LAKE COUNTRY SCENIC BYWAY
Community Designs: Osage and Nevis, MN
Acknowledgements

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INTRODUCTION

Lake Country Scenic Byway

The Lake Country Scenic Byway was designated for its many unique intrinsic qualities. Working with the Lake Country Scenic Byway Advisory Committee, byway officials, and other interested citizens, a project team from the Department of Landscape Architecture and the College of Natural Resources has studied the areas impacted by the Lake Country Scenic Byway in order to project alternative future land use patterns and develop alternative design scenarios for selected sites within the study area.

The research team will consider the implications of future growth patterns on the character of the area in the context of the opportunities and challenges that the area’s many amenities provide for its future. Emphasis will be on the area’s physical form.

The overall goal of the study is to empower the byway group and the larger community by creating useful materials that will help inform community decisions that impact the future of the byway, its communities, and the natural systems in the area.

Purpose of this Report

The research team will analyze the area’s natural systems, existing natural and cultural amenities, development patterns, and land uses.

The purpose of this report is twofold: First, to describe the application of the Land Transformation Model (LTM) (11) to an analysis and projection of land use for the Lake Country Scenic Byway study area in North Central Minnesota shown in figure 1. Second, to show how the LTM results can be applied to guide specific community planning and design.

![Figure 1. Lake Country Scenic Byway is located in the heart of Minnesota... and spans across Becker, Clearwater, Hubbard and Cass Counties.](image-url)
Study Area

The study area traverses Detroit Lakes, Park Rapids, Lake Itasca, Nevis, Akeley, and Walker, Minnesota. This is an area long known for its fishing, golfing, biking, and birding opportunities [1]. Additionally, the area is an important part of the northern forest ecosystem that provides high quality aesthetic features, important contributions to the resource supply for the forest products industry, and habitat for a wide range of game and non game wildlife species.

Our study focuses on the Lake Country Scenic Byway and its surrounding area. Although the area that can be described as the “Lake Country” expands across a large portion of northern Minnesota, we have limited a focused study area within 5 miles of the scenic byway itself.

Figure 2. Lake Country Scenic Byway: base land cover within 5 miles of the Byway.
Land Transformation Model (LTM)
The Land Transformation Model (LTM) is a digital tool developed by Michigan State University to assist planners and resource managers to develop better decisions that affect the environment and local and regional economies. The LTM uses population growth, transportation factors, proximity or density of important landscape features such as rivers, lakes, recreational sites, and high-quality vantage points as inputs to model future land use change. (12)

How it works
The LTM uses Artificial Neural Networks, similar to the intricate pathways established in the human brain. The Artificial Neural Network is a process that utilizes a machine learning approach to numerically solve relationships between inputs and outputs. (12)

The LTM relies on Geographic Information Systems (GIS), artificial neural network routines, land use data from at least two time periods and customized geospatial tools. Raw GIS data is first acquired, which is then processed and converted to an arc/INFO GRID format with cell sizes of 30m x 30m.
1. Data Acquisition and Description

1.1 Landsat Images

Landsat TM 5 data from 1990 and 1999 were used to generate land cover maps for these two dates for the study area. Ideally, multi-temporal images are desired for land cover classification. For this study one-date TM images were used given time and budget constraints.

All the images have been geo-referenced to Universal Transverse Mercator (UTM) projection, Zone 15, GRS 1980, NAD 83. Table 1 lists the acquisition date, path, row and rectification information of the images. The images are very close in their anniversary dates with little sun angle and view angle differences. Additionally, all of the images are of good quality and free of clouds. The study area fit within one scene for 1999, but for 1990, it crossed two paths. The two 1990 scenes were formed into a mosaic with histogram matching for their overlap area. Images from both years were then extracted to form a sub-image covering the study area—the five-mile buffer of Lake Country Scenic Byway. Figure 3 shows the 1999 TM data and the location and extent of the study area.

<table>
<thead>
<tr>
<th>Acquisition Date</th>
<th>Path</th>
<th>Row</th>
<th>RMS of Rectification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug. 07, 1990</td>
<td>28</td>
<td>27</td>
<td>N/A</td>
</tr>
<tr>
<td>Aug. 30, 1990</td>
<td>29</td>
<td>27</td>
<td>0.4 pixel</td>
</tr>
<tr>
<td>Sep. 16, 1999</td>
<td>29</td>
<td>27</td>
<td>0.25 pixel</td>
</tr>
</tbody>
</table>

1.2 Minnesota Gap Analysis Program (GAP) Land Cover

Gap Analysis is a focused process for assessing to what extent native animal and plant species are being protected [2]. The goal of Gap Analysis is to maintain biodiversity by identifying those species and plant communities that are not adequately represented in existing conservation lands. Common species are those not threatened with extinction. By identifying their habitats, Gap Analysis provides land managers, planners, scientists, and policy makers the information they need to make better-informed decisions when identifying priority areas for conservation. Gap Analysis came out of the realization that a species-by-species approach to conservation is not always effective because it does not address the continual loss and fragmentation of natural landscapes. By protecting regions already rich in habitat we stand a better chance of adequately protecting the species that inhabit them.

In Minnesota the GAP land cover is a detailed, hierarchically organized vegetation cover map produced by computer classification of combined two-season pairs of early-1990s Landsat 4/5 satellite imagery, as part of the Upper Midwest Gap Analysis Program (UMGAP) of the U.S. Geological Survey [3]. There are typically 4 levels or classes in Gap Analysis.

1.3 U.S. Geological Survey (USGS) Digital Elevation Models (DEM)

The DEMs were standardized to 30-meter grid cells, UTM Zone 15, NAD83, vertical units in feet and were joined into one statewide file. All the DEMs are Level 2 quality. Level 2 DEMs have been processed or smoothed for consistency and edited to remove identifiable systematic errors. A vertical RMSE of one-half of the contour interval, determined by the source map, is the maximum permitted. Systematic errors may not exceed one contour interval specified by the source graphic [4].
Table 2. Land cover classification scheme used for the study area.

<table>
<thead>
<tr>
<th>Information Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water and Others</strong></td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>Permanent open water, lakes</td>
</tr>
<tr>
<td>Lowland Forest</td>
<td>Lowland forested area. Forest was defined as a minimum of 70% canopy closure. It includes coniferous, deciduous, and mixed forest.</td>
</tr>
<tr>
<td>Upland Forest</td>
<td>Upland forested area. Forest was defined as a minimum of 70% canopy closure. It includes coniferous, deciduous, and mixed forest.</td>
</tr>
<tr>
<td>Agriculture/Grass</td>
<td>Includes planted cropland, range-land, fallow, and natural grassland.</td>
</tr>
<tr>
<td>Urban</td>
<td>Includes commercial, industrial, residential, and transportation.</td>
</tr>
<tr>
<td>Lowland Non-forested</td>
<td>Lands that are sometimes covered with water or have waterlogged soils.</td>
</tr>
</tbody>
</table>

1.4 DOT 2000 Roads

This data set contains roadway centerlines for roads found on the USGS 1:24,000 mapping series. Those roadways that are Interstate, Trunk Highway, or CSAH (county state/aid Highway) are current through the 2000 construction season. Other roads, if not updated, are depicted as shown on the published quadrangle [5].

1.5 DLG Hydrological Lake and Wetland Data

This 1:100,000 scale hydrography data was derived from USGS Digital Line Graphs (DLG)'s of the same scale. This data contains only the polygon portion of the DLG database.

Area features are attributed as lakes, wetlands, inundated areas, tailings ponds, sewage ponds, fish hatcheries, and other minor water body types [6].

1.6 National Forest

Natforest, which represents national forest boundaries within the state, is a layer of the State of Minnesota BaseMap 2001 which consists of a number of individual data layers or themes digitized from 1:24000 USGS 7.5-minute quadrangles. These data layers fall into the following broad categories: transportation system, civil and political boundaries, and surface water. Natforest originated as a polygon coverage with the United States Forest Service (U.S.F.S) [7].

1.7 Indian Reserves

Reservtn, which represents Indian reservation boundaries within the state, is a layer of the State of Minnesota BaseMap 2001, which consists of a number of individual data layers, or themes digitized from 1:24000 USGS 7.5-minute quadrangles [8].

1.8 Census Block

Census block level data with population information for 1990 and 2000 was obtained from the U.S. Census Bureau [9,12].
2. Data Classification and Processing

2.1 Land Cover Classification

Given the above data, a classification scheme (table 2) was established based on the abilities of the sensor and our research requirement and by referencing Anderson’s Land Use / Land Cover classification system. These classifications were developed through an unsupervised classification performed for both the 1990 and 1999 Landsat TM data using ERDAS IMAGINE, which uses the ISODATA algorithm to perform such classification. The term ISODATA stands for “Iterative Self-Organizing Data Analysis Technique.” It is iterative in that it repeatedly performs an entire classification (outputting a thematic raster layer) and recalculates statistics. “Self-Organizing” refers to the way in which it locates the clusters that are inherent in the data [10]. In summary, ISODATA was used to identify spectral clusters from image data.

The number of clusters, maximum number of iterations, and convergence threshold was set to 40, 60, and 0.99 respectively. Of the three parameters, the number of clusters is the most critical one. Different numbers such as 20, 40, and 60 were tested and 40 was found to work best. The output files are thematic maps with 40 different values represent 40 clusters. The resultant clusters were then reclassified to water, wetland, forest, crop/grass, and urban five classes through visual inspection of the original TM images and reference data like MN GAP.

Figure 4. Land Cover within the Scenic Byway Five-mile Buffer, 1990
Next, a lowland mask was generated from GAP data. The mask was then used to separate the five classes into six—water, lowland forest, upland forest, crop/grass, urban, lowland non-forested area—as defined in Table 2. Finally, a majority 3 by 3 filter was performed on both classification maps to reduce salt and pepper noises. Figures 4 and 5 show the classified land cover maps. Table 3 shows the statistics of the classified maps.

<table>
<thead>
<tr>
<th>Class</th>
<th>Area (Pixels)</th>
<th>Area (%)</th>
<th>Area (Pixels)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop/Grass</td>
<td>740940</td>
<td>26.59%</td>
<td>626882</td>
</tr>
<tr>
<td>Lowland Forest</td>
<td>63150</td>
<td>2.27%</td>
<td>62810</td>
</tr>
<tr>
<td>Lowland Non-Forested</td>
<td>29937</td>
<td>1.07%</td>
<td>27078</td>
</tr>
<tr>
<td>Upland Forest</td>
<td>1531240</td>
<td>54.96%</td>
<td>1639764</td>
</tr>
<tr>
<td>Urban</td>
<td>43600</td>
<td>1.56%</td>
<td>49292</td>
</tr>
<tr>
<td>Water</td>
<td>377417</td>
<td>13.55%</td>
<td>380805</td>
</tr>
</tbody>
</table>

Table 3. Land cover class statistics within study area for 1990 and 1999

Figure 5. Land Cover within the Scenic Byway Five-mile Buffer, 1999
2.2 Creation of Spatial Layers of Predictor Variables

Before the predictor or driving variables were created, a base map with 30-meter cell size was generated and used as the spatial mask. All the raw data were then processed in ArcGIS to generate 10 predictor variables.

Predictor variables created were elevation, slope, aspect, distance to interstate highway, county aid highway, distance to lakes, distance to streams, distance to lowland, distance to urban of 1990, and block-level population density change between 1990 and 2000. All of these variable layers had the same cell size and the same file extent as the base map.

LTM Predictor Variables

![Aspect](image1)

![Distance to lakes](image2)

![Elevation](image3)

![Distance to interstate](image4)

![Distance to streams and](image5)

![Slope](image6)

![Distance to county](image7)

![Distance to wetlands](image8)
2.3 Generation of an Exclusionary Layer

Development is prohibited within some areas such as natural reserves or parks, and these areas were excluded from land any transformation in land use. Our exclusionary layer included interstate highway, county aid highway in 1990, water and rivers, Itasca state park, Indian reservations, and the initial 1990 urban area. Figure 6 illustrates the exclusionary layer.

Figure 6. Exclusionary layer

Change in population density between 1990 and 2000
3. Land Transformation (LTM) Simulation

3.1 Urban Transformation Simulation for 2000
   Based on 1990 Data Layers

The 10 predictor variables, the exclusionary layer, and the two land cover maps were firstly converted to ASCII files and then entered into the land transformation model. The LTM model applied spatial rules that relate predictor variables to land cover transitions for each cell in the study area and integrated the predictor variables by artificial neural networks (ANN). The ANN in this model is a feedforward network with one input layer, one hidden layer, and one output layer. The model is trained using a backpropagation algorithm. The Stuttgart’s Neural Network Simulator version 4.2 (SNNS v4.2) was used for the design, training and prediction of the ANN [14]. To avoid over-training of the neural network, it was trained with 1/2 of the data and the cells in a cycle were presented to the network in random order. A cycle is defined as one complete presentation of all training cells to the network. The model run was set for 4000 cycles, which was believed adequate to stabilize the error level to a minimum value. The output from this step is a map of “change likelihood values,” which specifies the relative likelihood of change for each cell based on the ANN result given for the cell’s vector of predictor variable values. A change likelihood of 0 indicates “no readiness” to change whereas a value of 1 indicates the “highest readiness” to change to urban[11]. Figure 7 shows the resulting change likelihood maps.

Figure 7. Change likelihood map for study area. Cells with higher probability of change from non-urban to urban are mapped with the light areas.