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Using GIS suitability analysis to identify potential future land use conflicts in North Central Florida

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ABSTRACT: This article presents the Land Use Conflict Identification Strategy (LUCIS) that employs role playing and suitability modeling to predict areas where future land use conflict is likely to occur. A simple land use classification system of conservation, urban and agricultural land was derived from E. Odum's Compartment Model to organize land use suitabilities and compare land use preferences (Odum 1969). The strategy's six step process includes 1) developing a hierarchical set of goals and objectives that become suitability criteria, 2) inventory of available data, 3) determining suitabilities, 4) combining suitabilities to represent preference, 5) reclassifying preference into three categories of high, medium and low, and 6) comparing areas of preference to determine the quantity and spatial distribution of potential land use conflict.

A case study in north central Florida, USA, is used to demonstrate the strategy and to provide results for consideration and discussion. The study area occurs in a region with a trend of steady population increase that has resulted in conversion of lands with conservation and agricultural importance to urban use. Altogether the results suggest considerable conflict among the three basic land use classifications, but particularly between urban and agricultural land uses. LUCIS results have the potential to be used in at least three ways including decision support for local or regional planning activities, environmental regulation, or population modeling including representations of alternative futures (McHarg 1969, Lyle 1985, Steinitiz 1990, Steinitz et al 2003, Ahern 2001 and Hulse et al 2004).

Keywords: land use conflict, land use change, suitability analysis, land use preference, hierarchical goals, single utility analysis, multiple utility analysis, pairwise comparison, analytic hierarchy process, regional land use planning, alternative futures

INTRODUCTION

Each year of the last decade of the last century at least 300,000 more people arrived in the state of Florida than those who left it (BEBR 2005). That's just a number, but visualize it in real terms: from the time you sit down to breakfast with your coffee and newspaper to the time you brush your teeth and turn out the lights at night more than 800 people have entered the Sunshine State. Given Florida's current average population density of 116 persons per square kilometer, that is approximately 2,600 square kilometers of land use change every year. If protected lands and waters are excluded from consideration, the changed area exceeds 3,500 square kilometers per year. The current annual rate of population growth in Florida is 2.6%, which will double the current population in less than 30 years. Needless to say, planners and policy-makers are trying to find ways to anticipate and accommodate this rapid growth without sacrificing environmental integrity, economic viability and quality of life for all Floridians. Given national and global population trends, similar rates of land use change are an almost universal issue (Dale et al 2000). While this study uses north central Florida as a case study, the methodology has potential global application.

This paper will present a role playing approach to geographic information systems (GIS) suitability analysis aimed to improve regional planning by identifying probable areas of future land use conflict. It was developed in a graduate design studio at the University of Florida in collaboration with twelve students from the departments of landscape architecture and urban and regional planning and will be referred to as the Land Use Conflict Identification Strategy, or LUCIS, for short.

The conceptual basis for LUCIS was derived from the work of Eugene P. Odum, one of the 20th century's foremost ecologists (Table 1). Odum's classic "Strategy of Ecosystem Development" (1969) proposes four general land use types in a simplified model "so that growth-type, steady-state, and intermediate-type ecosystems can be linked with urban and industrial areas for mutual benefit" (Odum, 1969 p. 268). In Odum's Compartment Model, each area in a landscape can be grouped into one of four types: (1) productive areas, "where succession is continually retarded by human controls to maintain high levels of productivity;" (2) protective, "or natural areas, where succession is allowed or encouraged to proceed into the mature, and thus stable, if not highly productive stages;" (3) compromise areas, "where some combination of the first two stages exists;" and (4) urban/industrial, "or biologically non-vital areas" (Lyle, 2002 p. 178). Odum writes that by dividing land use into these categories, and "by increasing and decreasing the size and capacity of each compartment through computer simulation, it would be possible to determine objectively the limits that must eventually be imposed on each compartment in order to maintain regional and global balances in the exchange of vital energy and materials" (Odum, 1969 p. 268). He calls it a "systems-analysis procedure," and notes that it provides "at least one approach to the solution of the basic dilemma posed by the question 'How do we determine when we are getting too much of a good thing?'" (Odum, 1969 p. 268).

TABLE 1 A Strategic Approach to Future Land Use Allocation Derived from the Work of Eugene P. Odum in "Strategy of Ecosystem Development"

Odum's Strategic Ecosystem Development Land Use Classes	LUCIS Future Land Use Allocation Classifications
Productive	Agriculture — The Protection of Productive Agricultural Lands
Compromise	Conservation — The Protection of Environmentally Significant Lands
Protective	
Urban/Industrial	Urban — Aesthetically pleasing & functional with limits

The Compartment Model was used in LUCIS as a basis for classifying land use and determining land use preferences (Table 1). Three, rather than four categories were used to maximum the contrast among them. Agriculture served as a direct correlate of Odum's productive category, conservation as a combination of

Odum's protective and compromise categories and urban as the equivalent of Odum's urban industrial category. The combination of protective and compromise landscapes into one conservation category seemed justified because conservation lands are, in reality, comprised of a combination of productive and protective lands. Take for example a national forest; its multi-use mandate ensures that the goals of protection and production will both be met.

Others have cited the value of the Odum approach, though each used the four compartment model differently than did LUCIS. Guy Fabos, professor emeritus of landscape planning at the University of Massachusetts was a proponent of it as a basis for land use planning (Fabos, 1985). John Lyle (1934 – 1998), renowned professor of landscape architecture at California Polytechnic Institute at Pomona, renamed the compromise category "human ecosystems" and defined it as "those places in which human beings and nature might be brought to together after a very long and dangerous period of estrangement" (Lyle, 1985 p 15). This renamed compartment formed the basis for his much revered 1985 work, Design for Human Ecosystems.

Pioneering work on the development of alternative future land use plans has been accomplished by an increasingly long series of researchers, (McHarg 1969, Lyle 1985, Steinitiz 1990, Steinitz et al 2003, Ahern 2001 and Hulse et al 2004), most of whom have their roots in landscape architecture and environmental planning as do the authors here. LUCIS however, stops short of representing alternative futures, but instead focuses on the comparison of the results of three suitability analyses purposefully designed to capture biases inherent in the motivations of three stakeholder groups: conservationists, developers and farmers and ranchers dedicated to an agricultural future. The comparison of the suitabilities results in the identification of areas of potential future land use conflict. The three suitabilities are not alternative futures, nor is the representation of areas of land use conflict derived from the comparison of the three suitabilities. To our knowledge, this is a new tack in suitability analysis, one for which there no direct precedents.

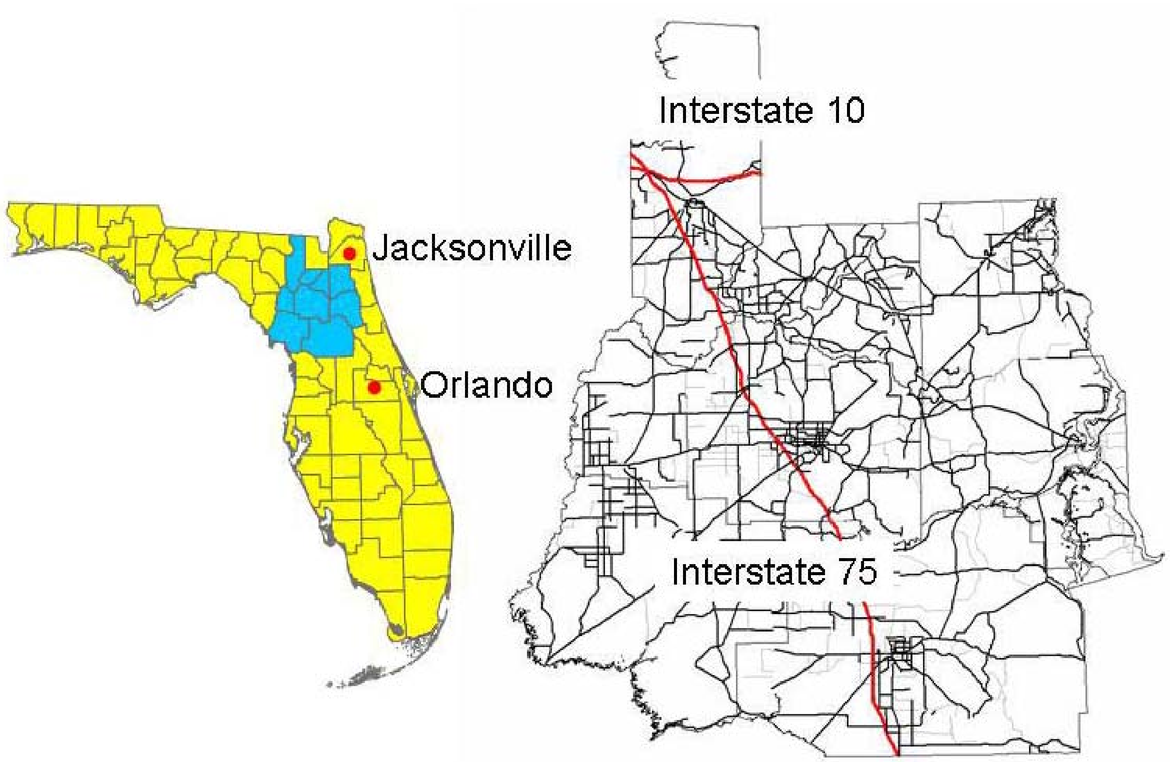
METHODS

LUCIS was developed using the Environmental Systems Research Institute's ArcGIS software. Although some analysis steps were conducted using vector GIS, ultimately all results were converted to grids and the final results were produced in a raster format. The cell size used in the case study was 100 m, however, any cell size could be employed in the methodology. The case study area, comprised of the Alachua, Bradford, Clay, Columbia, Gilchrist, Levy, Marion, Putnam and Union counties (Figure 1, page 61), contains two interstate highways (in red) I-75 traversing north-south and I-10 traversing east-west. There are four metropolitan areas in the study area, three within the I-75 corridor. Growth pressure from the Jacksonville Standard Metropolitan Statistical Area (SMSA) is being felt in the northeastern portion of the study area, even though its center is 18 km northeast of the study area boundary. The study area remains beyond the influence of the Orlando SMSA.

Three teams, each representing one of the land use classifications of Table 1, became expert advocates for their respective classification. Each team rated all lands in the study area for their relative suitability to support their assigned land use and the results were compared to identify areas of potential conflict. More specifically this was accomplished through six steps:

1. Define goals and objectives (that became the criteria for determining suitability)
2. Inventory data resources potentially relevant to each goal and objective
3. Analyze data to determine a relative suitability for each goal
4. Combine the relative suitabilities of each goal to determine preference
5. Normalize and collapse the preferences for each land use into three ranges, high, medium and low
6. Compare the ranges of land use preference to determine likely areas of future land use conflict

FIGURE 1 LUCIS Study Area including the following nine counties: Alachua, Columbia, Bradford, Union, Clay, Putnam, Marion, Gilchrist, and Levy.



The project continued and included the development of three alternative scenarios for allocation of projected population based on defined assumptions about 1) the sequencing and speed of the conversion of existing conservation and agricultural lands to urban use; 2) the densities at which new population was to be allocated; and 3) permanent set asides (or lack thereof) of lands with high conservation and agricultural suitability. The result was a range of alternative future land use scenarios with associated build out populations and dates. However, only steps one through six above are part of the LUCIS methodology and are addressed in this paper.

Step 1. Defining Goals and Objectives

The use of "goals and objectives" has long been advocated as a way to describe the mission to be undertaken by a planner or designer (Steiner 2000, Lyle 1985). "Goals and objectives" is a loose term that actually includes at least three elements organized in a nested hierarchy: a statement of intent, goals, and their supporting objectives. In some design and planning situations, further subdivision of objectives is needed, for example in the development of local government comprehensive plans in Florida, a list of policies support each objective (Florida Department of Community Affairs 2005, ESRI 1996)

The statement of intent is a concise description of the problem at hand that, at a minimum, defines the geographic area of study and identifies the desired product. Goals and objectives are a hierarchical set of statements (ESRI 1996) that first define what is to be accomplished or identified (goal), and second define how each goal is to be achieved (supporting objectives).

Step 2. Inventory of Data Resources

Traditionally in environmental planning the inventory phase has included a survey and presentation of the ecological and cultural characteristics of a study area and examination of the relationships among them (Steiner 2000, Lewis 1996, Lyle 1985, McHarg 1969). For the purpose of LUCIS, the inventory phase was simply the identification of GIS datasets with the potential to provide information relevant to the adopted goals and objectives. For the most part this was an examination of already available datasets, but in a few cases the creation of new GIS datasets or hybrids of existing datasets was necessary.

Step 3. Data Analysis to Determine Relative Suitabilities for each Goal

Following inventory, each group performed GIS analysis to create land use suitability layers representing their goals and objectives. First the analysis steps for each objective were diagramed in a common flowchart format. At a minimum each diagram consisted of a GIS dataset as the input, the GIS function used to determine suitability assignment, and the resulting dataset representing the relative suitability.

Assigning Suitability Values – The Single Utility Assignment Process

The assignment of suitability (utility) values for a single layer was called Single Utility Assignment (SUA) (Malczewski 1999, ESRI 1996). SUAs fall into two basic categories, in situ analyses and proximal analyses (Malczewski 1999, ESRI 1996). In situ analyses result in a characterization of the relative suitability of each pixel based on the evaluative criteria being applied (e.g., soils); proximal analyses produce a characterization of the relative suitability of each pixel based on its proximity to amenities (e.g., proximity to roads for convenient access or its inverse that serves as a measure of potential quiet) (Malczewski 1999, ESRI 1996). To create an "in situ" SUA, each group, in their role as experts, defined the relative suitability of each physical feature in the layer. Assuming this expert role created the scenario of "decision under certainty", i.e. "it [was] assumed that the uncertainty involved in [the] decision situation [was] either a known or a negligible determinant of the utilities" (Malczewski 1999 p 119). Uniformly, the range of SUA suitability values used was from 1 to 9 as follows:

1 = lowest suitability

2 = very low suitability

3 = low suitability

4 = moderately low suitability

5 = moderate suitability

6 = moderately high suitability

7 = high suitability

8 = very high suitability

9 = highest suitability

Nine suitability values were employed because it has been proven to be workable (ESRI 1996). More than nine values are difficult for humans to visually comprehend and fewer than nine values decrease the sensitivity of the process.

An example of an in situ SUA is suitability for visual preference based on habitat. It requires group consensus on the visual preference for all habitat classifications within the dataset. The process of assigning suitability values for features within the habitat dataset is accomplished by asking a single question: how visually pleasing is each habitat type? The range of values for suitability must, at a minimum, have two suitability values: one for lowest suitability and nine for highest suitability. The remaining values between one and nine are to be assigned by the experts or other chosen participants. No suitability values may exceed nine, nor may a suitability value be less than one. Further, suitability values are in equal intervals, therefore a suitability value equal to five is three greater than a suitability value equal to two. This is required because all suitability layers must be in the same units. Requiring the individual suitability layers to adhere to these simple rules eliminates the possibility of error when combining more than one SUA layer into a more complex suitability layer (Malczewski 1999, ESRI 1996). If individual suitability layers were allowed to contain non-bounded values then any mathematical manipulation (addition, subtraction, etc.) would result in what is commonly referred to as "apples and oranges".

Ranges for proximal suitabilities were created using the Euclidian "straight-line" distance function combined with a reclassification of distance into up to nine suitability values. Conceptually, the closer a cell location is to an amenity, the higher the suitability.

Combining Suitability Values: The Multiple Utility Assignment Process

Once an SUA was generated, there was the need to combine the results with other SUAs to produce a synthesis of the multiple criteria (spatial multicriteria analysis). In our process this step was called Multiple Utility Assignment (MUA) (ESRI 1996). This step can employ various combination strategies including weighted averaging, selection of maximum values, or "if, then, else statements" that allow for a complex set of choices. The combination strategy selected for this project, weighted averaging, was chosen for its simplicity. Individuals in each group, serving as the expert for their assigned area of study, decided the weights to be used for the development of MUAs at the goal and sub-goal levels. So through the use of the SUA and MUA processes each group developed a final suitability surface for each goal.

Step 4. Determining Preference

The next step was to combine the results for each goal into a map of preference for each land use type. This was also accomplished using the MUA process, but the technique for determining weights was different than that used at the goal and sub-goal level. It employed the systematic application of pairwise comparisons.

Pairwise Comparison or Analytic Hierarchy Process to Determine Weights

Each land use group followed a pairwise comparison methodology called "Analytic Hierarchy Process" (AHP) using Expert Choice© software (www.expertchoice.com) (Malczewski 1999, Saaty 1980). Weights resulting from pairwise comparisons using AHP were derived for a group of variables by comparing pairs of alternatives, just like the name implies. Each variable was compared to all other variables in pair sets assuring that all alternatives were included in weight development. The weights derived using the AHP pairwise comparisons determined the strength individual goals exerted on the final suitability layer. For example an AHP weight of 0.566 for a conservation biodiversity goal would mean that 56.6% of the final suitability surface was derived from the suitability values in the biodiversity suitability surface. The advantages of the AHP method are its simplicity, and its potential to support participation by a wide range of individuals including experts, community leaders, the general public, and/or other stakeholders in the process (Malczewski 1999, Saaty 1980). In fact, pairwise comparisons could be generated in a public meeting to demonstrate the influence that various weights have on the results of the MUA process. This incorporation of group opinion or preference was, by definition, the way in which each land use group transformed its relative suitability for each goal into a measure of their final land use preferences.

Step 5. Normalize and Collapse Preference into Three Ranges, High, Medium and Low

Land use preference is an indication of the level of preference exhibited by the individual land use groups for each cell within the study area. The values from the final preference surface for each land use group were normalized to allow for comparison among them. Then each preference surface was simply reclassified into three equal intervals. Other approaches to reclassification to derive preference from suitability could be employed, for example analysis of standard deviation or use of equal area. The equal interval method was chosen because there was no desire to capture equal areas of preference for each land use type, but rather to compare the relative strengths of those preferences.

Step 6. Identification of Potential Areas of Land Use Conflict

Since LUCIS is based on three land use classifications, the characterization of land use conflict can be conceived of as a cube, with each land use preference represented on one axis of the cube to form a three dimensional conflict space diagram. The cube is comprised of 27 smaller cubes each representing one of the unique combinations of high (H), medium (M) and low (L) preference for conservation, urban and agricultural land use (Figure 2).

To determine conflict areas, the three normalized and collapsed land use preference surfaces were combined and reclassified into areas of conflict and areas of no conflict as follows. Conflict occurred anytime the highest preference for a cell was the same for at least two of the land use classifications (Table 2, page 65). Of the 27 possible preference combinations, 12 produced conflict and 15 did not.

Use of Role-playing to Develop Suitabilities and Preferences

LUCIS utilized role playing as a means to capture bias (Thompson 1978). Each group's ultimate task was to determine the preference of lands in the study area for their particular land use classification. For example, the urban group was to identify urban development potentials without regard for other land use concerns. The presence of wetlands as opposed to uplands might be used as a criterion for lower relative suitability of land for urban development, but only so far as the presence of wetlands might increase the cost of development or make it more problematic, not because of the ecological value of wetlands. Conversely, the conservation group chose not to consider land costs in its determination of conservation suitability since regardless of the cost per acre, some lands have enormous conservation value. The role playing approach was chosen to mimic the reality of the free market and the unfortunate lack of a broadly subscribed land ethic. The result was the identification of some lands as highly suitable by all three groups. As the process played out, these were identified as the areas of potential future land use conflict.

TABLE 2 Classification of Areas of Conflict and Areas of No Conflict based on Preference Rankings for Conservation, Urban and Agricultural Land Uses (in that order)

Areas of Conflict		**Areas of No Conflict**	
Code	**Description**	**Code**	**Description**
LLL	All in conflict, all low preference	LLM	Agricultural preference dominates
LMM	Moderate urban preference conflicts with moderate agricultural preference	LLH	Agricultural preference dominates
LHH	High urban preference conflicts with high agricultural preference	LML	Urban preference dominates
MHH	High urban preference conflicts with high agricultural preference	LMH	Agricultural preference dominates
MML	Moderate conservation preference conflicts with moderate urban preference	LHL	Urban preference dominates
MLM	Moderate conservation preference conflicts with moderate urban preference	LHM	Urban preference dominates
MMM	All in conflict, all moderate preference	MLL	Conservation preference dominates
HLH	High conservation preference conflicts with high agricultural preference	MLH	Agricultural preference dominates
HMH	High conservation preference conflicts with high agricultural preference	MMH	Agricultural preference dominates
HHL	High conservation preference conflicts with high urban preference	MHL	Urban preference dominates
HHM	High conservation preference conflicts with high urban preference	MHM	Urban preference dominates
HHH	All in conflict, all high preference	HLL	Conservation preference dominates

RESULTS

Results are included for four of the six steps described in the methodology section with an emphasis on identification of land use conflict. The other steps for which results are described are goals and objectives; determining preference; and normalizing and collapsing preference into three ranges.

Goals and Objectives (Step 1)

Each group defined an overall statement of intent and supporting goals and objectives that became the outline of their criteria for determining suitability. Only the goals for each group are included here to demonstrate the range of criteria and the bias captured by each set.

Urban Goals:

Maximize opportunities for:

- residential development
- retail and office/professional commercial development
- medium and heavy industrial development

Agricultural Goals:

Maximize opportunities for:

- cropland/row crops
- timberland/silviculture
- livestock/pastureland
- orchards and groves
- nurseries/greenhouse production

Conservation Goals:

Protect and conserve:

- biodiversity
- surface waters for human and ecosystem use
- groundwater for human and ecosystem use
- areas where the process of fire shapes the landscape
- wetlands and floodplains for the services they provide such as flood control, filtration of contaminants, erosion control and nutrient recycling
- lands that provide ecological connectivity

Determining Preference (Step 3)

The final preference surfaces for conservation, urban and agriculture are found in Figure 3, page 67. One can begin to see predictable patterns emerging, for example preference for urban development is highest adjacent to roads and in proximity to existing urban areas; conservation preference is highest close to existing conservation areas, along stream corridors and, generally in areas away from major roads; agriculture preference is high on the fringe of urban areas as these agricultural uses originally supported the establishment of the towns in their present locations.

Normalize and Collapse Preference into Three Ranges, High, Medium and Low (Step 5)

Figure 4, page 68, uses conservation as an example of the visual results of normalizing and collapsing preference into three ranges of high, medium and low. Table 3, page 68, captures the percentages of the study area found in each preference range for each land use category.

The high preference range for conservation captures the single largest amount of the study area, followed by

FIGURE 3 Final preference maps.

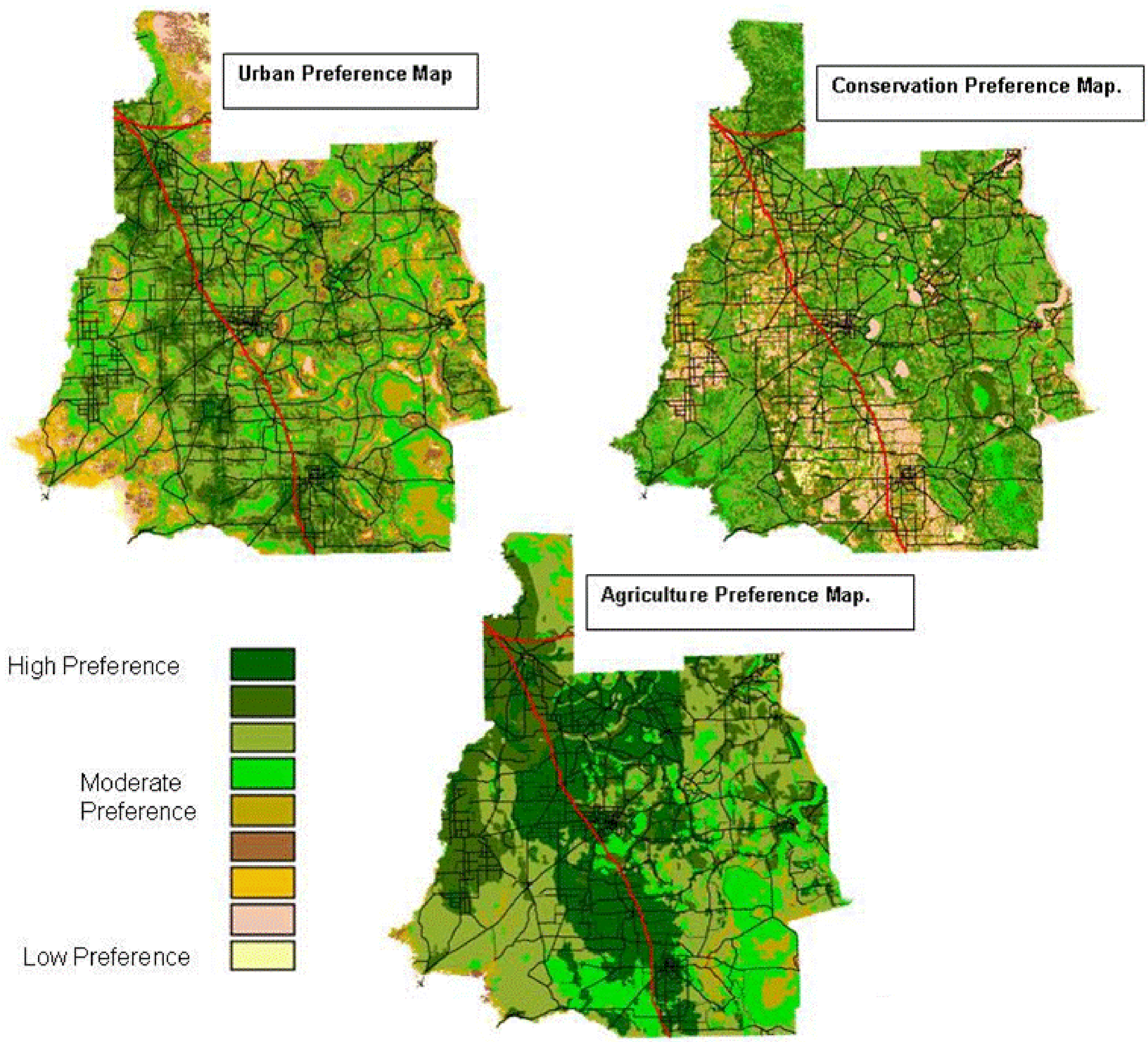


FIGURE 4 A comparison of the originally generated conservation preference values with the normalized and collapsed conservation preference.

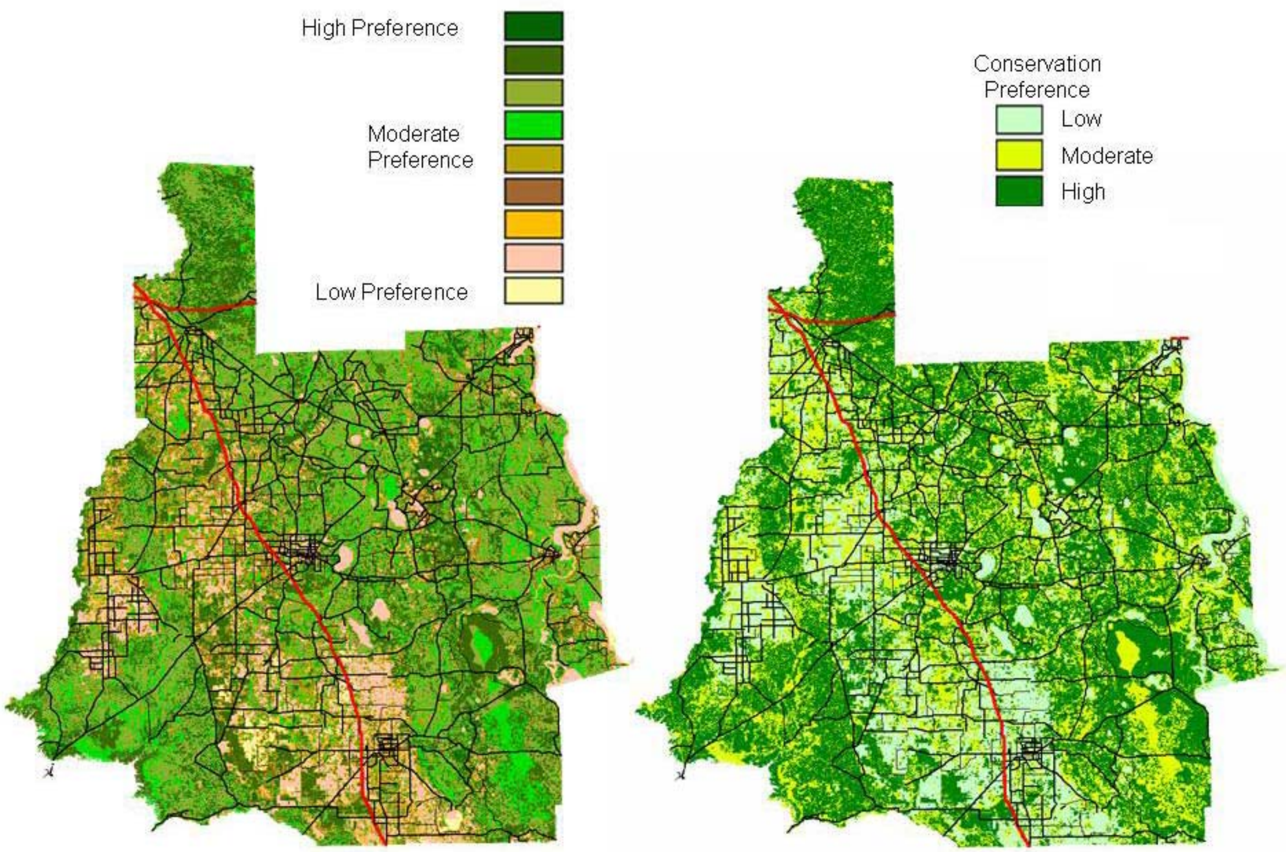


TABLE 3 Percentages of the Study Area Found in each Preference Range for Conservation, Urban and Agricultural Land Uses

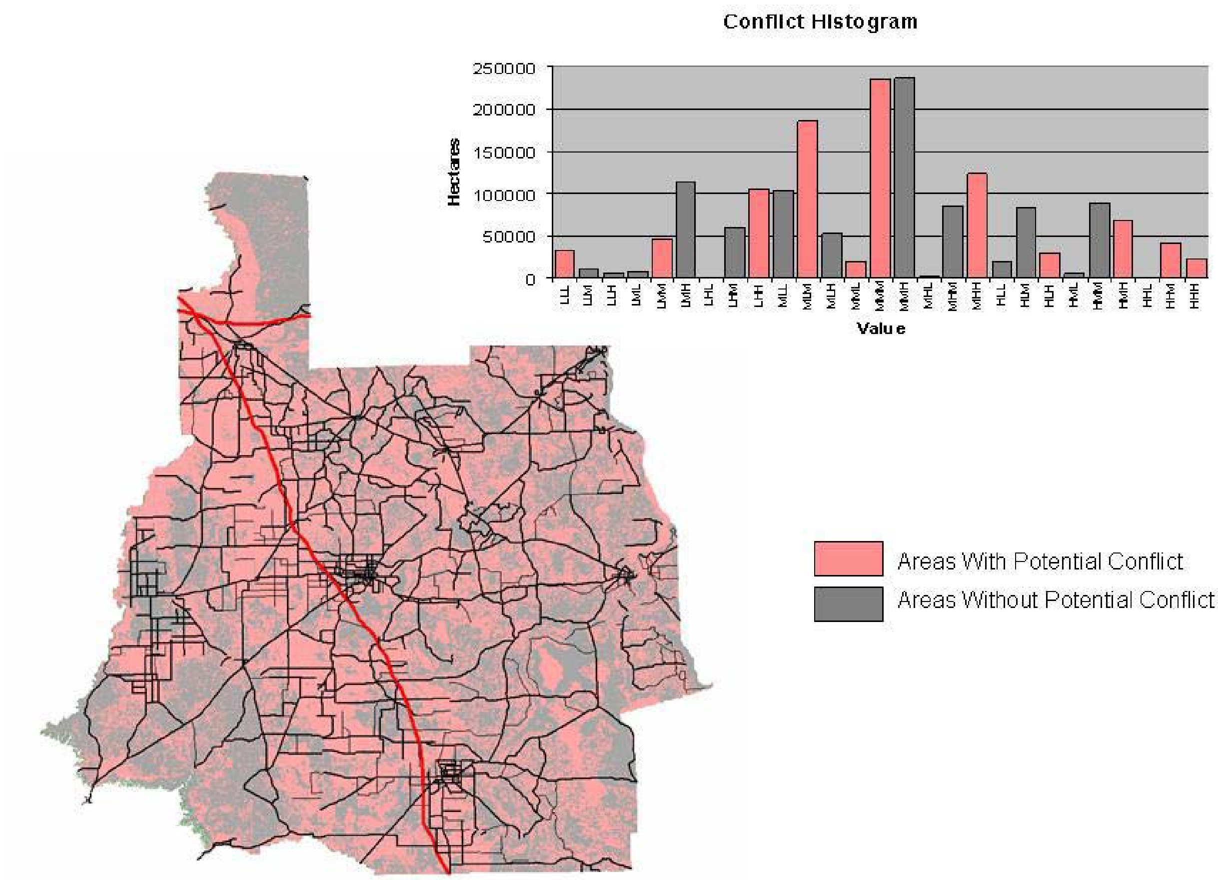
	Conservation	Urban	Agriculture
High Preference	48%	43%	43%
Moderate Preference	33%	47%	46%
Low Preference	19%	10%	11%

moderate preference for urban. The low preference range for each of the land use classifications captures less than 20 percent of the study area, with urban being the lowest at 10%. This last number suggests why urban growth seems to spread so uniformly across the landscape of the case study region, i.e., there are few conditions present that preclude urban development.

Identification of Potential Areas of Land Use Conflict (Step 6)

Figure 5 represents the application of LUCIS in the north central Florida study area. A histogram representing the distribution of cells among the 27 possible preference combinations is shown along with a map of the areas of conflict (red) and areas of no conflict (grey).

FIGURE 5 Areas of potential land use conflict, histogram and map.



Besides simply identifying areas of potential conflict, it is also possible to determine the character of the potential conflict and to map it for land use decision support. Figure 6 is a conflict map representing those areas where potential conflict with urban preference occurs. The orange areas are potential conflict between urban preference and agricultural preference (combinations LHH, MHH, LMM), the aqua areas are potential conflict between urban preference and conservation preference (combinations HHM, HHL, MML), and the yellow areas are potential conflict between urban preference and the other two land use classifications (combinations HHH, MMM, LLL). The black areas are urban preference without potential conflict. (The white areas are conservation and agricultural preference areas without potential conflict that are undifferentiated in this map.) The green areas are existing conservation lands that have been laid over the modeling results.

The majority of the conflict between urban and agriculture occurs along the Interstate 75 corridor where prime agricultural land is in the path of westward expansion of three existing urban areas. Most of the conservation and urban conflict areas occur west of the urban/agriculture conflict area where a north-south wetland system lies in the path of westward urban expansion. Similar mapping can be done from the perspective of the other land use classifications.

FIGURE 6 Areas of potential urban conflict and no potential urban conflict.

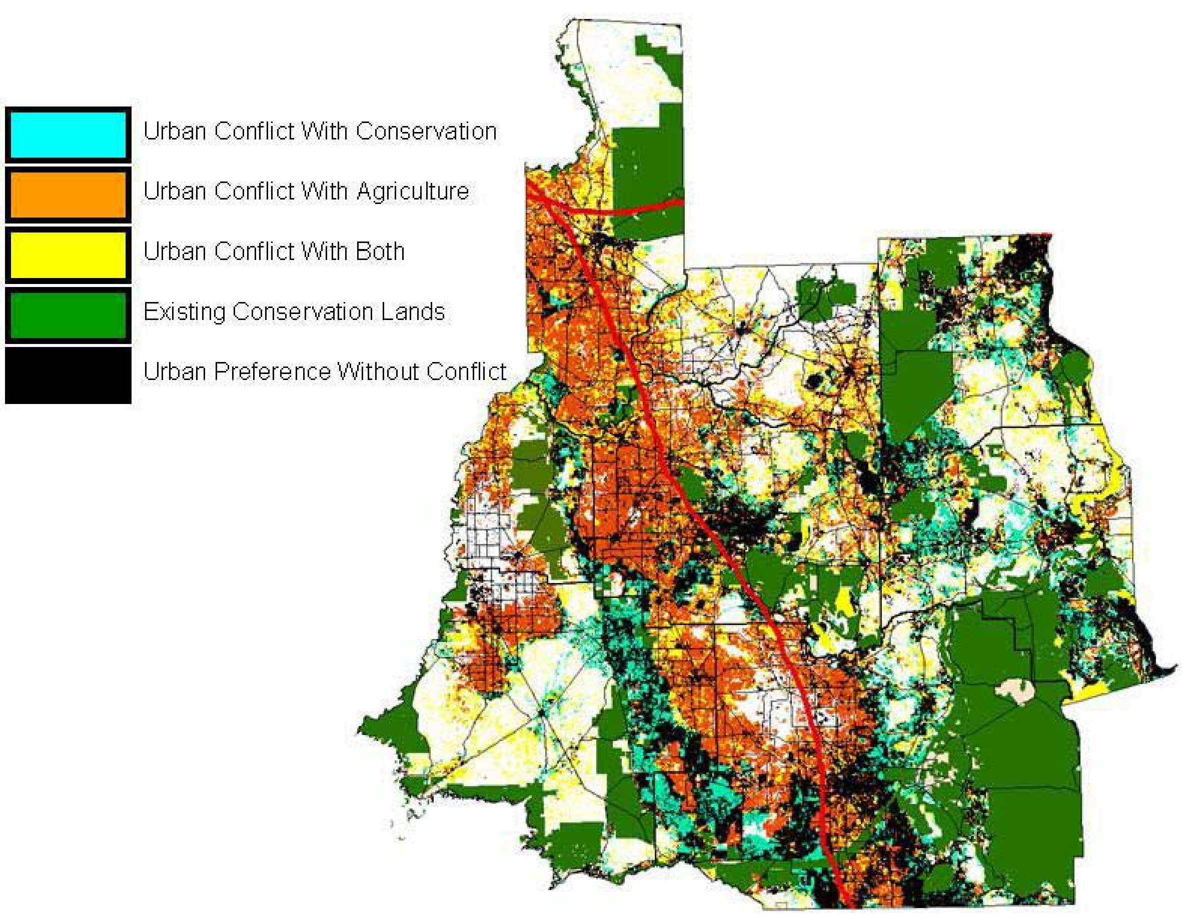


Table 4 is a tabulation of the relative percentages of the study area found within all the various combinations of the no potential conflict/potential conflict zones. Areas of potential urban conflict (areas of urban preference conflicting with areas of conservation preference, agricultural preference or both) are projected to occur in 47% of the study area. Areas of potential agricultural conflict are projected to occur in 45% of the study area. Areas of potential conservation conflict capture 36% of the study area. Areas of conservation preference with no potential conflict occur in 24% of the study area due to the quantity of lands already in protective status. Areas of urban preference with no potential conflict and agricultural preference with no potential conflict each occupy 10% of the study area. All together this suggests considerable conflict among the three basic land use classifications, but particularly between urban and agricultural land uses.

CONCLUSION

The LUCIS presented in this paper is a simple method for identifying the areas where future land use conflicts are most likely to occur. The results have the potential to be applied in a number of ways including decision support for local or regional planning activities, environmental regulation, or population modeling.

For example, a local or regional future land use plan might be modified to recommend protection for those areas of conservation preference with no potential conflict with, perhaps, little to no controversy. Or similarly, the no-conflict areas identified as having urban preference might be included within an urban reserve boundary or some other land use designation that suggests future development, again possibly with few objections. Environmental regulation might be designed to dissuade development in no-conflict/high conservation preference areas and encourage development in no-conflict/high

TABLE 4 Percentages of the Study Area In No Conflict Preferred for Conservation Land Use, No Conflict Preferred for Urban Land Use, No Conflict Preferred for Agricultural Land Use, Conflict Between Urban and Agricultural Preference, Conflict Between Urban and Conservation Preference, Conflict Between Conservation and Agricultural Preference, and Conflict Among All Three Land Use Preferences

Classification	Hectares	Percent of Study Area
No potential conflict and preferred for conservation land use	440,955	24
No potential conflict and preferred for urban land use	174,435	10
No potential conflict and preferred for agricultural land use	170,748	10
Potential conflict between urban and conservation land use preferences	201,992	11
Potential conflict between urban and agricultural land use preferences	351,874	20
Potential conflict between conservation and land use preferences	160,381	9
Potential conflict among all three land use preferences	284,505	16
TOTALS	1,787,890	100

urban preference areas. If protection for agricultural lands is a community concern, then a package of disincentives might also be created for the areas of no-conflict/high agricultural preference. Or, a community might choose to focus on resolving the future of the urban conflict areas as these are usually on the margins of existing urban areas and suggest where future contention will likely be high.

Further, LUCIS has the potential to either enhance the development of alternative futures by identifying those areas in the landscape about which decisions are likely to be most contentious or it could serve as a basis for sequencing the distribution of future population either as a surrogate for more complex population distribution models or in lieu of sufficient spatial data, for example locations of new road corridors and utility extensions. In the classroom studio setting, the results of the conflict mapping were used to identify a sequence for distribution of future population in order to visualize future land use alternatives. These alternatives represented a range of scenarios including a laissez faire option where existing densities and development patterns were allowed to continue unaltered; a new urban policies scenario in which increased densities in newly developed areas and infill in existing developed areas were combined to accommodate projected population growth in a smaller space than otherwise could be achieved; and a green infrastructure scenario where existing densities remained but a network of ecological areas was set aside to secure a modest framework of ecological connectivity and protection.

The results of LUCIS in the case study area were consistent with intuition and trend. With a steadily growing population, lands with environmental and agricultural value will continue to be subsumed by urban land uses in the absence of conscious policies of intervention or protection. It is possible to demonstrate the potential impacts of an array of policies using LUCIS as a one-time modeling strategy or iteratively to capture change over time. LUCIS combined role-playing to introduce and exaggerate bias with standard suitability analysis. In real land use scenarios beyond the classroom, the role-playing would not be required, but the biases of the parties involved could be easily captured and presented in contrast with one another. The result, we believe, will be a useful GIS strategy with the potential to bring together findings from the science of biological conservation and land use decision making.

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LITERATURE CITED

Ahern, J. 2001. Spatial Concepts, Planning Strategies, and Future Scenarios: a framework method for integrating landscape ecology and landscape planning. Iin J. Klopatek and R. Gardner, editors. *Landscape Ecological Analysis: Issues and Applications*. Springer-Verlag, New York, USA. Pp. 175201.

BEBR (Bureau of Economic and Business Research) www.bebr.ufl.edu. Accessed February 1, 2005.

Dale, V.H., S. Brown, R. A. Haeuber, N. T. Hobbs, N. J. Huntley, R. J. Naiman, W. E. Riebsame, M. G. Turner and T. J. Valone. 2000. Ecological Principles and Guidelines for Managing the Use of Land. Ecological Applications. Ecological Applications 10 (3):639-670.

ESRI, Environmental Systems Research Institute, Inc. 1996. Working with the ArcView Spatial Analyst. Environmental Systems Research Institute, Inc., Redlands, California, USA.

Expert Choice Software. www.expertchoice.com. Accessed March, 2004.

Florida Department of Community Affairs: Summary of Florida's Regional Forums on Growth Management. www.dca.state.fl.us/fdcp. Accessed February 1, 2005.

Hulse, D. W., A. Branscomb and S. G. Payne. 2004. Ecological Applications, 14(2).

Lyle, J.T. 2002. Design for Human Ecosystems. In Simon Swaffield, Ed. *Theory in Landscape Architecture: A Reader.* University of Pennsylvania Press, Philadelphia, Pennsylvania, USA. Pp 178.

Lyle, J.T. 1985. *Design for Human Ecosystems*. Van Nostrand Reinhold, New York, USA.

Malczewski, J. 1999. *GIS and Multicriteria Decision Analysis*. John Wiley & Sons, New York. USA.

McHarg, I. L. 1969. *Design with Nature*. Natural History Press for The American Museum of Natural History. Doubleday, Garden City, New York, USA.

Odum, E.P. 1969. The Strategy of Ecosystem Development Science Vol. 164:262-270.

Saaty, T.L. 1980. "The Analytic Hierarchy Process", McGraw Hill, New York, New York.

Steiner, F. 2000. *The Living Landscape: An Ecological Approach to Landscape Planning*. McGraw-Hill, New York, USA.

Steinitz, C. 1990. A Framework for Theory Applicable to the Education of Landscape Architects (and other environmental design professionals). *Landscape Journal* 9 (2):136-143.

Steinitz, C., H. M. Arias R., S. Bassett, M. Flaxman, T. Goode, T. Maddock III, D. Mouat, R. Peiser, A.

Shearer. 2003. *Alternative futures for changing landscapes, the upper San Pedro River Basin in Arizona and Sonora*. Island Press, Washington, USA.

Thompson, J. F. 1978. *Using Role Playing in the Classroom*. The Phi Delta Kappa Educational Foundation, Bloomington, Indiana, USA.