National Ecological Framework Guide

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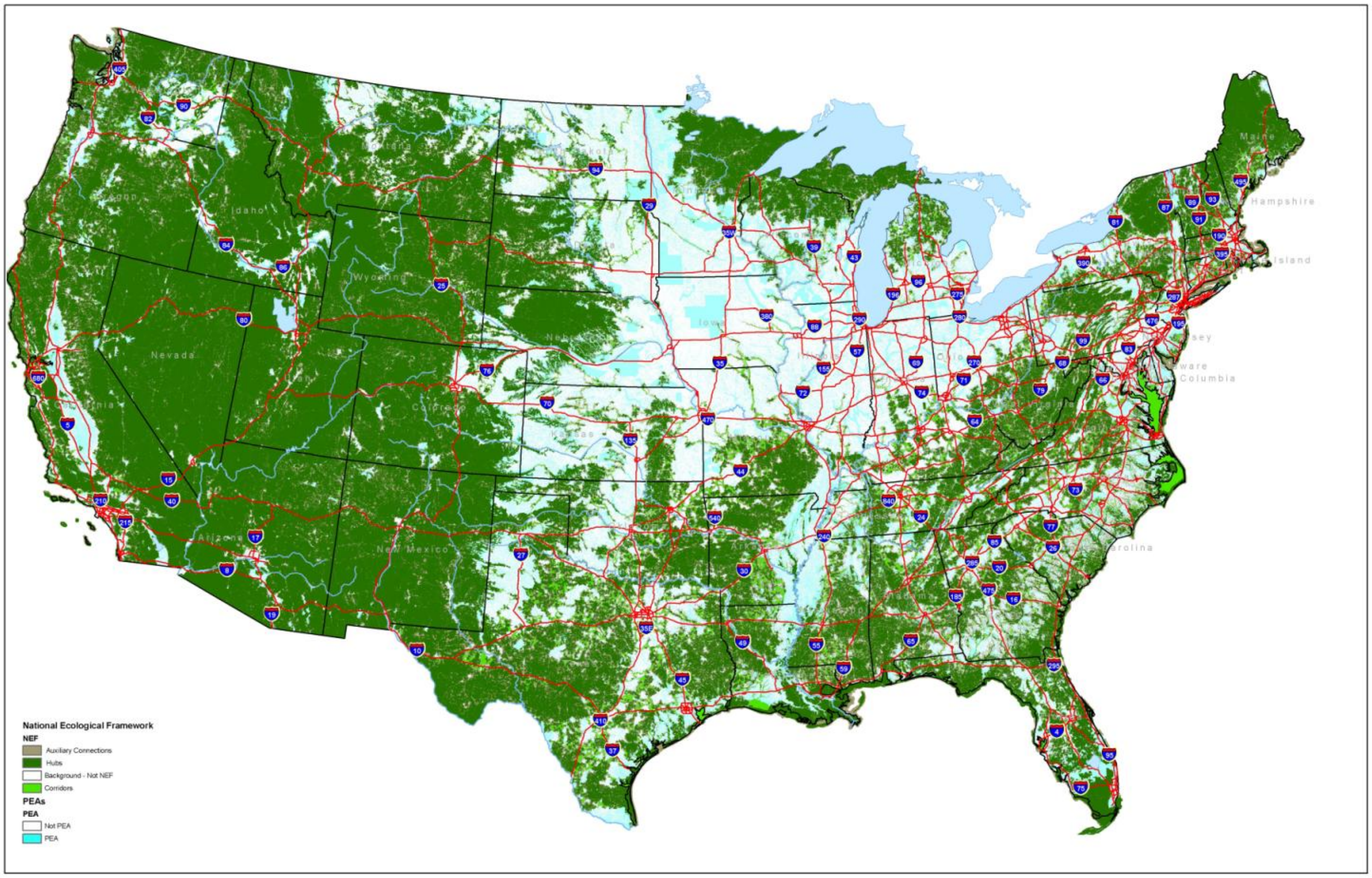

US EPA Region 4

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Version

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Introduction

The National Ecological Framework is a GIS based model of the connectivity of natural landscapes in the lower 48 United States. It was developed to provide a guide for the protection of the natural ecosystem processes that give us clean air, pure water and protected lands that are part of EPA's mission to protect. It was developed as an update to the Southeastern Ecological Framework from 2001.

The National Ecological Framework is an update to the Southeastern Ecological Framework with more current data and expanded range (US48). It follows the same methodology (Carr, et. al 2002) as the SEF except where noted in italicized boxes http://www.geoplan.ufl.edu/epa/download/sef_report.pdf

The original Southeastern Ecological Framework (SEF) was developed for Region 4 by the University of Florida between 1998 and 2001. The purpose of the SEF was to develop a mapped data set of ecologically important areas that could be connected with a hub/corridor model.

The SEF was created with data and information from the 1992 NLCD land cover data at a scale of 90 meters. The current National Ecological Framework (NEF) was begun as an update to the SEF with newer data (2001 through 2010). Beginning as an update to the SEF it became evident that it was feasible to reduce the scale of the first SEF from 90 meter resolution to 30 meter resolution and to do the modeling on a national scale with little more overhead than doing it for Region 4. This project fits very well with the efforts of the Office of Research and Development (ORD) Ecosystems Services Research Project (ESRP) for protection of ecosystem services.

The methodology used to develop the SEF is based on a hub-connector approach originally developed by Larry Harris, Reed Noss, and Tom Hoctor at the University of Florida. The methodology for the NEF follows closely that developed for the SEF.

The first step was to define areas of the landscape that are priority ecological areas (PEA's). These were combined and modified to give the hub structure. The hubs were then linked with corridors that are defined using a cost surface analysis. The cost surface was developed using energy accounting. This is based on assignment of the total non-renewable energy flow through the various landuse types from the 2001 NLCD. This then gives an approximation of the human disturbance on the landscape as an accounting of that accumulated energy flow. The least cost (determined by the least human disturbance path) between hubs was used to define the corridors that connect the hubs

The scheme of the modeling process was to:

1) Combine Priority Ecological Areas (PEAS) from a variety of sources including:
    a. USGS Protected Areas Database,
    b. The Nature Conservancy Ecoregional Portfolio Core Data Set,
    c. Fish and Wildlife Service Strategic Habitat Conservation Areas,
    d. roadless areas,
    e. first order stream reach catchments,
    f. mature forest patches, wetlands and
    g. several other data sources.
2) Exclude areas of high road density high urban or agriculture density, nearness to urban or agriculture and inappropriate land use type.
3) Develop hub structures for areas greater than 5000 acres by excluding smaller unconnected areas. (Hubs - 3734 areas greater than 5000 acres)
4) Develop connectivity between the hubs in appropriate natural areas utilizing computer based connectivity links and user identified linkages. (Total of 12,000 total links) Widen the single line connections to include appropriate land use for corridors.
5) Combine the Hubs and Corridors to give the National Ecological Framework (NEF)
6) Optimization of the NEF by developing connectivity to the NEF in both terrestrial and hydrologic connected areas. These are called auxiliary connection to the NEF
7) Determine areas that may be restored to a more natural setting that are contiguous with the hub/corridor framework.
8) Categorize the National Ecological Framework by type and ecosystem.

Potential uses for the NEF

- Highway planning to minimize ecological disturbance.
- Wetlands mitigation to maximize ecological connectivity.
- Protection of sole source surface water areas.
- Integration of habitat protection plans for local, state, and regional agencies.
- Create greenways to link local efforts with larger scale programs.
- Provide connectivity to help mitigate ecosystem changes due to climate change.
- Create innovative residential developments through conservation design and open space protection
- Reduce urban encroachment by creating buffers around wildlife refuges, national parks, state and local parks, and private wilderness areas.

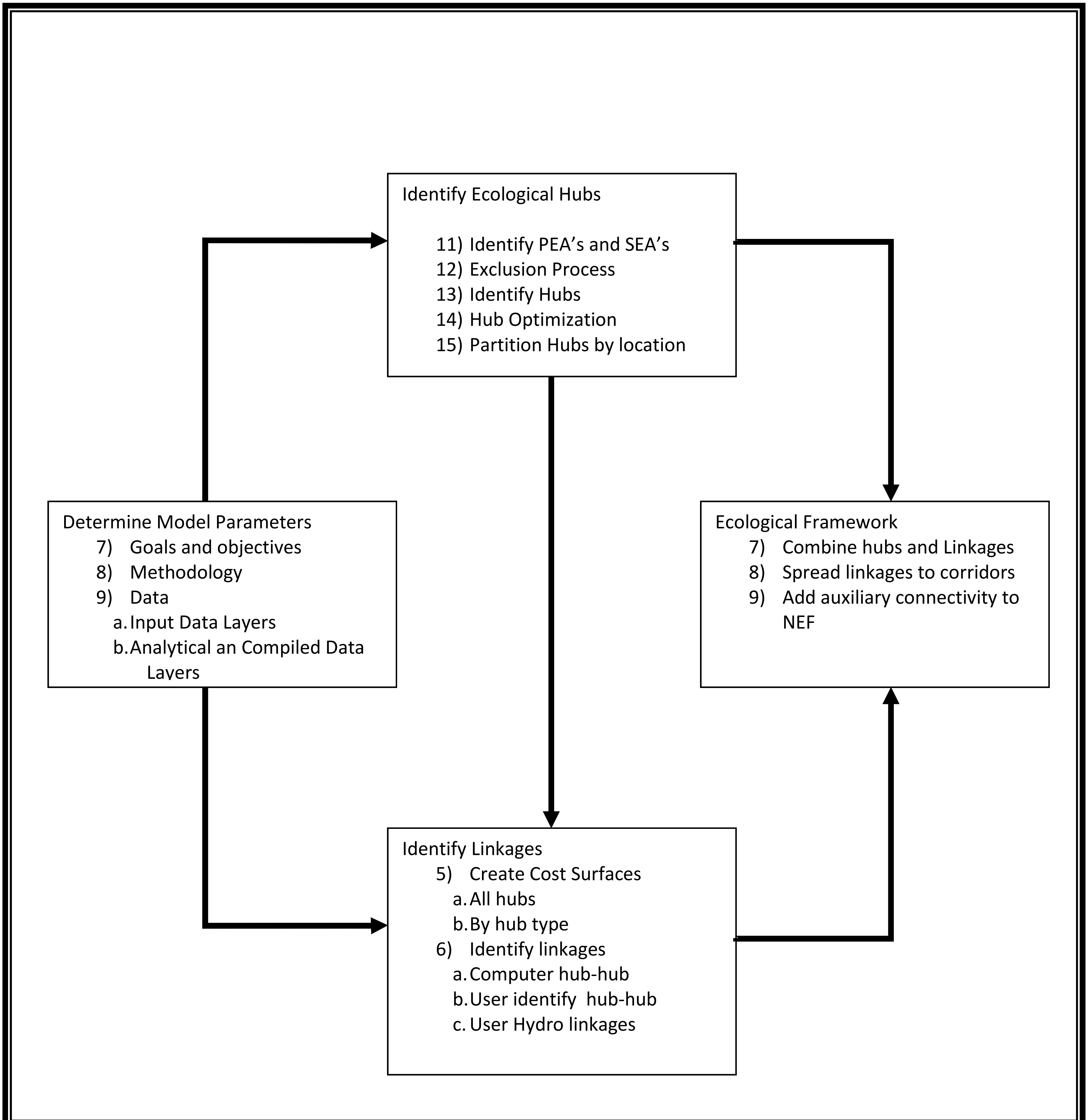

Figure 1 : Flow Chart of the processing involved in developing the National Ecological Framework

Priority Ecological Areas

The NEF analysis used only data layers that were consistent across the U.S. where the SEF had some data that was state based. Most of the individual state based data has been combined by the USGS Protected Areas Database.

Priority ecological areas (PEA's) represent areas of ecological interest for a variety of protection levels. Some are in some sort of protection such as national parks, refuges, forests along with state equivalents. At the opposite end of the scale are areas that represent conservation interest but have little protection such as areas in the data from the US Fish and Wildlife Service, The Nature Conservancy, and the Commission for Environmental Cooperation. Other priority areas are based on landscape features which serve to preserve ecological services, such as wetlands, roadless areas, mature forest, and landforms that represent potential wet areas that may or may not be existing wetlands. Priority Ecological Areas were determined from a variety of data sources. The model for the SEF used regional and some individual state layers. The NEF used only data that was national in scope. The USGS Protected Areas Database (USGSPAD v1.1) combines data from a variety of sources, including national, state and local data. Several of the state databases that were used in the SEF were included in the USGSPAD.

The first order stream data for the NEF, utilized the NHDPlus dataset which was a large improvement over the data for first order streams used in the SEF.

The PEA data layers are as follows

PEA_1STORDSTR

First order stream catchments from the NHDPlus database that have been masked by the Category 1 and 2 NLCD data (**cat12ter**).

PEA_1ORDSTR5K

First order stream catchments (**pea_1stordstr**) that were region grouped and filtered for groups that are larger than 5,000 acres. This is a subset of **pea_1stordstr** and was included to be able to locate those larger areas of first order natural areas that were contributing to hubs and corridors.

PEA_CECGRSLND

This data/map shows the grasslands priority conservation areas (GPCAs) within North America's Central Grasslands, an ecosystem considered among the most threatened in the continent and the world. The Commission for Environmental Cooperation is a 3 nation (US, Canada, and Mexico) intergovernmental organization to support cooperation among the NAFTA partners to address environmental issues of continental concern, including the environmental challenges and opportunities presented by continent-wide free trade.(see PEA_appendix for original metadata from CEC) http://www.cec.org/Page.asp?PageID=924&ContentID=2336

PEA_CECPAD

This data/map shows the protected areas of North America that are managed by national, state, provincial, or territorial authorities. Local shapefile CEC_NA_PA_GEO_07_08.shp (see PEA_appendix for original metadata from CEC).
http://www.cec.org/Page.asp?PageID=924&ContentID=2336

PEA_DIV

The NLCD2001 data was recoded into 6 separate habitat/landscape classes (similar to the habitat types coded from the NLCD92 data use in the Southeastern Ecological Framework Project, Carr, etal 2002). A focal variety was calculated **(hab_divmsk27)** for a 27x27 window within the **cat12ter** grid. The final **pea_div** mask was generated from the grid **hab_divmsk27** where the total variety was 5 or 6 within the 27x27 window.

VALUE	CLASSNAME	habitat type
11	Open Water	0
12	Perennial Ice/Snow	0
21	Developed, Open Space	0
22	Developed, Low Intensity	0
23	Developed, Medium Intensity	0
24	Developed, High Intensity	0
31	Barren Land (Rock/Sand/Clay)	0
81	Pasture/Hay	0
82	Cultivated Crops	0
127	Nodata	0
52	Shrub/Scrub	1
71	Grassland/Herbaceous	1
90	Woody Wetlands	2
95	Emergent Herbaceous Wetlands	3
42	Evergreen Forest	4
43	Mixed Forest	5
41	Deciduous Forest	6

PEA_FWSCHAB

This data represents approximately 290 species (polygon and lines) that are Fish and Wildlife Service critical habitat layers These data identify, in general, the areas where final critical habitat exist for species listed as endangered or threatened. (see PEA_appendix for original metadata from USFWS)
http://criticalhabitat.fws.gov/crithab/

PEA_HSIPLU
Data from the Homeland Security HSIP2007 data base was used to derive this PEA. Those classes used were beaches, military bases, Native American reservations, parks (National, state , county, local), national parks and monuments. Most of the data was originally from usgs national atlas . HSIP access/use constraints was either none or graphics for official use. The data used only included boundaries and was combined to one mask layer (graphic) where no identifying features of individual items were portrayed. Excluded data include:

AIRCRAFT ROADS, AIRPORTS, CEMETERY, GOLF COURSE, HOSPITAL, INDUSTRIAL COMPLEX, SHOPPING CENTRE, SPORTS COMPLEX, UNIVERSITY/COLLEGE

PEAMATURFORST Mature forest layer was defined by the NLCD canopy cover (**canopy_2001**) greater than 70%. Individual pixels greater than or equal to 70% canopy cover were recoded to a value of 1. (see PEA_appendix for original metadata for **canopy_2001.)**

The mature forest data from the canopy cover of the NLCD 2001 was not available for the SEF analysis, where plot data from the National Forest Service was used

PEA_MATFOR5K A regiongroup process was run in ArcMap on the **PEAMATURFORST** layer and only contiguous areas of 5000 acres or greater were included. This is a subset of **PEAMATURFORST** and was included to be able to locate those larger areas of mature forests that were contributing to hubs and corridors.

PEA_NLCDWETLNLCD
The wetland cover for classes 90-woody wetlands and 95-herbaceous wetlands of the **NLCD2001** were combined into a mask of wetland areas. (see PEA_appendix for original metadata for **NLCD2001.)**

PEA_RDLS5K
ESRI Streetmap 2003 was gridded at 30 m resolution to match the domain alignment of the **NLCD2001** dataset. An inverse mask was made from the areas that were not streets and this was masked with the n-index from the **NLCD2001**. A regiongroup was run on this mask. The region group of the roadless areas was then reselected for only those areas greater than 5000 acres and recoded to **PEA_RDLS5K** . (see PEA_appendix for original metadata for USA Streets 2003)

PEA_TNCPORT
(TNC_Portfolio_Terrestrial_Phase1_Public.shp)
(see PEA_appendix for original metadata from TNC)

Individual PEA layers for the NEF do not match the individual PEA layers of the SEF but are generally an upgrade to the layers in the SEF

PEA_USGPAD110
USGS Priority ecological areas ver 1.1. (see PEA_appendix for original metadata from USGS)

PEA_UPPTM2009
(see PEA_appendix for original metadata)

(Theobald, D.M. 2009. Protected lands of the continental US (UPPTM_200909). Unpublished dataset, Human Dimensions of Natural Resources and the Natural Resource Ecology Lab, Colorado State University. September 17.

UPPTM_200910 is a 90-m spatial resolution raster dataset that differentiates five types of protection: 1) private (unprotected); 2) private protected (with known conservation easement or other legal protection mechanism); 3) public protected (e.g., state, federal); 4) Tribal lands; and 5) military (bases, etc.). This dataset is for lands of the conterminous United States (CONUS). The ownership data were derived from the PAD-US database for the eastern US and the Protected Areas Database (PAD), Version 4.6 (unofficial release, 2007), with a number of additional publicly-available datasets for the west that provide more up-to-date protected lands, and particularly privately-owned, protected lands for the following states (more details follow): AZ, CA, CO, MT, UT, and WA. PAD v4.6 is an ArcInfo polygon coverage produced and distributed by the Conservation Biology Institute (CBI). The original CBI PAD was the product of a collaborative effort between the Conservation Biology Institute and World Wildlife Fund, USA. This Edition of the PAD provides an unofficial update to version 4 (2006); it contains boundaries of most federal and state owned/managed protected areas in the coterminous United States and Alaska, and includes county, city, and private reserves where data are available. The database also contains information about parcel type, ownership, size, and protection level and includes delineations of state boundaries.

PEA_WETNDX800

The wetness index was derived from the NHDPlus flow accumulation (**usa_fac**) and the slope of the DEM (**usademslope**) using the following equation:

grid **wet_ndx** = 100*(ln (flow accumulation/tan(slope)) + 3x3 mean of ln (flow accumulation/tan(slope))/2

The wetness index data was not available for the SEF analysis.

The values were not scaled by an area factor and were smoothed by ½ to make up for some inconsistancies across the national DEM, because of differences in the resolution of the DEM by USGS quad sheet. The data were then compared to the 2001 NLCD wetland classes, Region 4 FEMA flood zone classes, and Georgia National Wetlands classes. The cutoff for the wetness index PEA was chosen as 800, primarily based on the 2001 NLCD comparison, but also supported by the other analyses. (Moore,1991, Wollock, 1993)

Pea exclusion layer

The PEA exclusion layer combined 5 separate exclusions. These were

CAT3_NLCD0 =1 derived from **Cat12ter –** Nlcd land use catagories minus 22,23,24 (developed urban classes), 82(row crops), and 11,12(water) used to spread optimization of hubs. NLCD urbanclasses 22-24 and agriculture class
RCLSSDISTCL3 <3 **(<=dis2rdi)** road distance closer than 270m
RDDNS_3XCLD =1 **(<=rddens1)** high road density >3mi/sqmi
URB27_60MSK0 =1 large scale urban density greater than 60 %
URB9X9_60MSK =1 **(<=urbsum9x9)** small scale urban density greater than 60%

The combined dataset is **combxclud4 .** An attribute was calculated in the table and this attribute **combxclud4 .xclud** was coded for 1 if any of the above exclusions were present or 0 for no exclusion.

A grid was made from the attribute **combxclud4.xclud.** Output **XCLUDNLCD0**=1, all other areas = 0
Converted **XCLUDNLCD0** to xclud
Another copy of **XCLUDNLCD0** is **xclud1_0**

NATXCLUD is a mask of natural areas (N-index) that were excluded by **XCLUDNLCD0**
Xcludnlcd0 =1 to exclude those areas close to urban/high rd density/row crops

Hub development from PEAS

The fifteen PEA data layers were recoded to a mask of 1 or 0 for each PEA. These PEA masks were combined in a single coverage (**combinpea4)** along with with the data exclusion layer (**XCLUDNLCD0)** to build the final PEA exclusion data set **(peax_t5a)**. This PEAX layer was processed through the region group process in ArcMap to give the preliminary hub dataset. Individual raster groups that were smaller than 5000 acres were not included as hubs. After the smaller areas were excluded, the remaining hubs were optimized by expanding the preliminary hubs 150 meters into the Cat12ter dataset. (**Cat12ter –** Nlcd land use categories minus 22,23,24 (developed urban classes), 82(row crops), and 11,12(water)). In this process some of the original hubs from the PEAX areas greater than 5000 acres were merged by the optimization process. This left 3534 hubs in the national hub dataset that were contiguous areas greater than 5000 acres.

The following is a visual example of the process of combining the PEA's and developing the hubs.

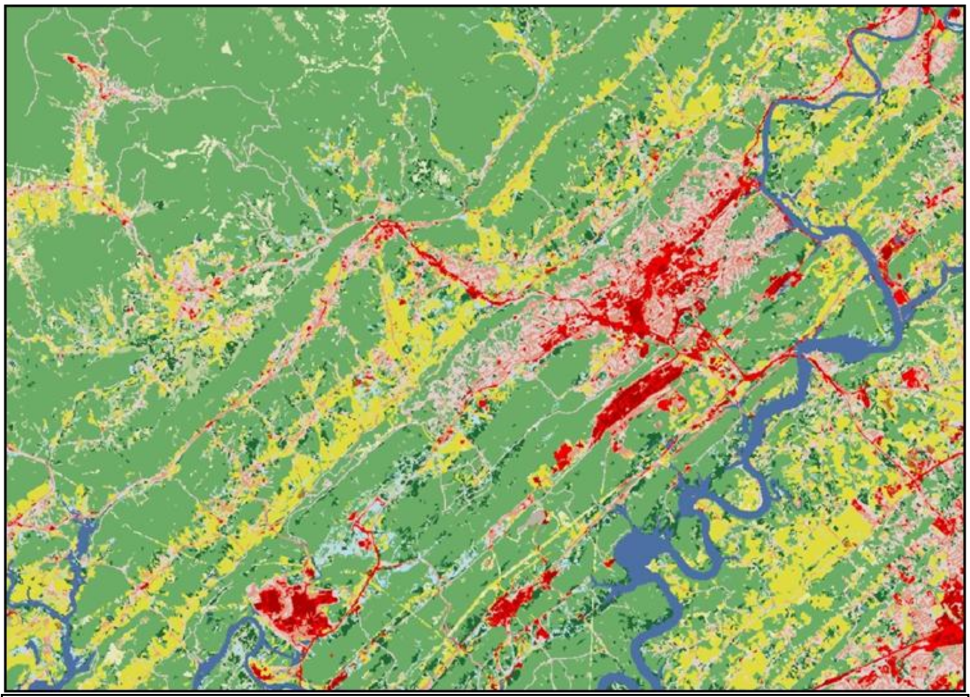

Figure 2: NLCD of Oak Ridge Tennessee used in the following graphic examples

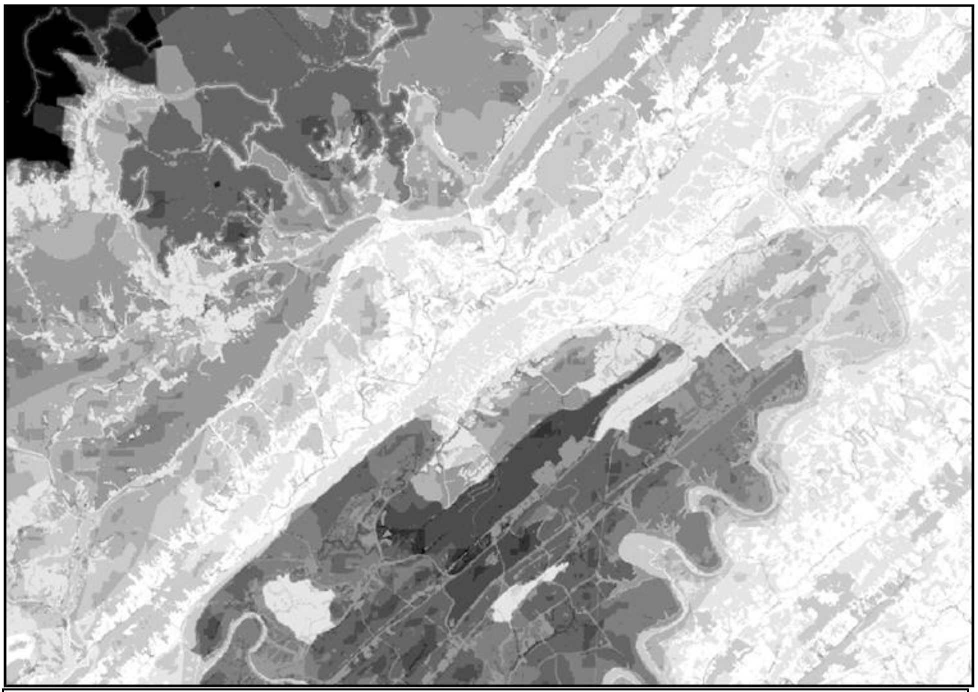

Figure 3: Combination of priority ecological areas. Shading indicates the number of PEAS. There are a maximum of 10 in this image

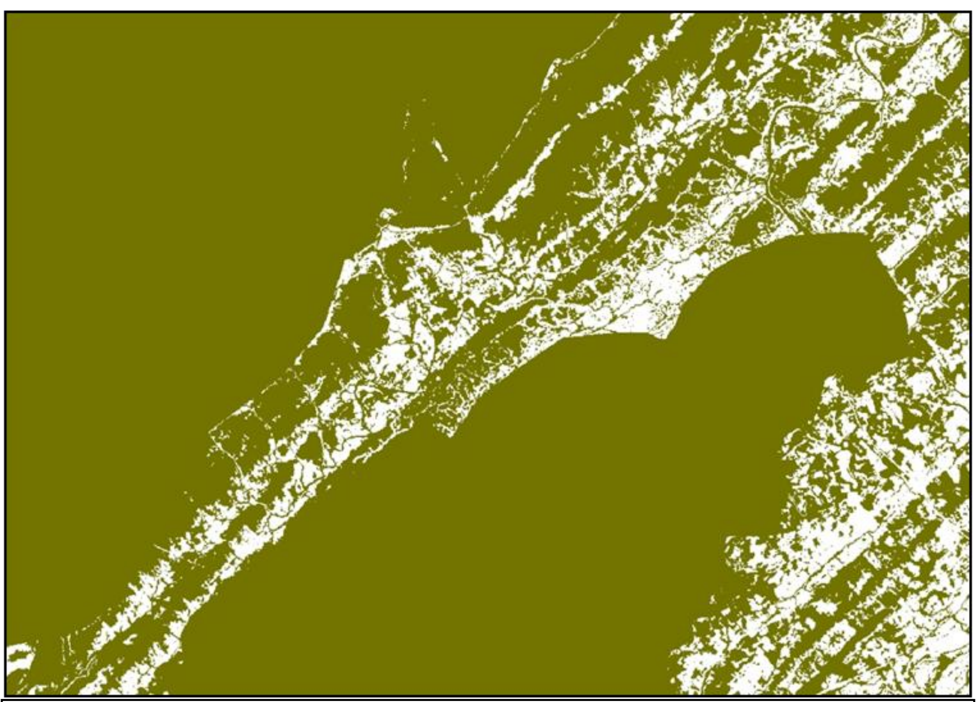

Figure 4: Mask of combined priority ecological areas.

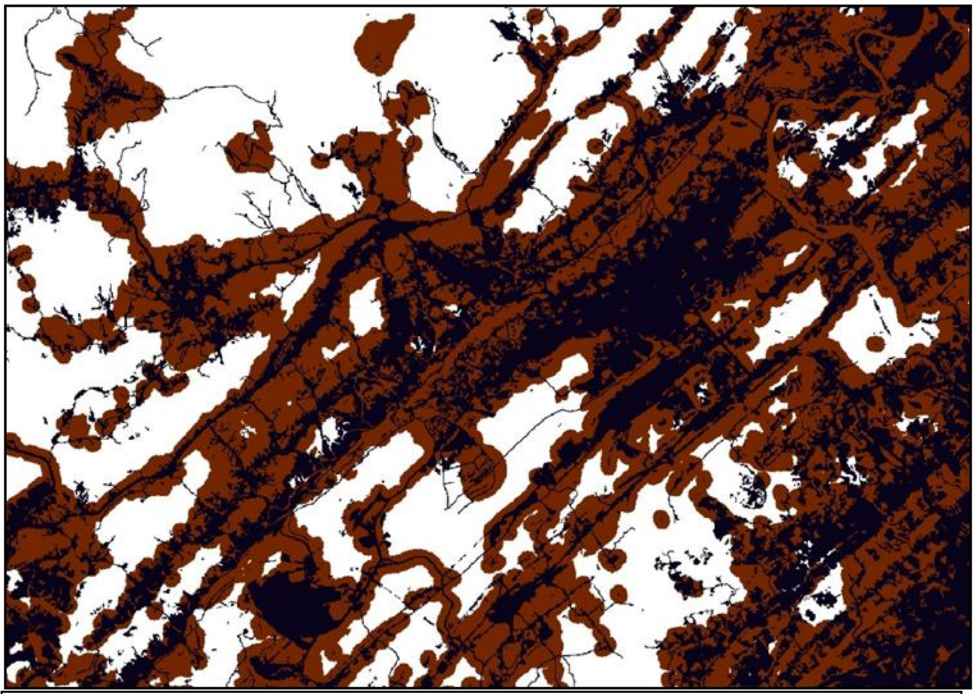

Figure 5: Exclusion Mask (brown) with u-index from NLCD (black)

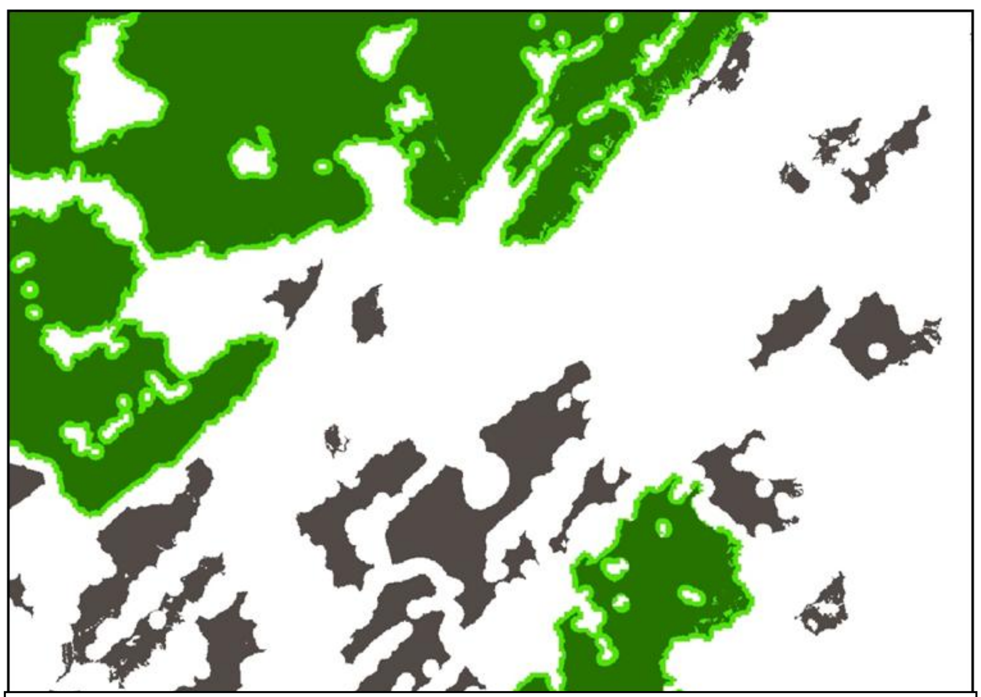

Figure 6: PEA's after exclusion (dark green) with optimization (light green). These are the Hubs. PEAs not meeting Hub criteria (5000 A) are shown in grey.

Figure 7: Final optimized Hubs

HUBS

Several hub layers were modified for specific purposes.

Hub1_0 -- Hub optimization recoded from **Hub1.** 1= hubs, 0 = background

Hub1nd -- Hub optimization recoded from **Hub1.** 1= hubs, nodata = background

In order to connect multiple hubs to each other, the total hub set was organized into 5 subgroups of hubs so that any hub was surrounded by hubs of a different subgroup.

hubs1a, hubs2b, hubs3c, hubs4d, hubs5e

The hub in the western US was isolated as **hubs5e.** The other grids (hubs 1-4) contain multiple hubs with each group as spatially isolated from the others as was feasible

Cost Surfaces

In order to develop linkages between the various hubs, a cost surface is required. This cost represents the impact of human disturbance on the landscape. Natural linkages between hubs utilize the least cost between the hubs. A cost surface was developed for connecting the individual hubs. The least cost path modeling uses this to define the least cost path between individual hubs (least human disturbance pathway between individual hubs). This cost surface was based on the eMergy principles of H.T Odum (1995) and the work of Brown and Vivas (2005)

The cost surface used for the SEF was a model of costs derived from expert opinion of Univ. of Florida staff.

For the NEF, the cost surfaces were derived from eMergy analysis and represent a more reliable measure of impact of human disturbance on the landscape.

The cost surface layer used for connecting least cost paths between Hubs was generated with several layers beginning with the NLCD2001 data(see figure). In this data there is no distinction for road type/class in the data. Many of the roads were embossed into the NLCD2001 data as class 21 (Developed, Open Space). To further differentiate road type in the land cover data the NLCD2001 was combined with a grid of the ESRI 2003 streetmap data. At the same time, a grid of railroads from the Bureau of Transportation Statistics (BTS) and the national network of streams from the NHDPlus us_flowline as combined with the roads and NLCD2001. The result was **combo2001_4.** (see figure)

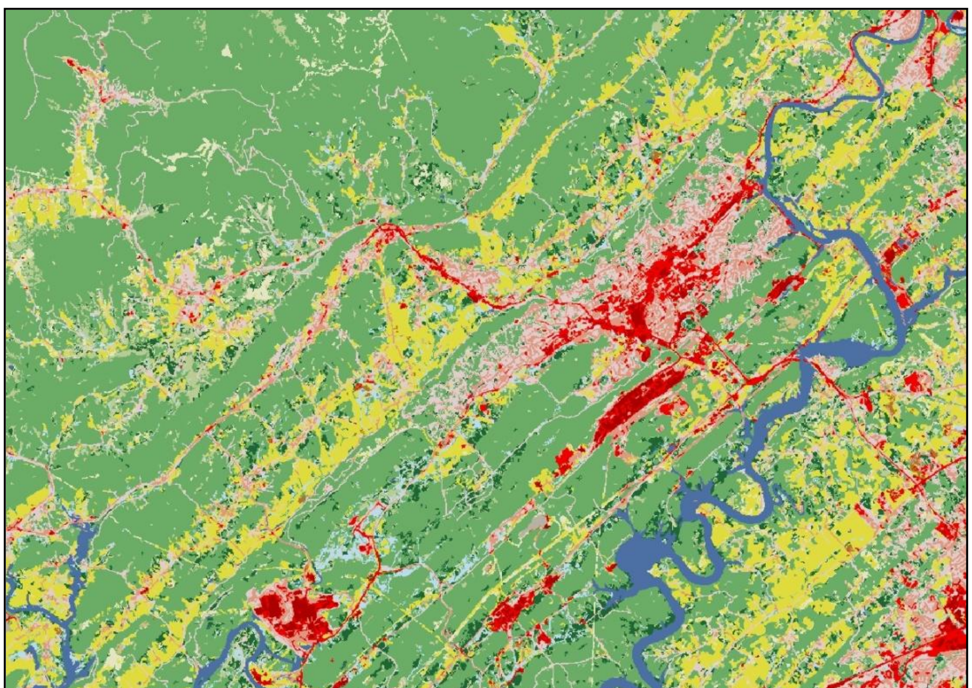

Figure 8: NLCD2001 of Oak Ridge Tn. Area

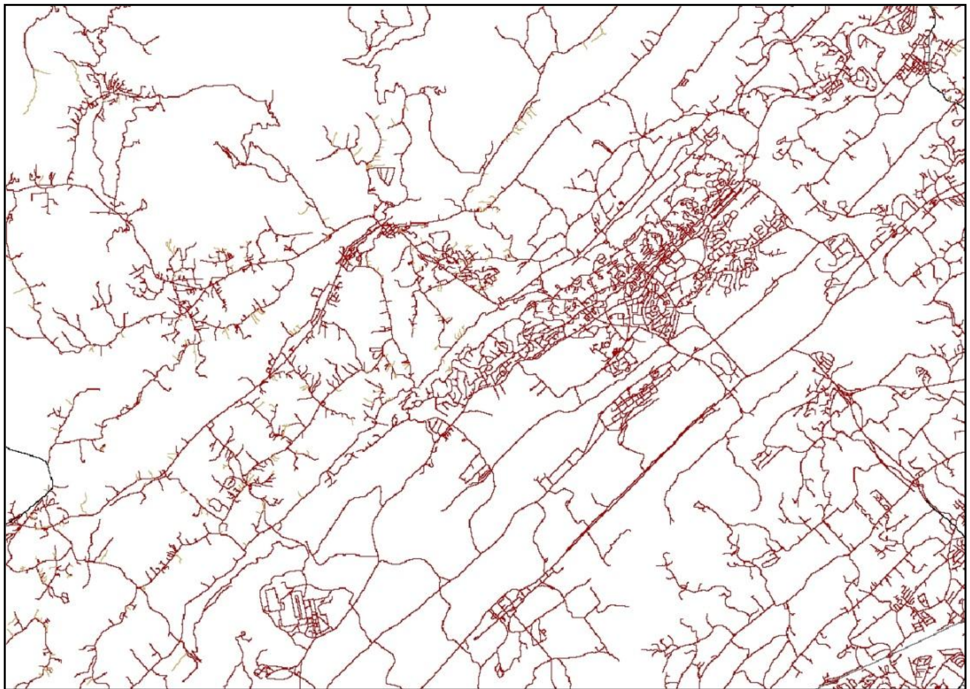

Figure 9: Grid of Streetmap 2003. Individual pixels contain attribute information about the road type.

Figure 10: Grid of railroads from BTS.

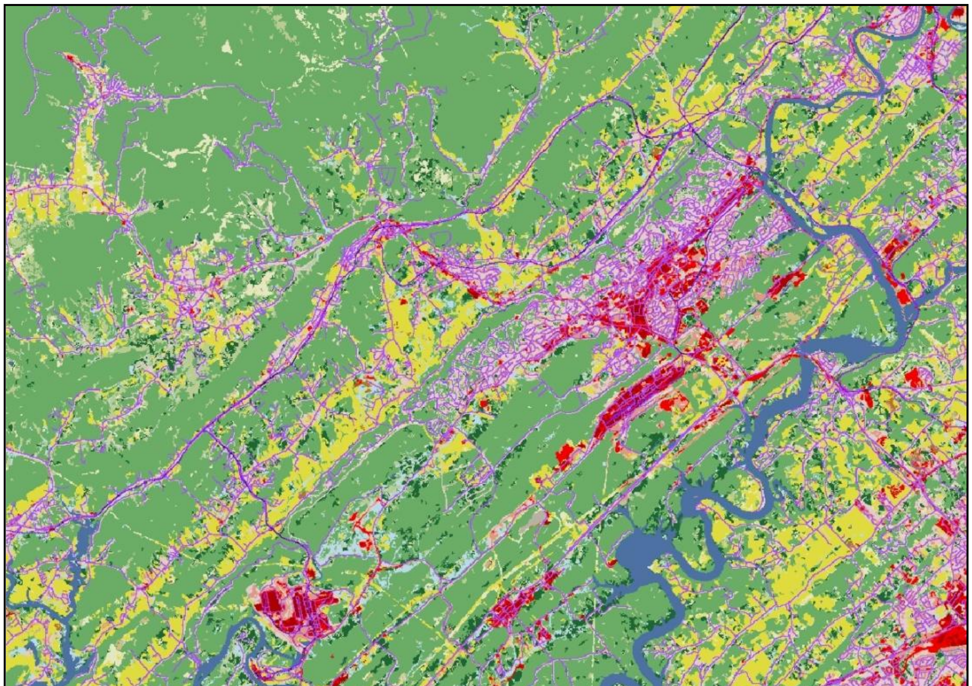

Figure 11: Grid of combined datasets **combo2001_4** with attributes for land cover, roads, rails, and stream network.

Land Use, Non-Renewable Empower Density, and Resulting LDI Coefficients

Land Use	Non-Renewable Empower Density (E14 sej/ha/yr)	LDI Coefficients
Natural EcoSystem	0.00	1.00
Natural Open water	0.00	1.00
Pine Plantation	5.10	1.58
Recreational / Open Space (Low-intensity)	6.55	1.83
Woodland Pasture (with livestock)	8.00	2.02
Pasture (without livestock)	17.20	2.77
Low Intensity Pasture (with livestock)	33.31	3.41
Citrus	44.00	3.68
High Intensity Pasture (with livestock)	46.74	3.74
Row crops	107.13	4.54
Single Family Residential (Low-density)	1,077.00	6.79
Recreational / Open Space (High-intensity)	1,230.00	6.92
High Intensity Agriculture (Dairy farm)	1,349.20	7.00
Single Family Residential (Med-density)	2,175.00	7.47
Single Family Residential (High-density)	2,371.80	7.55
Mobile Home (Medium density)	2,748.00	7.70
Highway (2 lane)	3,080.00	7.81
Low Intensity Commercial	3,758.00	8.00
Institutional	4,042.20	8.07
Highway (4 lane)	5,020.00	8.28
Mobile Home (High density)	5,087.00	8.29
Industrial	5,210.60	8.32
Multi-family Residential (Low rise)	7,391.50	8.66
High Intensity Commercial	12,661.00	9.18
Multi-family Residential (High rise)	12,825.00	9.19
Central Business District (Average 2 stories)	16,150.30	9.42
Central Business District (Average 4 stories)	29,401.30	10.00

Table 1: Empower density for various landuse type from Brown and Vivas 2005

Attributes Of Xr4combine90

Value	Base landcover	combined class dominant	Nlcd_90_r4	base mrg	drain_mrg	rail_mrg	road_mrg	combined eMergy
1	Deciduous Forest	Deciduous Forest	41	2	0	0	0	2
2	Deciduous Forest	Rail	41	2	0	4066	0	4068
3	Mixed Forest	Rail	43	3	0	4066	0	4069
4	High Intensity Commercia	Rail	23	10255	0	4066	0	14321
5	Deciduous Forest	River/Stream	41	2	0	0	0	2
6	Mixed Forest	Mixed Forest	43	3	0	0	0	3
7	Water	Rail	11	0	0	4066	0	4066
8	Water	Rail	11	0	0	4066	0	4066
9	Row Crops	Rail	82	87	0	4066	0	4153
10	Water	Water	11	0	0	0	0	0
11	Water	Artificial Path	11	0	0	0	0	0
12	High Intensity Commercia	High Intensity Commercia	23	10255	0	0	0	10255
13	Water	Rail	11	0	0	4066	0	4066
14	Evergreen Forest	Evergreen Forest	42	4	0	0	0	4
15	Mixed Forest	River/Stream	43	3	0	0	0	3
16	Row Crops	Row Crops	82	87	0	0	0	87
17	Pasture/Hay	Pasture/Hay	81	36	0	0	0	36
18	Row Crops	A40	82	87	0	0	1247	1334
19	Pasture/Hay	A40	81	36	0	0	1247	1283
20	Row Crops	River/Stream	82	87	0	0	0	87
21	Pasture/Hay	River/Stream	81	36	0	0	0	36
22	Mixed Forest	A40	43	3	0	0	1247	1250
23	Evergreen Forest	Rail	42	4	0	4066	0	4070
24	Mixed Forest	A40	43	3	0	0	1247	1250
25	Deciduous Forest	A40	41	2	0	0	1247	1249
26	Evergreen Forest	River/Stream	42	4	0	0	0	4
27	Pasture/Hay	A20	81	36	0	0	4066	4102
28	Deciduous Forest	Artificial Path	41	2	0	0	0	2
29	Evergreen Forest	Artificial Path	42	4	0	0	0	4
30	Deciduous Forest	A20	41	2	0	0	4066	4068
31	Deciduous Forest	A20	41	2	0	0	4066	4068
32	Mixed Forest	A20	43	3	0	0	4066	4069
33	High Intensity Commercia	Rail	23	10255	0	4066	0	14321
34	High Intensity Commercia	Artificial Path	23	10255	0	0	0	10255
35	High Intensity Commercia	Rail	23	10255	0	4066	0	14321
36	Evergreen Forest	Rail	42	4	0	4066	0	4070
37	Water	River/Stream	11	0	0	0	0	0
38	Low Intensity Residentia	Low Intensity Residentia	21	872	0	0	0	872
39	Woody Wetlands	River/Stream	91	0	0	0	0	0

Figure 12: Attribute table from combined dataset of NLCD2001, Streetmap 2003, Rail100k and NHDPlus us_flowline (**combo2001_4)**. Empower density assigned per pixel by data from Brown and Vivas 2005, scaled for 30m pixel size and then summed by pixel.

The cost surface used in the NEF analysis started with the individual pixel costs from combining values for the NLCD, Roads and Rails. The impact on the landscape was then modeled using an exponential spreading function out to 250 meters.

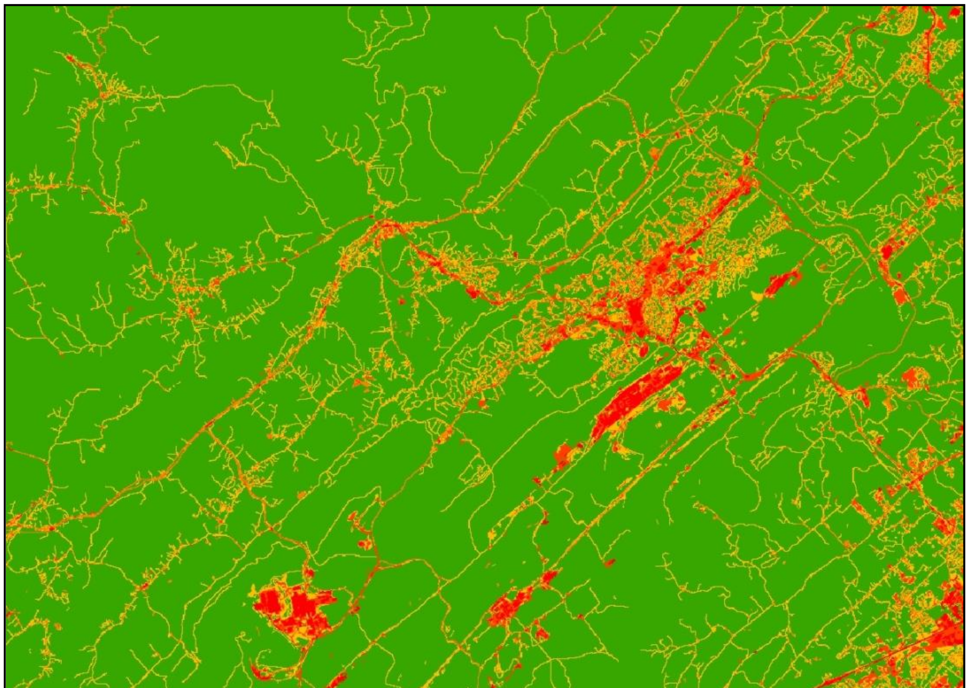

Figure 13: Nonrenewable Empower Density map of Oak Ridge Tn. US data set is **empdens14fp**

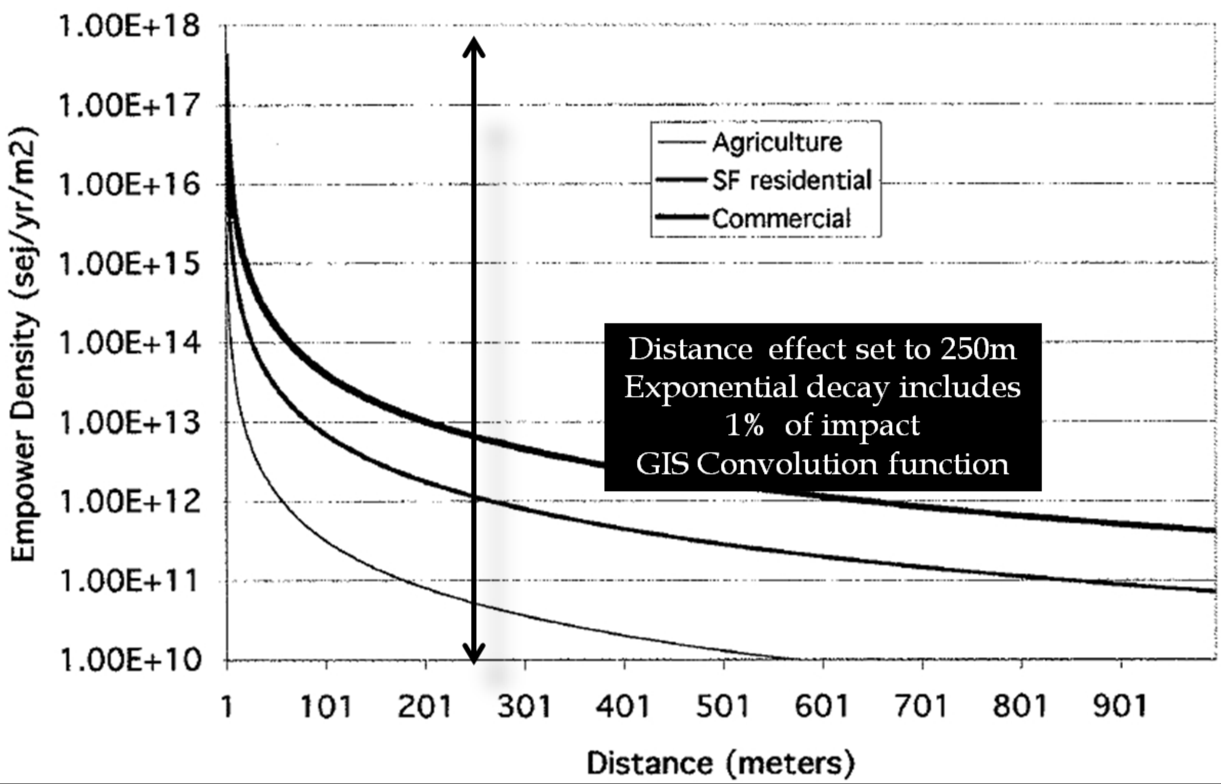

Figure 14: Distance effect of non-renewable empower density for individual pixels on surrounding pixels

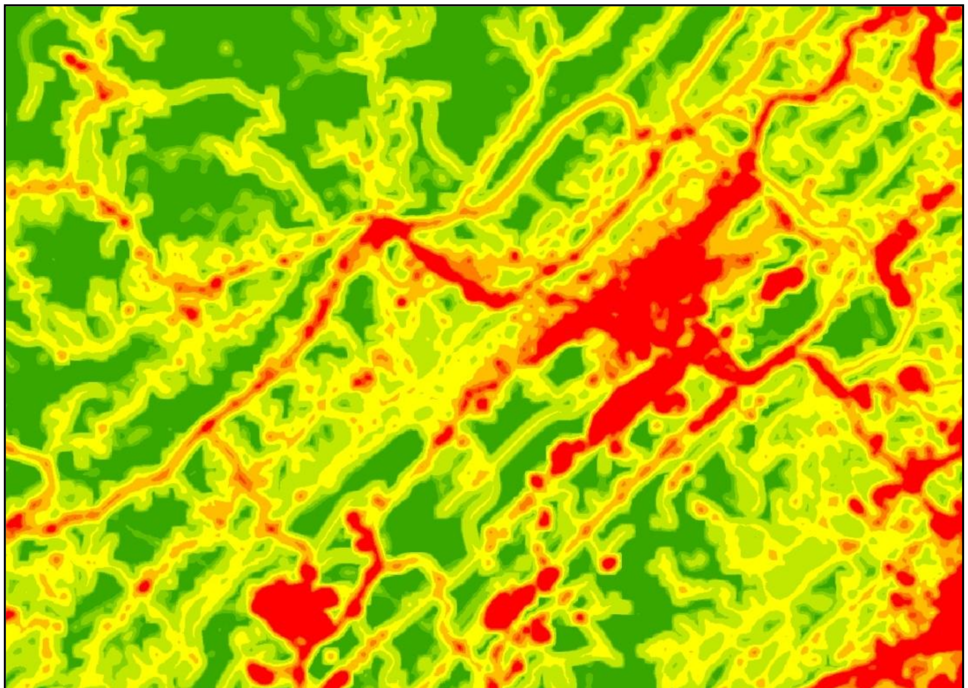

Figure 15: Result of exponential spreading of non-renewable empower density in a 250 m radius of each pixel (**ed_dist250i**). **ed_dist250i** -- Cost surface summed from e^{-kd} up to distance d=250. Summarizes spatial effect of nearest neighbor of empower density effect. Derived from **empdens14fp**. Because this is derived from a 250m summed window it represents an impact of human disturbance to the landscape at each pixel with an exponential decayed function of those pixels within 250 meters.

Not a true empower density but a synthesized impact of human disturbance to the local area from surrounding areas (pixels).

Cost distance Analysis and connectivity

The hubs were region grouped and then categorized into five groups which represented a nearest neighbor code so that each hub was coded differently than its neighbors. A cost distance was calculated for each of the 5 hub sets. This had to be done at 90m resample of the cost surface because the time required to run the cost distance at 30 m for each of the hubs was on the order of a month! The computer generated least cost path connections were made by calculating a path distance function for each of the cost distance pairs. This resulted in 8634 single cell path connections for joining the hubs.

For the SEF, the cost distance methodology and connectivity were done using an ArcInfo macro for each individual hub to hub linkage.

This was deemed as too time consuming for the entire U.S. NEF analysis. A computer generated cost path analysis was done between all hubs and supplemented with an improved individual hub to hub link analysis and hydrologic corridor connections to hubs.

Additional individual connections were made using an ArcView3.3 extension (spcstdst.avx) and the individual costdistance grids for the 5 hub sets (90m). This resulted in 2938 least cost pathways between hubs. After reviewing the links with the original SEF data it was revealed that some connectivity that was hydrologically based but not hub to hub had been left out in the NEF hub linkages, These were added across the US using the ArcView3.3 extension (spcstdst.avx) and a cost distance surface derived from all of the hubs. This resulted in another 232 least cost pathways to the hubs.

After all of the hub connections were made with the various least cost paths, the corridors were expanded using the original cost surface. The cost surface cutoff for the spreading of the least cost pathways to a corridor was chosen at a value of 500,000 (cumulative empower density * distance). This value was chosen by comparing the SEF and the NEF corridors to achieve a match that was similar to the SEF corridor size.

In generating the corridors, some of the corridors merged together leaving 10907 individual corridors connecting 3534 individual hubs in the final National Ecological Framework.

Connections

11804 from the 3 different types

rgalcncorr (2938), supplemental corridors user defined (3752, merged to 2938)

rgcord500k (8634), computer generated corridors

rgnewcon (232), hydrologic connections to hubs

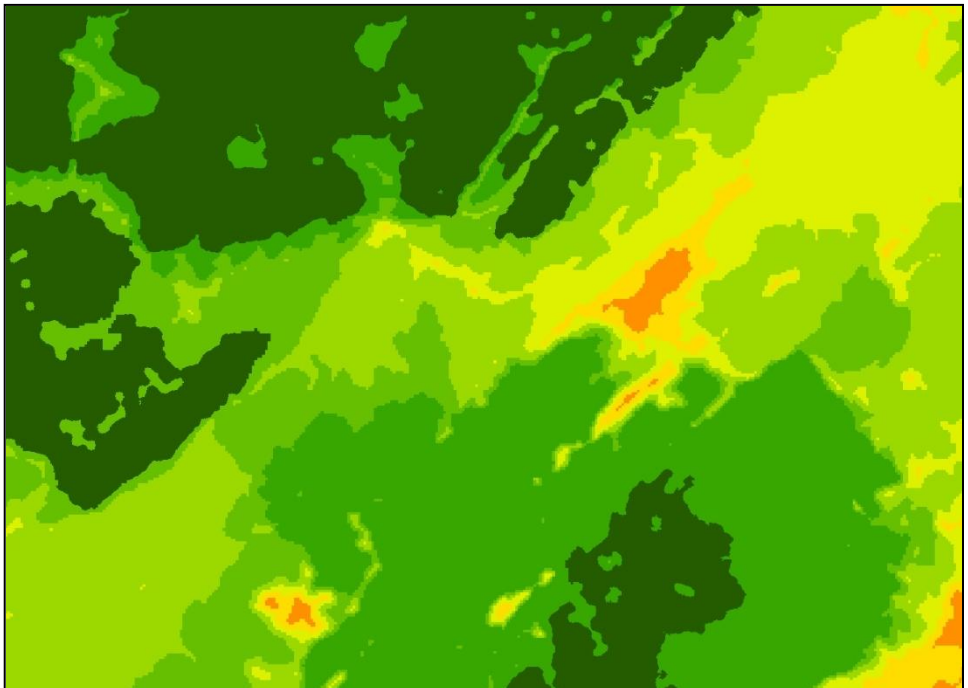

Figure 16: Cost distance map from hubs (dark green) using **ed_dist250i** as cost surface to spread from hubs.

Figure 17: Optimized hub data layer for Oak Ridge Tn example.

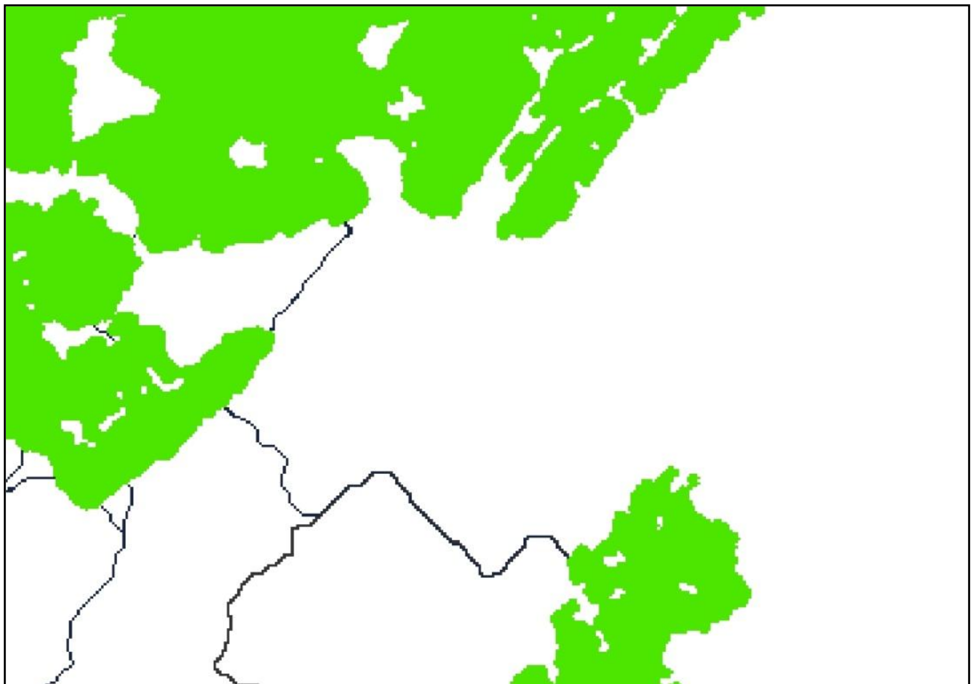

Figure 18: Example of single cell least cost pat generated between hubs (both computer generated and user generated).

Figure 19: Example of corridors (bright green) generated from least cost paths (black) between hubs (dark green). The corridors were calculated as a cost distance spreading from the least cost paths on the cost surface **ed_dist250i** The single cell connections between hubs were expanded on the cost theme (based on empower density). The corridor width of the expanded cells was chosen to best match the corridor width established in the SEF. This turned out to be a value of 500,000 (units in accumulated cost distance spread from the single cell connectors)

Final Optimization

After the hubs and corridors were combined to give the final NEF coverage, an optimization process was developed used the cost surface and modified with a terrestrial mask and a hydrologic mask. Cost distance surfaces were run for both of these using the final NEF as the source. A cutoff of 500,000 was used in both cases. The final optimizations were combined to give an auxiliary connectivity to the NEF. This represents landscape connectivity to the NEF with a slightly higher cost but does have areas that are contiguous to the NEF.

The optimization process for NEF was slightly different from the SEF. The SEF optimization (see Final Report) was combined with the hubs and corridors for the final SEF.

The optimization for the NEF was more expansive and stored as a separate coverage (auxiliary connections)

Polygon analysis

The final grid of hubs, corridors and auxiliary connections were individually region-grouped and converted to polygons. Information was tabulated for each of the three types of polygons for landcover, individual PEA coverage and human disturbance (Empower density). The following table is an example of the hub polygon attributes.

Hub attribute description

OBJECTID	ArcInfo ID
Shape	Polygon
ID	ArcInfo ID
GRIDCODE	Link back to grid regiongroup
pc_1stords	Percent PEA contiguous natural area in first order stream catchments
PC_1ordst5	Percent PEA contiguous natural area greater than 5000 acres in first order stream catchments
pc_cecgrln	Percent PEA CEC grasslands
PC_cecpad	Percent PEA CEC Protected areas
PC_div	Percent PEA landscape diversity
pc_fwschab	Percent PEA Fish and Wildlife Critical Habitat
pc_hsiplu	Percent PEA HSIP land use
pc_matfor5	Percent PEA contiguous mature forest greater than 5000 Acres
pc_matfrst	Percent PEA mature forest
pc_nlcdwet	Percent PEA NLCD2001 wetlands
pc_rdls5k	Percent PEA roadless areas greater than 5000 acres
pc_upptm20	Percent PEA Protected areas from Theobald
pc_usgspad	Percent PEA protected areas from USGSPAD 1.1
pc_wetndx8	Percent PEA of area with wetindex value greater than 800
pc_tncport	Percent PEA of area in TNC portfolios
Total PEA index	Gross sum of all PEA percentages
pc_water	Percent water from NLCD2001
pc_upforst	Percent upland forest from NLCD2001
pc_wetland	Percent Wetland from NLCD2001
pc_2181	Percent landuse Urban grassland(21) and Pasture(81) from NLCD2001
pc_ag82	Percent row crop (82) from NLCD2001
pc_urban	Percent Urban classes from NLCD2001
pc_undx	Percent U-index from NLCD2001
hA	area in Hectares
acres	area in acres
pc_upnofor	Percent in upland natural not forested from NLCD2001
catagory	Hub type
VALUE_12_13	Same as gridcode (link back to grid regiongroup)
MIN_disturb	Minimum value of Empower Density (Human disturbance index) in polygon
MAX_disturb	Maximum value of Empower Density (Human disturbance index) in polygon
MEAN_disturb	Mean value of Empower Density (Human disturbance index) in polygon
SUM_disturb	Total value of Empower Density (Human disturbance index) in polygon
Shape_Length	Perimeter of Shape
Shape_Area meters^2	Area in M^2
pc_nndx	Percent N-index from NLCD2001

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