IDRISI Focus Paper

Species Distribution Modeling in IDRISI's Land Change Modeler

Most species distribution models are based on the concept of a species' niche, the multi-dimensional envelope of environmental conditions that define the range in which a species can persist. These models generate a representation of the relationship between the presence of a species and a set of environmental factors. They then extrapolate the relationship to other locations in order to create maps of habitat suitability or maps of the species' geographic ranges.

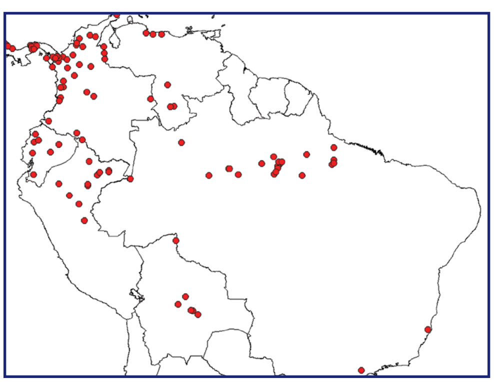
Such modeling is currently utilized in various application areas, for instance, to predict the impact of climate and environmental change on the distribution of organisms, conservation planning, and disease vector mapping. It has become an increasingly important tool for ecologists, environmental managers and planners.

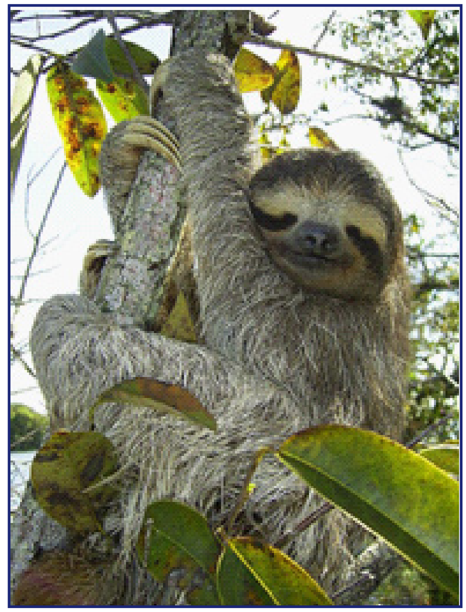
The Land Change Modeler, integrated within the IDRISI GIS and Image Processing system, features a comprehensive toolset for the analysis and exploration of the impacts of land change on biodiversity and conservation, including techniques for species distribution modeling based on the niche concept described above. With Land Change Modeler, one may develop habitat suitability and species distribution maps based on inputs of land cover, species data and environmental variables. This paper explores and provides an overview of the Mahalanobis Typicality algorithm, one of the many species distribution modeling techniques available within IDRISI.

SPECIES TRAINING AND ENVIRONMENTAL VARIABLE DATA

The species observation data, also referred to as the *training* data, will inform your choice of modeling technique. Such data is categorized as presence, presence/absence, or abundance. IDRISI also allows for species distribution modeling based on no training data, and in this case produces a theoretical model.

Presence data includes samples of locations where species are known to inhabit, presence/absence data includes samples of locations they are known to inhabit and not inhabit, and abundance data includes the numbers of species found at each location. Species data such as these can be found at a variety of online sites, for instance, the Global Biodiversity Information Facility (www.gbif.org) or HerpNET (www.herpnet.org). For our case study, we downloaded presence data of the Brown-Throated Sloth (*Bradypus variegatus*) from GBIF, containing only those records with geographic coordinates.





Empirical models relate the actual observations of the organism to the set of environmental conditions at that location. We therefore need to identify those environmental factors we believe may impact the persistence or range of the particular species. In IDRISI, these are termed the environmental variable maps. Variables usually relate to the seasonal and interannual availability of energy and water. One might include elevation and slope (because of their relationship to temperature and soil moisture), the first and second principal components of mean monthly Normalized Difference Vegetation Index (NDVI) imagery (as a statement of realized long term and seasonal growing conditions), the long term coefficient of variability in NDVI (as a statement of interannual variability), and the first two components of mean monthly precipitation and temperature.

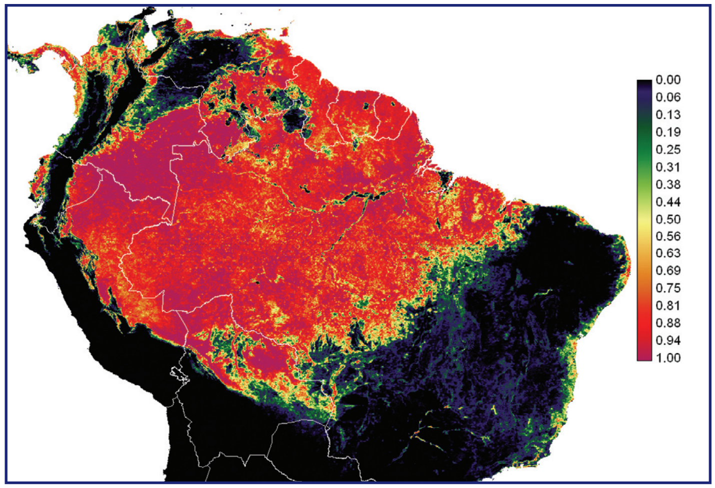
For our purposes, we chose annual mean temperature, temperature annual range, mean temperature of the coldest month (derived from MODIS land surface temperature), and elevation from SRTM (http://vterrain.org/elevation/SRTM/) as the environmental variables for modeling.

MODELING ALGORITHM

IDRISI provides a variety of both theoretical and empirical approaches for modeling habitat suitability and species distribution. Since we have presence data only, we are using the Mahalanobis Typicality technique. This algorithm assumes that the underlying species distribution is normal with respect to environmental gradients. The output is a typicality probabilities map with values ranging from zero to one which expresses how typical the pixel is of the examples on which it was trained. Thus a value of 1.0 would indicate a location with environmental conditions identical to the mean of environmental conditions in the training data. Values approach zero as conditions become more dissimilar to the observed mean. Any value greater than zero has some similarity to the training data.

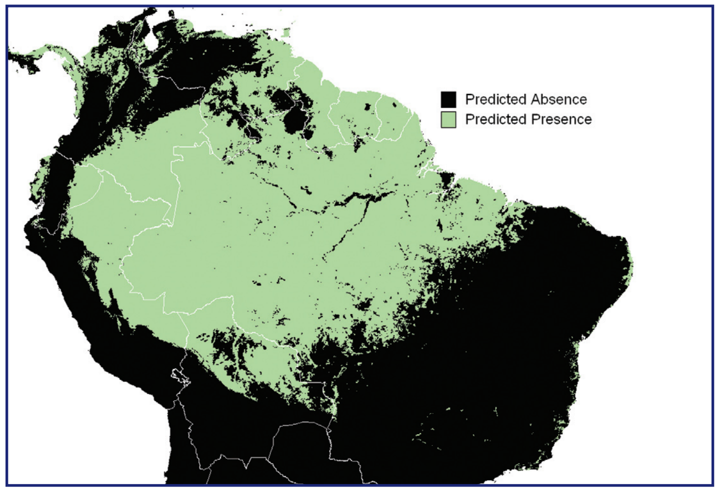
CASE STUDY: MODELING THE BROWN-THROATED SLOTH

The Brown-Throated Sloth (*Bradypus variegatus*) is an arboreal species distributed over Central America and Northern and Central South America. Because of its wide distribution and presumably large population, IUCN reports this species as one of least concern. Utilizing the data mentioned above, we ran the Mahalanobis Typicality modeling algorithm within Land Change Modeler (Implications tab, Habitat Suitability/Species Distribution panel) to generate our typicality map (first image on right).



The output typicality image represents how typical the environmental conditions are at any pixel to the environmental conditions found at the sample points in the training data. To develop a predicted range map from this output, we needed to refine the data by thresholding the typicalities with the RECLASS module.

The threshold specifies which typicality values will be considered part of the species range. As stated above, only typicalities equal to zero represent dissimilar conditions, and therefore any value above zero could be indicated. We advise experimenting with the threshold as there is no single method to define it. One way to approach this decision is to leave out of the analysis some of the independent observation data in order to select the threshold that maximizes the correct characterization of those points. In our case, we considered the species to be present in all locations with typicalities greater or equal to 0.5, and absent from all other locations, and generated our range map.



The output range map for *B. variegatus* (second image on right) produced here predicts the species to be present north of the Amazon and east of the Rio Negro. However, *B. variegatus* does not inhabit these regions. Although all locations inside the predicted range have suitable environmental conditions to host the species, not all of them are part of its realized niche. Indeed, these locations correspond to another species of sloth, *B. tridactilus*, with a range that does not overlap with that of *B. variegatus*.

This raises an important consideration when modeling species distribution. The geographic range of the species could represent either the fundamental (or potential) niche or the realized niche. The fundamental niche of the species represents the full range of environmental conditions under which the species can exist. However, pressure from species interactions may cause species to occupy just one portion of their fundamental niche. This smaller range is called the realized niche.

The output range map produced here represents the potential or fundamental species niche, not the realized niche. Factors such as competition with the other species of sloth may be constraining the species to occupy only part of the fundamental niche. Caution, therefore, must always be used when interpreting the modeled geographic range.

Species distribution modeling presents great potential in conservation planning efforts. Such modeling can be used as the basis for determining conservation sites, generating corridors, or calculating biodiversity measures, all of which can be accomplished with Land Change Modeler.

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