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Title

An Approach to Regional Habitat Connectivity-Fragmentation Analysis and Reporting

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Abstract

The Bureau of Land Management (BLM) is seeking ways to maintain and conserve existing habitat connections and restore severed connections between habitat patches. BLM is developing and testing a raster-based approach to describe and report the location and extent of terrestrial habitat connectivity and fragmentation over large regional landscapes using a 30-meter minimum mapping unit. This analysis is spatially explicit and repeatable, thus allowing for monitoring and reporting of changes in landscape conditions in broad regions over time. GIS technology is used to link regional habitat (land cover) data with land-use activities, disturbances, and associated management actions. This methodology is being applied in the prairie-grassland region, rangewide sagebrush/greater sage-grouse region, and other large regions of the western United States in support of the BLM assessment-inventory-monitoring, greater sage-grouse, land-use planning-NEPA, and vegetation management national strategies.

Introduction

The U.S. Bureau of Land Management (BLM) administers 261 million acres of public surface lands in the United States. In addition to managing for such things as grazing, mining, and recreation, the BLM is tasked with the maintenance and conservation of wildlife habitat. This paper describes a raster-based application to determine the location of existing habitat patches and evaluate the level of connectivity, or conversely fragmentation, in these patches over large, typically multi-state areas, at a minimum cell size of 30 meters. Our approach is designed to provide an easy to understand, seamless, regional context forming the foundation for more site-specific land-use planning and NEPA activities. It is an excellent tool for focusing management efforts. Either focal species (e.g. lesser prairie chicken) or general habitats (e.g. grasslands) can be analyzed in the open-architecture model structure. The application incorporates very large data sets from a wide variety of existing sources, and uses both habitat and disturbance-related information. By utilizing existing data, this approach avoids expensive and time consuming data creation projects. To be included in the model, data sources must meet the fundamental requirement that they cover the entire analysis area; in other words there can be no data 'holes'. The entire process is repeatable, and thus may be used to determine change on the landscape over time. This approach has certain functional limitations. For instance, it may not adequately address species with small home ranges due to scale limits of data inputs. Also, analytical results represent a snapshot in time, and are only as current as the data inputs used to conduct the analysis. Aquatic habitats and species are not addressed.

Model Structure

The first phase of model construction is the development of a structure flowchart (Figure 1). On one side of the model is a series of sub-model components corresponding to individual habitat capability features on the landscape, and on the other side are disturbance related features that affect the focal species or habitats under consideration. Construction of these sub-models requires extensive interaction between the GIS modeler and a wildlife biologist or related scientists. The number of sub-models present depends largely on the habitat requirements of the focal species or habitat and whether spatial data exists to effectively model the feature.

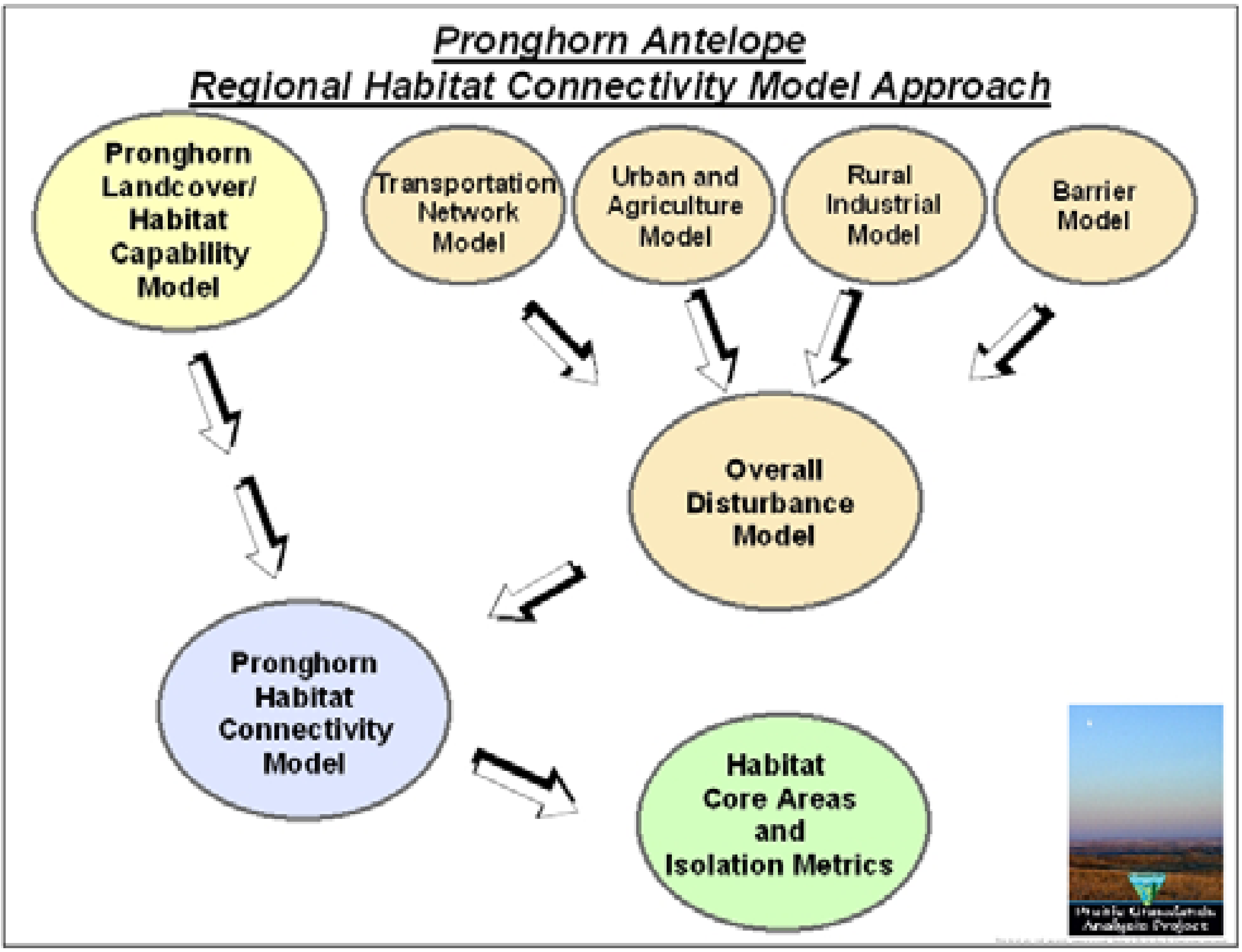

Figure 1. Model flowchart

For example, in a pronghorn antelope model, one unique sub-model is a barrier model (Figure 1), which takes into account the presence of fences that may adversely affect the movement and survival of the species. For a prairie chicken, fences are not a significant habitat issue, so no barrier sub-model is necessary. This open-architecture model style allows the modeler to design to the specific habitat requirements of a particular species.

Once the primary habitat capability and disturbance components are constructed, they are combined into a habitat capability sub-model and an overall disturbance sub-model respectively. The scored results from both models are integrated on a cell by cell basis to form the habitat connectivity model. Habitat core areas and isolation metrics are derived from the results of this work.

Primary Inputs

Major data inputs to the models include:

Habitat capability:
National Land Cover Data (NLCD),
GAP landcover,
Sagestitch,
NED elevation,
slope, aspect, and derivatives of slope and aspect,
fire perimeters,
seeded areas.

Disturbance:
Transportation network (roads),
railroads,
powerlines,
pipelines,
oil and gas wells,
solar arrays and wind farms
communication towers,
pits-mines-quarries,
agriculture,
urban development.

In general:
Land status,
other land management, political or ecological boundaries.

Many other sources of data are possible inputs depending on specific requirements or preferences of the focal species or habitat. In certain situations, elements from multiple landcover data sets may be combined to provide higher quality or more resolute information for the analysis. Since the goal is a seamless, broad regional data set, leveling or cross-walking of similar data sources from different states or districts may be required. In general, any unique data set which does not cover the entire analysis area cannot be considered.
All raster and vector inputs to the model are converted to ArcInfo grids with 30 meter cells and snapped to a common reference. Projections are typically in a customized Albers conic to obtain the most accurate acreage calculations at the regional scales involved.

Habitat Capability Model

Construction of the habitat capability model is largely controlled by the landcover components. Each landcover feature is given a relative scoring from greatest to least in terms of its relevance to the habitat preferences of a specific focal species or habitat. Additional features may be added to enhance the modeling, such as known slope or aspect related habitat preferences. For example, a species might only prefer north aspects on slopes less than 45 degrees. In these areas, habitat capability scoring can be adjusted up or down accordingly.
One unique feature is fire perimeters. In this modeling approach, fire is not considered a disturbance, rather it is a change in the seral state of the particular vegetative type present. Habitat capability scoring within a burned area is dependent on its effect on a given focal species or habitat. So, for example, burning a shrub community in an area of black-tailed prairie dog colonies would enhance the prairie dog’s habitat by removing predator cover, and thus the scoring for burned shrubs would be upgraded.
In some cases, an individual feature may not be as important as the relationship between two or more adjacent features, and in these situations, buffering or neighborhood functions are used to enhance or

diminish these relationships. For example, in the sage-grouse model, herbaceous wetlands immediately adjacent to sagebrush shrublands are considered to be prime areas for brood-rearing activities. In this case, we set up a focal function that finds all herbaceous wetlands within 105 meters of sagebrush shrublands (Figure 2, pink areas) and upgrade this area to a higher capability score than the remainder of the wetland.

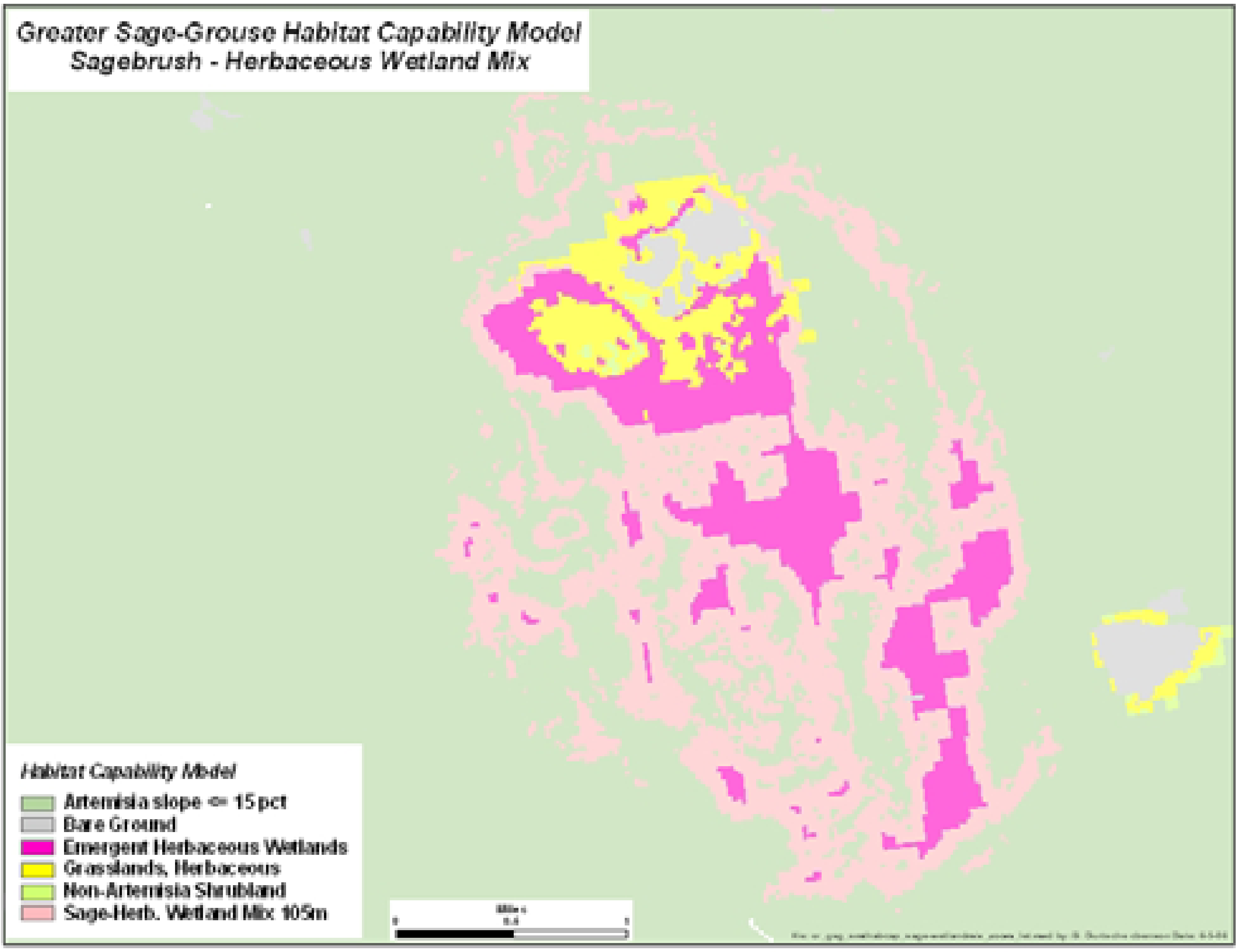

Figure 2. Neighborhood upgrades to habitat capability

Once all of these adjustments to basic landcover have been made, a single grid is created that identifies each habitat preference feature or feature relationship in the landscape on a 30 meter cell basis. This is known as 'Smart Habitat Capability' (Figure 3). The score attribute for each cell represents the habitat capability side of the model.

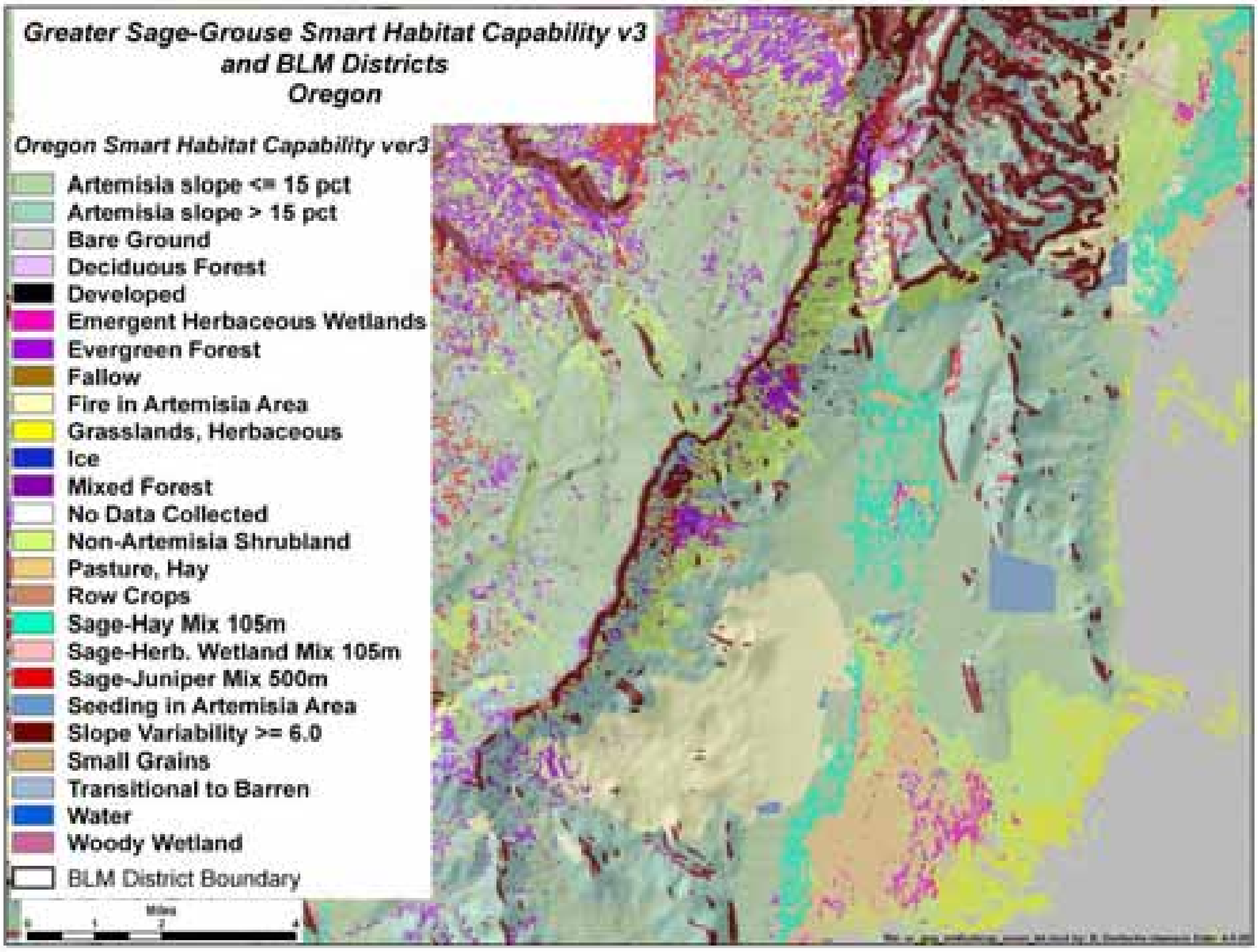

Figure 3. Smart habitat capability

Disturbance Model

The disturbance model is generally comprised of three sub-models, which are transportation, urban and agricultural development, and rural industrial. As stated above, some models may contain more or less sub-models depending on focal species or habitat requirements.

Transportation Sub-model. This model creates relative rankings of generalized transportation network features, mainly roads and railroads, based on the impact of the feature on a focal species or habitat. For example, in a sage-grouse model, a limited access highway (Interstate), is expected to have a large impact on the species, whereas a four wheel drive jeep trail is expected to have little impact. In certain models, a specific category of road/rail may cause impacts to be 'felt' much farther away than the road itself due for example to noise or pollution issues. In this case, an appropriate buffer is placed on the feature, and the buffered area is all scored with the same value as the road category. In some models, roads/rails may be rescored locally due to increased/decreased traffic related to some other feature. For example, this methodology has been applied to roads near actively drilled oil and gas wells, where daily traffic on four wheel drive trails is substantially higher than would be expected elsewhere on these roads.

Urban and Agriculture Sub-model. Those landcover categories representing all of the agricultural classes, such as row crops, small grains, pasturelands, irrigated and non-irrigated fields, orchards, etc, as well as commercial and residential urban developments are scored to reflect the relative impacts of these features on the focal species or habitat.

Rural Industrial Sub-model. Model elements in this group include such things as high voltage power lines, underground and aboveground pipelines, quarries, strip mines, gravel pits, oil and gas wells, solar arrays, communications towers, and any other industrial development feature that does not typically cover large bulk acreages in a landscape. As always, each feature is scored relative to its impact on a focal species or habitat. Buffers are constructed for those features that may impact a larger footprint than their physical limits. For instance, overhead power lines can be buffered either a constant distance or a view shed distance to account for raptors preying on rodents, rabbits, or other birds.

Once all of the disturbance sub-models have been completed, the overall disturbance model is calculated. This is accomplished by selecting the highest impact sub-model score from each input on a cell by cell basis.

Habitat Connectivity Model

To create the habitat connectivity model, the individual inputs from the habitat capability side and the disturbance side of the model must be integrated. This is done by selecting the highest model score from the two grid inputs on a cell by cell basis. The result is a four level relative habitat connectivity value system for each cell ranging from high viability to negligible viability (Figure 4). A high viability designation represents the highest level of habitat with few or no barriers. Interior patch linkage is intact. Moderate viability represents lower value habitat in which linkage function is largely intact. Low viability areas are typically barriers between habitat patches and linkages are not likely to be present. Negligible viability areas are entirely barriers to habitat patches and contain no linkages.

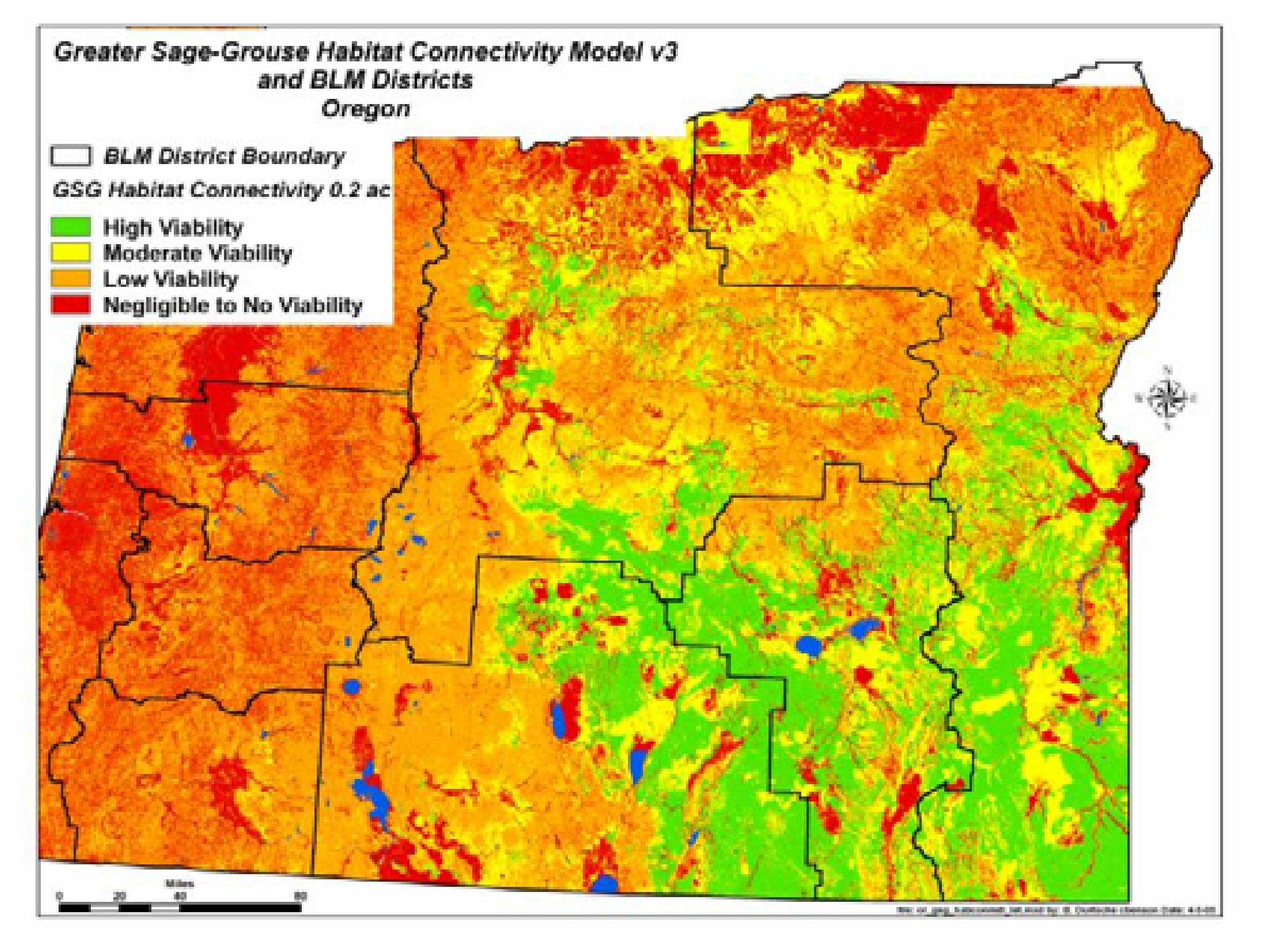

Figure 4. Habitat connectivity model at 30 meter cell size

Habitat Core Areas

Since the habitat connectivity model is analyzed at a 30 by 30 meter cell size, the complexity of the results at a regional scale is profound. In order to simplify patch boundaries over billions of pixels for the customer, a grid block function is used to select the best value for a selected block size (e.g. 40 acres). After this is applied, blocks are grouped using the regiongroup function so that a specific identifier can be developed for each connected group of patches. Each unique patch is defined as a habitat core area (Figures 5 and 6). The core area is the spatial basis for later statistical analysis of patch characteristics including land status, habitat capability components, landcover, patch isolation, and other pertinent information. These outputs provide managers, planners and biologists with the specific tools they need in their decision-making processes. Acreage statistics are provided in spreadsheet form at hierarchical levels from individual core areas (Figure 7) to multi-state regions. In addition, maps showing detailed core area boundaries and smart habitat capability, land status, etc, are embedded into the spreadsheets for quick evaluation purposes.

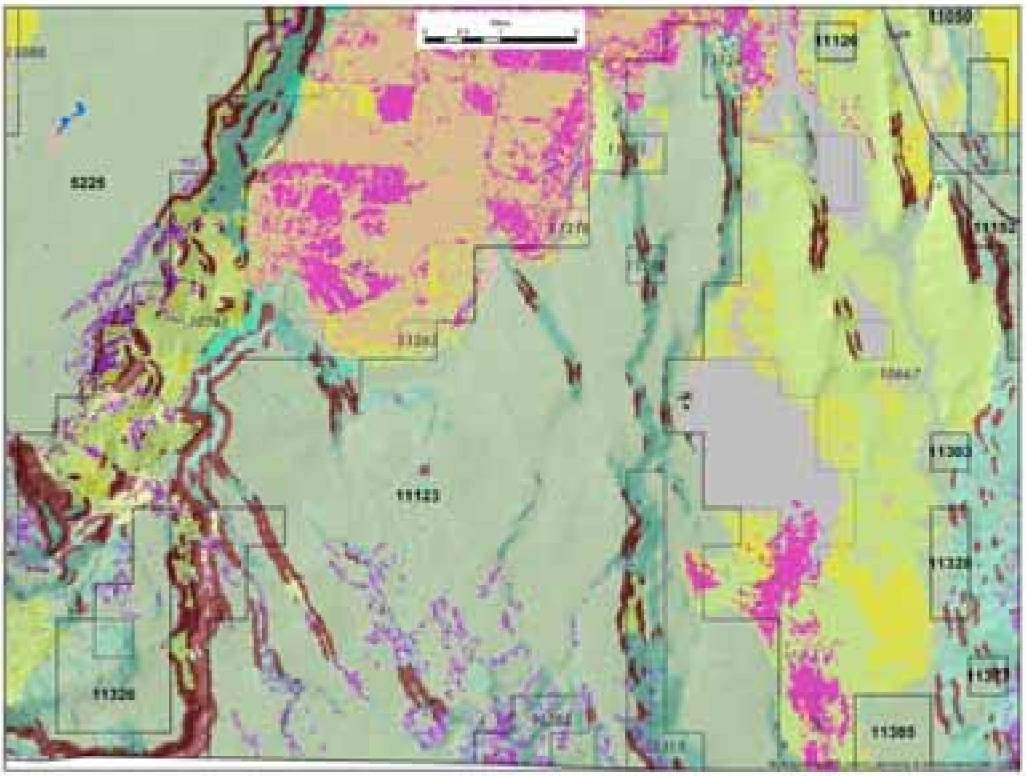

Figure 5. Core areas with unique identifiers, and smart habitat capability

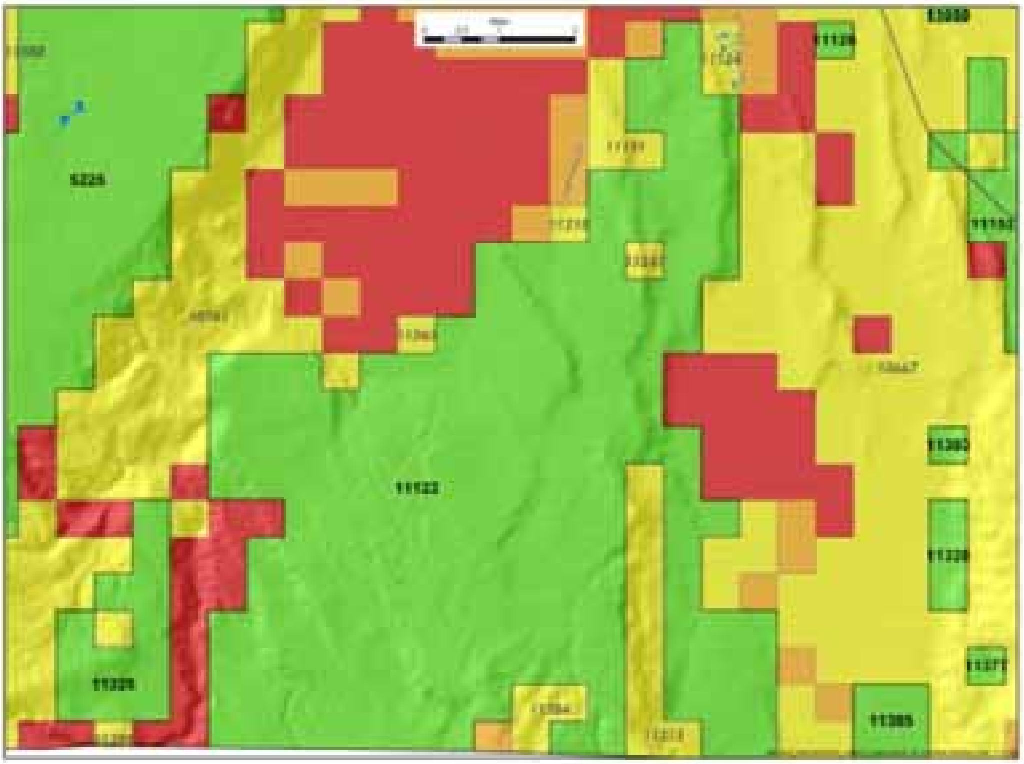

Figure 6. Core areas with unique identifiers, and habitat connectivity

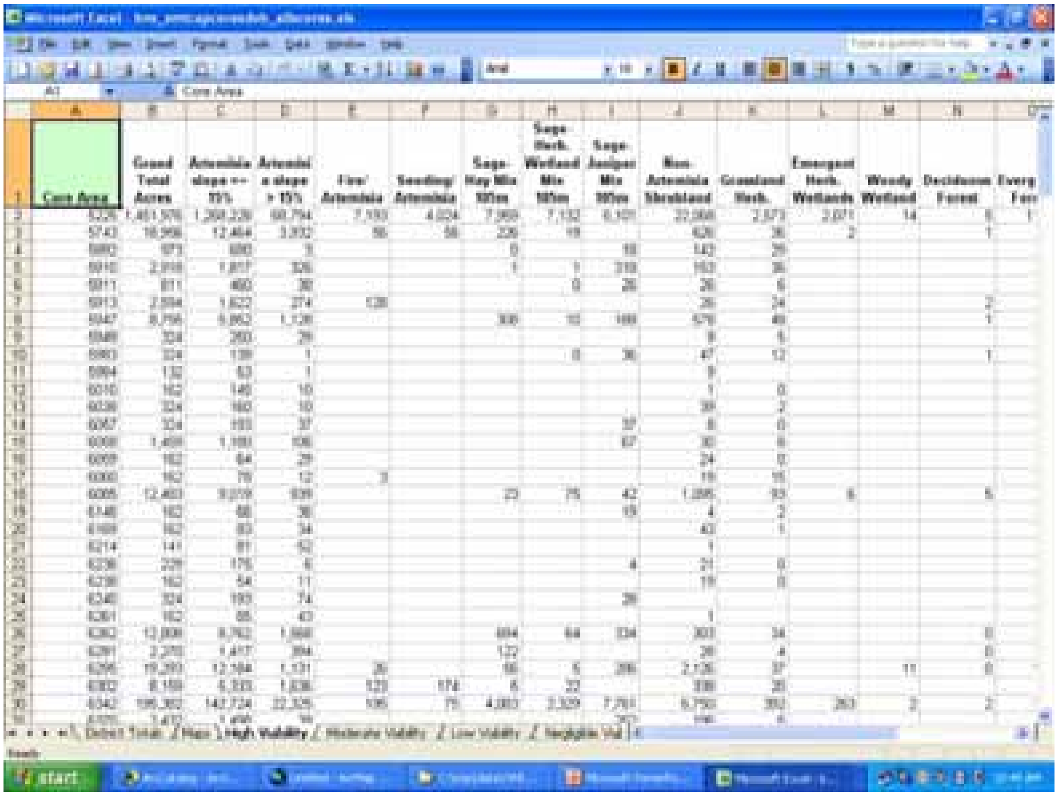

Figure 7. Core area statistics for smart habitat capability

Patch Isolation

The basic habitat connectivity analysis establishes the spatial arrangement and characteristics of patches in the landscape, but it lacks the ability to decipher the inter-patch relationships that fully define the habitat situation. We have developed a patch isolation metric that focuses on the spatial relationships between patches, and produces both visual and analytical isolation results (Figure 8). This metric first measures the half-distance in 360 degrees around each patch to each adjacent patch of like viability, ultimately forming a 'proximity polygon'. The maximum search distance between adjacent patches is defined by a biologist (in this example 10 kilometers) in reference to a species' maximum mobility. The area of each polygon normalized to the size of the patch is directly related to the isolation of the associated patch.
Since moderate viability core areas are also considered as habitat for a given species, albeit of lower quality, the contribution of these patches to connectivity must be taken into consideration when calculating patch isolation for high viability core areas. The methodology herein calculates isolation for high viability core areas first, and then upgrades the patch value where moderate viability core areas surround or otherwise connect the high viability patches. In Figure 9, the influence of the moderate viability patches (brown colors) effectively lowers the isolation values for the high viability patches (green and blues).

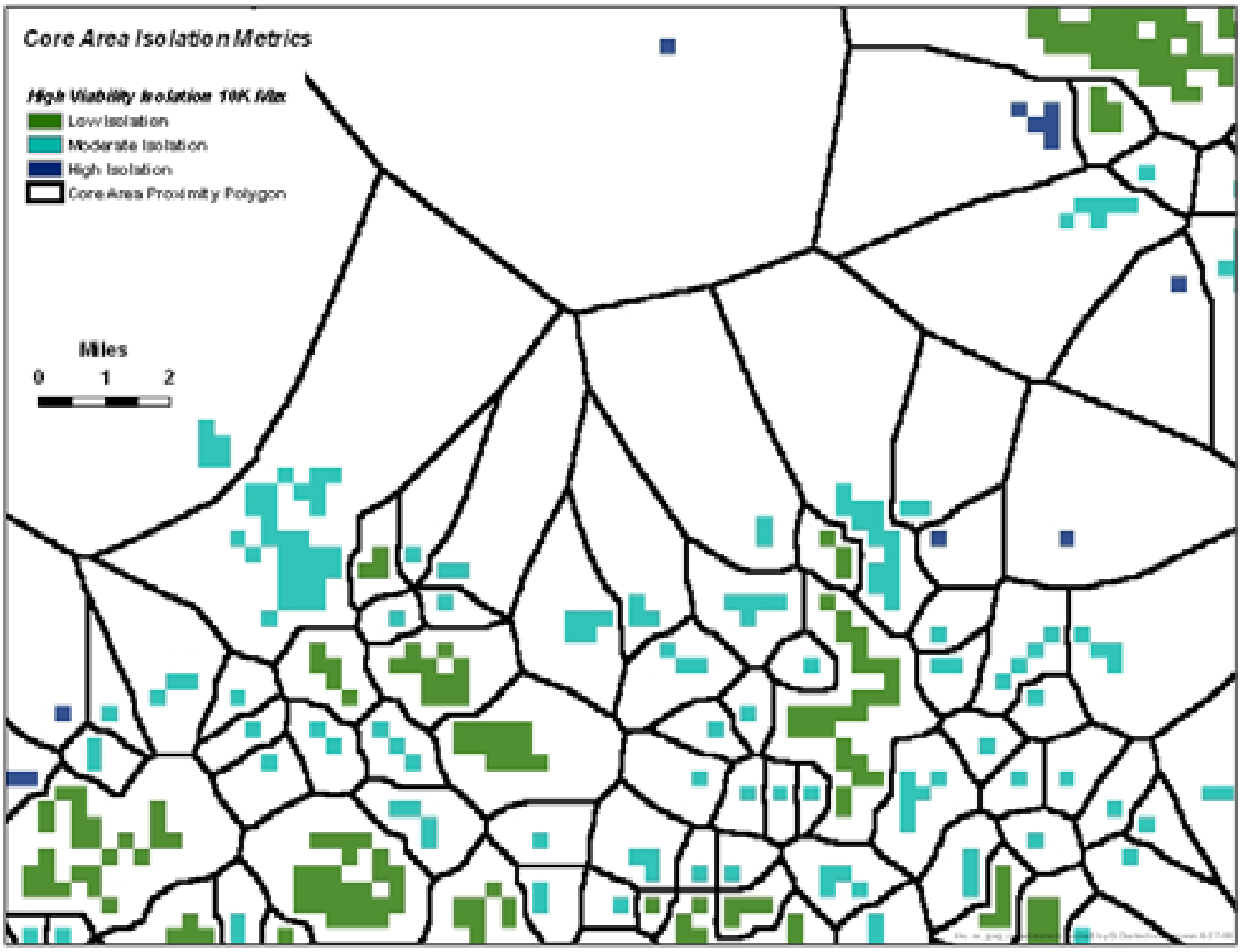

Figure 8. High viability core area isolation metrics

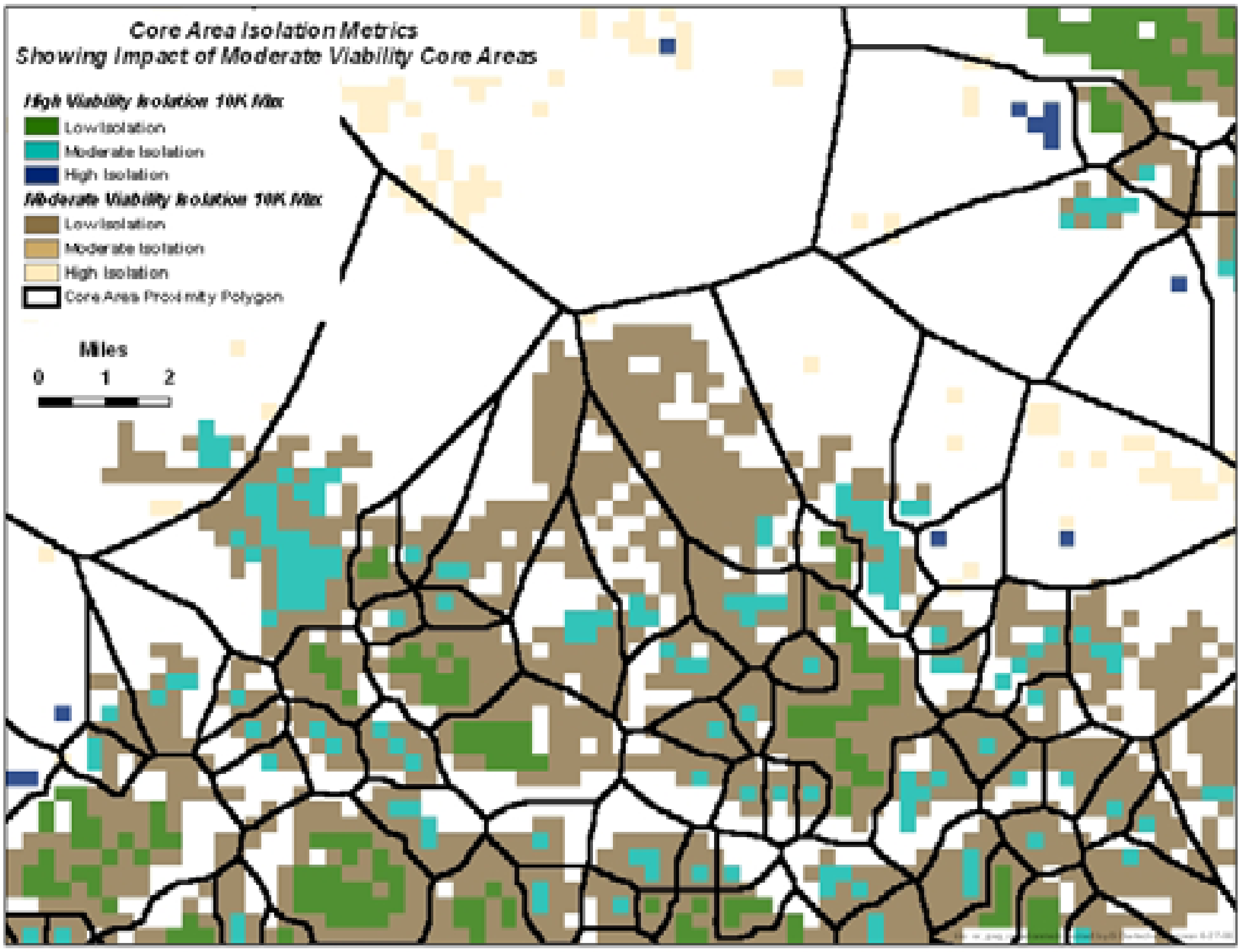

Figure 9. High viability core area isolation metrics showing moderate viability influence

Applications

This model can be used by land managers and planners as a screening method, to assist in project planning, as an aid in priority setting, and to focus management efforts and direct resources. For example, sagebrush habitats are locally encroached by pinyon and juniper forests, which will, if left unchecked, fragment otherwise continuous habitat. The model can be used to identify ‘choke points’ in connectivity and land managers can set priorities for specific areas for tree removal and sagebrush restoration.

Another example is the evaluation of priority restoration areas for sage-grouse habitat after wildfire. Higher priority areas would be where connectivity between adjacent high viability patches has been severed by the fire. 3D fly-throughs of model components using ArcScene (Figure 10) can be helpful in making rapid decisions where slopes or other spatial features may be a factor.

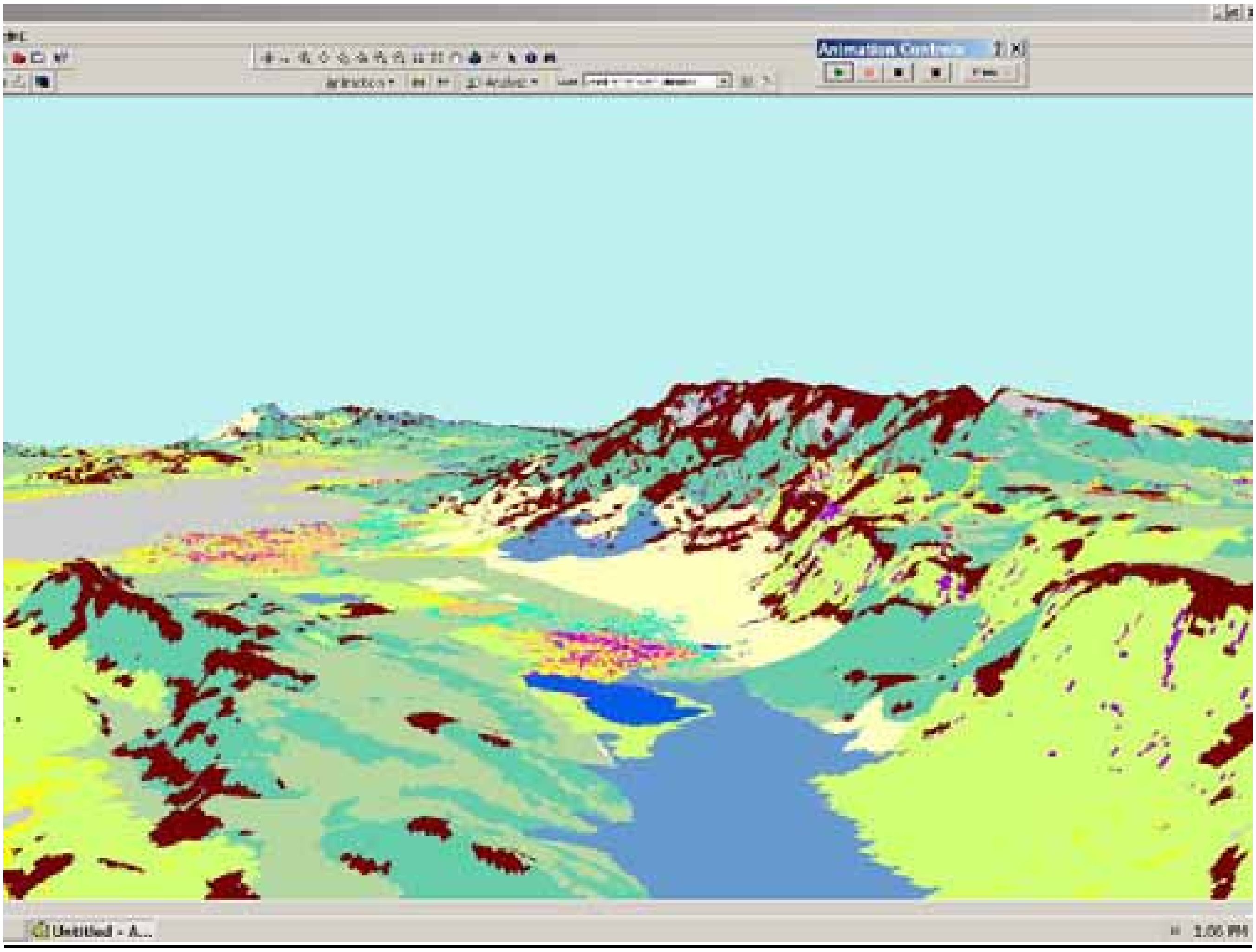

Figure 10.

Conclusions

The BLM has developed a broad regional habitat connectivity-fragmentation analysis which supports land managers, land use and conservation planning, and NEPA analysis. This application is designed to provide an easy to understand, seamless, regional context, forming the foundation for more site-specific activities. Also, it enables managers to set priorities for restoration and other projects in the context of limited budget resources. It is focal species and habitat driven, can be customized to a specific species in an open-architecture structural format, and integrates disturbances with habitat. Lastly, the model creates a spatially explicit snapshot which references a baseline set of conditions on the ground. In the future, it can be repeated periodically as a method to monitor change.

Some of the active projects in the western U.S. are shown in Figures 11 and 12. Figure 13 shows grassland habitat connectivity for a 317 million acre area of the prairie grasslands that stretches from Mexico to Canada. This demonstrates the regional nature of the analysis.

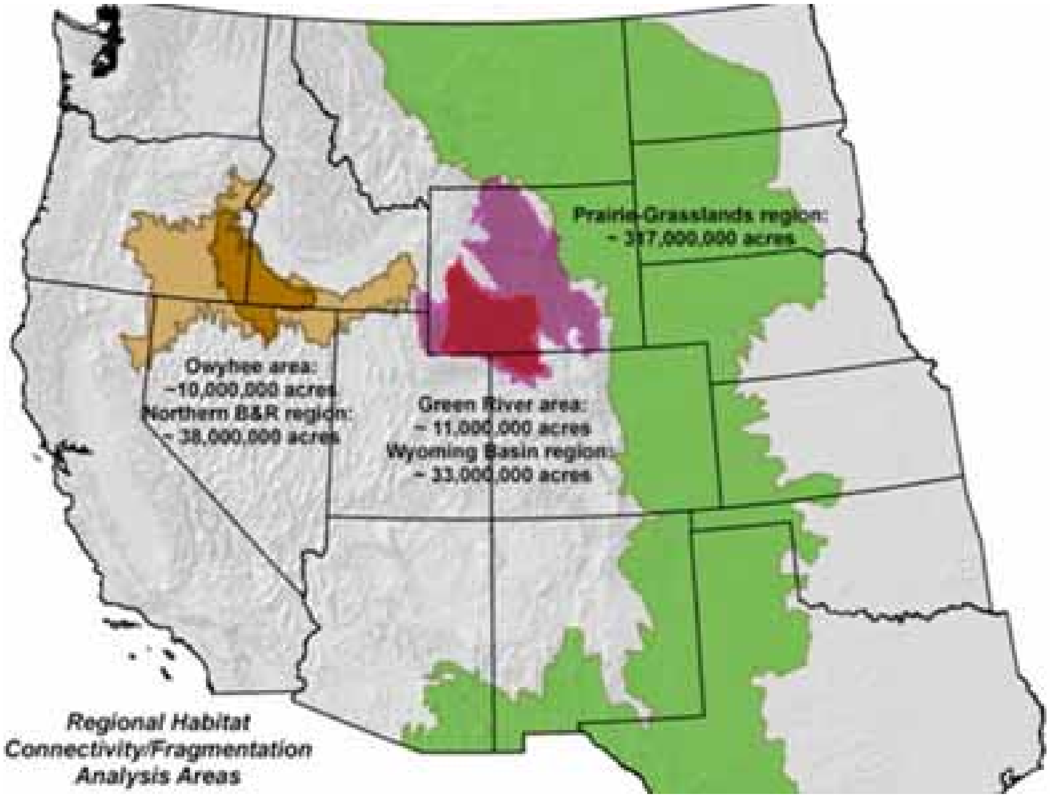

Figure 11. Active projects in the western U.S.

Figure 12. Other active projects in the western U.S.

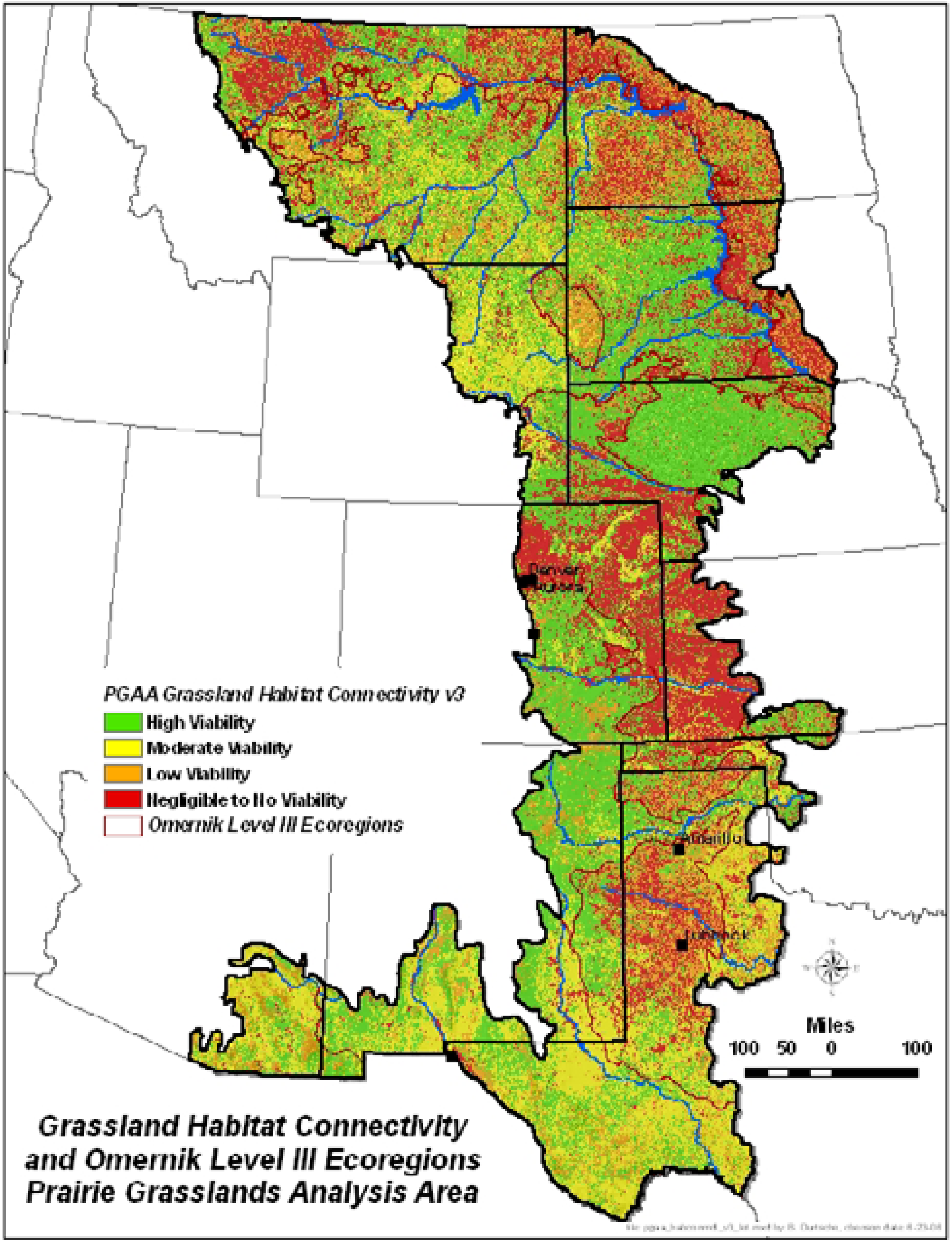

Figure 13. Detail of prairie grasslands analysis

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