Findings from Lab Two, Multi-Criteria / Multi Objective Land Allocation

Objective

To use arcGIS to create a future land use map that appropriately allocates development, agriculture, and nature preserves, protecting biodiversity in northeastern Washtenaw County.

Introduction

Habitat loss has been described as the primary threat to the loss of biodiversity at the landscape, species, and genetic levels (Wilson, 2002). In northeastern Washtenaw County, biodiversity is becoming more threatened as the area continues to face rapid economic growth. Land use for development and agriculture has led to the fragmentation of nature reserves throughout the area. Such fragmentation is seen by many landscape architects as a major issue for the protection of habitats; small habitats are found to be more homogenous than larger habitat in terms of soil content, species populations, and landscape character (Collinge, 1996).

Upon the observance of a 1995 land use map, I decided that an allotment of land conserving natural areas with fair distance from the urban growth of Ann Arbor should be a priority in land allocation. Since the three land use types influence each other through numerous and often unquantifiable interactions, each land use type was carefully considered. A target for allocation of developed, agricultural, and natural area was provided, with each land use type to equal 10%, 36%, and 54% of available land, respectively. This means that future land allocation would equate to 31.5% developed, 48.1 % natural, and 20.4% agriculture. With these goals in mind, I was able to produce allocations of these three land uses, while maintaining a commitment to the minimization of habitat fragmentation.

Methods

This study followed the directions provided in the lab handout, which can be summarized as a six step process. My first task was to use the vast compilation of maps and raster grids provided for this experiment to create a series of sub models for each land use type. In arcGIS, ModelBuilder and the Spatial Analyst tool box were used to quantify the criteria for each of the three land use suitability maps; all recommended criteria were used. Each criterion involved a model that produced a score (1-100) to be used for suitability mapping. The second step utilized the criterion to create the suitability maps in ModelBuilder. Each criterion was assigned a weight through the website provided in the lab handout; weights can be viewed in Tables 1, 2, and 3, below.

Table 1. Agriculture Weights

Maximum Eigen Value =5.02545

C.I.=0.00636306

Criterion	Weights (Eigen Vector)
Clay content	0.082844
Distance from ‘95 development	0.119167
Slope	0.20566
Distance from lakes and streams	0.282439
Distance from wetlands	0.30989

Table 2. Development Weights

Maximum Eigen Value =7.09481

C.I.=0.0158019

Criterion	Weights (Eigen Vector)
Slope	0.217408
Distance from Wetlands	0.183272
Distance from water	0.171845
Distance from ‘95 development	0.128599
Distance from major roads	0.112095
Distance from public lands	0.112095
Distance from Ann Arbor	0.074688

Table 3. Natural Area Weights

Maximum Eigen Value =4.01086

C.I.=0.00361984

Criterion	Weights (Eigen Vector)
Pre-settlement	0.336985
Distance from wetlands	0.289921
Distance from water	0.210858
Slope	0.162237

Third, weights were distributed with environmental protection as the primary objective. Water sources were secluded from agriculture and development. Since wetlands are a unique habitat that has been diminished in the state of Michigan, it was important to allocate natural areas around wetland habitats. In Table 1, it is clear that clay content was a low priority, since the data source was deemed unreliable (improper scale). In both agriculture and development, slope was a priority because of the prospect of erosion, which directly ties into the aim of environmental protection. Upon the creation of the weighted suitability maps, I discovered that each land use type had different ranges of scores (all within 1-100). To eliminate the prospect of preferences in the proceeding steps, each range was sliced into values from 1-100, through the equal area setting, giving each land use type equal value. I considered giving a preference to the natural land use type since it had the largest target area, but I was most concerned with grouping natural areas together to minimize fragmentation. If natural area was allowed to have a higher score range, the resulting allocation map might prescribe natural preservation to areas that are better suited today for agriculture or development

Once the three final suitability maps were created, I used the Band Collection Statistics tool to generate Table 4, which displays the correlation between each land use type. I proceeded to perform the land allocation through arcGIS's Highest Position tool, as directed in the lab handout. The final step involved the displaying of results through a comparison to the 1995 land use map, provided. This comparison was also carried out though the use of the various recommended spatial analyst tools.

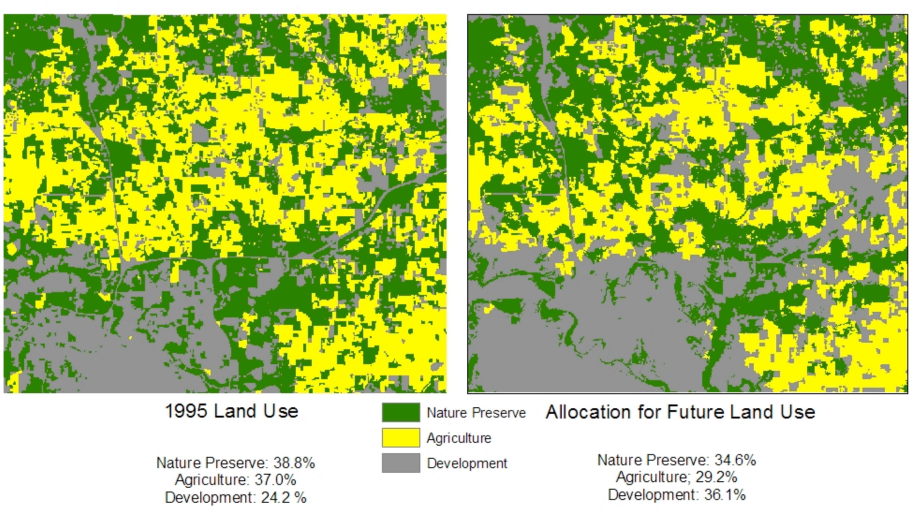
Results

Table 4. Multiple Objective Correlation Matrix

	Natural Area	Agriculture	Development
Natural Area	1.00000	-0.57136	-0.15542
Agriculture	-0.57136	1.00000	-0.16644
Development	-0.15542	-0.16644	1.00000

Table 4 illustrates the negative correlation between each land use type. Figure 1 shows two land use maps: "1995 Land Use" is a reclassified version of the provided raster dataset, while "Allocation for Future Land Use" illustrates the results of this lab's land use redistribution. Between the past and future maps, land allocated as nature preserve decreased by 4.6% of total land, agriculture decreased by 7.8%, and development increased by 15.4%.

Figure 1. Land Use of Northeastern Washtenaw County: 1995 vs. Future Allocation



Discussion

The land allocation model produced results that are surprising on several accounts. First though, the negative correlations illustrated in Table 4 communicate the fact that none of the land uses were conflicting. An analysis of Figure 1 proves that the modeling technique was relatively successful at minimizing habitat fragmentation, while completely missing the targets of future land use allocation. Many nature areas were clumped into larger habitats. As expected, most of these areas were distant from development, since agriculture was weighted to be closer to urban areas. Coincidentally, habitat corridors were common, strengthening an attempt to maintain biodiversity. Corridors are beneficial, providing access for mobile terrestrial species to large habitats relatively far away. However, they bring completely unintended benefits to the allocation strategy, likely attributed to the value of streams and tributaries in the suitability weighting. Unfortunately, this model did not erase habitat fragmentation, as there were many small areas placed as natural preserves that would not be able to support healthy population sizes of organisms in need of a large habitat area.

Land for natural preservation was short by 13.5% of overall land, while development was 4.6% steep and agriculture was 8.8% steep. Land allocation would have been closer to the target were more of the agricultural areas allotted for natural preservation. I stumbled across a more appropriate allocation when I neglected to rescale the agricultural score, which ranged from “0-59”. Since the highest areas were still much lower than the “1-100” scales of the other two land uses, much of the land that I present as agriculture was natural or development. To maintain consistency I sliced agriculture to a scale of “1-100”.

With the information that this model provides, it is easy to see that many patterns are at work, with and against each other, in ways that cannot be observed until the model is ran. Development virtually took over the southwest side of the study area since this is the closest area to Ann Arbor, while insulating the major roads crossing through the study area. The small natural areas may be indicating the presence of wetlands and tributaries. These patterns, and many more that go unnoticed after a quick glance, could not be easily predicted without running the model itself. If this weren’t a fictional situation it would be necessary, and relatively painless, to edit the criteria and tweak the weights. To ensure distance between natural preserved areas and development it would only seem wise to use this as a major criterion (however this would inhibit the planning of city parks). Since the recommended agricultural area is so small, it would be necessary to reduce the “1-100” scoring scale to “1-80” or “1-75”.

Given the stated objectives, it would be important to make these changes, as well as limit the amount of development by 6-9% overall land allocation. Perhaps another model could be run based on this model that works to allocate land in the developed area for parks and recreation. The 1995 land use map indicates a number of areas for outdoor recreation, so the model could use the Euclidean Distance tool to determine where these areas could be appropriately expanded, so that not to infringe upon other existing development. Adding or subtracting criteria, establishing more model parameters, and shifting weights are all ways that arcGIS makes the editing process of modeling very quick and simple.

Conclusion

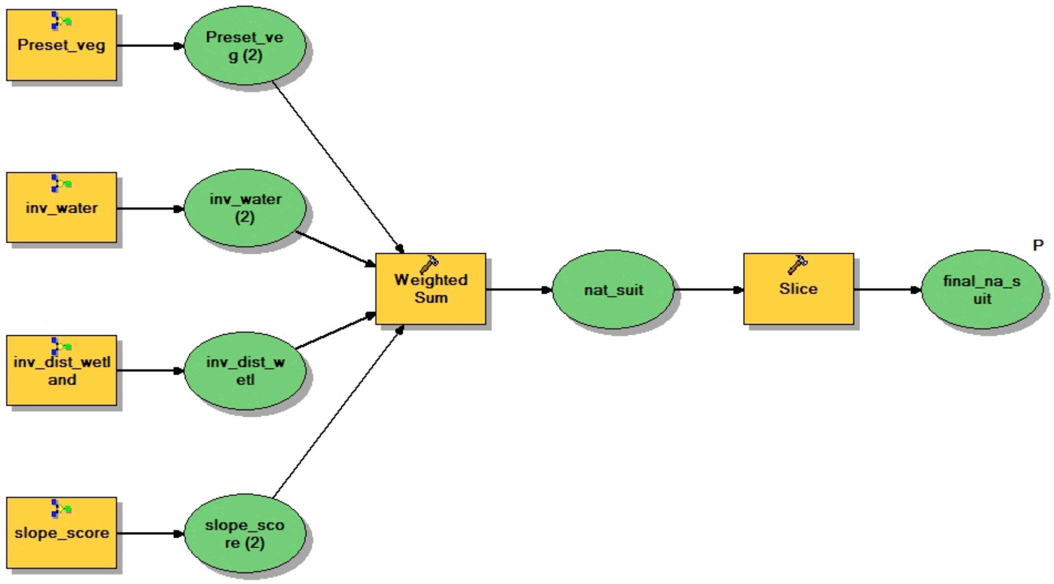
The model building function of arcGIS is invaluable to the formulation of land use allocation maps, because of its data processing capacity and flexibility. With the ability to run a model, display the results, and enable the user to edit and run the model again, this is a vital tool for land use planning, especially with specific goals, such as the protection of biodiversity.

Citations

Collinge, S.K. 1996. “Ecological consequences of habitat fragmentation: implications for landscape architecture and planning.” *Landscape and Urban Planning* 36:59-77.

Wilson, E.O. 2002. The Future of Life. Alfred A. Knopf, New York.

Appendix I - Example of Suitability Model: Natural Suitability



Appendix II – Suitability Maps