DEVELOPMENT OF A MODEL FOR DEFINING AND PREDICTING THE URBAN-WILDLAND INTERFACE FOR LeFLORE COUNTY, OKLAHOMA

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CHAPTER I

INTRODUCTION

It has become increasingly important to properly manage the natural resources in the transitional zones between urban areas and traditionally wildlands, often referred to as urban-wildland interfaces, because of growing population, a rapid expansion of urban areas and people leaving urban areas to settle in rural areas. To do this, one must first be able to understand the various land cover, economic, social, political, and historical factors that are involved in the make up of these zones. A definition can then be developed and the existence of these interface zones may be predicted and appropriate management concepts applied.

If natural resources managers are to be able to effectively manage urban-wildland interfaces they need first to be able to identify the interface zones. Numerous attributes such as vegetative cover, land use, housing density, housing location, population density, land ownership status, surface water features, topography and other characteristics that could potentially affect the resources or the resource users must be considered. To accomplish such an undertaking, attributes must be referenced by a common denominator. One factor that each of the attributes has in common is a specific spatial location; these factors can all be referenced by their geographic location.

The function of an information system is to assist managers in making decisions. It is the chain of operations that takes an analyst from data collection, data storage, definition of the interface zones from database attributes, and analysis of data, to the eventual identification of the interface on the ground. A geographic information system (GIS) is one type of information system that has been designed to work with data referenced by spatial or geographic coordinates (Star and Estes 1990). A GIS is useful for areas where the objective of management involves multipurpose, intensively managed areas because it can handle large quantities of spatial data and summarize data in the form of maps, tables and descriptive statistics. An automated GIS which uses a computer environment is a powerful tool that can handle the quantity and diversity of large data sets in an effective and accurate manner. Within a GIS, information is stored in layers or themes. In vector GIS, information is stored in coverages. Each type of information exists in its own coverage; examples of these are topography, hydrology, property boundaries, land cover/land use, and soil types. Besides data storage, a GIS can perform a variety of analytical and statistical calculations for individual data sets and for combinations of data sets. These calculations and analyses are useful for management purposes and include calculating distances from one location to another; determining those locations which are contained within specified boundaries or within given distances from identifiable areas; calculating acreage of available resources as well as identifying areas such as urban-wildland interfaces (Herrington and Koten 1988).

Need For The Study

The interface between urban and rural settings represents a paradox, with the urban and rural perspectives having some characteristics in common, as well as points of conflict. Many city dwellers depend heavily on rural landscapes for recreational activities. Suburbanites or people living in the interfaces may argue that the presence of agricultural operations negatively influences their living space. For example, prescribed burning, a recognized forest and wildlife habitat management tool, has strong negative connotation for many city dwellers. Urban noise, wildlife, domestic and farm odors, dust control, and concerns about non-point-source pollution are other issues. "Urban America" creates waste, the disposal of which often depends on using land in rural areas. Thus, a tension zone is created between urban and rural settings. Resource managers are now beginning to experience a deluge of conflicts involving such practices as fire suppression, recreational overuse, watershed management, and traditional forest management. A better understanding of this urban-wildland interface is of utmost importance if managers are to successfully understand and maintain the values of such lands. To overcome and address these concerns a set of directives expressed at a recent workshop held by the Oklahoma State University, Division of Agriculture and the Environment clearly indicate that attention is being focused on the conflicts that are becoming more evident in the transition zones between urban and rural settings (CAE 1994). These directives include:

- Develop educational programs that describe and promote urban planning relative to the best resource use at the urban rural interface, resource conservation in urban ecosystems as well as agro-ecosystems, with special reference to the interdependency of urban and rural ecosystems.

- Promote research and educational programs that develop optimal multiple uses of natural resources with special reference to systems that incorporate agriculture and/or forestry and recreational uses.
- Develop educational programs that inform urbanites about the role of agriculture and/or forestry in improving and sustaining the environment, thus replacing anecdotal perceptions with technical assessments of the issues.
- Develop research and educational programs that emphasize the interdependency of rural and urban areas in determining the best management practices for solid waste disposal.
- Disseminate information relating to the use of prescribed burning as a tool for the management of natural resources, pertaining to forests, rangeland, and wildlife habitat. The information should make special reference to fire behavior, fire control and identification of the differences between wildfires and prescribed burning.

These directives are important for future programs addressing the urban-wildland interface. However, managers must first be able to recognize the characteristics of such zones.

Study Objectives

The purpose of this project is to develop a pragmatic model for defining the urban-wildland interface through an identification and evaluation of land-use/land cover, and economic, social and other factors, that potentially describe and impact these interface zones. The importance of this study is to offer resource managers a clear perception of factors and variables associated with urban-wildland interfaces and in so doing provide a basis for rational decision-making in these areas. It is hoped that the derived model will be robust and comprehensive enough to describe urban-wildland interfaces throughout the southern region of the United States.

The primary objectives of this project include:

1. the identification and evaluation of variables and data sources that will be included in the urban-wildland interface model;
2. the development of the model using LeFlore County, Oklahoma as the study area; and
3. the evaluation of the results of the identification process and potential application of the model to other areas of Oklahoma and a multi-state region.

Scope And Limitations

Several limitations concerning the overall scope of this project and specific data analyses are necessary. These include:

1. the development and implementation of the model will be restricted to one county in Oklahoma;
2. data input will include, but not be limited to, information derived from census studies, satellite imagery, other digital data sources, and field work. Some of these data have been previously processed by the Geography Department at Oklahoma State University; and
3. the study will not extend beyond the validation process. It is hoped that follow-up surveys of peoples' opinions, beliefs, and expectations may be done in subsequent studies.

CHAPTER II

LITERATURE REVIEW

Urban-Wildland Interfaces

Since the landing of the Pilgrims on the eastern coast of North America in the 1690's, communities were created by clearing and developing wildlands. Every farm, town, and metropolitan area was originally carved from either forested areas or open and wild landscapes. Settlements were usually established along or near natural waterways and were often inter-concentrated (Clawson 1973). As time passed and technology progressed, development continued to spread and overcame obstacles presented by wildlands. Early settlers viewed these undeveloped lands as either a barrier to be conquered or as a major source of raw materials for commodity production. Today, people often view these areas with different attitudes and motivations. A very strong factor of this motivation has always been the desire to use available resources. Recently, however, the attraction of rural landscapes and the appeal of a home on a large lot have strongly influenced human decisions to move beyond established cities. Several articles, journals, books, and meetings have attempted to address aspects of the problem of land use conversion from wildlands to urbanized areas (Clawson 1971; Healy and Short 1981; California Department of Forestry 1981; Oklahoma State University Center for

Agriculture and the Environment 1994). The concept of the urban-wildlife interface as a newly developing problem in natural resource management is seen by some resource managers as novel. However, a closer and in-depth scrutiny reveals otherwise. The growth of the United States as a nation over the past two centuries is intricately tied to the concept of the conflict between urban development and pre-existing wildlands. Reports of disputes involving forest managers, government officials and city planners, and citizen activists appear frequently in the current news media (CNN Morning News of 08/07/94; NPR "All Things Considered" of 08/19/94; and the Daily Oklahoman of 12/16/94 and 07/07/94).

The urban-wildland interface of today differs from earlier urban encroachment in wildland settings. In the early part of this century, great numbers of people left their farms and moved to cities as factory jobs became available. After World War 11, people in urban areas began to migrate back toward rural areas, creating suburbs around cities. By the late 1950's an 'urban/rural fringe' surrounded many cities, with manufacturing enterprises and suburban development merging with rural farm communities. Presently, land use decisions are guided by complex laws and regulations. Certainly, the many major environmental and land use laws of the late 1960's and the early 1970's reflect society's attitude to the use of the land and natural resources in general; many of these laws are national in scope. However, environmental laws, land use laws and forest practice regulations at the state level have probably been aimed to a greater extent at interface concerns (Bradley 1984). Additionally, city and county jurisdictions have also developed a variety of ordinances to deal with problems perceived to exist on the interface. Many of these ordinances are in the context of new or revised comprehensive land use plans. The involvement of local government in land use activities has reached new levels (Ewert 1993). This is to be expected as local governments often have the most at stake and also frequently have the greatest power to directly address interface conflicts.

This aspect of development is not unique to the United States, as there are a number of such conflicts elsewhere in the world. Populations have shifted substantially and continue to shift relative to initial patterns, particularly in the developed countries. While the urban-wildland interface may be a long standing reality, only now are natural resource managers facing issues that are more complex, intense, and contentious (Shands 1988).

The zone of transition may be better understood by discussing the competing uses for urban fringe lands and the principal motivations of landowners. This also provides insight into the complexity of the problem and why the management of these areas are of interest to natural resource managers. Lee (1982) suggests that the interface can be characterized as an ecological condition in which human activities and artifacts interact with natural objects in a wildland ecosystem. This is illustrated by the urban-wildland interface fire hazard problem: the interface is characterized by the rapid transfer of heat from wildland fuels to fuels found in residential structures, or vice versa. Another adverse and significant problem involves the use of these areas for recreation: for example, the impact of all terrain vehicles on the vegetation within these sensitive areas. Other potential problems occur when people move to these areas and bring along domestic animals (dogs and cats) which may impact the existing natural wildlife population.

An interface can be accurately delineated by distinguishing between its geographic, social, and ecological components. The union of all three components, thus, represents a situation in which values are assigned to particular linkages between human activities and natural ecosystems in an area where residential development is located within or near a forest. Most interface issues are extremely complex, since they involve intersections in varying degrees between geographical, social and ecological components (Lee 1984).

Lee (1984) suggests that the management of the urban-wildland interface tends to reflect the social values commonly seen in an advanced industrial western society. Basically, these areas are seen as places to escape urban pressures and negative attributes such as traffic noise, congestion, or air pollution. With this idea of searching for peace and tranquillity shared among many people, this leads to the creation of areas that experience high levels of use and severe resource impact. Management tools, such as site-hardening (which involves designating areas to be used by visitors), highly visible law enforcement, and amenity development are common to many interface areas.

Bradley (1984) defines an urban-forest interface as a series of zones such as developmental, conversion, modified practice zones, non industrial forestry zones or parcelization zones, and forest zones (Figure 1). The development zone (residential development in a forest environment) is a very popular image of the urban-wildland interface; other types of development may also occur there. This zone is especially attractive for development because of the potential for lower market prices of land the greater the distance form urban areas. In many cases, these less developed surroundings are within easy commuting distance to cities and provide many amenities not found in an urban setting. Open spaces, trees, streams and lakes are a few of the attractions that may lead developers and home buyers to this zone.

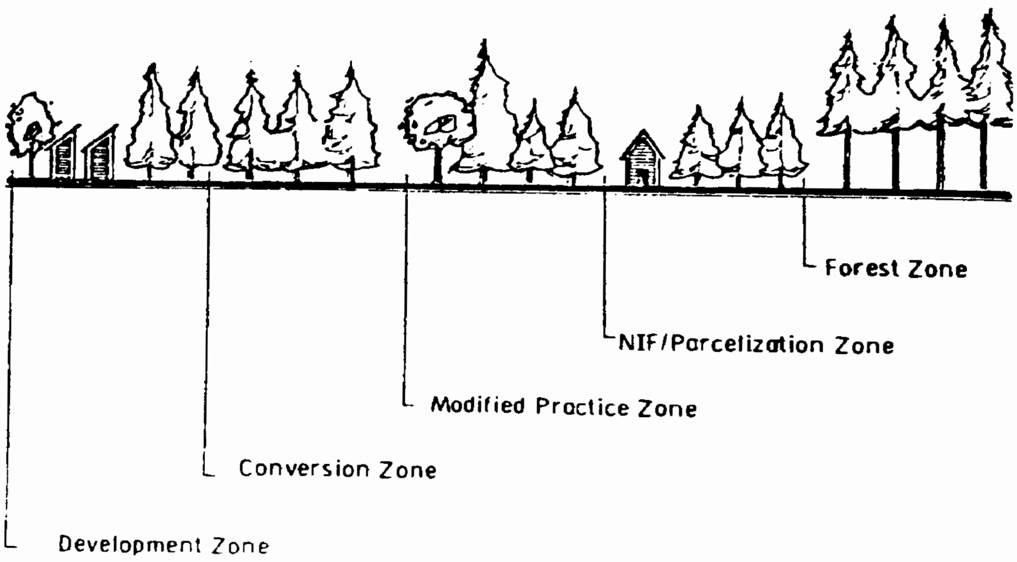

Figure 1. Illustration of the urban-wildland interface continuum ranging from the development zone to the forest zone (Bradley 1984).

The conversion zone is typically thought of as land in forest cover that is expected to change to another use fairly soon. This may be productive forest resource land or it may be marginal land. Conversion is usually prompted by an owner's expectation that a more profitable use exists for the land. Several factors may contribute to a landowner's decision to convert the land use, including favorable zoning laws by local government, change in tax status, or a change in the use of the adjoining lands. Like the development zones, the conversion zones may provide a logical and non-controversial transition of the landscape from one use to another. However, if such uses are inconsistent with jurisdictional constraints, individual perceptions of resource values, or prudent land practices, forest land conversion may continue to be a point of major controversy (Bradley 1989).

The modified practice zone, as the name implies, is an area in which traditional forest land management practices are modified to allow for continuation of the present forest uses, while at the same time making that use more compatible with adjacent land uses (Bradley 1989). Traditional forest management practices, such as widespread clear-cut harvesting without regards to visual impacts and water quality, are being re-evaluated. Presently, modifications include harvesting smaller areas and using different area shapes to create more pleasing viewsheds. Best management practices are now often implemented in most forest operations. These guidelines are designed to reduce the damaging impacts of forest operations on other aspects of the environment, such as water quality. Silvicultural practices are undergoing fundamental changes. Public land stewards have come under increasing pressure to implement strategies that balance opposing viewpoints between landscape-conserving protection and landscape-converting use. An impetus exists today to develop techniques and methods that help address this management problem (Long and Roberts 1992).

The non-industrial zone has also been widely termed the "non-industrial private forest (NIPF) and parcel size distinguishes this zone from the others. Two types of land uses are involved. The first involves landowners who have parcels ranging from 5 to 500 acres and have the main objective of growing trees in the non-industrial forest zones. The other is the large-lot landowner whose land use objectives may vary, but who has purchased a large tract of land in a zone where the local jurisdiction has restricted minimum lot size to 5, 10, 15, 25, or 50 acres. Often the land owner is seeking an affordable place to live or a place to escape on weekends where the amenities of the forest may be enjoyed. In zones of this type fewer problems generally exist. Management practices are less intensive and on a smaller scale than is usually found on industrial forest lands, often resulting in fewer conflicts with adjacent landowners (Bradley 1989). The forest zone consists of land whose principal management function is to produce natural resources, including wood and fiber, recreation, wildlife, fisheries, water, and forage. This land is held publicly or privately, usually in large parcels. Because it is a greater distance from urban development, few problems exist regarding land use conflicts or changing land use in the foreseeable future. This, however, does not mean that these zones are without problems. The problems often encountered here are conflicts between differing uses of the forest resource rather than problems associated with conflicts between forestry and urbanization (Bradley 1989). Studies of private landowners in Minnesota and southeastern Oklahoma showed that a major reason for owning land is for maintaining wildlife habitats (Bliss and Martin 1989; Walkingstick 1992). Other major resource uses are recreation and watershed management.

Cortner and others (1990) studied expectations of the public at large during wildfire occurrence in urban-wildland areas. They described the interface as an intermingling of wildlands with intersperse and adjacent development. These developments include wooden structures built within areas where fire is known to occur repeatedly. Homeowners and developers alike usually do not consider fire danger during building construction. However, they usually expect the local or nearest fire department and / or the Forest Service fire fighters to provide protection from wildfires.

Davis (1990) described three types of interfaces: classic, intermix, and isolated. Classic interface situations can be seen in many of the National Parks and State Parks, where subdivisions and other developments have become established along the park borders. In this case, the interface has a clearly defined boundary. In an intermix situation, developments such as homes or other structures are scattered throughout the wildland area. This haphazard pattern of land ownership presents the resource manager with a complex set of management problems such as easement rights and priorities for fire protection. In the isolated interface, wildland areas are essentially completely surrounded by development. Prime examples of this type of interface include municipal parks and greenbelts. Often, this was land that was deemed as prone to flooding, too steep, or containing some other factor that precluded development. The urban-wildland interface can also be thought as natural resource "eco-tones" in that they represent an area of transition between two communities that contain elements of both as well as some unique attributes (Ewert 1993). These attributes can be classified as social, spatial, ecological, and managerial (Figure 2 and Table 1). Social attributes include a greater diversity, both in ethnic and cultural terms, of the visitors, and a land ethic that is more focused toward the delivery of services. Examples include recreational opportunities, aesthetic residential sites, and watershed outputs rather than commodity production such as timber and grazing.

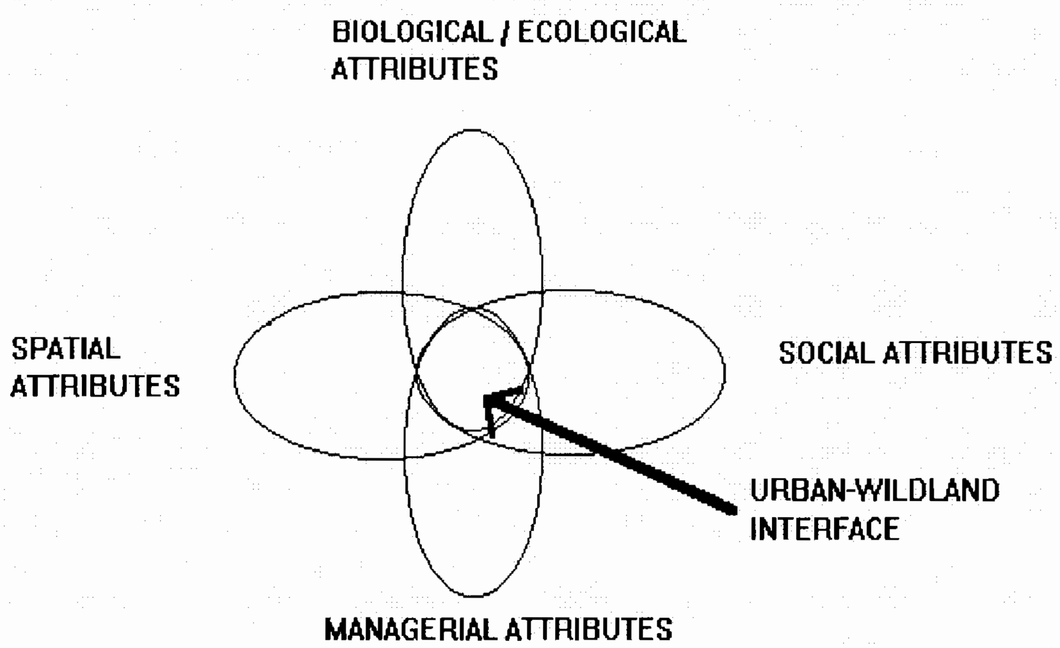

Figure 2. Diagrammatic relationship of the attributes that make up the urban-wildland interfaces.

Table 1. Examples of attributes related to urban-wildland interfaces (Ewert 1993).

Spatial Attributes	*Eco / Biological Attributes*
1) close proximity to urban centers	1) introduction of exotic species
2) high density year-round use	2) reduction of flora and fauna
3) increased non-site pollution levels	3) greater impact upon biological systems
Social Attributes	***Managerial Attributes***
1) changing land ethics	1) changing zoning strategies
2) higher demand on use of resources	2) saturation of available resources
3) emphasis on recreation	3) land ownership problems

Spatial attributes that are often associated with the urban-wildland interface include relatively small area size, close proximity to large population centers, ease of access and the clustering nature of many sites. In the latter case many urban-wildland sites tend to be stratified and clustered with use occurring in pockets, depending on the landscape and ease of access.

Ecological attributes of the urban-wildland interface imply a reduction in bio-diversity and wildlife habitat through human activities. Man's anthropocentric nature is largely to blame. Other ecological attributes include increased pollution from off-site (often referred to as non-point source pollution), the introduction of exotic plant species, a reduction in the efficiency levels in nutrient recycling, and an increase in soil toxicity through heavy metal concentration. Managerial attributes common to such areas usually center around ownership problems, development that tends to urbanize the wildland resources, and visitor control.

While multiple use concepts are widely acknowledged and often practiced, the externalities on the urban-wildland interface present a particularly difficult management challenge because of the concentrated nature of the activities. One group's activity is difficult to isolate from that of others because high levels of a variety of uses are often present at interface sites.

Ewert (1993) observed that the problems in urban-wildland interface centers on four important considerations for resources management and research. First, as previously described, wildland areas in close proximity to large urban centers present a natural resource that has unique attributes within easy accessibility to potentially millions of people. Second, these interfaces serve important social and ecological functions for society while simultaneously being extremely vulnerable to human impact and pressures. As a result of these impacts, interface areas deserve a higher level of research and management efforts in order to preserve the natural resource while meeting the demands of a diverse set of users. To lose the urban-wildland interface areas through overuse or incomplete management will deny substantial population segments an opportunity to experience a healthy and often spiritually refreshing experience in a natural setting that is relatively close to the area in which they live (Patterson 1991).

Brill (1989) suggests that public places such as the urban-wildland interface profoundly affect the public by providing and affecting the common good, and remaining open to general observation. This leads to the third consideration which involves a number of factors impacting the urban-wildland interface. Examples include urban encroachment and non-point source pollution, which can influence even more remote sites. From this perspective the urban-wildland interface presents a set of challenges that will be representative of many future wildland management settings.

Finally, the fourth major factor having profound impacts in many urban-wildland interface areas is the change in land use and land allocation. There are a number of trends relative to land use and land allocation. These include conversion of wildlands to developed areas, higher forest land prices, division of forest land into smaller areas and, increased land ownership inside or adjacent to interface areas by non-traditional landowners, such as second homeowners and investors (Healy 1984). While the ownership of land may be satisfying to a landowner, various problems may exist. First, without proper management, the land's overall productivity for a variety of purposes may decline. Not only timber production, but also fisheries, wildlife, and aesthetic resources may be adversely affected. Secondly, city dwellers are less aware of the interdependency of their activities on ecosystems, as evidenced in wildfire catastrophes. However, in the non-industrial forest land, few problems generally exist. Management practices are less intensive and on a smaller scale than usually found on industrial forest lands, resulting in fewer conflicts with adjacent landowners (Healy 1984).

Perceptions Of The Urban-Wildland Interfaces

Bradley's (1984) view of the urban-wildland interface continuum suggests a clear distinction between land uses and their associated opportunity and constraints. However, it is important to point out that in practice not all people have the same perception of the interface. Individuals are motivated to own or use land for different reasons. These decisions are a function of the owner's and / or resource manager's perception of the use of the land. These variations in perceived use leads to yet another more fundamental problem: agreement on a definition of the urban-wildland interface. Without some notion of where the problem lies and an understanding of its dimension, effective solutions are unlikely.

The issues of economics, aesthetics, physical and biological productivity, current use and jurisdictional boundaries are identified as inherent characteristics. When these characteristics are considered as a criterion by which the interface is defined, it becomes apparent that there is lack of consensus regarding those lands that constitute the urban-wildland interface. Without this consensus, concise problem definition can not be achieved and subsequent proposed solutions to perceived problems may be inappropriate. Using a proposed economic criteria, the interface between forest use and urbanization is approximately equal to the marginal land value for forest uses. As one moves away from this marginal land to areas that are more valuable for urban uses, urban values exceed the forest values. Conversely, one can also move away from the marginal land to areas that is are more valuable as forest. Therefore, a relevant point at which to compare land in forest uses with land in urban uses would seem to be at the marginal value. However, non-spatial attribute makes this definition difficult to characterize on a map. When one compares resource values at the margin, the idea of a fixed hierarchy of land use becomes almost irrelevant. Fixed hierarchy relates to the traditional land use concepts held by many for a long time. Farming for a long time was given priority. At the margin, which is where decisions are made, uses of forest land as forest compete evenly with urban related uses of forest land (Ewert 1993).

The value of forest land, whether for timber or for other purposes, varies widely. In this sense, the interface occurs within a band, possibly of uneven width, where uses of forest land with different values compete with urban land uses or values. Relative land values within the band are determined mainly by accessibility, relationship of uses to other activities, and productivity of the land itself for various purposes (Ewert 1993).

Vaux (1992) has proposed another dimension to the idea of the interface. He describes it as a political phenomenon and observes that conflicts in land use at the interface comes about because of sharply different views of the social value of forest lands. Social values derived from or dependent on mainly urban values are having an impact on forest land uses well beyond the traditional boundaries of urban areas. The interface is between different political forces, each of which has a differing set of perceptions about the value of forest to society. This definition directs attention to the political groups that compete for influence in determining how forests lands are used. According to this definition, however, all forest policy issues would be interface issues, since any controversy over the use of forest involves differences in view over the social values to be emphasized in forest policy.

From the aesthetic perspective, the interface is a wide and sometimes nebulous boundary distinguished, for the most part, by the presence or absence of trees. From a jurisdictional perspective, the interface is sometimes thought of as either the boundary between public and private land or where parcel size begins to change from relatively small to relatively large lots. Where structures appear on the landscape, the interface may be defined by a line drawn between the built and unbuilt environment. Finally, using physical and biological growth criteria, the interface may resemble a soil map, where highly productive lands are distinguished from less productive lands. Obviously, to come to terms with the "appropriate use" for interface lands and the mechanism whereby those uses are achieved without major conflict, all relevant factors and perceptions must be considered. These must be made an explicit part of the strategies and policies that are implemented in order to achieve land use and forest resource goals.

To briefly summarize, research in urban-wildland interface can be classified into a number of areas. Four of the more salient ones are: physical and biological impacts from high use levels, fire related issues such as homeowners awareness of the fire risk, recreation on interface lands, and changes in land use and land allocation.

Census Bureau Tiger/Line ™ Files

The Census Bureau TIGER System automates the mapping and related geographic activities required to support programs of the U.S. Census Bureau starting with the 1990 decennial census. TIGER is an acronym for Topologically Integrated Geographic Encoding and Referencing system. A glossary of terms relevant to the TIGER system is included in appendix 1. The Census TIGER system provides support for the following:

- Creation and maintenance of the digital geographic database that includes complete coverage of the United States, Puerto Rico, the Virgin Islands of the United States, American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, the Republic of Palau, the other Pacific entities that were part of the Trust Territory of the Pacific Islands (the Republic of the Marshall Islands and the Federated States of Micronesia), and the Midway Islands.
- Production of maps from the Census TIGER database for all Census Bureau enumeration and publication programs.
- Ability to assign individual addresses to geographic entities and census blocks based on polygons formed by features such as roads and streams (Census Bureau 1993)

The design of the Census TIGER database adapts the theories of topology, graph theory, and associated fields of mathematics to provide a disciplined, mathematical description for the geographic structure of the United States and its territories. The topological structure of the Census TIGER database defines the location and relationship of streets, rivers, railroads, and other features to each other and to the numerous geographic entities for which the U.S. Census Bureau tabulates data from its censuses and sample surveys. It is designed to assure no duplication of these features or area occurs The building of the Census TIGER data base integrated a variety of encoding techniques such as automated map scanning, manual map "digitizing", standard data keying, and sophisticated computer file matching. The goal is to provide automated access to and retrieval of relevant geographic information about the United States and its territories.

In order for others to use the information in the Census TIGER database in a geographic information system (GIS) or for other geographic applications, the Census Bureau releases periodic extracts of this database to the public, including the TIGER/Line ™ files. Various versions of these files have been published. The most recent release, the 1992 TIGER/Line ™ files, contains updates and revisions of the 1990 decennial census.

TIGER extract products are particularly valuable for use in a GIS environment and research in general because there is a direct linkage between the 1990 decennial census data products and the TIGER database extracts. TIGER's digital description of the Nation's legal and statistical entities includes Federal Information Processing Standards (FIPS) codes and the Census Bureau codes so that these can be matched easily with the 1990 census data. Related database files include the TIGER Geographic Names File which provides the bridge between the geographic entity codes, such as state, county, and minor civil division found in TIGER/Line ™ files and their official names. Other data base files are the Summary Tape Files which provide 1990 statistical data for a wide range of subject headings and geographic entities compatible with the TIGER/Line ™ files. Two other useful files are the TIGER/Urbanized Areas Limit files which contain just the features that form the boundaries of the 1990 census urbanized areas along with the codes in a reduced TIGER/Line ™ file format and the TIGER/Line ™ files for the 103rd Congressional District which contains just the features that form the boundaries of the districts of the 103rd Congress; each set of files covers one state. All these files are available to users from Customer Services of the Census Bureau.

Smaller files that relate only to an individual county are also available. In these files, geographic coverage for a TIGER/Line ™ file is a county or statistically equivalent entity. The county files have a coverage area based on their January 1, 1990 legal boundaries obtained in response to the Census Bureau's Boundary and Annexation Survey. Even though the Census TIGER database represents a seamless national file with no overlaps or gaps between parts, the county-based TIGER/Line ™ files are designed to stand alone as independent datasets. The files can be combined to cover the whole Nation and its territories. The files that pertain to LeFlore County, Oklahoma were used as the primary data source in this project.

The TIGER/Line ™ files contain data describing three major types of data:

- Line features including: roads, railroads, hydrography, miscellaneous transportation features and selected power lines and pipe lines, and boundaries
- Landmark features including: point landmarks such as schools and church areas and landmarks such as parks and cemeteries.
- Polygon features which include geographic entity codes for areas used to tabulate the 1990 census statistical data locations of area landmarks.

The line features and polygon information form the majority of data in the TIGER/Line ™ files. Some of the data describing the lines include coordinates, feature identifiers (names), feature classification, codes address ranges, and geographic entity codes. The files contain point and area labels that describe landmark features. These features provide locational references for field staff and map users. Area landmarks consist of a feature name or label and feature type assigned to a polygon or a group of polygons. Landmarks may overlap or refer to the same set of polygons.

Spatial objects in the Census TIGER data base are interrelated. A sequence of points define line segments and lines segments connected to define polygons. The Census Bureau uses topology as the foundation for organizing spatial objects in the Census TIGER database to explain how points, lines, and areas relate to each other. The Census TIGER database uses these points, lines, and areas to provide a disciplined, mathematical description of the earth's surface features. Topology provides a basic language for describing geographic features (Star and Estes 1990).

The recent and rapid development of GIS as a powerful analytical tool combined with the Census Bureau's Tiger/Line ™ files as a rich source of ample data has not given much time for both these entities to be integrated. The potential seems astronomical and already researchers, law enforcement agencies, and retail merchants are beginning to realize this vast untapped potential. Retail merchants, for example, often believe profitability is closely tied to customers location and spatial relationships between customers and the retailer. Many retailers are now actively using this strategy to gain advantage over their rivals. The very nature of the Tiger Line ™ Files lends itself to becoming an invaluable data source when integrated with remotely sensed data and GIS technology.

Landsat Multispectral Scanner images

Landsat MSS images are remotely sensed digital data which are obtained using multispectral scanners mounted on orbiting satellites. Since the launch of the first Landsat satellite in 1972, considerable research has been carried out towards the use of Landsat data for land use/land cover mapping in many parts of the world. Automated classification of satellite imagery is an established method of land cover mapping (Teply and Green 1991). These images have proven to be very useful in providing land cover information primarily because of their timeliness, large area coverage and relatively low cost. Landsat multispectral scanner data are unique because information about vegetation condition can be quantitatively related to differences in the amount of reflected or transmitted energy recorded in each of the four spectral bands. Reflectance from plants growing in their natural environment is the result of a combination of factors such as leaves, branches, dew, and dust. Using images taken at two different times of the year McDaniel and Haas (1982) successfully classified forest cover in northern Minnesota into species types. They concluded that Landsat MSS data are sensitive to seasonal change in vegetation growth conditions within relatively uniform vegetation / soil system. There are other reports that demonstrate the significant correlation between vegetation surface variables and remotely sensed data (Tucker et al. 1985). Teply and Green (1991) successfully demonstrated that digital processing of satellite imagery combined with field visits and aerial photographs as ancillary data, can accurately produce broad GIS coverages of forest and range vegetation type. When this simple relationship cannot be used, other statistical analysis techniques such as linear regression and image enhancement techniques have been employed. Landsat MSS has been used successfully in areas characterized by large homogenous cover units and where cover types are composed of only a few vegetation types (McDaniel and Haas 1982). Another use of Landsat MSS is in monitoring changes in forest stands by using multi-temporal data sets and principal component analysis (Vogelmann 1988).

These images have their limitations. It remains difficult to map some point and line features, particularly in digital form, due to the fact that they are not always recognizable at the spatial resolution of the data. Landsat MSS scenes have pixels of size 80 meters by 80 meters, which is a measure of resolution. Another constraint of satellite images is the distortion of features which comes about due to sensors type and curvature of the Earth's surface. Care, therefore, must be exercised when interpreting results. Mapping land cover types has also had limited success in high relief areas, particularly when associated with a complex mix of vegetation. The tropics provide abundant examples of such combinations. The problem arises mainly because of slope and terrain orientation which cause marked variation in the radiant energy intercepted by the sensors. As a result, cover types may have similar spectral reflectance but quite different radiance due to the shading effect of topography. This makes classification extremely difficult. With the continued advances in computer technology, more complicated algorithms are being used to overcome these problems (Ahmed et al. 1992). In addition, some researchers are beginning to overcome computation difficulties and are now doing classification using the Anderson Level III classes (Anderson et al. 1976) with Landsat MSS. Wolter and others (1995) in their studies dealing with comparing Landsat MSS and Landsat Thematic Mapper (TM) images showed that the 30-m spatial resolution of TM data is responsible for only slight increases in classification accuracy when compared with the cheaper Landsat MSS. When working with small budgets using multi-temporal TM data rather than MSS data, may not produce results that justify the added cost (Wolter et al. 1995).

As with all remotely sensed data and information derived from it, there is a degree of error in the quality of the usable information. In order to minimize this, ground truthing is a necessary phase of any analysis of remotely sensed data. Ensuing from this is the common practice of using remotely sensed data and field data and cross-checking continuously the results of the image analysis. Through the use of aerial photointerpretation techniques on photographs that are taken within the same time as the satellite images has also proven successful for ground-truthing (Sader et al. 1990).

Usually field collected data provide more accurate and precise results but the collection of data is slow. In rugged terrain it may be economically impractical or confined only to a few ground samples in accessible locations (Ahmed et al. 1992).

CHAPTER III

RESEARCH METHODS

Development of a model or a set of procedures for defining and predicting urban-wildland interfaces that covers a large area is a difficult task that requires a considerable amount of communication and planning. The primary goal of this study is to define and physically locate the urban-wildland interface so that resource managers may be able to study their characteristics and the interactions that take place among the attributes that define these areas. This study employs GIS, a very powerful modeling and analytical tool, and a hierarchical approach to develop a set of procedures that defines and predicts the interface zones. This approach requires that the critical factors, associated with the attributes, be evaluated. Only factors considered important are chosen for incorporation in the model. These factors will help determine the locations of the interface zones for an area of interest. A set of attributes or a criterion is used to define the urban-wildland interface. The area selected for this study is an area in southeastern Oklahoma, LeFlore County.

Study Area Description

The study area for this work is LeFlore County which is located in the southeastern part of Oklahoma (Figure 3). The county is bordered by Seqouyah County on the north; by Haskell, Latimer, and, Pushmataha Counties on the west; and by McCurtain County on the south. The eastern side is contiguous with the Arkansas state line (Figure 4). Poteau (population 8,200) is the county seat. The total area of the county is 1,582 square miles and has a population of 46,300 (Statistical Abstracts for Oklahoma 1993). Other major urban centers in the county are Pocola (population of 4,600), Heavener, (2,800), Spiro (2,500) and Arkoma (2,300). The large city of Forth Smith, Arkansas (55,000) lies east just across the Oklahoma / Arkansas state line (Figure 5).

Physiography

LeFlore County lies mainly in the Arkansas Valley and the Ouachita Mountains physiographic sections. Topography differences range from the nearly level flood plains of the Arkansas, Poteau, and Kiamichi Rivers to the steep mountainous areas in the southern part of the county. Many low ridges are adjacent to the rolling and undulating areas of the northern part of the county. The Poteau River drains the northern part of LeFlore County and then empties into the Arkansas River. The lowest point, 420 feet above sea level, is on the Arkansas River. Elevation of the valley areas range from 465 feet in the north to 920 feet in the south.

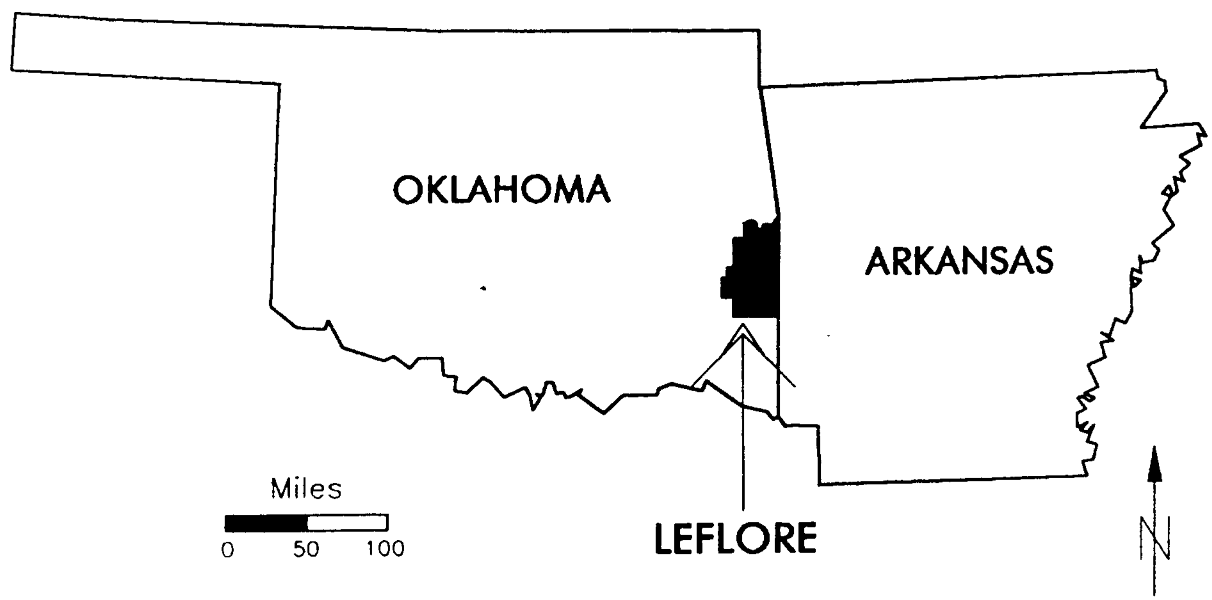

Figure 3. The location of LeFlore County in the state of Oklahoma.

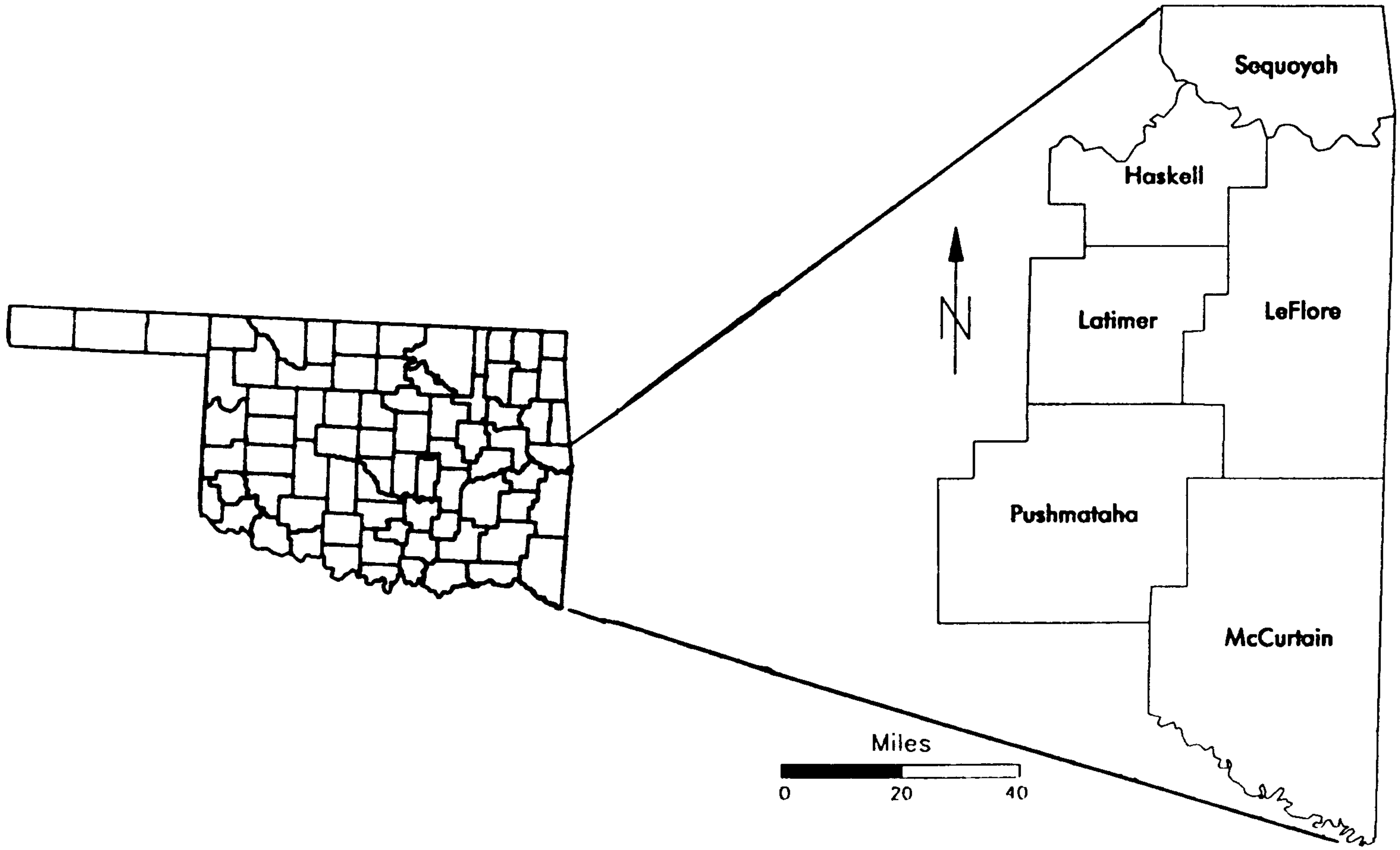

Figure 4. Map of southeastern Oklahoma showing LeFlore County and bordering counties.

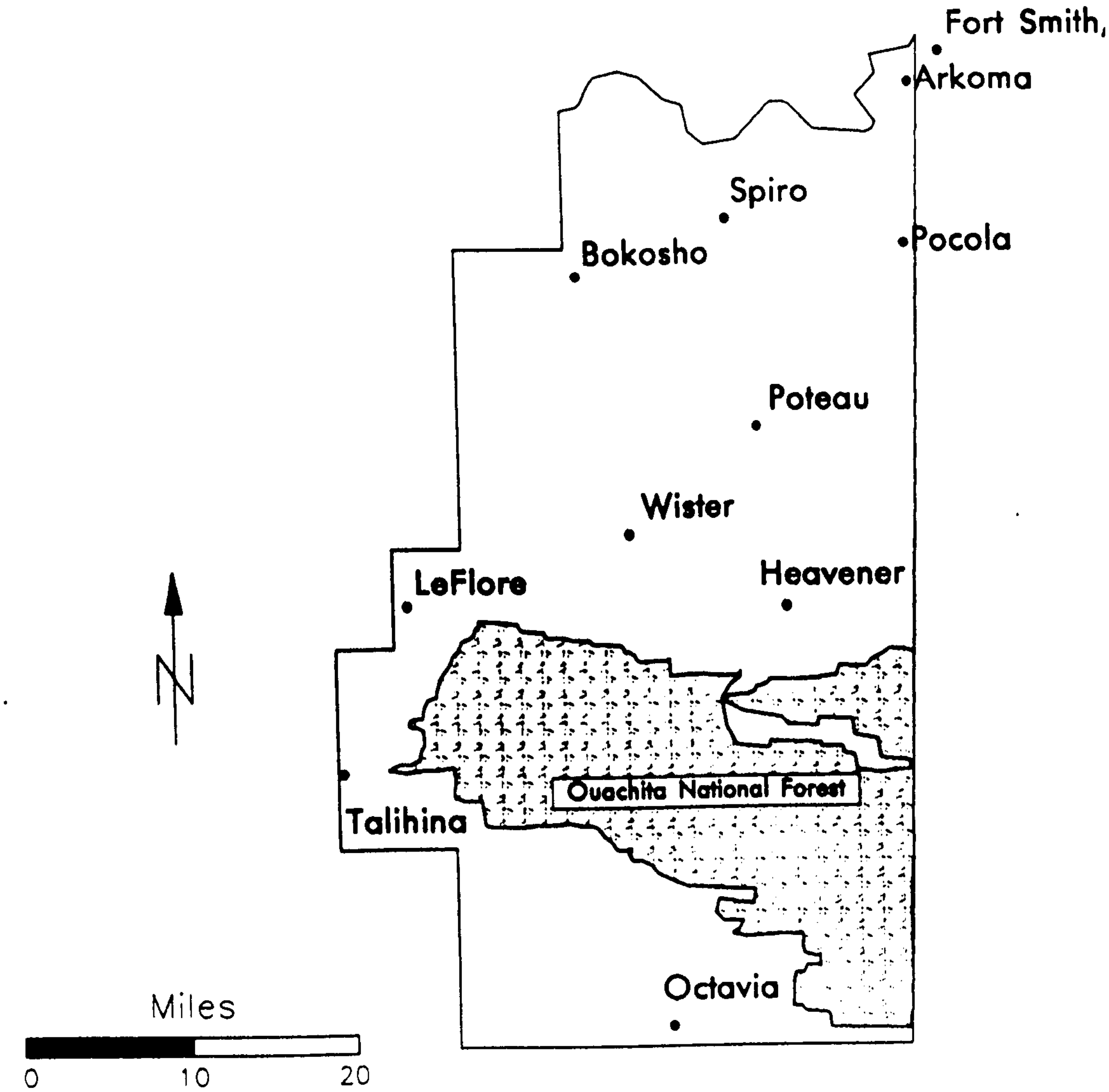

Figure 5. Location of major towns and Ouachita National Forest within LeFlore County, Oklahoma.

The hills and mountains range from 700 feet to nearly 2,400 feet (Statistical Abstracts for Oklahoma 1993).

Settlement

LeFlore County, named for Choctaw Chief Greenwood LeFlore, was included in the land claimed for Spain by Columbus in 1492 (Peck 1963). The county was included in the land claimed for France by LaSalle and later sold to United States in the Louisiana Purchase in 1803. Early settlement in the county was mainly by Choctaw Indians. Land allotments were made to the relocated Indians on the basis of the cash value of the land. At the time of statehood in 1907, the population of the county was about 29,000 (Peck 1963). Most of the early farmers lived on small farms that only provided subsistence. Cotton was the major cash crop and corn was grown for human and livestock consumption. In the past twenty-five years, the trend in farming has been away from cultivation and back to livestock farming. Many of the upland areas are now planted to pasture; the areas still cultivated are mainly in the bottomland of the Arkansas River. Many of the people now living on farms also have part-time jobs (Statistical Abstracts for Oklahoma 1993).

Natural Resources

Timber, water, fish, wild game, and scenic beauty are some of the natural resources of the region. LeFlore County was chosen as the study area primarily because it has a substantial economy based on natural resources. Woodland industries use hardwood and pine timber. Several sawmills and charcoal plants operate in the southern part of the county. The United States Department of Agriculture Forest Service, manages the Ouachita National Forest for present and expected flows of services and products. In November 1988, President Reagan signed into law a bill which established the Winding Stairs Mountain National Recreation and Wilderness Area. This, in effect, changed the management thrust of a large part of the Ouachita National Forest from one emphasizing timber-wildlife management to one primarily emphasizing recreational activities. Congress requires that these lands be managed for a variety of benefits including outdoor recreation, timber, water, forage, wildlife habitat, wilderness and minerals. By using careful management practices and coordinated uses, the Forest Service assures that the resource demands placed on the National Forest are met and the productivity and environmental quality are maintained (Management Plan for The Ouachita National Forest 1990).

Modeling Procedure

The primary reason for using GIS was to design a model that can be used as an analytical tool in decision making processes. GIS provides an integrated platform to store, analyze, update, and manipulate the various factors that are used to define the urban-wildland interface. In data manipulation, the set of procedures that define a criteria is called a data model. Models can be designed with the OVERLAY module and / or other modules in the PC ARC/INFO Core. The concept of GIS layers is especially important when modeling. Before computer use became widespread, the most widely used approach was to actually overlay registered (see glossary in Appendix 1) maps on paper or transparencies; each map corresponded to a separate theme. Today, computer GIS layers replace those hardcopy layers and allow much more flexibility for re-coloring, recoding, and reproducing geographical information (Steinitz et al. 1976). This study involved analysis and combination of Landsat Multispectral Scanner images, and Population and Housing data derived from Tiger/Line ™ files.

Two principle steps must be considered before GIS products can be generated: planning and processing. The planning step in this project included in-depth review of current GIS applications in forest resources management and discussions regarding potential variables that would make for a pragmatic cartographic model. Three main types of modeling approaches are available. These are simulation modeling in which the analyst attempts to faithfully represent the real world using computers, predictive modeling in which the analyst seeks to account for the way nature behaves by seeking out the most critical factors that dictates the way nature behaves and cartographic modeling in which the analyst presents detailed flow charts and careful plans to decide which data are important and how they should be used. For this work the latter approach was chosen. An outline of the cartographic modeling procedures used in this study is presented in Figure 6.

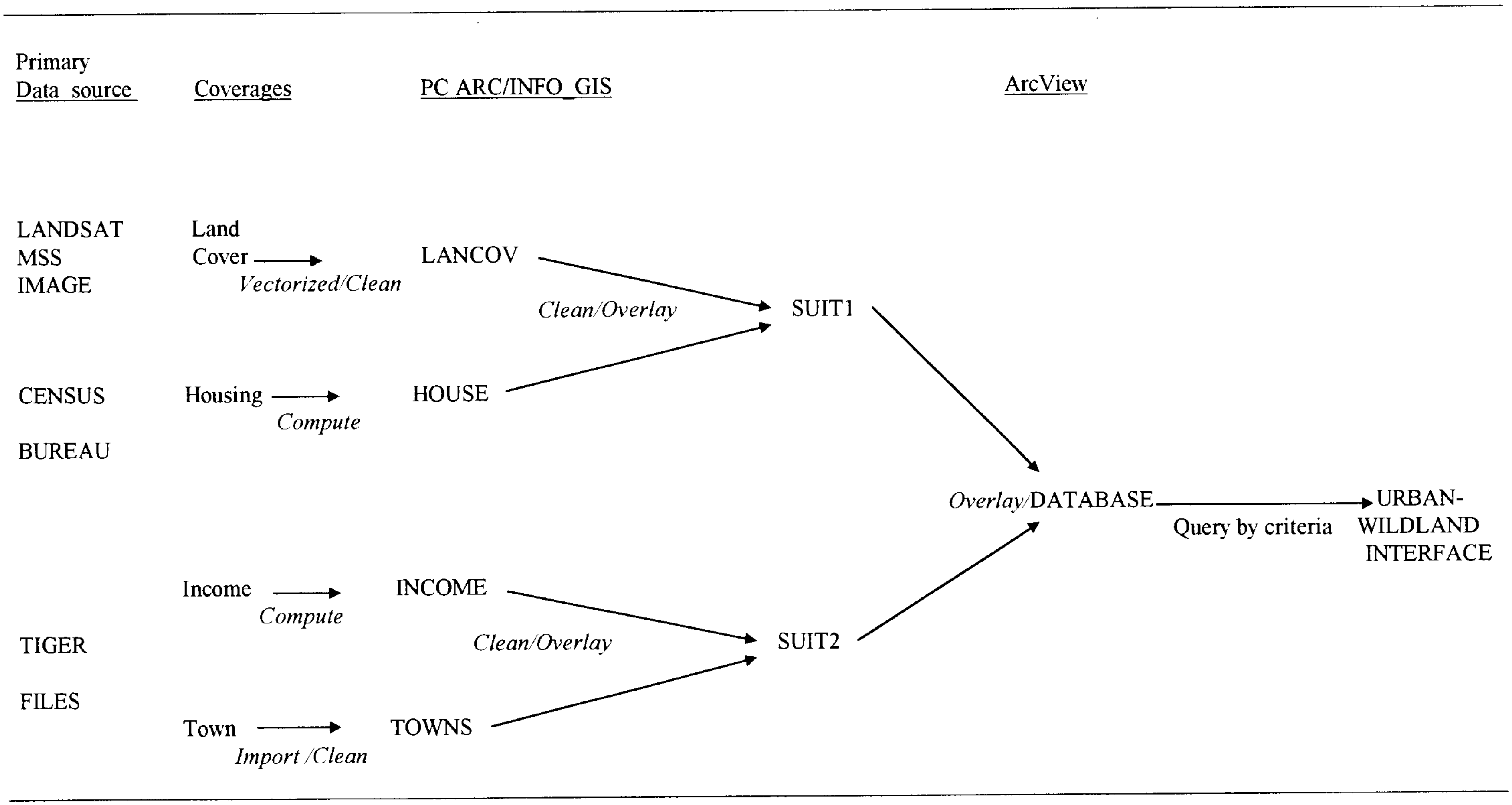

Figure 6. Flow chart depicting the cartographic modeling procedures followed in this study.

The rapid development of the personal computer technology has recently made micro-computer based geographic information systems a valuable tool for solving real world problems. Not so long ago, this computing capability was available to only a few researchers. More important to resource managers, computer monitors now have the capability to display graphics at very high resolution and in pseudo three dimensions. The software industry follows a similar trend; more powerful GIS packages are now available and these often have greater data processing and analyzing capabilities. This trend in the computing industry has made inexpensive applications available to small organizations.

The basic hardware components used in this study included a 486-based personal computer, a mouse, input device and a color PaintJet printer with the ability to produce high quality graphics. Marble and Peuquet (1983) state that all complete or full GIS perform the following major functions:

- DATA INPUT: normally consist of a mixture of manual and automatic digitizing operations together with associated data editing activities.
- DATA STORAGE AND RETRIEVAL: initial creation of the spatial database together with subsequent update operations and query handling.
- DATA MANIPULATION: Creation of composite variables through processing activities directed toward both spatial and non-spatial attributes of system entities.
- REPORT GENERATION: creation of both tabular and cartographic reports reflecting selective retrieval and manipulation of entities within the database.

For this work the popular GIS package PC ARC/INFO was used to do the overlay of the data layers and create the database using polygon and line topology. PC ARC/INFO stores its data files in dBase format. This is useful for complete integration of data from other sources such as the TIGER line ™ files. Additionally, this package allows for the easy updating of both spatial and attribute information. ArcView was used to manipulate the database by allowing queries to be performed with display of the results. Another useful feature of this software is its capability of producing high quality colorful paper maps.

Strategy For Developing The Model

The professional forestry community has realized that it would not be possible to put together a few simple sentences that adequately define the urban-wildland interface. Hence, one may never know if he has arrived at the 'real' interface, but may know whether he is moving in the right direction. Natural resource managers have chosen to use criteria to provide a common and reasonable understanding of what is meant by the urban-wildland interface. A large number of differing concepts have been suggested and explored. These have in common the development of a set of pertinent criteria that suggest an implicit and useable definition of the urban-wildland interface; the actual criteria differ however. A criterion is a category of conditions or processes by which the urban-wildland interface may be assessed. A criterion is characterized by a set of related indicators which are monitored periodically to assess change. A factor is a measure of an aspect of the criterion. It is a quantitative or qualitative variable which can be measured or described and which, when observed periodically, demonstrates trends. No single criterion or factor defines the urban-wildland interface; they must be looked at as a set of interrelated characteristics within a social and environmental context.

Development Of A Definition

For this project it was proposed that urban-wildland interface be defined or characterized by a set of criteria and related factors. The criteria selected must reflect the consensus of very diverse points of view; they do not reflect the particular needs or concerns of any one group. After much thought and evaluation the criteria selected for this study are:

- Physical and biological criteria which define the interfaces in terms of what actually constitutes the zone. This refers not only to flora and fauna but also to physical factors such as soil types. Ideally, an excellent measure of biological factors would be to incorporate the results obtained from Gap analysis projects; this is not yet available for Oklahoma. However, this may be closely depicted by soil types which distinguishes highly productive lands from the less productive lands. Vegetation, taken as the composite of the whole assemblage of plants growing in an area, responds to such physical environmental factors like climate, soils, hydrology, and elevation. Therefore, natural vegetation provides a good summary of the physical properties of any location.

- Jurisdictional criteria can view the interface as either the boundary between different land ownership status or whether the areas lie within the boundaries of minor civil divisions (such as town boundary limits). Differing sizes in parcels of lands may also be used to quantify this criterion. Often, residential lots within town limits are small in size when compared to lots outside of the town limits. State parks, National Parks and National Forests are often visited by urban residents and form the general public ownership category.
- Economic criteria can be measured by looking at median income levels per household. One may hypothesize that rural residents are often farmers or other people whose income is derived from working the land. However, wealthy homeowners often live in large houses on substantial property. Increased population and real personal income have been linked to urbanization of forested areas (Alig and Healy 1987). Urban expansion may remove forest land by clearing tracts for urban build-up or by moving into agricultural land that could be replaced from wildland.
- Development criteria can be measured by the presence or absence of man-made structures on the landscape. People make use of wildlands environments for their second homes and for cultural developments. The importance and validity of this criterion is increasing as fire and recreation related management problems arise because of this activity. Recent examples of large quantities of development being destroyed by fire is the Oakland Ridge fire in California in 1993. Lives were also

lost in this tragic event. The interspersed nature of development can be measured by the number of dwelling units per unit area.

- Aesthetic criteria views the interface as a wide and sometimes fuzzy boundary often distinguished by the presence or absence of vegetation. From a recreational viewpoint, the impact of visitors on the local flora and fauna is important. In an attempt to quantify this criterion, factors such as distance of the recreational site from the urban center, and number of visitors to the site for a period of time, may be used.

Data Input

The collection, verification and importing of spatial data is time consuming and is probably the most expensive component of any GIS project. Map mechanics, including coordinate system and map projection were selected and the scale for doing the work was determined. Appropriate data sources from which to create coverages to quantify the criteria previously described were chosen. An exhaustive search was conducted to verify that no suitable data already existed. These included land cover/land use coverage, and soil type coverage. Road networks, rivers and other relevant coverage were extracted and imported from TIGER/Line ™ files. Housing density for census groups, and income level by census block groups, and town boundaries, were explored using Tiger/Line ™ files (Figure 7).

The primary sources of data for this project were remotely sensed data and TIGER/Line ™ files. The development of GIS coverages, with their respectively linked attribute tables, has proven to be a major task in the planning phase. This has been repeatedly emphasized by past researchers and GIS system designers (Maguire 1988; Butler 1994). The time, effort and cost involved in constructing a wholesome, accurate and up-to-date GIS database is often greater than anticipated.

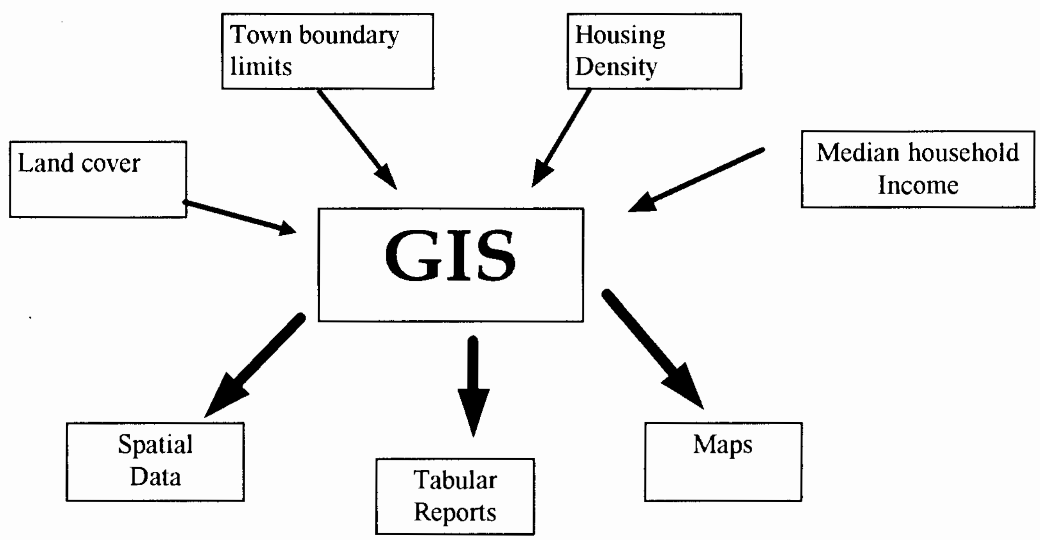

Figure 7. Diagram of data input in the Geographic Information System (GIS) and products output for data interpretation.

From the TIGER Line ™ Files thematic map for the town boundary limits was derived by importing the attributes of minor civil divisions relating to towns into PC

Arc/Info (Figure 8). Polygon topology was created while simultaneously creating a polygon attribute table.

For the land cover / land use data layer recent Landsat MSS images corresponding to Worldwide Reference System coordinates path 26 row 35 and path 26 row 36, which are centered at approximately 36° N, 940 49" W were acquired from EOSAT, in Sioux City, South Dakota. Image selection were based on three decreasing key constraints:

- at least 95 % cloud free
- at least two years old (to fit within project budgetary limits)
- image taken in late spring or summer

Satellite images acquired for this are ID LM5026035009208390 and ID LM5026036009208390 taken on the 23rd March, 1992. Fulfillment of the third constraint was compromised but the date was determined to be suitable. The contents of the tapes were loaded onto ERDAS, a raster-based GIS program resident in a 486-based personal computer made available by the Geography Department, Oklahoma State University. Preliminary analyses were performed with technical assistance provided by a research associate. Two Landsat Multispectral images span the study area and preprocessing of the data was performed. In order to obtain a contiguous image of the area, it was necessary to combine the two images by the process of mosaicking, using the STITCH function in ERDAS. The resulting image was then subsetted to cover only the study area. A 1:24,000 US Geologic Survey (USGS) map was selected as a base / reference map.

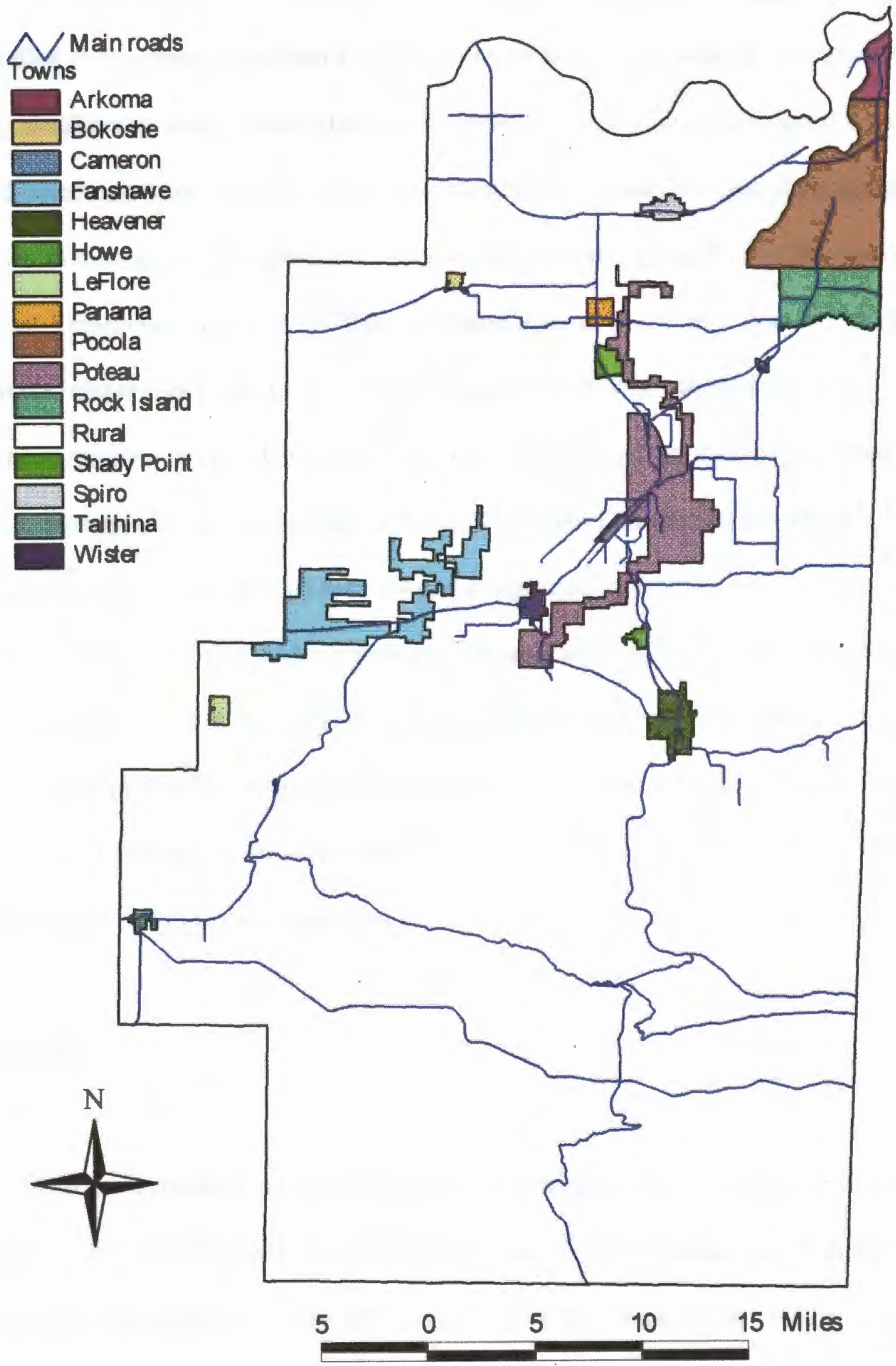

Figure 8. Thematic map of town boundary limits for LeFlore County.

One important aspect of spatial data is ground registration. Failure to register spatial data to the ground can lead to serious problems with the analysis and assessment stages. Registering spatial data to the ground requires transforming the original data to a ground based coordinate system. A coordinate system is simply the two dimensional (x, y) values that designate the position of a given point on the ground. For this work the Universal Transverse Mercator (UTM) coordinate system was used. This is a standard coordinate system and allows for the measurement of map units in meters. The registration process involved locating fifty four (54) ground control points from 7.5-minute USGS quadrangle map sheets and registering these on the satellite image. Using the Ground Control Point (GCP) function and a digitizing tablet, the points were entered into the computer. A first order transformation was used to register the image to the quadrangle sheets. Using the LRECTIFY module of the ERDAS GIS package the image was then resampled and an output image produced. The registration error for the rectified image was less than one pixel or less than 80 meters in both the X and Y axis. This is an acceptable error for this spatial data layer.

Classification

Both supervised and unsupervised classification techniques were used in classifying the image. A SEQUENTIAL CLUSTERING and ISODATA approach was used for unsupervised classification. The first stage in the classification procedure involved classifying the data using SEQUENTIAL CLUSTERING module which generated 28 spectral signatures using an unsupervised classification. With the sequential clustering pixels are examined one at a time. The spectral distances between each analyzed pixel and the means of the previously defined clusters are calculated. Each pixel either contributes to an existing cluster, or begins a new cluster based on spectral distances. In this method the analyst has more control over the process in that he can specify the number of clusters to be generated. With ISODATA, however, the analyst does have the option to define the maximum number of classes to be generated. Evaluation by the computer resulted in the creation of 50 classes Both methods use spectral distance and maximum likelihood criteria to determine which cluster a pixel is placed. Evaluation of the resulting signatures is possible using the ALARM and / or the ELLIPSE evaluation techniques. These techniques reveal to the analyst the degree of separability for the signatures. An analysis of the output files showed that areas which represented urban areas, improved pasture, water, and shadows had spectral reflectance values that were similar, making separation difficult. A post-supervised classification approach using training sample seeds was attempted but did not improve the separation of the spectral properties. More complicated methods such as using a fuzzy classifier were ruled out due to time and budget constraints. However, this problem was resolved using a masking technique. These resulting spectral signatures were then analyzed, evaluated and reclassified to produce land-use / land-cover classes (Gong and Howarth 1989).

The land-use / land-cover identified for the study area are outlined in Table 2. Standard per-pixel classification algorithms are based on the assumption that the distribution of spectral values for the land-use classes of interest demonstrate a normal distribution and are separable. This assumption tends to fail around the periphery of urban centers where land-use classes possess a wide range of spectral reflectance values that overlap in spectral space (Jensen and Hodgson 1987). This resulted in the difficulty of separating 'urban and built-up areas', which would have been useful in later analysis. Since ERDAS is a raster based GIS package, the resulting classification was in a raster format. The image was imported into the PC ARC/INFO and, using the GRIDPOLY command, the cell format was converted into polygons and simultaneously created a polygon attribute table (Figure 9).

While rigorous empirical test are desirable to test the classification accuracy for all data layers, it is sometimes not practical to do them due to reasons of inadequate knowledge, time, funds, or availability of adequate numbers of suitable check points. A general on the field check was made using the classified image. The constraint of time and money did not allowed for a more vigorous test to be conducted. The result of the field check was satisfactory.

Economic Data Layers

Land cover variables can not reveal how social systems work, nor do they indicate how social structures and values affect land use changes. To obtain a better picture of the effects of any land management decision, it is necessary to use additional "layers" of economic and social information

Table 2. Land use and land cover types for LeFlore County, Oklahoma.

Land Cover Type	Area in acres	Code
Croplands	17170.6	CL
Rangeland	191045.2	RL
Pasture	40023.7	PL
Pine	568136.4	PI
Hardwoods (Broadleaf)	180475.8	HW
Wetlands	14,453.6	WET
Urban and built-up areas	4047.1	UB
Lakes/Water	9272.5	WA
TOTAL	1,024,625	

The data either existed in various external sources, in this instance the primary sources are the Census Bureau 1992 Tiger Line ™ files, or analog data that could be digitized manually. Useful data from the Census Bureau 1992 Tiger Line ™ files are economic data on the median household income expressed as dollars per year per household and housing density measure in dwelling units per unit area. In the TIGER Line ™ files housing density is express as number of dwelling units per census group block (a statistical unit defined by the US Census Bureau).

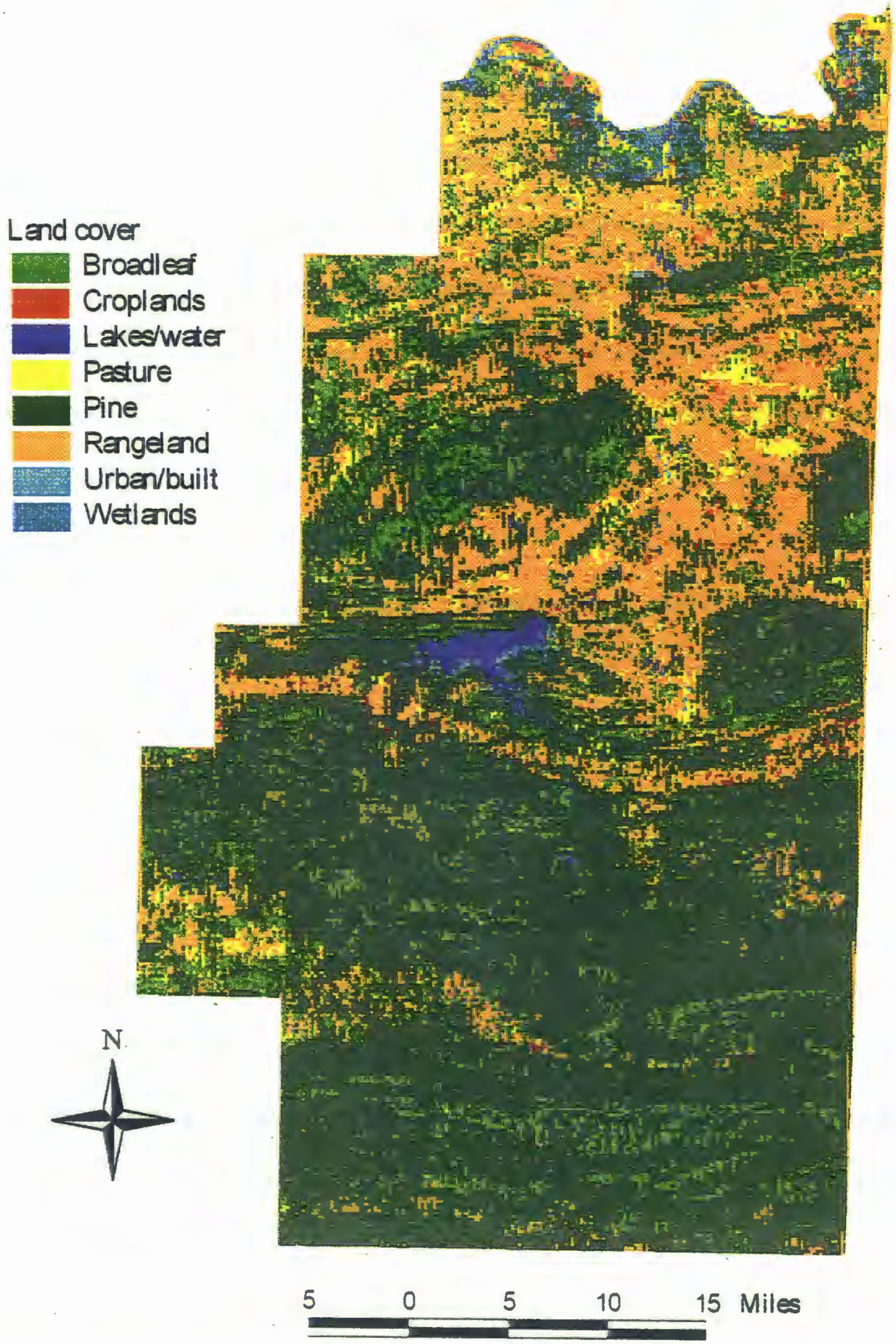

Figure 9. Land cover classification derived from analysis of 23 rd March, 1992 Landsat MSS satellite image for LeFlore County.

In order to express this variable in dwelling units per square kilometer the simple computation of dividing the number of dwelling units per census group block by the area of the census group block was done. Reclassification was done in order to present the variable in a more meaningful way. This produced the map shown in Figure 10. Housing density is used to measure urban development encroachment into the wildland areas. As one moves from an urban center, the number of dwelling units per acre decreases and one expects that in ideal wildland areas, no dwellings are present. For this project a conservative figure of 1 to 20 dwelling units per square kilometer was initially used to identify the urban-wildland interface zone. This range is appropriate and reflects the low population of the county.

Median household income was used to measure the economic activity of landowners. One may hypothesize that with higher income, one's interest in environmental concern becomes more varied. In certain cases this can be focused on the value of the land as a means of making a livelihood while in others it may be focused on the concerns for the environment (Smith 1994). A thematic map layer was created from data obtained from the TIGER Line ™ File and is shown in Figure 11.

After all of the data coverages were created and made compatible by registration, they were imported into ArcView, a powerful end-user GIS package. This software provided the means to visualize, explore, query and analyze the database spatially. Queries were done in ArcView using the query tool available within this software. Boolean operators such as "and", "or", "less than", "greater than" and "equal to" are used in the design of queries. ArcView also allows the building of very sophisticated queries. An example of a query used in this work is given below :

> (((([Leftowns] = 16) or ([Leftowns] = 0) and (([class]= "rangeland") or ([class]= "pasture") or ([class] = "pine") or ([class] = "broadleaf")) and ((([Housing density] >= 1) and ([Housing density] <= 10) and ([Median household income] >= $6,000) and ([Median household income] <= $18,000))).

Construction of the query requires that the syntax be properly done; care is especially needed in the use of the parentheses to ensure that the results be reasonable.

Different sets of attributes or numerical values, that lies within the range of the values found in the database, can be used in the construction of other queries. This feature of ArcView makes it useful in exploring the outcome of other predictions by altering the values. The example shown illustrates this

> (((([Leftowns] = 16) or ([Leftowns] = 0) and (([class]= "rangeland") or ([class]= "pasture") or ([class] = "pine") or ([class] = "broadleaf")) and ((([**Housing density**] **>= 1**) and ([**Housing density**] **<= 20**) and ([**Median household income**] **>= $10,000**) and ([**Median household income**] <= **$20,000**))).

The altered variables and its' corresponding value are shown in bold above.

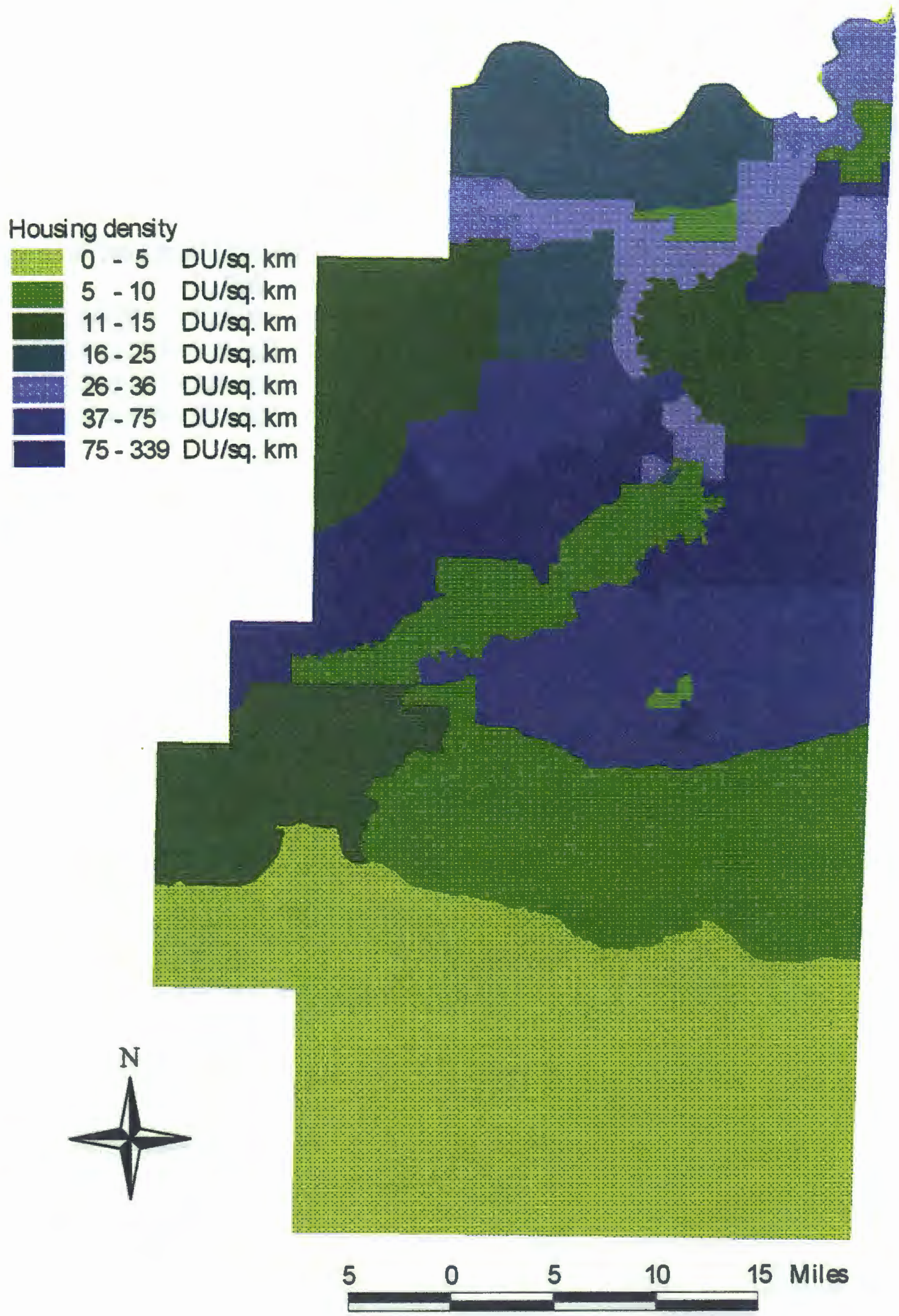

Figure 10. Thematic map of housing density, derived from 1990 U.S. Census, by census group blocks for LeFlore County.

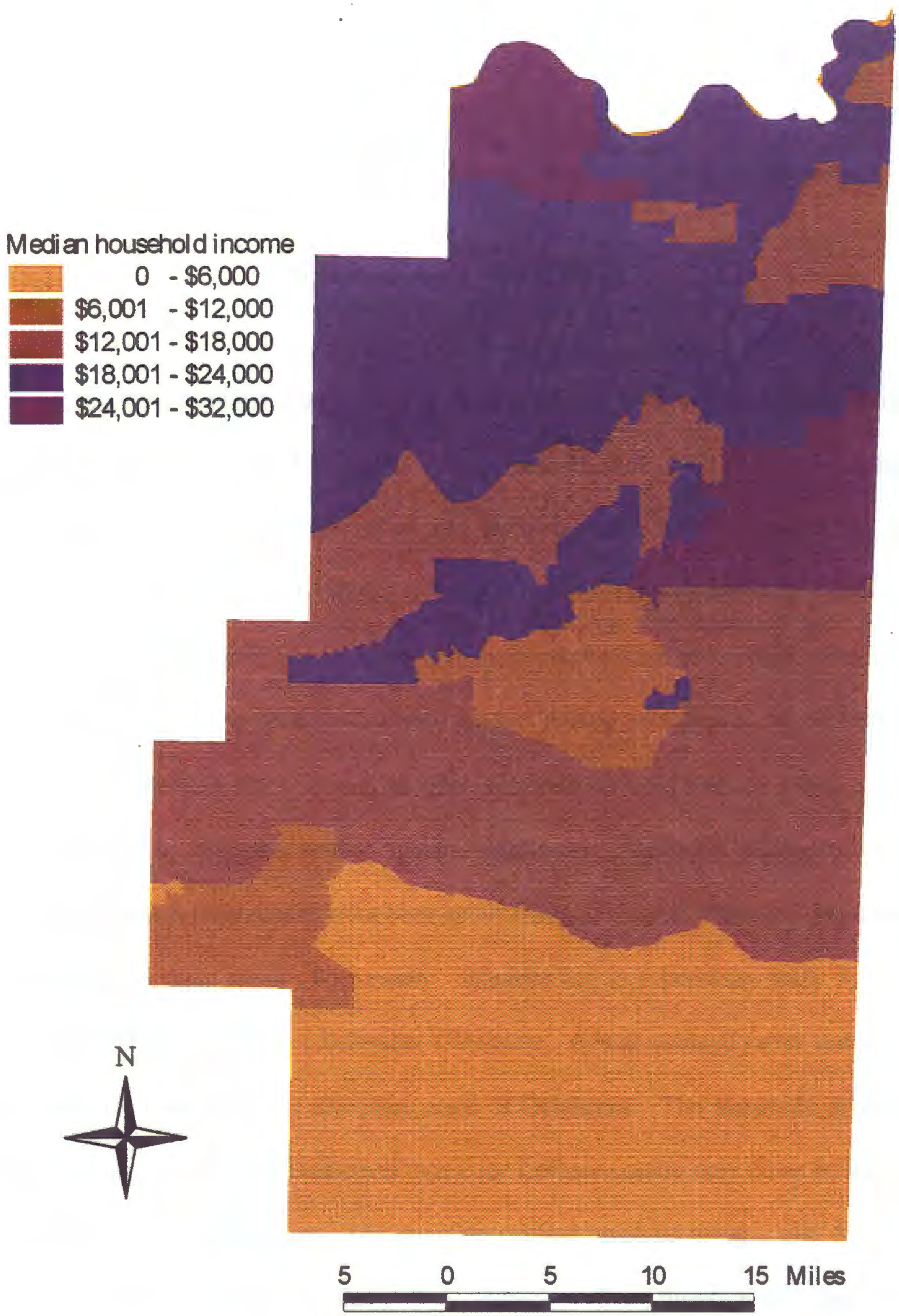

Figure 11. Thematic map of median household income, derived from 1990 U.S. Census, by census group blocks for LeFlore County.

CHAPTER IV

RESULTS AND DISCUSSIONS

Considerable effort was put into acquiring existing data, with special emphasis put into trying to obtain existing land use/land cover classification. This effort proved fruitless so acquisition of Landsat MSS tapes was made in May 1995. Pre-processing and preliminary classification of the image was made but several problems were encountered with clearly separating the spectral signatures, primarily because of the time of the year the images were taken (early spring when trees are just putting on foliage). Water bodies and shadows on mountain sides as well as open concrete-covered sites in urban areas and improved pasture indicated similar spectral signatures. Spectral differences were so minimal that much time would have been spent using additional computer algorithms to further separate these areas. Fortunately, inquiries led to a previous study by the Soil Conservation Service (SCS) in Stillwater, Oklahoma. A land use/land cover sampling was done between 1986-1989 for the entire state of Oklahoma. The statewide project pre-defined ninety-nine different land cover types; for LeFlore county only 20 or so land cover types were found to be present. The sampling method involved using a grid overlay and selecting sampling points at every 200 meters. The duration of the exercise and the sampling strategy of the previous study was inadequate for use in the current project. However, the results of the exercise proved to be useful in assisting with the classification of the 1992 image. In an attempt to correctly classify the study area image, the 1992 image was registered to the SCS dataset. This allowed the exploration of critical variables while maintaining the integrity of the 1992 Landsat MSS scene. This ability may benefit in the analyses of other areas where the importance of various factors such as land area may be included in the evaluation of the model. A masking approach was used to suppress the water areas and the ISODATA algorithm was applied. The newly classified image had 20 spectral signatures and these were analyzed and re-coded to give seven land cover categories. The previously masked water category was then added to give the eighth land cover type. The problem of the concrete covered areas and improved pasture was overcome using a supervised classification technique termed 'training seed-sample selection'. This involved selecting a set of sample pixels known to represent improved pasture and concrete covered areas and forcing the computer to recognize these areas in these pre-determined categories.

One of the advantages of using the GIS approach is that the database can be readily updated. The vast amount of existing data and continual changes can, however, add considerable time and cost to the study. This can be offset by better planning in the initial stages. One of the objectives of this project is the development of the actual procedures for creating the database.

Another limitation that was encountered during the study was the realization that Landsat MSS was relatively coarse in terms of resolution and that Landsat TM images with resolution of 30 meters by 30 meters or SPOT images, would have provided more detail land use and land cover categories. SPOT is available at two resolutions 10 by 10 meters and 20 by 20 meters. However, purchase of these images is costly. For an initial project such as this work, cost was a major limitation.

Perhaps the greatest power of a GIS database is the potential use for the management of natural resources. GIS has a wide range of analysis capabilities. Some perform operations on topology or spatial attributes of the geographic data, on non-spatial attributes of these data, or on the nonspatial and spatial attributes combined (Burrough 1986). GIS can also be used for predictive modeling as demonstrated in this study. With a little imagination, a GIS system can be examined, tested and resolved at reduced cost and time compared to traditional techniques. Additionally, new ideas and hypotheses may be tested that were much too labor-intensive to even think of prior to the introduction of GIS.

With the database formatted for ArcView queries can easily be built and the results visually displayed. The query tool in ArcView allows an analyst to select features and records in a table that relates to the attributes values. Using this tool, the following query was built. An area is considered to be an urban-wildland interface if the following criteria is met: Land cover is "pine" or "hardwood" or "rangeland" or "pasture"; areas are outside town boundary limits; housing density is greater than 1 but less than 15 dwelling units per square kilometer; median household income is greater than $6,000 but less than $12,000 per household per annum. Based on these constraints, the area in LeFlore County covered by this prediction is 95,129 acres. This is one of a large number of possible combinations resulting from changing the values of the attributes. For this study, a total of six sets of criteria or scenarios were chosen. These are summarized in Table 3.

Data in digital form can be used to create several type of products. For example they can be represented as paper maps, tabular summaries, graphs, charts, or annotated text. They can also be converted for use in other GIS packages, exported to graphics or desktop publishing environments, used in multimedia knowledge bases or used to create 35-mm slides. A PaintJet color printer (Hewlett Packard XL300) was used for producing the paper maps and transparency output. These are illustrated in Figures 12 to 17.

Table 3. Summary of results for the queries used to define the urban-wildland interface.

Criteria	Figure [1]	Outside Town Limits	Land cover class	Housing density (DU/ sq. km)	Median household income	Area in (sq. metres)	(acres)
1	12	yes	pine, hardwoods, pasture, rangeland	1- 15	$6,000 - $12,000	384,322,717	95,129
2	13	yes	pine, hardwoods, pasture, rangeland	1 - 20	$10,000 - $20,000	352,656,303	87,291
3	14	yes	pine, hardwoods, pasture, rangeland	1 - 15	$20,000 - $32,000	637,029,710	157,681
4	15	yes	pine, hardwoods, pasture, rangeland	1 - 10	not used	892,882,890	221,011
5	16	yes	pine, hardwoods, pasture, rangeland	not used	$6,000 - $18,000	913,374,085	226,083
6	17	yes	pine, hardwoods, pasture, rangeland	1 - 10	$6,000 - $18,000	375,301,543	92,896

[1] Each scenario or set of criteria is also presented as a thematic map.

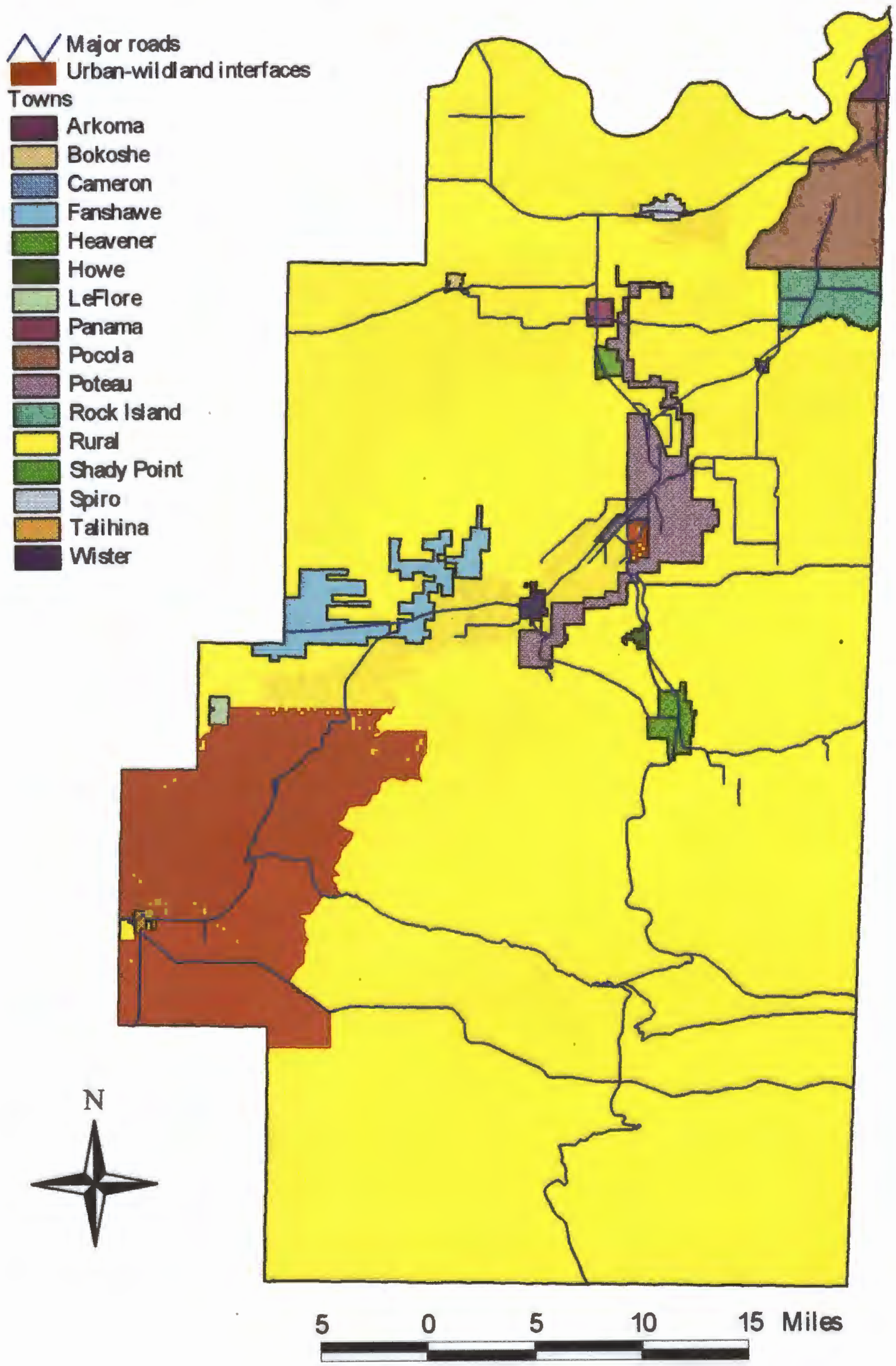

Figure 12. Map of LeFlore County showing urban-wildland interface locations, as predicted by Criteria # 1, overlaid with thematic map of town boundary limits.

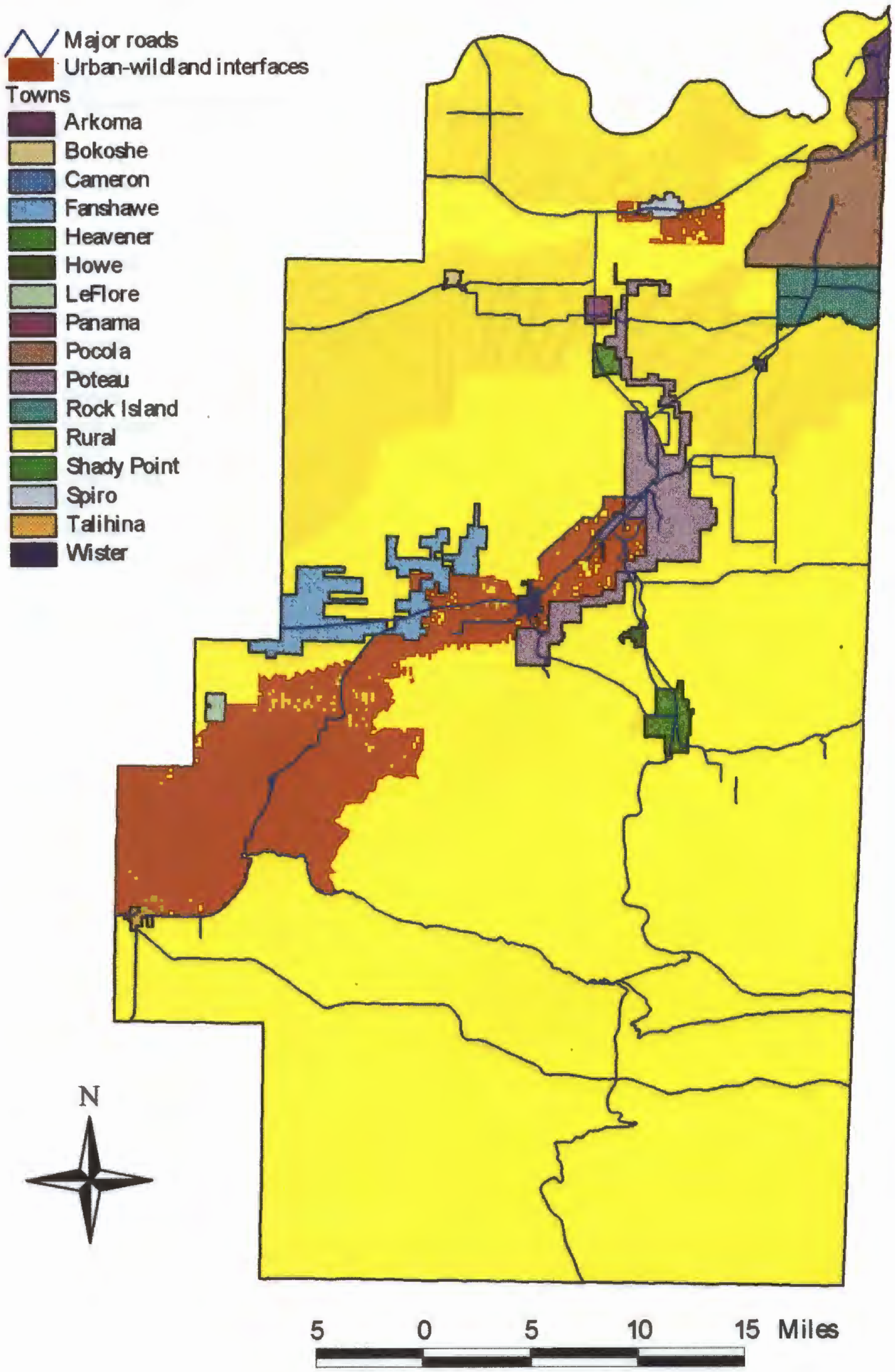

Figure 13. Map of LeFlore County showing urban-wildland interface locations, as predicted by Criteria # 2, overlaid with thematic map of town boundary limits.

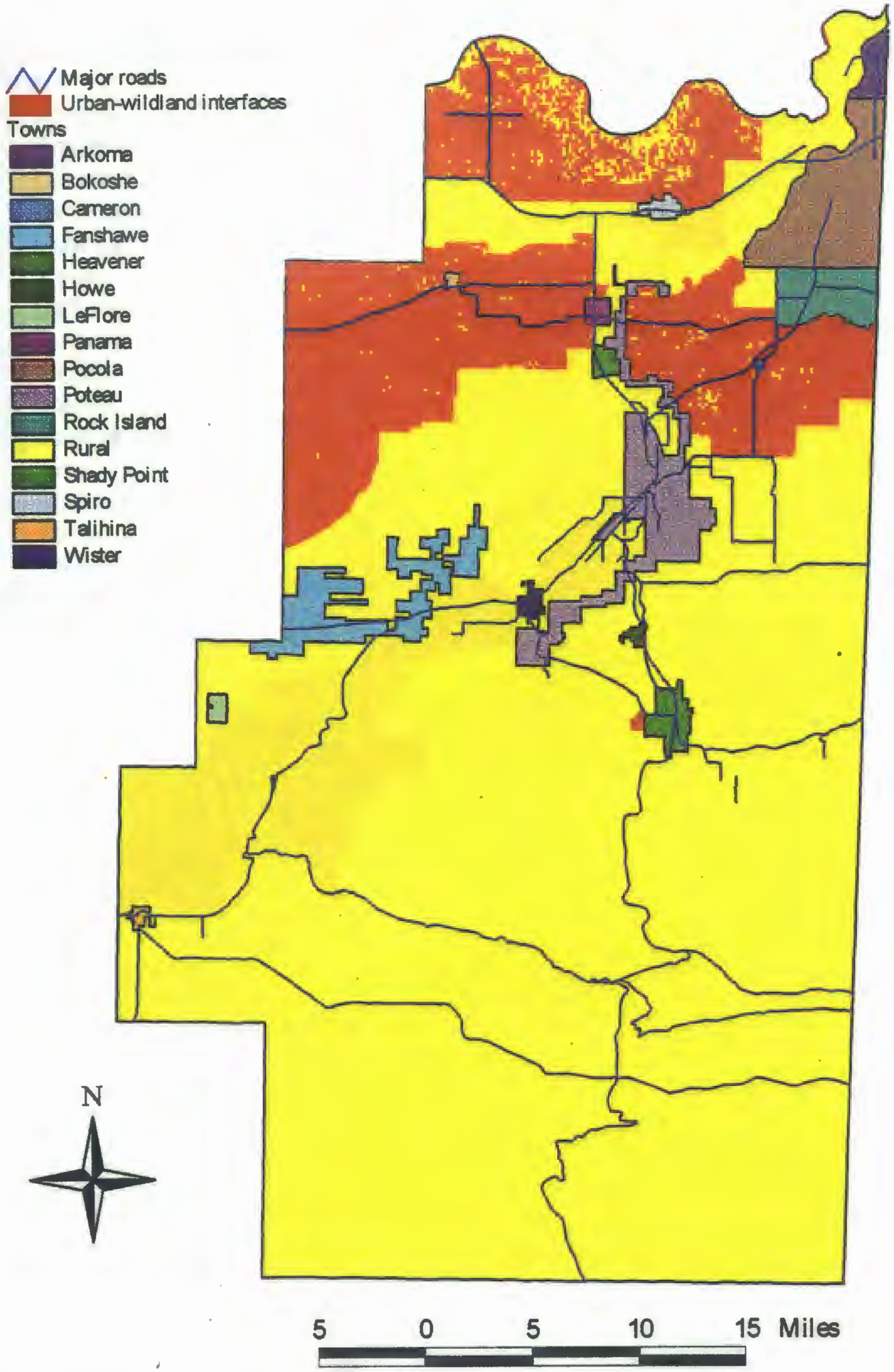

Figure 14. Map of LeFlore County showing urban-wildland interface locations as predicted by Criteria # 3, overlaid with thematic map of town boundary limits.

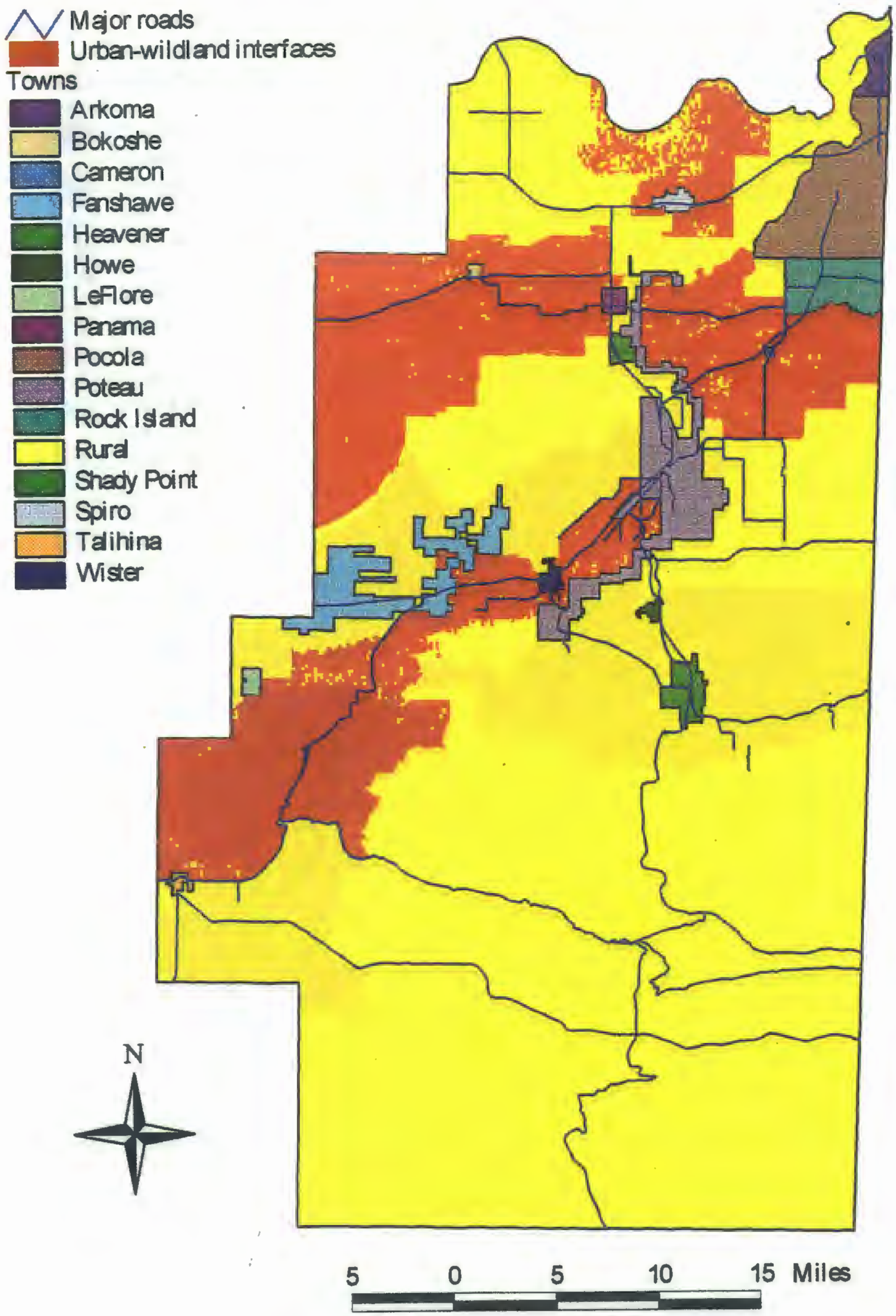

Figure 15. Map of LeFlore County showing urban-wildland interface locations as predicted by Criteria # 4, overlaid with thematic map of town boundary limits.

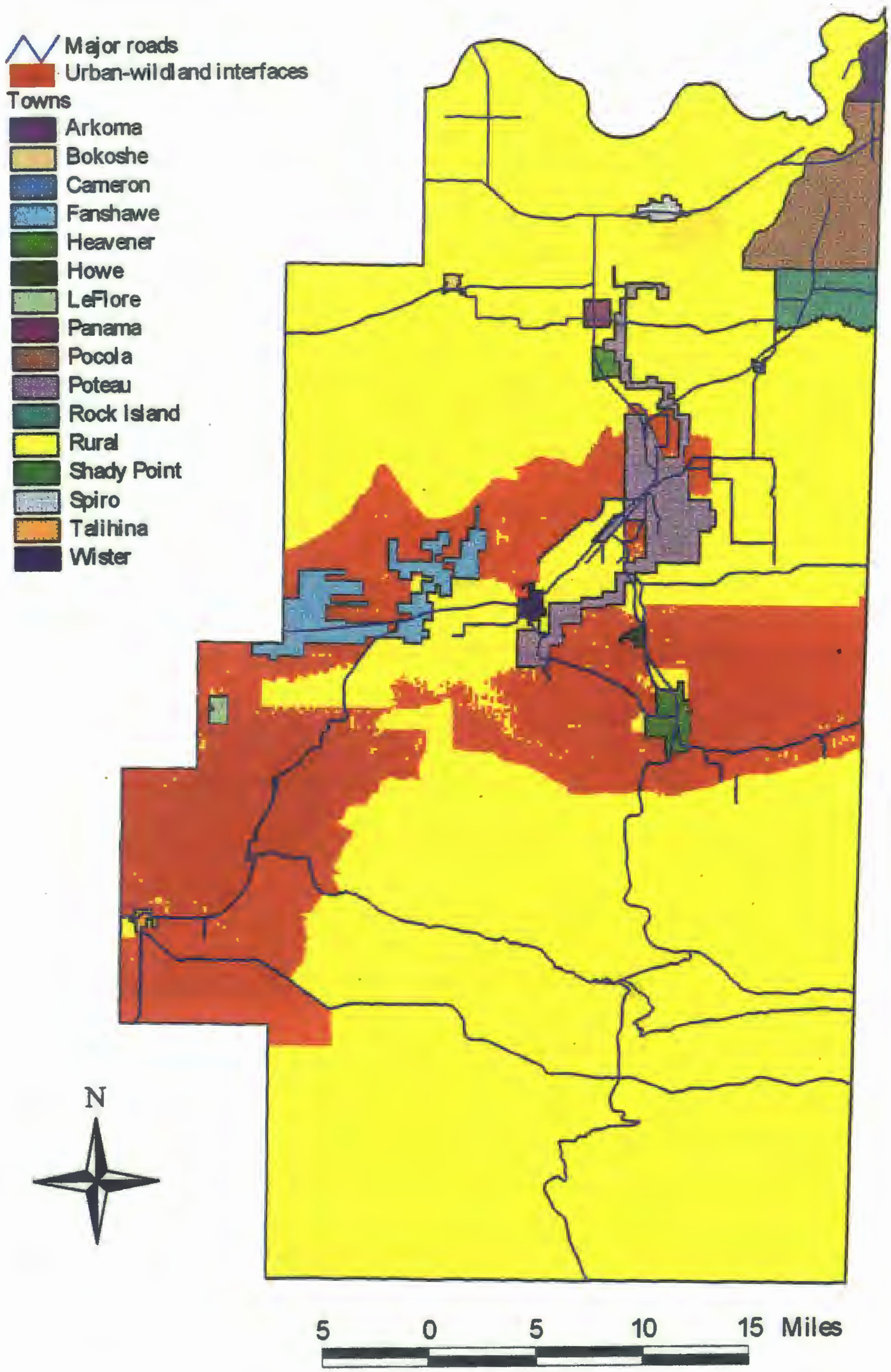

Figure 16. Map of LeFlore County showing urban-wildland interface locations as predicted by Criteria # 5, overlaid with thematic map of town boundary limits.

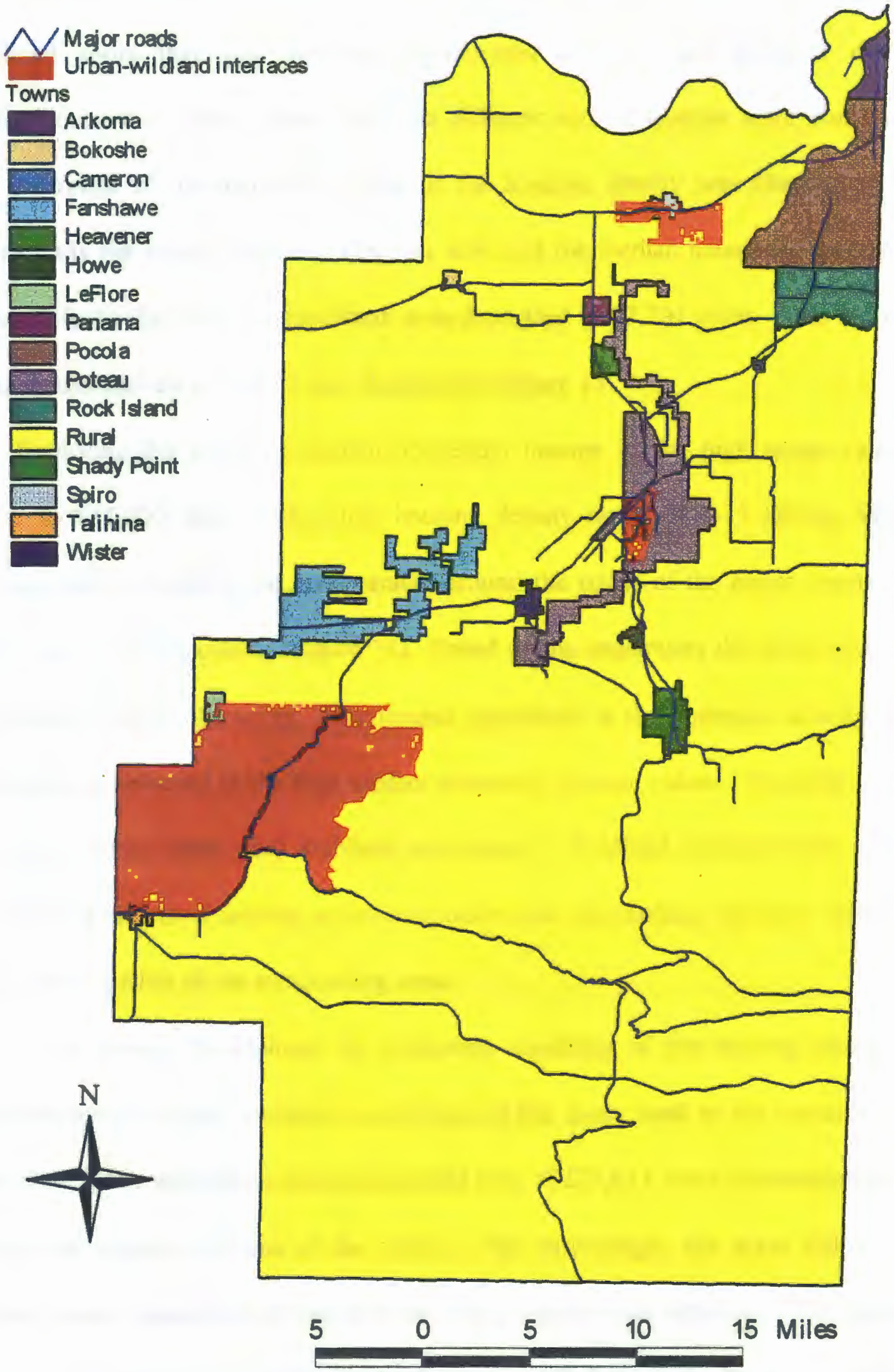

Figure 17. Map of LeFlore County showing urban-wildland interface locations as predicted by Criteria # 6 overlaid with thematic map of town boundary limits.

ArcView is an end-user software package which provides users with a variety of interrelated tools that can perform sophisticated queries, and produce dramatic visualization output. Using these tools, six different sets of queries were constructed. When the range of the numerical values of the housing density was changed to 1-15 dwelling units per square kilometer (DU/ sq. km) and the median household income was set from $10,000-$20,000, the predicted area decreased to 87,291 acres. This is Criteria # 2 and is summarized in Table 3 and illustrated in Figure 13.

Exploring the effect of median household income in the high range values of $20,000 to $32,000 along with a low housing density range of 1-15 DU/sq. km, the predicted result is found to be concentrated around the edges of the major towns in the northern section of the county (Figure 14). Based on the constraints the areas covered by this prediction is 157,681 acres. Mechanized agriculture is the dominant activity in this area and this is reflected in the high median household income values. Potential conflicts are likely to occur when such activities are present. Wildland encroachment for farm expansion and effects of farming activities (poultry and pig rearing) can have undesirable impacts water quality of the surrounding areas.

In an attempt to evaluate the prediction capability of the housing density, the median household income variable was left out of the query used in the construction of Criteria # 4. The result shows a large predicted area of 221,011 acres, concentrated in the northern and western sections of the county. Not surprisingly, the areas follow major roads and occur adjacent to towns, in areas of high agricultural activities. The elongated appearance of the predicted area between Poteau and Talihina is similar to that predicted by Criteria # 3. This is expected as the numerical values of the variables in Criteria #3 are captured in Criteria # 4.

A similar query (Criteria # 5) was built for the median household income leaving out the housing density variable. The result shows the predicted area to be concentrated in the middle part of the county as illustrated in Figure 16. A large portion is located near the town of Heavener. The Runestone Recreational Park, a publicly-owned park, is situated here and is the center of recreational activities for a large number of inhabitants from the nearby towns (Ouachita National Forest Management Plan 1990). Increase in leisure activities has been shown to be correlated with high income levels (Ewert 1989). As seen in previous criteria, agricultural activities are dominant in the surrounding area. The area predicted by Criteria # 4 and # 5 are 221,011 acres and 226,083 acres respectively. Difference between the predicted area is 5,072 acres (2.3%). This small difference may be indicative that both variables are equally strong in their predictability of the interface zone. It is noted, however, that even though the area difference is small, the location of the zones are different, as illustrated by comparing Figure 15 to Figure 16. This difference in prediction may be further explored by the use of additional variables such as land ownership status.

Finally, a query (Criteria # 6) that uses the lower range values for both the housing density and the median household income was built. The values are 1-10 DU/sq. km and $6,000 to $18,000 respectively. The predicted area is fragmented, with a large portion located between the towns of Talihina and LeFlore (Figure 17). The predicted zones near Poteau and Spiro are interesting in that some area lie adjacent to the town boundary limits.

The area predicted by this criteria is 92,896 acres, closely matching that predicted by Criteria # 1 and # 2.

Criteria # 4 and # 5 yielded the largest predicted area sizes of 221,011 and 226,083 acres respectively. When either the median household income or the housing density variable is left out, the predicted area size shows an increase. Comparison of the acreage values for Criteria # 1 and Criteria # 6 shows that predicted area are almost the same. Both these criteria contain numerical range values for median household income and housing density that does not differ greatly. The area in Criteria # 6 is however, fragmented (Figure 17). Criteria # 6 uses low range values for median household income and housing density and land cover types that are greatly impacted by land use changes. For all six criteria used, it is noticeable that the southern portion of the county showed no area as potential urban-wildland interface. This region has very low human population and economic activity and a large percentage of the area is part of the Ouachita National Forest. The consistency of five of the six criteria in predicting the area in the vicinity of the town of Talihina is also noteworthy. Perhaps, there are merits in looking more closely at this area in a future study. The values of the four input variables and the resulting estimation of total land area predicted to be urban-wildland interface are summarized in Table 3.

Evaluation Of The Model

The primary use of the model or set of procedures was to define and predict the occurrence of the urban-wildland interfaces. This is a prerequisite if natural resource managers are to be aware of potential problems associated with the management of these zones. When the objectives of this project are considered it seems logical to use a vector data structure. Geographic information systems can generally be distinguished by the spatial character of the data. The choice of a particular spatial data structure is one of the important early decisions in designing a geographic information system. Two major choices of data format structures are utilized in GIS: 1) cell encoding resulting in the storage of a grid data, also known as raster data structure; and 2) line or point encoding resulting in the storage of polygon data, also known as vector data structure. In deciding which of the two formats to use, one needs to look at and evaluate four important aspects. These are coordinate precision, mass storage of data, computing speed, and phenomenological factors. With the continued and rapid advances in computing technology, the aspects of computing speed and mass storage are becoming less and less important. In addition, the decreased cost of peripherals, such as scanners and electrostatic plotters, allows input and output of completely integrated images and GIS. However, when the need for locational calculation and numerical processing are needed in the analysis, it is better to use vector format. On the aspect of coordinate precision, vector is better in modeling real world phenomena. With the increase in use of Global Positioning Systems (GPS), which reduces the cost and provides higher throughput than traditional surveying methods, locational accuracies are improved. Raster is also based on a rectangular grid within rectangular coordinates and resolution can be either coarse or fine. On the subject of phenomenological consideration, factors such as surfaces which can be diffused is evaluated against depicting features as points, lines and polygons. The attribute of real world features, for example, soil types and land covers, are better represented by vector than by raster. In terms of being able to relate spatial position of one object to another (topology) vector is superior over raster. For this work the larger portion of the data are in vector format and, considering the factors stated above, it was the chosen format for the modeling procedures. The PC ARC/INFO is one of the most commonly used vector-based GIS software packages. The overlay, query, and map generation capabilities are also other major reasons for using the GIS software PC ARC/INFO along with ArcView which is able to incorporate relational database which permit quick exchange of data with spreadsheet programs such as Lotus 1-2-3. Furthermore, the relational database allows large numbers of attributes to be used, facilitating several types of analyses. It should be borne in mind that the decision to include certain variables is dependent on the analyst, and is, therefore, very subjective. Nevertheless, the attainment of the objectives and the usefulness of models to end-users are important aspects that requires consideration. The sources of the coverages offered more variables than deemed necessary for this project. Digital topographic data in the form of digital elevation models (DEM) or soil data (STATSGO) may be justified in other locations. It would be interesting to know the result if a coverage pertaining to the GAP Analysis Project of the Natural Biological Service was available and used in the model.

Results from such projects provide a better picture of the existing ecosystem structure for an area. There are other data layers that can be explored but efforts should be put into seeking existing digital data from other agencies. Satellite remote sensing is capable of providing information on development activities in the urban wildland interface (Forster 1985; Jensen and Toll 1982). In this study, the use of Landsat TM images instead of Landsat MSS could have improved the spatial analysis by increasing resolution.

Error Analysis

In order to make effective use of any GIS it is important that both users and modelers understand the error associated with spatial information. Typically there are three main source of errors: user error, measurement/data error, and processing error (Burrough 1986). User errors are more likely under the control of the user. Examples of this type of error include data age, scale, and coverage. Also, using land cover classification derived form satellite imagery can introduce errors in the GIS. Measurement/data error deals with variability in spatial information and the corresponding accuracy with which it is acquired. Like all measurements, spatial data have levels of accuracy that are limited by the measuring devices used. It is hard to draw a line of 0.2 millimeter width; it is also difficult to prevent paper documents from stretching and shrinking with changes in humidity. Field error measures the human limitations and care of individuals in collecting or validating data in the field. Processing errors are those inherent to the technique used to input, access, and manipulate the spatial information.

Of the two primary data sources used in this study, land classification accuracy was dependent on the skills of the initial classification process. Using data such as the Census Bureaus' TIGER Lines ™ files relies on the validity of the assumption that the integrity of the database is accurate and reliable. Another source of processing error is in the conversion of the raster land use classification to vector format. Re-sampling of the grid cells prior to vectorizing was necessary but also introduced errors. Data quality affects every use of the GIS to either a small or large extent. The various aspects of the database quality discussed previously need to be recognized so that the potential users can apply the database appropriately and effectively to natural resource management problems (Bolstad and Smith 1992).

An integral and yet largely forgotten and unnoticed component of a GIS is people. Without well-trained individuals and an adequate support staff, it is possible that an investment of thousands of dollars on state of the art equipment may be wasted. Within a University setting, however, this might not be necessary if cooperation between academic departments is likely to occur as was the case in this small but yet informative project.

Procedure For Defining The Urban-Wildland Interface

1. Data Acquisition

- Remotely sensed digital data are important sources of land use/land cover information, particularly up-to-date sources and high resolution quality. These data are available in several formats , the more commonly used ones being

Landsat MSS, Landsat TM and SPOT. Data from this source must be registered to a predetermined coordinate system, the preferred one being the Universal Transverse Mercator (UTM). Registration allows for spatial analysis of real world geography. Extraction of useful information is done by analysis of the properties of the pixel values, using computer algorithms available in raster-based GIS software packages such as ERDAS.

- The Housing and Population files found in the Census Bureau TIGER Line ™ Files provided data for the median household income and the housing density. These data are encoded and use of Dr. DooLittle, a decoding software package provided by the US Census Bureau, is necessary.

2. Data Preparation

- Remotely sensed data can be classified using supervised and unsupervised techniques. Sometimes both methods are used together. Using a combination of methods, eight land cover types were derived from the 1992 Landsat image. These are: pine, hardwoods, pasture, rangeland, wetlands, water/lakes, urban/built-up areas and croplands. Classification results were in raster format which had to be changed to vector format for compatibility to the other variables. This was done in Arc/Info using the GRIDPOLY command which also created a polygon attribute table.
- The data in the TIGER Line ™ Files are stored in digital format and, using Arc and Arc Plot software, were transformed into lines and polygons. Using

Arc/Info, topology was created from the lines and polygon, simultaneously building Arc Attribute Table and Polygon Attribute Tables. These tables were later joined with the polygons for the land cover types within Arc/Info. The result is the required database, which comprised 11,255 records, stored in 15 megabytes of disk space.

3. Data Analyses

- The database was imported into ArcView, where data manipulation, construction of queries, and visual display of the result of the queries were performed. Query construction is facilitated using several query building tools available in ArcView. Building queries is constrained only by the numerical values of the fields within the database and the number of records contained in it. Using the tools the following query was constructed:

  ((([leftowns] = 0) and ([leftowns] = 16)) and
  (([Class] = "pine") or ([Class] = "hardwoods") or ([Class] = " pasture") or
  ([Class] = "rangeland")) and (([median household income] = > $6,000)
  and ([median household income] = < $18,000)) and
  (([housing density] = > 1) and ([housing density] = < 10)))

- The versatility of ArcView enables an analyst to alter the numerical values within the range provided for selected variables or to eliminate certain variables when building the queries. The example below illustrates several altered values (shown in bold):

((([leftowns] = 0) and ([leftowns] = 16)) and

(([Class] = “pine”) or ([Class] = “hardwoods”) or ([Class] = “ pasture”) or

([Class] = “rangeland”)) and ((([median household income] = > **$12,000)**

and ([median household income] = < **$24,000)**) and

(([housing density] = > 1) and ([housing density] = < **20)**))

4. Data Output

- The visual display on the computer monitor can be used to make high quality maps by using the Layout feature of ArcView. Layout allows one to control the appearance of the finished product. Hardcopies in the form of transparencies and maps can be obtained by using a color printer such as Hewlett Packard XL300 PaintJet printer. Additionally, 35 mm slides can be produced using peripherals such as a Polaroid C1-3000 Camera connected to the computer.
- Results pertaining to the areas of the urban-wildland interface can also be presented in tabular format and statistical parameters such as means, standard deviations, summations, and range are easily obtained using the Statistical function in ArcView. The selected records for each query determines the predicted area, which can be converted to a shape file and added as a separate theme in another View or exported as a theme to another vector-based GIS package.

5. Computer Hardware Requirements

- Throughout this project a 486-based DX PC with a 0.28 dpi monitor, provided by the OSU Geography Department, was used. The Arc/Info, ArcView, Arc, and ArcPlot software operate best with 16 megabytes of RAM memory. Computer network servers provided storage space. Color printers are ideal for producing maps associated with GIS study.
- A Hewlett Packard InkJet 500C color printer and a Hewlett Packard XL300 PaintJet printer were used. Maps showing results are stored in graphic format which are large files requiring sufficient memory (six megabytes) for display and printing. A PaintJet printer with six megabytes of memory was used for color map generation. Another peripheral found to be useful is a digitizing tablet used for registering the data sets.
- Analog information, including land ownership status and roads can also be entered into the computer by a digitizing tablet.

6. Computer Software Requirements

- ERDAS, a raster-based GIS package was used to classify the Landsat MSS image.
- ArcPlot and Arc were useful in manipulating and creating the themes from the 1990 US Census data.
- Dr. DooLittle, a decoding software package, was used to create the census group blocks.

- Arc/Info provided the pathway for building topology from the arcs and the polygons used for data storage in the TIGER Line ™ Files. The database created was stored in Arc/Info.
- The complete database was subsequently exported to ArcView where analyses and results were carried out. Various formats, for example Windows Metafiles, bitmap and PCX graphic file format, can be used to store and export the results to other GIS environment.

CHAPTER V

SUMMARY AND CONCLUSIONS

The model described has the potential to provide valuable information to forest managers, county officials responsible for land use policies, and city planners in LeFlore County. The database was designed using a popular and easily accessible GIS package-PC ARC/INFO. This package allows the input, manipulation, and easy display of data. Using ArcView, an end-user GIS display software that is compatible with PC ARC/INFO, queries were built and results visually displayed.

GIS has emerged as an extremely effective tool for prioritizing and analyzing resource management alternatives. Conflicts over land use are, by definition, spatial. Consequently, GIS provides a means for focusing discussion of advantages and disadvantages of alternative land use allocation. Such conflicts over land use have created a demand for immediate access to information about land status and the spatial interrelationship of natural resources. Relevant data were acquired and created from existing sources, sorted and evaluated, and entered as coverages (layers of information) into a computer format. A number of queries relating to these coverages were designed which would identify an area as being an urban-wildland interface. This proved the versatility and usefulness of the model.

Preliminary ground-truthing in the form of locating and visiting the interface zones as predicted by the model was undertaken. Field evaluation and critique of the ability of the variables to define the interface was done. Such evaluations and critiques are necessary as model developers can often best determine the usefulness of a variable in a model or make suggestions as to which variables were not useful in the prediction. Additionally, other variables may be found and incorporated during field evaluation. Field evaluations are subjective in nature as definitions for assignment to land class types may differ from one observer to the next. For the four variables used, land cover is the only variable for which ground-truth accuracy can be determined. Use of the TIGER Line ™ files is based on the assumption that the data are of an acceptable quality and actual assessment of the accuracy of median household income is impractical since this information is derived statistically from other data.

The first objective of this study was to evaluate the variables that can be used in developing the set of procedures. The requirement of an immense amount of computing capability resulted in using four layers. Vector-based GIS is computer intensive. The four data layers deemed to be of importance are housing density, median household income, town boundary limits, and land cover types. For all the queries used in this study, areas are considered potential urban-wildland interface zone if the areas are outside of the town boundary limits and comprise land cover types pine or hardwood (broadleaf) or pasture or rangeland. Median household income and housing density were shown to be sensitive in predicting the location of the urban-wildland interface.

The second objective was to identify useful variables from a large available pool and develop a set of procedures for defining urban-wildland interface using LeFlore County. A detailed account of the procedures involved in the development of the model has been previously discussed. Selection of the four chosen variables was based on their availability in digital format (Census Bureau TIGER Line ™ Files) and their relative importance in measuring economic activities within the study area.

The final objective is the evaluation of the potential application of the model to other counties or regions in the southeastern United States. For areas near LeFlore County application would seem to be feasible and permissible. For other regions, however, physical land cover differences and different patterns of socio-economic activities may dictate that a different set of variables be used. This may be a different number of variables or different types of variables. The model or set of procedures involved in the study was presented earlier as a step-by-step guideline. These step-by-step procedures revolve around a process that is precise; the process is repetitive and dynamic in character in that resource managers can easily and readily update the database, alter the numerical values of the variables used to build queries, or even add or drop variables in building queries that define the urban-wildland interface.

Problems associated with the interface zones are major issues in the forestry profession. These problems are often social and institutional in nature rather than technical. The urban-wildland interfaces are zones where social, economic, and political factors interact in complex ways. The need for better tools to handle ever more critical natural resource problems is obvious, and the rapidly developing field of information technology provides the necessary machinery. GIS is a very powerful tool for analyzing vast amounts of spatial data which can aid in understanding of the importance of the variables that defines the interface zone. However, the limitations of GIS must be carefully considered when using the results produced from this approach for decision-making. More elaboration and analysis of the social aspects as related to the inhabitants of these zones needs to carried out. As they begin to understand the values, preferences, and attitudes of new residents, resources managers will be better able to demonstrate their role and responsibilities in issues relating to the interface zones.

Future Recommendations

This study could be used as a basis for future work in determining locations of urban-wildland interfaces. The variables employed in this study are those deemed to be essential for the study area and duplication of the model in areas outside the study area should be done bearing this in mind. The results produced by this model should not be seen as answers to the urban-wildland interface problems. Indeed, the problems go far beyond this initial phase. Emphasis should be placed on improving the methodology and other refinements considered for particular situations. Data accuracy was a problem repeatedly mentioned in this paper. The coverages could be improved in terms accuracy. Different quantitative values such as population densities for unit areas or ethnic make-up of a region could have been used in the model. Further exploration needs to be carried out in this area.

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APPENDICES

APPENDIX-A

Glossary of Terms

The following terms are used often in this thesis and definitions are provided to help the general readership in understanding the context in which the terms are used.

Accuracy
If applied to paper maps or map databases, degree of conformity with a standard or accepted value. Accuracy relates to the quality of a result and is distinguished from precision.

Attribute
A characteristic of a geographic feature described by numbers or characters, typically stored in tabular format, and linked to the feature by an identifier.

Base map
A map showing planimetric, topographic, geological, political, and/or cadastral information that may appear in many different types of maps.

Block group
A combination of census blocks sharing the same first digit in their identifying numbers within a census tract. Boundaries for block groups are not explicitly coded in the TIGER database but can be derived from it.

Census block
A small, usually compact area, bounded by streets and other prominent features as well as certain legal boundaries. Blocks do not cross block group, census tract, or county boundaries.

Census tracts
A small locally delineated statistical area within selected counties, generally having stable boundaries and, when first established by local communities, designed to have relatively homogenous demographic characteristics. Census tracts do not cross county boundaries.

Cluster
A spatial grouping of geographic entities on a map. When these are clustered on a map, there is usually some phenomenon causing a relationship among them (such as similar reflectance values)

Coordinate system
The system used to measure horizontal and vertical distances on a planimetric map. In GIS, it is the system whose units and characteristics are defined by a map projection. A common coordinate system is used to spatially register geographic data for the same area.

Database

Usually a computerized file or series of files of information, maps, diagrams, listings, location records, abstracts, or references on a particular subject or subjects organized by data sets and governed by a scheme of organization.

Digitize

A means of converting or encoding map data that are represented in analog form into digital information of *x* and *y* coordinates.

Format

The pattern in which data are systematically arranged for use on a computer.

Geographic information systems (GIS)

An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. Certain complex spatial operations are possible with a GIS that would be very difficult, time-consuming, or impractical otherwise.

Georeference

To establish the relationship between page coordinates on a paper map or manuscript and known real world coordinates.

Gridpoly

An ArcPlot command that converts raster files to vector files.

Group block

A statistical unit defined by the Census Bureau. These blocks have permanent boundary markers.

Household

Includes all the persons who occupy a housing unit.

Isodata

Stands for "Iterative Self-Organizing Data Analysis Technique". It is iterative in that it repeatedly performs an entire classification and recalculates statistics. Self-organizing refers to way in which it locates clusters with minimum user input.

Join

To connect two or more separate geographic data sets.

Layer

A logical set of thematic data, usually organized by subject matter.

Minor civil division

The primary political or administrative subdivision of a county.

Model

An abstraction of reality. Models can include a combination of logical expressions, mathematical equations, and criteria that are applied for the purpose of simulating a process, predicting an outcome, or characterizing a phenomenon.

Output

The results of processing data.

Peripheral

A component such as a digitizer, plotter, or printer that is not a part of the central computer but is attached through communication cables.

Phenomenological

Pertaining to the indefinite attributes or characteristics of real world features such as soil types and land cover types.

Pixel

One picture element of a uniform raster or grid file. Often used synonymously with cell.

Polygon

A vector representation of an enclosed region, described by a sequential list of vertices or mathematical functions.

Precision

If applied to paper maps or map databases, it means exactness and accuracy of definition. If applied to data collection devices such as digitizers, it is the exactness of the determined value.

Record

In an attribute table, a single "row" of thematic descriptors.

Rectify

The process by which an image or grid is converted from image coordinates to real world coordinates. Rectification typically involves rotation and scaling of grid cells, and so requires resampling of values.

Resolution

The size of the smallest feature that can be represented in a surface.

Registration

The process of making image data conform to another image. A map coordinate system is not necessarily involved.

Sequential clustering

An unsupervised classification method that analyzes pixels in an image line by line, and groups them by spectral distance. Clusters are determined based on relative spectral distance and the number of pixels per cluster.

Shape file

A simple, non-topological ArcView file format for storing the geometric location and attribute information of geographic features.

Table

Usually referred to as a relational table. The data file in which the relational data reside.

Theme

A collection of logically organized geographic objects defined by the user.

TIGER

Acronym for Topologically Integrated Geographic Encoding and Referencing data. A format used by the US Census Bureau to support census programs and surveys.

Topology

The spatial relationships between connecting or adjacent coverage features (e.g., arcs, nodes, polygons, and points).

Urban and Rural Population

As defined for the 1990 Census, the urban population comprises all persons living in urbanized areas and in places of 2,500 or more persons outside urbanized areas. The population not classified as urban constitutes rural population.

Vector data

A coordinate-based data structure commonly used to represent map features. Each linear feature is represented as a list of ordered x,y coordinates.

Viewsheds

Map which identify all areas that are visible from a particular, user specified viewing point or path.

APPENDIX-B

Examples of Records and Associated Fields That Make Up the Database.

AREA	LEFTOWN	BLCKGR	M.H.Income	CLASS	HOUSE_DEN
74025	0		0	Rangeland	0
16691.25	0		0	Wetlands	0
48190.49	0		0	Pine	0
306862.8	16	1	21563	Rangeland	18.76
136546.6	0		0	Rangeland	0
20947.46	0		0	Pasture	0
3235.375	16	1	21563	Pasture	18.76
1242074	16	1	21563	Rangeland	18.76
54051.81	0		0	Pasture	0
247.0195	0		0	Pine	0
21649.23	16	1	21563	Pine	18.76
302613.3	16	1	21563	Rangeland	18.76
38400	0		0	Broadleaf	0
51195.47	0		0	Rangeland	0
29933.17	0		0	Pasture	0
50334.41	0		0	Broadleaf	0
62554.64	0		0	Pasture	0
61569.05	0		0	Pine	0
47376.43	0		0	Broadleaf	0
19608.75	16	1	21563	Wetlands	18.76
1170021	16	1	21563	Pasture	18.76
43260	16	1	21563	Rangeland	18.76
32700	16	1	21563	Urban/built	18.76
35649.57	16	1	21563	Rangeland	18.76
67823.56	16	1	21563	Broadleaf	18.76
66493.09	16	1	21563	Broadleaf	18.76
53630.95	16	1	21563	Pine	18.76
104869.9	16	1	21563	Broadleaf	18.76
57600	16	1	21563	Wetlands	18.76
57600	16	1	21563	Broadleaf	18.76
17321.25	16	1	21563	Pine	18.76
86621.84	16	1	21563	Rangeland	18.76
164825.3	16	1	21563	Rangeland	18.76
173156.3	16	1	21563	Lakes/water	18.76
57600	16	1	21563	Pine	18.76
57600	16	1	21563	Broadleaf	18.76

115200	16	1	21563	Wetlands	18.76
403200	16	1	21563	Pine	18.76
57600	16	1	21563	Wetlands	18.76
172800	16	1	21563	Rangeland	18.76
27780	16	1	21563	Pasture	18.76
2179.984	16	1	21563	Wetlands	18.76
436982.1	16	2	26563	Rangeland	9.39
115200	16	1	21563	Pasture	18.76
748800	16	1	21563	Croplands	18.76
57600	16	1	21563	Pasture	18.76
230400	16	1	21563	Pine	18.76
57600	16	1	21563	Lakes/water	18.76
57600	16	1	21563	Broadleaf	18.76
8034.742	16	1	21563	Broadleaf	18.76
356589.5	15	1	21563	Rangeland	18.76
2425.922	15	1	21563	Broadleaf	18.76
44950.39	15	1	21563	Rangeland	18.76
57600	16	1	21563	Broadleaf	18.76
57600	16	1	21563	Wetlands	18.76
172800	16	1	21563	Broadleaf	18.76
57600	16	1	21563	Wetlands	18.76
172800	16	1	21563	Pine	18.76
292414.6	16	1	21563	Rangeland	18.76
8171.25	15	1	21563	Croplands	18.76
122528.1	15	1	21563	Rangeland	18.76
58875	16	1	21563	Wetlands	18.76
57600	16	1	21563	Broadleaf	18.76
403200	16	1	21563	Lakes/water	18.76
172800	16	1	21563	Pine	18.76
57600	16	1	21563	Pasture	18.76
230400	16	1	21563	Pasture	18.76
57600	16	1	21563	Rangeland	18.76
57600	16	1	21563	Pine	18.76
115200	16	1	21563	Rangeland	18.76
115200	16	1	21563	Broadleaf	18.76
5883.75	15	1	21563	Wetlands	18.76
784.3203	0		0	Rangeland	0
502.5625	0		0	Wetlands	0
196829.8	16	3	24226	Rangeland	13.48
590324.2	16	3	24226	Wetlands	13.48
75366.75	16	3	24226	Rangeland	13.48
234244.2	16	3	24226	Rangeland	13.48
18683.13	16	3	24226	Rangeland	13.48
120814.5	16	1	21563	Broadleaf	18.76
57600	16	1	21563	Wetlands	18.76

VITA

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