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Dynamics of Land Use Change in the Florida Panhandle Using GIS Optimization Models: A Framework to Determine the Impact of Climate Change on the Florida Panhandle

Jonathan Tuma, Scot Smith and Zoltan Szantoi

Geomatics Program, School of Forest Resources and Conservation,
University of Florida, P.O. Box 110565, Gainesville, Florida 32611-0565

Abstract: The western "panhandle" region of Florida experienced greater development in the years 2000-2010 than the previous 40 years and greater than nearly all other parts of the United States. One reason is the fact that much of the coastal land in the peninsula of Florida is already developed whereas much of the Panhandle is empty. Another reason is the fact that increasing temperatures and less severe winters in the Panhandle have made the region more attractive too people for habitation. Climate change is changing land use and land cover in the Panhandle in a number of ways with the most common shift being from managed forest and agricultural land to urban use. The consequences of this change have been increased pressure on the resources and exacerbated land use conflict. To address the challenges of future land use, a GIS optimization model was developed to determine the spatial and temporal status quo relationships between the drivers and resulting patterns of land uses due to climate change. Resulting models of land use preference and projected population allocation points to the direction of the limiting factor of climate change: saltwater intrusion and increasing water demand.

Key words: Land-use planning · Climate change · Conflict resolution · Land allocation · GIS optimization model

INTRODUCTION

Climate change is one of several pressures on land use encompassed under the broader term, global change. According to Vice Admiral Conrad C. Lautenbacher, Undersecretary of Commerce for Oceans and Atmosphere of the United States: "given the potential social and economic impacts of changing climate, there is a pressing need to increase knowledge of the mechanics of global, as well as regional, climate change impact and develop the ability to predict abrupt and gradual climate change events. Even gradual changes will affect distribution and how and where people live" [1]. As society moves away from land management on specific land use types and towards ecosystems, decision-making becomes highly complex and conflicts and disputes are inevitable.

Land use models are simplified reality achieved through reducing multi-faceted real world relations to ones that are easier to comprehend. Land use choices are so complex that resolution requires data from numerous sources and discussion from multiple viewpoints [2].

This study attempts to bridge the gap in knowledge and understanding between urban developmental land use and forest/agricultural land in a region located in the Florida Panhandle. A common planning and land management problem that involves multiple interests is the task of designating sites for specific uses [3]. This problem was addressed in this study by modeling land use status quo to determine conflicting land interest, assessing future land use availability based on population projection and allocation between existing forest land and intending urban development.

The focus of this research was to address the challenges of future land use, by using GIS models to determine the spatial and temporal status quo relationships between the drivers and resulting patterns of land uses due to climate change.

By conducting an assessment of land use conflict, this study aims to provide strategic framework for informed and intelligent decisions by using optimization model to address this future challenges of land use allocation. Optimization models are oriented towards

Corresponding Author: Jonathan Tuma, Geomatics Program, School of Forest Resources and Conservation, University of Florida, P.O. Box 110565, Gainesville, Florida 32611-0565, Tel: (352) 392-4990, Fax: (352) 392-4957.

producing solutions which optimize objectives narrowly defined by decision makers [4]. Multiple Criteria Analysis (MCA) is an optimization model which has been used before to address land use conflict [5, 6, 7 and 8]. In this study, Linear programming is used because it is more manageable and computationally faster than other optimization techniques.

The southeastern part of the United States is a rapidly growing region with population increasing by more than 30% between 1970 and 1990 [9]. The United States Global Change Research Program (USGCRP) concluded that this growth is projected to grow another 40% between 2000 and 2025 [10]. In addition, the number of farms in the southeast region decreased by 80% between 1940 and 1997 [11]. Land use change hind-cast or forecast models play a significant role in impact assessment of past and future activities. Moreover, land change models are used to prescribe “optimum” patterns of land use for sustainable resource development [12].

The USGCRP reports that the southeastern region of the United States has had an increasing temperature average since the 1970s, with the first decade of 200 being the highest on record [13]. This translates into an increasing Florida population which is a direct result of cold northern states. Between 1970 and 1985 the growth rate for the state was approximately four times the national average [14]. Each year Florida has gains over a quarter of a million new residents (Table 2) [15]. It is therefore hypothesized that as temperature continues to warm up more and more population will move to Florida and especially the panhandle as southern Florida has reached built-up status and become over populated. This will influence an increase in the demand for urban developmental land, thereby taking compromising land for agriculture-forest.

The task of seeking a reasonable balance among conflicting viewpoint is complicated further by spatial factors such as externalities effects, differential in land use capability, competition among different uses for specific locations and the fixed, short-term pattern of land ownership. Hence, in response to need, efforts to extend GIS technology to explore and represent the subjective matter of multi-party conflict and decision making have focused on integrating it with MCA.

Feick and Hall [16] incorporated MCA in a spatial decision support system (SDSS) to explore proactively land development conflict among multiple participants. Their focus was on selecting and evaluating sites for potential tourism development in a district of the island of Grand Cayman. To accomplish this, custom software was develop to accommodate input from and analysis of views of multiple non-expert participants and overcome the complexity of use and intrinsic single user perspective that characterize most GIS products. Their analysis of the problem illustrated that the relatively simple site selection and evaluation models used work rather well in exposing individual and sub-group dimensions of commonality and help to identify generally acceptable group decision outcomes.

Objective of Study: The overall objective of this study is to model land use conflict areas resulting from a change in the land use. This is based on two land use preferences: forest interest groups and urban developmental groups. The two hypotheses of the study were:

- The forest stakeholders intent is to maximize opportunities for forestry
- The urban stakeholders’ sole objective was to maximize and expand given the influx of a large number of populations moving in the area.

Description of Study Area: This study area was located in the Florida Panhandle region for Escambia, Santa Rosa and Okaloosa Counties as shown in Figure 1. The population is shown in Table 1. The region was used for agriculture and forestry for many decades, but has undergone rapid urban development in the past 30 years due to migration. This is especially true along the Gulf of Mexico coast. Inland land is still relatively sparsely populated, but this is likely to change.

Geographically the region is classified as a low-lying coastal plain filled with scrub vegetation as well as natural and planted plantations for pine trees. The soils are sandy making is a suitable location for housing and some forms of agriculture.

The study region has been hit by several major hurricanes in recent times and will almost certainly do so in the future. Climate change in the form of global warming is thought to foster large and stronger hurricanes, however since hurricanes are difficult to predict, that factor was not taken into account in this study.

Methods: The materials used in this study include GIS datasets, statistical data set and ArcGIS software. The GIS feature layers are collected from the Florida Geographic Data Library (FGDL). The Florida Statistical data is collected from the Bureau of Economic and Business Research at the University of Florida (Table 3).

Table 1: Population Escambia, Santa Rosa and Okaloosa Counties

	Estimate (2000)			Density
County	Number	Rank in state	Land area (sq.mi)	Person per sq.mi
Escambia	303,623	18	663.6	458
Okaloosa	188,939	24	935.8	202
Santa Rosa	136,443	31	1,015.8	134

Table 2: Historical census population (1940 – 2004)

County	1940	1960	1980	2000	2002	2004
Escambia	74,667	173,829	233,794	294,410	809,394	840,474
Okaloosa	12,900	61,175	109,920	170,498	178,971	185,778
Santa Rosa	16,085	29,547	55,988	117,743	124,956	133,721

Table 3: Data sets used in study

Item	Feature type	Item	Feature types
Land parcels	polygon	Cultural centers	polygon
Land use	polygon	Hospital	polygon
Prisons	points	Schools	points
Major roads	lines	Day care	lines
City Limits	polygon	Airport	polygon
Rail terminals	point	Hazardous	point

Table 4: Population in 2002 and Projected (2010 through 2030) (in thousands)

		Projection				
County	Estimate 2002	2010	2015	2020	2025	2030
Escambia	299.5	347.2	375.4	404.7	434.9	465.5
Okaloosa	177.0	219.6	245.7	273.2	301.7	330.8
Santa Rosa	61.1	80.9	93.5	107.1	121.4	136.2

The specific task to be completed for each objective is illustrated in Figure 2. The goal was to develop land use suitability by map algebra operations with weights assignment to specific layers to derive a final single utility.

To achieve the goal for agricultural land, datasets analyzed included parcel data, major roads, market nodes and land value were used.

Using land use data, a new field was added in its attribute table from which values was used for reclassification. Working with the Florida Land Use and Cover Classification (FLUCCS) system, forest were assign a 9, other agriculture a 5 and all others a 1.

Figures 2-9 are flow charts that show the models used to perform the analysis for the study.

The task to derive a suitable transportation layer involved the transformation of Euclidean distance. We calculated the zonal statistics and use its mean and standard deviation to reclassify the major roads and rail terminal. Using map algebra, weights were given to the final layer and added.

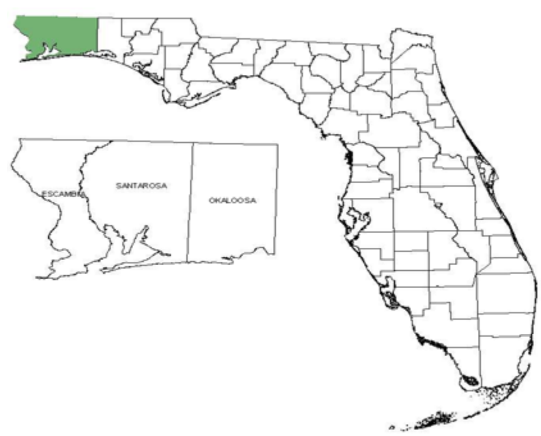

Fig. 1: Study Area

Market place suitability objective involved the use of city limits data set and the forest data set. A Euclidean distance on city limits, mean and standard deviation values were calculated by zonal statistics are used to reclassify the distance from the city center.

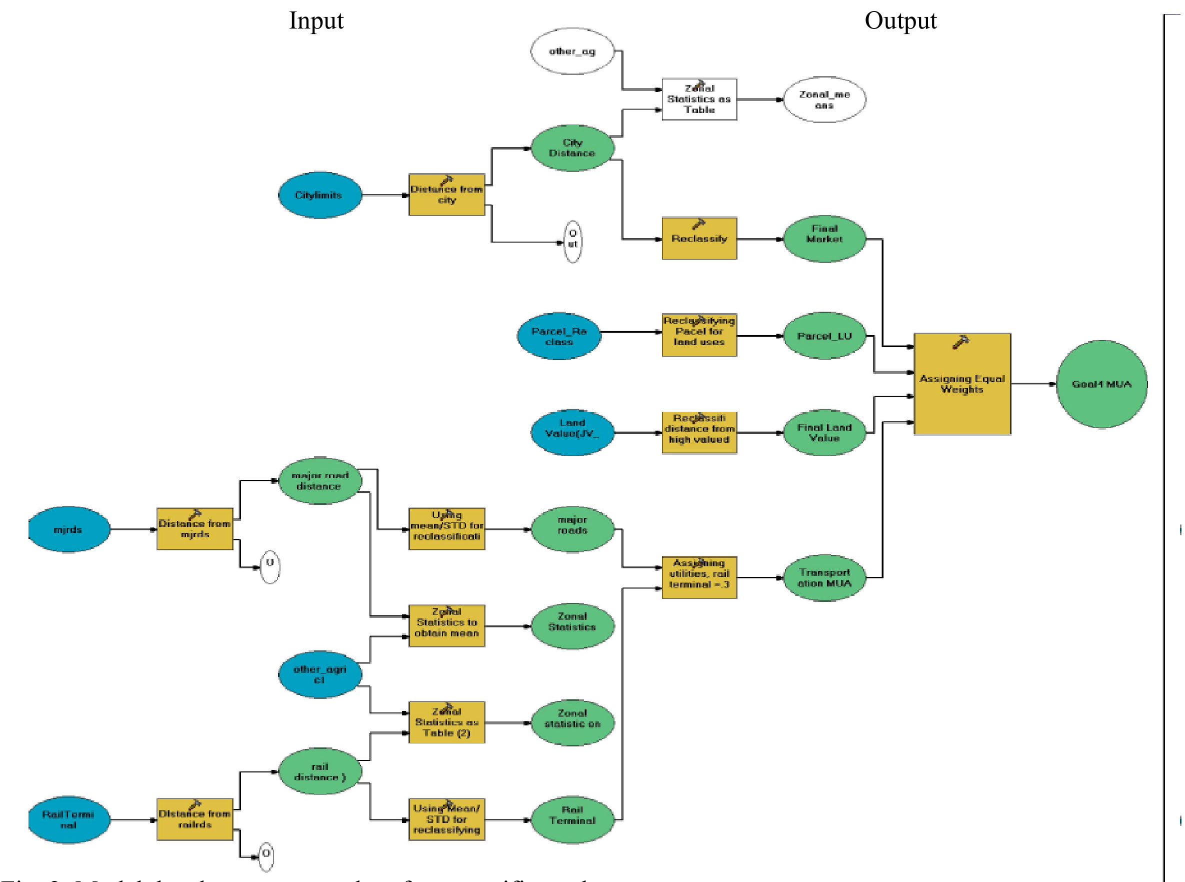

Fig. 2: Model development procedure for a specific goal

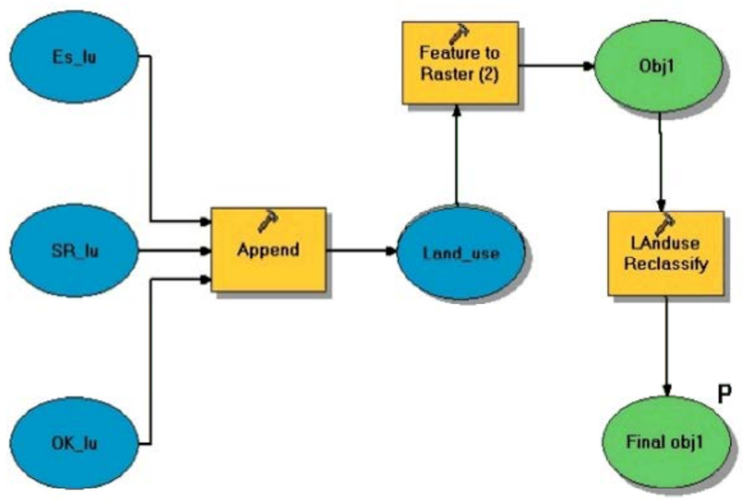

Fig. 3: Physical characteristics sub-model

The objective of urban development is to maximized development regardless of any other use. A reclassification of parcel data identified current urban lands. A recode was applied to extract residential development.

Potential land suitable future development is a function of the amenities in place or urban service area. Proximity analysis on commercial, urban centers and infrastructure was done.

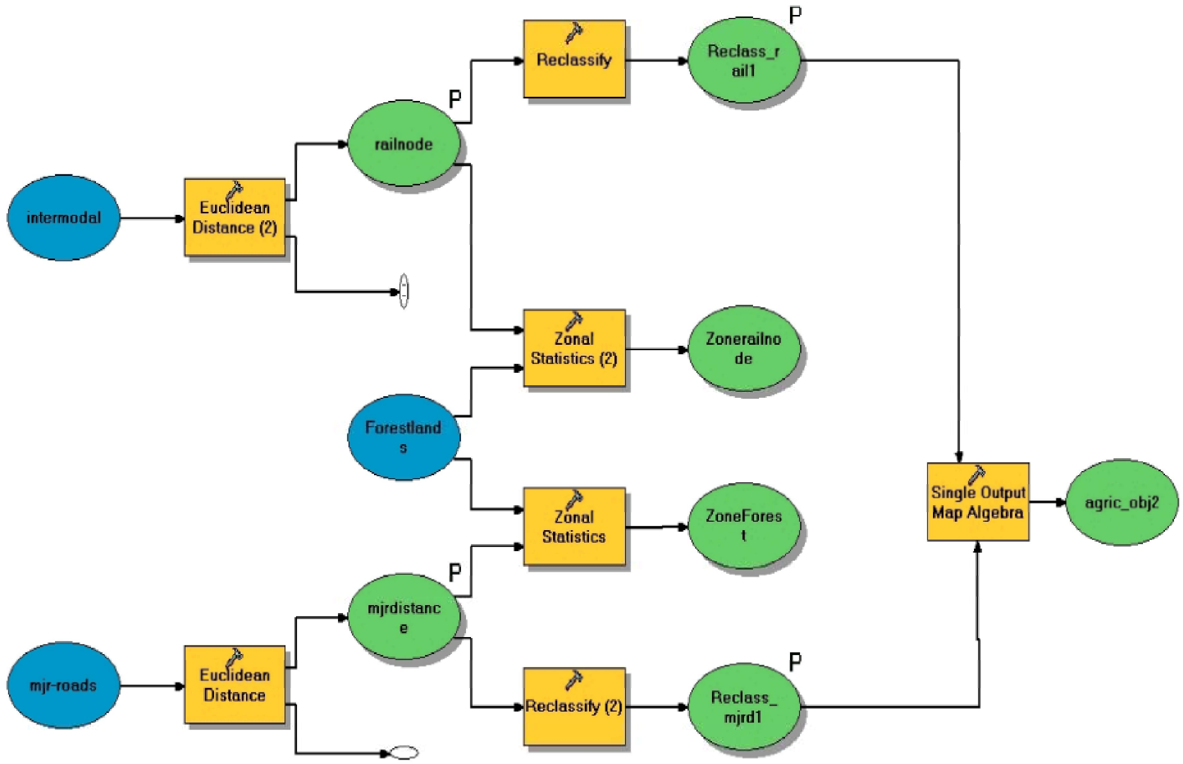

Fig. 4: Transportation Protocol Sub-model

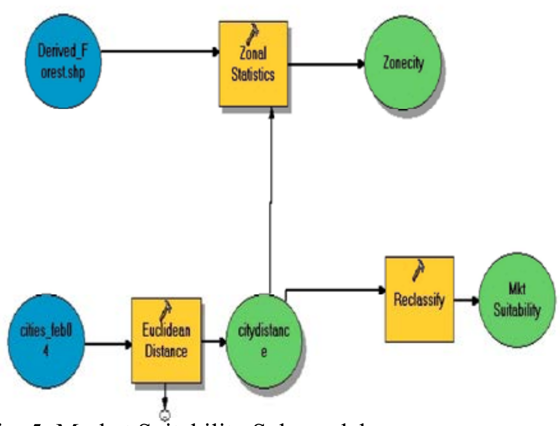

Fig. 5: Market Suitability Sub-model

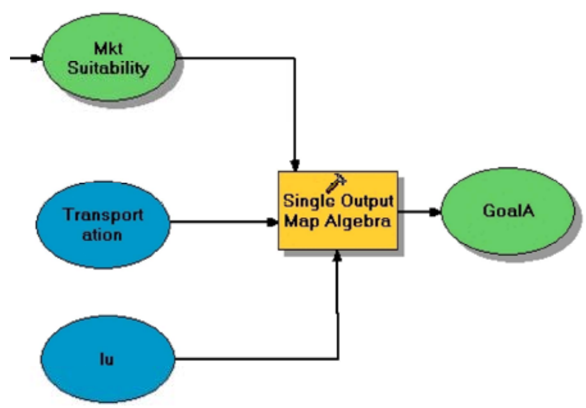

Fig. 6: Model for Forest Stakeholders

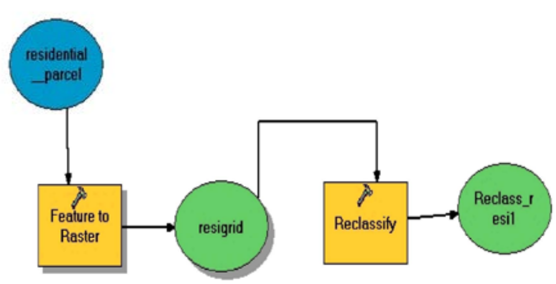

Fig. 7: Residential Land Use Extraction Sub-model

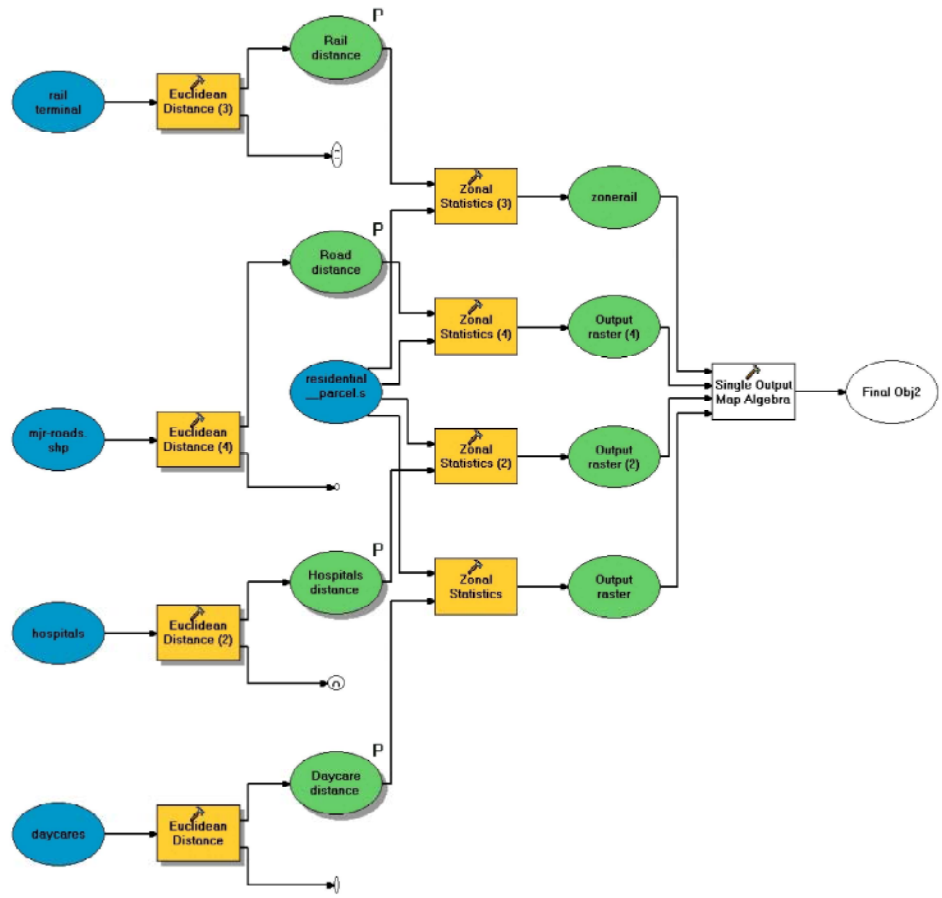

Fig. 8: Future Development Attraction Sub-model

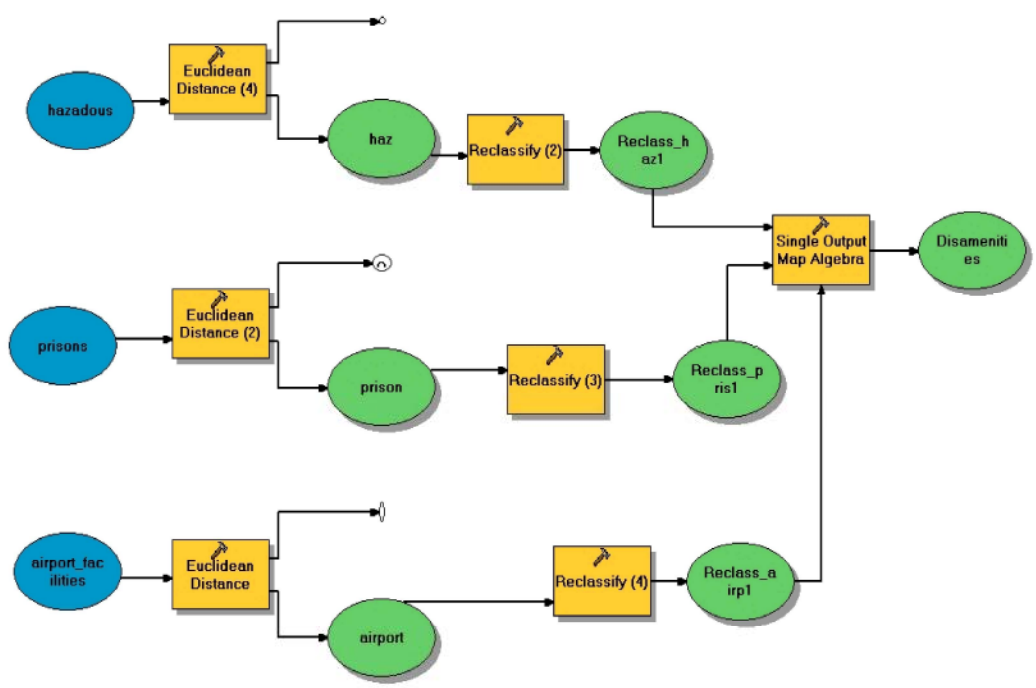

Fig. 9: Future Development Dis-incentives Sub-model

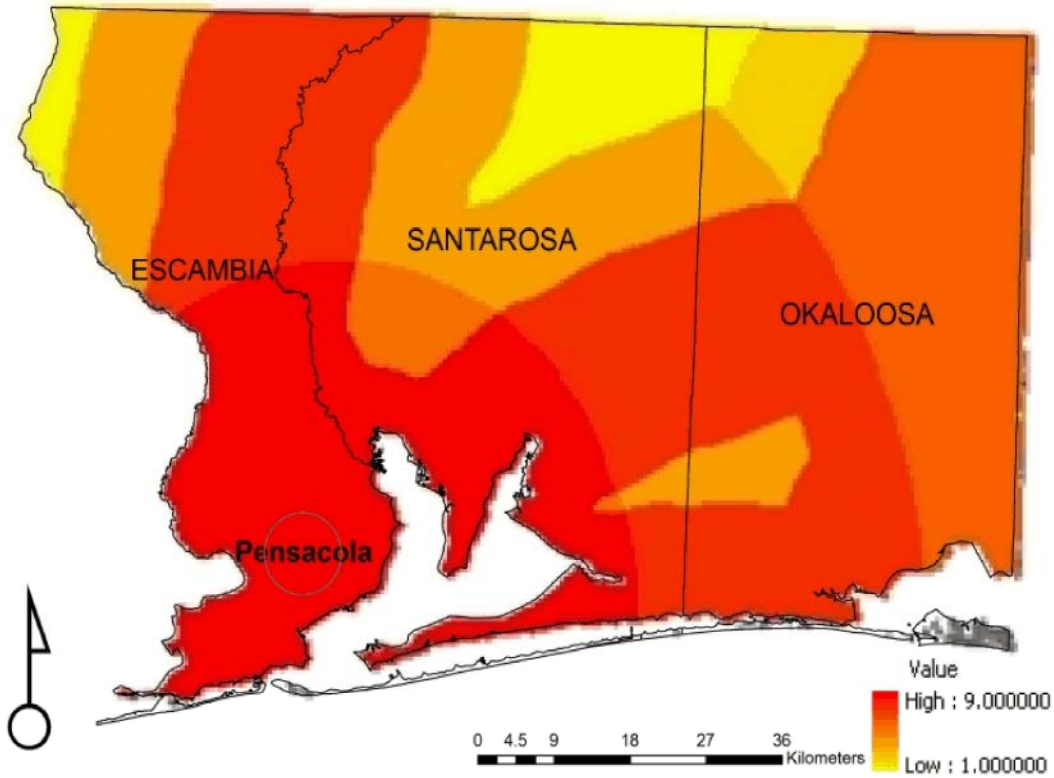

Fig. 10: Land Use Suitability for Forestry

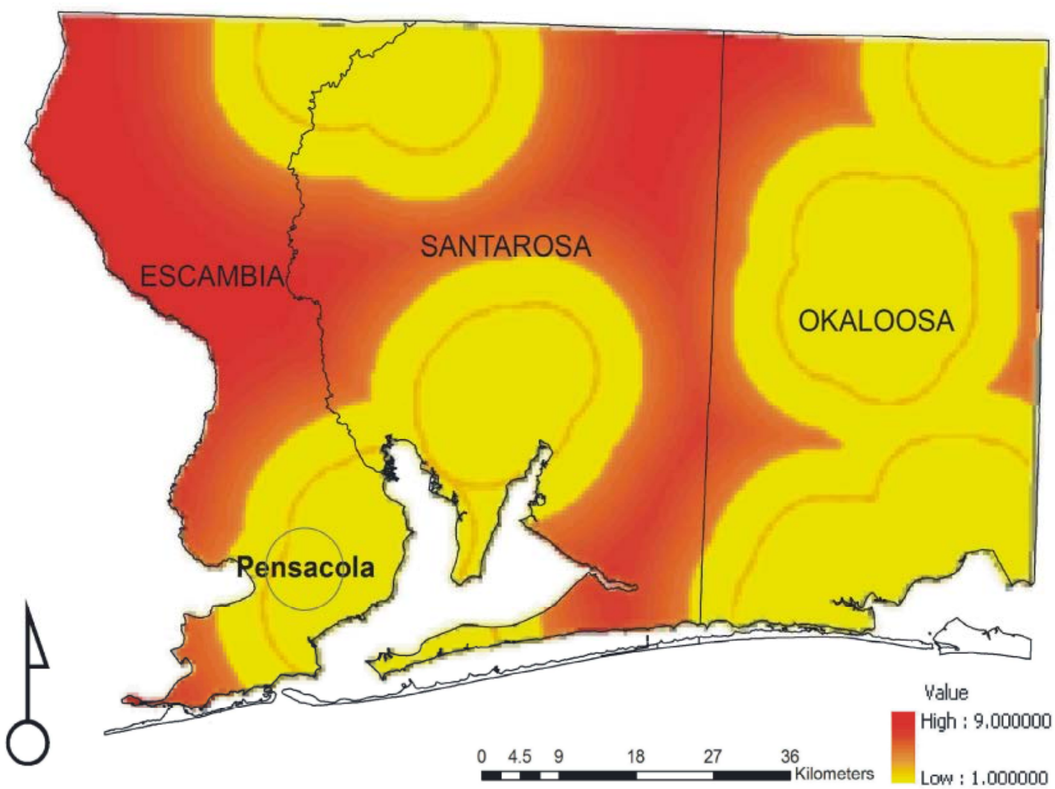

Fig. 11: Land Use Suitability for Urban

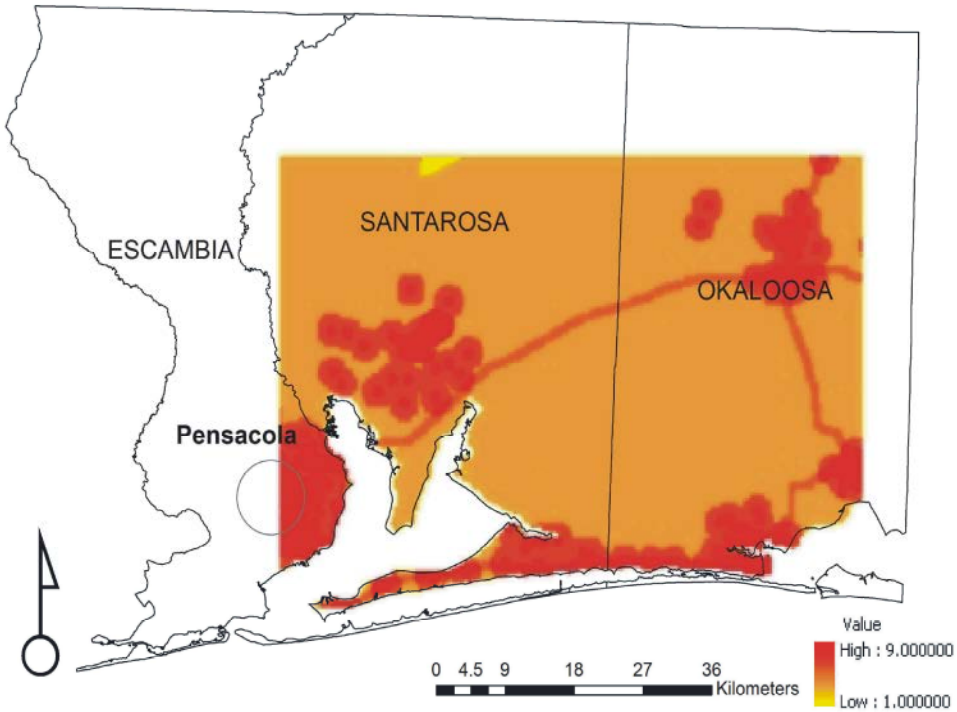

Fig. 12: Land Use Desirability for Forestry

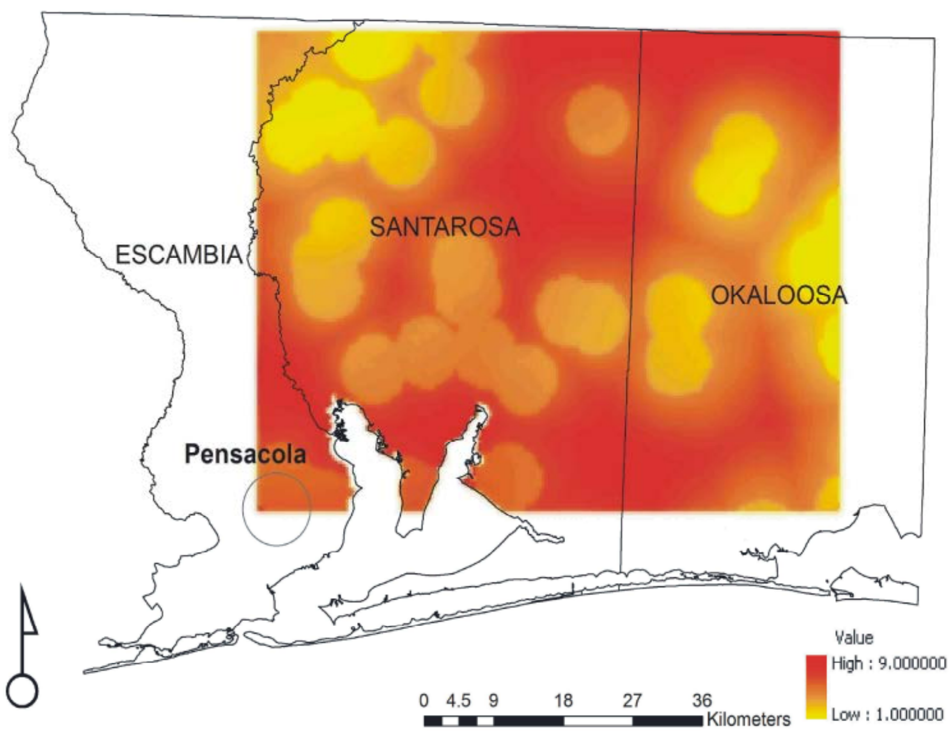

Fig. 13: Land Use Desirability for Urban

Certain areas do not and will not attract new urban developments. Such areas might include prisons facilities, hazardous waste materials, transportation exchange, heavy industrial and flood zones. These areas were buffered and a distance analysis performed before the final suitability was aggregated.

RESULTS

The results of this analysis are shown graphically in Figures 10 to 13. Figure 10 shows the land use suitability for forestry and Figure 11 shows the land use suitability for urban. Figure 12 shows the land use desirability for forestry and Figure 13 shows the land use desirability for urban.

DISCUSSION

The final suitability for the different goals, which are ranked from 1 (low) to 9 (high) show the vested interest of the different groups. This final surface is normalizing by finding the highest value for each cell and divide each cell by that highest value. For desirability, using equal interval and a standard deviation of 1, reclassify into 3 classes: high [3], medium [2] and low [1]. There are areas where urban preference is stronger than forest interest, as such urban land use prevails In other places forest interest is stronger than urban, hence forest land use prevails In areas where it could not be agreed upon, optimization techniques will be applied to resolve the issue.

Modeling land use status quo to determine conflicting land is important for knowing where the conflicts are and likely to occur is the first step towards developing equitable solution. A second phase of this study will be using this surface for assessing future land use availability based on population projection and allocation between existing forest land and intending urban development. The follow-up paper will use multiple objective linear programming to address this object function (s) for land use in order to optimize land use allocation. The paper will answer questions expressed such as "how much land to allocate to each of a number of land use types based on the population projected" (Table 4). The paper will show the amount of land require to accommodate the projected population at the existing population densities.

CONCLUSIONS

The GIS-based model employed in this study can be use to provide decision support in various decision and policy making context to allocate land. The model can also be extrapolated into other areas facing rapid land use change. This model attempts to fill the gap in the synergistic relationship inherent in the GIS based model and derived information of the limiting growth factors in the panhandle.

Global climate change will impact the Florida panhandle adversely. It might result in an increase in the demand for developmental land, thereby increasing the pressure on the demand for natural resources. On the one hand, land use will shift from forest stakeholders to urban stockholders. This will not be without hesitation and conflict. On the other, it will generate a limiting effect to the kind and extend of growth.

Although there are estimated projection of the population rising temperatures is associated with increasing sea levels and resulting salt water intrusion on to fresh water. This increase in salinity will limit the available fresh water and raise questions of the sustainability for future land developments. This will create a cap to urban land take over. Any increases will exacerbate the current water shortage situation.

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