ICIMOD

Introduction to
Corridors, Connectivity
and Linkage Mapping

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Goals and End-user needs

Geog and Dzongkhag eco-tourism growth planning

DOFPS to support forest and protected area management planning

Roads, communication and hydropower agencies investing in infrastructure with least disruption to habitats and ecosystems

Land agencies to identify priority easement or acquisition

Communities in securing livelihood without causing HWC and loss of naturalness

Other state and non-state organizations advocating and implementing biodiversity conservation, ecosystem integrity and environment

Step 1: Framing the Question - Project Scoping.

Step 2: Building Blocks - Connectivity Model Inputs.

Step 3: Button Pushing - Running the Model.

Step 4: Post-Production - Refining Model Outputs.

Step 5: So What? - Model Results and How To Use Them.

To Answer the following questions:

What aspect(s) of ecology do we need to understand?

What are the critical patches in our ecological landscape?

How are those patches interconnected across our area of interest?

Step 1: Framing the Question: Scope and Articulate

Ecological connectivity as a local and larger conservation priority

Different context for different interest groups and at different scales in space and time

Understand this context, identify stakeholders, project partners, and align expectations of all

Discuss the specific goals and anticipated outcomes of the connectivity

What decisions will be informed by the connectivity assessment?

Who will be making these decisions?

What do they need from you?

Connectivity for what?
- Structural connectivity for contiguity and connections between important blocks of landscape
- functional connectivity for ecological functions of a species, group of species, or ecological process
  - what species, functions, and movements need to be represented?
- What elements of the landscape are critical to specific type of connectivity

Step 1: Framing the Question: Scope and Articulate: Contd.

What is the area of interest for connectivity

Spatial extent (national, sub-regional or regional scale?)

What Outputs are Required?
- What products are expected from connectivity modeling efforts?

How will model results be communicated, and to whom?
- maps depicting connectivity,
- discrete connectivity zones (i.e. polygons),
- continuous surfaces showing graduated connectivity metrics?
- Or are both types of outputs?

What other layers to consider or analyze with connectivity model outputs?

How will these outputs inform discussions and improve decisions on land use and conservation planning?

Step 2: Building Blocks – Connectivity Model Inputs

Clearly define study area boundary

Define the appropriate spatial extent of analysis

Buffer study area to address problems arising from edge effect
- HCA can be limited to the spatial extent of AOI;
- resistance surface must include the entire buffered area.

Habitat blocks, core areas, resource patches - Circuitscape calls them "focal nodes".
- Already identified or designated for their ecological significance (e.g. national parks, protected areas, wildlife sanctuary, nature reserves, etc)

Resistance Surface or "friction surface" raster representing relative ease or difficulty to pass through any given pixel
- Combine several input layers of landscape metrics into a composite index.
- Human Footprint Data- Assign resistance scores to different footprint types based on consensus, expert opinion, published literature, or dedicated study
- Land Cover-Assign resistance scores to land cover types, distance, density, edges
- Topography-Related Metrics-slope, aspect, landform, curvature, terrain ruggedness, or wetness.
- Wildlife Habitat, species distribution, movement, dispersal datasets

Converting input layers to resistance surface

Determine values in an input layer representing range of resistance to connectivity

Assign resistance values to input layer values

Assign resistance values to each discrete value

Linear transform continuous values to fit values into standardized resistance range

Weight each rescaled input layer, then combine them together:
- Resistance = {(w1 * [input 1]) + (w2 * [input 2]) + ... + (wn * [input n])} / 100
- for n input layers, where
- -- w is the weight assigned to each input layer, and
- -- [input #] is the input layer (in raster format)
- NOTE: all w values must add up to 100.

Habitat Suitability Modeling

- Quality of habitat
- As cost-layer for least-cost path
- Relates suitability to factors (landuse/cover, elevation, topo, distance to stream, road, house, soil, etc); resolution & source of data

Literature-based – suitability score

Rule-based – factor weights & class scores combine using additive and geometric means

Empirical/statistical – presence/absence, abundance data; relate to habitat factors (GLM,GAM), ANN, CARTs, GA to depict probability of occurrences; need good set of field observations, time consuming

ethics:

- Honesty, credibility
- Sensitivity analysis by changing assumptions on input data and model structure
- Reliable GIS coverage of features and factors/classes
- Redundancy, correlated variables

Assumption:

- Animals prefer to move across landscape using the same rules used to select habitat (food, water, shelter/protection, reproductive opportunities)

Habitat factors and metrics

Categorical and categorize continuous factors (slope, elevation, topo-features, aspect, distance from… , etc)

Fewer categories/classes based on biological/ecological understanding

Resolution and source of data, classification accuracy, etc

Domain expertise on factor weights, spatial scope and size for eating, resting, breeding habits/behaviors, etc

Modeling habitat patches/blocks

Cluster of raster pixels good enough, big enough, close enough to support survival and breeding (determined by moving windows size reflecting neighborhood, sufficient resources, threshold area and habitat quality to support sustenance and breeding)

Habitat patches used as start and end-points of corridors, stepping-stones in the matrix

In this present context, conserved areas, protected areas, sanctuaries, CFs, reserved forests, sacred are considered habitat blocks

Linkage design

Union of single-species corridors constitute the preliminary linkage design

Tweak design to accommodate more focal species not modeled, buffer against edge effects (300m), remove areas likely to increase financial costs at diminishing marginal ecological utility

Recommend measures to mitigate barriers and effectively manage linkage

Consider including additional habitat patches

Overlay known species occurrence map and seek expert advise

Buffer perennial waters (100m)

Resilience to impacts of climate change

Mull over other aspects of linkage design; modeling only leverages scientific knowledge – functional corridors should emerge out of continuous refinement often harnessing subjective/qualitative intelligence

Step 4: Post-Production – Refining Model Outputs

locate the output files in the folder specified in the "Base output file name" text box

- cumulative current map – basemap for all results spatial data layers
- log file – information about modeling results, errors or failures

Prepare the data for the manipulation, analysis, and mapping:

Quality control – inspect log files for reported errors, open cum.current map in GIS for quick scan whether the output is realistic

Clip to study area-to remove the buffered area

Document the workflow process to generate data and map products with a list of inputs, assumptions, intended uses, limitations, outputs, and anticipated (or suggested) future improvements

Understandable and reproducible for validation and results verification

Present, Deliver and Inspire decision-making

Map the continuous connectivity surface, clipped to your study area in a way that shows the differences high connectivity regions, and regions with moderate, low, or no connectivity. Display connectivity as some form of "heat map", where graduated colors intuitively represent different levels of current/movement across the landscape (e.g. graduated from blue for "cool" or low-connectivity values, to red for "hot" or high connectivity values). This allows audience to understand the full representation of connectivity across the entire landscape: from narrow, focused regions of movement to broader, more diffuse regions, and everything in between.

Map discrete "zones" of connectivity: the realities decision-making often dictate a need for clear lines to be drawn on a map. For such instances, it may be useful to extract and delineate the highest connectivity regions within your study area. You can achieve this by analyzing the histogram of your cumulative current raster values, setting an appropriate threshold, and reclassifying your data. You can also identify "areas of high connectivity" in a binary fashion - that is, pick a single threshold, above which values are "in" and below which they are "out." Alternatively, you may wish to classify your image into connectivity classes - "high/moderate/low", "high/higher/highest", and so on.

Change detection and other overlays: detect change by running your connectivity model for "before" and "after" scenarios (make sure you don't change the model settings in Circuitscape between runs), and then subtracting one raster from the other to identify areas of change. Discrete "connectivity zone" can be compared similarly for areas of overlap, agreement, and discordance.

Also compare connectivity from different model runs for range of ecological phenomena

Step 5: Model Results and How to Use Them

Produce meaningful and understandable results connectivity models and data

Compile a brief summary of modeling results, their general interpretation pertinent to questions in Step 1. for both technical and less technically inclined people

Present the results of work to stakeholders, project partners, and end-users (identified in Step 1) of the connectivity maps.

Share preliminary impressions, initiate discussion in view of the new perspective acquired from the results presentation

Review, Validate, Interpret, Summarize and Use Results

Articulated a vision for the connectivity modeling work that guided your efforts throughout all subsequent steps. With the modeled connectivity for your study area, find answers to the following questions?

How can you use this new understanding of your landscape?

How can the decision makers involved or interested in your work use this information to better inform the conservation and land use planning discussions that need to consider connectivity?

How can you present and illustrate the results of all of your hard work in the most effective and impactful way possible?

Closing Thoughts/Reflections

There are an infinite ways to define, measure, and map connectivity, with countless different approaches and software platforms. Not one of them is the universally right approach, and none will guarantee the ideal answer to every question, every time.

A great deal of thought is required at the outset of a connectivity research project, to ensure that objectives are clear, methods are transparent and appropriate to the goals, and expectations are aligned across stakeholders.

Connectivity modeling is a time- and labor-intensive process. Before initiating a project you should make sure you have the required capacity to see the project through.

It is absolutely essential that you have detailed documentation of the process followed. This information is as important as the model results themselves.

Lots of different ways to present connectivity model results. The "right way" depends on the bigger discussion that improved knowledge of connectivity is informing, and the target audience you're trying to reach.

Connectivity modeling is an evolving practice, and the tools and approaches suggested here will eventually be replaced by new methods, approaches and programs.

Getting started is the most difficult part - we have done that. The next step is to grow a supportive community of practice as a forum for sharing ideas, best practices, and results.

Connectivity Modeling Cheat-sheet

Reference:

Greg Chernoff (2016). A Guide to Using Ecological Connectivity Modelling in Municipal Planning

Miistakis Institute

CONNECTIVITY MODELING CHEAT SHEET

STEP 1: FRAMING THE QUESTION – PROJECT SCOPING
Articulate the Question. Identify Needs. Align Expectations

- Who is involved?
- What decisions are they making?
- Stakeholders (workshop)?
- How does connectivity fit in?
- Who needs what from this work?
- What are the expected outcomes?

- Connectivity for what?
- Structural or functional (or both)?
- What is the area of interest/influence?
- Interested in change over time?
- Identify project needs and resources (budget, data, and people)

STEP 2: BUILDING BLOCKS – MODEL INPUTS
Assemble the Required Pieces

Study Area:
- Where?
- Buffer appropriately!

Perceptual Scale

Resource Patches:
- What's being connected?
- How to map it?
- Input data sources?
- Required certainty/effort?

Resistance Surface:
- What affects movement?
- How to map it?
- Input data sources?
- Required certainty/effort?

STEP 3: BUTTON PUSHING – RUNNING THE MODEL
(In Circuitscape)

Prepare your data:
- Export to Raster
- Match extents, raster resolutions, coordinate systems

Model Parameters:
- Input raster data
- Modes, settings, and options
- Select desired outputs

Press the button:
- Prepare your machine! (power settings, updates, etc.)
- Hit "RUN"!

STEP 4: POST-PRODUCTION – REFINING MODEL OUTPUTS
In between the Model and the Maps

Clip Outputs:
- Remove buffered (edge effect) area

Quality Control:
- Visually inspect model outputs
- Check log file

DOCUMENTATION!:
- Keep excellent notes
- Document whole process
- Goal: replicability

STEP 5: SO WHAT? – MODEL RESULTS AND HOW TO USE THEM
Translating Model Outputs into Useful Information

Project Summary:
- Brief (1-2 pages)
- Narrative, not overly technical
- Interesting!

Presentation:
- To project partners
- To other stakeholders?

Map outputs:
- Recall your research question & answer it
- Map continuous surface, or discrete, or both?

Thank you

Protect the pulse.