MADAGASCAR DISSERTATION/THESIS PROJECT

MA62 - Landscape ecology in Madagascar

Landscape ecology basically concerns looking at patterns in the environment and inferring the ecological processes which produced these patterns. It's therefore a very broad topic which gives you lots of scope to choose a pattern that you would like to investigate, develop a conceptual model of how the environment might be working and select some potential processes to test.

In the Mahamavo dry forest and wetland complex in Western Madagascar, there are basically two main ways to approach a dissertation on landscape ecology.

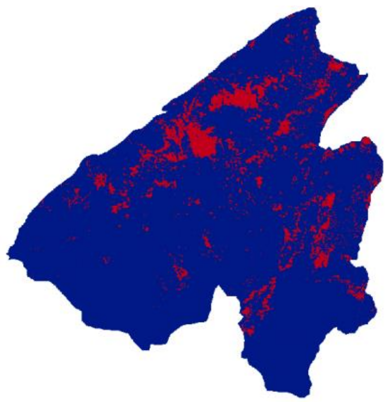
- select a group of organisms (flowering plants, forest birds, wetland birds, mammals or reptiles and amphibians) and investigate how each of the species in that group responds to the configuration of the landscape.
- select an environmental process such as fire or deforestation and investigate why it occurs where it does and investigate how the process affects the landscape.

<u>Organisms and response to landscape configuration</u>

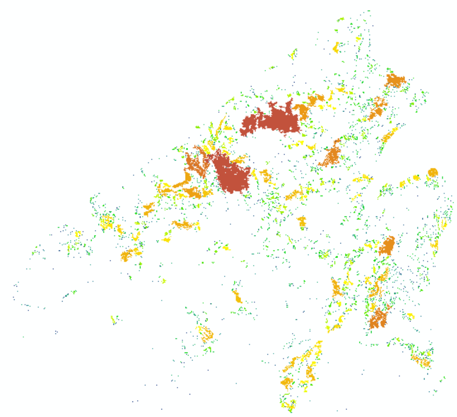
When you look at the maps of the field site you can see that the environment is patchy. There are lots of forest patches in Mahamavo which differ in shape, compactness, fragmentation, connectivity etc. Some species will perceive the environment as a set of patches, others as a continuum. Some species are widespread, whereas others are rare and only found in certain parts of the landscape. Area effects and landscape configuration may explain this variation.

If you decide to take this general approach, you need to choose a taxonomic group to study (plants, forest birds, wetland birds, herps, mammals), join the field science teams to contribute to data collection during the field season on the sample routes and opportunistically in other places (especially smaller forest fragments). You then return to base camp and query the database records from 2009 to 2014 and GIS datasets to produce a massive table of data to analyse. Then build some models to test the sensitivity of each plant/reptile/bird/lemur species to landscape configuration. Identify which species are area sensitive, edge sensitive, connectivity sensitive. The results from this would be useful for conservation planning, prioritisation and inform land management e.g. identifying optimal places for reforestation.

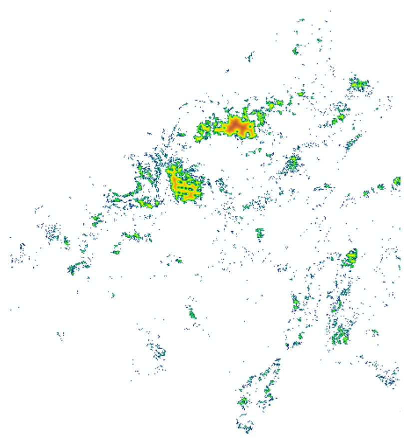
Here are some maps of 2011 landscape configuration covariates derived from a map of forest patches. The first map was made by classifying a 30m Landsat image acquired in June 2011 to forest non-forest. (Note that if you want to study wetland birds, it's possible to do a similar thing with a wetland / non-wetland classification). To account for the dynamic nature of the landscape, these maps are prepared afresh every year. Next it is possible to calculate and map forest patch area, the distance of every forested pixel from the forest edge, compactness, and the distance to the edge of the nearest neighbouring forest patch (a measure of isolation).



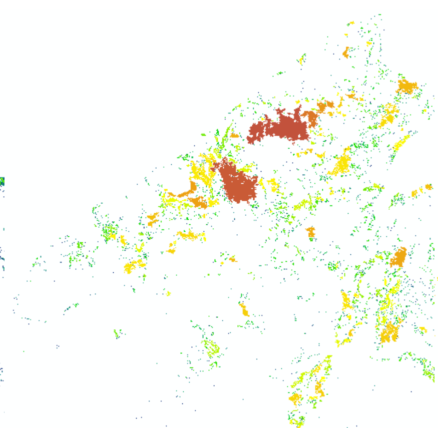
forest / non-forest



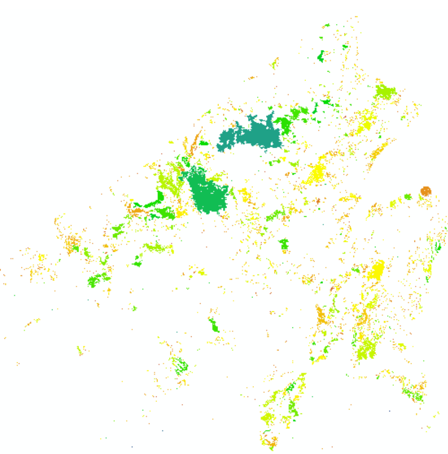
patch area



edge distance



perimeter:area



isolation

N.B. can be made into a patch level covariate by calculating a zonal statistic. Median is probably best

All colour ramps go from red = high to blue = low

Please note that it is also possible to produce maps of the same covariates derived from 300m resolution data from the MERIS instrument on ENVISAT if you want to investigate the effect of covariate scale on the landscape responses. You might recall that landscape features, classic example is coastlines, have fractal geometry and that the answer you get depends on the scale at which you measure.

You might want to overlay all the unique spatial records for species within a given group with these (or other additional configuration maps) in a similar way to the first stages of making a distribution model. You could then just perform regression on this table. However, this is not recommended.
If you want to robustly test whether a species responds to a configuration metric, it is necessary to firstly ensure that the sample units you choose have been sufficiently well sampled that you can be confident of having true absence data (rather than concluding that a species doesn't like a particular kind of forest patch just because you haven't looked hard enough). Occupancy modeling on detection histories to generate an estimate of occupancy rather than naïve observed presence/absence helps with this issue. The second problem is that it is important that if the sample units are forest patches, you must aggregate the presence/absence data to the level of the patch, as otherwise if just the raw records (potentially containing many presences per patch) are used then there will be pseudo-replication which wrecks your ability to draw valid inference.

This gets you a table like this:

Patch	sp 1	sp 2	sp 3	sp n	area (m2)	P:A ratio (dimensionless)	median edge dist (m)	Isolation (m)
1	0 /1							
2								
3								
n								

Now you can legitimately do a multiple linear regression, or something more sophisticated like a regression tree.

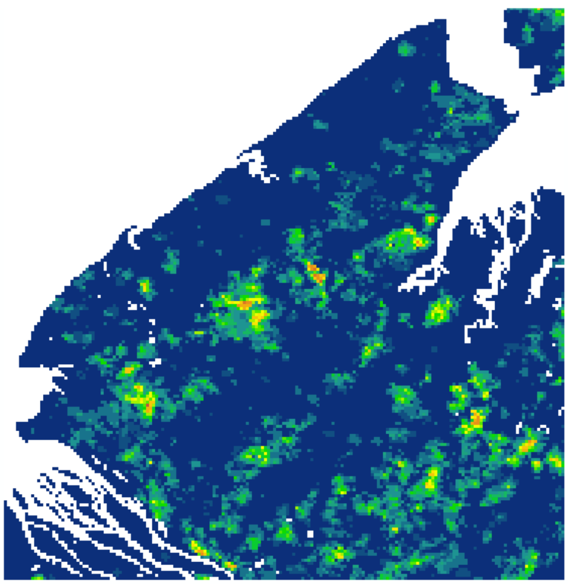
At this stage, you will find that some species in a group have no response to landscape pattern, whereas others have a significant edge, area, compactness, or isolation sensitivity. You might then investigate this further with respect to ecological or life-history attributes of the species. For example, you might study 60 species of forest birds and tabulate significant responses or even beta parameters and then develop some hypotheses about why species might respond to the landscape and collect relevant covariates. Eg for bird species you might collect from literature data on body mass, wing areas, diet, family in order to test things like whether larger birds would only be able to persist in larger patches or that only species with strong wing-loading would be able to disperse well or that birds of prey need large patches.

Environmental processes

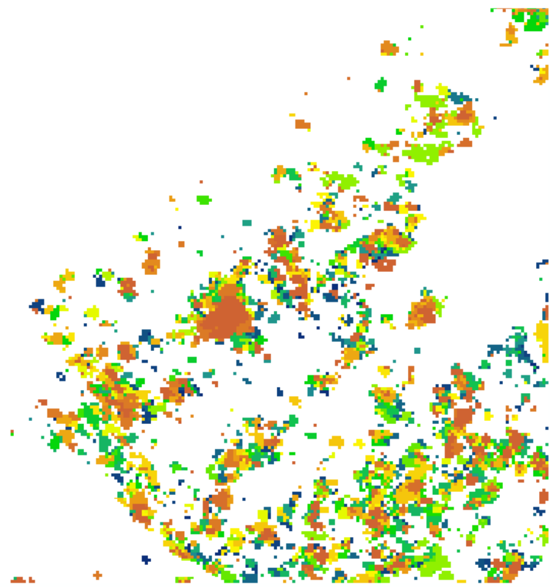
The alternative approach to landscape ecology is to directly consider the relationships between different landscape patterns. In principle, it is not necessary to do fieldwork to undertake this kind of analysis as all the data will typically be derived from remote sensing and other spatial datasets. However, experience has suggested that it is much easier to generate hypotheses and correctly interpret spatial data when one makes field visits to the study landscape. This typically involves walking around the forest, savannahs and wetlands with printed maps of various derived remote sensing products such as burn history maps in order to fully understand them.

Fires

Here's an example derived from a time series of the MOD45A1 monthly burned areas product at 500m resolution.



Number of months in which burning occurred during the period 2000-2011. Blue = 0, Red =17



Time (months) since the last burning occurred Red=1, Blue=132.

You might use these patterns of fire frequency and interval since the last fire in combination with other data sets such as time series of land cover classifications and maps of other relevant factors such as climate, water availability, soils etc to explore how the fire regime affects vegetation succession in order to ask whether frequent burning of savannah (to provide green grass for cattle during the dry season) is inhibiting forest regeneration.

Climate

Another way to use this kind of landscape approach would be to investigate likely climate change impacts on dry forests. Western Madagascar is predicted to get hotter and drier in the future, although the effects will be somewhat buffered by the Indian ocean, so impacts may be smaller than in

continental regions. Here's an interesting question: under the climate change scenarios predicted to 2020, 2050 and 2080 under the A2A and B2B CO2e emission scenarios by the Hadley models, how will the predicted changes to precipitation and temperature regimes in the Mahamavo watershed affect the forests here?
Getting the 1km gridded current climate data and climate data in future modelled scenarios is very straightforward. The tricky bit is then identifying the bioclimte envelope conditions that currently support Madagascar western dry forest and then asking where these conditions will still exist in Madagascar in 10, 40 and 70 years time.
You could apporach this by resampling the digital data from the Moat and Smith (2007) Landcover classification or using the GLOBCOVER classification or the MODIS land cover class products and coupling this with the Hijmans (2005) WORLDCLIM current climatology data to derive an envelope and then mapping that envelope with the future offsetted climate data from the Hadley model outputs and seeing how much they overlap in space. Ie where will forest be lost, where could it persist, where might become suitable. This approach ignores the effects of human land cover change ie deforestation and the rates at which forests can disperse. A more sophisticated approach to assessing climate change impacts in Mahamavo might be to make some RS parameterized physical distributed hydrological models for the watershed. You may also wish to explore scaling of these processes using finer resolution RS data such as Landsat data or multi-sensor fused data.

Erosion

Forests provide an important function in slowing water run-off in the wet season and preventing soil erosion. The vertisols in Mahamavo are very fragile and thin soils. It would be really neat to use the revised universal soil loss equation to evaluate the difference to soil conservation that historical forest loss has caused and evaluate whether soil loss is inhibiting forest regeneration in savannah areas.

Land cover change

The Mahamavo landscape is very dynamic. There is an excellent, long-term RS archive. It is possible to generate a time series of either MODIS or Landsat land cover class. This data permits you to ask why land cover changes in the past (especially forest loss, regeneration) occurred in the locations that they did by constructing a statistical model of transition probabilities in time periods as a function of landscape covariates. Such a modeling exercise would permit different hypotheses for landscape change to be distinguished eg deforestation , drought etc. It is also possible to use Markov chains and or cellular automata to forecast the future landscape configuration.

<u>Further Reading</u>
NB. The best book to start with is definitely Turner et al.

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A, (2005) Very high resolution interpolated climate surfaces for global land areas. International Journal of Climatology 25, 1965-1978

Kull KA (2006) Isle of fire: the poltical ecology of landscape burning in Madagascar. Chicago

Lindenmeyer DB (2010) Large-scale landscape ecology lessons from Tumut. Cambridge.

Lindenmeyer & Hobbs (2007) Managing and designing landscapes for conservation. Blackwell.

Moat J, Smith P (2007) Atlas of the vegetation of Madagascar. Kew

McGarigal, K., S.A. Cushman, M.C. Neel and E. Ene. (2002) FRAGSTATS: Spatial pattern analysis program for categorical maps. Computer software program produced by the authors at the University of Massachusetts, Amherst. http://www.umass.edu/landeco/research/fragstats/fragstats.html.

Newton AC (2007) Forest ecology and conservation: a handbook of techniques. Oxford.

Turner MG, Gardner RH, O'Neill RV (2003) Landscape ecology in theory and practice: pattern and process. Springer

MODIS land product algorithm theoretical basis documents (ATBDs) website
http://modis.gsfc.nasa.gov/data/atbd/land_atbd.php

FAO ECVs website
http://www.fao.org/gtos/topcECV.html