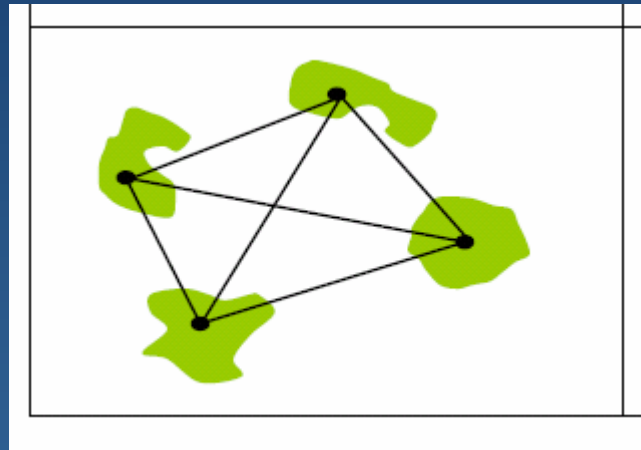


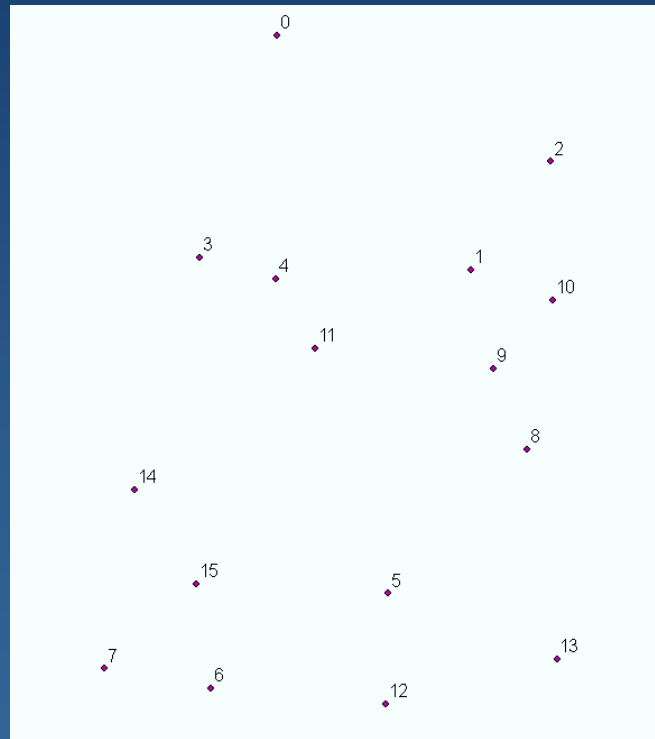
# Least Cost Path Analysis and Functional Connectivity

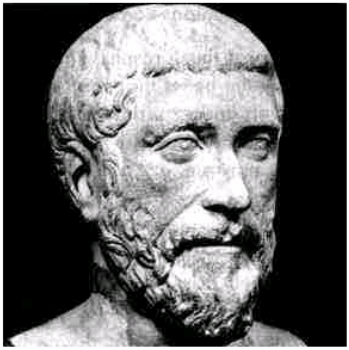


Eva Strand, NR505  
GIS Applications in Wildlife Sciences

# Distance analysis

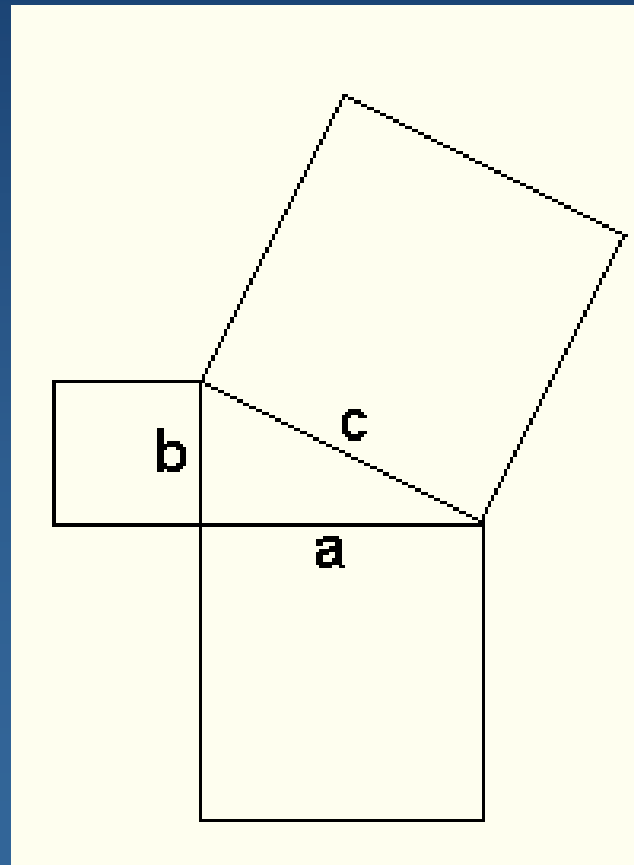
How far away is each point from all other points??



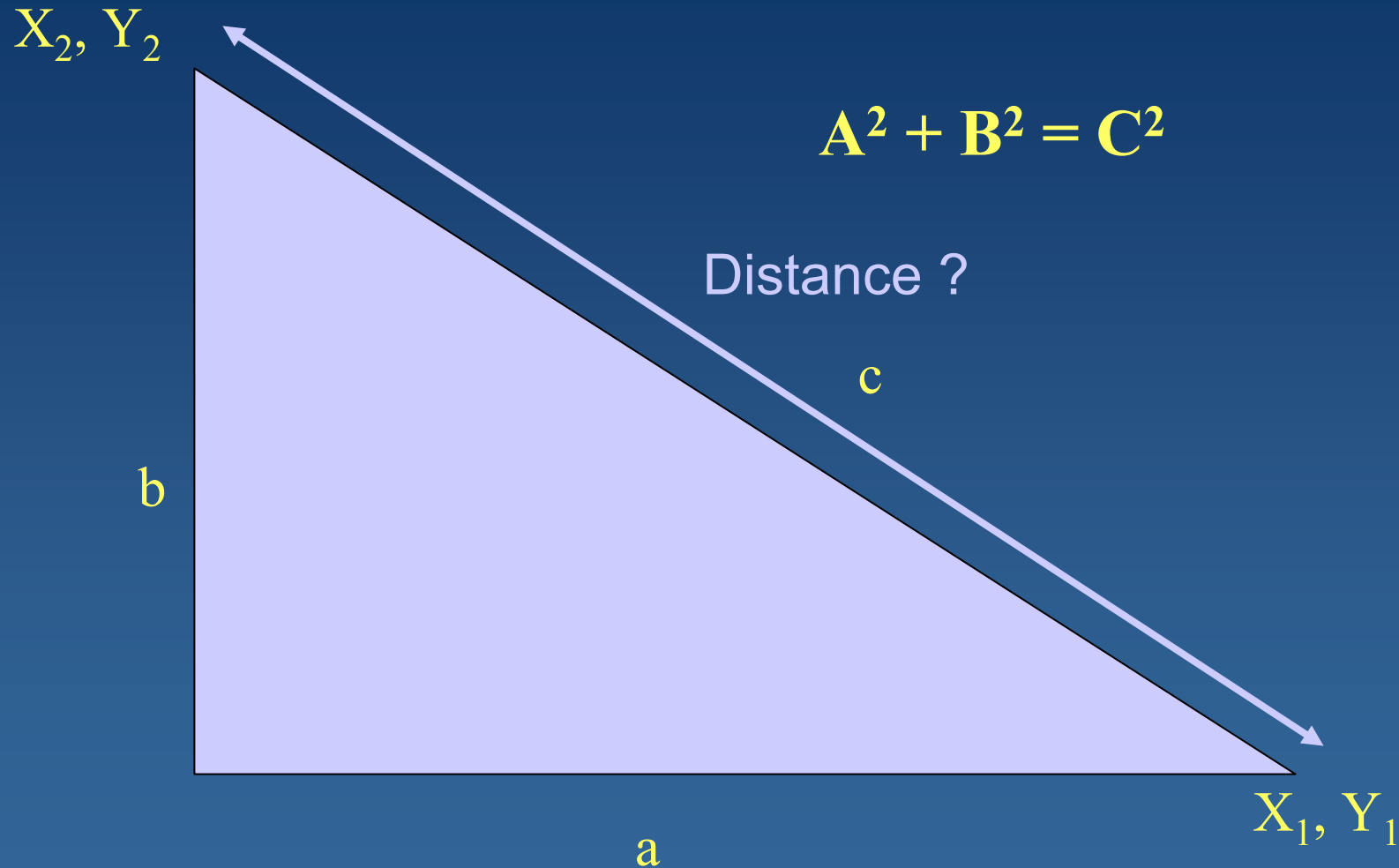


# Pythagoras' Theorem

$$a^2 + b^2 = c^2$$



$$\text{Distance} = \sqrt{(|x_1 - x_2|)^2 + (|y_1 - y_2|)^2}$$





# POINT DISTANCE in ArcToolbox

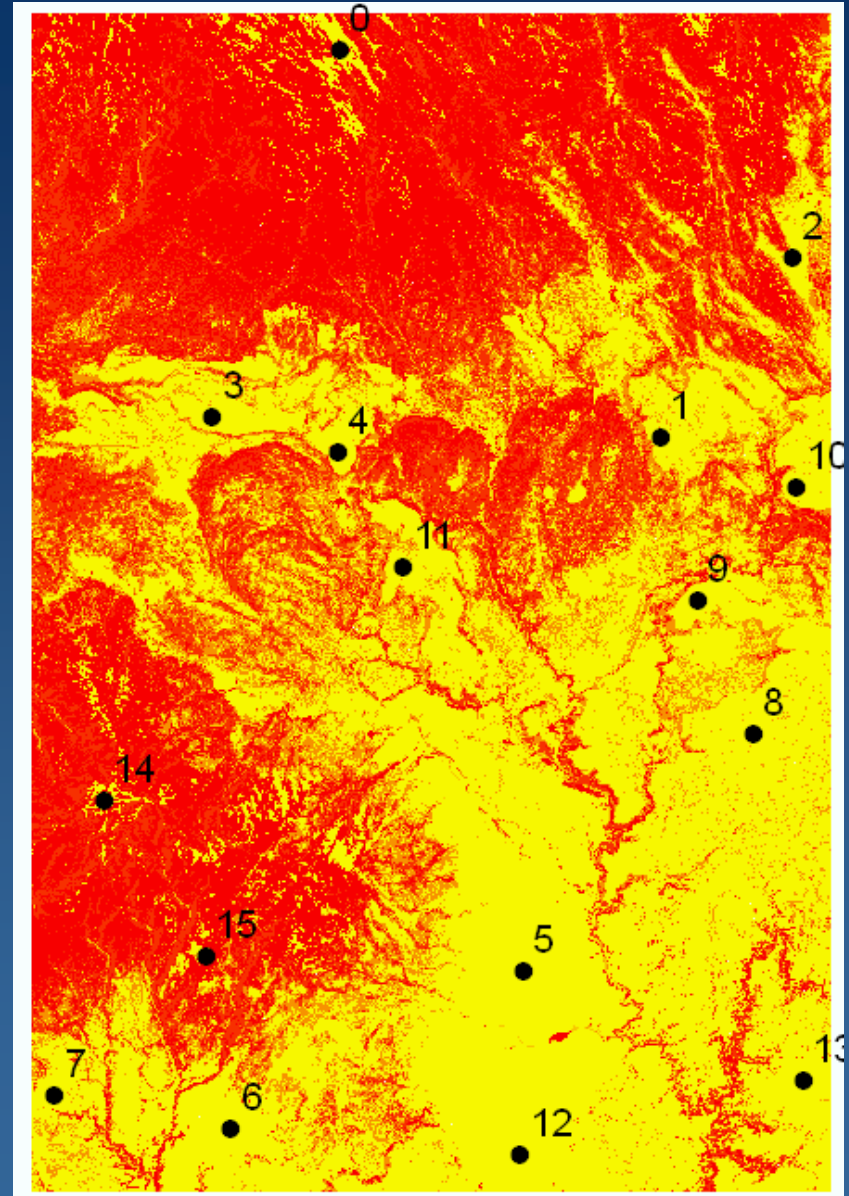
The screenshot displays the ArcGIS interface with the ArcToolbox open to the Proximity > Point Distance tool. The Layers window shows the 'source\_points' layer selected. The 'Attributes of source\_points\_PointDistance' table is open, showing the following data:

OID	INPUT_FID	NEAR_FID	DISTANCE
0	0	12	41414.123975
1	0	6	40098.849647
2	0	7	40093.986748
3	0	13	41787.340517
4	0	15	33858.636706
5	0	5	34758.536315
6	0	14	29069.235736
7	0	8	29557.589247
8	0	9	24268.77021
9	0	11	19287.936016
10	0	10	23379.662503
11	0	4	14889.407799
12	0	1	18578.113750
13	0	3	14362.707161
14	0	2	18417.318488
15	0	0	0
16	1	12	27058.543760

The map on the right shows 16 numbered points (0-15) distributed across the workspace. Point 16 is located at the bottom left, and point 0 is at the top center.

# Least cost distance?

-  Difficult to traverse
-  Easy to traverse



# Least Cost Modeling Assumptions

- Landscape connectivity facilitates movement of organisms among patches
- Connectivity is desirable according to conservation scientists
- Reserves that are connected support larger populations and are less likely to succumb to local random extinction
- Greater genetic exchange between populations increases heterozygosity and minimizes loss of genetic variation

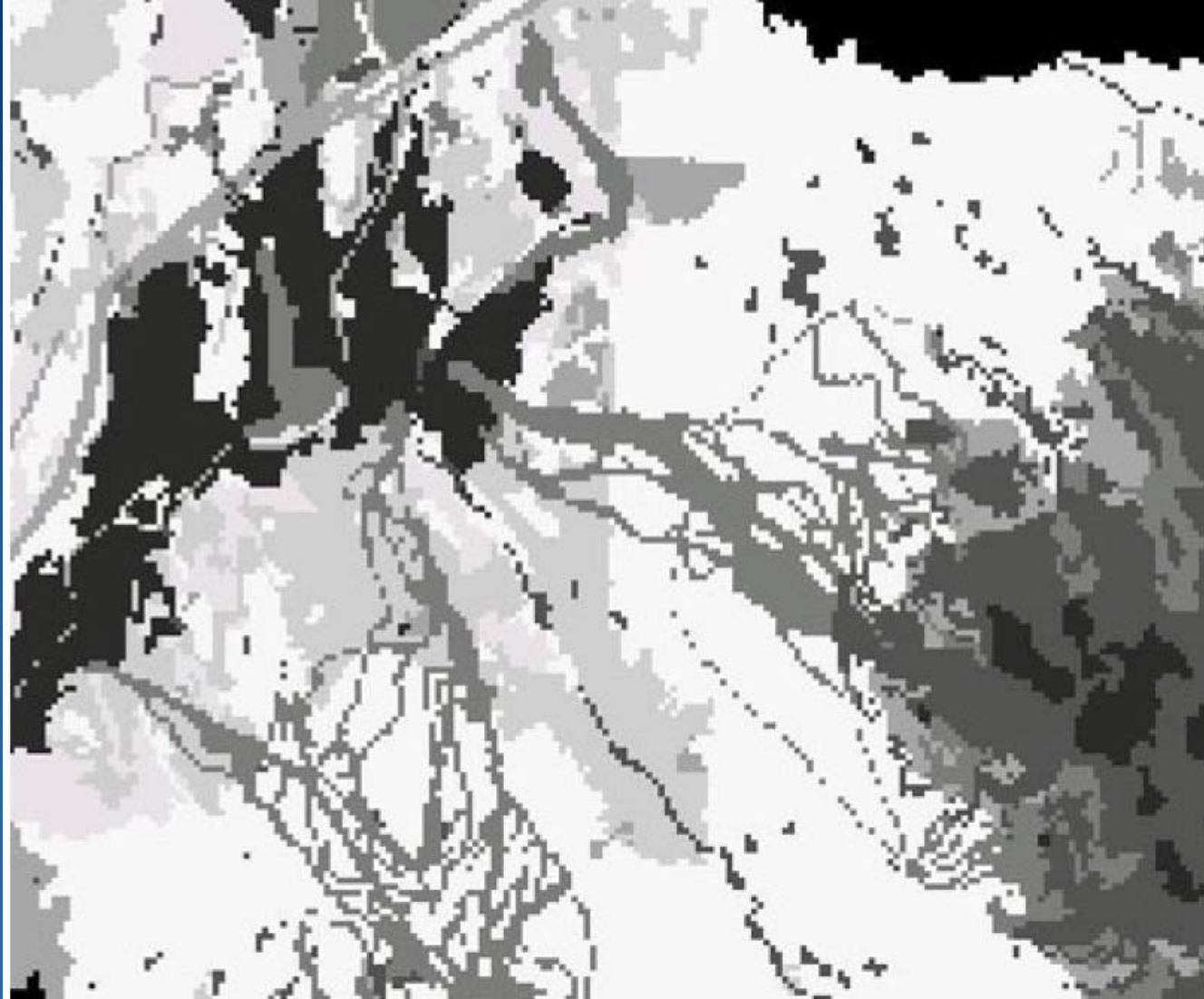
# What is Least Cost Modeling?

- A method to measure effective distance between habitat patches
- Measures connectivity between existing or potential reserves
- The distance between habitat patches and an organisms dispersal speed and survival can be directly related.
- Requires two spatial data layers
  - ✓ A resistance/friction surface indicating travel cost
  - ✓ A source patch layer to which the cumulative travel cost for each cell is measured
- Least cost modeling has been enabled by GIS technology

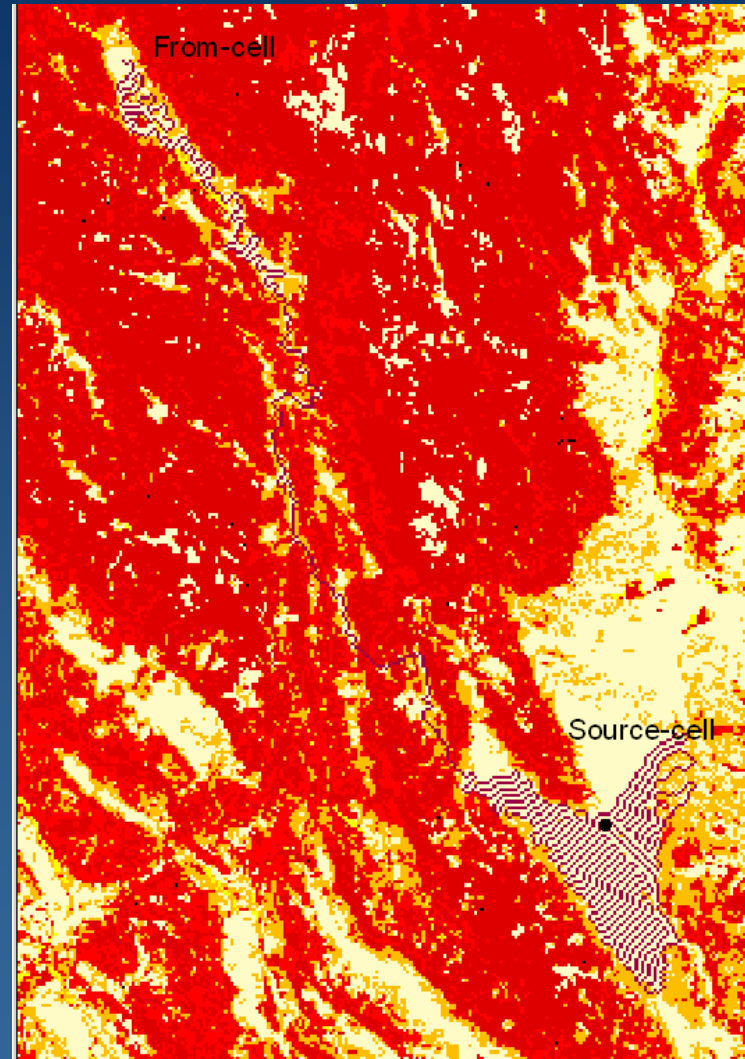
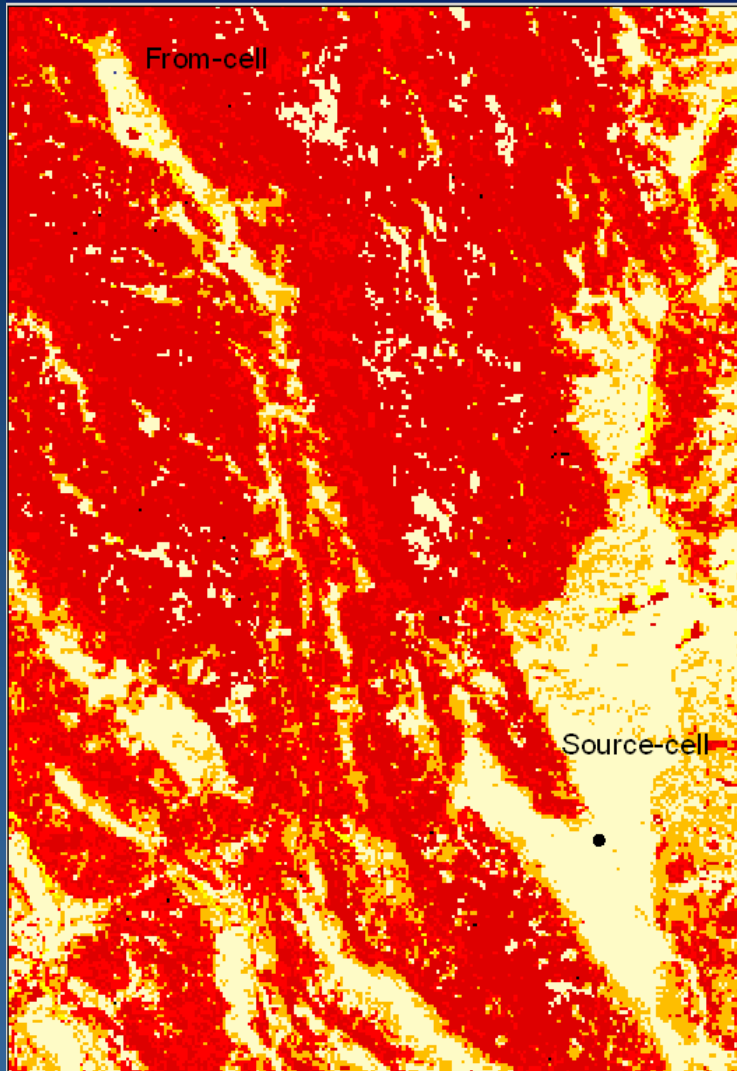


## Example of resistance surface

Dark habitats represents higher resistance

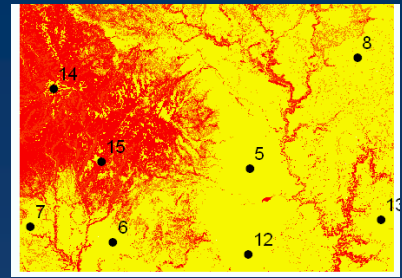


# Resistance surface example



Darker color –  
more difficult habitat to traverse

# In ArcInfo Grid.....



`costdist = COSTDISTANCE (sourcegrid, costgrid, backlinkgrid,  
allocgrid)`

where:

**sourcegrid:** a grid that identifies those cells to which a least accumulated cost distance for every cell is calculated

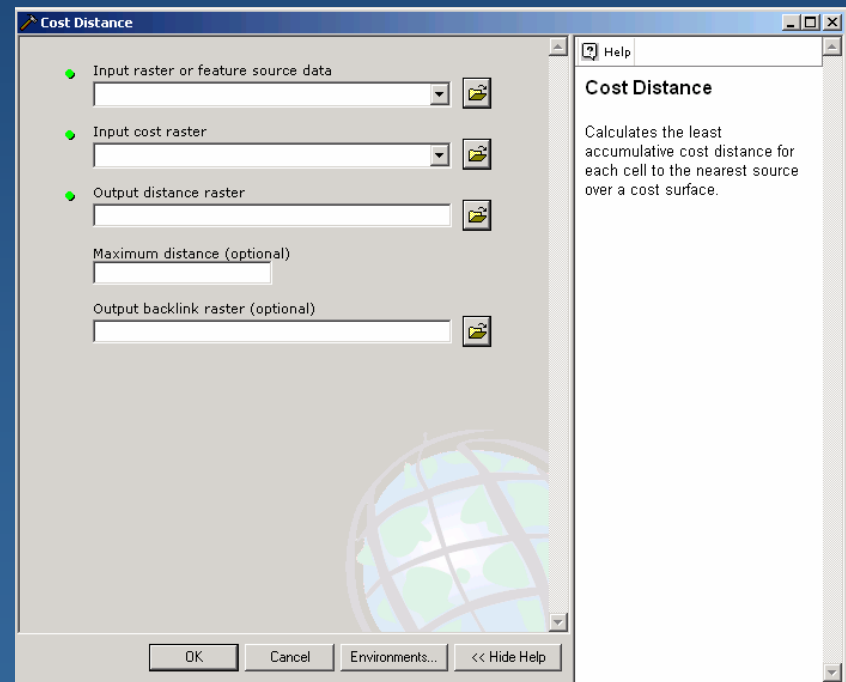
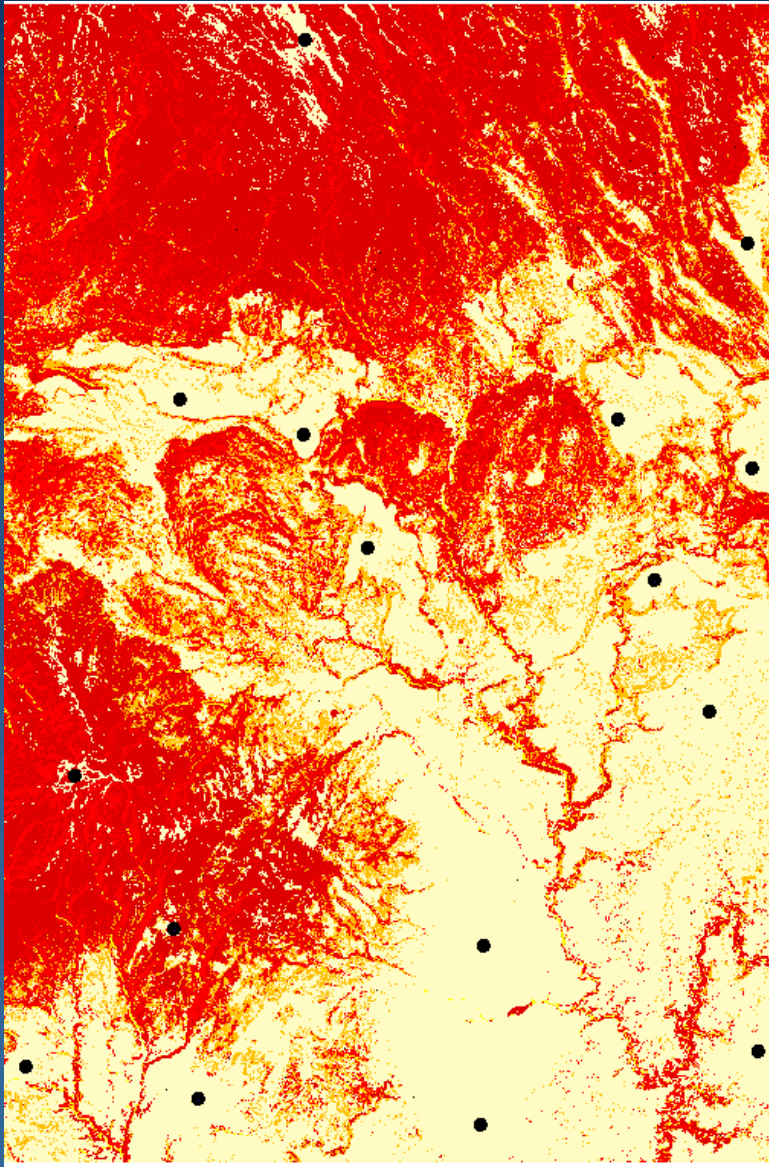
**costgrid:** resistance surface

**backlinkgrid:** the output cost back link grid. Contains values from 0 through 8, which defines the direction or identifies the next neighboring cell (the succeeding cell) along the least accumulative cost path from a cell to reach a source.

**allocgrid:** the name of the output cost allocation grid. The cost allocation grid identifies for each cell, which source would require the least accumulative cost to reach.

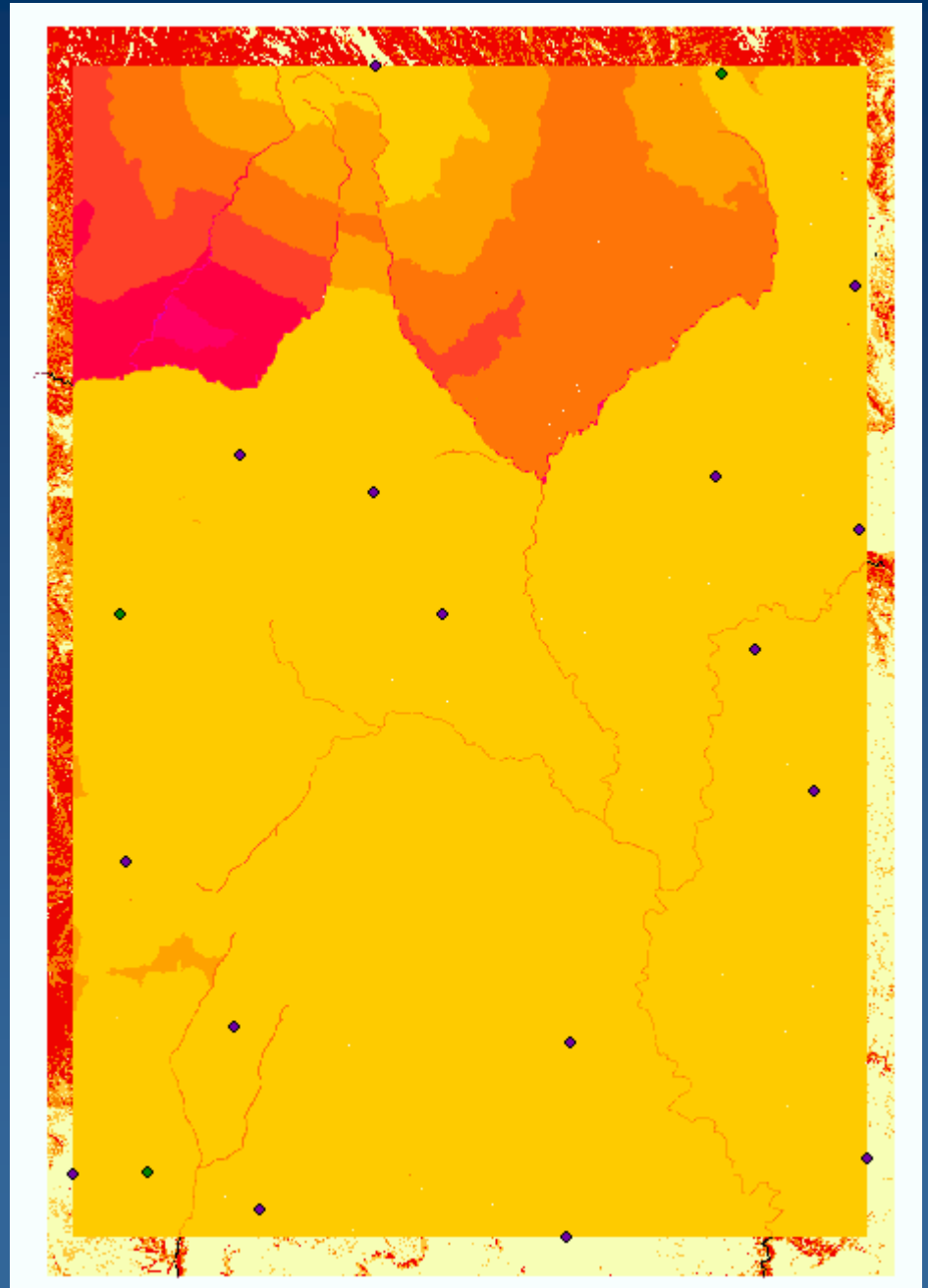
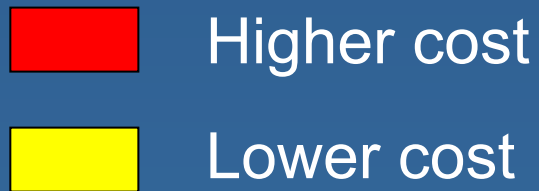
# COSTDISTANCE

A resistance surface (cost grid) overlaid with points that make up the source grid



COSTDISTANCE in ArcToolbox

The COSTDISTANCE command in ArcInfo or ArcToolbox calculates for each cell the least-accumulative-cost distance over a cost surface to a source cell or a set of source cells.





# In ArcInfo Grid.....

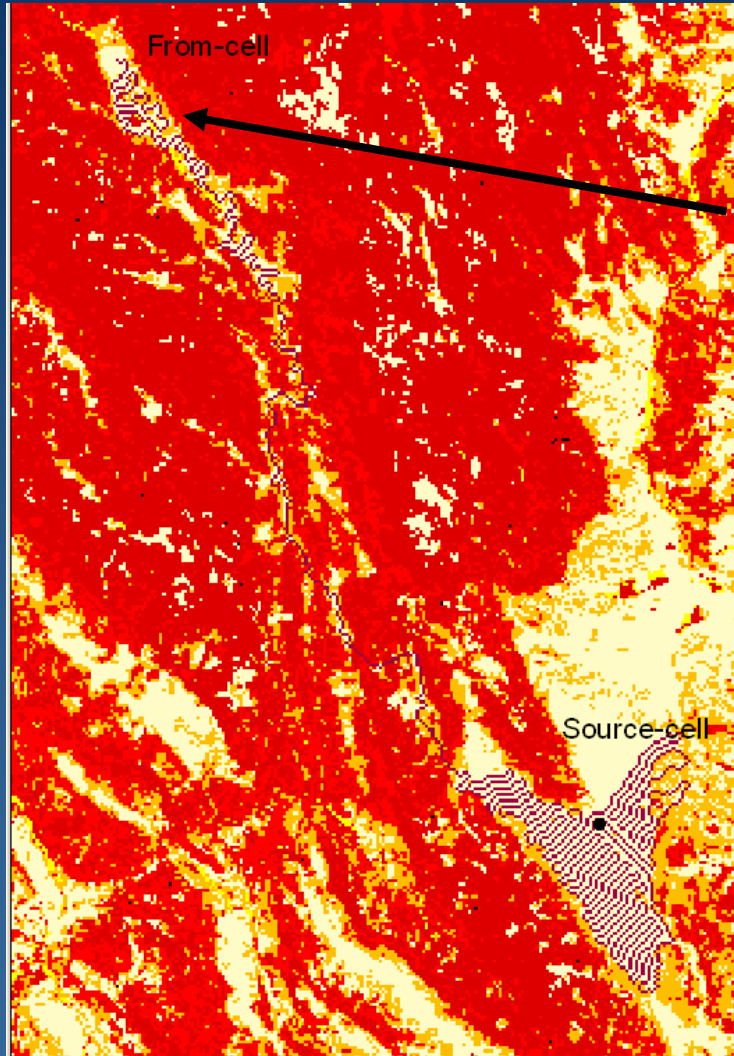
`costpathgrd = COSTPATH(fromcell, costdist, backlinkgrd)`

Calculates the least-cost path from a source to a destination

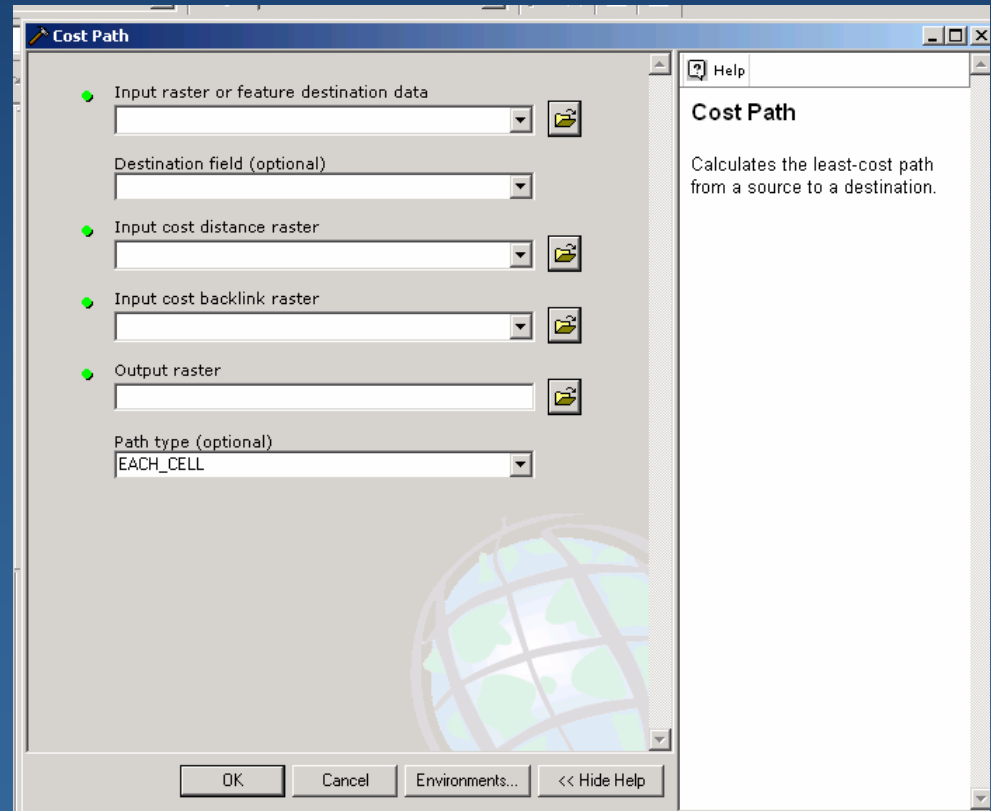
where:

- fromcell:** a grid that identifies cells from which the least cost path is determined to the least costly source. Consists of cells which are to be considered in the COSTPATH calculations having valid values ('0' is a valid value), and the remaining cells must be assigned to NODATA
- costdist:** output from COSTDISTANCE
- backlinkgrid:** the output cost back link grid. Contains values from 0 through 8, which defines the direction or identifies the next neighboring cell (the succeeding cell) along the least accumulative cost path from a cell to reach a source.

# COSTPATH

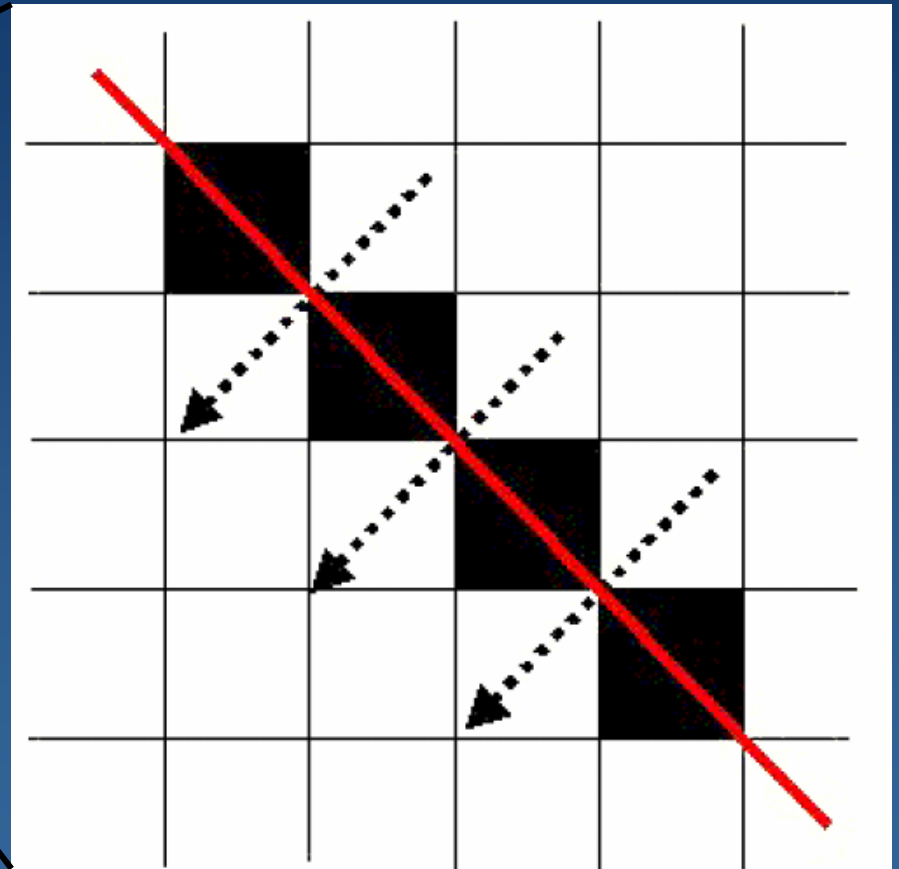
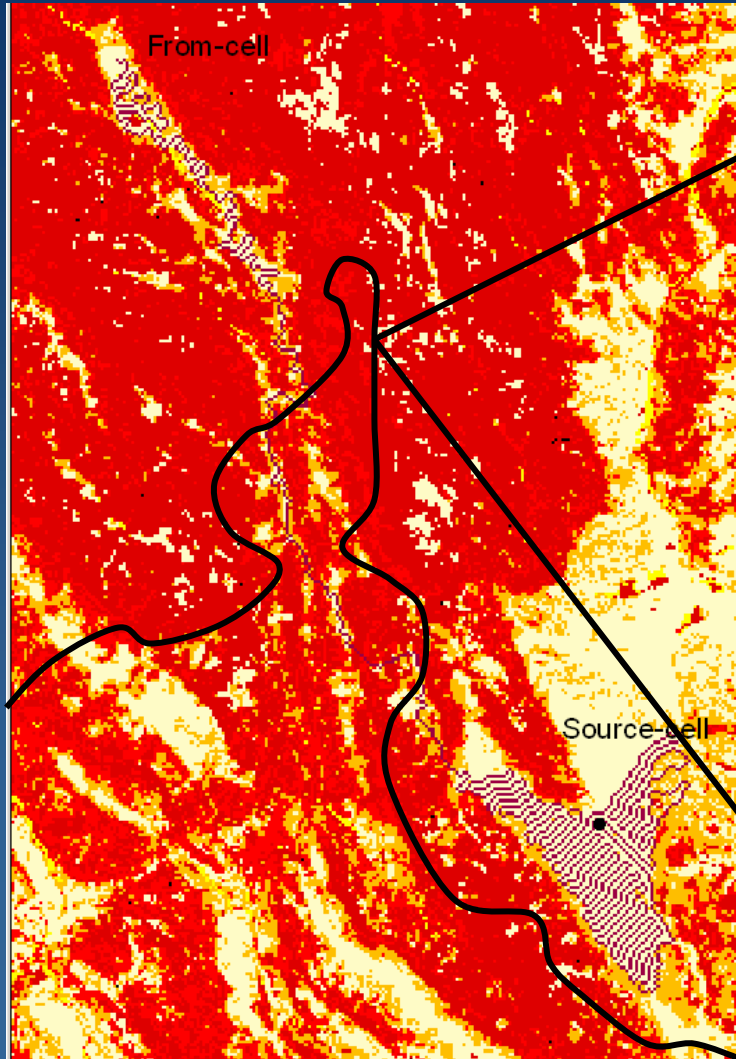


`costpathgrd = COSTPATH(fromcell, costdist, backlinkgrd)`



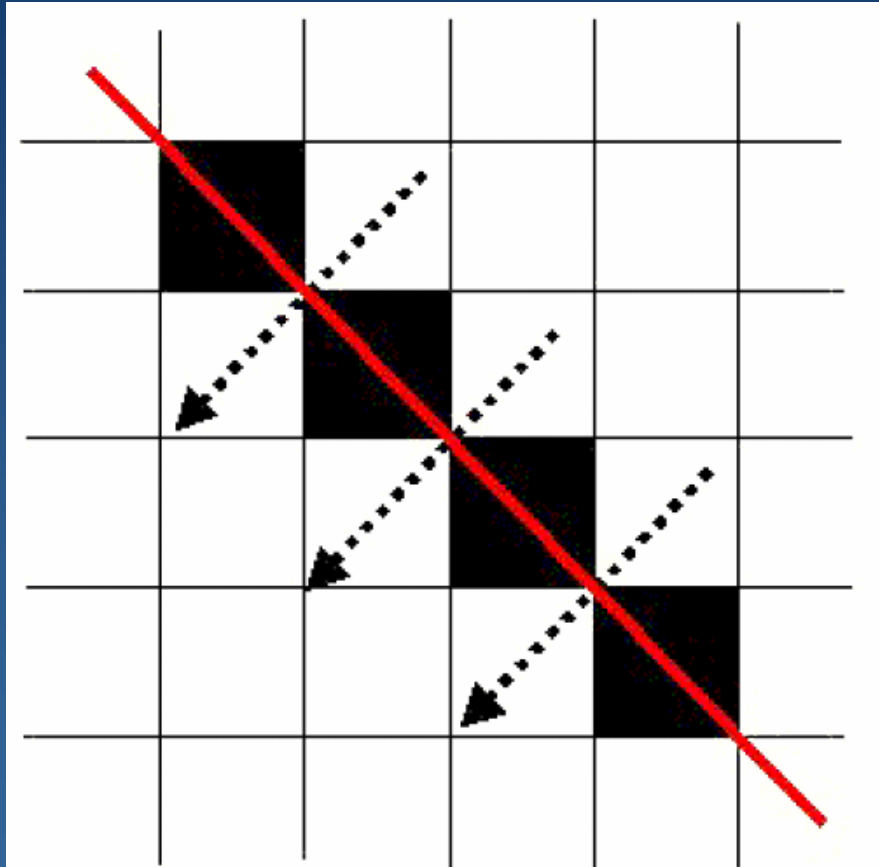
COSTPATH in ArcToolbox

# Linear features in the resistance surface??



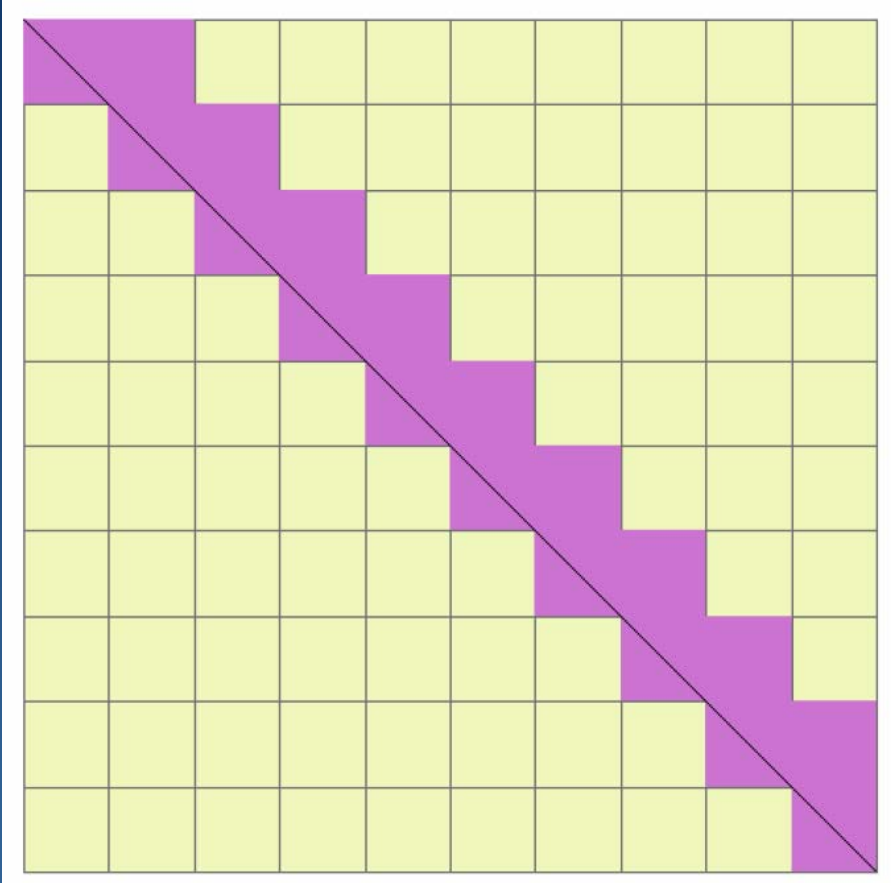


# Cracks in the resistance surface



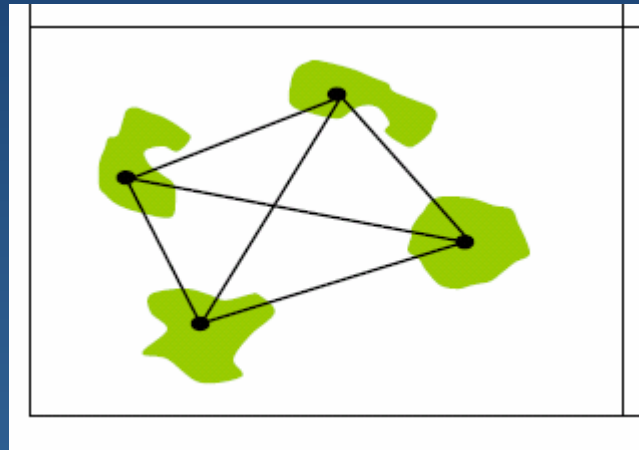
- Cracks are created when linear features are converted to raster data
- The organism may find 'inexpensive' non-existing shortcuts

# Solutions



- Make buffer before converting to raster
- use the linegrid command
- the cell size should be no larger than half the width of the most narrow polygon feature
- Aggregate cost-weights to a coarser resolution using a moving window

# Functional Connectivity



# Functional Connectivity

- *FunConn* modeling tool in ArcGIS 9.x  
<http://www.nrel.colostate.edu/projects/starmap/>
- Developed by Dr. David Theobald, CSU
- Offers improvements over least-cost-path analysis
- Allow landscape connectivity to be examined from a functional perspective
- Based on graph theory

**Citation:** Theobald, D.M., J.L. Norman, and M.R. Sherburne. 2006. FunConn v1: Functional Connectivity tools for ArcGIS v9. Natural Resource Ecology Lab, Colorado State University.

# What is the advantage of using *FunConn*?

- Computationally efficient
- Complex fine scale landscapes can be modeled across large regions
- Evaluates landscape connectivity between all patches not only adjacent patches (1<sup>st</sup> order neighbors)
- Edges and corridors can have user-defined weight attributes
- Calculate metrics such as patch area, corridor width and average cost distance

# Two FunConn Tools

## Habitat Modeling

Generates a terrestrial habitat quality surface (raster), functional patches, and a landscape network

Habitat surface is based on species-vegetation affinity

Only a landcover dataset is necessary input

## Landscape Networks

Generates a landscape network based on existing data

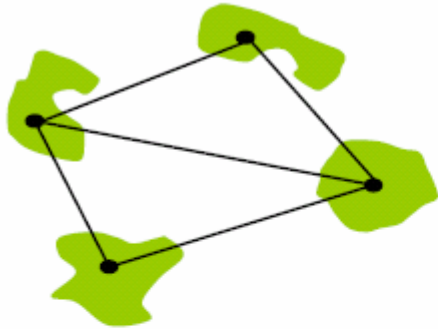
Analysis of existing landscape networks

Tools: Processing	– <i>generates landscape network</i>
Analysis	- calculates shortest paths etc.
Export	- exports network to a matrix format

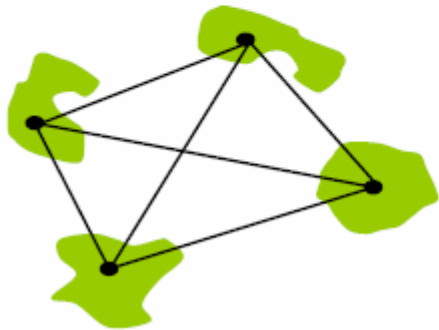
# System Requirements

- ArcGIS ArcInfo version 9.1
- Spatial Analyst active
- c:\temp directory for storage of output data
- Input data in the same coordinate system and datum
- Land cover layer for the study area

# Intro to Graph Theory



Planar Graph:  
Nodes, edges



Non - Planar Graph:  
Nodes, edges

Nodes represents functional habitat patches  
(points or polygons)  
Edges represent the distance between patches



# Terminology

**Patch** – a habitat area

**Linkage** – least-cost pathways between patch edges

**Corridor** – optimal movement pathway between adjacent habitat patches

**Cluster** – group of patches that function as a single patch

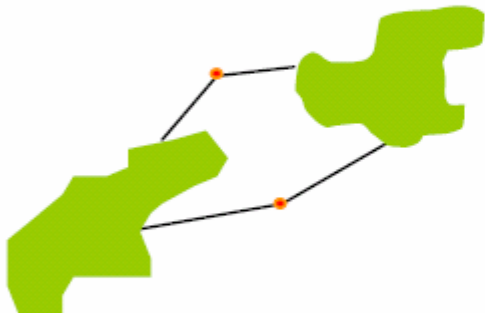
**Walk** – a sequence of nodes connected by edges

**Cycle** – a ‘walk’ that ends at the first node

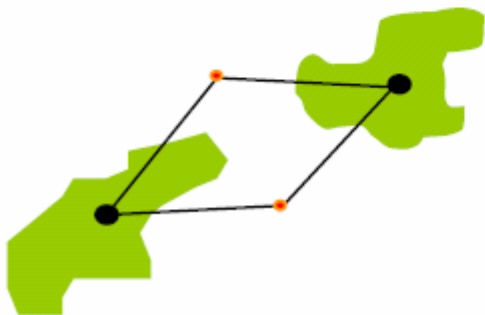
**Core seed** – area of high quality habitat from which functional patches originate



Corridors

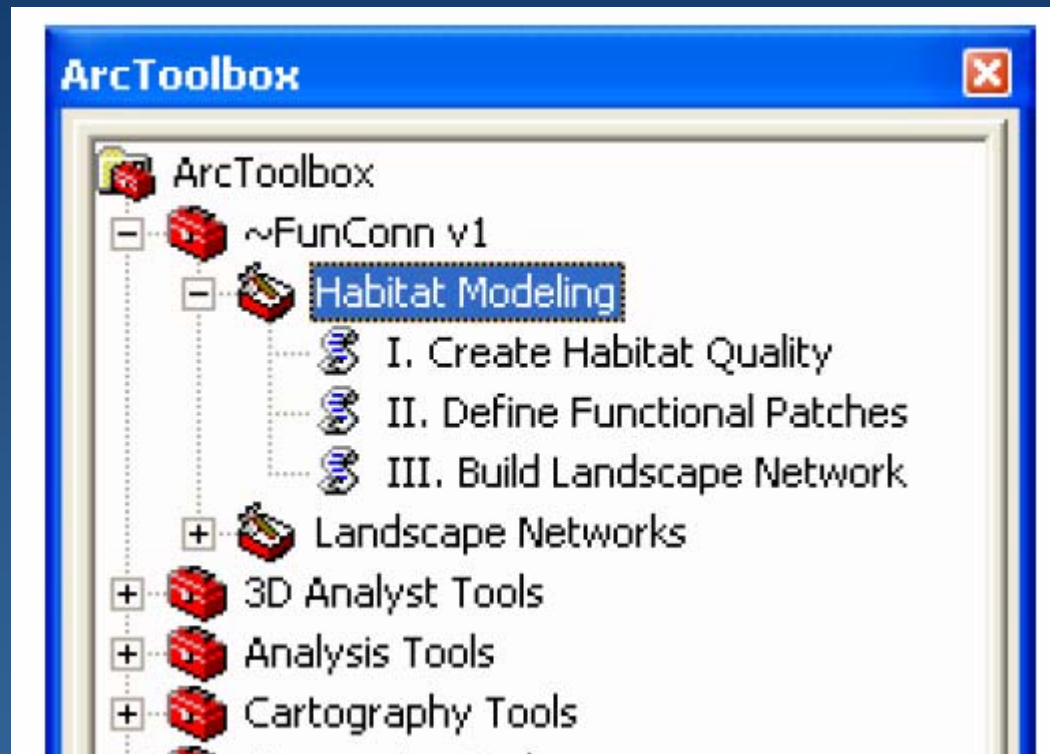


Linkages



Edges

# FunConn Tool in ArcToolbox



# Create Habitat Quality Map



I. Create Habitat Quality

Land Use/Cover Raster  
C:\lynx\lvp\_swigp

Resource Quality Reclass Table  
C:\lynx\habitat\_quality.dbf

Resource Quality Threshold  
75

Minimum Patch Size (ha)  
264

Patch Structure Reclass Table  
C:\lynx\patch\_structure.dbf

Land Use/Cover with Disturbance Raster  
C:\lynx\lvp\_disturb

Disturbance Reclass Table  
C:\lynx\disturbance.dbf

Aggregation Factor  
3

Habitat Quality Output Raster  
C:\lynx\results\lynx\_hq

**Land cover** – classified by the resource quality reclass table

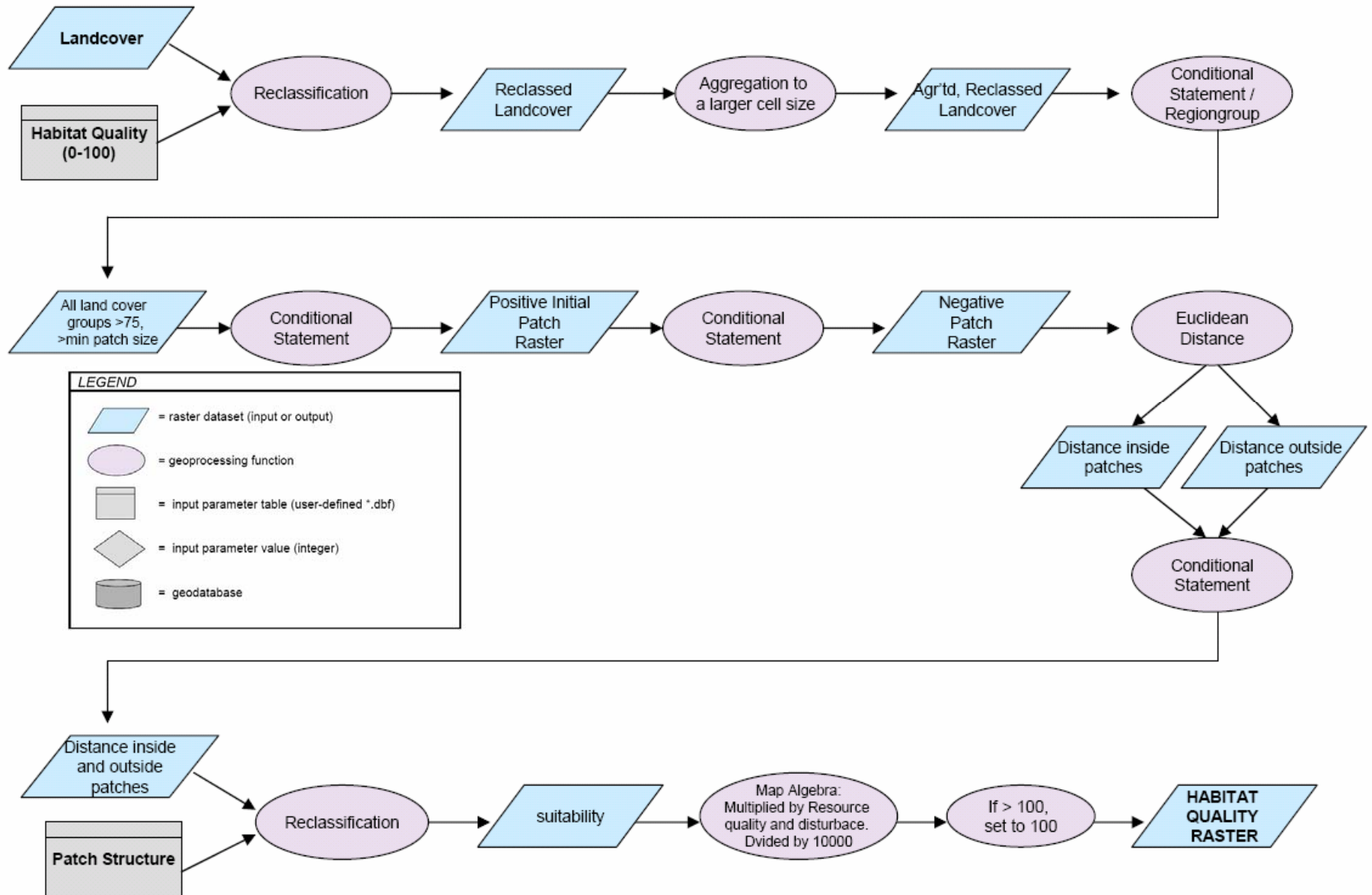
**Disturbance** – classified by the distance from disturbance (roads, development etc.) reclass table

**Patch structure** – classified by the patch structure reclass table, which explains edge sensitivity

The 3 resulting rasters are combined to create the habitat quality raster

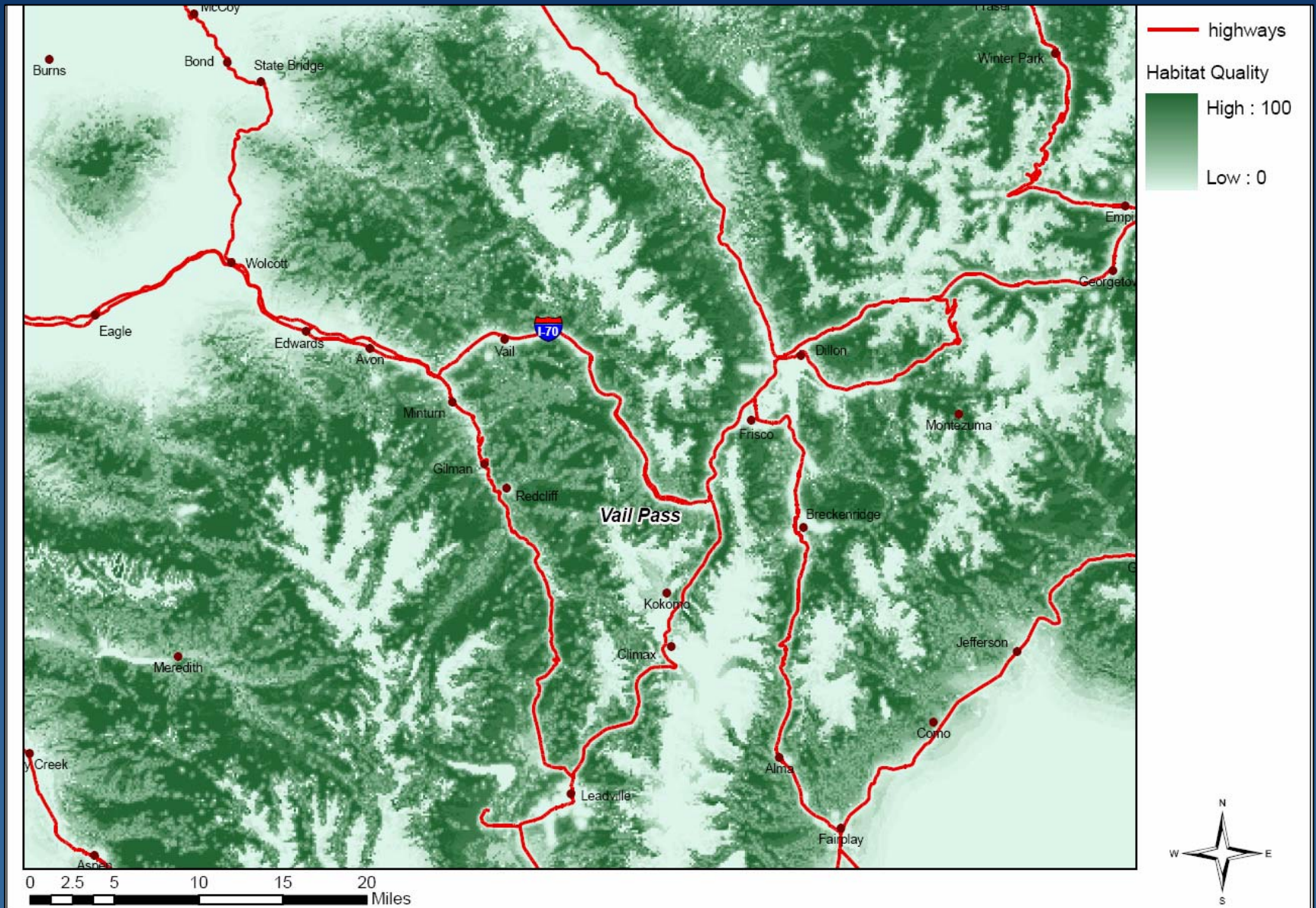
# Habitat Modeling Geoprocessing Steps

## 1) Create Habitat Quality Tool





# Lynx Habitat Quality Map



# Define Functional Patches

II. Define Functional Patches

Habitat Quality Raster  
C:\lynx\results\ex\_hq

Minimum Patch Size (ha)  
264

Patch/Foraging Radius (meters)  
917

Core Habitat Percentage  
0.1

Resource Quality Threshold  
75

Functional Patches Output Raster  
C:\lynx\results\ex\_patches

OK Cancel Environments... Show...

Minimum size

Max foraging radius

Core habitat

Quality threshold (based on habitat quality raster)

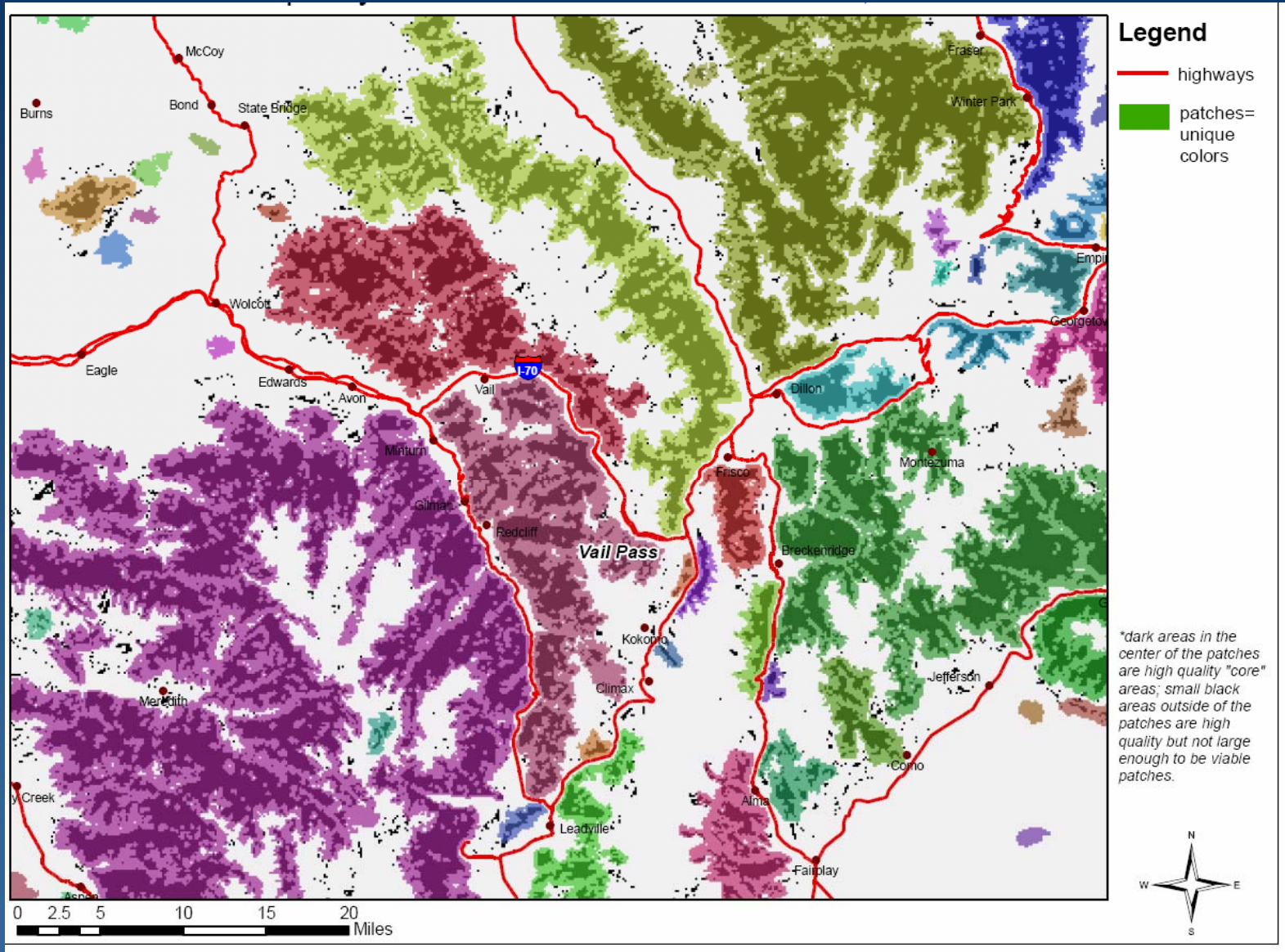
# Define functional patches overview

- 1) Areas greater than the quality threshold are kept and regiongrouped
- 2) Areas less than the minimum core habitat percentage times the area of the foraging radius are eliminated
- 3) A cost surface is created from the habitat quality raster, cells of high quality have a low cost and vice versa
- 4) The remaining patches are grown outwards across the cost surface to a distance equal to the foraging radius.
- 5) Patches less than the minimum patch size are eliminated.





# Functional Patches of Lynx Habitat



# Build Landscape Network Tool

- Creates a landscape network representing habitat patch connectivity
- Creates a cost surface incorporating user-defined permeability values (may originate in layers such as slope)
- The functional patches are grown across the surface until they meet – the meeting point is called the allocation boundary
- Linkages between patches are defined and corridors are created

# Build Landscape Network Tool

III. Build Landscape Network

- Functional Patches Raster
- Land Use/Cover with Disturbance Raster
- Landcover Permeability Reclass Table

Additional Permeability Raster (optional)

Aggregation Factor: 3

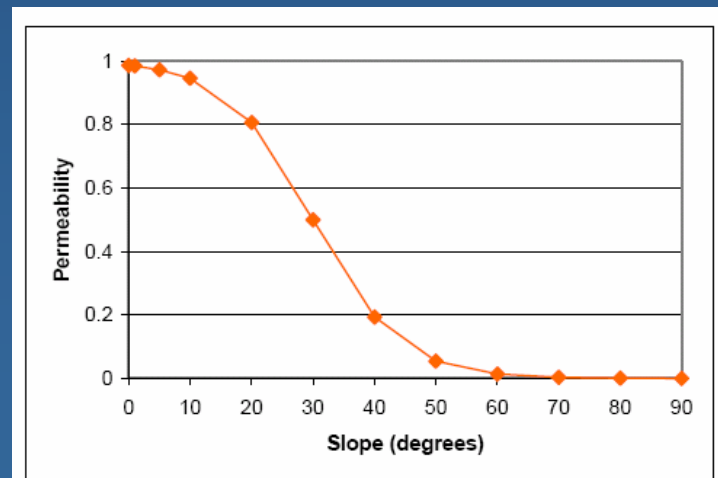
Links Qn Value: 10

- Output Landscape Network

OK Cancel Environments... Show Help >>

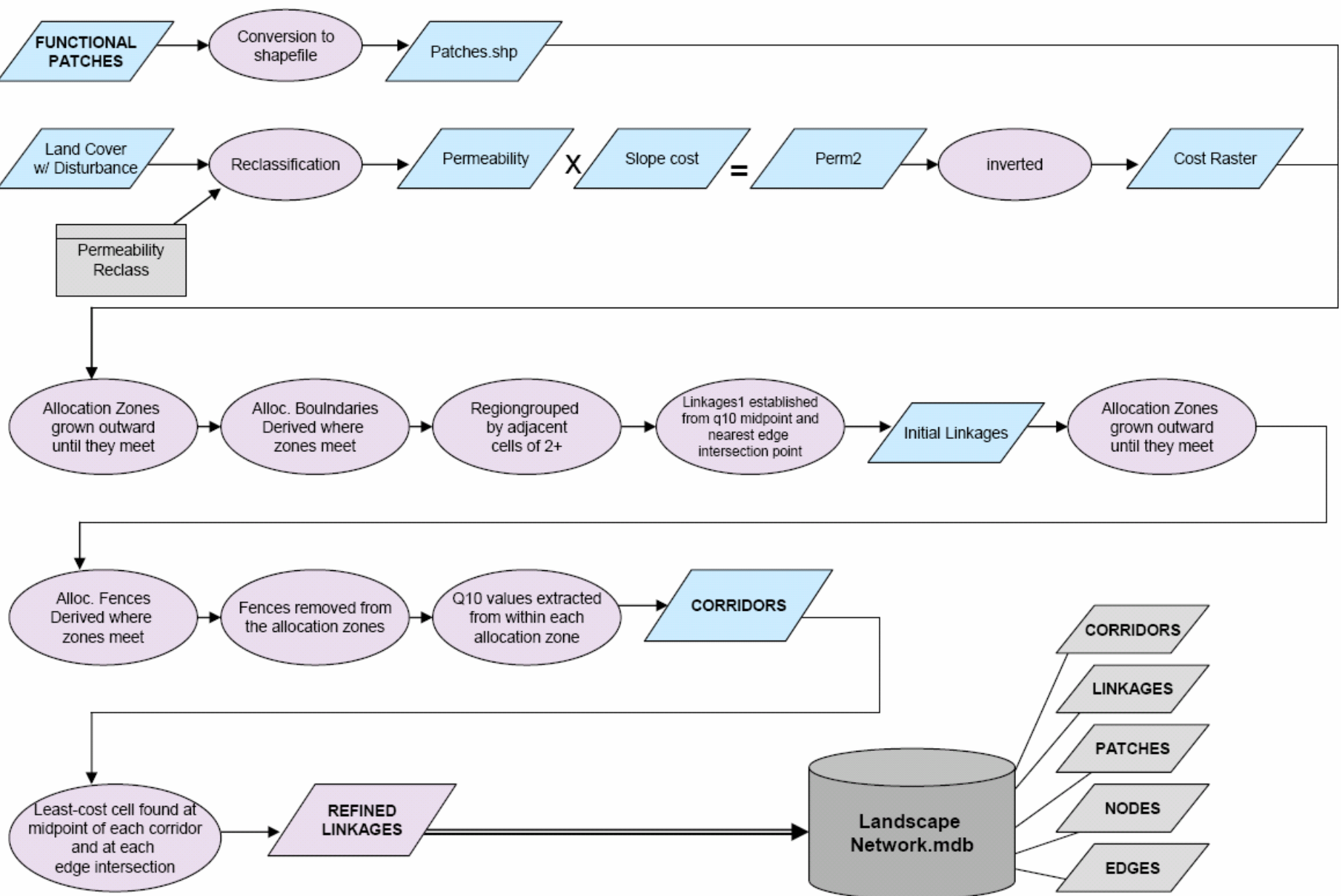
# Permeability raster

- Permeability is the inverse of resistance
- Is NOT the same as habitat quality, but rather describes how readily the organism can move through
- Permeability can be a function of for example habitat type or topography,



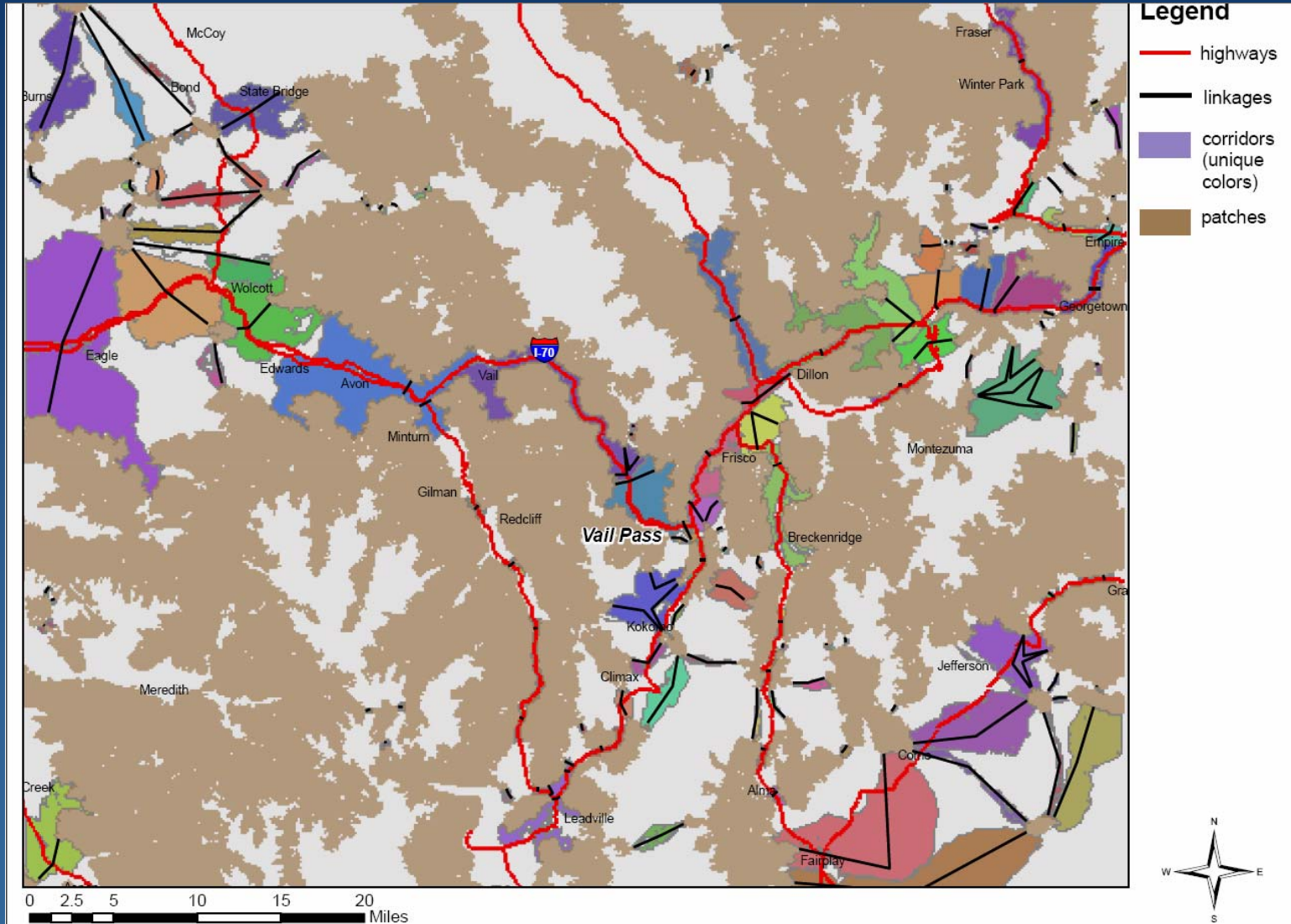
# Habitat Modeling Geoprocessing Steps

## 3) Build Landscape Network Tool

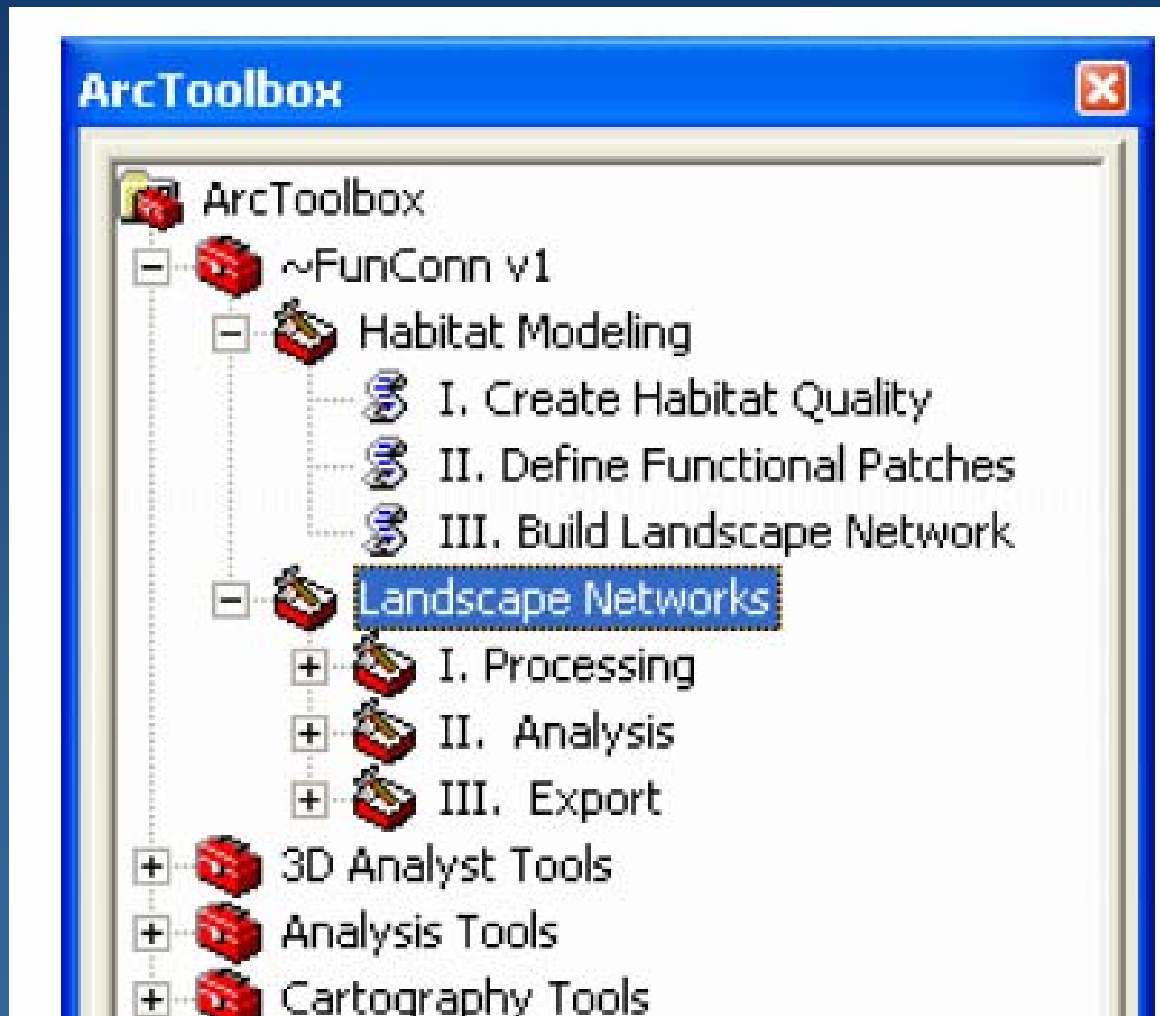




# Lynx Landscape Network



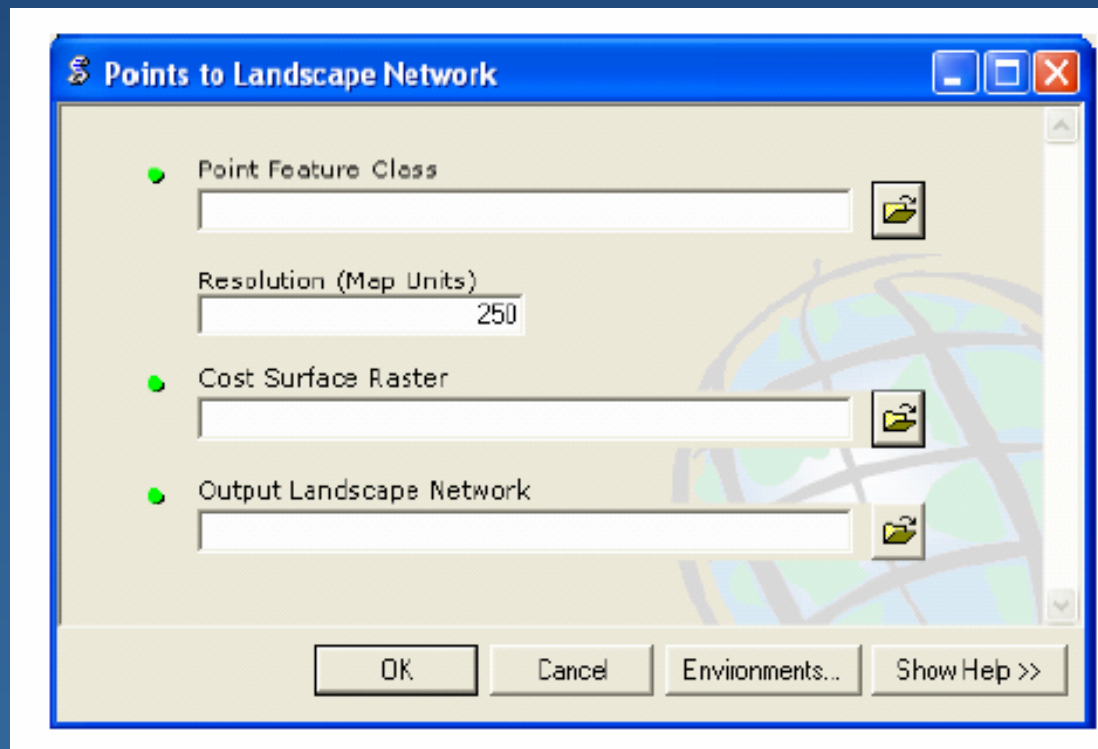
# Landscape Networks Tool





# Landscape Networks Tool: 1. Processing

- Generates a landscape network based on existing point or polygon features such as species sampling points, plot centroids, or management units.



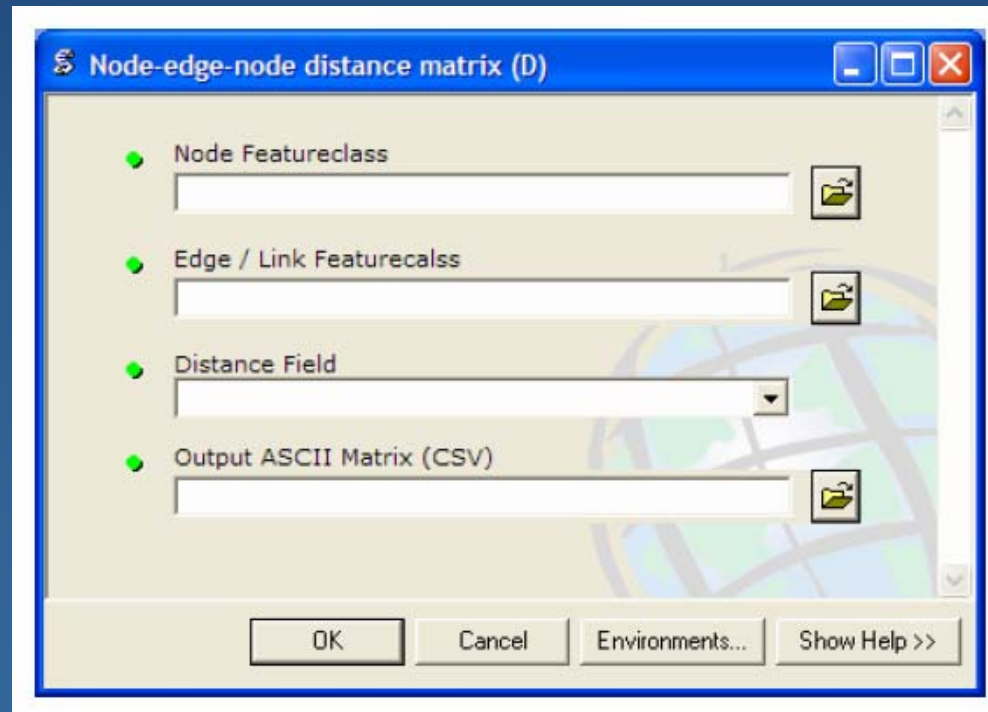
# Landscape Networks Tool: 2. Analysis

- Computes the most efficient route for an organism to disperse through all habitat patches of a landscape
- Inputs:       Line features: edges, linkages, or corridors  
                  Weights for the line feature

Other tools: Edge Calculator Tool  
              Neighborhood selection tool  
              Node calculator tool  
              Shortest path tool

# Landscape Networks: 3. Export Sub-Toolset

- Produces a matrix of distances between 1srfer neighbors
- Edges, linkages, or corridors can be used to calculate distance.



# FunConn User Guide

Lynx example