Introduction

Landscape Context:
An integrated measure of the quality of the ecological processes maintaining the elements of an area, and the connectivity of the area with the surrounding landscape (Tuffley and Comer 2005).

Geographic information systems (GIS) provide tools to help prioritize areas on the landscape, identifying the highest priority, most viable sites for protection. The continuing expansion in digital mapping of infrastructure and landuse-landcover provides a wealth of data with which to investigate the spatial distribution of both human impacts to the environment and the biodiversity elements we wish to conserve.

As a surrogate for directly measuring the quality and connectivity of the landscape, we modeled the location and intensity of anthropogenic disturbances in the landscape, making the broad assumption that these disturbances are affecting the quality and connectivity of landscape processes, and, by extension, having an impact on the elements of biodiversity supported by that area.

We present a generalized methodology for using available data to construct landscape integrity models for large areas, and evaluate the usefulness of the Colorado model using independently collected information about the quality of mapped natural communities throughout the state.

Methods

Our model used a series of sigmoid curves based on the function:

\[ y = \frac{1}{1 + \exp\left(\frac{x - \alpha}{c}\right)} \times w \]

where:
- \(x\) = shift curve to right or left
- \(\alpha\) = denominator spatial of curve, or slope of the rapidly-diminishing part of curve.
- \(c\) = scalar to adjust total distance of interest (distance in meters divided by 20)
- \(\times\) = distance to impact from threat
- \(w\) = weight of threat (maximum value)

By adjusting the shift and spread of the curve (a and b), it can be tailored to specific threats. Different values of a and b were used to derive four decay curves describing gradual, moderate, moderately abrupt, and abrupt distance decay behavior. The inflection point of the curve marks the distance where the effect of the impact is reduced by half. These curves are asymptotic at both ends, therefore the results of the equation must be manually adjusted to equal the maximum weight at zero distance and minimum weight at a distance at which the weight becomes essentially zero ("cutoff distance").

Each individual impact type has its own relevant weight and decay function type. The individual layers are then additively combined to produce an overall landscape integrity layer.

Distance Decay:
The lessening in force of a phenomenon or interaction with increasing distance from the location of maximum intensity.

The distance-decay model of landscape integrity is a cumulative, continuous surface of relative impact. The distance-decay function represents a mathematical curve describing the decrease of impact over distance.

The choice of curve for the distance decay function is determined by how the disturbance is believed to behave in the real world.
Results

Urban Development

The Urban Development layer was derived from the Southeast Regional GIS (SE Regional GIS) Landuse. Although urban development areas were not given different impact weights and their distances along the landscape were calculated separately. The final output was the maximum value from the two calculations to represent overall impact of urban development.

Tilled Agriculture

The Agricultural layer was also derived from the SE Regional GIS Landuse. This was calculated for the base impact of agriculture and then the layers in it were to be incorporated as above.

Oil and Gas Wells

The oil and gas well layer was derived from the Colorado Oil and Gas Conservation Commission (COGCC) well data released. Activity producing wells were given different impact weights and their distances along the landscape were calculated separately. The final output was the maximum value from the two calculations to represent overall impact of oil and gas development.

Roads

The road layer was derived from the U.S. Census Bureau 2010 TIGER/Line Files. Roads were separated into primary (interstate or U.S. Highway), secondary (state and county), and local roads. The final output was the maximum value from the two calculations to represent overall impact of roads.

Major Utility Lines

The data used to acquire complete and associated utility line (transmission and power transmission lines for the utility and road network) was obtained from the U.S. Department of Commerce, U.S. Census Bureau, Geography Division, TIGER/Line Files. This data was used to calculate the impact along the utility lines. The final output was the maximum value from the two calculations to represent overall impact of utility lines.

Surface Mines

The surface mine layer was derived from the Colorado Division of Reclamation, Mining, and Energy database. Only active mine sites were used. Mines were separated into the major categories (coal, metallic, and nonmetallic) and given different impact weights and calculated separately. The final output was the maximum value from the two calculations to represent overall impact of surface mining activities.

The individual impact layers were added together to create the final landscape integrity layer representing the cumulative impact to an area from the included land use.

Final Landscape Integrity Layer:

- **None**
- **Moderate**
- **Low**
- **High**

![Final Landscape Integrity Layer Image]
Discussion

Testing the landscape integrity model against an independent evaluation of landscape integrity

We used a sample of plant community occurrence records from the CNHP Biotics database (2008) to generate landscape integrity scores, and compared the scores with the viability ranks of A, B, C, or D assigned by ecologists during field inventory work. The ranks typically reflect the degree of negative anthropogenic impact to a plant community observed by the ecologist in the field.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Viability</th>
<th>Rank Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Excellent</td>
<td>AB – good quality occurrences, likely to persist if current conditions continue in effect</td>
</tr>
<tr>
<td>B</td>
<td>Good</td>
<td>CD – poor or marginal quality occurrences, not likely to persist without direct intervention</td>
</tr>
<tr>
<td>C</td>
<td>Fair</td>
<td>CD – poor or marginal quality occurrences, not likely to persist without direct intervention</td>
</tr>
<tr>
<td>D</td>
<td>Poor</td>
<td>CD – poor or marginal quality occurrences, not likely to persist without direct intervention</td>
</tr>
</tbody>
</table>

If landscape integrity scores are reflecting the ecologist’s field evaluation of rank, we would expect:

- a difference in location of mean (AB-ranked with lower scores than CD-ranked)
- a difference in the shape of the distributions (due to zero-truncation of possible scores, the AB group is expected to have more zeros, and hence a more positively skewed distribution.

Applications

Colorado Biodiversity Scorecard

Landscape integrity was scored for eleven of Colorado’s widespread ecological systems. Scores formed part of an overall biodiversity status score for occurrences of these ecosystems.

Conclusions

The model is not a substitute for on-the-ground evaluation

BUT

- It does reflect trends in viability as assessed by field ecologists
- It is useful as an initial evaluation for areas yet to be surveyed
- It is a good summary for landscape-level assessment where complete field survey is impractical

References


For more information

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