

Quick tutorial: Applying Circuitscape to Connectivity Conservation

This is a very simple exercise to get you up and running with Circuitscape. It involves analyzing connectivity on a simple ‘cartoon’ landscape, with outputs shown in the document below. Some additional data are provided so that those with GIS software can experiment more.

Circuitscape exploits connections between random walk theory and electrical circuit theory. It treats landscapes as conductive surfaces, and uses resistance, voltage, and current to predict important aspects of movement and connectivity. More pathways mean more options and more robust connections. Current flowing across the landscape can be used to identify areas important for connectivity, especially *pinch-points*. These are portions of the landscape where movement is funneled through a narrow area, making a linkage vulnerable because the loss of a small amount of habitat can sever the linkage entirely.

How Circuitscape works:

A raster **habitat map** specifies conductance or resistance at each cell in a landscape. A raster **focal node map** specifies points or polygons (usually core habitat areas) between which connectivity is to be modeled. Circuitscape creates a graph (network) by converting habitat cells to nodes and connecting them to their immediate neighbors. The program calculates pairwise resistances and creates maps of current flowing between focal nodes.

We will create maps of current flowing across a simple landscape, and compare them with least cost corridor results. We’ll also create voltage maps, which can be used to identify important barriers and restoration opportunities.

1. Download and install Circuitscape if you haven’t already from:

<http://www.circuitscape.org/Circuitscape/Download.html>

2. Download the tutorial data and save it somewhere easy to find on your hard drive:

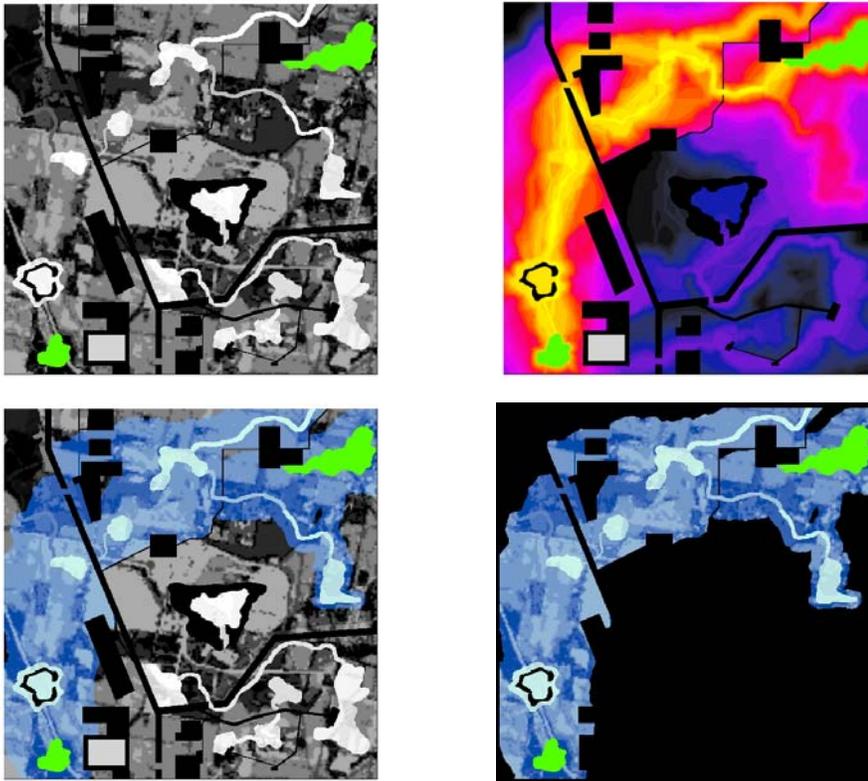
http://www.circuitscape.org/Downloads/Circuitscape_tutorial.zip

The ***Tutorial_data*** folder contains two GIS grids in ASCII format:

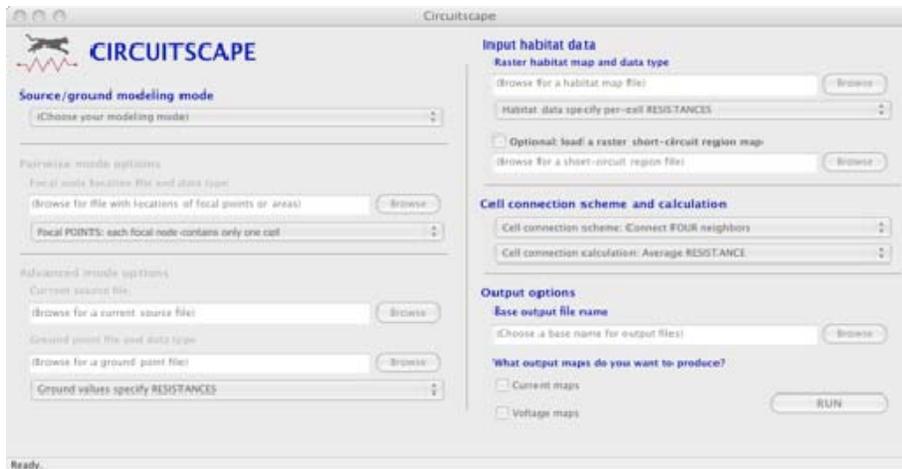
- *2_Core_Areas.asc* has two core areas, numbered 1 and 4. The rest of the grid is NoData.
- *Corridor_resistances.asc* is a dispersal habitat map clipped to a least-cost corridor run between the two core areas. Resistance values vary from 1 to 100, plus NoData areas that act as complete barriers (like highways and shopping malls).

These data are displayed in the ArcMap project file ***Circuitscape_tutorial.mxd***.

To get the clipped dispersal habitat, I went through the following process. The picture on the upper left is what the full resistance map (Resistances.asc) looks like, with good dispersal habitat in white and increasing resistance in darker shades. The two core areas we are trying to connect are in green. The picture on the upper right is a least-cost corridor between the two core areas (produced using the CostDistance function in ArcGIS). Warmer colors are closer to the optimal (least cost) route. In the lower left is the clipped resistance map (in shades of blue over the full resistance map), and the lower right panel is the clipped portion only. **The one in the lower right is the resistance map we'll use for this tutorial.**



3. Start Circuitscape. A terminal window and a user interface like this will open:



Under *Source/ground modeling mode* choose:
Pairwise: iterate across all pairs in focal node file

Under *Focal node location file and data type* browse to:
Tutorial_data\2_Core_Areas.asc
 And choose ***Focal Regions***

Under *Raster habitat map and data type* browse to:
Tutorial_data\Corridor_resistances.asc
 And choose ***Habitat data specify per-cell RESISTANCES***

Under *Cell connection scheme and calculation* choose:
Connect EIGHT neighbors and ***Average RESISTANCE***

Under *Base output file name* browse to:
CS_OUTPUT and create an output file with name ***“tutorial.out”***

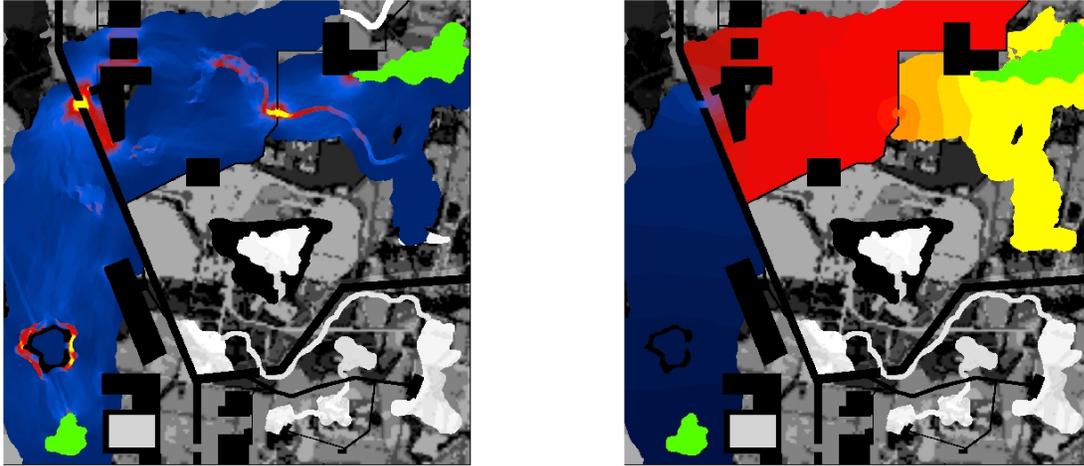
Check the boxes next to *create current maps* and *create voltage maps*.

Click *Options* (in the menu bar). Don't check any at this point, but this'll give you an idea of some of the additional settings available to you. Additionally, under *File*, there are options for running in batch mode and for saving run settings.

Then, press run. Circuitscape creates ASCII current and voltage maps for each pair of core areas, plus a cumulative current map that sums up current between all pairs (just one pair in this case).

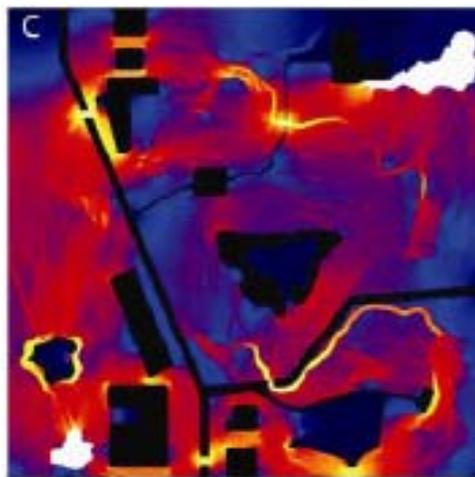
4. Interpret results.

To view the results, you will need to import the map into a GIS. But for now, just have a look at the maps below.



On the left is a current map, with warmer shades showing higher current flow. On the right is a voltage map. If you think of water flowing from the upper core area to the lower, current is the water's speed, and voltage is the water level. The roads act like dams. Looking at the voltage map, what parts of the map would breaching a dam increase the flow the most?

So, why clip out a least-cost corridor? This is one way Circuitscape can complement common least-cost corridor analyses. It can be used to compare between different corridor designs (like different corridor widths). It can also show pinch-points within corridors- these are areas that should be priorities for protection. Lastly, it can keep Circuitscape results limited to areas that don't require dispersers to move unreasonable distances. Still, it's good to run Circuitscape on a full landscape too. Current densities from a run using the full resistance map are shown below:



Note that a second route, providing extra pathways, shows up.

Extra: Try running and interpreting results with extra core areas and with the full resistance raster (*Resistances.asc*).

The *Extra_Data* folder contains alternative core area and resistance grids that you can experiment with on your own:

- *5_Core_Areas.asc* has five core areas in the same region, numbered 1 through 5. The rest of the grid is NoData.
- *Resistances.asc* is a resistance map for the same region, but has not been clipped to a least cost corridor.

Some hints on manipulating and displaying input and output data in ArcGIS:

Input data-

You can easily export ESRI grids and shapefiles (handy for core areas) to ASCII format using the “Export to Circuitscape” plug-in available on the Circuitscape website. Note: this has not yet been updated for ArcGIS 10.

Displaying outputs -

You’ll need to experiment with different ways of displaying current maps in ArcMap by right-clicking on the map files in the Layers pane, clicking **properties**, and selecting the **Symbology** tab. Try different ways of displaying the current map- start by selecting “Stretched” in the Show pane, choose a color ramp that you like (there are rainbow ramps that display nicely), and under “Stretch” choose Standard Deviations.

For the current map above, I used a stretched renderer, and tweaked Min, Max, Mean, and Std Dev settings. Have a look at the settings I used in Circuitscape_tutorial.mxd.

You can get the most control by using a classified renderer - often the “Quantile” classification method produces nice maps. The classified renderer allows you to exclude extreme values too, which can help focus on more relevant values. I find it helpful to exclude areas of highest current (typically found in the core areas) and areas with 0 current.

Once you’ve created a color ramp you like, you can import it into other layers by clicking “import” in the Symbology window for the other layers.