UTILIZING GIS TO ASSESS THE IMPACT OF URBANIZATION ON TIMBERLAND AVAI LABILITY IN SOUTHEASTERN LOUISIANA

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ABSTRACT

This study illustrates how remotely-sensed data and GIS can be utilized to allow planners to evaluate the relationship between land use, environmental protection policies, and resource availability. The case study examines St. Tammany Parish in Louisiana which has experienced tremendous population growth and land use change in the past two decades. To date, work has been completed on developing most of the coverages. The preliminary results indicate that applying remotely-sensed data on land use change and timber production potential allows planners to identify potential areas to maintain for timber production and other resource values. .

INTRODUCTION

Projecting the future availability of timber in the United States has been problematic historically, primarily due to fluctuating markets for timber, changing landowner objectives, and a number of data and analytical problems. During the past two decades, however, social and institutional factors have emerged as important determinants of timber availability nationwide. The increased development and urbanization of areas that traditionally have been important sources of raw materials is one of the more obvious social factors. The impact has involved not only the obvious effects of a reduced forest land base, but it also has resulted in increased public concern regarding management activities and often new regulations limiting timber harvesting. Most often, these new regulations are not federal policies. Greene and Siegel (1994) noted that of the 644 forest regulatory laws in the United States in 1992, more than 80 percent were at the local level. Moreover, they conclude that by 2040, these regulations could result in as much as a 14 percent reduction in the annual supply of softwood stumpage from the region.

Currently, however, policy makers, regulators, and landowners have little information on how changes in land use could affect resource availability from southern forests. A Geographical

Information System (GIS) allows for a graphical depiction of the spatial and temporal dimensions of the biological, economic, legal, and social attributes related to land use change and resource availability. A GIS would facilitate an assessment of the relationships between land use, urbanization, and the provisions of a myriad of goods and services from southern forests. Moreover, it would allow policy makers and analysts a means of evaluating the effects of future land use scenarios on forest distribution.

The primary purpose of the study was to examine the relationships between land use, urbanization, and timber availability in St. Tammany Parish. The specific objectives addressed by the study were to:

1. Develop a Geographic Information System (GIS) that incorporates data on timber stand conditions, land use, and population density.

2. Project changes in timberland availability under various scenarios regarding future land use patterns and population densities.

METHODS

Accomplishing the objectives required initially obtaining the data and developing a GIS for the parish. The GIS then was utilized to model land use change and the factors influencing change. The methods employed in developing the GIS and the land use change models are described below.

Land cover data were obtained from two sources: Stennis Space Center/Environmental Enterprises, USA, Inc.; and the United States Geological Survey (USGS) Southern Science Center. Land cover classification developed at Stennis was the result of a commercial space technology project by NASA and the private firm Environmental Enterprises, USA, Inc. of Slidell, Louisiana. Stennis used the cluster modules of Erdas 7.2 with 1981 multispectral satellite (MSS) image to categorize land cover into one of 9 groups: coniferous forests, deciduous forests, mixed coniferous/deciduous forests, pasture/agriculture/grasses, cypress/wet deciduous scrub, high density marsh, low density marsh, water, and urban/inert. Hydric soil groups digitized from the general soils maps of St. Tammany Parish aided in the determination of wetland (cypress/wet deciduous forest, high density marsh, low density marsh) and riparian (deciduous forests) cover types. The resulting land cover image created had 80 meter resolution. Land cover classifications were field verified by Stennis personnel.

The USGS Southern Science Center developed land cover for St. Tammany Parish as part of the National Geographic Assessment Program (GAP). 1993 Thematic Mapper (TM) satellite scenes with 30 meter resolution were categorized into 21 groups by the USGS. The USGS also incorporated information from the 1989 National Wetlands Inventory to aid with land cover classification. Hydric soils were not used. ESARL personnel performed extensive field verification of the land cover at more than 180 randomly selected locations throughout St. Tammany Parish.

Both the Stennis Space Center and the USGS images were imported into Grid (ArcInfo's raster module). The USGS image was filtered to remove small areas of land cover consisting of only a few pixels (specks) resampled (with the specks removed) to provide a land cover grid with 80 meter resolution. The resulting USGS grid was then spatially comparable to the Stennis Space Center grid. Next, the land cover of both grids was reclassified into 7 groups: pine forests, deciduous forests, mixed forests, wetlands, agriculture/grasses/crops, urban/inert/barren, and water.

Most of the generalizations from the USGS categories to this new classification scheme are obvious. However, the field verification of the USGS land cover classification resulted in several needed changes. Our field verification indicated that both young pine plantations and thinned pine forests appear as a mixed land cover type on the satellite images. In the reclassification of the USGS land cover, the mixed as well as evergreen shrub/scrub cover types were included in the pine forest category. Certain forestry practices (windrowing, bedding, and burning) and grasses within pine plantations will also produce a land cover reflectance that is indistinguishable from that of agriculture/grasses/crops. To remedy this problem, areas that were classified as an agriculture/grasses/crops cover type in 198 1, but were classified as evergreen, or mixed forests in 1993 were identified and reclassified as pine forests. We also identified areas that were classified as coniferous forests in 1981, but were classified as agriculture/grasses/crops in 1993. The field verification revealed that most of these lands were industrial forests that had been replanted with pine. No conversions from forests to agricultural lands were found by field verification. The 1982 through 1992 Census of Agriculture (LEAP 1998) indicates that the number and size of farms, and acreage of farm lands have greatly decreased in St. Tammany Parish since 1982.

With both land cover grids now spatially compatible and with similar land cover, a change detection analysis was performed. We identified areas that were pine or mixed forests in 198 1 and remained pine or mixed forests in 1993, and areas that were pine or mixed forests in 198 1 but were urban/inert/barren in 1993. The hydric soils mask used by Stennis to determine wetland areas was inherently applied in the change detection analysis (i.e. no pine forest was located on hydric soils).

Two covers resulted from the change detection analysis: a point cover containing the dependent variable (forested parcels that were developed), and a polygon cover containing the area of contiguous land use. The point cover contained all the centroids of the grid cells that either remained pine or mixed forests from 1981 until 1993, or that changed from pine or mixed forests to urban/inert/barren during that time. These points were used to define the dependent variable (1 if a point changed to urban occurred, 0 if it remained forested). Approximately 11,500 points were randomly selected for use in the logistical regression analysis. A polygon cover was created from the grid that contained our change detection results. This polygon cover contained the contiguous area of land cover. When intersected with changed points, we found the contiguous area of land cover associated with our dependent variable.

Demographic coverages were developed from U.S. Bureau of the Census (1993) data. Variables were developed for population and density, income, education, and type and location of employment. We intersected the demographic coverage with the point coverage of randomly selected locations. This yielded a point coverage with a unique identifier for each randomly selected point containing the relevant demographic information for that point.

The primary and secondary roads coverage contains the high speed highways (interstates, US routes, and some state routes) in St. Tammany Parish. The coverage was derived from the USGS I: 100000 digital line graph files of primary and secondary roads for Louisiana (LAGIC 1998, USGS 1989). This coverage was used to develop variables representing the Euclidean distance to the nearest major road.

Preserved lands include wildlife refuges and management areas, recreational areas, public and private conservation areas (such as Nature Conservancy lands) and typically are unavailable for development. We obtained the coverage identifying preserved lands from the Nature Conservancy (Swan 1997).

Many St. Tammany Parish residents commute to New Orleans to work. Lake Pontchartrain separates the parish from New Orleans and must be crossed by one of three bridges by St. Tammany commuters. Two bridges (U.S. 11 and Interstate 10) connect Slide11 to New Orleans (these are collectively referred to as the twin spans) and the third connects Mandeville to New Orleans (Causeway). The portions of the parish nearest these access points grew rapidly between 1981 and 1993, suggesting that distance to these locations may be an important factor in urbanization. We marked the entrance of the twin spans and the causeway bridge to form a coverage. A database that recorded the Euclidean distance from every location in "changed points" to the bridges to New Orleans was developed for the analysis.

The parish soil series from the 1990 Soil Survey of St. Tammany Parish were used to develop the soils coverage. The mylars (approximately 75) of the series were obtained from the State Soil Scientist and scanned on a large format scanner. The photobases used to create the survey (obtained directly from the published soil survey) were scanned and imported into Grid. We registered and rectified the photobases using USGS 7.5 minute Digital Raster Graphic (DRG) maps of the parish, transforming them into the UTM coordinate system. The mean error between the DRGs and photobases was less than 7 meters. The scanned mylars were registered and rectified using the corrected photobases, and have less than 5 meters of associated error. Overall, the error for the 75 soils series maps created by this process was within 15 meters of the DRGs. Figure 1 illustrates the process.

The soil series were identified and a common boundary between adjacent, overlapping covers was created. We removed the overlap from adjacent covers, then joined the 75 covers into 1 coverage containing the soil series for the entire parish. The boundaries between adjacent soil maps (now all contained in 1 cover for the parish) were verified, and adjustments were made so that soils series with identical identifiers met at a common point along the boundary. We removed the common boundary and verified that the soil series were properly labeled. We

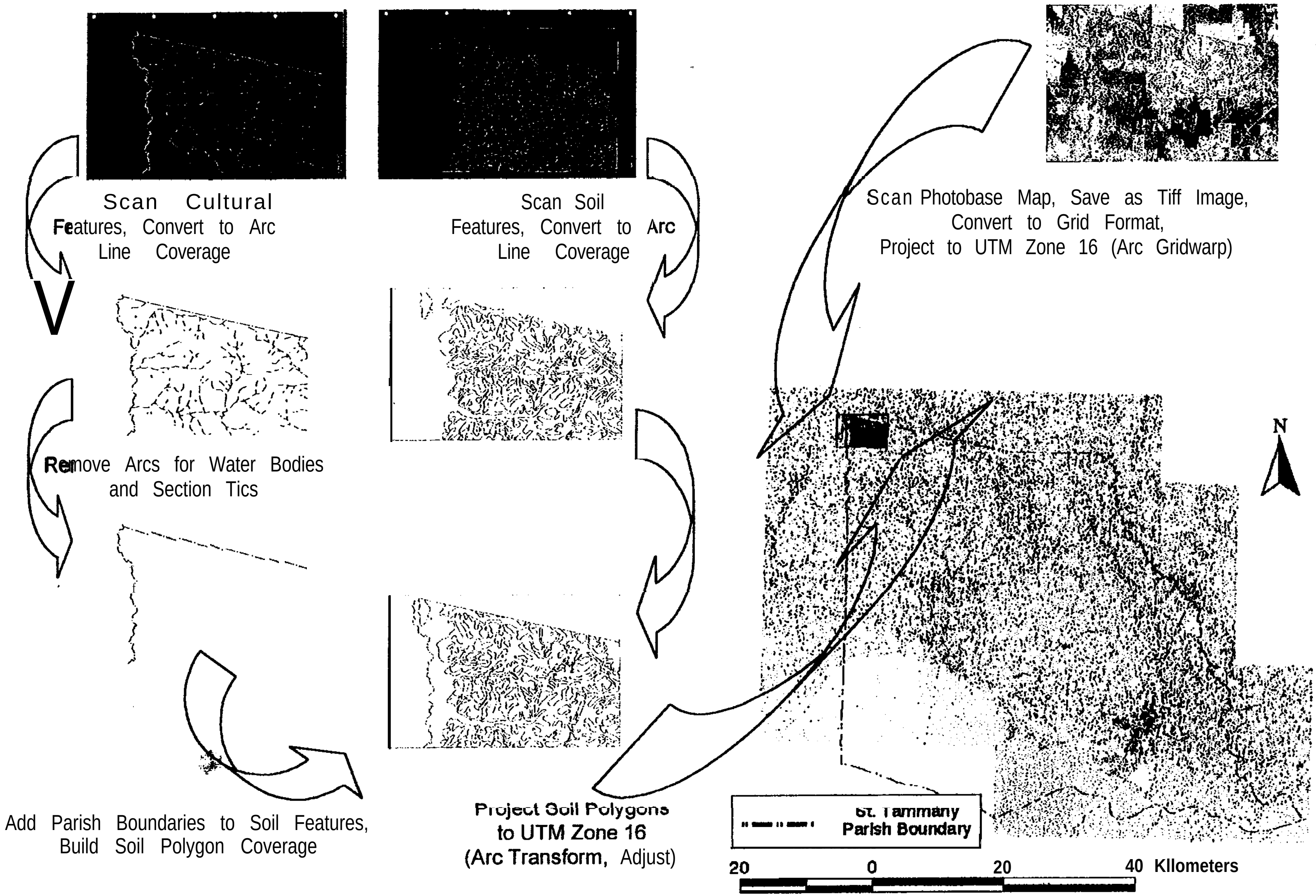

Figure 1. Schematic diagram of the steps used in creating a digitized soil map projected to UTM Zone 16.

clipped this with a 124000 scale coverage of the parish boundary, created from the USGS DRGs, and verified that the soils cover did not fall short of this boundary.

The soils coverage (containing all the series for the parish with no internal boundaries) was intersected with the "changed points" to identify the soil series, and ultimately the site index and building limitations at those points. For this analysis, site index was obtained from the parish soil survey and refers to the height a loblolly pine tree located on a specific soil type can obtain in 50 years. The parish soil survey categorizes soil building limitations as slight, moderate, or severe, primarily due to wetness.

Logistical Regression Analysis

We used logistical regression to estimate the probability that a particular parcel of pine. or mixed forests would be developed. The dependent variable was binary, with zero (0) indicating that the parcel of land was pine or mixed forest in 198 1, and remained pine or mixed forest in 1993. A one (1) indicates that the parcel of land was pine or mixed forest in 1981 but was developed (urban/inert/barren) in 1993. Based on prior research (Munn and Evans 1998. Alig et al. 1988, Alig 1986), several independent variables were evaluated, including population density (POPDEN), per capita income (PERCAP), percent of population with at least some college education (COLLEGE), distance to access points to New Orleans (TWIN, CAUSE), and site index (SI). In addition to these independent variables, we included the distance to a primary or secondary road (NROAD), percentage of workers in agriculture and forestry (PAGFOR), percentage of workers that work in the state but out of the parish (PINCOS), the mean house value (HVAL), and building limitations (BLDLIM). Munn and Evans (1988) suggested the size of the surrounding forest significantly influenced conversions to urban land use. Because our data were derived from satellite images and not USDA Forest Service Forest Inventory Analysis data, this variable was modified to be the area of contiguous land cover (forested or urban). Table 1 lists the variables used in the logistical regression analysis and their associated geographic data set and coverage.

Univariate and correlation analysis were conducted to assess the relationships between the dependent variables and the explanatory variables, and among the explanatory variables. The results of this analysis indicated that the demographic variables selected for the analysis (POPDEN, HVAL, PERCAP, COLLEGE PAGFOR, AND PINCOUTS) were highly correlated and significantly influenced the probability a parcel would be developed. POPDEN provided the greatest explanatory power of the demographic variables and thus was selected for use in the multivariate regression model.

Distance to the nearest primary or secondary road (DNROAD), the twin spans (TWIN), the causeway (CAUSE), and the area of contiguous land use (AREA) significantly influenced the probability of development, but were correlated with one another. The univariate analysis indicated that parameter estimates for the variables TWIN and CAUSE are equivalent (95 percent confidence interval of the estimated parameters for the variables overlap). To simplify the model and reduce the effect of multicollinearity, we generated a single variable ACCESS,

Table 1. Logistical regression analysis variables and the geographic data sets and covers from which they are derived.

Variable	Description	Geographic Data Set (Source)	Cover
CHANGE	Parcel remains forested = 0 Parcel developed = 1	Land Use (Stennis Space Center, USGS SSC)	changed points
AREA	Area of contiguous land cover (Ha)	Land Use (Stennis Space Center, USGS SSC)	changed points
PRESERV	Lands off limits to development (wildlife management areas, parks, etc.) (binary)	Preserved Lands (Nature Conservancy)	preserved
DNROAD	Euclidean distance from sample point to nearest class 1 or 2 road (km)	Primary and Secondary Roads (USGS DLG)	demographic
TWIN	Distance to Slide11 access points to New Orleans (km)	Access to New Orleans (USGS DLG)	access
CAUSE	Distance to Mandeville access point to New Orleans (km)	Access to New 'Orleans (USGS DLG)	access
ACCESS	Distance to closest access point to New Orleans (generated from twin and cause)		
POPDEN	Population density by block (persons/square km)	Demographic Data Set - TIGER 92 line files & STF 1 A,(US Census Bureau)	demographic
HVAL	Mean house value in 1989 dollars (by block)	Demographic Data Set - TIGER 92 line files & STF 1 A,(US Census Bureau)	demographic
PERCAP	Median percapita income by block group	Demographic Data Set (Wessex First Street)	Demographic
COLLEGE	Number of people that have at least some college education	Demographic Data Set (Wessex First Street)	Demographic
PAGFOR	Percent of population working in agriculture and forestry by block group	Demographic Data Set (Wessex First Street)	Demographic
PINCOUTS	Percent of population who work out of the parish but in the state by block group	Demographic Data Set (Wessex First Street)	Demographic
BLDLIM	Building limitations (binary - slight or moderate = 0, severe = 1)	Soils Data Set (Soil Survey of St. Tammany Parish, LA)	Building Limits
SI	Loblolly pine site index (base age 50)	Soils Data Set (Soil Survey of St. Tammany Parish, LA)	Site Index

defined as the distance from a parcel to the closest access point to New Orleans. The variables DNROAD, ACCESS, and AREA were included in the multivariate analysis.

Building site limitations (BLDLIM) proved to be insignificant in the univariate analysis, and was omitted from the multivariate analysis. The univariate analysis indicated that site index (SI) was positively related to the probability that forested parcels would be developed. This relationship and the fact that building limitations and site index were significantly correlated suggested that the value of the site index variable did not reflect the importance of a parcel of land for timber production. Site index was more likely a more exact measure of building site suitability. The four major population centers in the parish are constructed on soil series that have severe building limitations. A higher loblolly pine site index in these areas more than likely indicates that a parcel of forest land is less wet than a parcel with a lower site index, thus making it more desirable for development. Due to the uncertainty involved with interpretation, site index was not included in the multivariate analysis.

Equation 1 is the logistical model used for the analysis (Hosmer and Lemeshow 1989):

$$\pi(x_i) = \frac{e^{\beta_0 + \beta_1 x1_i + \beta_2 x2_i + \beta_n xn_i}}{1 + e^{\beta_0 + \beta_1 x1_i + \beta_2 x2_i + \beta_n xn_i}} \Longrightarrow \pi(x_i) = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x1_i + \beta_2 x2_i + \beta_n xn_i)}} \qquad (1)$$

where for each parcel "i":

$\pi(x_i)$ = probability that a 0.64 Ha parcel will change from pine forest to urban land,
β_0 = maximum likelihood estimates of the intercept,
β_n = maximum likelihood estimates of the influence of independent variables x 1 through xn, and

Equation 2, the logit equation, is the log transformation of Equation 1.

$$\ln[\pi(x_i)] = \beta_0 + \beta_1 x1_i + \beta_2 x2_i + \beta_n xn_i + \varepsilon_i \qquad (2)$$

where for each parcel "i":

$\ln[\pi(x_i)]$ = log probability that a 0.64 Ha parcel (80 meter X 80 meter pixel from the satellite image) will change from pine forest to urban land,
PO = logit estimates of the intercept, and
β_n = logit estimates of the influence of independent variables xl through xn
ε_i = random error

We developed two logit models: one with continuous explanatory variables (Equation 3) and the other with the continuous explanatory variables collapsed into categories (Equation 4):

$$\text{CHANGE} = f(\text{POPDEN}_i, \text{DNROAD}_i, \text{ACCESS}_i, \text{AREA}_i) \quad (3)$$

where for each parcel "i":

CHANGE_i = 1 if parcel "i" changed from pine forest to urban, 0 if it remained pine forest
POPDEN_i = population density of the block containing parcel "i" rounded to the nearest 100 persons per km^2
DNROAD_i = the distance (km) to the nearest primary or secondary road
ACCESS_i = the distance from the Twin Spans in Slide11 or the Causeway in Mandeville to parcel "i" rounded to the nearest 10 km
AREA_i = the area (Ha) of land cover for parcel "i" (pine forest area if change = 0, urban land area if'change = 1)

and

$$\text{CHANGE}_i = f(\text{PD1}_i, \text{PD2}_i, \text{PD3}_i, \text{PD4}_i, \text{PD5}_i, \text{PD6}_i, \text{NR1}_i, \text{NR2}_i, \text{NR3}_i, \text{DA1}_i, \text{DA2}_i, \text{DA3}_i, \text{A1}_i, \text{A2}_i, \text{A3}_I, \text{A4}_i) \quad (4)$$

where for each parcel "i":

CHANGE_i = 1 if parcel "i" changed from pine forest to urban, 0 if it remained pine forest
PD1_i = (omitted comparative variable) 1 if population density is 0 persons per square km (mode), otherwise 0
PD2_i = 1 if population density in the census block is greater than 0 but less than 100 persons per km^2, otherwise 0
PD3_i = 1 if population density in the census block is greater than 100 but less than or equal to 200 persons per km^2, otherwise 0
PD4_i = 1 if population density in the census block in the census block is greater than 200 but less than or equal to 300 persons per km^2, otherwise 0
PD5_i = 1 if population density in the census block is greater than 300 but less than or equal to 500 persons per km^2, otherwise 0
PD6_i = 1 if population density in the census block is greater than 500, otherwise 0 (persons per km^2)
NR1_i = 1 if the distance from parcel "i" to the nearest primary or secondary road is less than 1 km, otherwise 0
NR2_i = 1 if the distance from parcel "i" to the nearest primary or secondary road is greater than or equal to 1 and less than 2 km, otherwise 0
NR3_i = (omitted comparative variable) 1 if the distance from parcel "i" to the nearest primary or secondary road is less than 1 km, otherwise 0
DA1_i = 1 if the distance from parcel "i" to the nearest access to New Orleans is less than 10 km, otherwise 0

Table 2. Estimated maximum likelihood parameters for Equation 3 * : continuous independent variables

Variable	Parameter Estimate	Standard Error	Wald	Pr >
INTERCEPT	-0.6823	0.1148	85.6934	0.0001
POPDEN	0.00652	0.000278	571.9731	0.0001
DNROAD	-0.2025	0.0437	24.3961	0.0001
ACCESS	-0.1236	0.00752	216.2282	0.0001
AREA	-0.00028	0.000034	74.51	0.0001
Model Goodness of Fit (n: 1079=0 and 10,526 = 1)				
Test		**Prob >**		
-2 Log L	3218	.0001		
Score	4116	.0001		

Table 3. Contingency tables for 4 probability thresholds for Equation 3[a]: continuous independent variables

Observed Number of Parcels		Predicted Number of Parcels		
	Probability level = 25%	Developed	Remaining Forested	Total
	Developed	640 (59)[b]	439 (4)[c]	1079
	Remaining Forested	439 (41)[d]	10,087(96)[e]	10,526
	Total	1079	10,526	11,605
	Probability level = 50%			
	Developed	438 (41)	641 (6)	1079
	Remaining Forested	148 (25)	10,378 (99)	10,526
	Total	586	11,019	11,605
	Probability level = 75%			
	Developed	318 (30)	761 (7)	1079
	Remaining Forested	46 (13)	10,480 (100)[f]	10,526
	Total	364	11,241	11,605
	Probability level = 90%			
	Developed	219 (20)	860 (8)	1079
	Remaining Forested	22 (9)	10,504 (100)[f]	10,526
	Total	241	11,364	11,605

Percent of observations predicted correctly	
Probability level = 25%	92.4
Probability level = 50%	93.2
Probability level = 75%	92.0
Probability level = 90%	92.4

a. probability of development = *f*(popden, dnroad, access, area)
b. sensitivity – ratio of parcels predicted to be developed that were observed to have been developed
c. false negatives – ratio of parcels predicted not to be developed that were observed to have been developed
d. false positives ratio of parcels predicted to be developed that were observed to have not been developed
e. specificity – ratio of parcels predicted not to be developed that were observed not to have been developed
f. value rounded to the nearest 1 percent

through the manipulation of the probability thresholds to meet specific certainty criteria. Figure 2 depicts the observed and predicted development patterns for five thresholds.

By categorizing the variables, meaningful odds ratios are obtained that provide insight into which independent variables most greatly influence the probability that a parcel of forested land will be developed. Table 4 indicates that the distance to the bridges connecting St. Tammany Parish to New Orleans (DA1-3) was the most important factor influencing the probability that a parcel of forested land will be developed. A parcel of forested land within 10 km of either access point to New Orleans was 240 times more likely to be developed than a parcel of forested land more than 30 km away. A parcel of forested land between 10 and 20 km from the access points to New Orleans was 100 times more likely to be developed than one more than 30 km away.

Population density (PD2-6) was the second most important factor influencing the probability that a parcel of forested land will be developed. A parcel of forested land in a block with more than 500 people per square kilometer was 126 times more likely to be developed than a parcel with a population density of 0 people per square kilometer. A significant correlation existed between population density and distance to the nearest access point to New Orleans and a linear regression analysis indicated that population density was significantly influenced by distance to the access points to New Orleans. However, the distance from the access points alone explained little of the variation associated with population density (approximately 27%), suggesting that other factors (i.e. taxes, amenities, zoning, etc.) greatly influence population density. Multicollinearity likely exist in the logit models, but the mean maximum likelihood parameter estimates are unbiased. Probabilities of development predicted using the mean parameter estimates should not be biased. Table 5 is the contingency table associated with the categorized explanatory variables. Categorizing the independent variables reduced the percentage of parcels correctly predicted to be developed at the 90 percent threshold, as well as increased the number of false positives.

These preliminary results indicate that the modeling/GIS approach could be useful in not only explaining current land use changes trends, but also in predicting future land use scenarios based on projections of the independent variables. This will prove to be valuable to researchers as well as local government planners or land managers. In St. Tammany Parish, for example, the local government has recently adopted growth management zoning. The model developed as part of this study will allow planners to evaluate future growth patterns based on population projections and the limitations on growth due to zoning. More important to resource management, the results will highlight areas of primary concern to local forest industry in terms of future timberland availability and productivity.

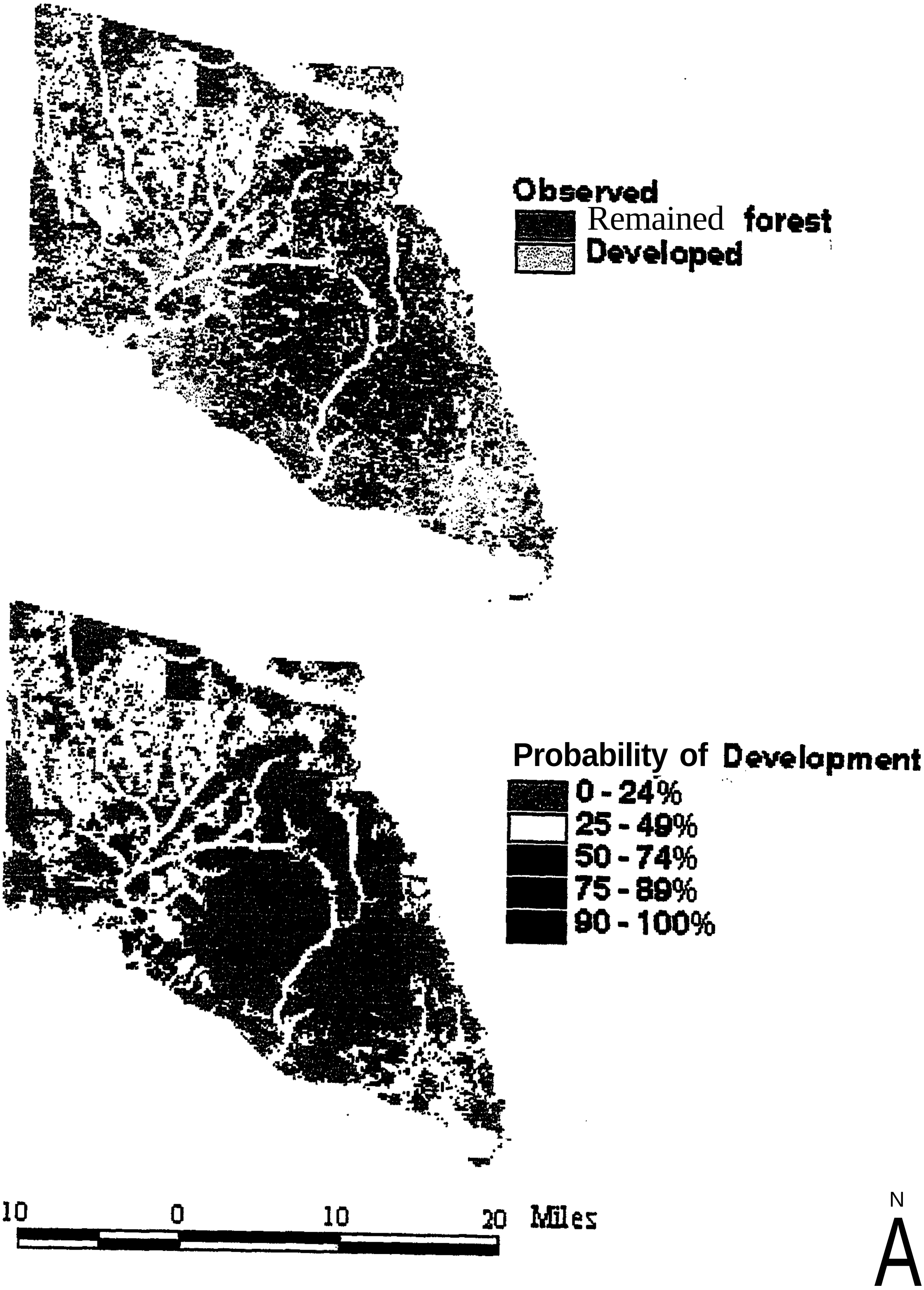

Figure 2. Observed and predicted development for pine and mixed forest parcels in St. Tammany Parish.

Table 4. Estimated maximum likelihood parameters for Equation 4*: categorized independent variables

Variable	Parameter Estimate	Standard Error	Wald	Pr >	Odds Ratio
INTERCEPT	-9.4654	1.0203	86.0566	0.0001	
PD2	0.82	0.181	20.5279	0.0001	2.271
PD3	2.1938	0.1913	131.5429	0.0001	8.969
PD4	3.2736	0.2181	225.3282	0.0001	26.407
PD5	3.5853	0.2187	268.7785	0.0001	36.064
PD6	4.8368	0.2261	457.6136	0.0001	126.071
NR1	0.476	0.1312	13.1635	0.0003	1.61
NR2	0.3423	0.1425	5.7733	0.0163	1.408
DA1	5.4807	1.0047	29.7551	0.0001	240.014
DA2	4.6049	1.004	21.0357	0.0001	99.972
DA3	2.9118	1.0195	8.1575	0.0043	18.39
AR1	1.5273	0.1519	101.148	0.0001	4.606
AR2	1.267	0.1288	96.7146	0.0001	3.55
AR3	0.7461	0.139	28.809	0.0001	2.109

Model Goodness of Fit (n: 1079 = 1 and 10,526 = 0)		
Test		Prob >
-2 Log L	3354	0.0001
Score	4894	0.0001

Table 5. Contingency tables for 4 probability thresholds for Equation 4[a]: categorized independent variables

Observed Number of Parcels	Predicted Number of Parcels: Developed	Predicted Number of Parcels: Remaining Forested	Total
Probability level = 25%			
Developed	741 (69)[b]	338 (3)[c]	1079
Remaining Forested	545(42)[d]	9981 (95)[e]	10,526
Total	1286	10,319	11,605
Probability level = 50%			
Developed	530(49)	549(5)	1079
Remaining Forested	226(30)	10,300(98)	10,526
Total	756	10,849	11,605
Probability level = 75%			
Developed	327(30)	752(7)	1079
Remaining Forested	74(19)	10,452(99)	10,526
Total	401	11,204	11,605
Probability level = 90%			
Developed	75(7)	1004(9)	1079
Remaining Forested	12(14)	10,514(100)	10,526
Total	87	11,518	11,605

Percent of observations predicted correctly	
Probability level = 25%	92.4
Probability level = 50%	93.3
Probability level = 75%	92.9
Probability level = 90%	91.2

LITERATURE CITED

Alig, R.J., F.C. White, and B.C. Murray. 1988. Economic factors influencing land use changes in the south-central United States, USDA Forest Service Research Paper SE-272, Southeastern Forest Experiment Station, Asheville, NC. 23 p.

Alig, R.J. 1986. Economic analysis of factors influencing forest acreage trends in the Southeast," Forest Science, Vol. 32, pp. 119- 134.

Greene, J.L. and W. C. Siegel. 1994. The status and impact of state and local regulation on private timber supply, USDA Forest Service General Technical Report RM-255, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO. 22 p.

LAGIC (Louisiana Geographic Information Center). 1998. Louisiana State University Department of Geography and Anthropology. Baton Rouge, Louisiana. http://atlas.lsu.edu/lagic/

LEAP (Louisiana Electronic Assistance Program). 1998. Center for Business and Economic Research (CBER), Northeast Louisiana University. Monroe, Louisiana. http://leap.nlu.edu/.

MUM, Ian A. and David L.Evans. 1998. The southern commercial timberland base: changes and projections. In: Proceedings, First International Conference on Geospatial Information in Agriculture and Forestry, ERIM International, Ann Arbor, MI. pp. 181-188.

Swan, Mark. 1997. The Nature Conservancy, Baton Rouge, LA. Personal communication. July.

Bureau of the Census. 1993. TIGER/Line Files ™ 1992. Machine-Readable Data Files. Washington, D.C.

U. S. Geological Survey. 1989. US GeoData, Digital Line Graphs from l:lOO,OOO-Scale Maps: Data Users Guide 2. Department of Interior, U.S. Geological Survey, National Mapping Division. Reston, Virginia.

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