# Spatial Planning for Connectivity

**Dr. Annika Keeley, World Bank and Center for Large Landscape Conservation**

**June 28, 2022**

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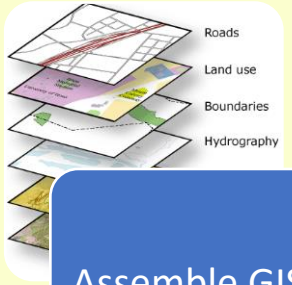
# Outline

- Overview of spatial planning process for ecological corridors
- Introduction to the Wildlife Corridor Mapping Tool
- Working through the tool
- Priority Actions for Connectivity Tool (if time permits)

# Steps to Identify and Prioritize Corridors

Define ecological objectives

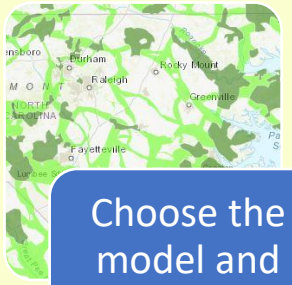
Select focal species or structural connectivity approach




Assemble GIS data layers


Assign resistance values

Define what is being connected



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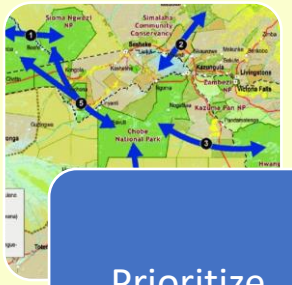

Prioritize corridors

Assess the potential utility of the identified corridors

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# Wildlife Corridor Mapping Tool

Dr. Grant Connette, Smithsonian Institution

Dr. Nirmal Bhagabati, WWF-US, and others

https://grmcco.users.earthengine.app/view/corridor-mapping-tool-v3

# Wildlife Corridor Mapping Tool

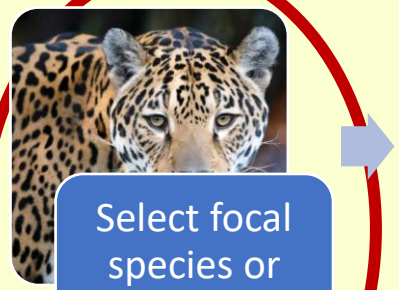
Dr. Grant Connette, Smithsonian Institution

Dr. Nirmal Bhagabati, WWF-US, and others

1. Convert recent satellite imagery into a **land cover map**,
2. **Draw linear features** such as roads, railways, pipelines and fences
3. Convert land cover and linear feature datasets into a **cost surface**
4. Indicate **source patches** of wildlife
5. **Identify potential wildlife movement corridors** based on the relative difficulty of reaching any area on the landscape from the source patches.

https://grmcco.users.earthengine.app/view/corridor-mapping-tool-v3

# Steps to Identify and Prioritize Corridors



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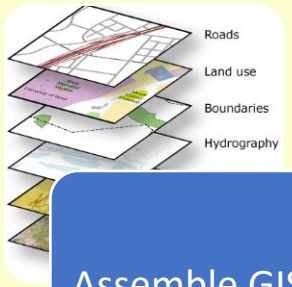


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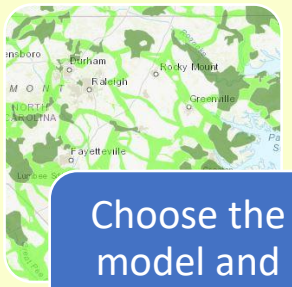


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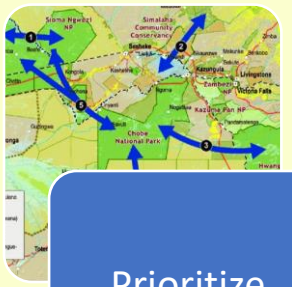

Prioritize corridors

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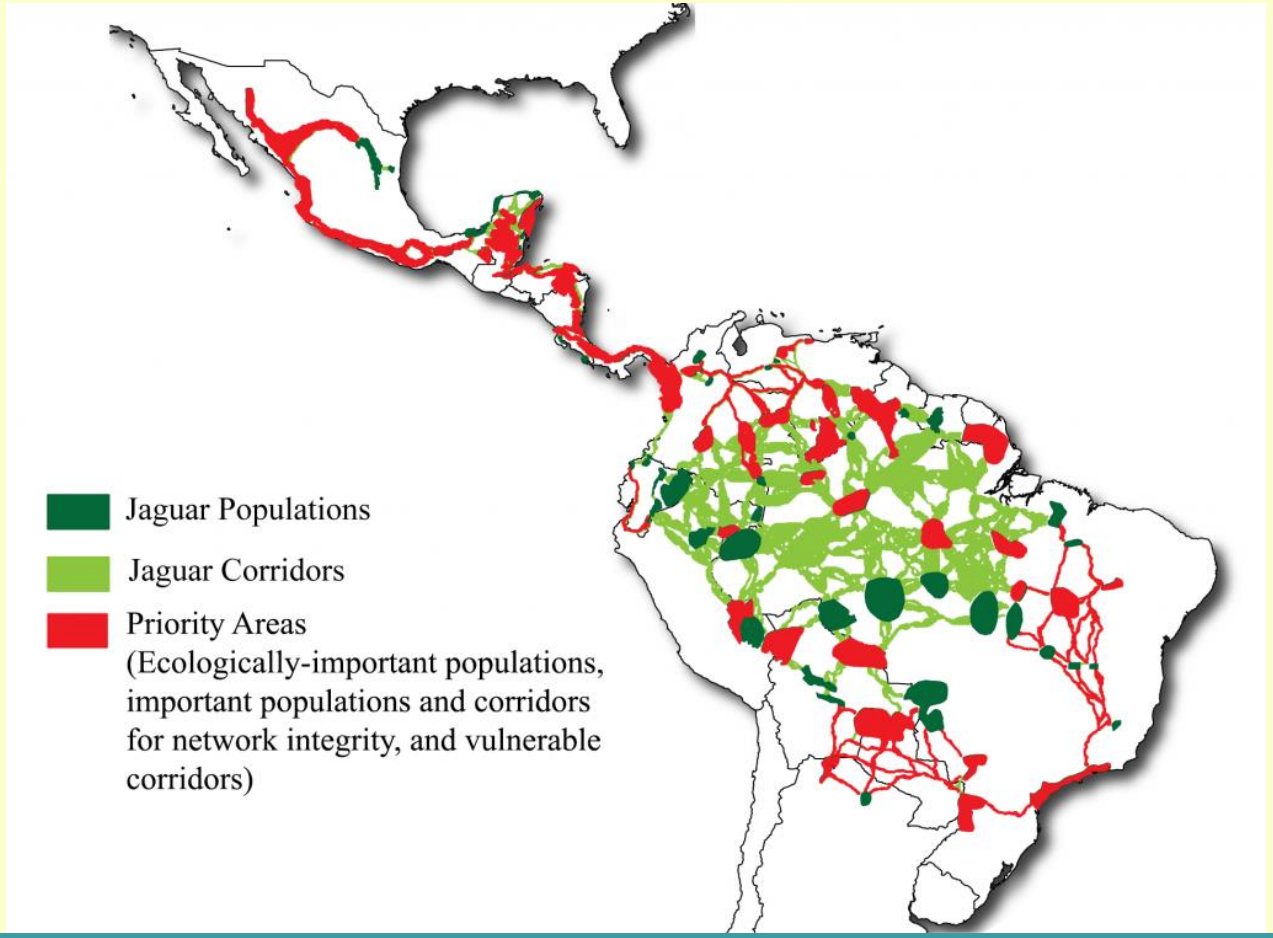
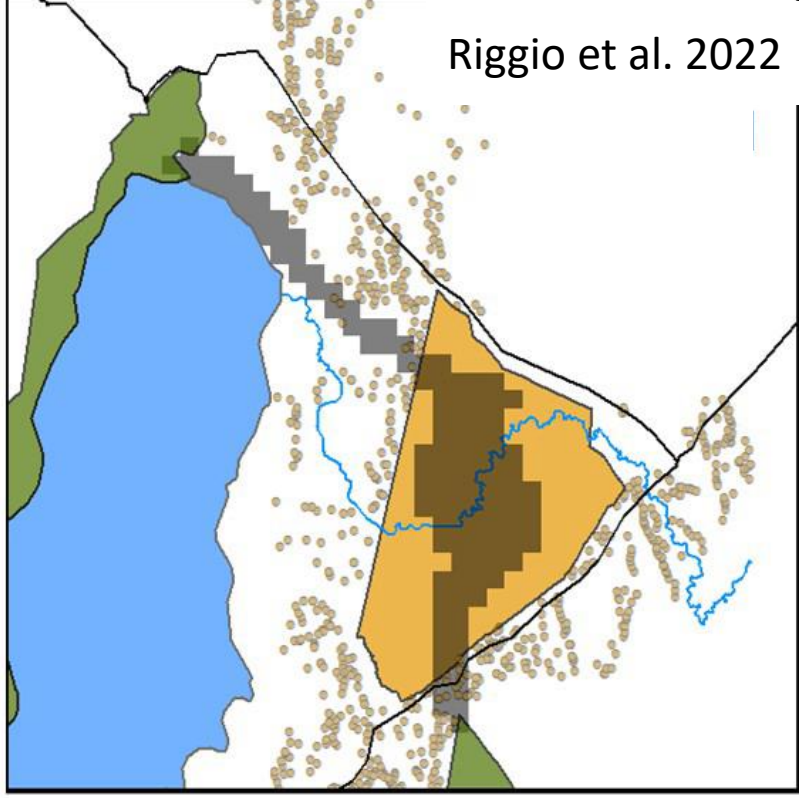
# Focal Species Considerations

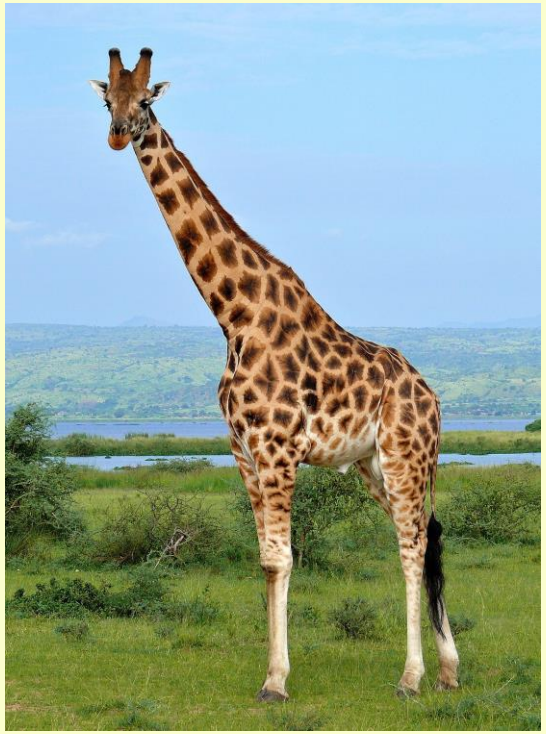


# Focal Species Considerations

- Flagship species AND
- Species with limited dispersal capabilities
- Habitat specialists
- Species important for ecological processes such as pollination
- Species sensitive to barriers
- Keystone species

Riggio et al. 2022



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# Structural Connectivity

A measure of habitat permeability

based on the physical features and arrangements of habitat patches

presumed to be important for organisms to move through their environment

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A measure of habitat permeability

based on the physical features and arrangements of habitat patches

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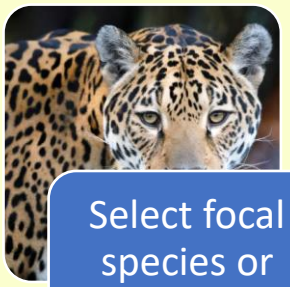
# Functional Connectivity

The degree to which evidence indicates that

landscapes facilitate or impede the movement of organisms

# Questions?

# Steps to Identify and Prioritize Corridors

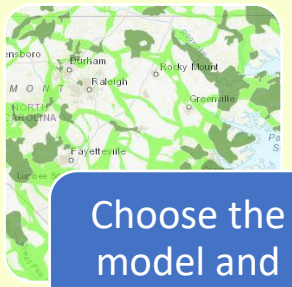


Select focal species or structural connectivity approach


Assemble GIS data layers


Assign resistance values

Define what is being connected

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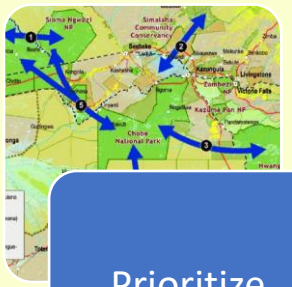

Prioritize corridors

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# Assembling GIS layers: global resources

| Dataset | Description | Source |
|---|---|---|
| Land cover | 2020 ESA World Cover at 10 m. | https://esa-worldcover.org/en |
| Human Impact Map | detailed global land use modification datasets for 1990, 2000, 2010, and 2015; 0.09 $km^2$ resolution | Theobald et al. 2020. Earth System Science Data 12. |
| Tree height | 2021 - value in meters | Lang et al. 2022. arXiv preprint arXiv:2204.08322 |
| Canopy cover | Global Forest Cover Change from "continuous fields" dataset, 30 m resolution, percentage of each cell of forest >5 m in height. | Sexton et al. 2013. International Journal of Digital Earth, 130321031236007. |
| Global Forest Intactness | Captures both habitat loss, quality, and fragmentation effects | Beyer et al. 2020. Conservation Letters 13, e12692. |
| World Database on Protected area | The World Database on Protected Areas (WDPA) is the most comprehensive global database on terrestrial and marine protected areas. | https://www.iucn.org/theme/protected-areas/our-work/world-database-protected-areas |
| Global Forest Change | Global Forest Change 2000–2019 | https://data.globalforestwatch.org/datasets/14228e6347c44f5691572169e9e107ad |
| IUCN Red List of Threatened species | Global datasets of species threats, ranges, actions | https://www.iucnredlist.org/ |
| Roads | OpenStreetMap | https://www.openstreetmap.org/ |
| WorldPop | High resolution global gridded data, including human density | https://www.nature.com/articles/sdata20171 |
| WorldClim | Global climate data | https://www.worldclim.org/ |
| Worldometer | Global stats | https://www.worldometers.info/, |

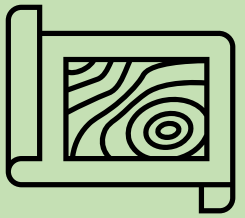
# 1. Select study area

Directions

- Choose a small area (~100 $km^2$) with a road running through the middle
- Draw a rectangle

Save

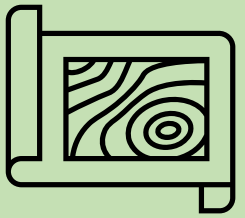
# 2. Create a land cover map



Tell the tool what is forest, grassland, developed area

Save

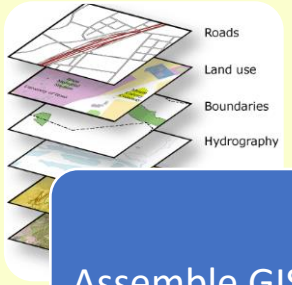
# 3. Add existing roads



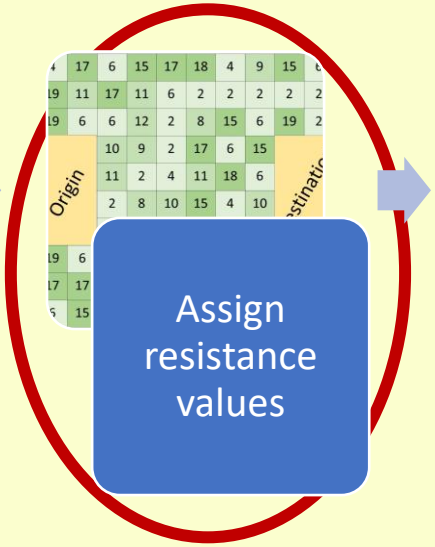
Save

# Steps to Identify and Prioritize Corridors

Select focal species or structural connectivity approach

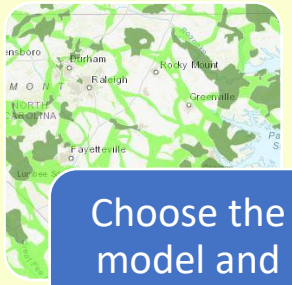



Assemble GIS data layers

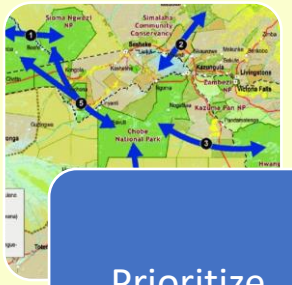



Assign resistance values

Define what is being connected




Choose the model and create connectivity map



Prioritize corridors

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# Resistance Map

| | | | | | | |
|---|---|---|---|---|---|---|
| 32 | 38 | 75 | 17 | 13 | Terminus 2 | |
| 42 | 37 | 44 | 12 | 50 | | |
| 53 | 51 | 75 | 44 | 68 | 19 | 55 |
| 26 | 10 | 73 | 35 | 23 | 64 | 17 |
| 24 | 33 | 48 | 64 | 17 | 51 | 59 |
| Terminus 1 | | 35 | 12 | 11 | 59 | 18 |
| | | 25 | 12 | 13 | 84 | 86 |

Resistance = difficulty of crossing the pixel for the species of interest.

# Estimating resistance values
(called travel costs in the Wildlife Corridor Mapping Tool)

**Focal Species**

- Inverse of habitat suitability
- Resource selection functions
  - Based on point data, steps, or paths
- Mechanistic models
- Expert opinion

**Structural**

- Degree of human modification/naturalness

# Estimating resistance values

**Focal Species**

- Inverse of habitat suitability – Spear et al. 2010. Molecular Ecology
- Resource selection models – Zeller et al. 2012. Landscape Ecology
  - Based on point data, steps, or paths
- Mechanistic models – Golden et al. 2022. Environmental Modelling & Software
- Expert opinion – Rabinowitz et al. 2010. Biological Conservation

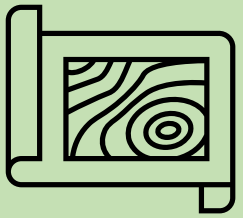
**Structural**

- Degree of human modification/naturalness – Theobald et al. 2012. Conservation Letters

# Resistance values for elk

| Land cover | Travel Costs |
|---|---|
| Forest and Woodland | 1 |
| Chaparral | 40 |
| Mixed Desert and Scrub | 90 |
| Riparian Woodland and Shrubland | 20 |
| Agriculture | 70 |
| Developed, Medium - High Intensity | 100 |
| Developed, Low Intensity | 70 |
| Roads | 90 |

# 4. Assign travel costs (aka resistance values)



Save

# Questions?

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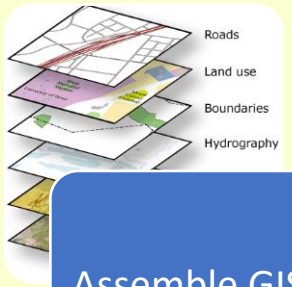
# Steps to Identify and Prioritize Corridors

Select focal species or structural connectivity approach

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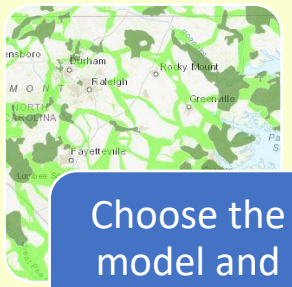


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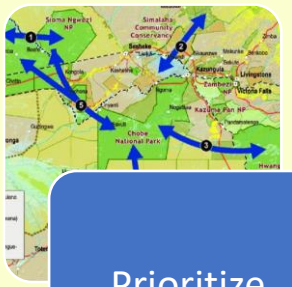

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# 5. Create Wildlife Source Areas

Resource: Global Protected Area map

Save

# Steps to Identify and Prioritize Corridors

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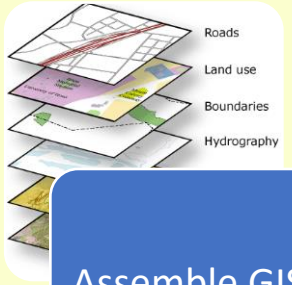


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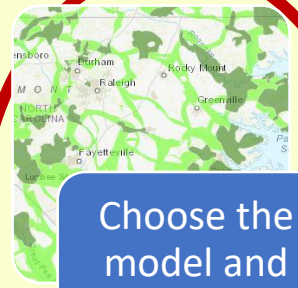
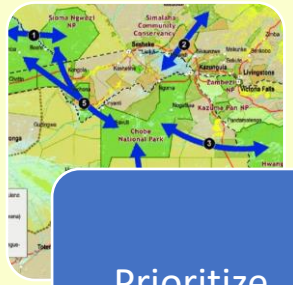



Choose the model and create connectivity map



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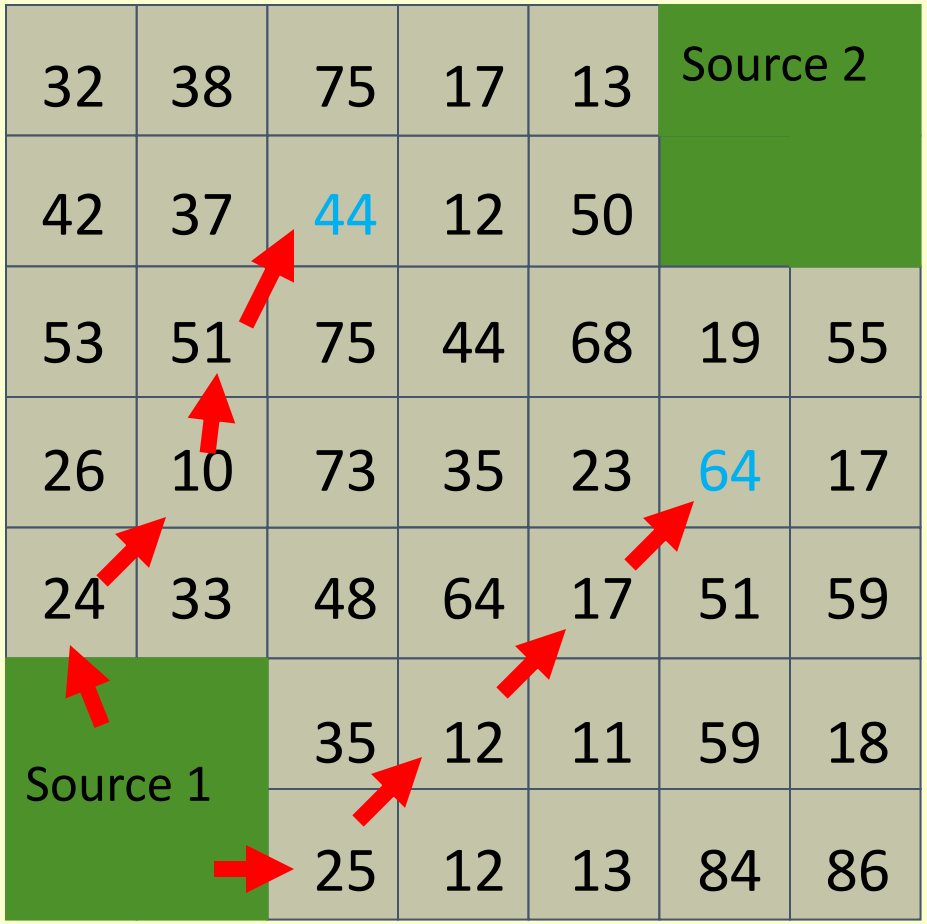
# From Resistance Map to Cost Map




Resistance = difficulty of crossing the pixel for the species of interest.

Cost = lowest sum of resistances from a source to a cell

Cost Source 1 to this cell = 25+12+17+ ½ (64) = 86.

Cost from Source 1 to this cell = 107.

Credit: Dr. Paul Beier

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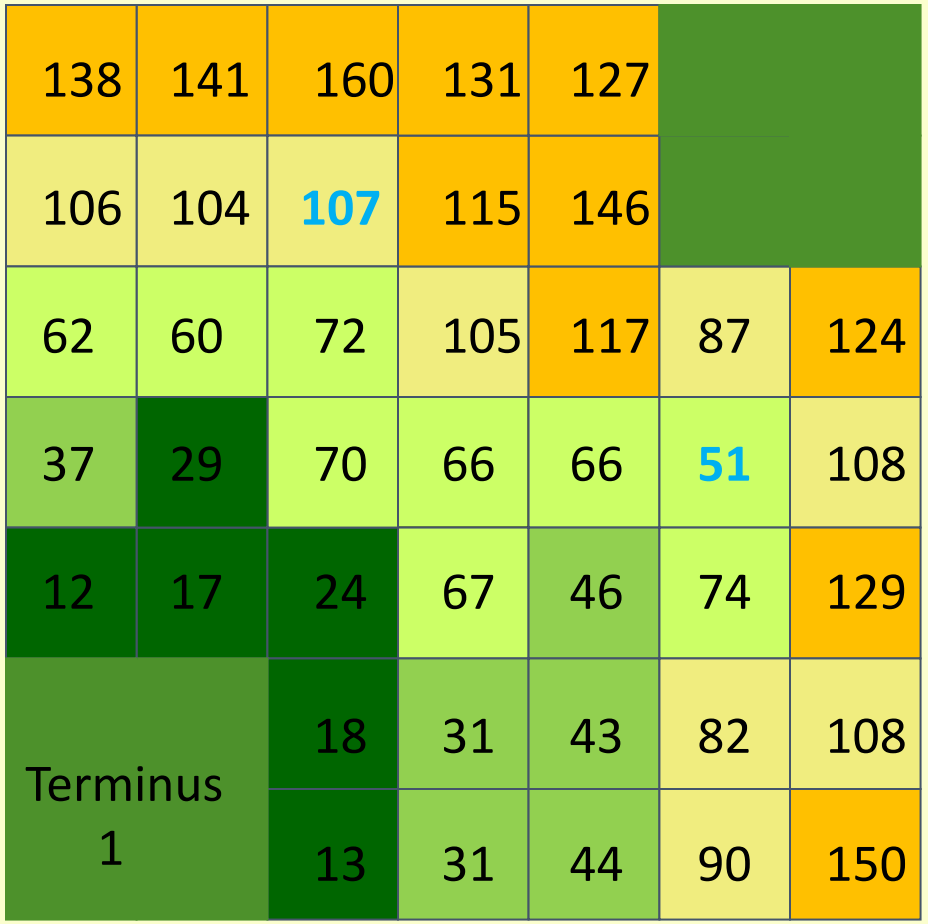
# Least Cost Modeling: Cost Map




Cost distance – cost of travel from Source 1 to *each cell*

Credit: Dr. Paul Beier

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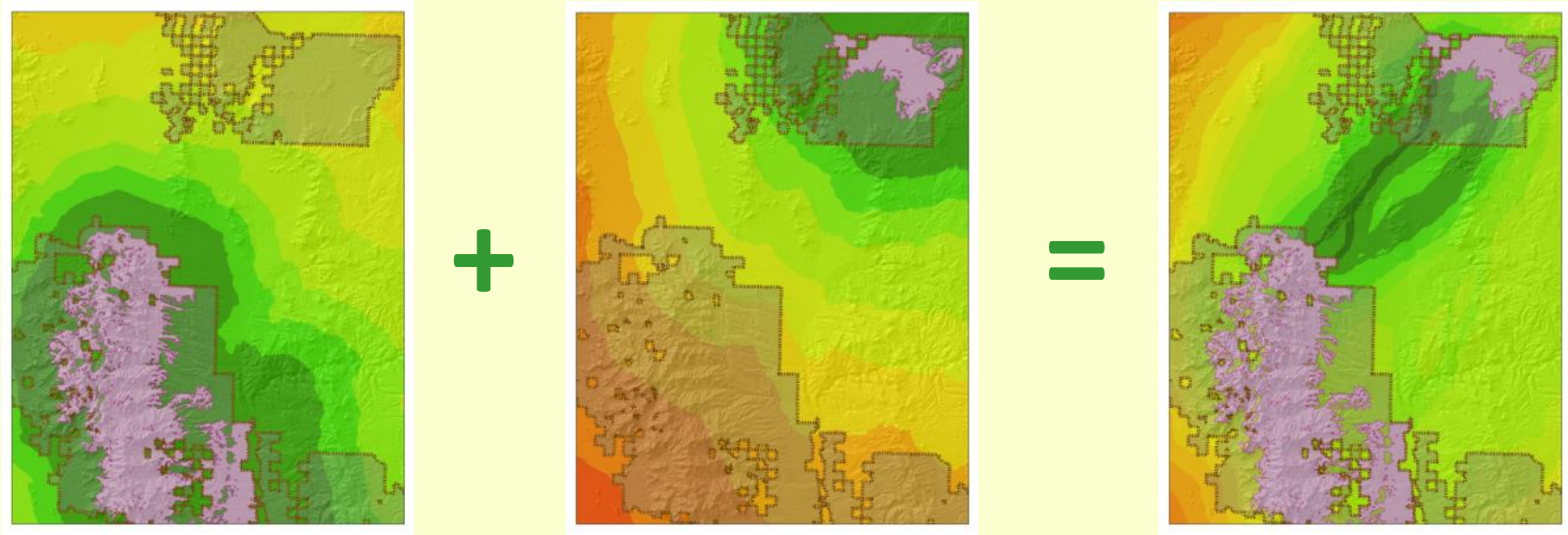
# Least Cost Modeling: Least-cost corridor



Cost Map1 + Cost Map2 = Least Cost Corridor

Least-cost modeling identifies the area where the animal would have the lowest cost of movement.

It is NOT a predicted path (animals do not have perfect knowledge of the landscape).

Credit: Dr. Paul Beier

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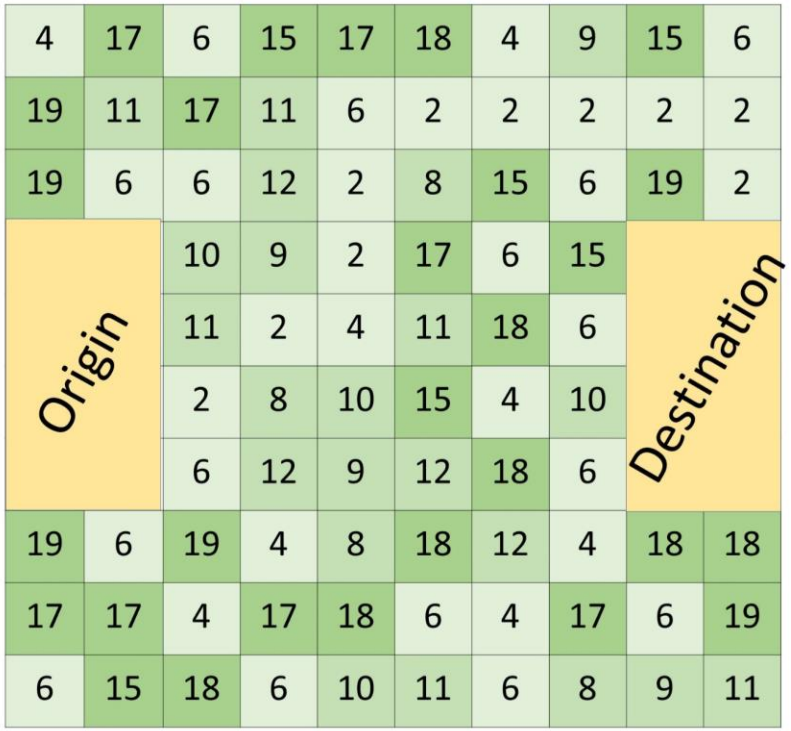
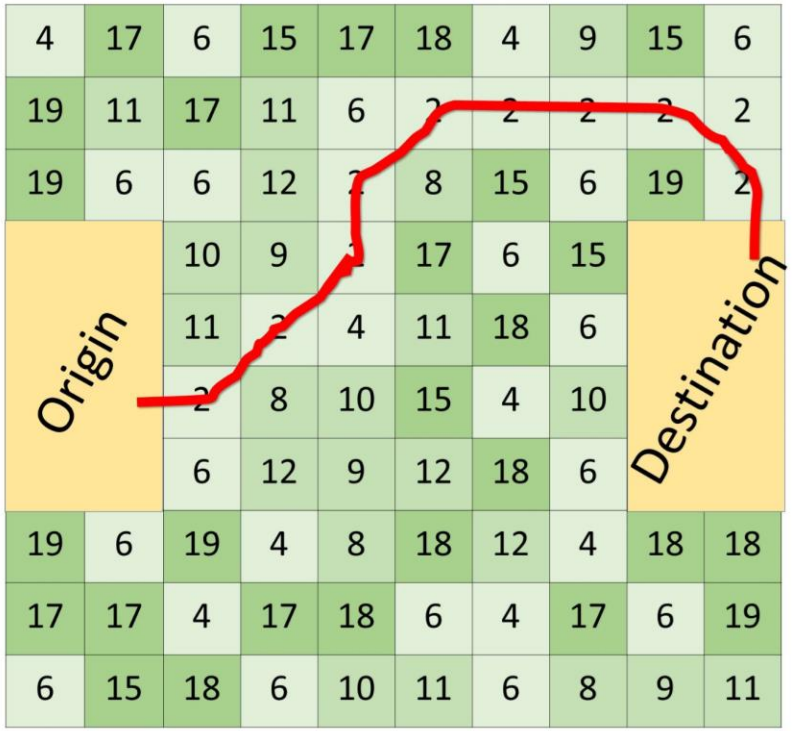
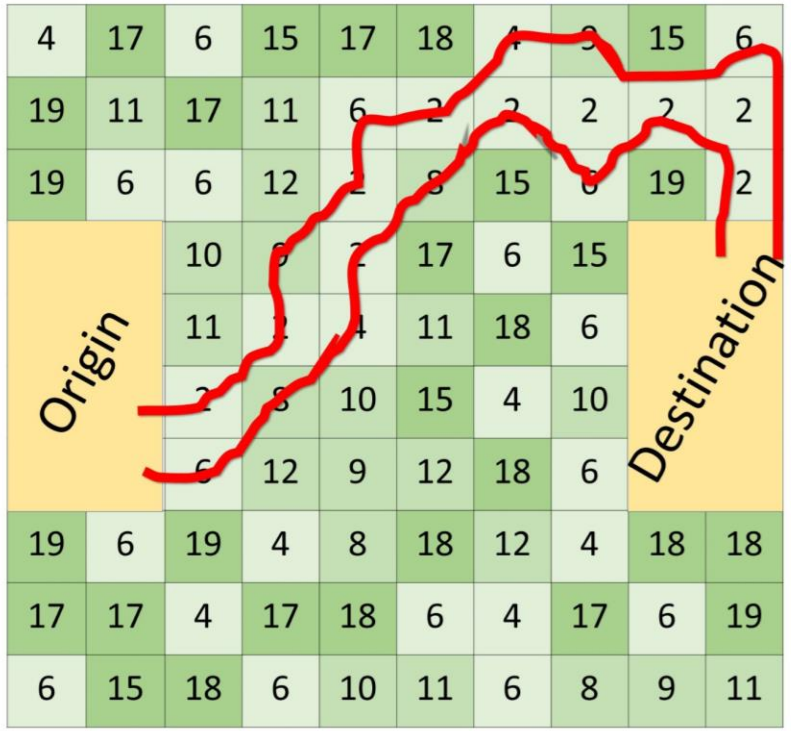
# Modeling least cost corridors




Cost map




Least-Cost Path




Least-Cost Corridor

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# Modeling corridors

Rudnick et al. 2012. The Role of Landscape Connectivity in Planning and Implementing Conservation and Restoration Priorities. Issues in Ecology

- Least Cost Paths/Corridors
- Factorial Least Cost Paths
- Circuit Theory
- Graph Theory
- Resistant Kernel
- Individual-based movement model
- Spatially explicit population modeling

# Modeling corridors

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- Circuit Theory
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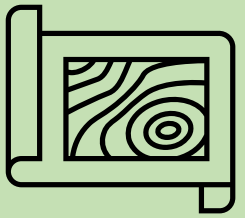
- Resistant Kernel
- Individual-based movement model
- Spatially explicit population modeling

Every approach helps model some aspect of connectivity.

No single approach is best for all tasks.

You can use more than one approach per task.

# 6. Run connectivity analysis!



# 7. Create alternative scenario and re-run analysis

# Other connectivity planning tools

https://conservationcorridor.org/corridor-toolbox/programs-and-tools/

# Questions?

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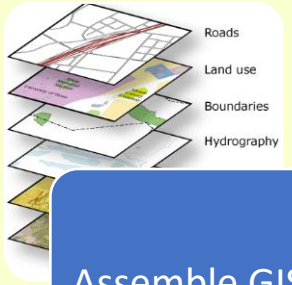
# Steps to Identify and Prioritize Corridors

Select focal species or structural connectivity approach

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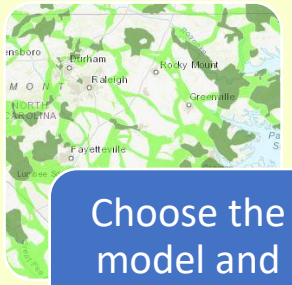


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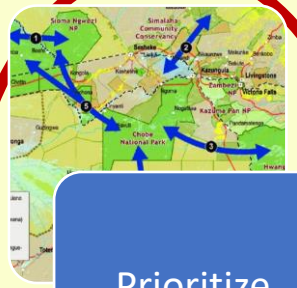

Prioritize corridors

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# Priority Actions for Connectivity Tool

**Priority = Value + Threat + Opportunity**

Value: the benefits to biodiversity and human well-being provided by a corridor

Threat: factors that increase the likelihood that the connectivity value of a corridor will be reduced in the future.

Opportunity: factors that influence conservationists' ability to successfully implement desired connectivity conservation actions within or around a corridor.

# Priority Actions for Connectivity Tool

- Variable name
- Variable description
- Reason for inclusion
- Proposed Categories
- Example data sources

# Priority Actions for Connectivity Tool

| | VALUE VARIABLES | | | | | | THREAT VARIABLES | | | | OPPORTUNITY VARIABLES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Biodiversity | Ecosystem services value | Climate adaptation value | Connected habitat significance | Dispersal/migration use | Corridor dweller use | Linear infrastructure development | Climate change exposure | Habitat loss | Human population expansion | Economic opportunity | Land use compatibility | Community values | Tenure security | Jurisdictional complexity | Local community governance | Civil society capacity | Social capital | | |
| Variable weight | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | |
| **Corridor Name** | | | | | | | | | | | | | | | | | | | **Reviewer** | **Recommended conservation action(s)** |
| Corridor1 | 25 | 2 | 3 | 1 | 2 | 1 | 1 | 11 | 3 | 3 | 2 | 2 | 3 | 1 | 2 | 1 | 1 | 2 | | |
| Corridor2 | 10 | 3 | 2 | 2 | 1 | 3 | 2 | 2 | 1 | 2 | 3 | 1 | 2 | 3 | 2 | 3 | 2 | 1 | | |
| Corridor3 | 7 | 3 | 2 | 2 | 2 | 2 | 3 | 5 | 1 | 1 | 2 | 1 | 3 | 2 | 1 | 2 | 3 | 2 | | |

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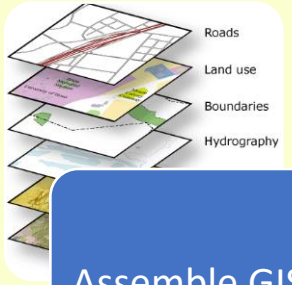
# Priority Actions for Connectivity Tool

| Corridor | VALUE | THREAT | OPPORTUNITY | OVERALL |
|---|---|---|---|---|
| Corridor1 | 0.500 | 0.600 | 0.500 | 0.517 |
| Corridor2 | 0.514 | 0.200 | 0.583 | 0.489 |
| Corridor3 | 0.542 | 0.467 | 0.417 | 0.477 |

# Steps to Identify and Prioritize Corridors

Define ecological objectives

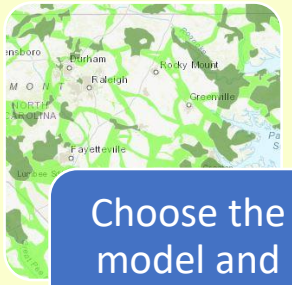
Select focal species or structural connectivity approach



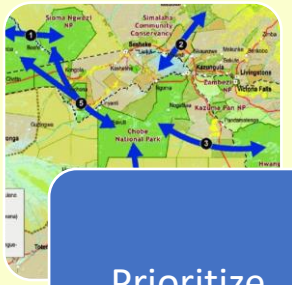

Assemble GIS data layers


Assign resistance values

Define what is being connected



Choose the model and create connectivity map



Prioritize corridors

Assess the potential utility of the identified corridors

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# Questions?

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