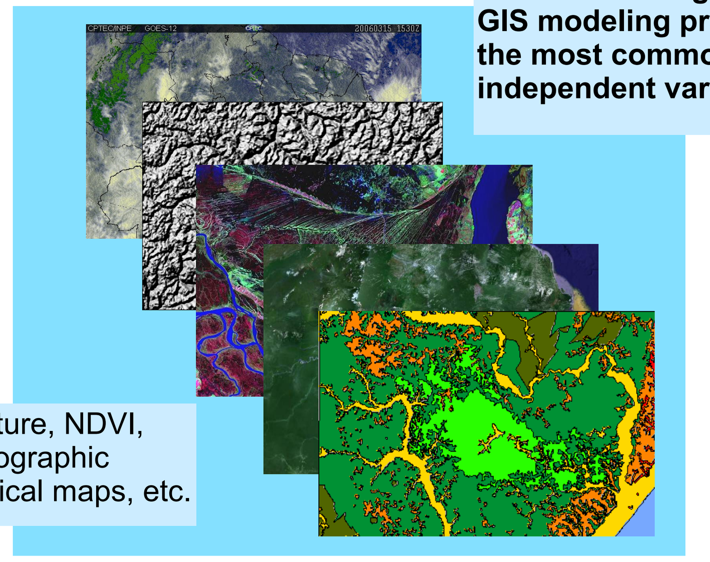
The term ecological niche was popularized by Hutchinson (1957), which states it as a hypervolume n-dimensional, where each dimension represents the interval conditions or the needed resources for certain specie.

For instance, the niche for a vegetal species could include the temperature interval, the luminosity intensity required for photosynthesis, moisture regime and minimum amount of nutrients in the soil.

Fundamental niche comprises the environmental interval conditions without considering the interspecific competition or predation. The **realized niche** consist the part of the fundamental niche where the species really occupies



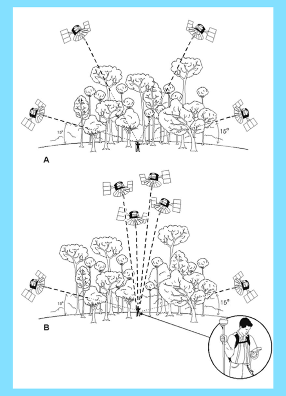
Remote sensing and GIS modeling provides the most common independent variables.



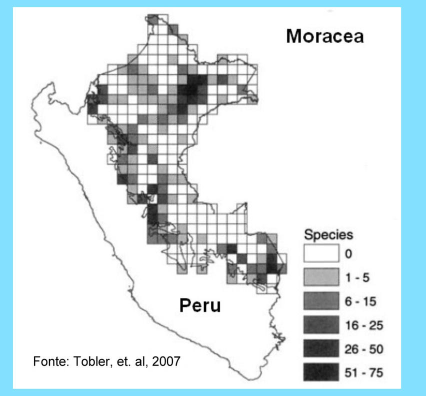
Surface temperature, NDVI, precipitation, topographic features, categorical maps, etc.

Common problems with data acquisition

Difficulties in receiving the digital signal under forest cover which contributes to site coordinates inaccuracies



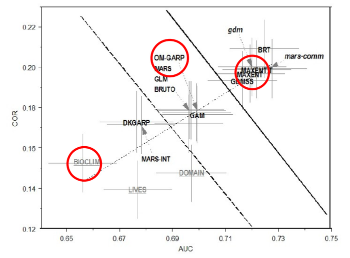
The majority of presence data, especially in tropical countries, are from herbariums and museum collections, which usually contain geographical positioning errors.



Cells with 0.5º of spatial resolution

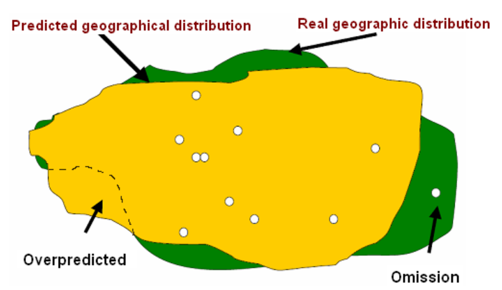
50% of the collection are within 9 cells

The aim of this study is to evaluate the sensibilities of SDM to positioning error using synthetic data. Three models from different categories were assessed, bioclimatic envelope, genetic algorithm and maximum entropy.



Source: Elith et al. (2006)

Model errors and performance measurements

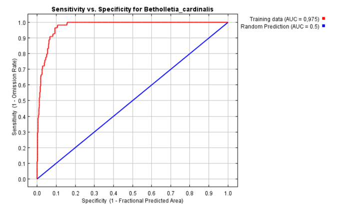


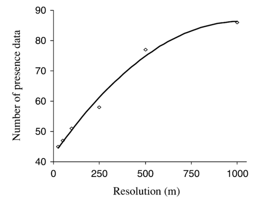
		Real +	Real -
Predicted	+	a	b
	-	c	d

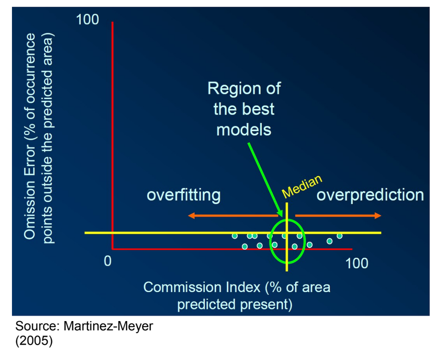
Comission errors (b); Omission errors (c)

Assessment measure	
Prevalence	(a + c) / N
Sensitivity	a / (a + c)
Specificity	d / (b + d)
False positive rate (commission)	b / (b + d)
False negative rate (omission)	c / (a + c)
Kappa index	$\frac{(a+d) - \frac{(a+c)(a+b)+(b+d)(c+d)}{N}}{N - \frac{(a+c)(a+b)+(b+d)(c+d)}{N}}$

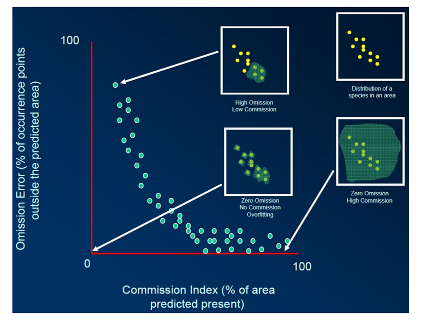
Source: (Fielding e Bell, 1997)

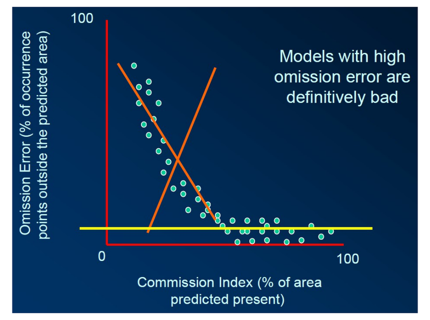






Source: Martinez-Meyer (2005)

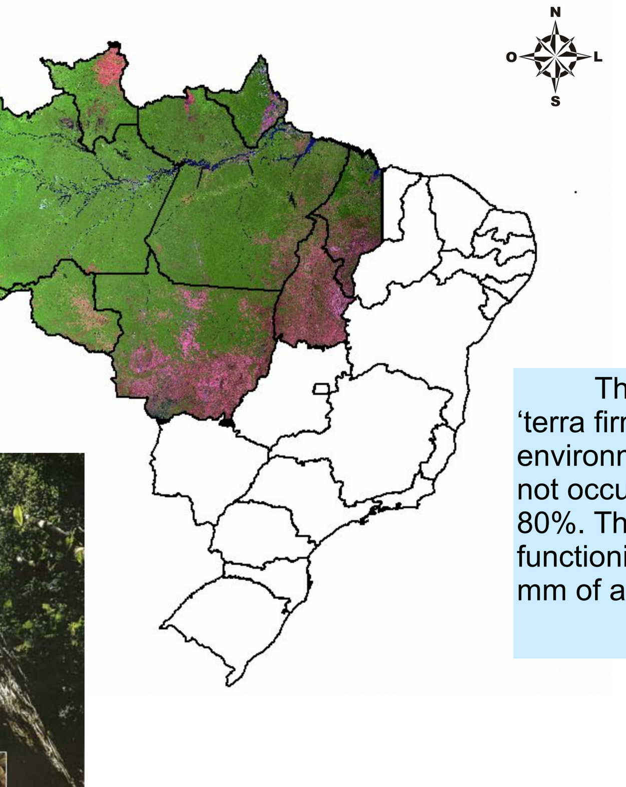




Some species are naturally rare. The number of samples may affect the models performance

Study area and dataset

The artificial specie was based on a real Amazon plant, the Brazilian nut tree (*Bertholettia excelsea*).

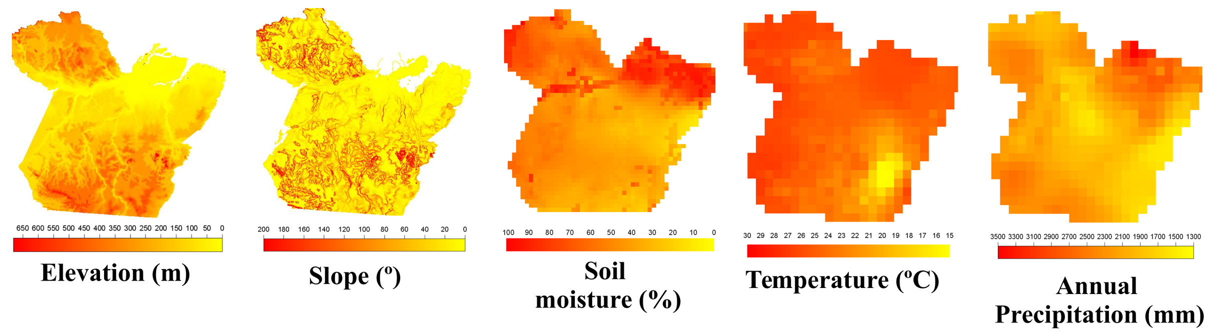


This virtual specie is found on cluster patterns, on 'terra firme' terrain, because does not tolerate acidic environments and saturated soils from floodplains. It does not occur on heights over 1600 m and slopes steeper than 80%. The temperature optimal range for physiological functioning is between 22ºC and 32ºC. It requires 1700 mm of annual precipitation and 10% to 65% soil moisture.

150 samples were generated

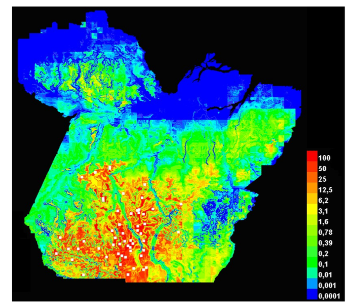
Divided into calibration (100) and validation (50)

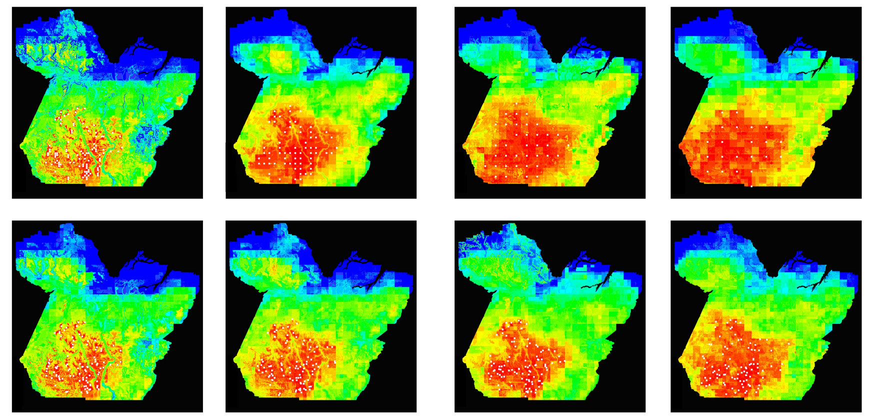
Predictive variables
Spatial resolution: 1 km, 25 km and 50 km



$$\Pr(X = x_k) = p_k \quad \text{for } k = 1, 2, \ldots$$

$$H(X) = -\sum_{k \geq 1} p_k \log p_k.$$





Samples will aggregated if they fall into the same cell, therefore, the number of samples will decrease, affecting SDM performance.

	Nº Samples
Training	100
10 km	100
0,25º	66
0,5º	39
1º	24

Omissão

	Bioclim Centroi d	Bioclim Polar	GARP Centroi d	GARP Polar	Maxent Centroi d	Maxent Polar
10 km	0	0	14,67	10,67	4,14	3,4
0,25º	0,67	0,61	4	3,33	5,52	4,76
0,5º	4	1,33	10,67	2	4,83	4,76
1º	6	2,11	6	4	2,07	2,04

Área mínima

	Bioclim Centroid	Bioclim Polar	GARP Centroid	GARP Polar	Maxent Centroid	Maxent Polar
10 km	7,45	8,24	20,2	21,08	3,23	2,68
0,25º	11	12,17	19,9	21,56	4,55	6,57
0,5º	10,05	12,57	19,61	22,47	5,31	8,38
1º	10,01	16,73	21,62	23,57	6,6	9,16

Kappa

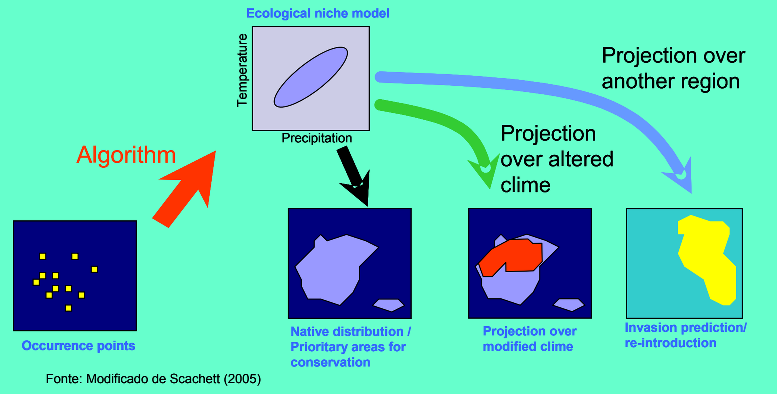
	Bioclim Centroid	Bioclim Polar	GARP Centroid	GARP Polar	Maxent Centroid	Maxent Polar
10 km	0,5036	0,4456	0,4121	0,4462	0,3994	0,4045
0,25º	0,3502	0,3474	0,3909	0,4053	0,3384	0,3442
0,5º	0,3051	0,3229	0,3841	0,3912	0,3381	0,3352
1º	0,2916	0,3004	0,3893	0,395	0,3304	0,3276

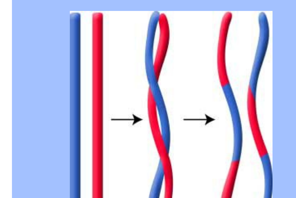
AUC

	Bioclim Centroid	Bioclim Polar	GARP Centroid	GARP Polar	Maxent Centroid	Maxent Polar
10 km	0,993	0,980	0,923	0,959	0,978	0,973
0,25º	0,975	0,979	0,912	0,941	0,933	0,964
0,5º	0,978	0,973	0,907	0,933	0,923	0,963
1º	0,925	0,955	0,893	0,925	0,936	0,944

Modeling fundamental niche

Bioclimatic envelopes



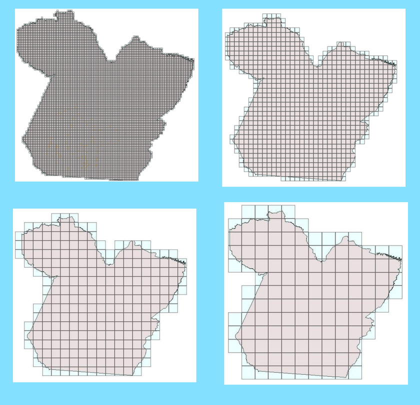


Genetic algorithms
GARP (Genetic Algorithm f

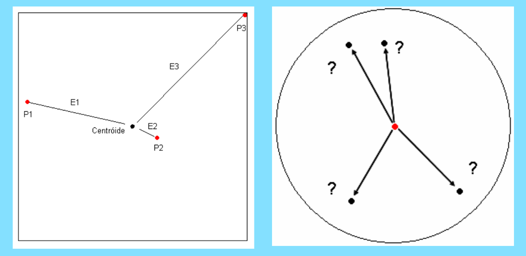
Parents chromosome	Children chromosome
110010101010100101	110010101010110110
101010001010011110110	101010001010011100101
10111010111000100101	10111000101000100100
11001000101000100100	11001010111000100101
11001110101011101101	11001110101001110110
10101000101001110110	10101000101011101101

'Children' chromosome	Chromosome (mutated)
110010101010110110	111010101010000101
10101000101001100101	10101000101001110110
10111000101000100100	11111010111000100101
11001010111000100101	11001100101000100100
11001110101001110110	11001110101001110110
10101000101011101101	10101000101011101111

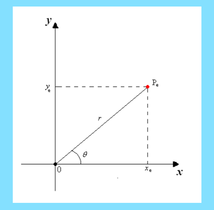
Positioning errors simulation



Coordinate displacements at four scales (10 km, 0.25º, 0.5º and 1º) were introduced using two methods: sample coordinates projection towards cellular center point, and errors with normal distribution in polar coordinates parameters.



The first approach reflected changes in grain size and is commonly adopted when dealing with herbarium and museum database, whereas the second approach simulated the problem in obtaining a GPS signal under the forest canopy



Conclusions

1. More than one measure is needed to evaluate the sensibility, each model performance varied according to the assessment metric and type of error (cellular center projection/polar parameters).
2. If the error are up to 10 km, it is possible to apply any of the models without bigger performance losses;
3. When the errors have unknown spatial scale and under the premise of errors with Gaussian distributions, it is advisable to use GARP-BS which can cope more noisy data