Quantifying Connectivity of a Fragmented Landscape

A Costa Rica Story

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Table of Contents

"A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise."
- *Aldo Leopold (1949)*

Landscape-Level Fragmentation

<u>Threatens Species Survival</u>

Depletes Critical Habitat

Disrupts Resource Availability

Creates Migration Barriers

Isolates Sensitive Species

Lowers Carrying Capacity

Decreases Reproductive Success




Alvarados Salamander, Cocoa Clubtail Dragonfy, Painted Ocelot, Great Green Macaw

Processing Landscape-Level Connectivity

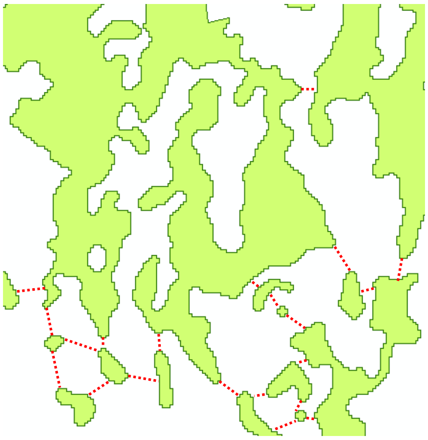
CONEFOR Sensinode 2.6

1. Allows identification and prioritization of critical sites for ecological connectivity.
    a) Relatively ranks importance of habitat patches and links in landscape connectivity.

2. Quantify importance of habitat patches and links relative to landscape connectivity.
    a) Considers both inter- and intra-patch connectivity.
    b) Structural Connectivity: Spatial arrangement of habitat.
    c) Functional Connectivity: Measure of habitat availability (reachability).

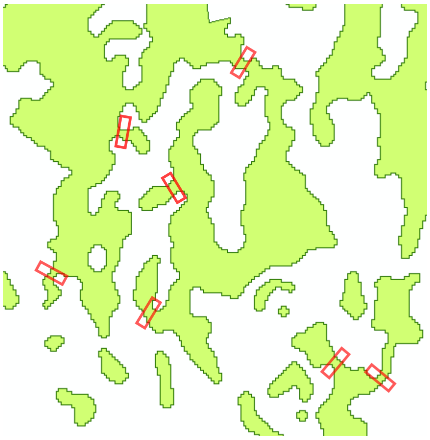
3. Evaluates impact of habitat and land-use changes on landscape connectivity.
    a) How does landscape connectivity change with the removal or addition of specific habitat patches or links?

<u>PROBABILITY OF CONNECTIVITY</u>



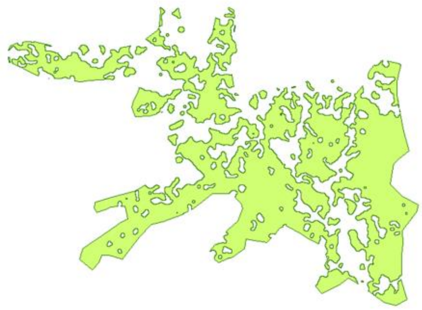
Probability of direct dispersal between habitat patches based on shortest Euclidean distance paths between all pairs of patches.

<u>BINARY CONNECTIVITY</u>



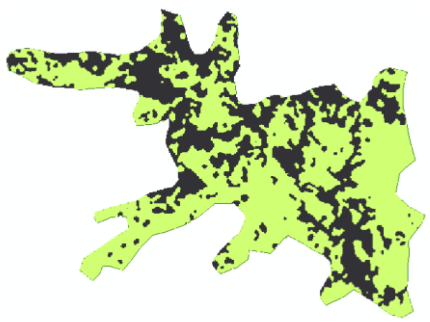
Habitat patches are either directly connected or not connected through naturally existing forest links, or corridors.

Processing Landscape-Level Connectivity



ArcMap 10.1

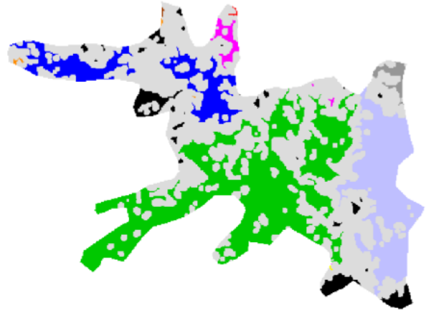
"CONEFOR inputs" function: input a vector file of forest landcover, computes node and link files for probabilistic connectivity analysis where Euclidean distance is measured for every pair of nodes and shortest path is recorded as the link.



Binary raster: forest = 2, non-forest = 1, missing data = 0. Input raster into GUIDOS to create CONEFOR node and link input files.

GUIDOS

Morphological Spatial Pattern Analysis (MSPA) to identify core habitat (nodes) and bridges (links). File used as input to identify components.



Components analysis identifies and characterize components in the landscape. Component is a network of nodes and links that are all connected; every node is reachable via other links and nodes within the same component. File used as input to create CONEFOR node and link input files.

CONEFOR Sensinode 2.6

Benefits

1. Landscape-level analysis.
   - Current habitat connectivity

2. Relatively rank core habitat and links to help identify & prioritize critical sites for ecological connectivity.
   - Streamline resource and conservation management.

3. Customize analysis to account for species-specific attributes, to represent level of quality of habitat or weight of importance of specific attributes.
   - Dispersal distances
   - Species behavior
   - Habitat requirements
   - Food & shelter requirements
   - etc.

4. Analyze theoretical additions of core habitat and links to determine best placement for increased connectivity of landscape.

5. Evaluate theoretical removal of core habitat or links to see how connectivity is effected.

6. Can pull results with unique node and link I.D.'s into *ArcMap 10.1* for mapping and visual exploration.

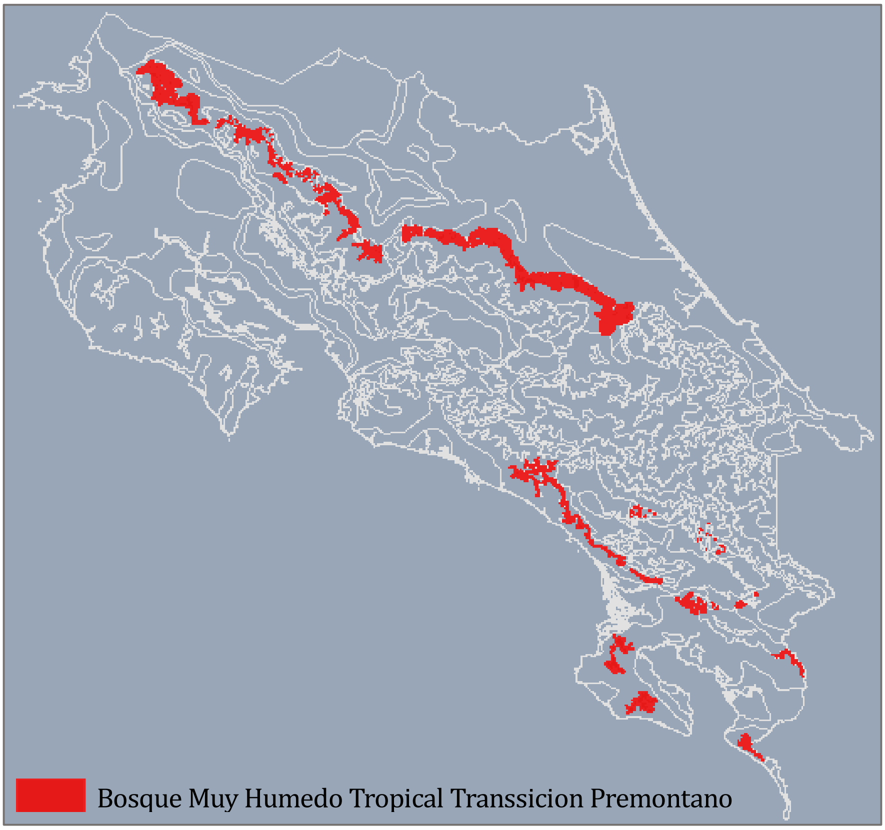
Limitations

1. Computationally intense analyses
   - From 20 minutes to multiple hours depending on analyses chosen.

2. Size limitations
   - GUIDOS
     - 5000 x 5000 pixel limitation
     - Best option; calculates binary connectivity model to account for naturally existing links.
   - ArcMap 10.1
     - No size limit
     - Not best option; calculates links as Euclidean shortest path distance between each pair of nodes, which means paths do not necessarily follow existing forest links.

Evaluation of a Biological Life Zone

"VERY WET TROPICAL MONTANE FOREST TRANSITION"



ARCMAP 10.1

LIFE ZONE AREA:	1826 square kilometers
ORIGINAL DATA:	"cob_2010_reclass.shp"
PROJECTION:	CRTM05
PROCESSING:	Feature to Binary Raster 30 square meter resolution

GUIDOS

PROCESSING:	MSPA & Components for CONEFOR inputs

CONEFOR

ANALYSIS MODEL:	Binary Connectivity

GUIDOS: Top 5 Components by Area

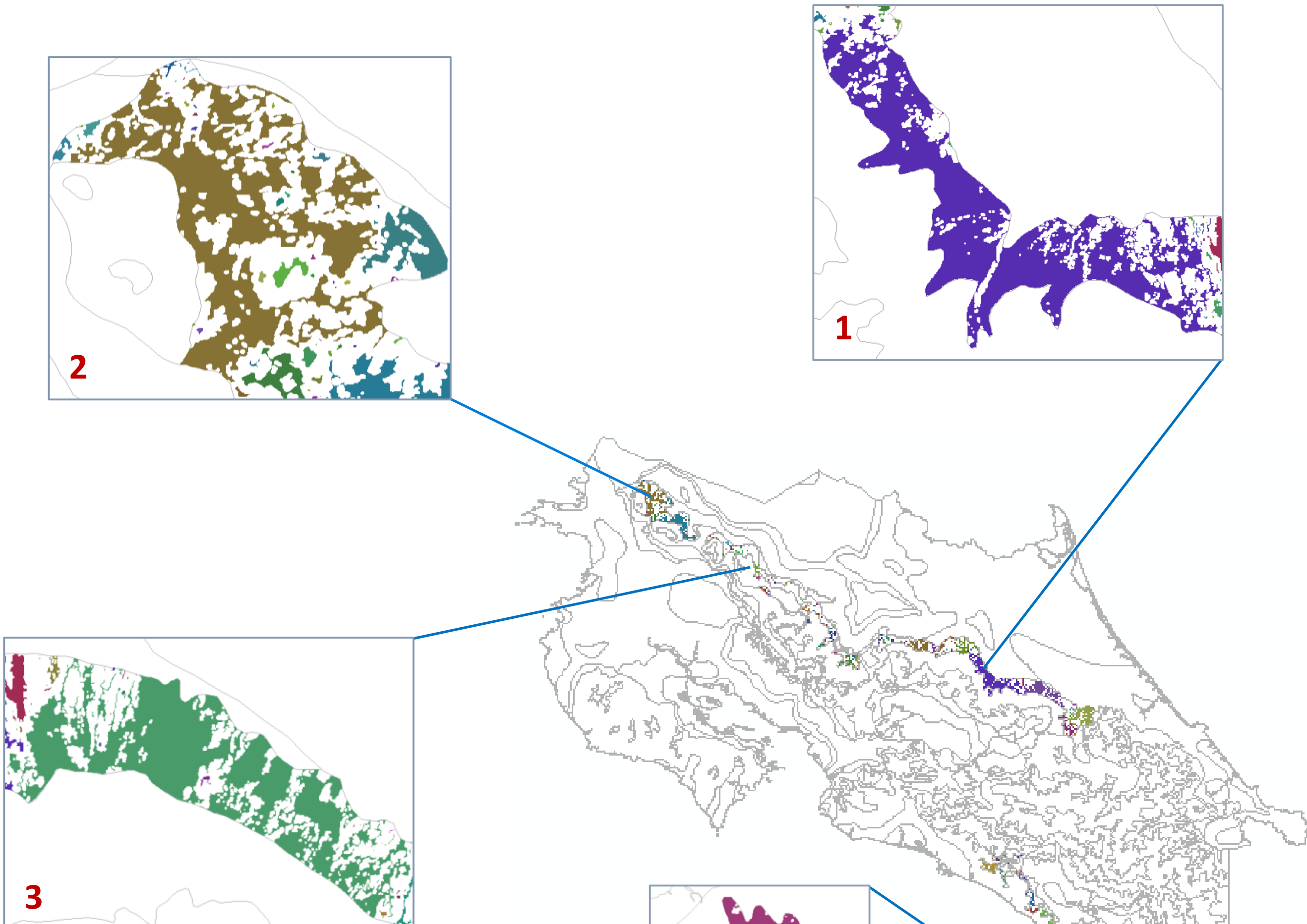
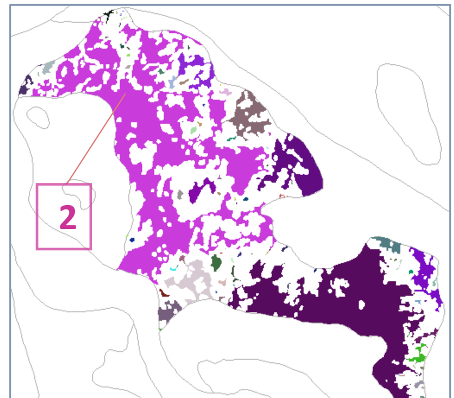


Table 1 characterizes the components by area and number of nodes and links found within each.

1216 Total Components

Component	Area (km2)	Nodes (#)	Links (#)
1	100.0	118	337
2	70.5	26	48
3	64.6	182	573
4	57.7	1	0
5	55.3	2	2

CONEFOR: Top 5 Nodes by Relative Importance

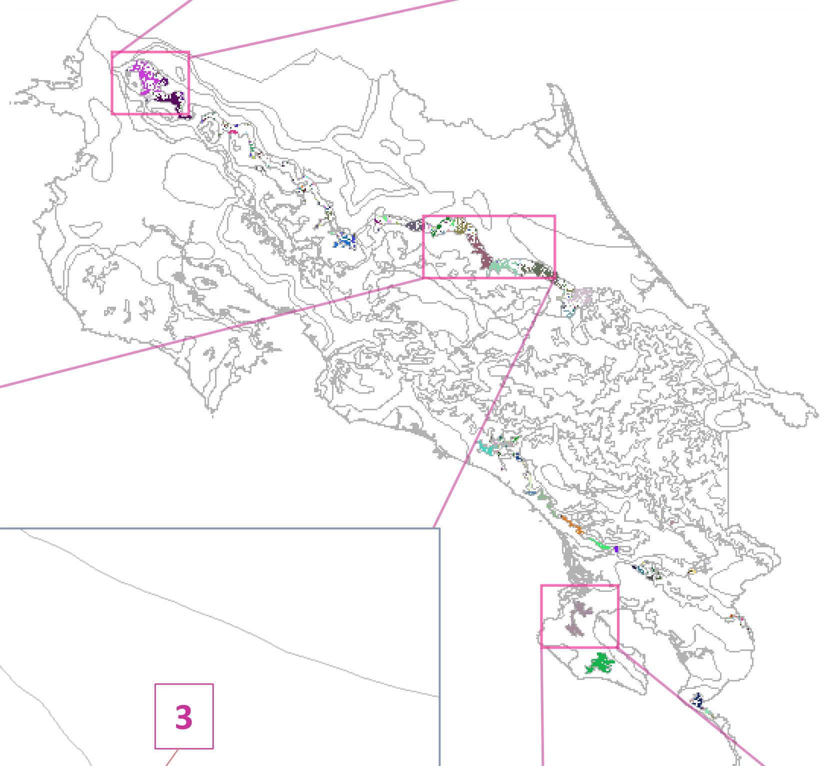


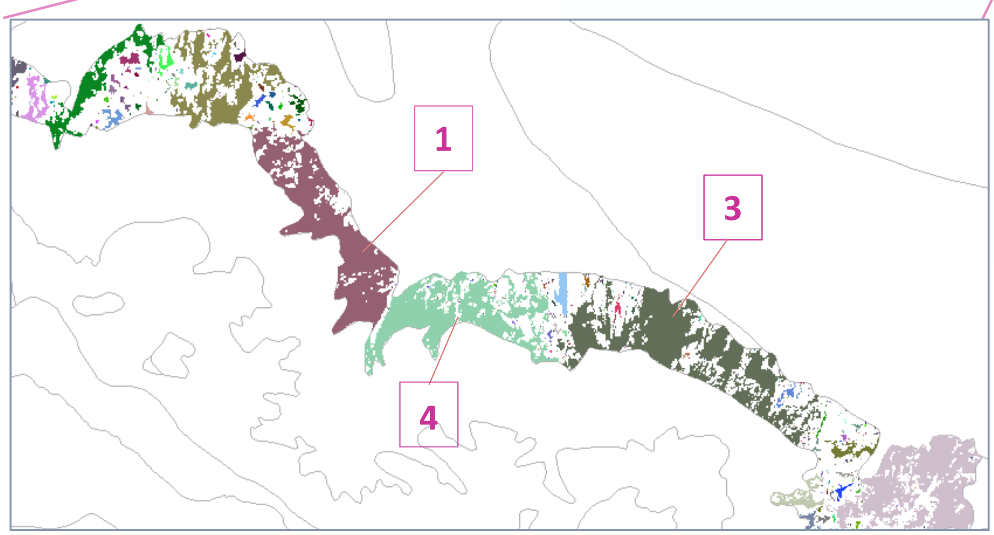
Nodes 1 and 4 (right), along with nodes 2 and 5 (below), are all found within the top five components described on the previous page.

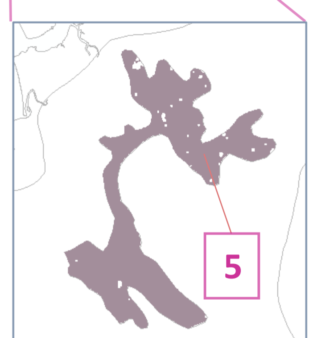
Table 2 shows the area in squared kilometers for each of the top five nodes and also quantifies the number of links each node is involved in.

Node	Area (km2)	Links (#)
1	54.5	9
2	64.5	9
3	61.4	63
4	43.3	41
5	57.7	2

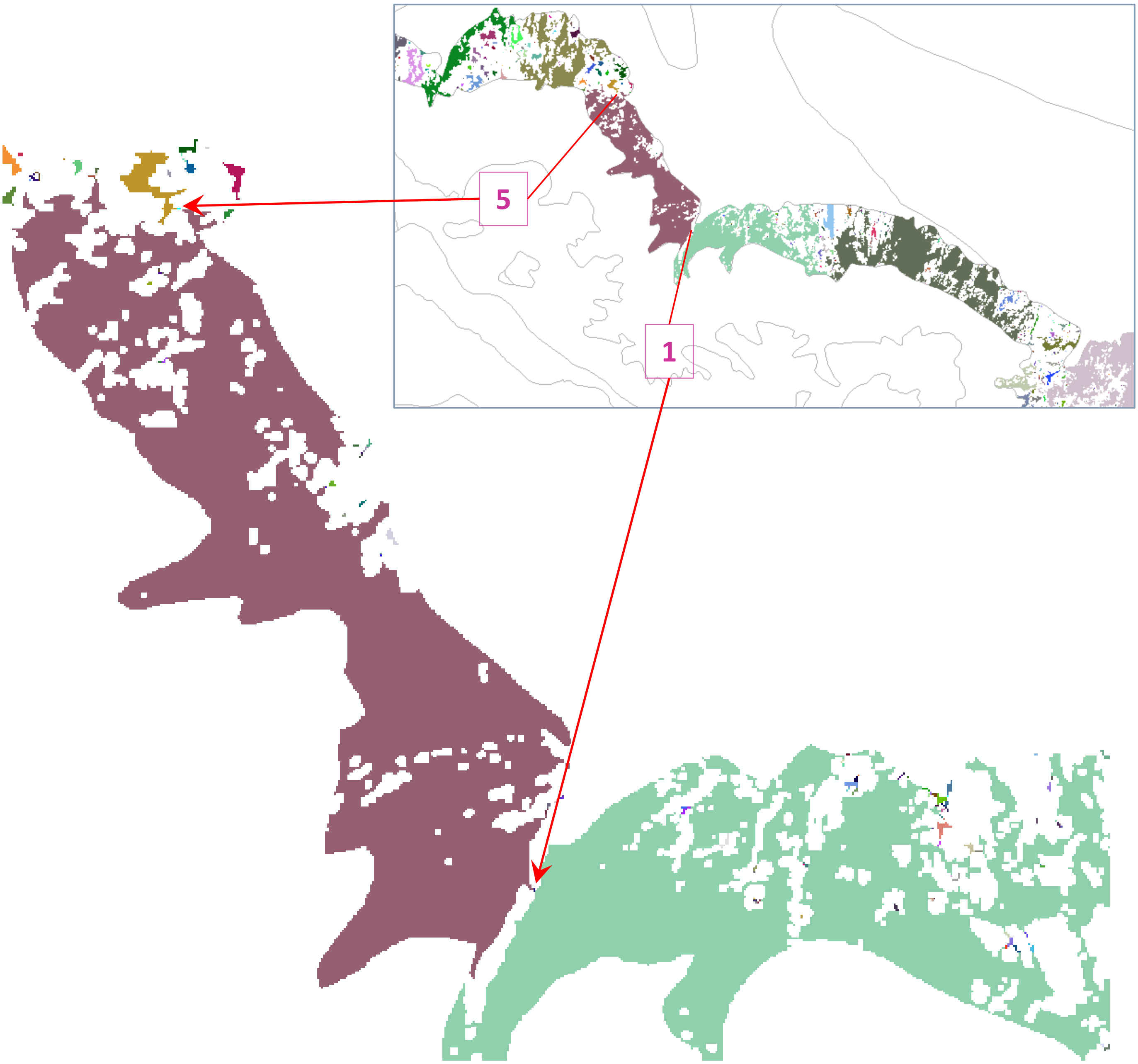
Table 2







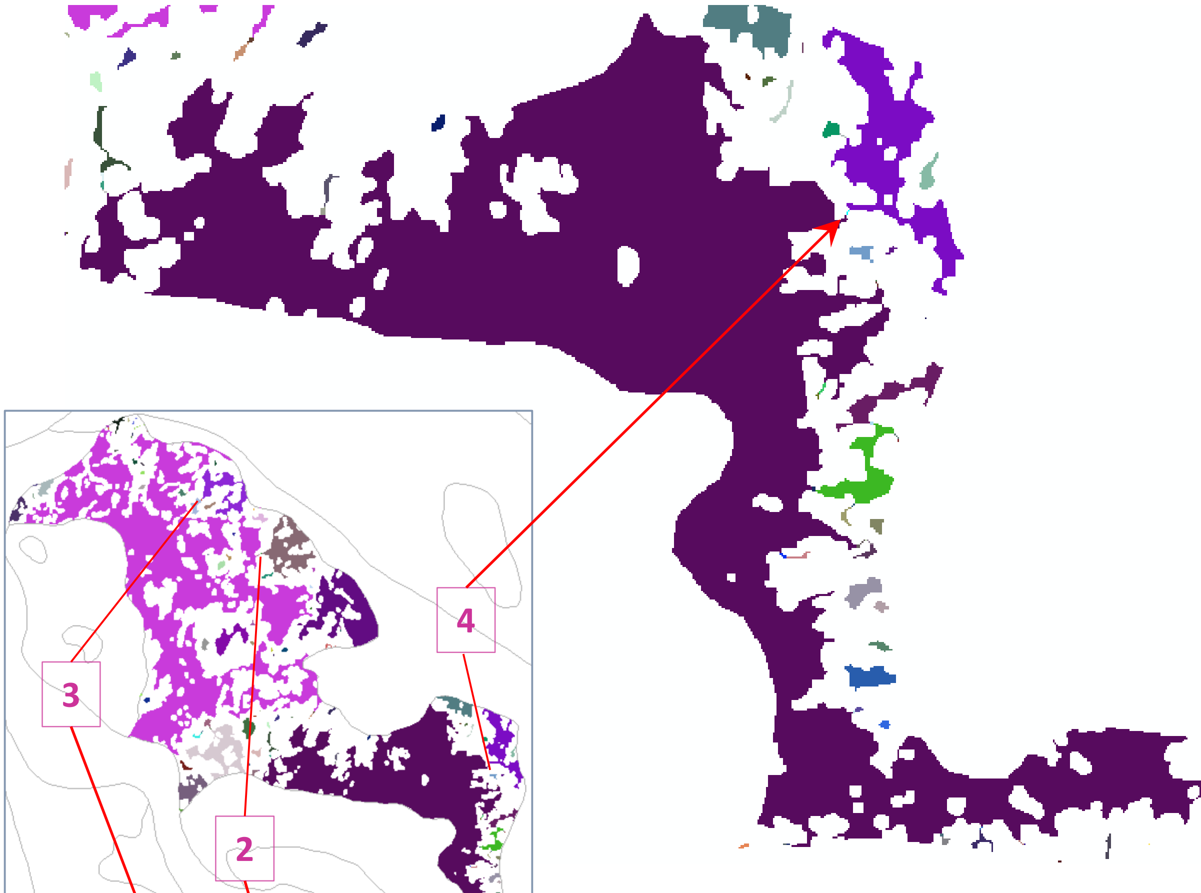
CONEFOR: Top 5 Links by Relative Importance

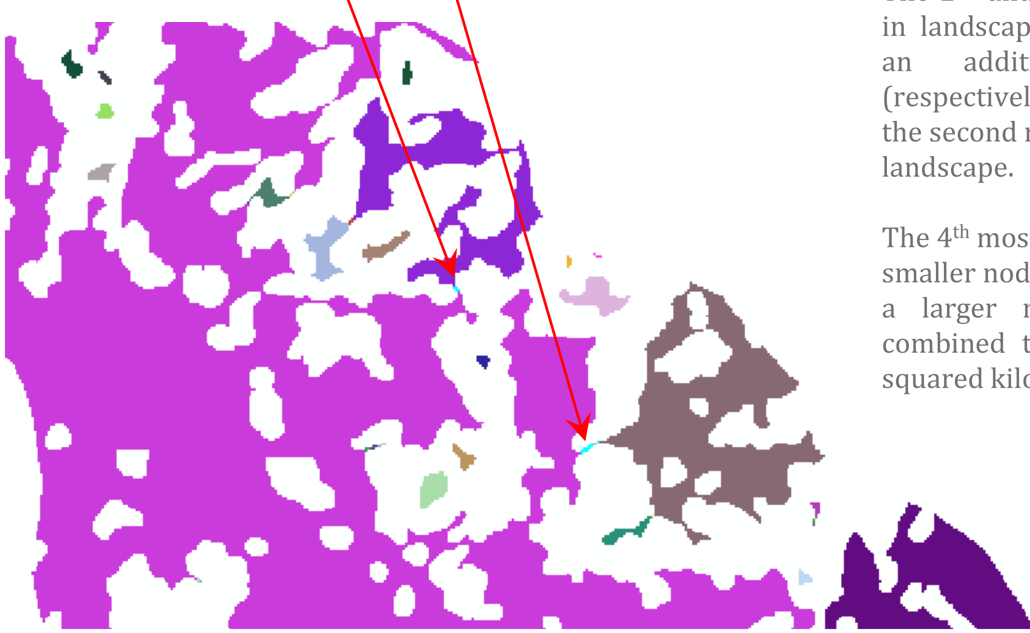


The top most importance link (#1) is connecting two of the most importance nodes relative to landscape connectivity within this biological life zone. This link is very small in size, but is a critical component in maintaining landscape connectivity.

The 5th most important link (#5) in maintaining landscape connectivity is not located between two of the top five nodes but is found connecting an additional 0.63 squared kilometer area to the top most important node in landscape connectivity.

CONEFOR: Top 5 Links by Relative Importance





The 2nd and 3rd most important links in landscape connectivity are linking an additional 3.4 and 1.9 (respectively) squared kilometers to the second most important node in the landscape.

The 4th most important link is linking a smaller node with an area of 2.5km^2 to a larger node of 46.3km^2 for a combined total habitat area of 48.8 squared kilometers.

Summary & Future Work

Identification of Components, Nodes & Links

Due to size limitations, identification of important habitat patches (nodes) and the natural bridges between them (links) was specific to a biological life zone. As a result, additional connectivity based on existing habitat via neighboring life zones was not taken into account. However, identification of important components, nodes and links within the life zone does take into account the amount of connectivity these individual features contribute, whether by containing large amounts of connectivity within themselves or by maintaining continuous regions of non-fragmented habitat. Additionally, evaluation of individual biological life zones has significance when considering many sensitive species have specific habitat requirements which may correspond to unique characteristics of biological life zones.

It is apparent that the relative importance of components, nodes and links in landscape-level connectivity are inter-related and involve much overlap. The largest component within the 'Very Wet Tropical Montane Forest Transition' biological life zone contained two of the most important nodes and two of the most important links for maintaining landscape-level connectivity. The second largest component encompassed the second most important node and the second and third most important links and the fourth largest component was the fifth most important node. The fourth most important link was a critical connection within the third largest component while the fifth largest component was not identified as containing additional nodes or links of relative importance.

Future Work – Exciting!

1. Theoretical habitat analyses for prioritizing future management decisions:
    a) Adding nodes and/or links and evaluating change in connectivity which can take into account future additions to, or remediation of, critical habitat.
    b) Taking away nodes and/or links and evaluating change in connectivity which can take into account disappearing habitat and existing natural links.
2. Exploring options for including multiple biological life zones and larger regions for landscape-level analyses.