Incorporating GIS into the Development of Community-Based Index Models to Better Capture the Watershed Response to Proposed Planning Designs

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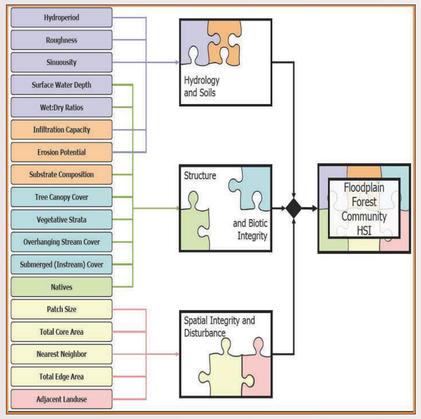
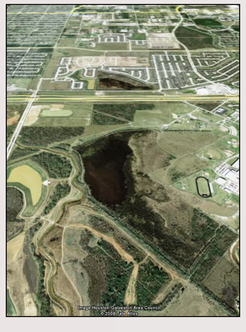
Introduction

Despite the fact that landscape level processes dictate ecosystem function and sustainability, past U.S. Army Corps of Engineers (Corps) ecosystem restoration planning and management decisions have typically been made on a project-by-project basis. Watershed planning, centered on the strategic restoration of land and water resources at the landscape level, has the potential to provide dramatic benefits by restoring ecosystem-level functions and services. Attaining ecosystem integrity (i.e., health, biodiversity, stability, sustainability, naturalness, wildness, and beauty) is the goal of ecosystem restoration and management and of particular concern to the Corps. Here, we advocate the development of community-based index models to capture ecosystem integrity using six primary components: ***Biotic Integrity, Vegetative Structure, Hydrology, Soils, Spatial, Integrity*** and ***Disturbance***. The effort to combine the variables in mathematical algorithms could then be viewed as community index modeling under the traditional Habitat Evaluation Procedures (HEP) paradigm. For purposes of organization, the community based index models are constructed from combinations of components - the analogy we use is one of puzzle building. The individual model components are represented as "pieces" of the ecosystem puzzle, that when combined capture the essence of the system's functionality. Modelers and planners alike can use this approach to develop community index models for any setting, and by loosely coupling GIS therein, can improve the efficiency and effectiveness of the alternative design and evaluation process.



The Engineer Research and Development Center's (ERDC's) Habitat Evaluation and Assessment Team strives to develop spatial-explicit index models that broadly capture existing, baseline conditions, and compare changes that would occur to the resources present under "what if" project scenarios or alternatives. These tools are not meant to exhaustively capture the full range of all plant, animal, and physical characteristics of the project area, but provide an approach to make comparisons between potential plans and select those with the highest benefits.

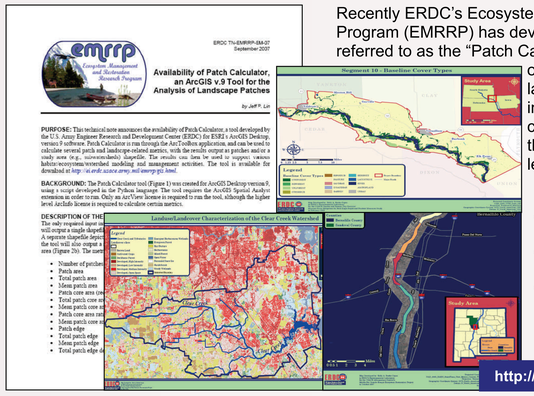
Common GIS-Based Models Parameters



The inherent complexity of ecosystem restoration planning at the watershed scale requires comprehensive modeling of spatial characteristics and dynamics system-wide. Some common parameters to consider include:

- Total Edge
- Edge Density
- Total Core Area
- Number Core Areas
- Core Area Distributions
- Patch Distribution & Isolation
- Diversity & Evenness Indices
- Landscape Shape Index
- Patch Size and Density
- Largest Patch Index
- Contagion
- Connectivity
- Proximity Index
- Aggregation Index
- Adjacent Land Use
- Interspersion & Justaposition
- Types of Human Disturbance
- Landscape Division Index
- Similarity Index
- Buffering

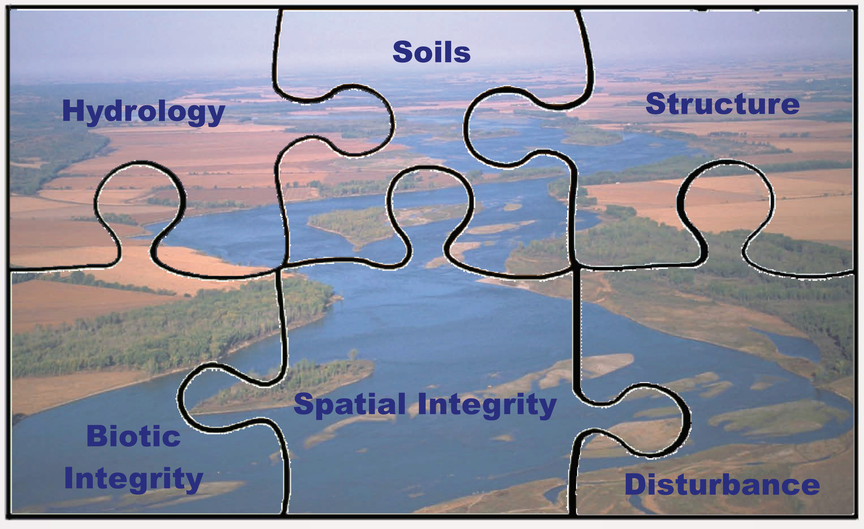
ERDC's Patch Calculator



Recently ERDC's Ecosystem Management and Restoration Research Program (EMRRP) has developed an ESRI ArcGis Desktop v. 9 toolbox referred to as the "Patch Calculator" that automates the calculation of over 13 of these commonly assessed landscape scale metrics. Our team has incorporated these directly into several community based index models and applied these models in several ongoing feasibility-level studies:

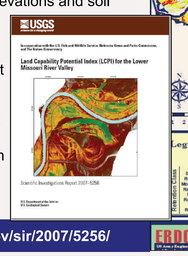
- **Clear Creek Flood Risk Management Study (Galveston District)**
- **Missouri Recreational River BiOp (Kansas City and Omaha Districts)**
- **Middle Rio Grande Ecosystem Restoration Study (Albuquerque District)**

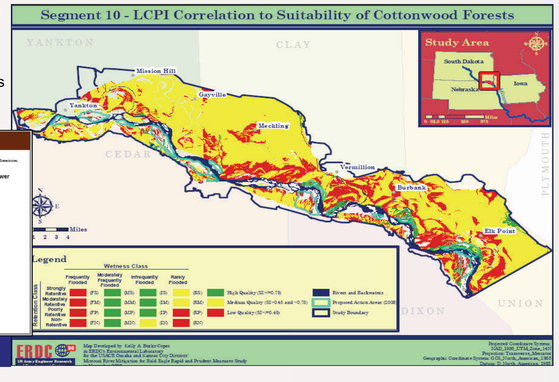
http://el.erdc.usace.army.mil/elpubs/pdf/em07.pdf



Land Capability Potential Index (LCPI)

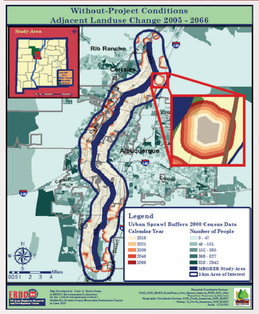
In an ongoing community modeling exercise for the Omaha & Kansas City Corps Districts, ERDC has collaborated with the U.S. Geological Survey (USGS) to develop a Land Capability Potential Index (LCPI) that integrates fundamental components such as hydrology, hydraulics, land-surface elevations and soil permeability. Expert elicitation and ground truthing were used to correlate the LCPI to forest stand age and aerial extent thereby guiding the planning team in its efforts to select, prioritize and design effective ecosystem restoration and preservation initiatives along the Missouri River.



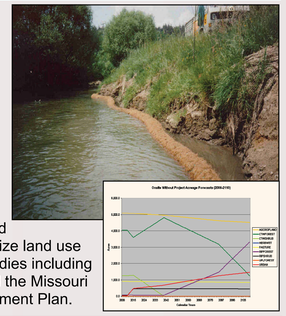


http://pubs.usgs.gov/sir/2007/5256/

Landuse Conversion Modeling

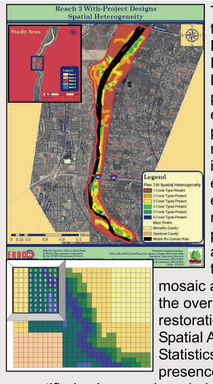


Typical planning activities must address land use conversions that threaten the ecological integrity of proposed ecosystem alternatives. Of particular concern is the loss of habitat posed by urban sprawl and natural succession as it relates to vegetative cover changes. ERDC has developed a series of heuristically-based expert models to characterize land use conversions on several studies including the Middle Rio Grande and the Missouri River Cottonwood Management Plan.



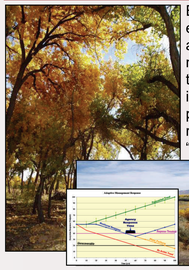
Spatial Heterogeneity Index (SHI)

In the desert southwest, fully functioning bosque ecosystems contain multi-aged stands of cottonwood forests, coyote willow shrubland, wet meadows, marsh wetlands, oxbow ponds, and open water areas spread across the landscape in a dynamic mosaic. Biotic legacies from preceding bosque forests, propagules from adjacent cottonwood stands, forest structuring processes, and the generation of spatially diverse complexes combine to produce both overall compositional diversity and patch diversity (habitat breadth).

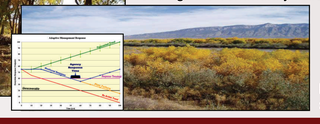


To capture the essence of these unique ecosystems, ERDC developed the Spatial Heterogeneity Index (SHI). Based on the fundamental principles of landscape ecology (namely that spatial patterns influence flows of materials, energy, and information into and out of the ecosystem; and that ecological processes create, modify, and maintain spatial patterns), the SHI model offers a simple, yet robust technique to capture the landscape mosaic and quantify its contribution to the overall integrity of the bosque restoration initiatives. Using ArcGIS Spatial Analyst tools (Neighborhood Statistics) and cover type maps, the presence of interspersed habitats is quantified using a roving window, and the functional capacity of the ecosystem sustainability is measured.

Future Directions



ERDC's intention has always been to develop index models that can be effectively used in the future to evaluate and compare similar communities across the country, and to evaluate the benefits of proposed project management plans in real-time with adaptive management in mind. As such, the community model development process described here is assumed to be iterative - as new information becomes available under the typical Corps planning paradigm, ERDC promotes model revision. The following areas of research are considered important to improving veracity of the information "feeding" the community index models:



- **Ecosystem Response to Climate Change**
- **Ecosystem Services Quantification**
- **Site Selection and Prioritization**

ERDC is actively pursuing these research initiatives. Contact the authors for more information

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