# DEVELOPMENT OF A SPATIALLY EXPLICIT LAND USE/ECONOMIC IMPACT ASSESSMENT MODEL

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ABSTRACT.—Land use decisions impact both the environment and economy of a region. Objectives of this study are: 1) to create a tool, integrating GIS and IMPLAN that will aid the prediction of land use change and quantification of the spatially-dependent economic impacts that result, and 2) to apply the new tool to compare the current allocation of land to corn, soybeans, hay, and forest in St. Clair County, Illinois with an income-maximizing land allocation scenario; and 3) examine the regional economic impacts of shifting to the income-maximizing scenario. The four land uses considered in this study are corn, soybeans, hay, and forest. A land use modeling tool is utilized to determine the income maximizing land use production capabilities for each pixel representing the research areas in St. Clair County. Impact Analysis for Planning (IMPLAN) is used to conduct an economic analysis and comparison of St. Clair County under the current and income-maximizing land use allocation. Results indicate that much of the land use within the county is utilized below its maximum potential. IMPLAN output reveals that St. Clair County is better suited for and would benefit from an expansion in production of hay and forest. Model results suggest that land use decisions in the study area are based on factors additional to economic returns.

Land use decisions impact both the environment and economy of a region. Computer tools developed through research in the field of economics allow the measurement of impacts that occur as a result of changes in an economy. Also, natural resource managers have enlisted prediction-based computer models of landscape change and environmental impact. While several researchers have sought to combine economic impact and land use change models (e.g. Irwin and Geoghegan 2001; Chomitz and Gray 1996; Baker 1989), these efforts have fallen short in their ability to simultaneously predict spatially explicit economic and environmental impacts. The purpose of this research is to develop a tool that will integrate the economic utility of input-output (I-O) analysis and the geo-spatial power of GIS to create a spatially explicit land use/economic impact model.

## IMPLAN and Input-Output Analysis

While I-O analysis and economic land use change models have provided answers to key development questions, several deficiencies exist in each tool. Through I-O analysis, a framework can be developed to collect, categorize, and analyze information on interindustry and interdependencies throughout an economy (Shaffer 1989). This powerful tool allows the user to measure the industry-specific impacts resulting from a single transaction (Miernyk 1965). IMPLAN is an I-O analysis computer model developed by the United States Forest Service in 1982 (Siverts 1985). The major shortfall of I-O analysis is in the aspatial nature of the model's geographic range. IMPLAN I-O tables are first established at the national level and then divided by region, county, or zip code (a recent innovation) (Holland et al. 1997).

## GIS and Land Use Models

Land use models created with the aid of GIS, are designed to predict the rate and direction of land use change resulting from economic aspects of human behavior (see Irwin and Geoghegan 2001; Baker

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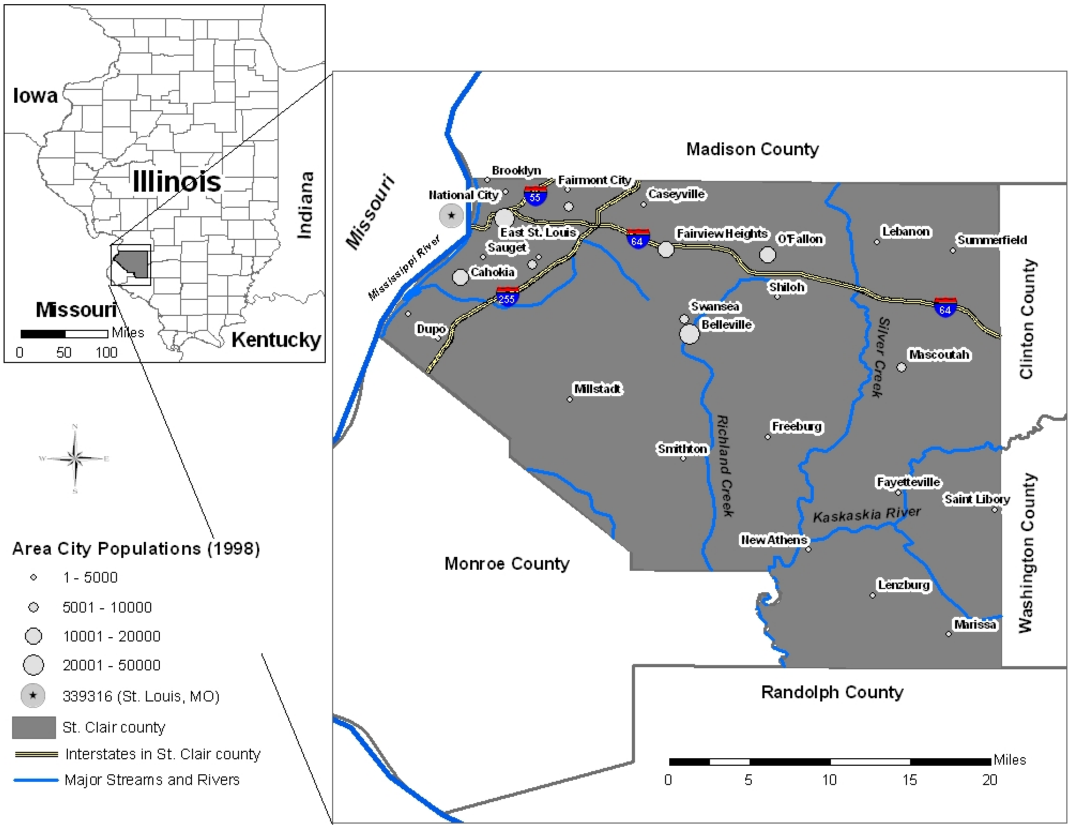



Figure 1.—Location of St. Clair County, Illinois.

1989). Irwin and Geoghegan (2001) categorize models of land use change as being either non-spatially explicit or spatially explicit. Non-spatially explicit economic models of land use change attempt to estimate where land use change is likely to occur based on the assumption of a homogeneous landscape (von Thünnen 1966). The available "resolution" of these land use change models is considered ineffective for identifying variation at the field or pixel level (Irwin and Geoghegan 2001). Spatially explicit economic models of land use change are characterized by the application of economic value as determined by a number of attributes that are unique to each pixel in the study area (Irwin and Geoghegan 2001).

### Study Objectives

The purpose of this study is to create a tool, integrating GIS and IMPLAN that will aid the quantification of spatially-dependent economic and environmental impacts. Specific objectives of this study are; 1) to apply the new tool to compare the current allocation of land to corn, soybeans, hay, and forest in St. Clair County, Illinois with an income-maximizing land allocation scenario; and 2) examine the regional economic impacts of shifting to the income-maximizing scenario.

## Study Area

St. Clair County is located in southwestern Illinois along the Mississippi River (fig. 1). The U.S. Census Bureau (2003) estimates St. Clair County's 2002 population at 2.58 hundred thousand with its largest population centers in East St. Louis and the county seat, Belleville.

St. Clair County possesses a variety of land uses from urban to wetland. Productive soils and close proximity to major shipping ports in St. Louis, MO and the Mississippi River have also allowed St. Clair County to become a chief contributor to the Illinois agricultural sector. St. Clair County contains over 245 thousand acres (57 percent of the county) allocated to the production of various agricultural goods, as well as over 56 thousand acres (13 percent) of forested and forested wetlands (USDA 2002). Soybeans and corn have been the main agricultural products with 92 thousand acres of soybeans and 72 thousand acres of corn being produced in 2001 (USDA 2002). The county is also home to Illinois' largest contiguous tract of forest maintained along the Kaskaskia River.

## Methodology

### Spatial Database Development

Spatial data were collected in this study to examine the current land use in St. Clair County and to evaluate the economic returns that would be expected from the current land uses (i.e., corn, soybeans, hay, and forest production). Geospatial analysis was conducted primarily in raster format utilizing ArcGIS 8.x (ESRI 2002).

The current allocation for each land use is derived from the USDA's cropland data layer (USDA 2002). From the cropland data layer, all areas with the value of 1, 3, 5, and 64 were identified as corn, hay, soybeans, and forest production respectively. These areas were individually classified and identified as the current land use allocation for this study. Determining the income maximizing land use allocation required the creation of production, gross income, and net income layers for each land use. The creation of each of these layers is described below.

Production levels for the three traditional agricultural crops (corn, soybeans, and hay) were taken directly from the soil survey geographic database (SSURGO) produced by the USDA (1999). This digital soil database identifies production levels for many agricultural crops at the pixel level for all of St. Clair County. According to the SSURGO data, the range of corn production in St. Clair County is between 57 and 163 bushels per acre (bpa) with the mean production at 102.9 bpa. Soybean production ranges between 20 and 54 bpa with a mean of 34.8 bpa. Hay production ranges between two and six tons per acre with a mean of 3.3 tons per acre. Forest production ranges between 2.9 thousand and 9.8 thousand with a mean of 3.8 thousand board feet fiber per acre per year.

Pixel level forest production levels were determined by the following procedure. Forest productivity in St. Clair County was determined by soil class using soil surveys provided by the USDA (1978) Natural Resource Conservation Service for St. Clair and neighboring Illinois counties (Washington, Clinton, Randolph, Monroe and Madison). The surveys list site index (SI) for soil types containing forest vegetation at the time of the survey. Additionally, site index data presented by Woolery, Olson, Dawson, and Bollero (2002) were also used where soil types in the study area matched soil types used in the Woolery study.

Tree species used to estimate site index varied greatly among the soil series. To find the best estimate an interspecies site index relationship was developed between species listed. This relationship was developed by computing a regression equation for two species occurring on the same soil class (Avery and Burkhart 2002). Site index values were recorded in eastern white oak (*Quercus alba)* equivalents. Where a site index score was only available for species other than white oak, a regression equation was used to correlate the appropriate tree species to white oak site index. Where site index measurements were not present and were not available, the State Soil Geographic (STATSGO) database was utilized (USDA 1994).

Along with site index information, USDA soil surveys include a cubic meters per hectare estimate of fiber production. Correlations were drawn based on the relationship stated by the USDA between site index and fiber production. The correlation equation was then used in Spatial Analyst to convert county-wide site index values to county-wide fiber production per acre values.

A gross income layer was created for each land use. Gross income was calculated in a GIS by multiplying unit production level of each pixel times the per unit price of each commodity. Per unit prices were taken from the Illinois Agriculture Statistics Service (IASS 2003) 2002 reports on 2001

**Table 1.—Commodity price, consumer price index (CPI) conversion factor, and 1997 dollar equivalents.**

| Commodity | Unit of Measure | 2001 Price Per Unit | CPI Conversion Factor | 1997 Dollar Equivalents |
|---|---|---|---|---|
| Corn | Bushels | $2.05 | 0.906 | $2.26 |
| Soybeans | Bushels | $4.50 | 0.906 | $4.97 |
| Hay | Tons | $88.00 | 0.906 | $97.13 |
| Forest (uplands) | Mbf | $180.00 | 0.906 | $198.68 |
| Forest (bottoms) | Mbf | $101.00 | 0.906 | $110.38 |

prices. 2001 prices were used to match available land use data and then deflated to reflect 1997 prices to run with the available IMPLAN model. Prices used in the analysis appear in Table 1.

Net income or return to farm layers, were calculated in a GIS by subtracting from the gross income layer, all expenses incurred with producing the respective land use. To measure incurred expenses, an enterprise budget was constructed for each land use. Corn, soybean, and hay budgets were created by the University of Illinois extension office (UIUC Farmlab 1999) for Illinois agriculture, and were then modified by researchers at Southern Illinois University to more accurately represent expenses for the southern Illinois region (see Peterson 2003). Forest budgets were constructed based on information obtained from the Illinois Department of Natural Resources (IDNR) district forester for St. Clair County. The IDNR provided estimates of inputs necessary to establish and manage a one-acre forest stand for a fifty-year rotation (Brown 2003).

### Economic Analysis of St. Clair County

Impact Analysis for Planning (IMPLAN) is used to conduct an economic analysis and comparison of St. Clair County under the current and income-maximizing land use allocation. Total input, total output, total value added, and total employment were measured to compare economic impacts. Total input values were derived based on land use allocation, land use unit production, and price per unit. This value was then input in IMPLAN, which calculates output, value added, and employment for each land use.

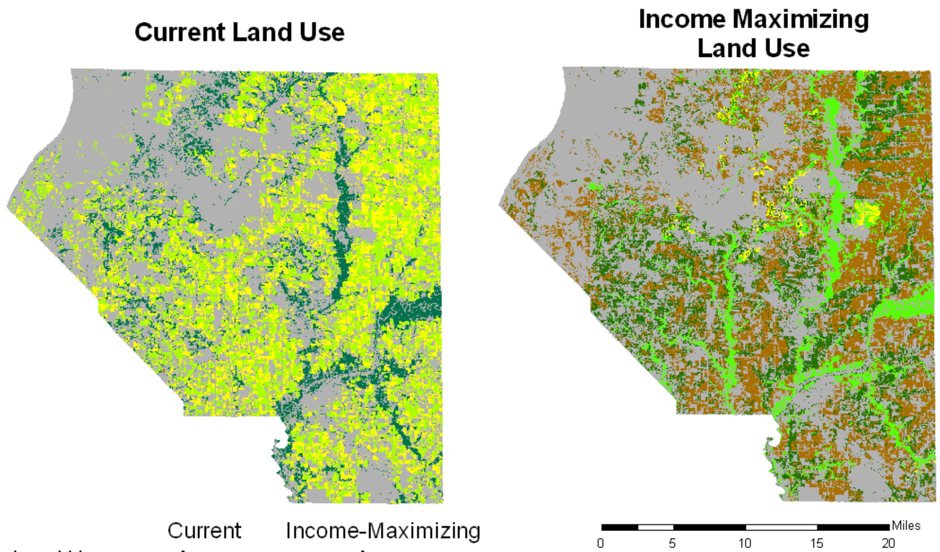
A national IMPLAN model was used in this analysis to simulate a closed economic system within St. Clair County. Regional Purchase Coefficients (RPC) for each sector in IMPLAN identify the percentage of purchases that are made within the region of analysis. RPCs within the primary sectors of this analysis for the national model are 0.90 or greater.

## Results and Discussion

### GIS-Based Analysis

Graphical results showing a comparison between the current land use allocation and the income-maximizing allocation scenario are provided in Figure 2. GIS analysis of land use in St. Clair County reveals a large difference between current and income maximizing land use allocations. Currently, there are about 8.2 million bushels of corn and 3.4 million bushels of soybeans produced on a combined 1.64 hundred thousand acres, or 38 percent of the 4.30 hundred thousand acre county. 1.99 thousand tons of hay are currently produced on 925 acres. Annually, over 164 million board feet of fiber are produced on 42.4 thousand acres within St. Clair County.

The income-maximizing solution yields a reduction in row crops (corn and soybeans) and an increase in both hay and forest production. Corn production would be severely reduced to approximately four thousand acres, or a total of just under 63 thousand bushels. Reductions in soybean production are not as severe, however only 36 thousand acres would be allocated for the production of nearly 1.36 million bushels. A change toward the income maximizing land use would stimulate the greatest increase in hay production of 460 thousand tons on over 100 thousand acres. Forest production would also increase to 260 million board feet fiber per year on 62 thousand acres.




| Land Use | Current Acres | Income-Maximizing Acres |
|---|---|---|
| Other | 222,704 | 222,704 |
| Corn | 71,961 | 3,988 |
| Soybeans | 91,801 | 36,088 |
| Hay | 925 | 105,039 |
| Forest | 42,402 | 61,975 |
| Total | 429,793 | 429,793 |


Figure 2.—Current versus income maximizing land use in St. Clair County.

### Economic Impact Analysis of Current versus Income-Maximizing Land Use in St. Clair County

Economic impact analysis of the income-maximizing land use scenario indicates that, in the four categories of economic analysis (total input, total output, total value added, and total employment) great opportunities exist for increased income generation (table 2). Total input for corn and soybeans would be reduced by approximately $27 million under the income maximizing allocation, however a $44 million hay increase and a $26 million forestry increase create a $43.7 million net expansion in production.

IMPLAN results indicate that total output, or value of products created from the land use inputs, would expand by over $32 million under the income-maximizing land use allocation. Total value added throughout the economy would also likely expand by more that $14 million. Finally, under a shift to the income-maximizing land use allocation, St. Clair County would likely benefit in the creation of 724 jobs.

## Conclusions

Land use allocation has a large impact on the economic and environmental health of a region. While most land use decisions are based primarily on economic returns, failure to maximize returns creates two economic dilemmas: 1) a reduction in income from primary production and value-added processing within the county, and 2) a decrease in economic exchanges among businesses within the county. All too often, landowners underestimate or overlook the productive potential (and income potential) of forest lands. In fact, results of this analysis suggest that forestland cover is substantially less than optimal in the St. Clair County study area.

While economic return-to-landowner values were central to the results in this analysis, other land use development strategies can easily be employed in the model. Values can be altered based a potential increase in demand for an agricultural crop, a need to maximize job creation, water quality objectives, aesthetic considerations, etc. Results in this analysis suggest that St. Clair County agriculture is better

**Table 2.—Value and benefits of current and income maximizing allocation of land use.**

| Economic Measure | Land Use | Current | Maximizing | Net Benefit from switching to income maximizing |
|---|---|---|---|---|
| **Input** | Corn | $18,363,801.00 | $1,423,687.00 | -$16,940,114.00 |
| | Soybeans | $17,020,227.00 | $6,751,784.00 | -$10,268,443.00 |
| | Hay | $191,274.00 | $44,669,115.00 | $44,477,841.00 |
| | Forest | $24,914,807.00 | $51,394,885.00 | $26,480,078.00 |
| | **Total** | **$60,520,109.00** | **$104,239,471.00** | **$43,719,362.00** |
| **Output** | Corn | $43,924,849.00 | $3,793,748.00 | -$40,131,101.00 |
| | Soybeans | $44,468,663.00 | $17,640,352.00 | -$26,828,311.00 |
| | Hay | $491,842.00 | $30,005,964.00 | $29,514,122.00 |
| | Forest | $65,608,777.00 | $135,339,418.00 | $69,730,641.00 |
| | **Total** | **$154,494,131.00** | **$186,779,482.00** | **$32,285,351.00** |
| **Value Added** | Corn | $22,523,107.00 | $1,945,300.00 | -$20,577,807.00 |
| | Soybeans | $24,162,291.00 | $9,585,061.00 | -$14,577,230.00 |
| | Hay | $260,408.00 | $15,886,767.00 | $15,626,359.00 |
| | Forest | $32,256,601.00 | $66,539,719.00 | $34,283,118.00 |
| | **Total** | **$79,202,407.00** | **$93,956,847.00** | **$14,754,440.00** |
| **Employment** | Corn | 473.0 | 40.9 | -432.1 |
| | Soybeans | 546.5 | 216.8 | -329.7 |
| | Hay | 11.2 | 684.1 | 672.9 |
| | Forest | 765.7 | 1,579.5 | 813.8 |
| | **Total** | **1,796.4** | **2,521.3** | **724.9** |

suited for the production of hay and rangeland in opposition to row cropping. Forestry is already well established within the county, and forest industry expansion, in light of modern water quality concerns, would likely provide economic and environmental benefits.

A major contribution of the methodology developed in this paper lies in the functionality of the model for creating spatially explicit input data for use in IMPLAN, a proven I-O economic analysis tool. This new generation of spatially explicit economic impact analysis will allow field and pixel-level analysis, resulting in the ability to simultaneously examine economic and environmental impact at a level of resolution previously unavailable.

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