LINKING ECOLOGICAL AND SOCIAL DIMENSIONS OF MISSOURI LANDSCAPES

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entiled:

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A candidate for the degree of Master of Science, and hereby certify that in their opinion it is worthy of acceptance.

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1.1 Introduction

Two key ingredients in the quality of life of Missourians include a healthy natural and social environment. The former may be viewed as the ecological fabric of air, water, landforms, fauna & flora, etc, that comprise the natural setting of people's lives. The social environment may be described in terms of attributes of Missouri residents and the social relationships (e.g., economic, political) in which they are engaged. From a spatial or geographic perspective, the natural and social environments come together in the concept of *landscape* – the spatial configuration of abiotic, biotic and anthropogenic components that materialize as a functional entity, of which, serve as human's environment (Leser 1997). The recent emergence of the concept 'multifunctional landscape' may even better reflect the synthesis of ecology, economics, culture, history and aesthetics into one definition of landscape (Soini 2001). This concept also incorporates a key assumption of the recent natural resource philosophy of ecosystem management—i.e. that people are part of the ecosystem (or "natural" environment). All of the above suggests that ensuring the quality of life for Missourians is equivalent to:

1. sustaining the ecological integrity of Missouri landscapes and;
2. sustaining the cultural and social integrity of people's lives as embedded in those landscapes.

These two aspects, although materially united in the landscape, have traditionally been approached separately through the domains of the natural and social sciences ; that is, through sciences concerned with:

- the nature, structure, and processes of ecological systems (ecology/biology, etc.), and;

- the nature, structure, and processes of human social systems, as reflected in the networks of social relations (e.g., economic, political) among people living in places.

Depicting both the nature of and interrelationships between ecological and social systems is indeed challenging – even more so when attempting to incorporate the aforementioned notion that people are part of the Ecosystem (or natural world). While ecological systems are made up entirely of biophysical processes and entities, human social systems have both material and non-material dimensions. Only the former can be depicted spatially, in the process conveying information regarding the impacts of humans on ecological landscapes. But immaterial social entities and processes play a major role in affecting the concrete behaviors through which ecological impacts are generated. One way of envisioning the relationship between social and ecological systems is described by Lewis and Slider (1999) and presented in Figure 1.

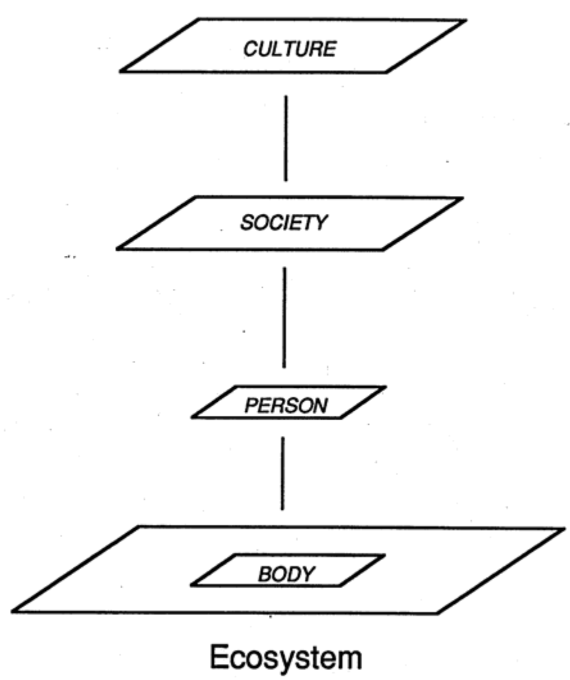

Figure 1. A framework for addressing the linkages between social and ecological systems (Lewis and Slider 1999)

First, as humans we are embodied beings with material needs -- food, shelter, health, etc. -- that confirm that we are indeed part of the natural world or Ecosystem. Our bodies are located in physical space via a spatial frame of reference with respect to all other material entities, including the Ecosystem. We actually *interact* with ecological systems exclusively through our bodies; and all the consequences for the status and integrity of ecological systems resulting from the complex of human actions at various scales are 'played out' at this biophysical level.

At the same time, when we consider the human individual as a *person*, it is evident that a person is more than his or her body. A person is a self-interpreting being -- someone to whom things matter or are *significant*. Through one's experiences a person establishes an identity and a point of view and interacts both with ecological systems and with other people based on that point of view. Thus one's identity and point of view both shape and strongly influence the biophysical behaviors through which a person interacts with the Ecosystem. An individual's beliefs, motivations, attitudes and other psychological attributes are not, however, themselves material entities amenable to location via a biophysical spatial frame of reference.

Moreover, humans are not only self-interpreting individuals; they are also social beings. People *interact* with one another and when interactions are repeated they form *relations* with one another. A *group*, or more inclusively, a *society* – may be understood as the web of social relations and processes that form the essence of collective life. While these relations are immaterial in nature, when people act in relational contexts they simultaneously interact biophysically with ecological systems, affecting their integrity for better or worse.

In this way persons act -- and engage in social relations -- through their bodies and on the basis of what is significant to them. But what is meaningful to a person is not exclusively a matter of his or her own creation. For in any society, meaning is embodied in patterns of beliefs, values, modes of aesthetic expression, and so on, that come to be *shared* by members of that society and passed on from generation to generation. Meaning is expressed in symbols, and *culture* may be understood as the shared patterns of meaning that find expression in peoples' interactions with one another, in their formation of personal identities and, of particular interest here, in their interactions with the material world -- whether the latter be viewed as manipulating ecological systems to extract various resources or as the simultaneous shaping of 'cultural landscapes.

In this light Figure 1 depicts the basic idea that human social systems are simultaneously material and symbolic (i.e., immaterial). It also makes more explicit the levels at which these two central aspects of human life need to be addressed in ‘linking the ecological to the social’ -- i.e., people's biophysical interactions with the Ecosystem, and the individual, social and cultural contexts within which the Ecosystem is significant to people.

This project focuses on the biophysical level of Figure 1 in the sense that the social data for this report consists of data abut people in places – that is, data that can be represented spatially via a biophysical frame of reference. Thus one of the foregone conclusions of this study will be that information provided here should be integrated with results from other studies that focus on the psychological, social and cultural entities, relations, and processes that influence peoples’ material interactions with ecological systems. Thus, for example, the research perspective of Brunckhorst (2005) focuses on linking the domains of landscape ecology, institutional theory, and design theory in exploring the social dimension of sustaining regional ecological landscapes. Only when all of these aspects of the 'social' are fully integrated will we be truly be able to understand the 'linkages between the social and the ecological.'

For Missouri, the composition and spatial distribution of the ecological landscape has recently been described by means of an ecological classification system (ECS) structured in terms of a hierarchy of ecological units (Nigh and Schroeder 2002). For some time, moreover, the Bureau of the Census within the U.S. Department of Commerce has systematically collected data on characteristics of people in places—i.e., spatial, socio-geographic data that describes people in terms of demographic (e.g., age, sex, etc.), social (e.g., education, marital status, etc.) and economic (e.g., income, occupation, etc.) characteristics. Recognizing that people are part of the ecosystem implies that the integrity of ecological and social systems is inextricably linked. Now that the ecological landscape in Missouri has been depicted spatially with the aid of the ECS, a key initial concern is to begin to examine the relationship or correlations between spatially-explicit ecological and social data for Missouri. This does not mean that causal relationships will be found simply by linking social and ecological datasets – Figure 1 suggests that much additional social information gathered via different methods will be required in uncovering such relationships. It does, however, lay the groundwork for hypothesizing about socio-ecological interrelationships and performing subsequent analyses to test those hypotheses. By exploring and identifying the ecological distribution of social-geographic data, we can begin to investigate systematically the idea that people are part of the landscape.

Understanding the relationships between the ecological and social dimensions of Missouri landscapes is critical for sustaining the mutually-interrelated integrity of each. That is to say, ecological sustainability depends upon and contributes to social sustainability, given that peoples' relations with one another and their actions arising from those relations have direct effects on the ecological integrity of natural landscapes. This is of more than passing interest in Missouri. For example, a recent study by the Brookings Institution (2002) has highlighted the need for integrating the ecological and the social dimensions at the landscape level. The study examined the "direction, scope, and implications of development in the state (Missouri) -- as well as the potential role of state and local policy in shaping those trends" (Brookings Institution 2002). It concluded that Missouri's current pattern of population growth:

- is eroding the state's rural heritage;
- is threatening the environment & natural areas;
- imposes significant costs on communities & taxpayers; and
- is hurting Missouri's competitiveness by eroding its quality of life.

The consequences of such growth prompt a need for better understanding the link between people (and their actions) and Missouri ecosystems. Knowing which (and how) ecosystems are being affected by socio-economic factors may help natural resource managers prioritize strategies for protecting those ecosystems through planning and education efforts. Such understanding may also help people better appreciate and articulate a sense of place and pride in where they live, which in turn would hopefully encourage them to better protect and care for their ecological environment.

1.2 Literature Review

There are several areas of relevant literature that will be important for this project. These include: (1) Studies that focus on spatially explicit links between people and the landscape; (2) Ozark-Ouachita Highlands Assessment; and (3) Spatially explicit reports/studies of people in places in Missouri.

1.2.1 Studies that focus on spatially explicit links between people and the landscape

A number of studies have examined links between people and the landscape in which the latter is delineated either in terms of particular levels within an ecological classification system (e.g., ecological subsection and/or land type association) or political/administrative spatial units such as county or metropolitan area. Studies that have incorporated genuine ecological boundaries have addressed the social dimension in terms of only one or two variables (e.g., housing density).

At a relatively broad spatial scale, Radeloff, Hammer, & Stewart (2005) examined selected social data on housing from the U.S. Census at a particular level of ecological resolution in studying the presence and impact of rural and suburban sprawl with respect to forest fragmentation in the U.S. Midwest. First, housing density (i.e., houses/km^2) was calculated for census geographic units spatially situated within ecological subsections. Here housing density was classified into three groups (i.e., low, medium, and high). Then the amount of forest land within census geographic units associated with the three housing density classes was calculated for U.S. Midwest subsections. The authors concluded that there was strong housing growth between the decades of 1940 and 2000 and that suburban and rural sprawl had occurred in particular subsections. With respect to these subsections, moreover, higher density settlements in urban areas were not proliferating as rapidly as were low and medium density settlements in suburban and rural areas. In terms of land and forest conservation, these results suggest future widespread threats to forests in the vicinity of low and medium density settlements and immediate localized threats to ecosystems surrounding urban areas (suburban sprawl) may be expected (Radeloff, Hammer, and Stewart 2005).

In an earlier study at a finer spatial scale, Radeloff et al (2000) examined the relationship between the ecological landscape (e.g., land cover data) and certain social phenomena (i.e., housing density) in the Pine Barrens of Wisconsin. Utilizing spatial data organized at the level of census block, they found that the highest housing densities occurred in blocks along lakes and other water bodies and that lower housing densities were found in forested and agricultural blocks (Radeloff and et.al. 2000). This exemplifies the linkage of a particular social variable (housing density) at a given level of spatial resolution – the census block – to a broad ecological characteristic (landscape type).

In the above two studies, the landscape is spatially delineated in terms of both ecological boundaries (e.g., subsection) reflecting natural characteristics of the land and political-administrative-statistical boundaries (e.g., county, census block) reflecting arbitrary socially-imposed boundaries on the landscape. In linking social characteristics of people to the places where they live, most studies have utilized political-administrative-statistical boundaries to delineate the landscape. This is true even if part of the focus is on a particular land or ecosystem type (e.g., forest). Several such studies are described below.

Because of population growth and migration, land use change and modeling thereof have become an increasingly important focui of recent research (Brown, Pijanowski, and Duh 2000; Brown 2003; Guo et al. 2003; Martin-Duque 2003; Conway and Lathrop 2005; Nikodemus et al. 2005). Brown (2003) investigated land use and its effects on amounts of forest cover in the Upper Midwest region of the United States. In addition to land uses identified from aerial photo interpretation, he obtained land use information in county socio-economic profiles containing 22 variables from the U.S. Census of Population & Housing. While many variables are identical to those comprising the socio-economic dimension in this study, there is little consideration given to the ecological dimension other than the amount of forest cover. From a spatial perspective, county boundaries do not effectively capture or characterize the ecological variation on the landscape. Overall, Brown's article sheds some light on relationships between land use and ecological integrity (with respect to forest cover). However, further integration of comprehensive socio-economic information about people in places delineated in terms of ecological boundaries would assist in natural resource planning while contributing to the interdisciplinary landscape ecology literature.

In another example of a socio-economic snapshot of people in the landscape, Theodori and Luloff (2000) selected a set of variables from the 1992 *Census of Agriculture* (e.g., number of farms, market value of crops, farms with sales over $100,000, etc.) to determine the amount of urban presence and pressure associated with rural communities in four Pennsylvanian counties. These were profiled based on a variety of variables from the 1990 Census of *Population and Housing,* including area in square miles; population; population change; age; education; and family characteristics.

The final phase of this study consisted of a general population survey from a random sample of residents of the four Pennsylvanian rural localities.

The above authors first looked at the rural landscape in terms of urban presence and pressure, then at the demographics of the people who lived in these localities, and finally at community attachment as expressed by a sample of these people measured through a qualitative survey. While this study did not include specific ecological information, it demonstrates the potential of synthesizing quantitative and qualitative methods to enhance understanding of people's relationships to the landscape.

A study by Parker (2003) utilizes the distinction between metro and non-metro counties as a tool for spatially differentiating the national landscape in the United States. The author highlights differences in poverty, % of college graduates, average earnings, full-time year-round jobs, low skill jobs, housing costs, and natural amenities. He finds that even though some non-metro areas have micropolitan centers within them, there are still noticeable differences between the non-metro and metro areas of the U.S with respect to a variety of social variables. Non-metro areas have fewer college graduates, a smaller share of workers employed full-time year-round, a lower share of jobs in management and professional occupations, higher poverty rates, and lower earnings in general. However, housing expenses are a smaller part of the budget and natural amenities are more plentiful in non-metro areas (Parker 2003). These factors may or may not have any direct, immediate impact on the environment, but indirect, longer-term effects on the nature and character of the landscape are to be expected.

As noted above, most studies linking people and the landscape do so by delineating the latter in terms of socially-imposed arbitrary boundaries of a political, administrative, or statistical nature. There are relatively few examples of research that explicitly links the social and *ecological* dimensions of landscapes. This has been noted recently by two scholars in calling for more studies of this nature. Pebley (1998) points out that socio-ecological studies can benefit both environmental researchers and demographic researchers alike. She states that the shift from the social context of human behavior to the physical context (i.e., ecological) will be a direct result of demographic studies that integrate the ecological dimension. In a desperate call for more interdisciplinary research, Liu (2001) states the importance of integrated studies not only for urban but also rural areas. With respect to biodiversity conservation, the author states that it may be more important to study rural and less-populated areas because in these areas it should be easier to conserve biodiversity. Liu's paper summarizes 10 socio-ecological studies that may lead the way for integrated studies to follow.

1.2.2 Ozark-Ouachita Highlands Assessment

Much more representative of the kinds of studies linking people and places in Missouri (and elsewhere) are the reports comprising the Ozark-Ouachita Highlands Assessment. As is the case with the majority of studies described in the previous section, this social assessment does not employ ecological boundaries in relating social attributes of people to the landscape. It does, however, reflect the kinds of social variables, trends, and other spatial factors that will need to be incorporated in the socio-ecological approach described in this thesis.

The Ozark-Ouachita Highlands Assessment was an interagency effort coordinated by the U.S. Forest Service to collect and analyze ecological and socio-economic data concerning the Ozark Highlands in Missouri, Arkansas, and Oklahoma (USDA Forest

Service 1999). The Missouri portion of the assessment area included 50 counties in the central and southern areas of the state that are part of the Ozark Highlands. The purpose of the assessment was to provide information to facilitate an ecosystem-based management approach on public lands in the Ozark Highlands. Results are contained in a series of reports focusing on air quality, aquatic conditions, terrestrial vegetation and wildlife, and social and economic conditions.

Of particular interest here is the fourth report entitled *Social and Economic Conditions* (USDA FS 1999). This report includes chapters on historical background; social and demographic conditions and trends; communities; local economies; outputs of specific resources (ex. timber, recreation, minerals, and range); and attitudes, values and opinions of people in the region. All of the above topics are described and investigated at the county level of spatial analysis utilizing data from the 1990 Census of Population & Housing and other sources. Counties within the assessment area are classified as either metropolitan or non-metropolitan and also on the basis of whether or not they contain national forest lands. Of the 50 Missouri counties within the assessment area, 26 contain National Forest land. Assessment highlights and implications for this latter group of counties were presented and further discussed by Lewis (2004).

One of several important findings in the Ozark-Ouachita assessment was that the population in the overall assessment area grew nearly 50 percent over the time period 1970-1996. This was well above the state and national averages in terms of population growth (Missouri: 15%; Oklahoma: 29%; Arkansas: 31%; and the Nation: 31%). In addition, it was found that more than half of the assessment area population (and 60 percent in the Missouri portion) live in the open country – that is, in predominantly unincorporated areas. It was also reported that two and a half percent of total U.S. output of forest products was attributed to the assessment area. Thirteen of the 26 national-forest-land counties in the Missouri portion of the assessment area were classified as “timber-significant” – i.e., counties where the forest products industry is especially important. Nine counties in the Missouri portion of the assessment area were identified as “minerals-significant;” and 19 counties in this area were “travel-significant,” indicating that these landscapes are especially important as destinations for tourists and/or recreation enthusiasts. A final result of the report noted widespread agreement in a survey of assessment area residents that “…different uses of national forests should be balanced (e.g., recreation, timber management, mining, wilderness, wildlife)…” (USDA FS: 239).

This study was completed in late 1999 and exemplifies one which discusses relationships between ecological and social dimensions of Missouri landscapes. It does provide an excellent example of the kinds of demographic and socio-economic foci that merit attention in a regional assessment, in the process yielding some significant information on the socio-economic attributes and activities of people living in a major component of Missouri’s ecological landscape. However, as noted above, the landscape is spatially depicted in terms of political, administrative, and statistical boundaries employed in the U.S. Census, as opposed to ecological boundaries reflecting the natural character of the land.

1.2.3 Spatially explicit reports/studies of people in places in Missouri

1.2.3.1 U.S. Bureau of the Census

Data collected by the U.S. Bureau of the Census is the broadest and most ubiquitous data on spatially-explicit social attributes of people in Missouri. A number of important censuses conducted by the Census Bureau include: the Census of Population and Housing, the American Community Survey (which will become the replacement for the decennial Census of Population & Housing in 2010), Small Area Income and Poverty Estimates, the Current Population Survey, the American Housing Survey, the Economic Census, and the Annual Survey of Manufactures. For this study, the Census of Population and Housing (U.S. Department of Commerce: Bureau of the Census 2001) is the most important of the above. Often, moreover, the most useful information from this data is contained in summaries prepared by Missouri state agencies that use census data in reporting on conditions in Missouri.

1.2.3.2 The Office of Social and Economic Data Analysis (OSEDA)

The Office of Social and Economic Data Analysis (OSEDA) at the University of Missouri-Columbia has produced many reports using U.S. Census data. OSEDA reports for Missouri focus on such social variables as population change (Dranginis 2002; Hobbs 2002a), employment status (Hobbs 2004c), educational attainment (Hobbs 2002d), income (Hobbs 2002f; Hobbs 2004a) and poverty levels (Hobbs 2002b; Hobbs 2002c; Hobbs 2002e; Hobbs 2004b), and others. Demographic profiles have also been constructed for all Missouri counties; in addition, profiles that include 29 categories of socio-economic variables have been constructed for the entire state at the level of block group and census tract. OSEDA also produces visual presentations (e.g., PowerPoint) and data tables depicting data from the 2000 U.S. Census of Population & Housing for administratively defined geographic areas in Missouri such as University Extension regions, Department of Economic Development (DED) regions, and Missouri Department of Transportation (MODOT) districts.

1.2.3.3 MERIC

The Missouri Economic Research and Information Center (MERIC) within the Missouri Department of Economic Development (DED) has also produced a variety of socio-economic reports utilizing census data. Categories of socio-economic variables in MERIC reports include: demographics, land use (e.g., agriculture and farms), economic indicators (e.g., economic momentum), industry reports (e.g., tourism), occupation (e.g., Missouri occupational profiles), and community issues (e.g., economic impact analyses). In addition to reports at the county level (or other levels of the census geographic hierarchy [Figure 2]), DED/MERIC issues a variety of reports in which 13 economic development regions (delineated by DED/MERIC) constitute the geographic units of analysis.

1.2.3.4 The Brookings Institution study

As noted briefly in the Introduction, in 2002 the Brookings Institution issued a report entitled *Growth in the Heartland: Challenges and Opportunities for Missouri*. This report examined the path of development trends across the Missouri landscape and the implications of those trends for the quality of life of state residents. Missouri was selected for analysis because of the variety apparent throughout its landscape. “The state is highly urban yet deeply rural”, state the authors (Brookings Institution 2002:3). It has metropolises, suburbs, and many small towns; in a sense, therefore, Missouri is a miniature representation of the nation.

The study reported that Missouri's human population grew modestly during the 1990's and that growth was well distributed around the state. Growth has, however, slowed since the year 2000. Rural area population grew approximately 11% in the last decade, and many of Missouri's rural areas experienced population growth at a faster rate than that of the overall state population growth (9.7%). At the same time, four medium-size metropolitan areas -- St. Joseph, Joplin, Columbia, and Springfield -- emerged as some of the fastest-growing areas in the state. In addition, 680 square miles of Missouri's landscape was converted to urban use, a 35% increase in urban land area between the years 1982 and 1997 (2002:4).

The Brookings study also found that Missouri is decentralizing. "As it grew in the 1990's, the state's population moved ever outward across the state's landscape" (2002:4). Sixty percent of Missouri's population growth in the 1990's occurred outside the St. Louis and Kansas City's metropolitan areas. Unincorporated and open country areas grew at a faster rate than cities and towns in Missouri. Residential, commercial, and other developments have also followed suit and have located all across Missouri. As further evidence of this pattern, Daryl Hobbs of OSEDA at the University of Missouri-Columbia writes that "a growing proportion of Missouri's population is choosing to live in the open country, especially in those counties that combine natural resource amenities with proximity to employment and recreation opportunities" (Hobbs 2002a). The implications of the above for the status and integrity of the state's ecological landscapes are surely substantial.

Another major conclusion of the Brookings study is that while many Missourians have benefited from the pattern of growth noted above, the decentralizing effects of growth are cutting into some of those benefits. As noted in part in the introduction, Missouri's current pattern of growth is:

- imposing significant costs on communities and taxpayers;
- eroding the state's rural heritage;
- threatening the environment and natural areas;
- hurting Missouri's competitiveness by eroding its quality of life;
- straining the state's transportation systems; and,
- isolating low-income and minority Missourians from opportunity.

It is clear from the Brookings study that patterns of population growth in Missouri pose severe challenges to the ecological and social sustainability of Missouri landscapes (2002:44-54). Thus the need for better understanding the spatially-explicit relationships between people's actions and the ecological integrity of Missouri landscapes is clearly evident.

1.2.3.5 Summary of relevant literature

Relevant bodies of literature that are important in understanding the link between the social and ecological dimensions of Missouri landscapes include: the few studies that focus on the spatially explicit links between people and the landscape; the Ozark-Ouachita Highlands Assessment; and various spatially explicit reports/studies of people in places in Missouri. For much of the literature above, links between the social and ecological dimensions of landscapes are described with respect to socio-political boundaries instead of ecological constructs. An exception to this, in focusing on the links between people and the landscape, Radeloff et al (2005) frame the social dimension in terms of the phenomenon of rural sprawl *and* the ecological dimension with respect to ecological subsections. Therefore, the Radeloff study serves as a model in linking the social and ecological dimensions and in achieving the objectives presented in chapter 2.

An additional relevant body of literature to this research, the Ozark-Ouachita Highlands Assessment, represents an important source of socio-economic information on people who live in the landscapes within and adjacent to portions of Missouri. While this assessment is not framed in respect to ecological boundaries, its socio-economic element draws a comprehensive picture of people in the landscape and serves to justify the selection of certain socio-economic variables as described in chapter 3 (Materials and Methods).

The last source of literature – spatially explicit studies linking people and the landscape – is also important because it provides additional information on the socio-economic dimension in Missouri. Here, mainly socio-political boundaries are utilized in associating socio-economic attributes of people with the landscape. However, in a report by the Brookings Institution (2002) looking at population growth patterns in Missouri, the impact of socio-economic behaviors on Missouri landscapes is realized. While the literature mentioned above focuses mainly on the material/physical dimension of people on the landscape, the report by the Brookings Institution introduces the immaterial aspect of the social dimension in terms of people's behavior/actions/attitudes. Although not a specific objective of this research, bringing the 'immaterial' into socio-ecological studies of this sort establishes a stronger foundation in understanding the interrelationships between people and the landscape.

2 Purpose and Objectives

The overall purpose of this study is to better understand the interrelationships of people and places in Missouri by systematically exploring the nature and emergence of *socio-ecological* relationships at different levels of geographic scale. In doing so, it is important to preserve the holistic dimension of Missouri landscapes by integrating spatially-depicted ecological units with socio-economic characteristics of people also arrayed along a spatial continuum. Other studies have explored relationships among people and the ecosystems in which they live or work, but without the benefit of a spatial hierarchy of ecological units such as the ecological classification system (ECS) recently completed for Missouri (Nigh and Schroeder 2002). In this study, the 'social landscape' is spatially delineated according to the geographic hierarchy for the U.S. Census. The focus of the study is also consistent with the adoption of a landscape perspective as part of landscape ecology (Field et al. 2003).

The specific objectives of this study are to:

- Describe the kinds of people who are living in different Missouri landscapes.
    - Do different landscapes in Missouri also differ in terms of people who live there, as reflected in social profiles of people in ecological places? For example, do people living in plains landscapes differ from those in hills landscapes with respect to education and/or income?
- Identify the socio-economic attributes that are prominent in different landscapes.
    - Are socio-economic attributes of people in Missouri (e.g., income or education level) systematically associated with particular ecological units? At what scales do certain socio-ecological characteristics emerge? For example, at a coarse scale the average level of education may be prominent in an ecological unit, while at a fine scale household income may be important.

- Examine the spatial manifestations of social diversity and fragmentation across the landscape.

    - How are socio-ecological relationships spatially distributed across ecological units? Are ecological units characterized by a broad (diverse) or narrow range of socio-economic attributes of people who live within them? Are these attributes spatially distributed across ecological units uniformly or in patterns that are fragmented or clumped together spatially?

A final research question synthesizing the above is:

- What are the potential implications of relationships among the data in terms of ecological and social sustainability of Missouri landscapes?

    - This includes assessing the relationship between ecosystem features & the social characteristics of people who live in and visit those ecosystems as a basis for constructing a research agenda for future work.

3 Materials and Methods

This chapter begins with a description of the ecological and socioeconomic datasets used in this study. This is followed by a look at the three methods employed in addressing the study objectives. The first involves the construction of socio-economic profiles for ecological units. The social variables, GIS pre-processing steps, and statistical analyses associated with profile construction are described. The second method focuses on the identification of prominent socio-economic attributes for ecological units. These are identified with the aid of Classification & Regression Tree Analysis (CART) analysis. CART is introduced via a review of literature and a description of its sampling procedures, pruning techniques, products (descriptor variables), and tree replicates. The third method utilizes the results of the CART analysis to create maps and measure patterns of diversity and fragmentation of socioeconomic attributes in ecological units. The FRAGSTATS spatial statistical package is employed to help quantify these patterns.

3.1 Materials

The two major types of spatial data to be used in this project are: a) descriptions of Missouri landscapes in terms of an ecological classification system (ECS) structured in the form of a hierarchy of ecological units; and b) social and demographic attributes of people from the 2000 US Census of Population & Housing summarized at the block group level of the census geographic hierarchy. Levels of the ecological hierarchy define units which vary qualitatively and are generated on the basis of a number of underlying ecological variables (i.e., geology, soils, topography, and vegetation). Census data comprising a broad range of social and economic variables (e.g., age, education, income, etc.) spatially depicted in terms of a socio-geographic hierarchy are provided via the Missouri Spatial Data Information Service (MSDIS). Linking data on Missouri from the ECS and census spatial hierarchies yields a resultant set of data for the state in the form of spatial units simultaneously characterized by ecological and social variables.

3.1.1 Ecological Data

Ecological data for this project is organized according to the Missouri Ecological Classification System (ECS) which itself incorporates the National Hierarchical Framework of Ecological Units (Cleland et al. 1997), a spatial-hierarchical representation of the ecological landscape. The national hierarchy is a systematic framework for delineating ecological regions (units) at various spatial scales (Table 1). At the broadest level (domain), ecological units represent broad zones of similar climate; while at the finest spatial level (landtype phase), ecological units are based on soils, slope position, and plant associations.

The National Hierarchical Framework supplies the framework within which Missouri's ecological landscape has been classified into ecological units. The Missouri Ecological Classification System (ECS) Project involves an interagency team currently under the auspices of the Missouri Resource Assessment Partnership (MoRAP). This interagency team applied the aforementioned National Hierarchy of Ecological Units to Missouri. Sections and subsections were first created for the state in 1993-1994, and matched to the boundaries created for surrounding states (Nigh & Schroeder, 2002). As of 2002, the Missouri ECS had been refined to the landscape level of resolution as reflected in the hierarchical unit landtype association [LTA]. Finer ecological levels (e.g., ecological land types [ELTs]) are currently being mapped for Missouri.

Table 1. Ecological Classification System (ECS): Ecological Units of the National Hierarchy

Ecological Unit	Design Criteria	Polygon Size
Ecoregion		
Domain	-Broad climatic zones or groups	1,000,000s of square miles
Division	-Regional climatic types -Vegetational affinities -Soil order	100,000s of square miles
Province	-Dominant potential natural vegetation -Highlands or mountains with complex vertical climate/vegetation/soil zonation	10,000s of square miles
Subregion		
Section	-Geomorphic province, geologic age, stratigaphy, lithology -Regional climatic data -Phases of soil orders, suborders, or great groups -Potential natural vegetation-potential natural communities (PNC)	1,000s of square miles
Subsection	-Geomorphic province, geologic age, stratigaphy, lithology -Phases of soil orders, suborders, or great groups -Subregional climatic data -PNC-formation or series	10s to 1,000s of square miles
Landscape		
Landtype Association (LTA)	-Geomorphic processes, geologic formation, surficial geology, and elevation -Phases of soil subgroups, families, or series rock type, geomorphic process -Local climate -PNC-series, subseries, plant associations	1,000s to 10,000s of acres
Land Unit		
Landtype	-Landform and topography -Phases of soil subgroups, families, or series -Rock type, geomorphic process -PNC-plant associations	100s to 1,000s of acres
Landtype Phase(ELT-P)	-Phases of soil subfamilies or series -Landform and slope position -PNC-plant associations or phases	Less than 100 acres

(Source: Atlas of Missouri Ecoregions 2002).

Ecological units within the hierarchy on which this study focuses – as well as the non-hierarchical unit of LTA Type, are defined below.

- **Section:** distinct biogeographic regions established according to geomorphology, potential vegetation, and major soil groups
- **Subsection:** subdivisions of sections and established according to section criteria but at a finer resolution
- **Land type association (LTA):** subdivisions of subsections based on local patterns in topography, geological parent materials, soil types, and vegetation communities
- **LTA Type:** groupings of ecologically similar LTAs and are not subdivisions of any of the above levels of the hierarchy; does not constitute an official ecological unit

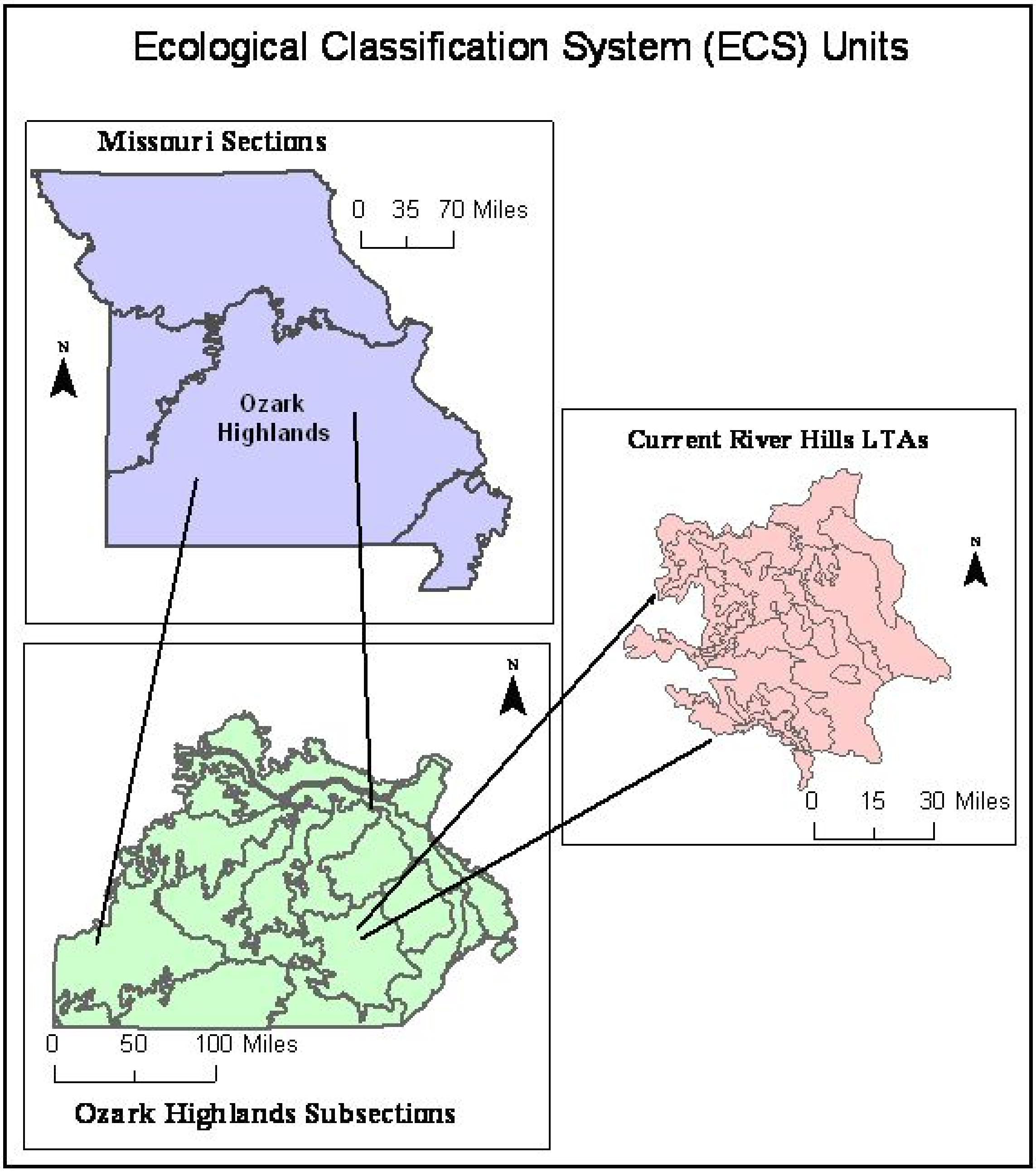

Figure 2. ECS Hierarchy for Missouri: Sections, subsections, and landtype associations (LTAs).

Missouri is encompassed by one domain (Humid Temperate) and parts of three divisions (Hot Continental, Subtropical, and Prairie) and three provinces (Eastern Broadleaf Forest [Continental], Lower Mississippi Riverine Forest, and Prairie Parkland [Temperate]). Missouri's four ecological sections (Figure 2) include: (1) the Ozark Highlands (OZ) which is composed of plains, hills, forest breaks, and other rugged landscapes; (2) the Central Dissected Till Plains (TP) comprising mostly flat expanses dissected by several hilly landscapes; (3) the Osage Plains (OP) which is a gently rolling landscape; and (4) the Mississippi River Alluvial Basin (MB) comprising alluvial plains and unique sand ridges and hills. Within these sections of Missouri are 31 subsections, more than half of which are located in the OZ section. Encompassed by both section and subsection boundaries, a particular landtype association (LTA) is specific to (i.e., only found in) a given section and subsection. There are 264 LTAs that comprise the ecological landscape in Missouri. *LTA type* – a non-hierarchical unit derived from the grouping of ecologically similar LTAs. It is also a 'unit' of interest in this study and is partially represented in the ECS coverage data (i.e., only boundaries are depicted – no additional coverage information). There are 25 LTA Types for Missouri. A complete listing of Missouri's ecological units comprising the levels of section, subsection, LTA, and LTA Type may be found in Appendices 1 and 2.

Figure 2 provides an example of levels of the ecological hierarchy when applied to Missouri. Therein is depicted the Ozark Highlands section (one of four encompassing the entire state), its 16 subsections, and the 9 LTAs within the Current River Hills subsection. Geographic Information System (GIS) coverages for these levels of the ECS in Missouri include: a) data found in Table 1; b) land use information from a Missouri land cover classification; and c) ecological unit boundaries.

3.1.2 Socio-economic Data

The socio-economic data compiled in the 2000 U.S. Census of Population & Housing for Missouri was utilized in this study. The census is administered in order to ensure an accurate apportioning of state representatives to Congress. It is also used to aid federal, state, local, and tribal governments in distributing fiscal resources (USDC Bureau of the Census 2002).

The Census Bureau employs its own geographical classification scheme as a framework for interpreting, analyzing, and understanding census data. It classifies the census geography into three categories – legal/administrative entities, statistical entities, and a mix of the two. Examples of administrative entities include: congressional district, county, incorporated place, minor civil division, state, and voting district (USDC BC 2002):5). Examples of purely statistical entities include: *block group*, census block, census county divisions, census designated place, census tract, metropolitan area, public use microdata area (PUMA), rural, urban, urbanized area, urban cluster, and zip code tabulation area (ZCTA) (USDC BC 2002):6). American Indian, Alaska Native, and native Hawaiian entities have a mix of both legal and statistical uses.

The core spatial hierarchy, along with most classificatory units unique to specific levels of that hierarchy, may be found in Figure 3. Statistical units of the core census spatial hierarchy at the state level and below may be defined as follows (see Figure 4 for a Missouri example).

- **State:** A primary governmental division of the United States.
- **County:** the primary legal division of every state except Alaska and Louisiana

- **Census tract:** small statistical subdivision of a county with generally stable boundaries (averaging about 4,000 persons); a boundary of a state or county is always a census tract boundary
- ***Block group*:** a statistical subdivision of a census tract; contains between 300 and 3,000 people and is the lowest-level geographic entity for which the Census Bureau tabulates sample data (SF-3 data – see below)
- **Block:** generally bounded by streets, legal boundaries, and other features; a block is the smallest geographic unit at which the Census Bureau tabulates 100% count data (SF-1 data – see below)

For this study the *block group* level of the spatial hierarchy is especially relevant.

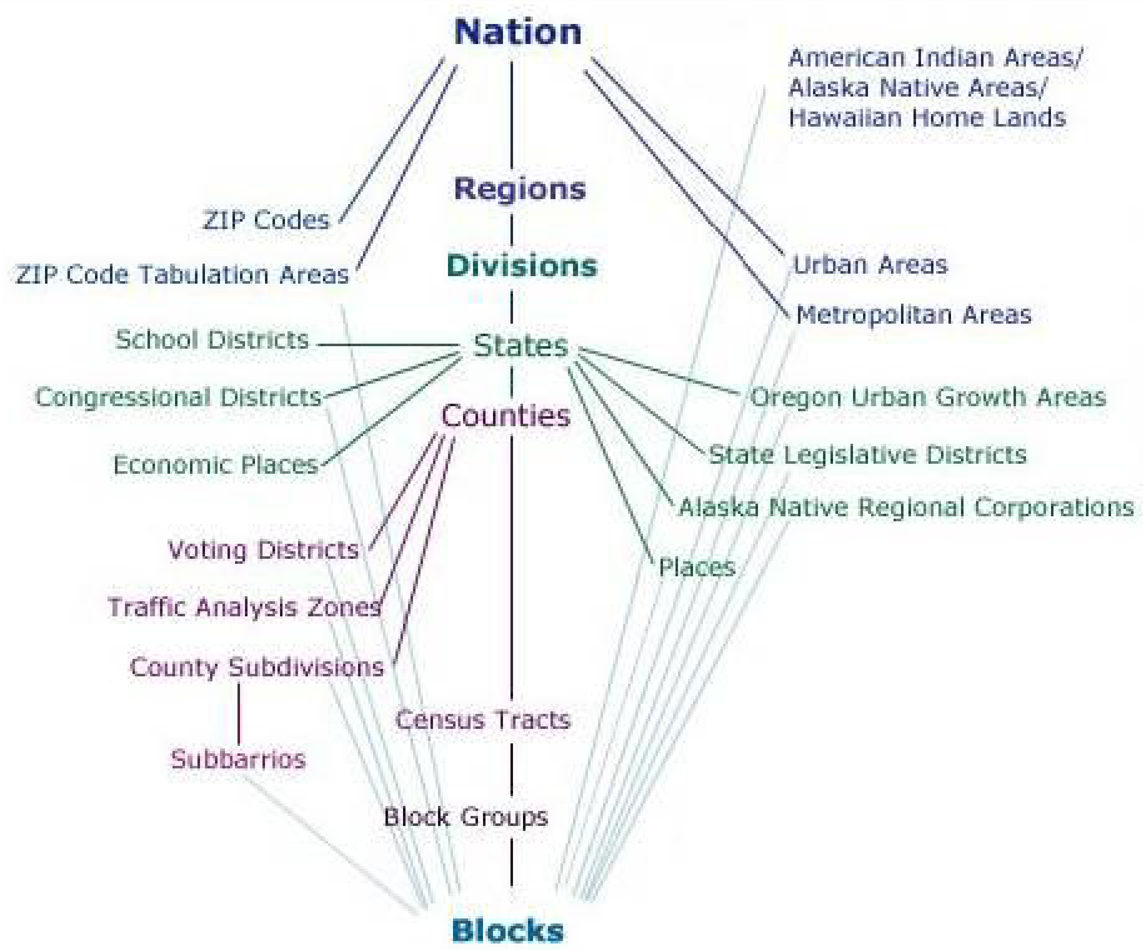

Figure 3. Geographic Hierarchy for 2000 U.S. Census. (U.S. Census Bureau 2000)

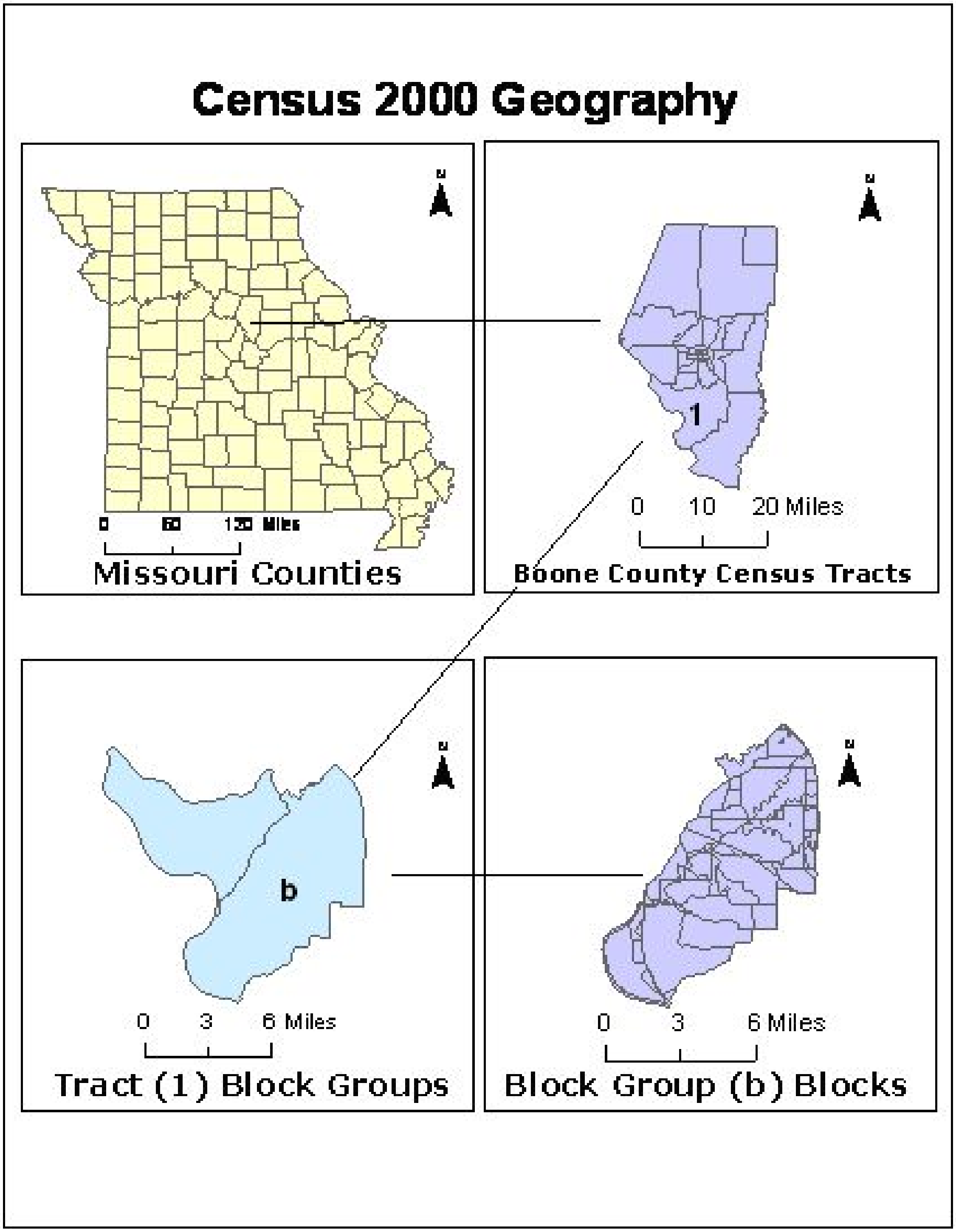

Figure 4. 2000 Census Geographic Hierarchy for Missouri: counties, tracts, block groups, and blocks.

With respect to the collection of socio-economic data associated with census geographical boundaries, two questionnaires varying in length – a short form (SF-1) and a long form (SF-3) – are administered to the public. The short form (SF-1) census questionnaire is utilized to acquire data aggregated to the level of *census block* on sex, age, race, Hispanic or Latino origin, household relationship, tenure, and vacancy characteristics for all people and housing units. Three-thousand variables were compiled from the U.S. Census 2000 short form survey. Data for the long form (SF-3) is summarized by *block group* (as opposed to census block) for confidentiality reasons. The long form – given to approximately 1 in 6 people in the state – contains 5,300 variables representing such categories as marital status, school enrollment, ancestry, migration, labor force status, income, and value of home. Thus, the block group level is important to this study because it is the lowest census geographic level for which the most detailed information about people (SF-3) can be obtained.

The Census Bureau has released data from the 2000 Census of Population and Housing in a variety of layouts, including formatted summary file data (SF-1 through SF-4), tables, maps, special reports, briefs and demographic profiles. Online data retrieval is also possible through American FactFinder (AFF). The Missouri Spatial Data Information Service (MSDIS) has compiled a data table of approximately 220 SF-3 variables from the U.S. Census of Population & Housing's original set of over 5,300 variables. These 220 variables were chosen as those best suited for many different agency and lay-person applications. Because this list is used by University of Missouri's Office of Social and Economic Data Analysis (OSEDA) in constructing profiles for Missouri counties, tracts, and block groups, it was deemed to constitute a good core dataset for describing the social dimension of Missouri landscapes in this study.

It is important to note that the census geographic units are either political (e.g., county) or statistical (e.g., block group) in nature. Political and statistical boundaries invariably do not coincide with ecological boundaries.   Therefore, the spatial boundaries associated with the U.S. Census geography are not representative of the ecological dimension of Missouri landscapes.

3.2 Methods

3.2.1 Constructing social profiles for ecological units

In constructing social profiles for ecological units, the first step involves GIS processing. This enables selected profile variables to be included in subsequent analyses. Statistical techniques are then applied to investigate potential differences in ecological units according to socio-economic profile variables.

3.2.1.1 GIS processing—linking socioeconomic data with ecological data

There are two kinds of Geographic Information Systems (GIS) representations or *coverages* utilized in this study. Coverages are spatial representations of certain spatial features (e.g., ecological units or block groups) and usually include attributes describing the features (e.g., elevation, area, etc.) and/or objects within them (e.g., vegetation, people, etc.). The former represent the ecological coverage according to Missouri's ECS and the latter reflect the socio-geographic coverage of Missouri obtained from the U.S Census.

Combining the above yields a single coverage which includes all the pertinent ecological and socioeconomic data in a spatial context. That is to say, with each block group there are associated 220 socio-economic variables and one ecological variable – the ecological unit. This step of reconciling the ecological and social datasets was accomplished using ArcGIS 9.1.

With respect to creating the socio-geographic and socio-ecological coverages, a first step involves linking socio-economic data from the SF-3 table to the census block group geography as represented within a GIS framework.[1] This is accomplished via a 'join' operation in ArcGIS. A second GIS step involves intersecting boundaries of sections, subsections, and land type associations (LTAs) – via ArcGIS – with boundaries of census block groups. Thus, data identified on the basis of spatially delineated ecological units (e.g., section, subsection, LTA, etc.) is linked to data identified on the basis of spatially delineated socio-economic units (e.g., census block groups). Figure 5 illustrates this linkage of data from the ecological and social hierarchies.

Once this is completed, an *urban mask* is applied to the block group geography and corresponding socio-economic data. That is to say, block groups with 90% or greater urban population are deleted from this and subsequent analyses to limit the amount of urban effect on potential relationships in the spatially much more extensive non-metropolitan areas of the state. This is important because urban areas (representing smaller portions of Missouri in terms of land area) contain large numbers of block groups in relatively small areas. They also tend to differ significantly from rural areas with respect to a variety of social attributes. For these reasons, interpretation of socio-ecological relationships would be more challenging if urban areas were included. This is because an ecological unit that includes both urban and rural populations would likely have higher average values for various socio-economic attributes than ecological units with no urban areas. While it is important to investigate socio-economic attributes and behaviors of the state's urban population and their ecological implications, this is not a specific focus of this research project.

[1] This is constructed via a set of polygons with spatial coordinates that is 'superimposed' on a focal geographic area.

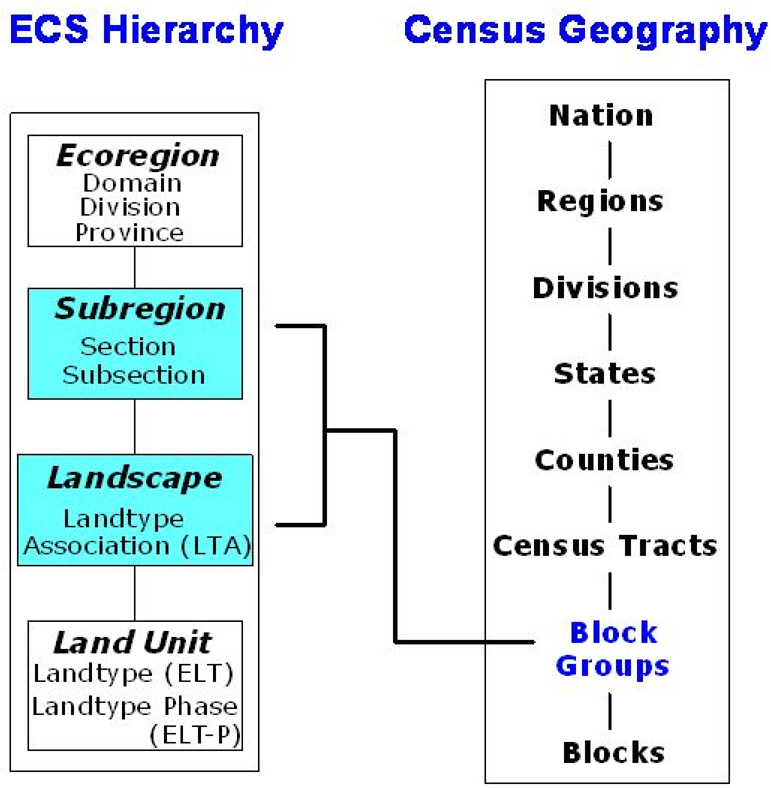

Figure 5. Linking the spatial hierarchy of Missouri's ecological classification system (ECS) with the geographic hierarchy of the 2000 U.S. Census. (Sources: Nigh & Schroeder 2002; U.S. Census Bureau 2000)

In accomplishing all the above, a more general problem arises due to the fact that block group boundaries invariably do not coincide with those of ecological units (i.e., subsection, LTA, etc.) [Figure 6]. For example, when block groups are superimposed onto ecological subsections, a given subsection may 'encompass' all or parts of 30 block groups. Twenty of these block groups may lie completely within the subsection boundaries and hence the people who live within those block groups may be clearly identified as living within that ecological subsection. However, the boundaries of the remaining ten block groups may to varying degrees extend beyond the subsection boundary (Figure 6). For these 'boundary overlapping' block groups, the social variables assigned to an entire block group must be *area-weighted* to reflect that portion of the block group that is actually within the boundaries of the ecological unit. In this way, ecological units can be assigned social variables obtained from the area-weighted block groups that 'fall within' the actual ecological unit boundaries.

The area-weighting procedure assumes that the population in any given block group is distributed evenly across the landscape. While this may be the case for some block groups, others will likely have a compartmentalized arrangement of people within them. Thus the method employed here is only one way of integrating these social and ecological (i.e., socio-ecological) datasets. Other techniques may also be employed. One such method would involve interpolating population distribution based upon night-light satellite imagery. This technique, however, is beyond the scope and resources of this project.

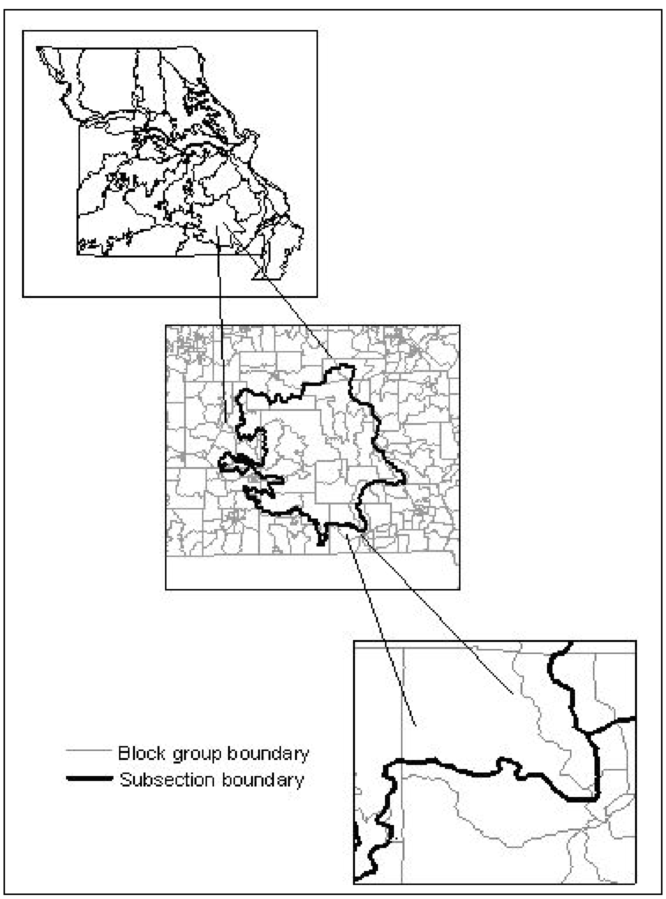

Figure 6. The problem of synchronizing boundaries of ecological and social units

Once the U.S. Census dataset (220 variables) and the Missouri ECS dataset are integrated, the resulting combined dataset provides the basis for constructing social profiles of ecological units. However, one problem still exists within this newly formed socio-ecological dataset – each block group will have a distinct value for any given social variable. In order to construct a single profile value for an ecological unit, the individual block group values for that social variable must be combined into one mean value for that ecological unit. Because block groups and partial block groups vary in size, another area-weighting step (i.e., area-weighted mean) must be employed via ArcGIS. That is to say, if a particular ecological unit is dominated by one large block group and two small block groups, the one large block group will 'exert a greater influence spatially' than the smaller block groups and hence contribute more to the area-weighted mean value attributed to that ecological unit.

3.2.1.2 Social profiles for Missouri ecological units: Variables and analysis

In order to describe people within Missouri ecological units and to facilitate comparisons between the social and ecological dimensions of those units, social profiles were generated for each of Missouri's four ecological sections. There are a total of 220 variables within the original socio-economic database. Such a large number of variables is, however, unwieldy for this analysis; thus a representative set of 31 profile variables was selected (Table 2). The 31 variables were selected because they are representative of seven basic social categories describing people in places in Missouri; these include population attributes, age, race, education, occupation, income, and housing. These variables thus constitute the set of social descriptors for people living within any given ecological unit.

The Statistical Product and Service Solutions (SPSS) package was utilized in constructing the 31 variable-profiles. Each profile variable is represented by a mean value for people situated within an ecological unit. Social profiles for the ecological units of subsection and LTA Type are located in Appendix 3. ANOVA analyses were conducted for ecological sections employing the SPSS statistical package. The purpose in performing ANOVA is to investigate the potential differences in socio-economic attributes of people across sections. Variables that are significantly different statistically are identified.[2]

[2] Statistical difference is defined at the .05 significance level. Due to constraints, both time constraints and potentially limited analytical value, ANOVA analyses were not conducted for subsections and LTA Types.

Table 2. Social profile for ecological sections in Missouri.

Social variables
Population
Total persons
Persons per sq mile
Urban population
On farms
Age
0 to 9
10 to 19
20 to 44
45 to 64
Over 65
Race
White alone
Black alone
Minority population
Education
Less than 9th grade (No high school)
High school grad or GED
Bachelors degree
Occupation
Management, professional & related
Service
Sales and office
Farming, fishing, & forestry
Construction, extractions & maintenance
Production, transportation + material moving
Income
Median HH Income
Average HH income of HHs < $200k
Median family income
Average family income
Per capita income
Mean poverty ratio
Housing
Renter occupied units
Median year moved in
Average age of units
Median house value
Average house value

3.2.2 Identifying prominent socio-economic attributes for ecological units

3.2.2.1 Classification and Regression Tree Analysis (CART)

Classification and Regression Tree Analysis (CART) is applied in this study as a tool to identify social variables that serve to differentiate people by particular ecological units. CART can be described as a complement or alternative to statistical techniques such as multiple regression, analysis of variance (ANOVA), and discriminant analysis (De'ath and Fabricius 2000; Karels, Bryant, and Hik 2004). It attempts to capture the variation in a dependent variable based on one or more independent variables. The relationship between the dependent and independent variables can be exploratory, descriptive, or predictive in a given analysis. *Classification trees* are constructed in exploratory or descriptive analyses and *regression trees* are constructed in predictive analyses (De'ath & Fabricius 2000). This project utilizes classification trees for describing ecological units according to social attributes of people who live within them.

CART originated over two decades ago and has achieved popularity as a robust statistical technique (Breiman et al. 1984; Lawrence and Wright 2001). It has been employed in various ecological applications including ecological land classification (DeLain 1997; Hansen et al. 2000; Franklin 2003) and predicting spatial distributions of plant and animal species (Miller and Franklin 2002; Fan et al. 2003; Thuiller, Araujo, and Lavorel 2003). However, few if any studies have been conducted exploring linkages between ecological and social data via CART analysis.

In CART observations in a dataset are recursively partitioned into subgroups that are as homogenous as possible (Scull, Franklin, and Chadwick 2005). The end result is a dendritic figure composed of branches and nodes (some of which are terminal or 'end' nodes). End nodes are also referred to as 'leaves'. Each end node (leaf), represents an independent variable and this variable may appear more than once throughout the classification tree. The process of building a tree involves the 'splitting' of observations into groups in such a way as to have a "maximum reduction in deviance over all allowed splits of all leaves" (Venables & Ripley 2002). There are several ways of measuring reduction in deviance (i.e., average node impurity) in order to split observations into homogeneous groups. These include the entropy index, the Gini index, and the twoing index. The Gini index, an inequality measure used in the RPART package of S-Plus/R, attempts to segregate the largest dependent variable class into a separate group (De'ath & Fabricius 2000).

Once all the splits are made, the final number of groups created by CART consists of all end nodes, i.e., nodes that cannot be split any further. As noted above, each end node represents a set of observations that are homogeneous with respect to certain pre-determined attributes. The RPART package within S-Plus & R and employed in this study utilizes the 20-case threshold as a stopping criterion in which end nodes must contain at least 20 observations (Venables & Ripley 2002). However, trees can be extended manually so that each end node contains only one observation.

3.2.2.2 Procedures for conducting and interpreting CART analysis

Prior to describing the procedures for using and interpreting CART analysis, a particular level of the ecological classification system (ECS) must be selected for analysis. Three ECS levels were chosen for CART analysis: section; subsection; and LTA Type. Subsection and LTA Type analyses were conducted by section for: MB subsections and LTA Types; OP subsections and LTA Types; OZ subsections and LTA

Types; and TP subsections and LTA Types. In performing a social classification of ecological units, a random sample of block groups within a particular ecological unit (e.g., MB4 subsection) at a given ECS level (e.g., MB subsection) is taken. . The size of the block group sample is the same for each ecological unit and is determined by the smallest number of block groups within ecological units at a given ECS level. For example, when sections are being classified, the section with the least number of block groups provides the baseline sample size for all sections (Figure 7). In this case, the sample size is 116 block groups.

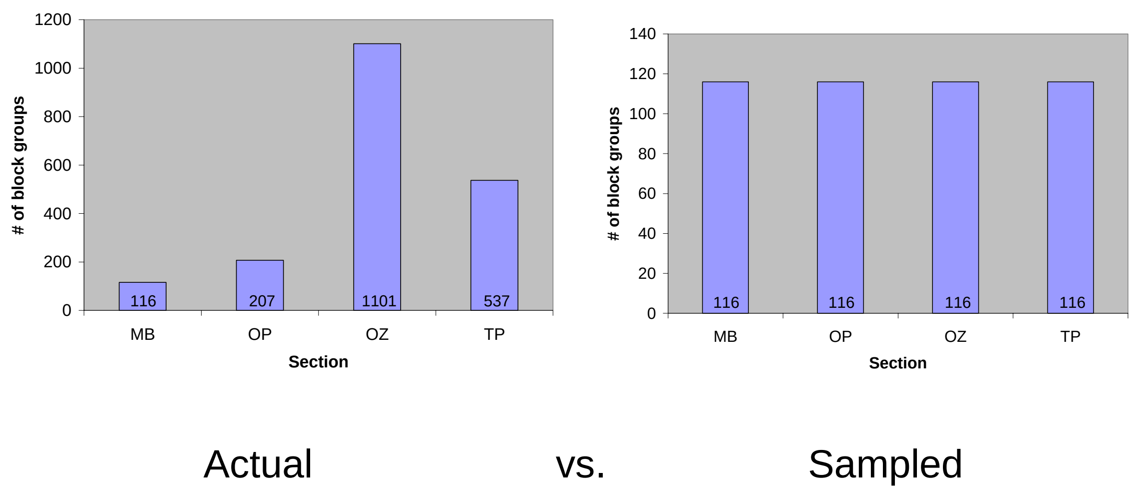

Figure 7. Number of block groups per section and number chosen in an equal random sample.

Each sampling unit (i.e., block group) may be described in terms of socio-economic characteristics in the form of 220 variables from the U.S. Census of Population & Housing. Since this original set included some variables that were peripheral to the interests of this study, a subset of 85 census variables was selected as input to the CART analysis of Missouri's ecological units. Recall that only 30 of the 220 census variables are utilized in constructing social profiles. Numerical values for socio-economic variables in classification trees are of four kinds: 1) proportions of people in a block group in decimal form; 2) value in dollars; 3) time in minutes; and 4) age in years.

The block group was selected as the sampling unit for this study. An important consideration in this sampling process is that of pseudo-replication. This may occur when the actual sample space is smaller than the inferred space of interest (Hurlbert 1984). A pseudo-replicate is a sampling unit that is utilized two or more times in a given analysis. Sampling methods can encourage or preclude the presence of pseudo-replicates. Sampling without replacement ensures that no sampling units are selected more than once and hence no pseudo-replicates are produced in the sample; however, the process is non-random. For example, if the Mississippi River Alluvial Basin (MB) block groups were sampled without replacement, then every block group within that section would be sampled (since it was the section with the least number of block groups), resulting in a non-random sample. Sampling with replacement represents a viable *random* sampling technique; however, it has the potential of introducing pseudo-replication into a sampling scheme. In the case of MB block groups, when they are sampled with replacement, several block groups have a probability of being selected a multiple number of times. Therefore, some pseudo-replicate block groups are included in the CART analysis.

Because a random sampling scheme is statistically more powerful, sampling with replacement was chosen for this study. The potential presence of pseudo-replication was monitored in the sampling process and found not to be a problem, including for the sampling of MB block groups.

This sampling process is replicated 10 times to ensure an accurate representation of the social dimension within ecological units, particularly those with many block groups. More specifically, for each ECS level, 10 replicate classification trees are created and the most representative tree is utilized in subsequent analyses. For example, at the *section* level, 10 replicate classification trees are created in utilizing the 85 U.S. Census variables that are assigned to each block group. The most representative replicate is identified as the tree that exhibits the variables most common to all other trees in describing people in Missouri sections. The location of social variables on the tree also aids in determining which replicate is most representative.

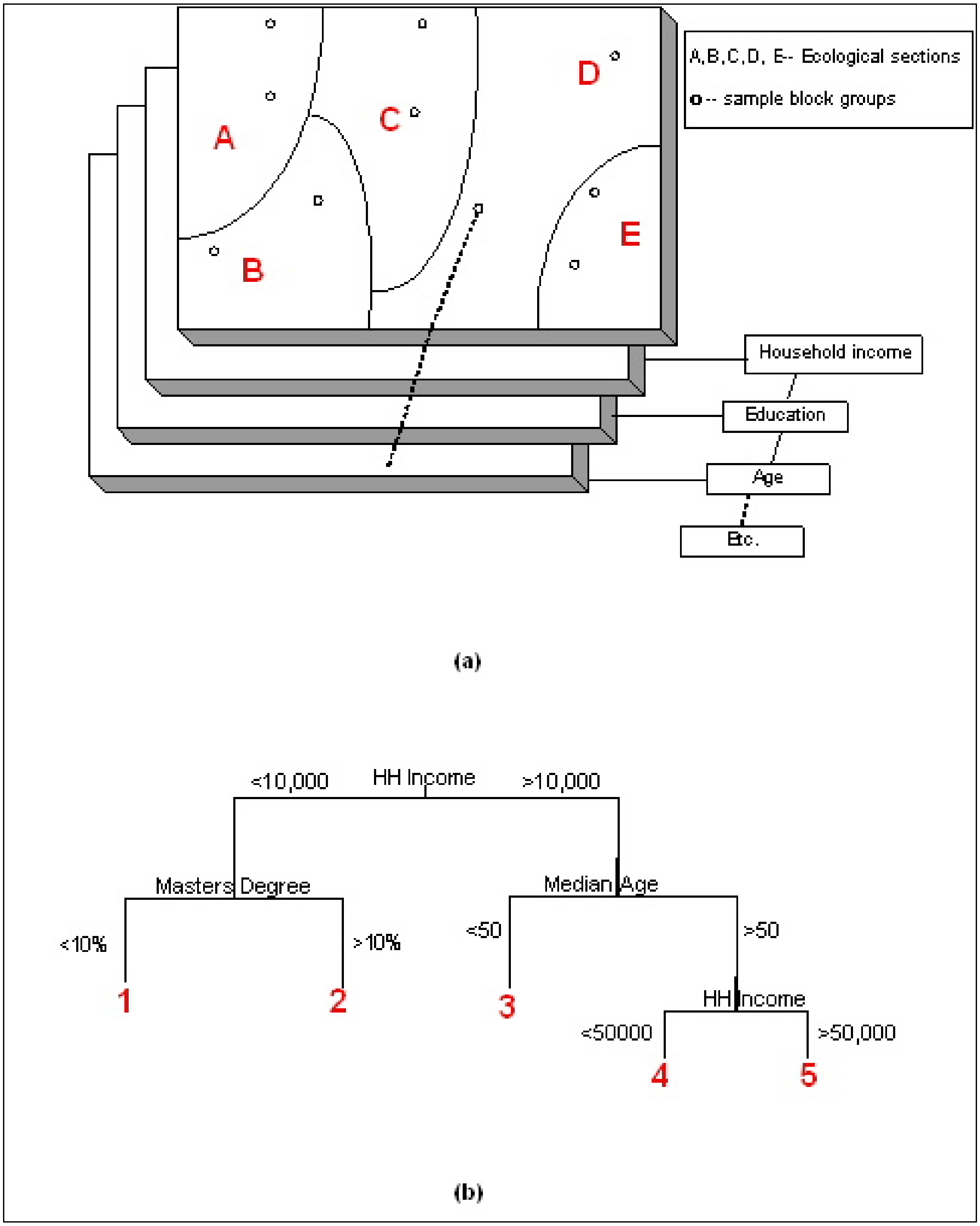

Figure 8. Example of a Classification & Regression Tree (CART) Analysis. **(a)** Ecological sections (A, B, C, D, and E) may be depicted spatially in terms of block groups across the landscape. An equal-sampling procedure is employed in each ecological unit (2 block groups per section). The layers represent various socio-economic variables that are included in the analysis. These variables are taken from the U.S. Census Bureau's 2000 Census of Population & Housing and aggregated at the block group level. **(b)** Example of a classification tree. End nodes denoted by the numbers (1-5) represent sets of block groups that are similar according to particular socio-economic characteristics ('independent' variables) but differentiated according to ecological units ('dependent' variable). Variables depicted in the tree represent a few variables out of the original 85 that are utilized in CART analyses. These variables serve to sort and describe block groups on the tree with respect to ecological units.

A depiction of the sampling process and tree construction is accompanied by Figure 8. This study utilizes CART analysis in order to identify those social variables that maximize the variance between ecological units (e.g., the 4 sections at the section level of the ECS – MB, OP, OZ, and TP) and minimize the variance within an ecological unit. Thus CART analysis is effectively differentiating ecological units according to socio-economic variables characterizing block groups that fall within those units. This is done through the R-PART package within R which sorts block groups with certain associated social variables into end node sets. Each block group within a given end node set is spatially situated within a particular ecological unit (Figure 9). CART *attempts* to find the spatial arrangement in which all elements of a given block group set (i.e., end node) fall within a particular ecological unit. While the actual pattern that results is one in which block groups within a given end node set are distributed across all ecological units (Figure 9), it is usually the case that one ecological unit clearly contains the most block groups. End node sets can be described by bar charts or figures as the number of block groups situated within each ecological unit at a given ECS level.[3] Notice in Figure 9, for example, that the CART process has sorted the block groups into 4 end nodes according to three social variables. At each end node one of the four ecological sections accounts for the largest number of block groups.

[3] Because the process of including identifiers for particular block groups on classification trees is quite cumbersome, especially with larger trees, this was performed only for the tree at the section level.

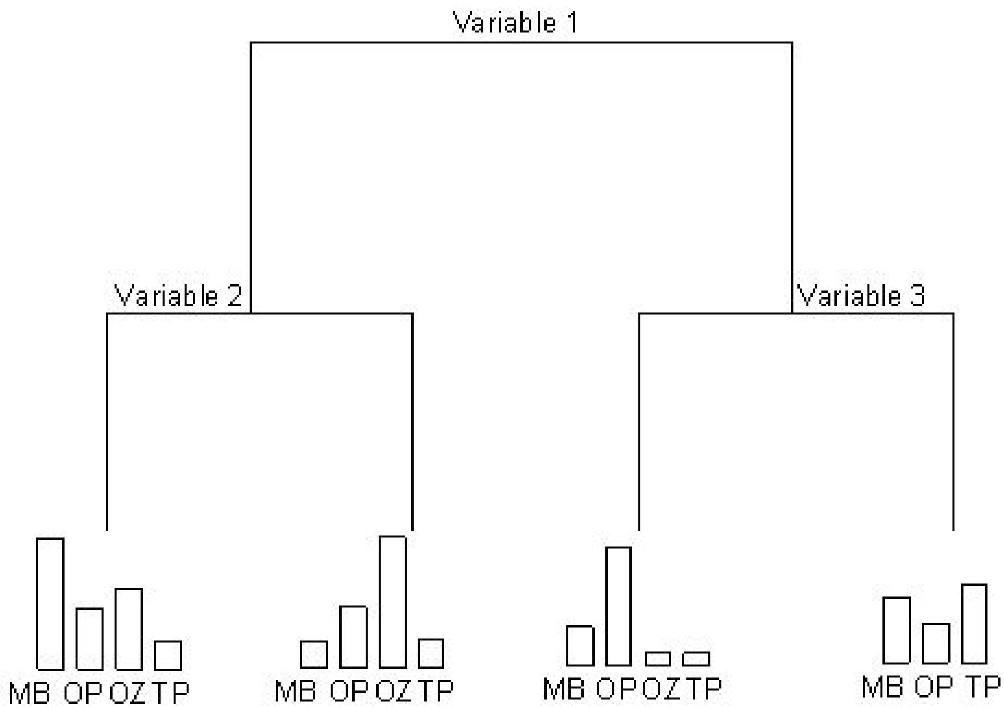

Figure 9. End node set distributions. Each end node set contains block groups from most of Missouri's 4 sections.

In this light, CART actually identifies the spatial arrangement in which *most* elements of a particular block group set (i.e. end node) fall within a particular ecological unit (e.g., OZ). This allows particular social variables describing those block groups – i.e. those which function in tree establishment – to be linked to ecological units. In Figure 10, for example, if household income is less than $10,000 and less than 10% of people within a block group have a Masters degree, then that block group is partitioned to the left-most branch of the tree as end node 1. This end node contains the set of block groups that on an overall basis best correlates with a specific ecological unit. That is to say, each of the block groups in this end node is located in a particular ecological unit (e.g., section) – i.e., will have an ecological designator – and in creating these end node sets CART attempts to make them as homogenous as possible, that is, to maximize the number of block groups with one particular ecological designator (e.g., section).

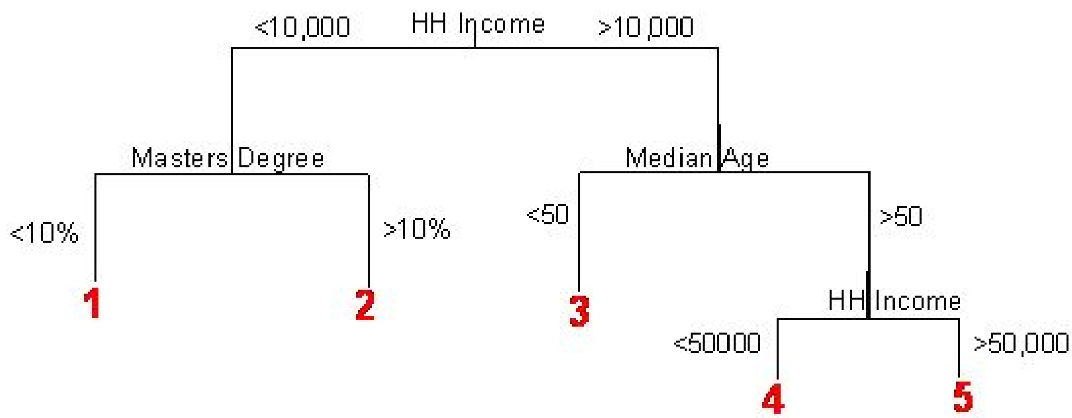

Figure 10. Classification tree example with particular social variables that function in tree establishment.

In general, only a few variables (in this case, from the 85-variable set of block group attributes) are operative in – i.e., actually serve to steer – establishing the classification tree. All other social variables would not, therefore, be depicted as nodes in the classification tree, since they play no role in the partitioning of attributes across the ecological entities. Tree variables are those that serve to differentiate block groups into end nodes that spatially correlate best with the ecological units, i.e., are dominated by block groups spatially situated within a particular ecological unit. For this project, it was decided that all trees would be 'grown' to a size equal to the number of the ecological units within the ECS level at which the analysis was conducted (i.e., section, subsection, LTA Type).[4] CART analyses for ecological subsections and LTA Types were conducted for each of the four ecological sections in Missouri.

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[4] However, due to methodological limitations, this is not always possible for all classification trees. For a given CART analysis, a tree in which the number of end nodes differs only slightly (a few more or less) from the number of ecological units is generally considered to be satisfactory.

Generally the socio-economic variables defining nodes in the upper portions of classification trees explain the most variation among ecological units (in terms of socio-economic attributes). These 'most prominent' socio-economic variables are most important in contributing to the identity of the end nodes (sets of block groups) of the classification tree because at these higher tree nodes many observations (i.e., block groups) are being sorted. Visually, nodes containing many block groups result in longer leaves (vertical distances) on the tree. The most prominent socio-economic variable for any classification tree is the variable positioned at the first node (root node). At this node, *all* block groups are being sorted according to one variable. Thus in Figure 10, for example, the most prominent socio-economic variable is household income. This serves to sort all block groups according to whether average household income is greater or less than $10,000. Subsequent nodes and the corresponding less-prominent variables describe subsets of block groups that are derived from the total set of block groups located at the root node. In Figure 10, these less-prominent (but still very important) socio-economic variables are: attainment of a Masters Degree; median age; and, again, household income.[5] Discussion of the prominent socio-economic may best be framed in terms of the following questions, "At what ECS level (e.g., section, subsection) do prominent socio-economic variables emerge, and what implications can be drawn with respect to the prominent socio-economic variables associated with particular ecological units?"

To further elucidate this process, a CART table may be generated to complement each classification tree. This is simply a tabular representation of the structure and prominent variables of a classification tree. A CART table depicts ecological units on the

[5] The example in Figure 10 illustrates the fact that the same variable (here, household income) can function to differentiate units (here, block groups) at more than one node on a classification tree.

vertical axis, while the horizontal axis represents the node levels of the classification tree. Table entries contain socio-economic variables found at tree nodes that contribute to the social description of ecological units. In this way, the socio-economic variables that are important in sorting block groups into end nodes (to which ecological unit designators may be attached) are juxtaposed in tabular form as opposed to being situated on classification tree branches. This in turn facilitates comparisons between ecological units with respect to their prominent socio-economic variables.

3.2.3 Measuring socio-economic diversity and fragmentation for ecological units

3.2.3.1 GIS processing – cartographic techniques

We have seen that end nodes of a classification tree consist of sets of block groups that display similar social characteristics in terms of the social variables driving the partitioning process (see Figure 10). In the following discussion of social diversity and fragmentation, end nodes will be referred to as ***'social groups'***. Maps based on the CART analyses may be created by color-coding social groups (spatially-delineated sets of block groups) and superimposing them on maps delineated in terms of ecological units. Since these units (section, subsection, etc.) usually contain more than one social group a given ecological unit in a CART map will usually exhibit multiple colors.

3.2.3.2 Landscape metrics for social diversity and fragmentation

In CART maps the basic unit that is mapped across the ecological landscape is a block group from a particular social group (end node). Two immediate topics of interest relate to the overall composition and distribution of social groups across the ecological landscape. With respect to the former, ***social diversity*** refers to the degree to which social groups distributed across a given ecological unit are similar or different. If the overall composition of an ecological unit consists of a variety of social groups – that is, sets of block groups that vary more or less extensively according to certain socio-economic characteristics (e.g., one group may be wealthy and well-educated while another group may be poverty-stricken and poorly-educated) – then that ecological unit may be identified as one of (relatively) high social diversity. If social groups within a particular ecological unit are similar according to a specific set of socio-economic characteristics (e.g., high-income, highly-educated, expensive-housing) then that ecological unit may be said to exhibit ***social homogeneity***.

In contrast to the overall *composition* of social groups, ***social fragmentation*** describes the spatial *distribution* of social groups across an ecological unit. This entails assessing the degree to which block groups that are socially-similar (i.e., part of the same social group) 'clump' together or are dispersed across the ecological landscape.

Social diversity and homogeneity (actually a lack of or low value for diversity) are measured by the landscape metric of Simpson's Diversity Index (SIDI). SIDI measures the probability that any two random partitions of the landscape (in this case, two block groups) are derived from the same social group (e.g., block groups comprising a given end node). SIDI is measured on a 0 to 1 scale. An SIDI value equal to 1 reveals a very diverse social pattern in which an ecological unit contains multiple social groups (block groups from multiple end nodes). In contrast, an SIDI value of 0 reveals a very non-diverse (i.e., homogeneous) pattern in which an ecological unit contains only a few social groups (block groups from few end nodes). Because of the ease in interpretation of this scale for diversity (i.e., 0-1), SIDI was chosen for this analysis (McGarigal & Marks 1994). In this light, social diversity on the landscape reflects the presence of many social groups, while social homogeneity reflects non-diverse patterns in the sense of having few social groups on the landscape.

The measure of social diversity and homogeneity for a given ecological unit is determined by answering the question "how many block groups in this unit come from the same social group (i.e., end node on the classification tree)?" If in a given ecological unit all the block groups come from the same social group, then that unit would be considered as having 100% social homogeneity (see Figure 11). That is to say, all the block groups are described by the *same* socio-economic variables and associated values for the social group. Thus people living in an ecological unit with high social homogeneity (SIDI ~ 0) are similar with respect to certain socio-economic characteristics (variables) depicted in the classification tree. For example, if the classification tree variables differentiating a certain social group (end node) describing people within an ecological unit were high school education, median family income, and sales/office occupations, then it could be said that the block groups in a particular ecological unit are socially homogeneous with respect to these variables.

However, if in a given ecological unit the block groups come from a variety of social groups (i.e., end nodes on the classification tree) in roughly equal proportions, then that ecological unit would have high social diversity. Under this scenario, people would differ socially and in most cases, this would reflect several distinct social groups within a particular ecological unit. Thus, for example, one social group may be characterized by block groups in which the majority of people those who have Bachelors degrees and a household income greater than $40,000. However, another social group may be defined as having only a basic education (i.e., less than 9^{th} grade only) and a household income less than $25,000. Yet another group may be described solely by housing characteristics (e.g., average age of units is greater than 42 years old). All three of these groups, however, would be represented within the focal ecological unit.

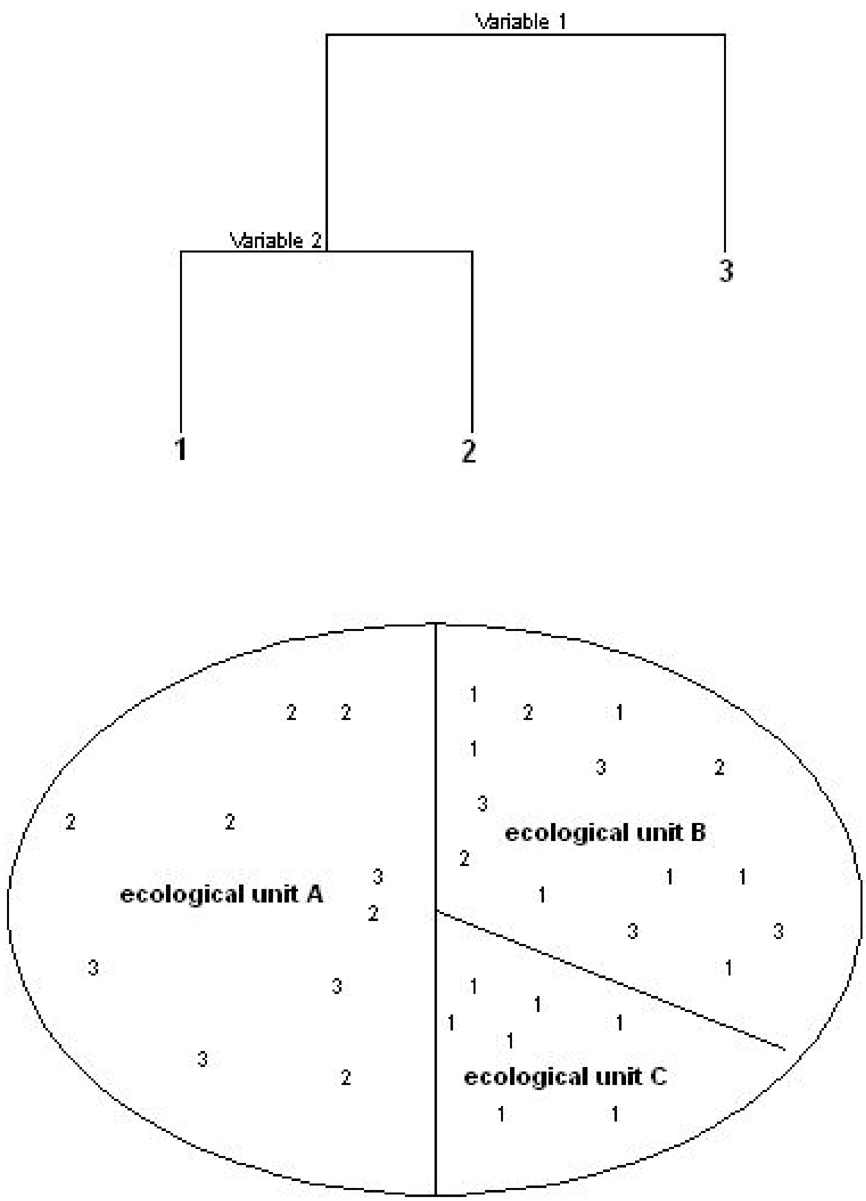

Figure 11. Social diversity and homogeneity. The classification tree (top) results have three social groups (end nodes) where each contains a set of block groups with their associated socio-economic characteristics. Those block groups are located spatially on the ecological landscape. The three ecological units (bottom) exemplify three different levels of social homogeneity. Ecological unit C has high social homogeneity; ecological unit A has moderate social homogeneity; and ecological unit B has high social diversity.

Social fragmentation refers to the spatial distribution of social groups across the ecological landscape. The degree of social fragmentation for an ecological unit is determined by answering the question "how are block groups from one or more social groups (i.e., end nodes on the classification tree) distributed across a given ecological unit?" That is to say, "are block groups found in dense clumps or dispersed widely across the ecological landscape?" If the block groups from a specific social group (end node) are clumped within the ecological unit then there is low fragmentation (Figure 12); if block groups from the given social group are 'dispersed' across the ecological unit, then social fragmentation is high.

The degree of social fragmentation across an ecological unit is measured by the landscape metric ***perimeter-to-area ratio*** (PARA). PARA is a measure of shape complexity and is utilized here to assess the extent to which social groups cluster on the landscape. In other words, are similar types of people (social groups) grouped spatially or are they spatially dispersed? Specifically, for an ecological unit PARA measures the perimeter around a social group (set of block groups with similar socio-economic characteristics) divided by the area occupied by that social group. Each ecological unit is analyzed separately in measuring the PARA. It is measured on a scale from 0 to ∞ (infinity) with 0 reflecting a dense or clumped spatial pattern and a higher number indicative of a more fragmented spatial pattern (McGarigal & Marks 1994). One limitation of this measure is that it is sensitive when measuring complex shapes (e.g., curved or elongated ecological units) because values for this metric will sharply increase with shape complexity. If an ecological unit is naturally very elongated, curved, etc. – such as is characteristic of alluvial plains subsections – then the PARA will be higher no matter what the degree of social fragmentation. Also, if there is high social homogeneity (fewer social groups) in the ecological unit, the PARA will usually be lower as well. Nonetheless, for this study PARA provides a relatively accurate measure of the ‘social fragmentation’ within most ecological units – the extent to which social groups are clumped or dispersed on the ecological landscape.

Measures of social diversity and fragmentation of social patterns within ecological units were obtained via the FRAGSTATS statistical package. Input data included ecological units with their corresponding social groups (end nodes).

On an overall basis, *socio-ecological* relationships are explored by relating the classification of ecological units by *social* variables to the classification of land units by *ecological* variables and through investigating patterns of homogeneity and fragmentation of those ecological units. Such relationships may then be interpreted in terms of implications for ecological and social sustainability. Landscapes and/or landscape patterns in which social variables play a significant role may be identified.

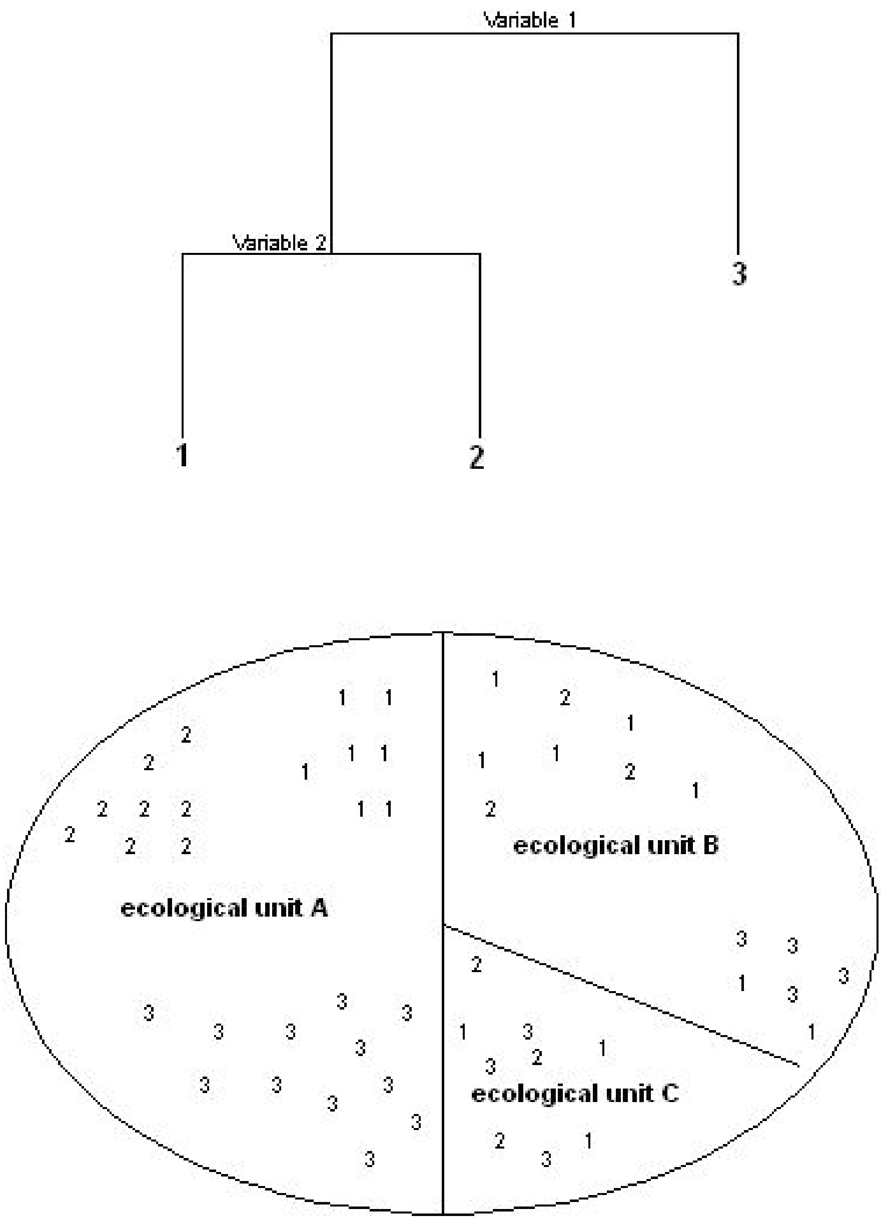

Figure 12. Social fragmentation. The classification tree (top) has three social groups (end nodes), each consisting of a set of block groups with similar social characteristics in terms of the tree variables. Classification tree results are based on a sample of block groups from each of the ecological units. In the lower portion, the block groups are spatially distributed across the ecological landscape. The three ecological units in the bottom portion display three different patterns of social fragmentation. Ecological unit 'C' is very fragmented because no social group clumps together; ecological unit 'B' is moderately fragmented because partial clumping of social groups is present; and ecological unit 'A' exhibits social patterns in which the social groups are spatially clumped.

4. Results

The results presented in this chapter provide a very broad picture of the social characteristics of people living in ecological places in Missouri. The latter are represented in terms of three levels of the ecological hierarchy (ECS): sections (4); subsections (31); and LTA Types (25). Three sets of results are discussed: (1) Social profiles for ecological units; (2) Prominent socio-economic attributes for ecological units; and (3) Socio-economic diversity and fragmentation across ecological units.

4.1 Social profiles for ecological units in Missouri

The social profile for ecological sections is intended to convey a variety of socially relevant attributes of people identified according to ecological units in which they live. For this study, the social profile consists of area-weighted mean values for 31 variables reflecting seven key attributes of people in places: population, age, race, education, occupation, income, and housing.

The social profile for the four ecological sections in Missouri may be found in Table 3. From a statewide perspective focusing on social characteristics of people living in Missouri's 4 ecological sections, statistically significant differences (i.e., $p<.05$) across sections were found for twelve of the 31 social variables used to construct the social profiles (Table 4 and Figure 13). Variables related to age and most pertaining to income did not display statistically significant differences at the section level. In presenting results below and to facilitate comparisons across the state's four ecological sections, particular attention is given to five important social variables – identified here as *focus variables* – population density, high school education, median household income, mean poverty ratio, and median house value. For particular sections, other social variables which distinguish that ecological unit from others in a statistically significant fashion are also highlighted.

For the Mississippi River Alluvial Basin (MB), each of the values for the five focus variables was the lowest when compared with those of other sections. The population density is 25 persons per sq mile which is significantly less than densities for OP ($p = .029$) and TP ($p = .006$).[6] The proportion of persons with only a high school education in the MB section is 40%, which is not statistically different from values of this variable for the other three sections. The median household income in MB is $28,180, which differs significantly from OP ($p = .031$) and TP ($p = .042$). The mean poverty ratio for MB is 2.17 which did not differ significantly from ratios of other sections. The median value of a home in MB is $60,046 and this value differed significantly from TP's median house value ($p = .000$).

For the Osage Plains (OP) section, the population density is 62 persons per sq mile, the second highest among the four sections. This differed significantly from MB. The percentage of high school educated persons is 43%, also the second highest among the four sections and this variable did not show significant differences across sections. The median household income for OP residents is $37,051 and the mean poverty ratio is 2.40, each being the highest out of all sections. OP is different than MB statistically based on median household income; however, OP is similar to other sections with respect to mean poverty ratio. In OP, the median value of a home is $77,959, the second highest among sections; this is still, however, significantly less than the median value for houses in the TP section.

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[6] Post-Hoc analyses of the ANOVA results were generated by the LSD method and significant values noted above are defined at the .05 level.

Table 3. Social profile for ecological sections in Missouri.

	Sections			
Social variable	**Mississippi Basin**	**Osage Plains**	**Ozark Highlands**	**Till Plains**
Population				
Total persons	100338	197954	1290571	524216
Density (persons per square mile)	25	62	51	66
Urban[a]	0.03	0.04	0.03	0.03
On farms[a]	0.07	0.18	0.10	0.22
Age[a]				
0 to 9	0.12	0.13	0.13	0.13
10 to 19	0.15	0.16	0.15	0.15
20 to 44	0.33	0.32	0.32	0.31
45 to 64	0.25	0.25	0.26	0.25
Over 65	0.15	0.14	0.14	0.16
Race[a]				
White alone	0.93	0.97	0.97	0.98
Black alone	0.05	0.01	0.00	0.01
Minority Pop	0.07	0.03	0.04	0.02
Education[a]				
Less than 9th Grade	0.16	0.07	0.11	0.07
High school grad or GED	0.40	0.43	0.41	0.46
Bachelors degree	0.05	0.09	0.07	0.09
Occupation[a]				
Management, professional & related	0.22	0.28	0.24	0.29
Service	0.13	0.13	0.15	0.14
Sales and office	0.20	0.21	0.21	0.20
Farming, fishing, & forestry	0.05	0.03	0.02	0.03
Construction, extractions & maintenance	0.12	0.14	0.14	0.13
Production, transportation & material moving	0.28	0.21	0.24	0.21
Income ($)				
Median household	28180	37051	32578	35556
Average for households < $200k	34033	41877	37236	40068
Median family	32773	41726	37061	40432
Average family	40264	47947	44444	47406
Per capita	14218	16463	15444	16488
Mean poverty ratio[b]	2.17	2.40	2.28	2.39
Housing				
Renter occupied units[a]	0.25	0.16	0.16	0.18
Median year moved in	1992	1993	1993	1991
Average age of units (yrs.)	34	35	31	40
Median house value ($)	60046	77959	67790	105011
Average house value ($)	74024	89744	80804	118680

*Profiles for ecological sections were generated from U.S. Census of Population & Housing data for block group statistical spatial units. 'Urban' block groups were deleted from this analysis (i.e., 90% or greater urban population).

[a] – Proportion of population within ecological unit boundary to which social variable applies

[b] – **Mean poverty ratio**: Index showing the average degree of poverty in an area. A poverty ratio of 1.0 reveals people who have an income at the poverty level. A poverty ration of 2.0 reveals people who are living at twice the poverty line (Blodgett 2000).

Table 4. Section: ANOVA results depicting variables with significant differences

Variable	Section	Sum of Squares	df	Mean Square	F	Sig.
Population density (persons per square mile)	Between Groups	194310.60	3	64770.20	3.11	**0.025**
	Within Groups	40742827.77	1957	20819.02		
	Total	40937138.37	1960			
Urban population	Between Groups	0.02	3	0.01	1.20	0.310
	Within Groups	12.84	1957	0.01		
	Total	12.86	1960			
On farms	Between Groups	5.76	3	1.92	28.16	**0.000**
	Within Groups	133.56	1957	0.07		
	Total	139.32	1960			
Age						
0 to 9	Between Groups	0.01	3	0.00	0.15	0.930
	Within Groups	43.85	1957	0.02		
	Total	43.86	1960			
10 to 19	Between Groups	0.01	3	0.00	0.08	0.968
	Within Groups	64.89	1957	0.03		
	Total	64.89	1960			
20 to 44	Between Groups	0.04	3	0.01	0.09	0.963
	Within Groups	244.89	1957	0.13		
	Total	244.93	1960			
45 to 64	Between Groups	0.02	3	0.01	0.07	0.976
	Within Groups	182.25	1957	0.09		
	Total	182.27	1960			
Over 65	Between Groups	0.07	3	0.02	0.69	0.559
	Within Groups	69.00	1957	0.04		
	Total	69.07	1960			
Race						
White alone	Between Groups	0.22	3	0.07	0.06	0.981
	Within Groups	2426.43	1957	1.24		
	Total	2426.66	1960			
Black alone	Between Groups	0.25	3	0.08	50.11	**0.000**
	Within Groups	3.31	1957	0.00		
	Total	3.56	1960			
Minority Pop	Between Groups	0.24	3	0.08	18.92	**0.000**
	Within Groups	8.45	1957	0.00		
	Total	8.69	1960			
Education						
Less than 9th Grade	Between Groups	1.12	3	0.37	17.50	**0.000**
	Within Groups	41.65	1957	0.02		
	Total	42.76	1960			
High school grad or GED	Between Groups	0.95	3	0.32	1.23	0.298
	Within Groups	506.12	1957	0.26		
	Total	507.07	1960			
Bachelors degree	Between Groups	0.18	3	0.06	7.07	**0.000**
	Within Groups	16.92	1957	0.01		
	Total	17.11	1960			
Occupation						
Management, professional & related	Between Groups	1.18	3	0.39	4.00	**0.008**
	Within Groups	192.44	1957	0.10		
	Total	193.62	1960			
Service	Between Groups	0.05	3	0.02	0.57	0.637
	Within Groups	57.61	1957	0.03		
	Total	57.66	1960			
Sales and office	Between Groups	0.06	3	0.02	0.36	0.780
	Within Groups	100.57	1957	0.05		
	Total	100.63	1960			
Farming, fishing, & forestry	Between Groups	0.09	3	0.03	8.70	**0.000**
	Within Groups	6.45	1957	0.00		
	Total	6.53	1960			
Construction, extractions & maintenance	Between Groups	0.10	3	0.03	1.20	0.308
	Within Groups	54.12	1957	0.03		
	Total	54.22	1960			
Production, transportation & material moving	Between Groups	0.61	3	0.20	2.37	0.069
	Within Groups	167.80	1957	0.09		
	Total	168.41	1960			

Statistical differences are defined at the .05 significance level.

Table 4. Cont.

Variable	Section	Sum of Squares	df	Mean Square	F	**Sig.**
Income						
Median household	Between Groups	9076875874.16	3	3025625291.39	2.41	0.065
	Within Groups	2459282329772.24	1957	1256659340.71		
	Total	2468359205646.40	1960			
Average for households < $200k	Between Groups	7683646234.39	3	2561215411.46	1.54	0.203
	Within Groups	3257396077577.53	1957	1664484454.56		
	Total	3265079723811.93	1960			
Median family	Between Groups	10090603075.72	3	3363534358.57	2.06	0.103
	Within Groups	3194598367171.99	1957	1632395690.94		
	Total	3204688970247.71	1960			
Average family	Between Groups	7568738924.08	3	2522912974.69	1.05	0.367
	Within Groups	4679972097681.42	1957	2391401174.08		
	Total	4687540836605.50	1960			
Per capita	Between Groups	772348588.31	3	257449529.44	0.88	0.449
	Within Groups	569863500456.48	1957	291192386.54		
	Total	570635849044.79	1960			
Mean poverty ratio	Between Groups	8.72	3	2.91	0.44	0.722
	Within Groups	12832.89	1957	6.56		
	Total	12841.61	1960			
Housing						
Renter occupied units	Between Groups	0.89	3	0.30	6.37	**0.000**
	Within Groups	91.60	1957	0.05		
	Total	92.49	1960			
Median year moved in	Between Groups	1325.85	3	441.95	0.00	1.000
	Within Groups	10170815317.31	1957	5197146.30		
	Total	10170816643.16	1960			
Average age of units	Between Groups	33555.53	3	11185.18	5.97	**0.000**
	Within Groups	3669321.28	1957	1874.97		
	Total	3702876.81	1960			
Median house value	Between Groups	543255121970.21	3	181085040656.74	16.41	**0.000**
	Within Groups	21591820417631.20	1957	11033122339.11		
	Total	22135075539601.40	1960			
Average house value	Between Groups	558641624531.09	3	186213874843.70	12.01	**0.000**
	Within Groups	30339677497446.10	1957	15503156615.97		
	Total	30898319121977.20	1960			

Statistical differences are defined at the .05 significance level. Significant variables are identified in bold.

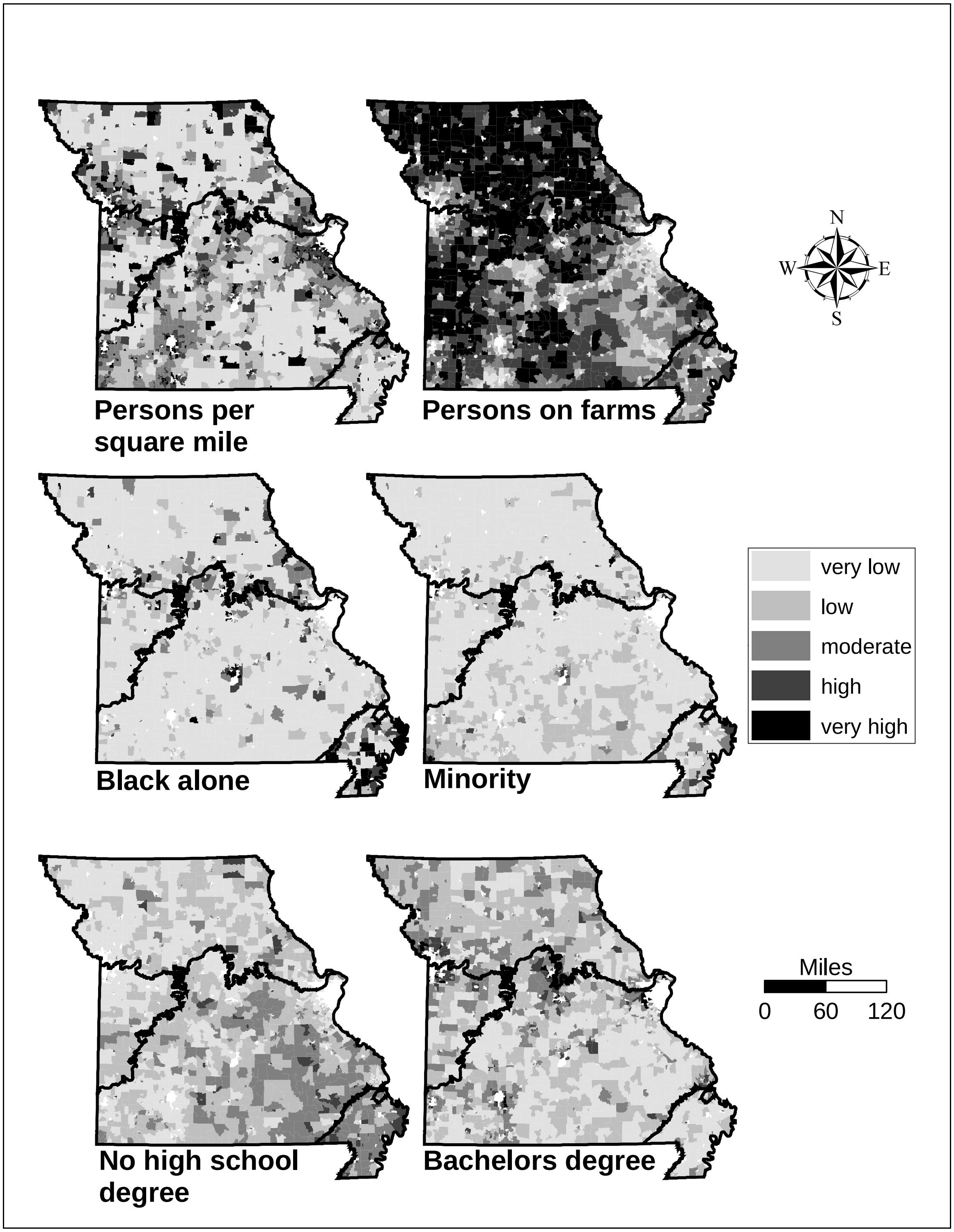


Figure 13. Variables that displayed statistically significant differences across the 4 ecological sections of Missouri. Differences are defined at the .05 significance level. Here, block groups are color-coded on a light to dark scale reflecting the values for each of the variables of which represent proportions of people within block groups (with the exception of persons per square mile which is a whole number).

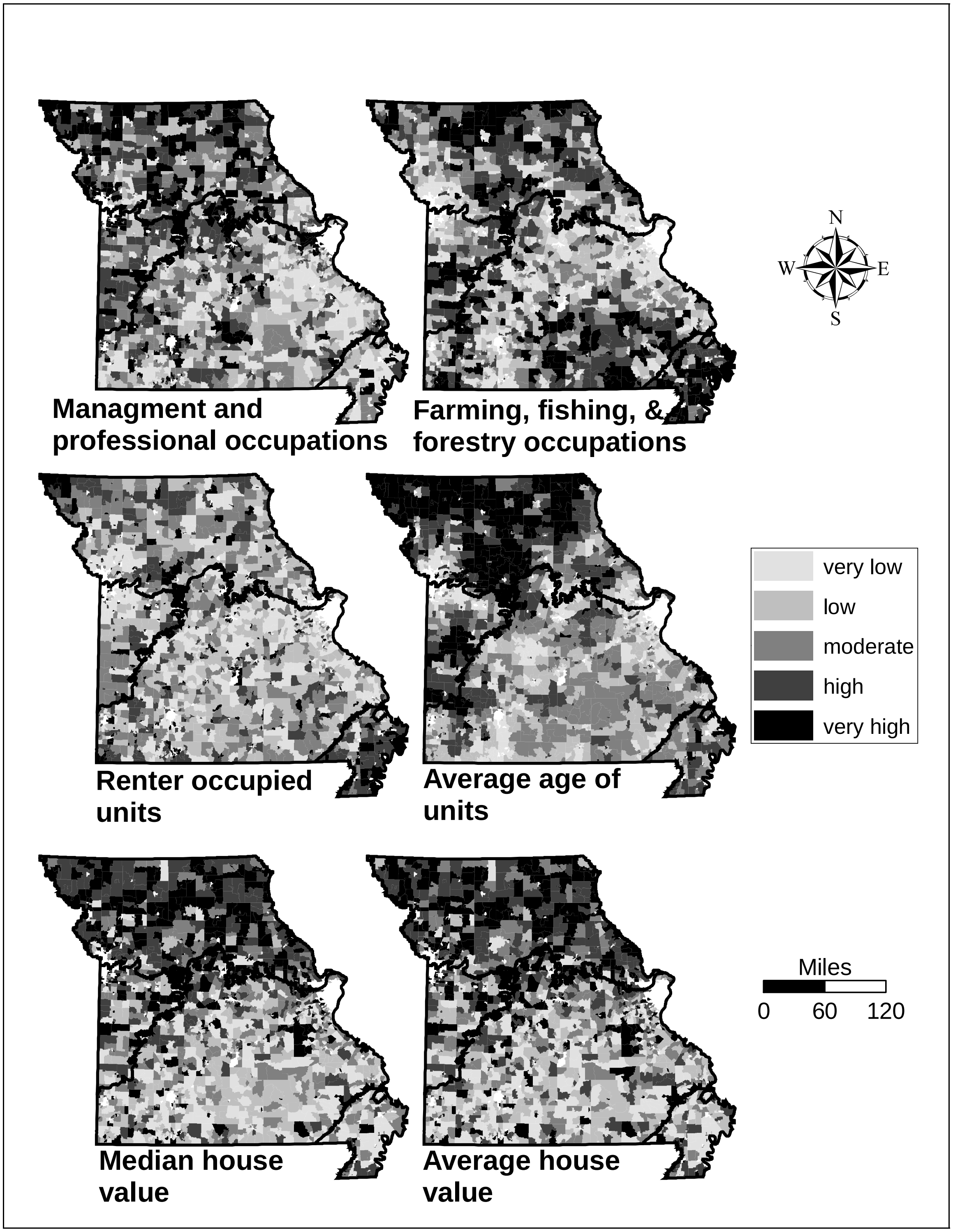


Figure 13. Cont.

Within the Ozark Highlands (OZ) section, values for each of the five focus variables are the second lowest among the four sections. The population density is 51 persons per sq mile, significantly greater than that for MB, but less than densities for the two Plains sections. Two-fifths of people within OZ have only a high school education while the median household income is $32,578, slightly higher than MB but less than that of the Plains sections. The mean poverty ratio is 2.28 and the median house value is $67,790. Although the latter is somewhat greater than that for MB, it is significantly less than that for TP (p = .000).

The Central Dissected Till Plains (TP) displays the highest values for three of the five focus variables (i.e., population density, high school education, and median house value). TP differs significantly from all other sections with respect to median house value (MB [p = .000]; OP [p = .002]; OZ [p = .000)]). TP differs significantly from only one other section in regards to population density but is similar to all sections with respect to high school education. Median household income and mean poverty ratio are second-highest among the four sections. The median household income variable is the only one that reveals a statistical difference (MB [p = .042]).

Subsections and LTA Types: Social Profiles. The complete set of social profiles for Missouri's 31 ecological subsections and 25 LTA Types may be found in Appendix 3. Due to the overall scope of this study along with its associated time frame, ANOVA analyses were not conducted for subsection and LTA Type ecological profiles.

4.2 Prominent socio-economic attributes & social diversity and fragmentation for ecological units

In continuing to consider linkages between socio-economic variables and ecological units for Missouri, this next segment of results comprises output from Classification and Regression Tree (CART) analyses for the three ECS levels of section, subsection, and LTA Type for Missouri. In an attempt to find the set of socio-economic variables that best differentiates variation in people among ecological units, a block group spatially situated within any given ecological unit must have equal opportunity for inclusion in CART analyses. This may be demonstrated at the section level where a random sample of 116 block groups was taken in each of the four ecological sections in Missouri (Figure 6). Every block group, in addition to being characterized by a variety of social attributes, also has an ecological designator corresponding to the ecological unit within which the block group is situated. In the CART analysis, block groups are partitioned by means of prominent socio-economic variables to yield end nodes comprised of block groups with similar socio-economic characteristics. At subsection and LTA Type levels of the ECS hierarchy, CART results are discussed for each ecological section.

The spatial content (diversity) and distribution (fragmentation) of the prominent socio-economic attributes across ecological units is the next focus of attention. As discussed in Chapter 3, *social diversity* refers to the number of distinct social groups (end nodes of the classification tree) that are found within an ecological unit. Diversity is expressed in terms of degrees of homogeneity and heterogeneity. It is measured with Simpson's diversity index (SIDI). *Social fragmentation* refers to the spatial distribution of people with similar social characteristics across an ecological unit. This is reflected in the extent to which block groups from a particular end node (one social group) are clustered or dispersed across the landscape. Fragmentation is measured with the perimeter-to-area ratio (PARA) [see section 3.2.3.2].

4.2.1 Ecological sections

Prominent socio-economic variables. Figure 13 presents the most representative classification tree that was constructed for social analysis at the level of ecological section in Missouri. The most prominent socioeconomic variable in the section classification tree was 'less than ninth grade education' or, equivalently 'no high school education' (Figure 14). At the first or highest node of the classification tree, this variable served to separate or differentiate the original 464 sample block groups into two sets – an end node on the left side of the tree and a node that is further subdivided on the right. If at least 10 ½ % of people in a block group had no high school education, then that block group was partitioned to the left side of the tree. Notice that 95 of the 116 block groups within the Mississippi River Alluvial Basin (MB) fit this description and were partitioned to the end node on the left side of the tree – that is, they were sorted into a set of block groups that had at least 10½ % of their people with no high school education. Although 75 additional block groups from the 3 other sections also comprised this end node, the 95 MB block groups clearly predominate. This exemplifies how the CART process attempts to sort block groups in a way that resultant end nodes are dominated by block groups from a particular ecological unit. Hence the social (via the social variables that 'do the sorting' at each tree node) is linked to the ecological (in ecological designators of block groups at end nodes, one of which will predominate at a given end node).

Returning to the top node of the classification tree, these 294 block groups in which less than 10 ½ % of people had no high school education were partitioned to the second node on the right side of the tree. This second node further partitioned the latter set of block groups according to the variable median house value. If the median house value for a block group in this set was >= $81,350, then that block group was sorted into what turned out to be an end node on the far right of the tree (149 block groups) of which 79 TP block groups were the majority.

For a given block group with less than 10 ½ % of people with no high school education and a median house value < $81,350, the socio-economic variable ‘percent public assistance income’ further partitioned remaining block groups to one of three end nodes. Of the remaining 145 block groups to be sorted at the ‘percent public assistance income node’, 35 were sorted to the right if they have greater than 1/10 a percent of people who receive public assistance. Twenty-four of these 35 block groups are situated within the OZ section. The 110 block groups that have less than 1/10 a percent of people receiving public assistance were sorted into the two remaining end nodes with respect to having attained only a high school degree. If a block group in this set of 110 had greater than 36% of its people with only a high school degree, it was partitioned to the left side of the ‘high school’ node. Eighty-three block groups met this criterion, of which 39 are located in the OP section. The 27 block groups with less than 36% of its people with only a high school degree were sorted to the right side of the ‘high school’ node and situated primarily within the OZ section (17 block groups).

It is noteworthy that the classification tree revealed that another education variable – high school education – was prominent in the classification process. This reinforces the role of education as important in differentiating among people in ecological sections in Missouri. Also, it is evident that no end node contains block groups exclusively from one ecological section suggesting that no section is perfectly described by any individual socio-economic variable. In addition, notice that it took two end nodes to most effectively describe the OZ section.

Table 5 depicts the social variables operative at different levels or nodes of the classification tree and their partitioning into (i.e., linkage with) ecological sections. It shows that the Mississippi Basin section is able to be described well by only one split (or tree branching) and hence one social variable – 'no high school education'. The Till Plains (TP) is another example of a section being described by a small number of tree branchings and associated social variables (2) – no 'high school education' and 'median house value'. However, as evident from Figure 14 as well, it took four branchings (and associated social variables) to yield an end node dominated by block groups from OP (or, more metaphorically, to create an OP end node); and it took two end nodes resulting from both 3 and 4 tree branchings (and associated social variables) to create/describe an OZ end node.

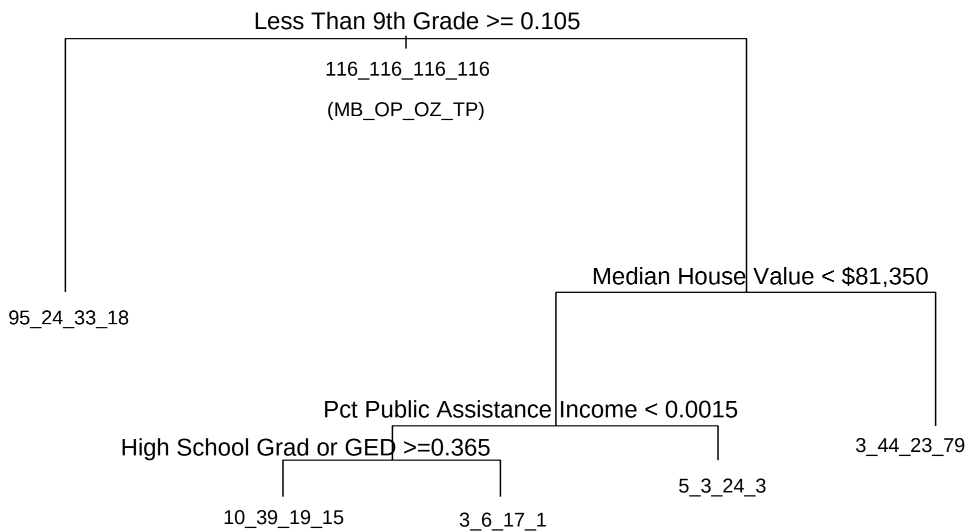


Figure 14. Section classification tree. Classification tree results are based on samples of 116 block groups from each of the 4 ecological sections. Each end node is comprised of a set of block groups from the four sections, one of which clearly has the most block groups. Units for socio-economic variables on classification trees vary according to the substantive nature of the variables. Units may be: 1) Proportions of people in a block group in decimal form; 2) average or median monetary values; 3) average time in minutes; and 4) average or median age in years.

Table 5. CART table for ecological sections in Missouri

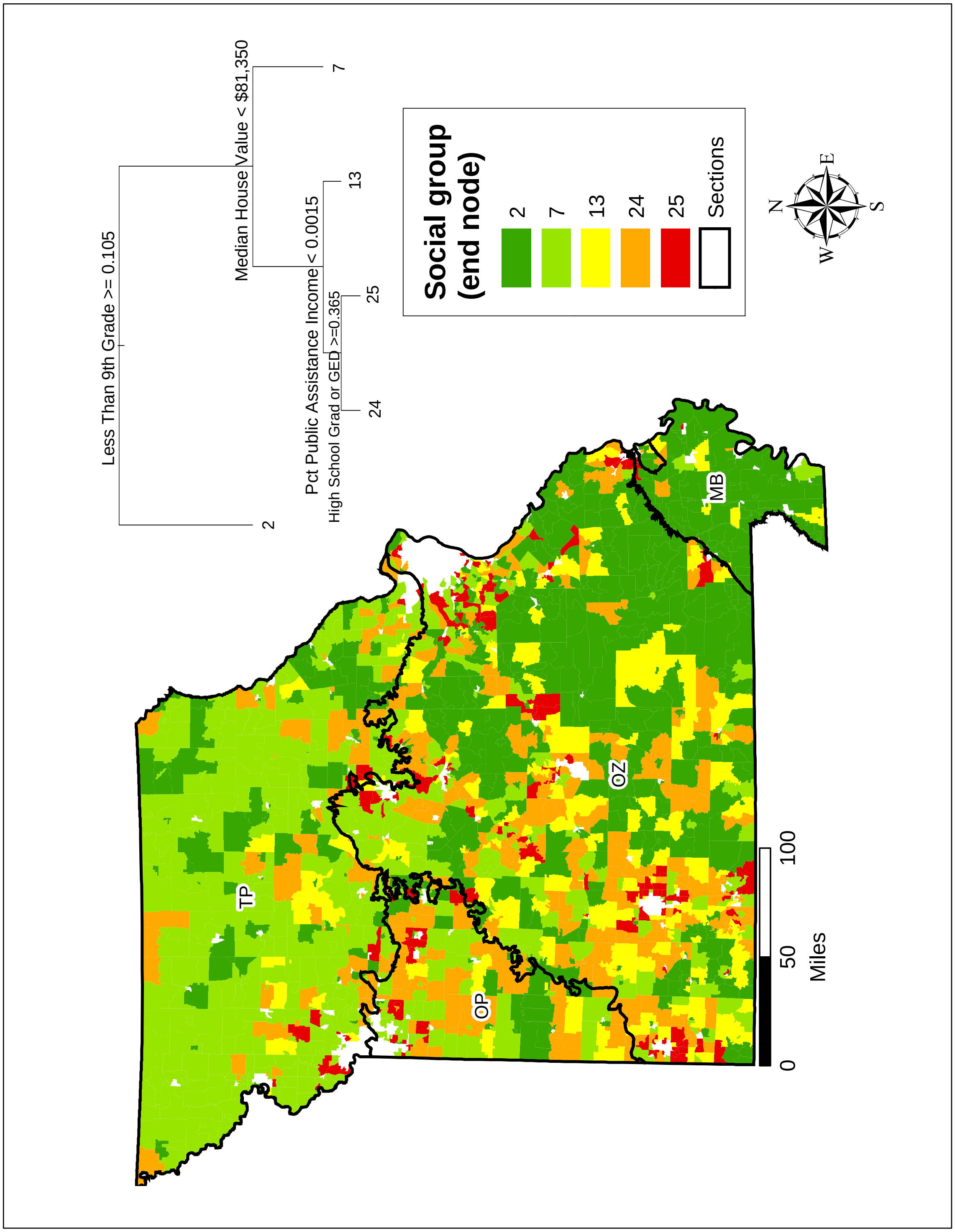
	Node Level			
Section	1	2	3	4
MB	Basic educ >=.105			
OP	Basic educ <.105	Med hval <$81,350	Pct pub assist inc <.0015	High school >=.365
OZ	Basic educ <.105	Med hval <$81,350	Pct pub assist inc >=.0015	
OZ	Basic educ <.105	Med hval <$81,350	Pct pub assist inc <.0015	High school <.365
TP	Basic educ <.105	Med hval >= $81,350		

Node level reflects the number of times a given block group has been sorted by a social variable on the classification tree. An end node is assigned an ecological unit designator (here, section) reflecting the ecological unit within which the majority of block groups at that end node are situated.

Figure 15 depicts the spatial distribution of end nodes comprising the classification tree derived for ecological sections.[7] The Mississippi Basin (MB) and the Till Plains' (TP) sections exhibit a relatively homogeneous social pattern – that is to say, they are dominated by a single social group (i.e., one color). The Osage Plains (OP) and Ozark Highlands' (OZ) sections exhibit heterogeneous social patterns – that is, multiple social groups (depicted in different colors) are spatially located on the landscape.

Another important point concerns the extension of social groups (block group colors) across section lines. Take for example, less than 9th grade education. This lower-education social group is evident in MB; however, it also extends across the MB section boundary line and notably into southeast portions of OZ. Other small pockets of lower education social groups are found in OP and TP as well. Another pattern is manifest on the outskirts of urban areas (suburbia), where the dominant social group reflects areas that are differentiated spatially according to how many people only completed a high school education (orange and red patterns in Figure 15). This pattern is evident in all sections except MB. For these sections, house value and public assistance income also serve to differentiate the social dimension. In viewing Figure 15, OP and OZ seem to contain the most 'diverse' and 'fragmented' social patterns with respect to the prominent socio-economic variables in the classification tree – 9th grade education (no high school), house value, public assistance income, and high school education. In contrast, MB and TP are dominated by particular social groups (less diverse) that are spatially 'clumped' (less fragmented).

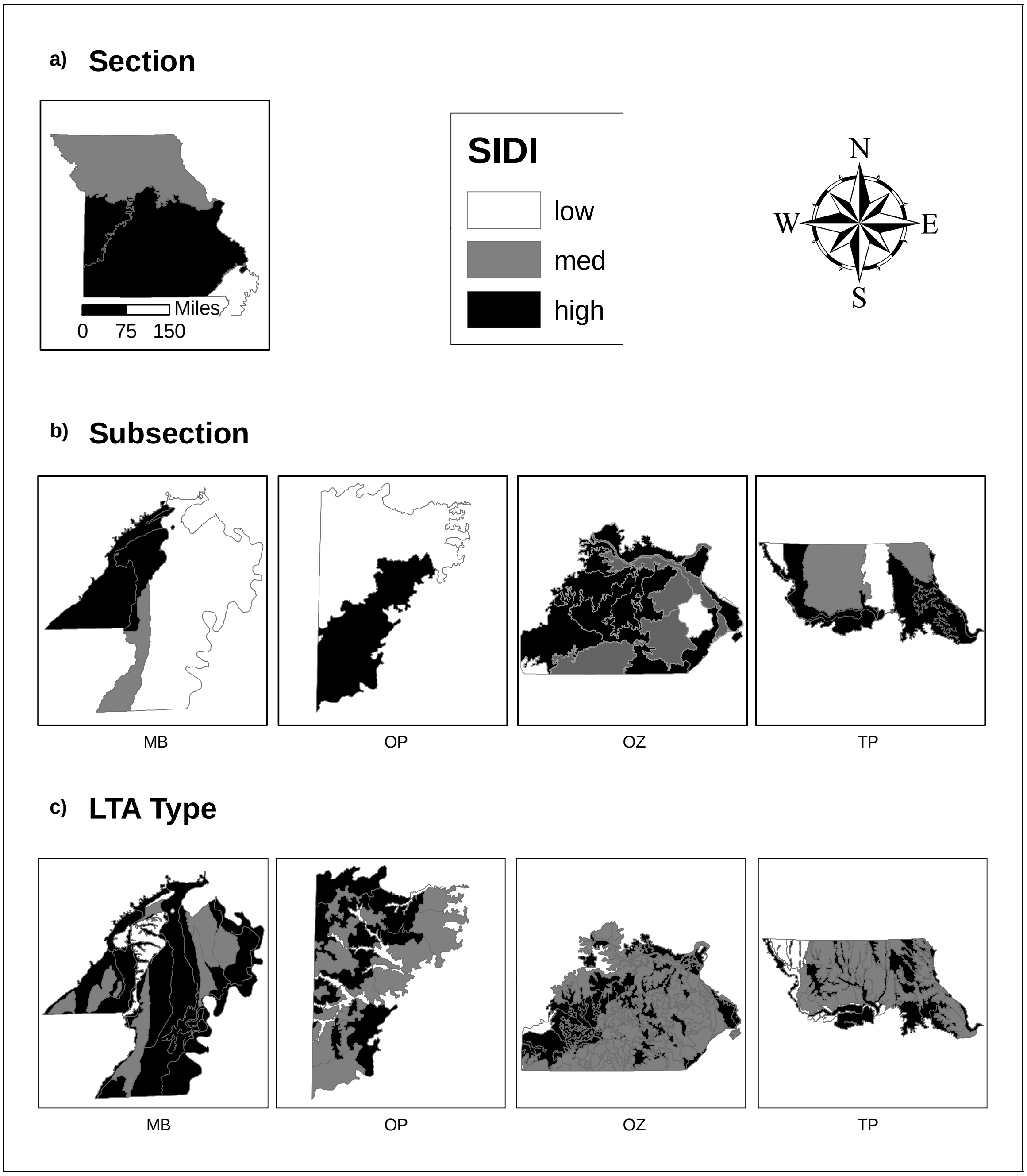
[7] In the discussion which follows, these figures will be referred to as 'CART maps'.



A *social group* is a set of block groups (end node) distinguished according to one or more socio-economic attributes.

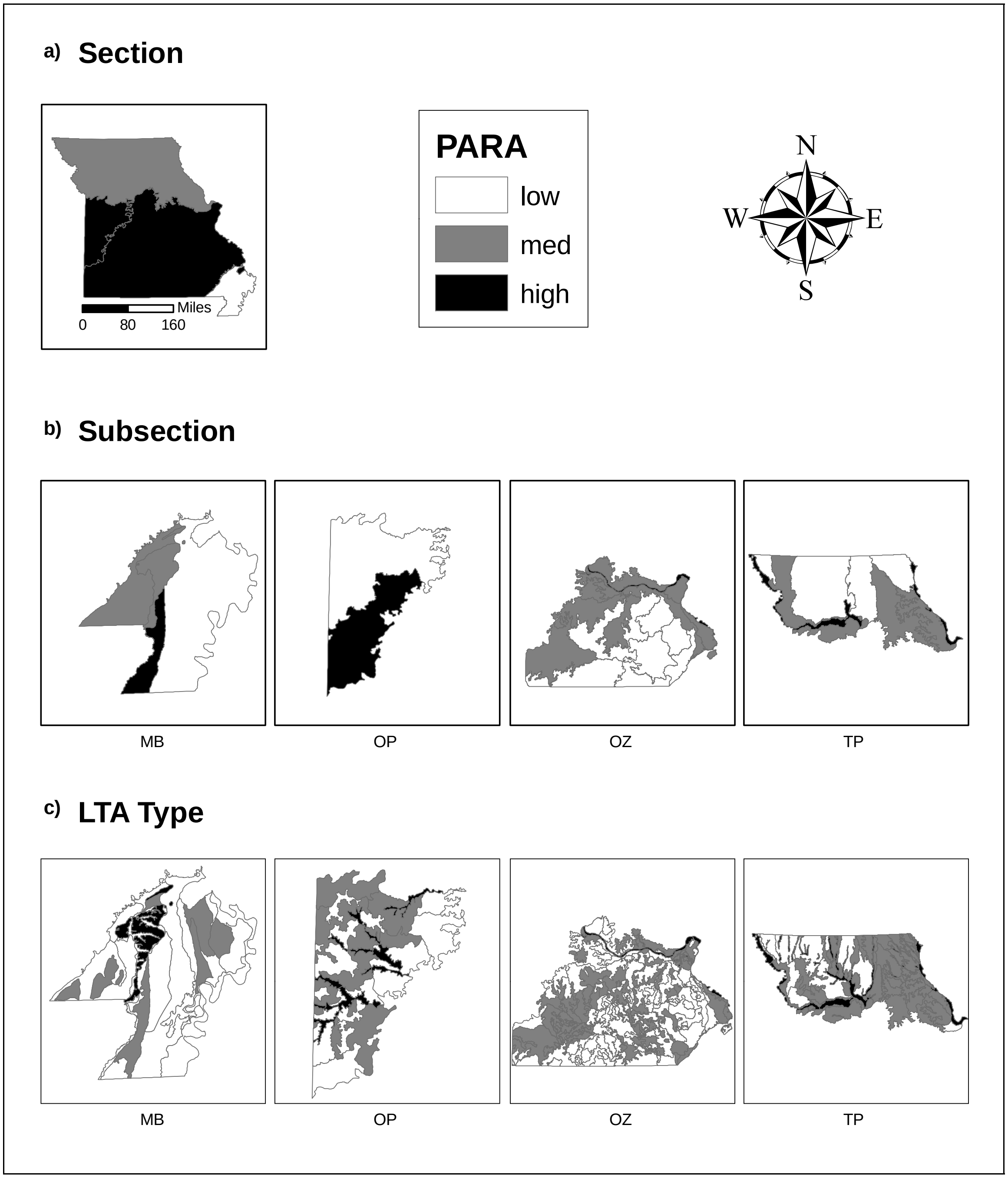
Figure 15. CART Map: Missouri ecological sections.

Social diversity and fragmentation. On an overall basis, therefore, social diversity and fragmentation varied considerably across Missouri's four sections. Figure 16a reveals that the Mississippi River Alluvial Basin (MB) was the least heterogeneous sections with respect to prominent socio-economic variables (SIDI=.227); the Central Dissected Till Plains (TP) exhibited a moderate degree of social heterogeneity (SIDI=.513); while the Osage Plains (OP) and Ozark Highlands (OZ) were the most heterogeneous (SIDI=.716 and .710 respectively). With respect to social fragmentation (Figure 17a), the Mississippi Basin and exhibited the least fragmented social patterns (PARA=2.38); while the Till Plains displayed a moderate degree of fragmentation (PARA = 2.52). In contrast, the Osage Plains and Ozark Highlands' social patterns were the most fragmented (PARA=3.94 and 3.99 respectively). In other words, in the MB and TP sections, social attributes of people situated therein were distributed more in 'clumps' or a spatially-grouped pattern, while OP and OZ sections displayed more fragmented social patterns.



Simpson's Diversity Index (SIDI) measures the socio-economic diversity for an ecological unit – the number of social groups in an ecological unit relative to the total number of social groups identified at a given ECS level. Social groups are identified by end nodes of the classification tree (sets of block groups with similar socio-economic characteristics). A higher SIDI value reflects greater socio-economic diversity (heterogeneity) in an ecological unit, and a lower value indicates greater social homogeneity.

Figure 16. Socio-economic diversity of ecological sections (a), and subsections and LTA Types by section (b and c).



Perimeter-to-area ratio (PARA) measures the socio-economic fragmentation (clumped or dispersed spatial patterns) of social groups within ecological units. Social groups are identified by end nodes of the classification tree (CART analysis), which are sets of block groups with similar socio-economic characteristics. A higher PARA value reflects a greater degree of social fragmentation for an ecological unit.

Figure 17. Socio-economic fragmentation of sections (a), and subsections and LTA Types by section (b and c).

4.2.2 Ecological subsections

The process of identifying the prominent socio-economic attributes along with their spatial content (diversity) and distribution (fragmentation) for ecological sections was also employed for ecological subsections (31) and LTA Types (25) in Missouri. The rest of this chapter examines results for subsections and LTA Types for each of the state's four ecological sections. There are 4 subsections in the Mississippi Basin, 2 in the Osage Plains, 16 in the Ozark Highlands[8], and 9 in the Till Plains. For LTA Types, there are 3 in the Mississippi Basin, 3 in the Osage Plains, 11 in the Ozark Highlands, and 8 in the Till Plains.

4.2.2.1 Mississippi Basin (MB)

Prominent socio-economic variables. Figure 18 consists of a classification tree with four end nodes. The variable at the root node of the tree, mean travel time to work, sorted block groups according to the four MB subsections. A 23 ½ minute or longer commute time to work resulted in block groups being sorted to the left of the first split. Those block groups with people who on average took less than 23 ½ minutes commuting to work were sorted into an end node to the right of the first split. The second node resulted in the sorting of 'longer commute block groups' by the variable owner-occupied units. Block groups with people who had long commutes and 43% or less of residents who owned a home were sorted into the far left end node on the tree. If block groups contained people who had long commutes and greater than 43% of its people who were homeowners, then farming, fishing, and forestry occupations served to sort these block groups into their corresponding end nodes at the bottom of the tree. Table 6 summarizes

[8] Only 15 subsections in the Ozark Highlands are included in the CART analysis. Subsection OZ2 did not have enough block groups to be adequately represented so it was dropped from the analysis.

prominent social variables leading to end nodes for MB subsections. An interesting pattern from the CART table is that employment-related, housing, and occupational variables were the particular kinds of prominent variables that described people in MB subsections.

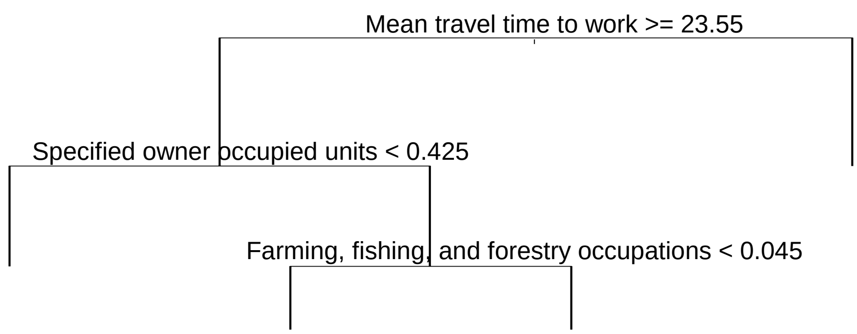


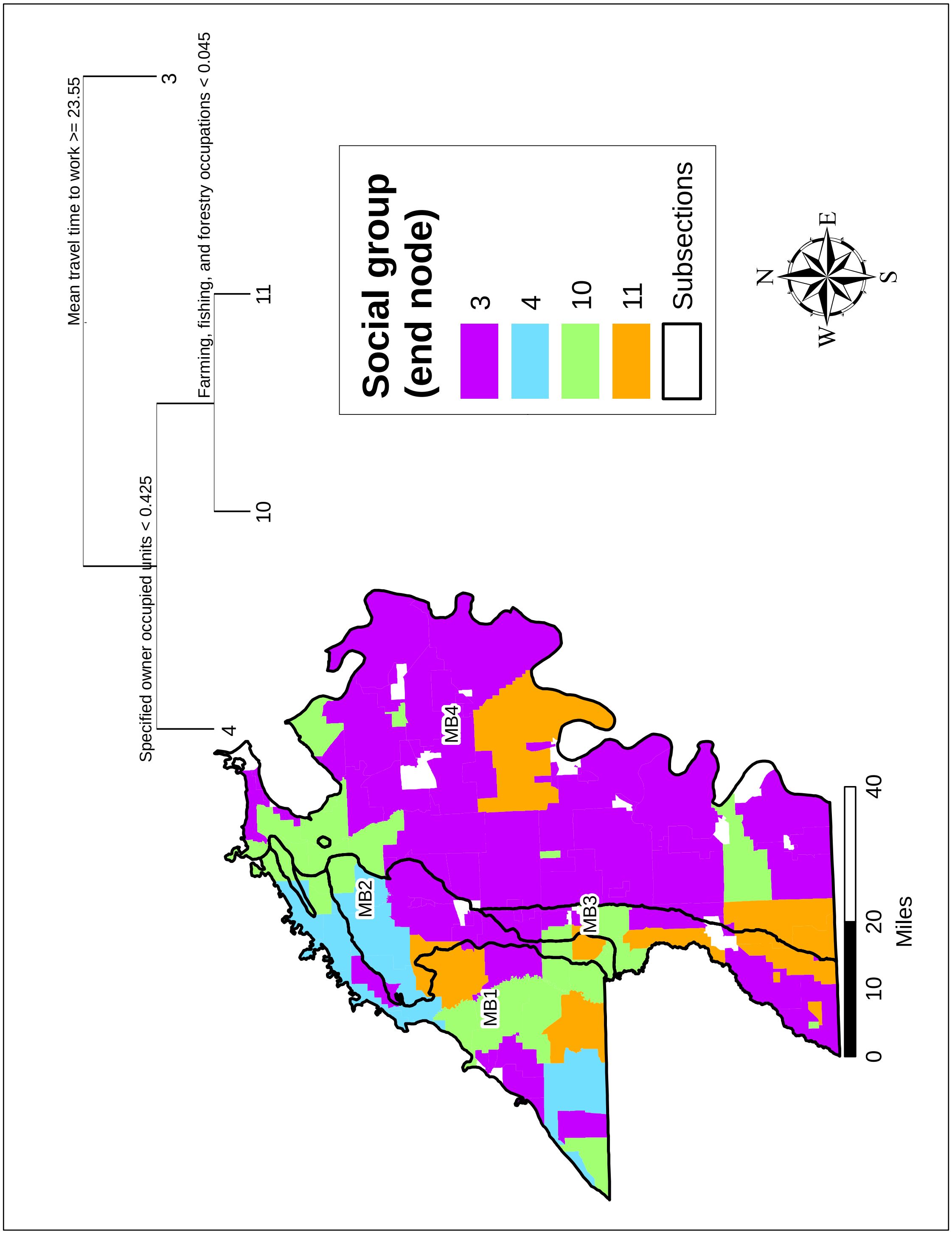
Figure 18. Mississippi Basin (MB) subsections classification tree. Classification tree results are based on samples of block groups from each of the 4 MB subsections. Units for socio-economic variables on classification trees vary according to the substantive nature of the variables. Units may be: 1) Proportions of people in a block group in decimal form; 2) average or median monetary values; 3) average time in minutes; and 4) average or median age in years.

Table 6. CART table for Mississippi Basin (MB) subsections

	Node Level		
Subsection	1	2	3
MB1	Avg commute time >=23.55	Specified owner occupied units <0.425	
MB2	Avg commute time >=23.55	Specified owner occupied units >=0.425	Farming, fishing, forestry occupations <0.045
MB3	Avg commute time >=23.55	Specified owner occupied units >=0.425	Farming, fishing, forestry occupations >=0.045
MB4	Avg commute time <23.55		

Node level reflects the number of times a given block group has been sorted by a social variable on the classification tree. An end node was assigned an ecological unit designator (here, MB subsection) reflecting the ecological unit within which the majority of block groups at that end node are situated.

Social groups (i.e., end nodes comprising block group sets) and variables from the MB subsection classification tree (Figure 18) were mapped (Figure 19) and this spatial information was inserted into FRAGSTATS to determine the social homogeneity and fragmentation of each MB subsection (Figure 16b and Figure 17b). The social group defined by higher proportions of people with short work commute times was located in the Mississippi River Alluvial Plain (MB4) subsection, the dominant subsection of MB in terms of area. The variable owner occupied units is the counterpart to the renter-occupied units variable that emerged in the section classification tree discussed earlier. The owner-occupied social group reveals fewer people who own houses in the Black River Alluvial Plain (MB1) and Crowley's Ridge (MB2) subsections. The St. Francois River Alluvial Plain subsection (MB3) was most prominently associated with greater proportions of people (>= 4.5%) employed in farming, fishing, and forestry occupations.



A *social group* is a set of block groups (end node) distinguished according to one or more socio-economic attributes.

Figure 19. CART Map: Mississippi Basin (MB) subsections.

Social diversity and fragmentation. Social diversity varied somewhat across MB subsections (Figure 15b). Subsections MB1-3 were socially heterogeneous (SIDI = .733, .699, and .595 respectively) while MB4 was socially homogeneous (SIDI = .402). Social fragmentation differed similarly across subsections MB1-3 & MB4. Perimeters to area ratio (PARA) values for MB1-3 were 6.45, 6.44, and 6.86 respectively and 2.75 in MB4 (Figure 16b). Therefore, subsections MB1-3 were socially fragmented while MB4 contained clustered social patterns (with respect to prominent socio-economic variables).

4.2.2.2 Osage Plains (OP)

Prominent socio-economic variables. Because the Osage Plains section only has two subsections (OP1 & OP2), the classification tree had two end nodes. Figure 20 depicts a tree with only a root node at which the prominent variable median household income serves to partition block groups according to whether income value was greater or less than $32,220. Table 7 reveals that subsection OP1 was dominated by block groups with a higher median household income, while a lower median household income predominated in subsection OP2.

The CART map for the Osage Plains (OP) subsections is presented in Figure 21. This revealed a north/south distinction between household income levels. A likely explanation for this is the urban influence from Kansas City, MO. Higher-income social groups are closer to Kansas City in the north part of OP where the Scarped Osage Plains (OP1) subsection is located. Lower-income social groups are located in the south parts of OP1 and extensively in the Cherokee Plains (OP2) subsection.

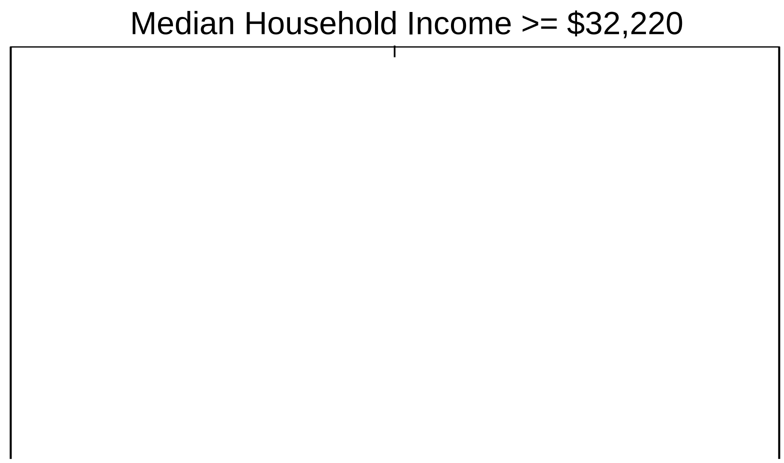
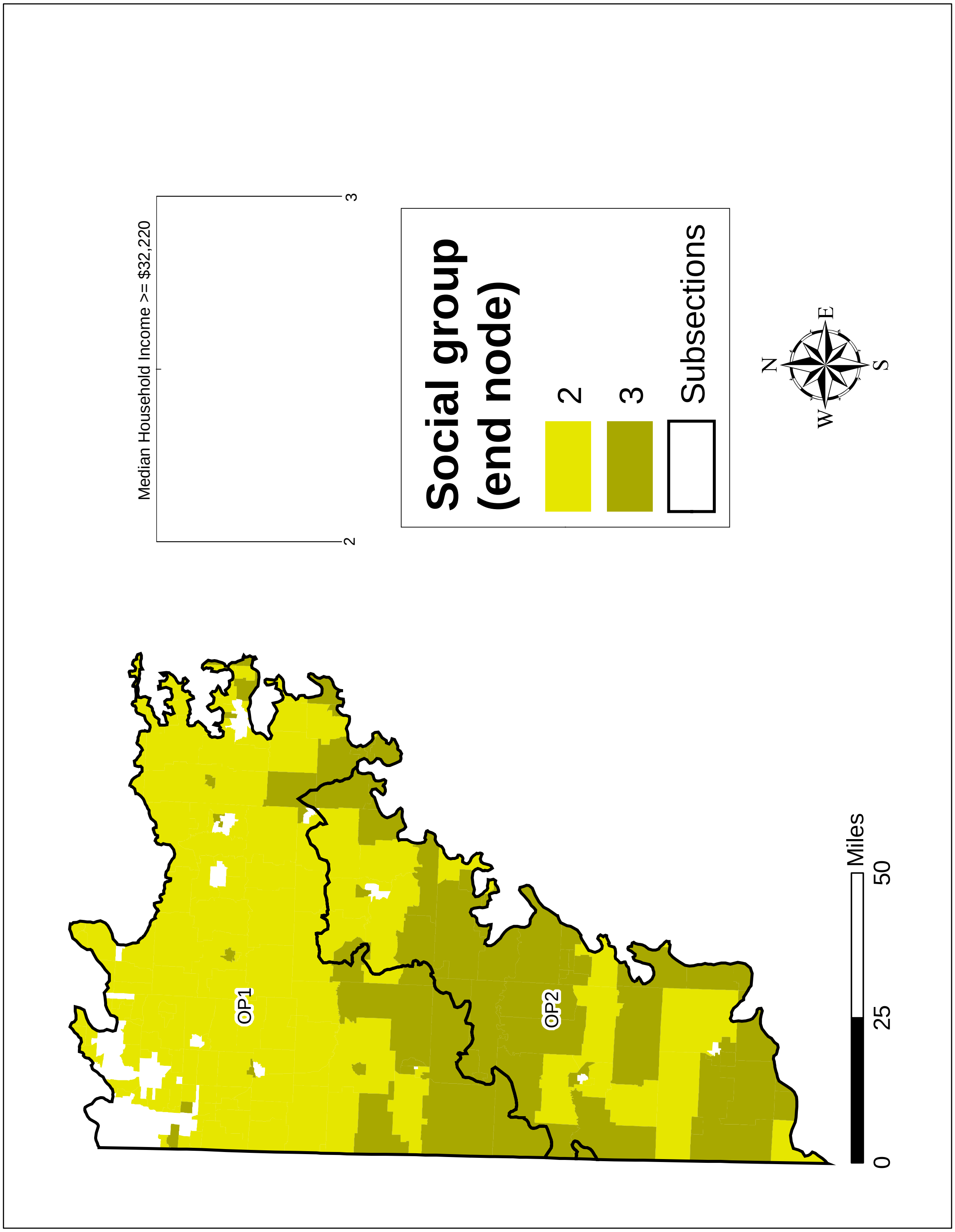


Figure 20. Osage Plains (OP) subsections classification tree. Classification tree results are based on samples of block groups from each of the 2 OP subsections. Units for socio-economic variables on classification trees vary according to the substantive nature of the variables. Units may be: 1) Proportions of people in a block group in decimal form; 2) average or median monetary values; 3) average time in minutes; and 4) average or median age in years.

Table 7. CART table for Osage Plains (OP) subsections

	Node Level
Subsection	1
OP1	Median household income >=$32,220
OP2	Median household income <$32,220

Node level reflects the number of times a given block group has been sorted by a social variable on the classification tree. An end node was assigned an ecological unit designator (here, OP subsection) reflecting the ecological unit within which the majority of block groups at that end node are situated.



A *social group* is a set of block groups (end node) distinguished according to one or more socio-economic attributes.

Figure 21. CART Map: Osage Plains (OP) subsections.

Social diversity and fragmentation. OP1 was the more socially homogeneous of the two subsections. SIDI values for OP1 & OP2 were .357 and .465 respectively (Figure 15b). OP1 was also the less fragmented socially in terms of median household income than was OP2. PARA values for OP1 & OP2 were 2.6 and 3.11 respectively (Figure 16b).

4.2.2.3 Ozark Highlands (OZ)

Prominent socio-economic variables. Because over half of all Missouri subsections are located in the Ozark Highlands (OZ), the OZ subsection classification tree is much larger than those for other subsections. It should also be noted that the Springfield Plateau subsection (OZ2) was not included in the CART analysis for OZ subsections because of an insufficient number of block groups (2); therefore, 15 of the original 16 subsections were analyzed. Figure 22 contains twenty end nodes. The variables at the first three nodes are median family income, graduate education, and minority status. Beyond the second node level, a wide range of variables describes block groups within ecological units. The 19 variables used in the sorting process for this tree are depicted in Table 8.

The first node level on the CART table reveals eight subsections (depicted at 10 end nodes) that are associated with a median family income (MFI) greater than $36,940. Seven subsections (also depicted at 10 end nodes) are associated with an MFI lower than $36,940. After the MFI-driven partitioning, the second node level contains two nodes whose sorting variables are ‘graduate and professional degree attainment’ and ‘persons who are in a minority’. The latter differentiates the lower MFI subsections. One lower MFI subsection (i.e., OZ3) is characterized as having greater than 10% minority population (hence the end node emanating from level 2). However, the remaining low MFI subsections are characterized by minority percentages that are below 10%. For the higher MFI subsections (i.e., those on the left side of the tree), graduate degree attainment was the basis for partitioning subsections. Six out of eight higher MFI subsections were characterized as having greater than 2.5% of people with a graduate or professional degree. The two subsections with higher MFI but with fewer than 2.5% of people having attained a graduate or professional degree were the OZ13 and OZ16 subsections located near St. Louis.

Other social variables which served to further differentiate block groups at lower node levels of the tree may be observed in Figure 22 and Table 8. It is again worth noting that higher tree levels (and accompanying longer vertical branches on the tree) contain social variables that are more significant in the overall partitioning process (since they are in effect 'sorting' more block groups) than lower levels. This is the basis for identifying 'median family income' in Figure 22 as the 'most prominent' social variable and 'graduate/professional degree' and 'minority' as 'prominent' variables.

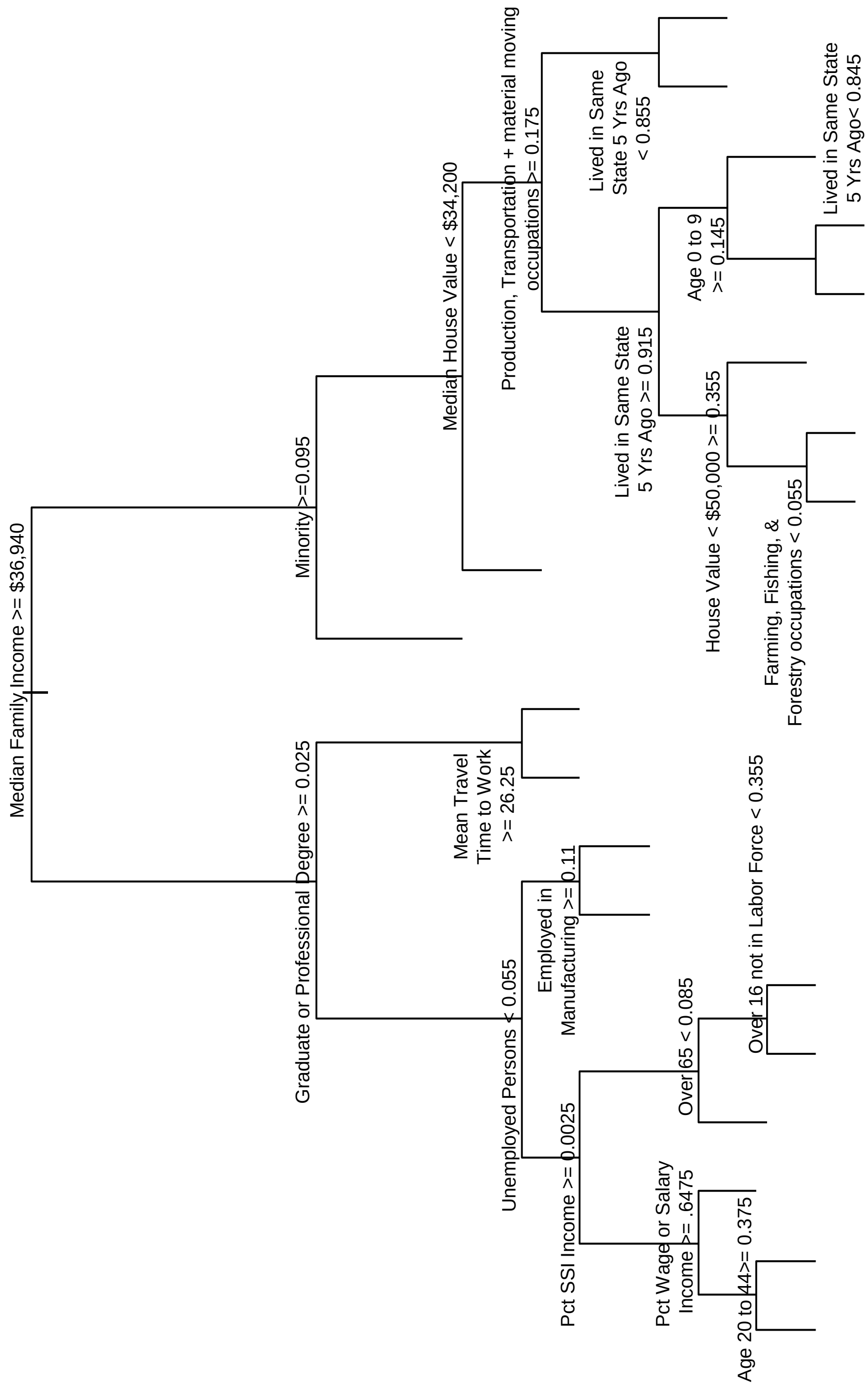


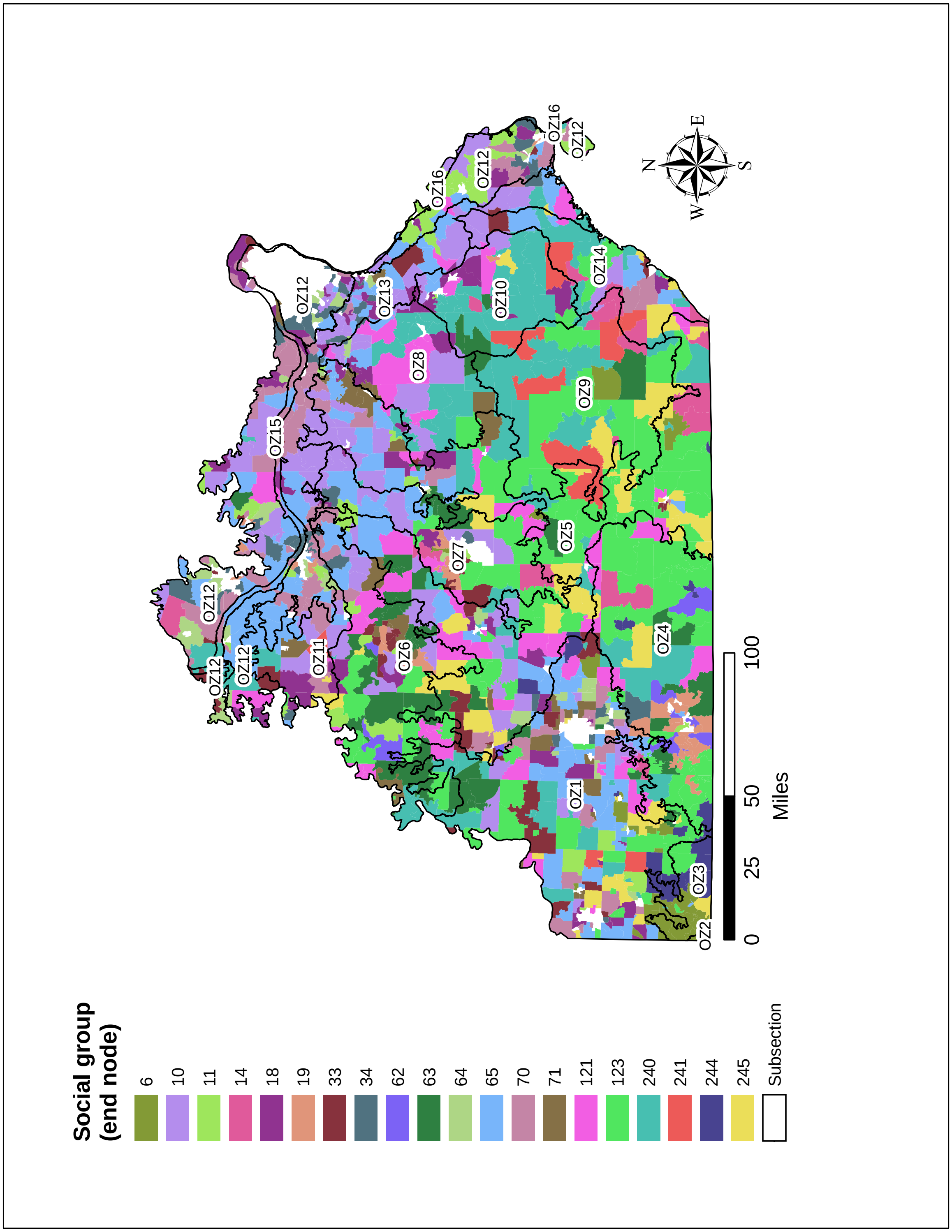
Figure 22. Ozark Highlands (OZ) subsections classification tree. Classification tree results are based on samples of block groups from each of the 15 OZ subsections. Units for socio-economic variables on classification trees vary according to the substantive nature of the variables. Units may be: 1) Proportions of people in a block group in decimal form; 2) average or median monetary values; 3) average time in minutes; and 4) average or median age in years.

Table 8. CART table for Ozark Highlands (OZ) subsections

Subsection	Node Level 1	2	3	4	5	6	7
OZ1[a]	n/a	n/a	n/a	n/a	n/a	n/a	n/a
OZ3	Median Family Income <$36,940	Minority >=.095					
OZ3	Median Family Income <$36,940	Minority <.095	Median House Value >=$34,200	Production, transportation, & material-moving occupations >=.175	Lived in same state 5 yrs ago <..915	Age 0 to 9 >=.145	Lived in same state 5 yrs ago <.845
OZ4	Median Family Income >=$36,940	Graduate or professional degree >=.025	Unemployed >=.055	Employed in manufacturing <.11			
OZ4	Median Family Income <$36,940	Minority <.095	Median House Value >=$34,200	Production, transportation, & material-moving occupations <.175	Lived in same state 5 yrs ago <.855		
OZ5	Median Family Income <$36,940	Minority <.095	Median House Value >=$34,200	Production, transportation, & material-moving occupations >=.175	Lived in same state 5 yrs ago <..915	Age 0 to 9 >=.145	Lived in same state 5 yrs ago >=.845
OZ6	Median Family Income >=$36,940	Graduate or professional degree >=.025	Unemployed <.055	%SSI income >=.0025	%Wage or salary income <.6475		
OZ6	Median Family Income <$36,940	Minority <.095	Median House Value >=$34,200	Production, transportation, & material-moving occupations <.175	Lived in same state 5 yrs ago >=.855		
OZ7[a]	n/a	n/a	n/a	n/a	n/a	n/a	n/a
OZ8	Median Family Income >=$36,940	Graduate or professional degree >=.025	Unemployed <.055	%SSI income <.0025	Over 65 >=.085	Over 16 not in labor force >=.355	
OZ8	Median Family Income <$36,940	Minority <.095	Median House Value >=$34,200	Production, transportation, & material-moving occupations >=.175	Lived in same state 5 yrs ago >=..915	House value less than 50k <.355	
OZ9	Median Family Income <$36,940	Minority <.095	Median House Value >=$34,200	Production, transportation, & material-moving occupations >=.175	Lived in same state 5 yrs ago <..915	Age 0 to 9 <.145	
OZ9	Median Family Income <$36,940	Minority <.095	Median House Value >=$34,200	Production, transportation, & material-moving occupations >=.175	Lived in same state 5 yrs ago >=..915	House value less than 50k >=.355	Farming, fishing & forestry occupations >=.055
OZ10	Median Family Income >=$36,940	Graduate or professional degree >=.025	Unemployed >=.055	Employed in manufacturing >=.11			
OZ10	Median Family Income <$36,940	Minority <.095	Median House Value >=$34,200	Production, transportation, & material-moving occupations >=.175	Lived in same state 5 yrs ago >=..915	House value less than 50k >=.355	Farming, fishing & forestry occupations <.055
OZ11	Median Family Income >=$36,940	Graduate or professional degree >=.025	Unemployed <.055	%SSI income >=.0025	%Wage or salary income >=.6475	Age 20 to 44 <.375	
OZ12	Median Family Income >=$36,940	Graduate or professional degree >=.025	Unemployed <.055	%SSI income <.0025	Over 65 <.085		
OZ12	Median Family Income >=$36,940	Graduate or professional degree >=.025	Unemployed <.055	%SSI income >=.0025	%Wage or salary income >=.6475	Age 20 to 44 >=.375	
OZ13	Median Family Income >=$36,940	Graduate or professional degree <.025	Avg commute >=26.25				
OZ14	Median Family Income <$36,940	Minority <.095	Median House Value <$34,200				
OZ15	Median Family Income >=$36,940	Graduate or professional degree >=.025	Unemployed <.055	%SSI income <.0025	Over 65 >=.085	Over 16 not in labor force <.355	
OZ16	Median Family Income >=$36,940	Graduate or professional degree <.025	Avg commute <26.25				

-Node level reflects the number of times a given block group has been sorted by a social variable on the classification tree. An end node was assigned an ecological unit designator (here, OZ subsection) reflecting the ecological unit within which the majority of block groups at that end node are situated.
-Subsection OZ2 is not included in this CART analysis because it could not meet the minimum sample size (only contains 2 block groups).
[a] Subsections OZ1 and OZ7 were represented in the OZ subsection CART analysis, however, no end node contained a majority of block groups within them.

The Ozark Highlands (OZ) section contains 16 subsections (including OZ2 which had too few block groups for CART analysis). Because of the size of the OZ subsection classification tree, many social groups 'dotted' the landscapes of the Ozark Highlands (Figure 23). This hampers the interpretation process when viewing the OZ subsections CART map – where each social group (i.e., end node) is depicted spatially via its own color. However, a few subsections (e.g., St. Francois Knobs & Basins [OZ10]) were easier to interpret because they were characterized by only a few colors. Clearly such subsections should have higher social homogeneity relative to those characterized by many social groups. In view of the cluttered nature of the CART map, the varying degrees of social homogeneity and fragmentation across OZ subsections may be better portrayed through the landscape metrics of Simpson's diversity index (SIDI) and perimeter to area ratio (PARA) rather than visually in the original CART map (Figure 23).



A *social group* is a set of block groups (end node) distinguished according to one or more socio-economic attributes.

Figure 23. CART Map: Ozark Highlands (OZ) Subsections.

Social diversity and fragmentation. Social diversity within OZ subsections is depicted spatially in Figure 16b and is represented via bar charts in Figure 24 below. The most homogeneous social pattern (SIDI = .611) was found in the alluvial plain subsection (OZ16) and the most heterogeneous social pattern (SIDI = .912) was found in the Springfield plains subsection (OZ1).

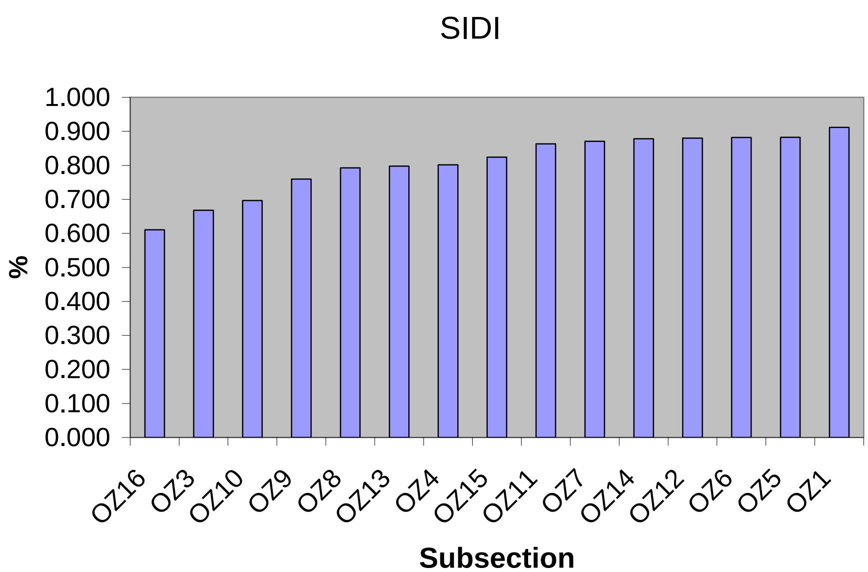


Figure 24. Simpson's diversity index for OZ subsections (displayed from lower to higher).

There seems to be a pattern in social homogeneity according to the Simpson's diversity index. Most of the subsections with higher social homogeneity (lower SIDI values) seem to be the most remote and/or rugged subsections in Missouri. The Mississippi River Alluvial Plain (OZ16), Elk River Hills (OZ3), St. Francois Knobs & Basins (OZ10), and the Current River Hills (OZ9) subsections all exhibit relatively high social homogeneity and are fairly rugged topographically. These subsections are either flood prone, very remote, forested, or hilly landscapes.

The four most socially heterogeneous subsections are the Springfield Plain (OZ1), the Central Plateau (OZ5), the Osage River Hills (OZ6), and the Outer Ozark Border

(OZ12) subsections. These tend to be less rugged and are in the vicinity of major metropolitan areas. They are more conducive to development/settlement except in the case of the Osage River Rills (OZ6), the most rugged of these four subsections. Because OZ6 is very ecologically diverse and since there is high social heterogeneity, it is hypothesized that the ecological sustainability of this subsection may be threatened.

Social fragmentation varied considerably across OZ subsections. Fragmentation was depicted spatially in Figure 17b and is presented in a chart below according to PARA values (Figure 25). PARA values for OZ subsections ranged from 4.17 in the Current River Hills subsection (OZ9) to 20.18 in the Mississippi River Alluvial Plain subsection (OZ16). Subsections with clustered social patterns like OZ9 are remote, forested, and less populated (e.g., OZ10, OZ4, and OZ8). Subsections with fragmented social patterns occur around urban areas (OZ12 and OZ13) but especially within subsections that have boundaries curvilinear in shape such as OZ15 and OZ16.

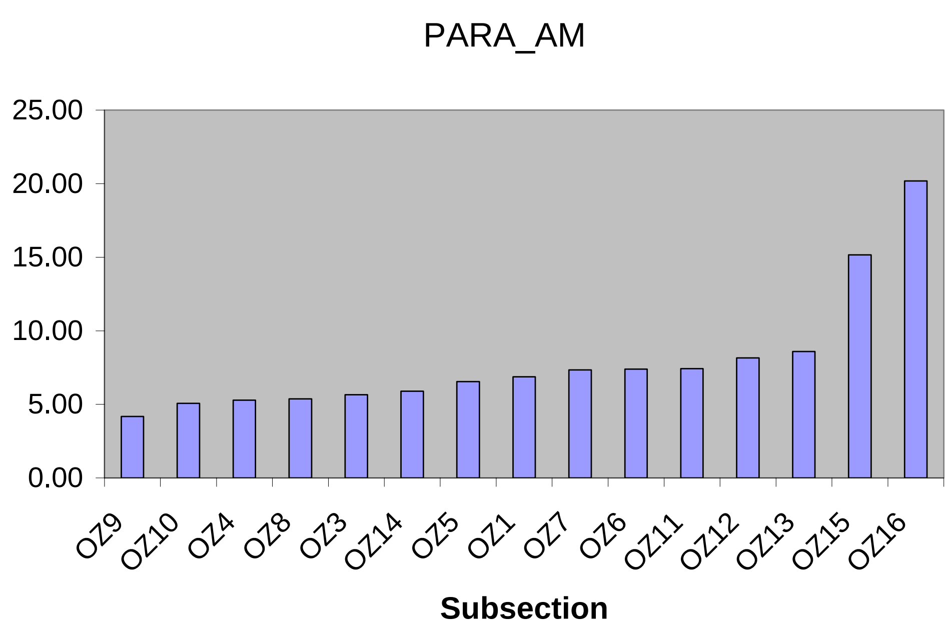


Figure 25. Perimeter-to-area ratio for OZ subsections (displayed from lower to higher).

4.2.2.4 Central Dissected Till Plains (TP)

Prominent socio-economic variables. Figure 26 depicts the classification tree for TP subsections. This tree yields nine end nodes in which each of the nine subsections is represented (i.e., contains the majority of block groups at an end node). At the root node of the tree, the housing variable 'average age of units > 51 years' immediately sorts block groups into an end node (older-aged houses) which is assigned the subsection designator TP2 (Table 9). All subsequent end nodes are characterized as having block groups with an average age of a house less than 51 years old (i.e., right side of tree). These 'younger average-aged house' block groups are first sorted according to proportions of people with household income in the range of $50,000-$99,999. For those block groups with younger houses and less than ¼ of residents in the $50,000-$99,999 household income range (the left pathway from the second node), the housing variable 'median year moved in' subsequently serves to further partition the block groups. For those block groups with younger houses and more people (>25%) in the $50,000-$99,999 household income range (the right pathway from the second node), the variable 'percent of poor persons' subsequently sorts the block groups.[9] Remaining block groups at the 'poor persons' node are further sorted according to enrollment in private school, household income $25,000-$49,999, mean travel time to work, and bachelors degree attainment.

Table 9 reveals that 8 out of 9 TP subsections are characterized by average age of houses < 51 years of age. Of those 8 subsections, six have greater than 25% of people with a household income between $50,000 and $99,999. Of those six subsections with younger houses and a greater percentage of people with a higher household income, two

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[9] Poor person: U.S. Census definition describing a person living at or below a specific poverty level (Poverty levels vary by family size.)

(TP8 and TP9) contain more than 8% of poor persons. In other words, TP8 and TP9 contain both a fairly high percentage of (upper) middle income residents and a not insignificant number of poor people. With respect to the other four subsections which contain younger houses, greater %'s of people with a high household income, and less than 8% poor persons, two of the subsections (TP3 and TP6) have a higher % of people enrolled in private school. In other words, TP3 and TP6 contain many relatively well-off people, fewer poor people, and more children enrolled in private education.

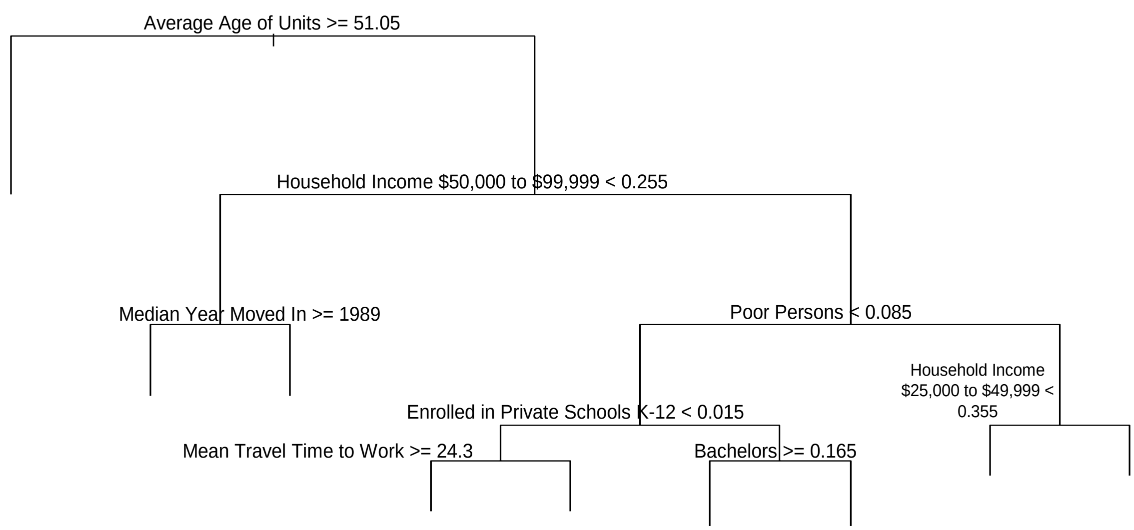


Figure 26. Till Plains (TP) subsections classification tree. Classification tree results are based on samples of block groups from each of the 9 TP subsections. Units for socio-economic variables on classification trees vary according to the substantive nature of the variables. Units may be: 1) Proportions of people in a block group in decimal form; 2) average or median monetary values; 3) average time in minutes; and 4) average or median age in years.

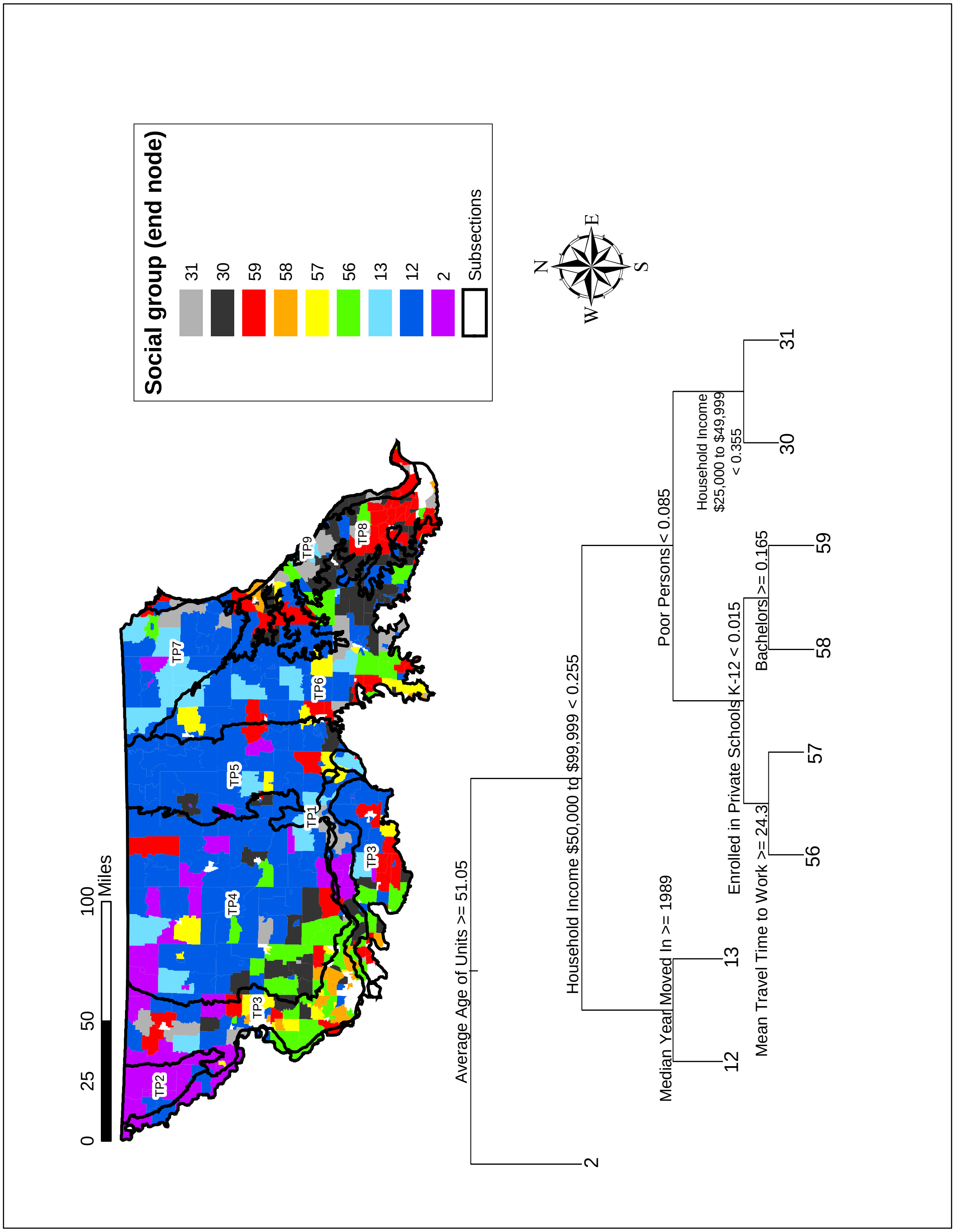
Table 9. CART table for Till Plains (TP) subsections

	Node Level				
Subsection	1	2	3	4	5
TP1	Average age of units <51.05	Household income 50k to 100k >=.255	Poor persons < .085	Enrolled in private school k-12 <.015	Average commute time >=24.3
TP2	Average age of units >=51.05				
TP3	Average age of units <51.05	Household income 50k to 100k >=.255	Poor persons < .085	Enrolled in private school k-12 >=.015	Bachelors >=.165
TP4	Average age of units <51.05	Household income 50k to 100k >=.255	Poor persons < .085	Enrolled in private school k-12 <.015	Average commute time <24.3
TP5	Average age of units <51.05	Household income 50k to 100k <.255	Median year moved in >=1989		
TP6	Average age of units <51.05	Household income 50k to 100k >=.255	Poor persons < .085	Enrolled in private school k-12 >=.015	Bachelors <.165
TP7	Average age of units <51.05	Household income 50k to 100k <.255	Median year moved in <1989		
TP8	Average age of units <51.05	Household income 50k to 100k >=.255	Poor persons >= .085	Household income 25k to 50k <.355	
TP9	Average age of units <51.05	Household income 50k to 100k >=.255	Poor persons >= .085	Household income 25k to 50k >=.355	

Node level reflects the number of times a given block group has been sorted by a social variable on the classification tree. An end node was assigned an ecological unit designator (here, TP subsection) reflecting the ecological unit within which the majority of block groups at that end node are situated.

Several patterns become evident in the TP subsections CART map (Figure 27). First, the tree separates urban and rural social characteristics. On the left side of the tree, social groups (denoted by end node numbers 2, 12, and 13) are described based on the age of the housing unit (very old or less than very old) and by lower proportions of block groups with an income between 50 and 100 thousand dollars. On the other hand, the right side of the tree partitions social groups (associated with particular subsections) that have younger average ages for houses and higher proportions of households with income between 50 and 100 thousand dollars. This seems to reflect an urban/rural distinction. Notice the patterns of color from the left side of the tree and compare it with the patterns of color from the right side of the tree. Blue and purple (rural) form a 'V'-shape with the remaining colors outside the 'V' (urban). Also, if one were to draw a horizontal line through the middle of the Till Plains, it would serve as the border for how far urban influences have migrated north from the metropolitan regions of Kansas City and St. Louis.

The second social pattern is concerned with the average age of houses and is associated with the Deep Loess Hills (TP2). TP2 is situated in the far northwest corner of the state and is dominated by block groups in which the average age of the house is at least 51 years old. Very few other block groups outside TP2 fit this description.



A *social group* is a set of block groups (end node) distinguished according to one or more socio-economic attributes.

Figure 27. CART Map: Till Plains (TP) Subsections.

Social diversity and fragmentation. Social diversity varied considerably across TP subsections (Figure 16b and Figure 28). The most homogeneous social pattern was found in TP2 (SIDI = .243), while the most heterogeneous social pattern was found in TP3 (SIDI = .854). This is an interesting pattern because these two subsections are adjacent to one another. The only difference is that TP3 extends from St. Joseph south to the Missouri River near Kansas City and then extends out to the east following the Missouri river, while TP2 is located north of St. Joseph. Social heterogeneity in TP3 is more than likely due to the presence of urban areas comprising parts of this subsection. Social homogeneity in TP2 is more likely due to its rural nature.

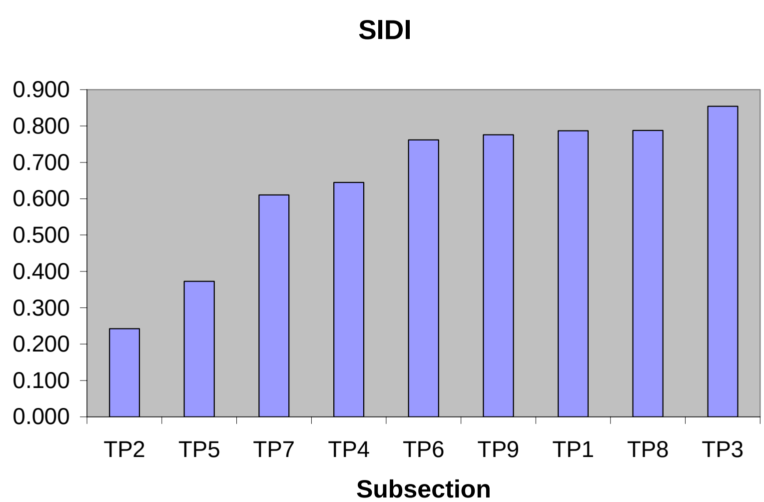


Figure 28. Simpson's diversity index for TP subsections (arranged from lower to higher values).

Social fragmentation within subsections also varied across the Till Plains (Figure 17b and Figure 29). The social pattern in TP2 was most clustered (PARA = 2.62) and in TP9 it was most fragmented of all TP subsections (PARA = 10.11).[10] The Mississippi River Alluvial Plain (TP9) and Missouri River Alluvial Plain (TP1) subsections are likely more fragmented because of their shape rather than the distribution of social groups

[10] Fragmentation values for subsections with curvilinear boundaries will be enhanced to some degree by subsection shape.

within them. This is because alluvial plain subsections have *curvilinear* shapes and hence PARA values increase. This is the case for the TP1 and TP9 subsections, both of which are alluvial plains. The next most highly fragmented subsections seem to be those in the vicinity of major metropolitan and other urban areas – Mississippi River Hills (TP8), Loess Hills (TP3), and Claypan Till Plains (TP6). The least fragmented subsections appear to be those with minimal urban presence – those most distant from Kansas City and St. Louis – the Deep Loess Hills TP2, Chariton River Hills (TP5), Grand River Hills (TP4), and the Wyaconda River Dissected Till Plains (TP7).

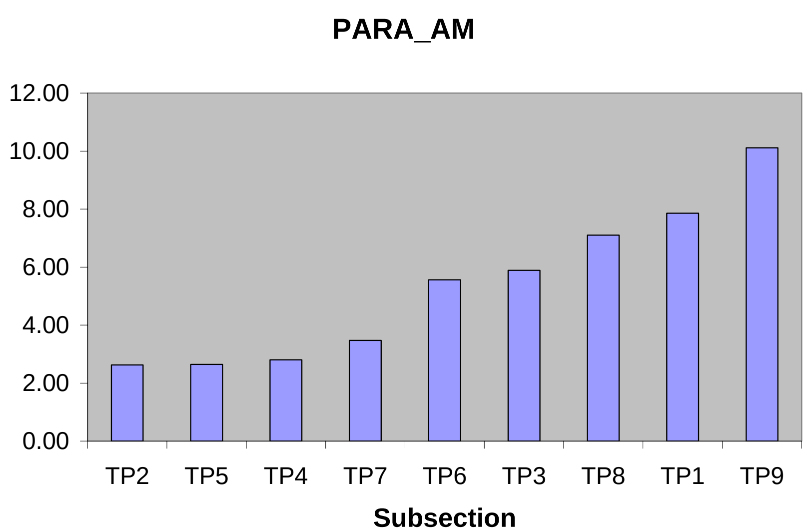


Figure 29. Perimeter-to-area ratio for TP subsections (arranged from low to high).

4.2.3 LTA Type

Having looked at the prominent socio-economic attributes and their spatial representation for ecological sections and subsections, the focus now turns to LTA Types – groupings of similar landtype associations (LTAs). There are 25 LTA Types distributed across the four ecological sections in Missouri. Three are within the Mississippi Basin, 3 within the Osage Plains, 11 within the Ozark Highlands, and 8 within the Till Plains.

4.2.3.1 Mississippi Basin (MB)

Prominent socio-economic variables. There are three LTA Types that may be found within the MB section and the classification tree for LTA Types contains three end nodes (Figure 30). The two social variables that best differentiated the three LTA Types in the MB section were minority status and percentage of poor persons. Block groups with less than 2.5% of persons belonging to a minority were partitioned to the left end node of the tree. Block groups with greater than 2.5% of persons in a minority went to the right and were sorted further in terms of the percentage of poor persons. If block groups were characterized by 2.5% or more minority population and 17% or more poor persons, they were sorted into the middle end node. The end node at the far right of the tree is characteristic of 2.5% or more of minority persons but fewer than 17% poor persons.

Table 10 reveals that the MB alluvial plains is characterized by block groups with greater than 2.5% minority residents and more than 17% of residents who are poor. The sand ridges and hills LTA Type also has a relatively greater minority population but less than 17% poor population. Crowley's ridge hills LTA Type is differentiated exclusively on the basis of having very few persons of minority status.

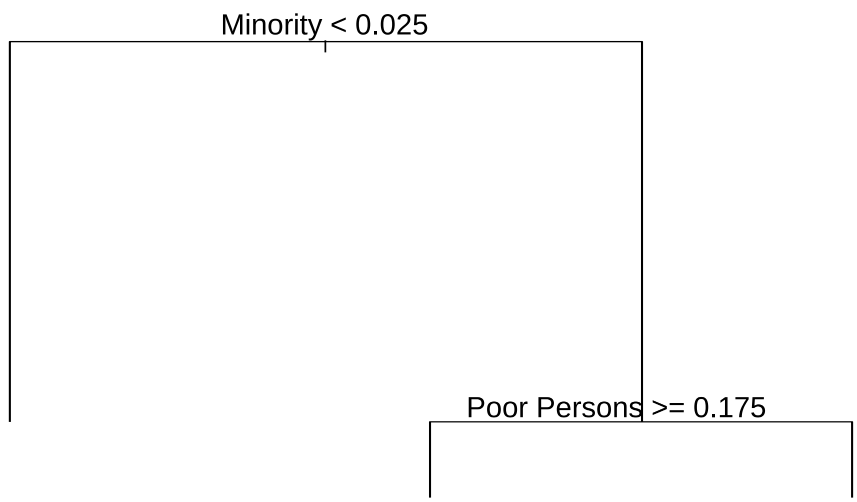


Figure 30. Mississippi Basin (MB) LTA Types classification tree. Classification tree results are based on samples of block groups from each of the 3 MB LTA Types. Units for socio-economic variables on classification trees vary according to the substantive nature of the variables. Units may be: 1) Proportions of people in a block group in decimal form; 2) average or median monetary values; 3) average time in minutes; and 4) average or median age in years.

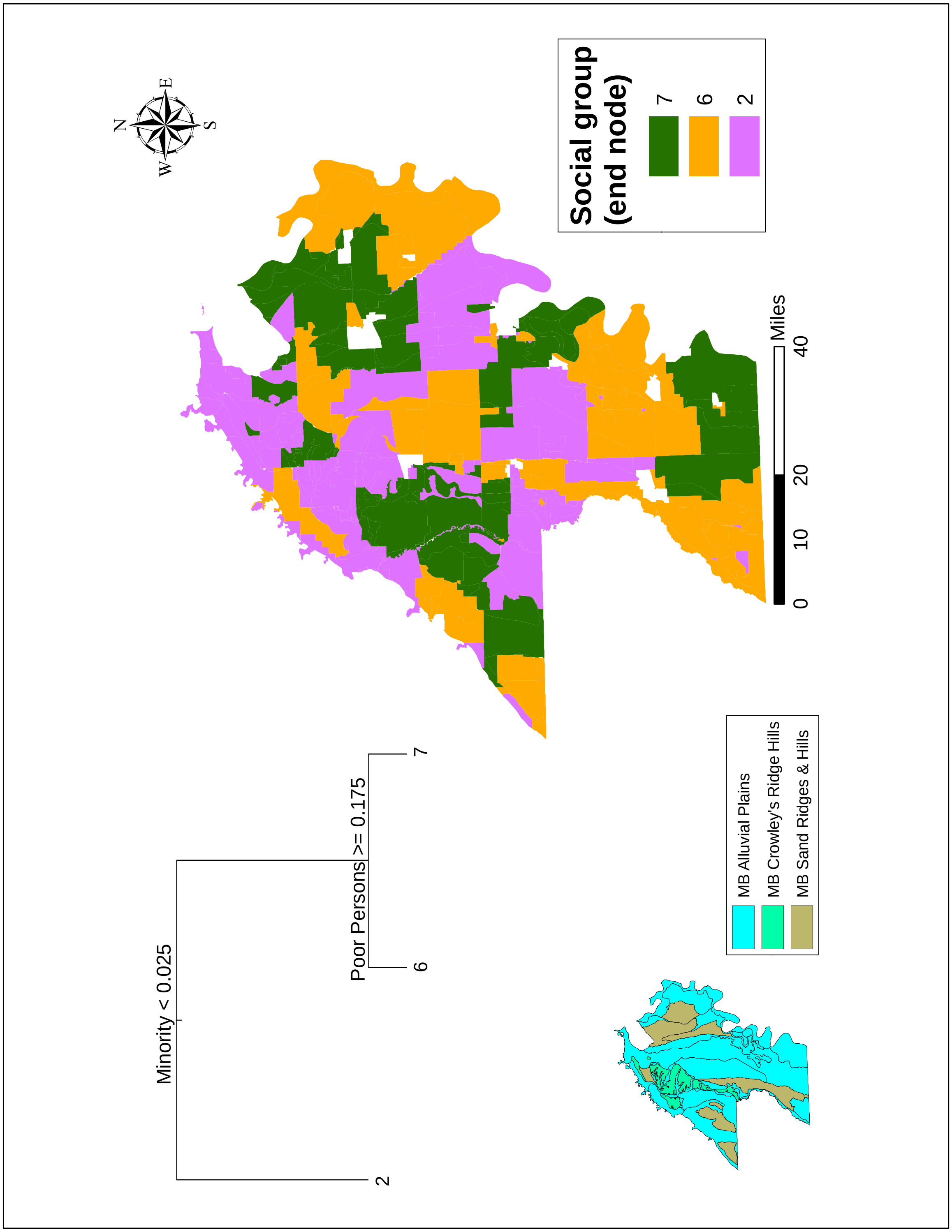
Table 10. CART table for Mississippi Basin (MB) LTA Types

	Node Level	
LTA Type	1	2
MB Alluvial Plains	Minority >=.025	Poor persons >=.175
MB Crowley's Ridge Hills	Minority <.025	
MB Sand Ridges & Hills	Minority >=.025	Poor persons <.175

Node level reflects the number of times a given block group has been sorted by a social variable on the classification tree. An end node was assigned an ecological unit designator (here, MB LTA Type) reflecting the ecological unit within which the majority of block groups at that end node are situated.

Figure 31 illustrates the presence and spatial pattern of social groups derived from the LTA Type classification tree for the Mississippi Basin ecological section. Also provided in Figure 31 is a map of the three LTA Types within the MB section. It is evident from this latter insert that a given LTA Type may be distributed in a spatially non-contiguous way across an ecological unit (here, section). This complicates the step of overlaying LTA Types with the CART map of social groups. Therefore, it is easier to visually compare the LTA Type map and the CART map separately in relating social groups with LTA Types. These results were inserted into FRAGSTATS for additional statistical analysis.

The variable ‘minority’ is located at the root node of the classification tree revealing its importance in creating social groups with respect to LTA Types in the Mississippi Basin. This process led to the creation of three social groups (end nodes) – one immediate and two arising from partitioning of block groups at the second node (poor persons). These two prominent variables describe the three social groups in LTA Types for the Mississippi Basin. The social group with less than 2.5% minority population was immediately partitioned to an end node (Figure 31). The social groups with more than 2.5% minority population were further sorted by how much of the block group’s population were considered poor. A higher proportion of poor persons was living in the alluvial plains, a predominantly agricultural LTA Type. The larger map in Figure 31 is the spatial representation of these three social groups (end nodes).



A *social group* is a set of block groups (end node) distinguished according to one or more socio-economic attributes.

Figure 31. CART Map: Mississippi Basin (MB) LTA Types.

Social diversity and fragmentation. Patterns of social diversity were similar for the alluvial plains and sand ridges & hills LTA Types within the Mississippi Basin (MB); however, both of these differed from the Crowley's Ridge hills LTA Type. Greater social diversity was found in the alluvial plains and sand ridges & hills LTA Types (SIDI = .660 and .642 respectively), while the Crowley's Ridge hills displayed lower social diversity (SIDI = .389) (Figure 16c). It is again worthwhile to mention that social diversity and homogeneity of these ecological units are assessed exclusively with reference to the prominent social variables in the classification tree.

Patterns of social fragmentation are similar to those for social diversity. The alluvial plains and sand ridges & hills LTA Types were comparable in their levels of social fragmentation while the Crowley's Ridge hills LTA Type was distinctly different (Figure 17c). However, the alluvial plains and sand ridges & hills LTA Types exhibited lower social fragmentation (PARA = 5.88 and 7.92) while the Crowley's Ridge hills had higher social fragmentation (PARA = 12.18). This is inconsistent with respect to the observed social diversity patterns. It is expected that a socially homogenous LTA Type (i.e., Crowley's Ridge hills) would also have lower social fragmentation. However, the Crowley's Ridge hills LTA Type has high fragmentation. This is likely due to its complex (*dissected*) shape (Figure 31) which likely enhanced values for the PARA and hence its overall degree of fragmentation.

4.2.3.2 Osage Plains (OP)

Prominent socio-economic variables. Figure 32 consists of a tree with two variables related to housing and migration that best sorted block groups into the three LTA Types within the OP section. 'Average house value' is the partitioning variable at the root node and 'lived in same county 5 yrs ago' is located at the second node. Table 11 reveals that average house value is less than $135,000 in the alluvial plains and prairie plains. At the same time, the alluvial plains has a higher percentage of people who have resided in the same county for the past 5 years (i.e., 5 years before the census was administered) compared to the prairie plains. The OP prairie/savanna scarped & dissected plains LTA Type is sorted solely on its characteristically higher average house value.

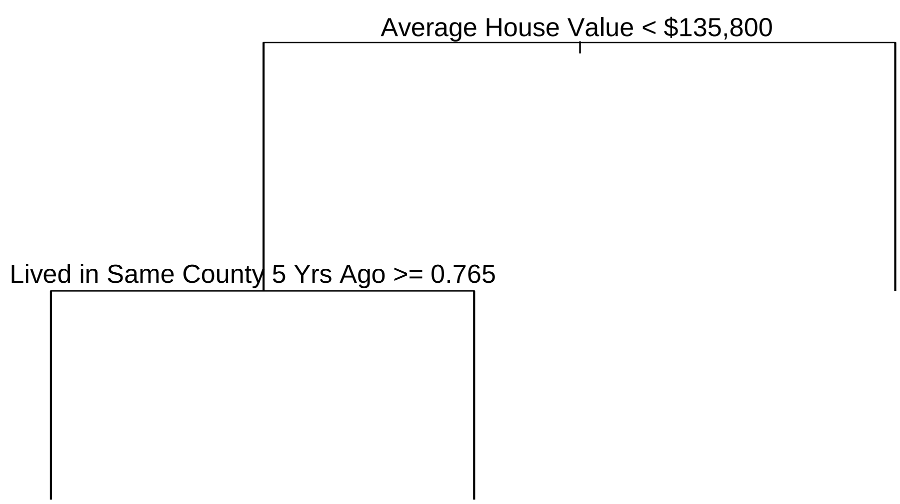


Figure 32. Osage Plains (OP) LTA Types classification tree. Classification tree results are based on samples of block groups within the 3 OP LTA Types. Units for socio-economic variables on classification trees vary according to the substantive nature of the variables. Units may be: 1) Proportions of people in a block group in decimal form; 2) average or median monetary values; 3) average time in minutes; and 4) average or median age in years.

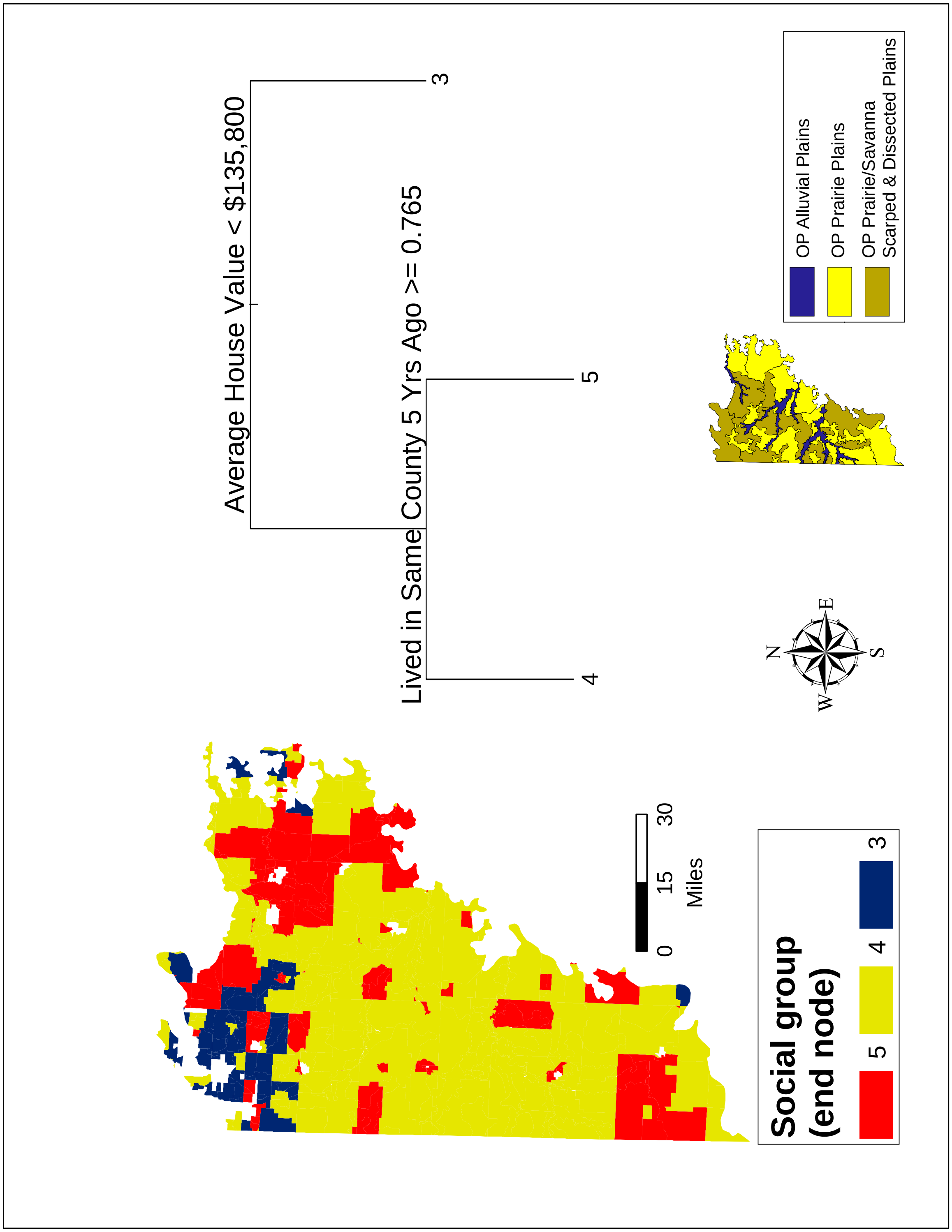
Table 11. CART table for Osage Plains (OP) LTA Types

	Node Level	
LTA Type	1	2
OP Alluvial Plains	Avg house value <$135,800	Lived in same county 5 years ago >=.765
OP Prairie Plains	Avg house value <$135,800	Lived in same county 5 years ago <.765
OP Prairie/Savanna Scarped & Dissected Plains	Avg house value >=$135,800	

Node level reflects the number of times a given block group has been sorted by a social variable on the classification tree. An end node was assigned an ecological unit designator (here, OP LTA Type) reflecting the ecological unit within which the majority of block groups at that end node are situated.

Figure 33 illustrates the presence and spatial distribution of social groups derived from the LTA Type classification tree for the Osage Plains (OP) section. Also depicted therein is a map of the 3 LTA Types within the OP section.

The predominant social group which extended across the Osage Plains section, particularly the southern two-thirds, reflects people with lower average house values who have migrated to the area in the last 5 years (i.e., 1995-2000). The other social group partitioned by the prominent social variable at the second node – more people who migrated – is spatially dispersed primarily in the northeast and southwest corners of OP.



A *social group* is a set of block groups (end node) distinguished according to one or more socio-economic attributes.

Figure 33. CART Map: Osage Plains (OP) LTA Types.

Social diversity and fragmentation. Social diversity varied across the three LTA Types within the Osage Plains (Figure 16c). The alluvial plains LTA Type was socially homogeneous (SIDI = .234), while the prairie and prairie/savanna scarped & dissected plains were socially heterogeneous (SIDI = .468, and .514) relative to the alluvial plains.

Social fragmentation was similar for the prairie LTA Types; both, however, differed from the alluvial plains LTA Type (Figure 17c). The PARA values for the prairie plains and the prairie/savanna scarped & dissected plains differed slightly and were 5.55 and 6.11 respectively. It should be noted that the major metropolitan area of Kansas City is predominantly within the prairie/savanna scarped & dissected plains LTA type and it is expected that social fragmentation would be relatively higher here. On the other hand, the PARA value for the alluvial plains was more than twice the PARA value of the other two LTA Types (PARA = 13.32). This is more than likely due to its curvilinear shape. Thus social patterns present in the alluvial plains may well be hidden from this analysis.

4.2.3.3 Ozark Highlands (OZ)

Prominent socio-economic variables. Figure 34 presents the classification tree for LTA Types of the Ozark Highlands (OZ) section. The tree contains 11 end nodes representing ten of the eleven LTA Types in the OZ section. One LTA Type, the 'OZ oak savanna/woodland [dissected] plains', does not represent a majority of block groups at any of the end nodes on the classification tree (Table 12). This is because prominent variables in the tree did not serve to sort block groups in a way that the majority of block groups at a given end node fell within the OZ oak savanna/woodland [dissected] plains. The 'OZ rugged hills and forest breaks' LTA Type contains the majority of block groups in two end nodes (Table 12). Variables that served to partition block groups on this tree included those related to population, income, housing, commute time, education, labor force, and migration. It is interesting that four variables were also part of the OZ subsection CART analysis. These include the most prominent variable, 'median family income' (MFI), which is the root node in both the OZ LTA Type and OZ subsection trees. Block groups that had a higher MFI were partitioned into more complex social patterns in which six social variables functioned in further sorting of block groups. At the second node level, the variable on the left side – persons on farms – served to further differentiate the block groups with higher MFI. Other variables such as house value, commute time, labor force, and 'lived in same state', subsequently sorted the remaining 'higher MFI' and 'fewer persons on farms' block groups.

In contrast, a less complex social pattern is associated with the block groups with MFI less than $35,720. This is reflected in the three (as opposed to five) social variables operative in defining the right side of the tree. For lower MFI block groups, an income source variable (i.e., % wage or salary income) emerged as the partitioning variable at the second node. An educational variable ('less than 9th grade' [or 'no high school']), and one related to migration ('moved in last 5 yrs') served to sort the remaining block groups on the right side of the tree.

Table 12 reveals that six of the 10 LTA Types identified in the CART analysis were recognized as having higher median family income (MFI) [>=$35,720] associated with people living there. It is noteworthy that these high MFI Types constitute different types of landscapes (alluvial plains, dolomite glade woodlands, forest hills, prairie plains, savanna plains, and forest breaks). Five of the 6 higher MFI Types are further characterized as having less than 12% of people on farms. The OZ prairie plains LTA Type is the only one of these that has greater than 12% of people on farms. Of the four LTA Types characterized by lower MFI, three are those in which less than two-thirds of people living within geographical boundaries defined by those types earn a wage or salary income. These three LTA Types are all comprised of oak forests to varying extents. The one LTA Type with lower MFI and a higher percentage of people with wage or salary income is the OZ igneous knobs.

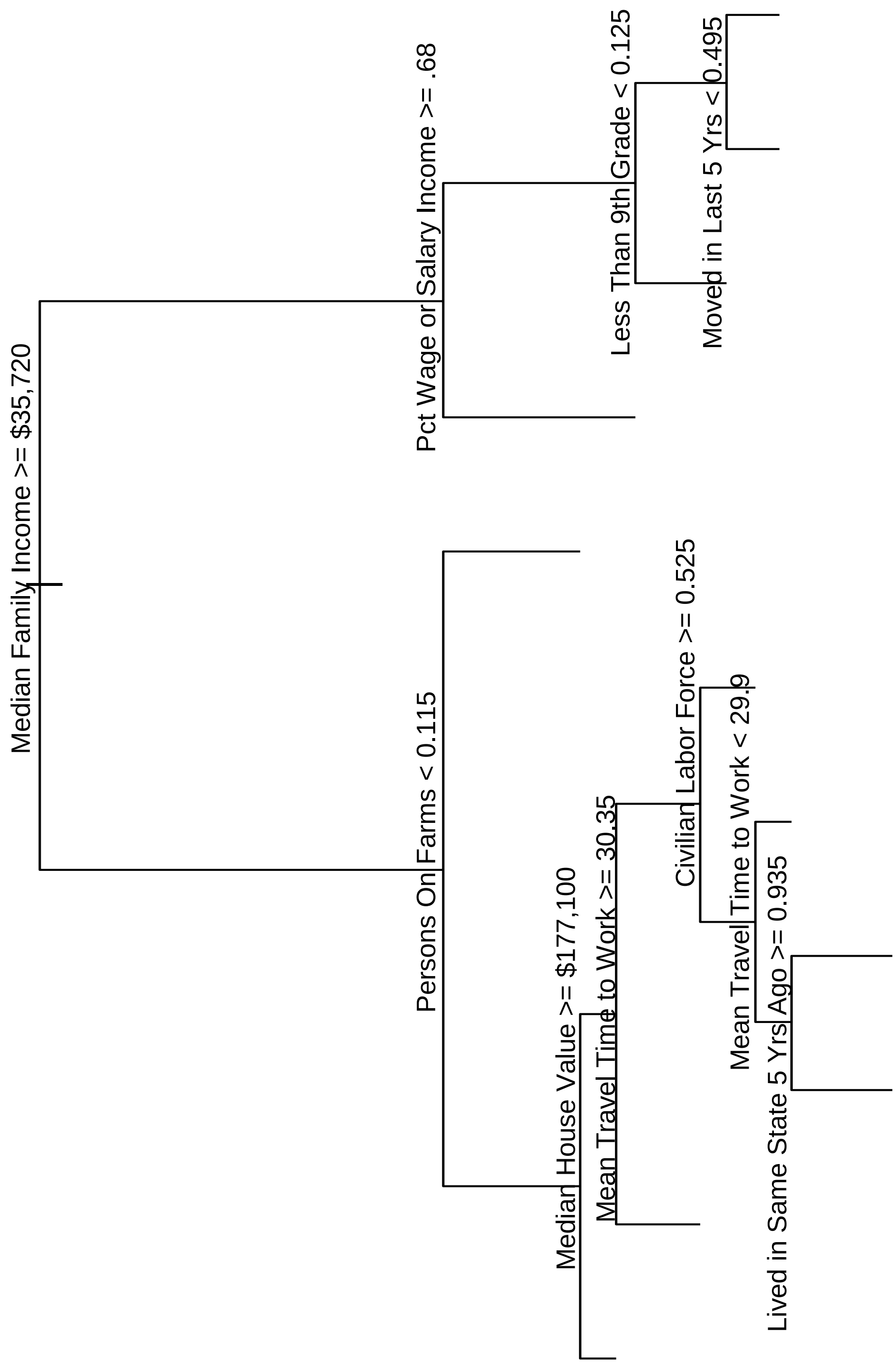


Figure 34. Ozark Highlands (OZ) LTA Types classification tree. Classification tree results are based on samples of block groups from each of the 11 OZ LTA Types. Units for socio-economic variables on classification trees vary according to the substantive nature of the variables. Units may be: 1) Proportions of people in a block group in decimal form; 2) average or median monetary values; 3) average time in minutes; and 4) average or median age in years.

Table 12. CART table for Ozark Highlands (OZ) LTA Types

LTA Type	Node Level 1	2	3	4	5	6	7
OZ Alluvial Plains	Median family income >=$35,720	Persons on farms <.115	Median house value >=$177,100				
OZ Dolomite Glade/Woodlands	Median family income >=$35,720	Persons on farms <.115	Median house value <$177,100	Avg commute time >=30.35			
OZ Igneous Knobs	Median family income <$35,720	% wage or salary income >=.68					
OZ Oak Savanna/Woodland (Dissected) Plains	n/a	n/a	n/a	n/a	n/a	n/a	n/a
OZ Oak Woodland Dissected Plains & Hills	Median family income <$35,720	% wage or salary income <.68	No high school education <.125				
OZ Oak Woodland/Forest Hills	Median family income >=$35,720	Persons on farms <.115	Median house value <$177,100	Avg commute time <30.35	Civilian labor force >=.525	Avg commute time <29.9	Lived in same state 5 years ago >=.935
OZ Oak-Pine Hills	Median family income <$35,720	% wage or salary income <.68	No high school education >=.125	Moved in last 5 years <.495			
OZ Pine-Oak Woodland Dissected Plain	Median family income <$35,720	% wage or salary income <.68	No high school education >=.125	Moved in last 5 years >=.495			
OZ Prairie Plains	Median family income >=$35,720	Persons on farms >=.115					
OZ Prairie/Savanna (Dissected) Plains	Median family income >=$35,720	Persons on farms <.115	Median house value <$177,100	Avg commute time <30.35	Civilian labor force >=.525	Avg commute time <29.9	Lived in same state 5 years ago <.935
OZ Rugged Hills & Forest Breaks	Median family income >=$35,720	Persons on farms <.115	Median house value <$177,100	Avg commute time <30.35	Civilian labor force <.525		
OZ Rugged Hills & Forest Breaks	Median family income >=$35,720	Persons on farms <.115	Median house value <$177,100	Avg commute time <30.35	Civilian labor force >=.525	Avg commute time >=29.9	

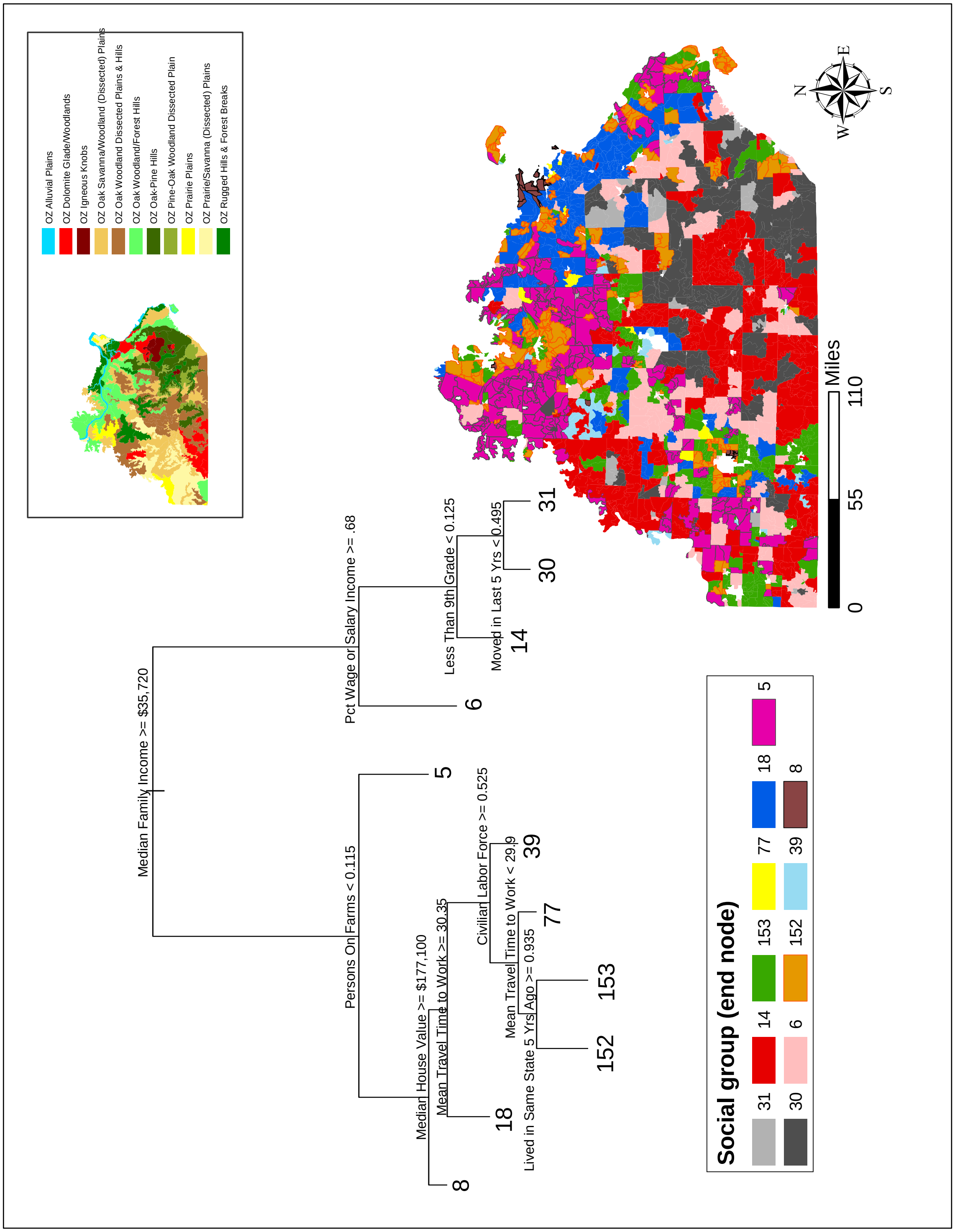
-Node level (1-7) reflects the number of times a given block group has been sorted by a social variable on the classification tree. An end node was assigned an ecological unit designator (here, OZ LTA Type) reflecting the ecological unit within which the majority of block groups at that end node are situated.
-The OZ Oak Savanna/Woodland (Dissected) Plains LTA Type was not included in the classification tree because it never represented the majority of block groups at an end node.
-Two end nodes had a majority of block groups in the same OZ LTA Type (OZ Rugged Hills & Forest Breaks).

Figure 35 depicts the presence and spatial distribution of social groups derived from the classification tree for LTA Types in the Ozark Highlands (OZ). The Ozark Highland section contains 11 LTA Types. Compared to the CART map depicting subsections in the Ozark Highlands (Figure 23), the CART map depicting LTA Types in the Ozark Highlands (Figure 35) is much more interpretable. This is aided by the smaller number of social groups (eleven instead of nineteen in the OZ subsection tree).

Several patterns emerge from the CART map for LTA Types in the Ozark Highlands. The first is related to higher median family income (MFI) and the proportion of block groups' people that live on farms. Notice the social group identified via end node number 5. This represents high proportions of families with a higher MFI and who live on farms. This seems to be an important socio-economic characteristic distinguishing people within the OZ prairie plains, OZ oak savanna/woodland dissected plains, and the OZ oak woodland dissected plains.

Another pattern of interest on the CART map relates to social group defined by end node number 18. This group is distinguished by higher median family income (MFI), fewer people living on farms, median house value less than $176,000, and longer travel time to work. With respect to this latter variable, it is noteworthy that this is associated with LTA Types surrounding and to the south of the St. Louis metropolitan area along interstate route 55.

Three social groups, defined by the end nodes 14, 30, and 31, are the subject of another social pattern (Figure 35). Some characteristics of these social groups are similar – lower median family income (less than $35,000) and fewer sources of income derived from wages or salary. However, these groups differ according to proportions of people with less than a 9th grade education (i.e., no high school experience) and migration (i.e., moved in the last 5 years). With respect to education, the social group associated with end node 14 contains more educated persons (oak woodland/dissected plains and hills LTA Type) than do those social groups defined by end nodes 30 and 31. The latter social groups (having more people with no high school education) are most associated with people living within the oak pine hills and the pine-oak woodland dissected plains LTA Types, respectively. In terms of migration, the social group defined by end node 30 (oak-pine hills) contains fewer people who have settled within the last five years than does the group defined by end node 31 (pine-oak woodland/dissected plains).



A *social group* is a set of block groups (end node) distinguished according to one or more socio-economic attributes.

Figure 35. CART Map: Ozark Highlands (OZ) LTA Types.

Social diversity and fragmentation. Social diversity varied moderately among LTA Types for the Ozark Highlands (Figure 16c and Figure 36). The OZ prairie plains LTA Type was the most socially homogeneous (SIDI = .562), while the OZ rugged hills & forest breaks was the most socially heterogeneous LTA Type (SIDI = .863).

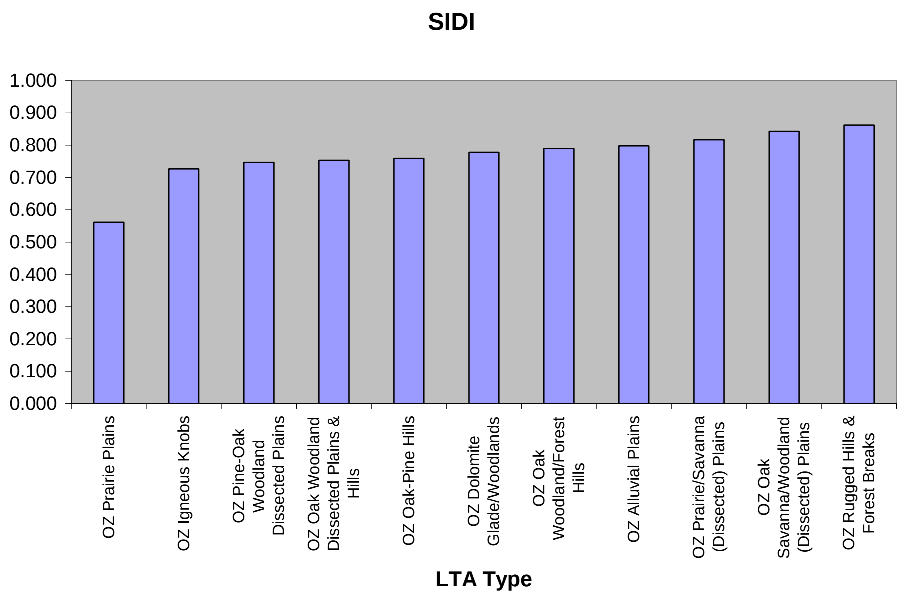


Figure 36. Simpson's diversity index for Ozark Highland LTA Types (arranged from lower to higher).

Besides the LTA Types that contain urban areas (oak savanna/woodland dissected plains; prairie/savanna dissected plains; alluvial plains), it seems that some of the most rugged LTA Types (i.e., rugged hills & forest breaks and oak woodland/forest hills) are also the most socially heterogeneous, with the exception of the igneous knobs LTA Type. At the subsection level, however, some of the most rugged subsections were socially homogenous (Figure 36).

Levels of social fragmentation were fairly grouped for Ozark Highlands LTA Types with the exception of the OZ alluvial plains (Figure 17c and Figure 37). The oak woodland dissected plains & hills displayed the most clumped social pattern (PARA = 6.56) while the alluvial plains had the most fragmented social pattern (PARA = 18.52), far exceeding all other LTA Types. However, as noted earlier in introducing the FRAGSTATS metrics SIDI and PARA, very elongated and/or irregularly-shaped ecological units will have higher PARA values regardless of the social patterns associated with them. The OZ alluvial plains is likely an example of this.

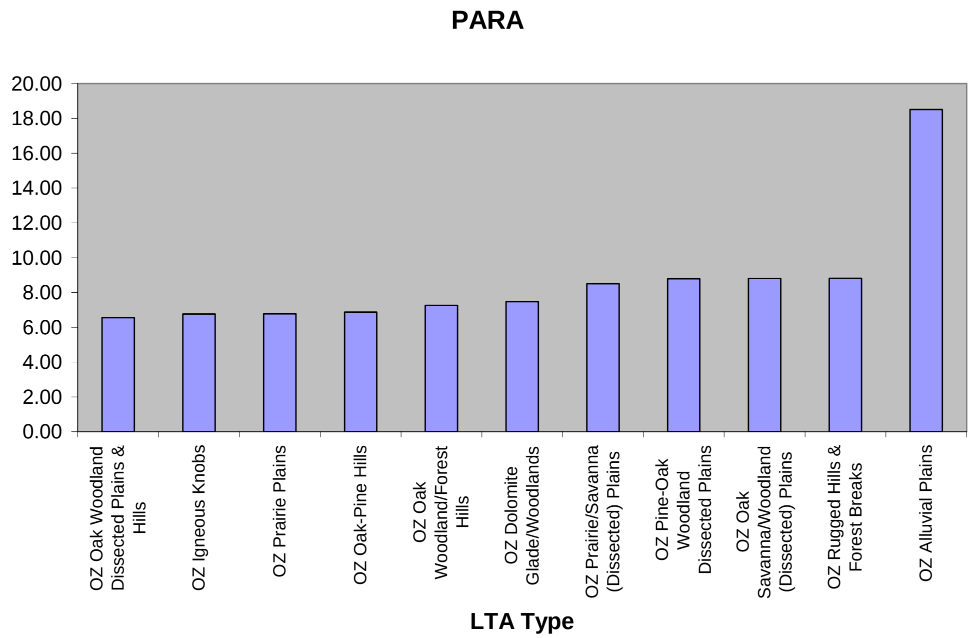


Figure 37. Perimeter-to-area ratio for Ozark Highland LTA Types (arranged from lower to higher).

For the most part, the fragmentation seems to depend entirely on how irregularly-shaped the LTA Type boundary is rather than the diversity of social patterns within the LTA Type boundary. Recall that a given LTA Type may be comprised of a number of spatially discrete (i.e., non-contiguous) areas, each with its own boundary. In the Ozark Highlands, each LTA Type boundary has curved features, with the exception of the extreme case of the alluvial plains. In light of this, it is noteworthy that three of the four most fragmented LTA Types (excluding the alluvial plains) are ‘dissected plains’ LTA Types. The term ‘dissected’ might suggest that fragmentation is going to be higher (exception: oak woodland dissected plains & hills LTA Type) because the shape of the

LTA Type boundary is ‘dissected’ (i.e., irregular), this therefore, increasing the PARA. In order to determine how clustered or fragmented the social pattern really is, further analysis must be conducted.

4.2.3.4 Central Dissected Till Plains (TP)

Prominent socio-economic variables. Figure 38 depicts the classification tree for LTA Types within the Till Plains of Missouri. There are 8 LTA Types within the Till Plains (TP) section. The tree yields nine end nodes with the housing variable ‘average age of units’ serving as the root node or most prominent social variable. This was also the most prominent variable in the TP subsection analysis. Block groups with an average age of house greater than 51 years were partitioned to the left side of the root node, while those with an average age of less than 51 years were sorted to the right. The latter block groups were subsequently sorted with respect to seven other social variables, the most prominent of which was median family income (MFI) at the second node. If the block groups had ‘younger’ houses and MFI was greater than $38,000, then they were partitioned to the left side of the MFI node. Conversely, block groups with younger houses and MFI less than $38,000 were partitioned to the right side of the MFI node. ‘Higher MFI’ block groups were in turn split according to mean travel time to work, while ‘lower MFI’ block groups were sorted with respect to an income source variable – percent retirement income.

Table 13 reveals that all LTA Types in the Till Plains section displayed an average age of houses of less than 51 years except the TP Loess Prairie Hills and Blufflands. Of the 8 LTA Types that had ‘younger’ houses, five were characterized by a MFI greater than $38,000. These ‘younger house, high MFI’ LTA Types were: TP alluvial plains, loess prairie hills and blufflands, low prairie plains, woodland/forest breaks, and woodland forest hills. Among these 5 types, three were differentiated according to whether people had a relatively high (greater than 20 minutes) mean travel time to work – TP alluvial plains, woodland/forest breaks, and woodland/forest hills. Two other LTA Types with relatively low mean travel times to work were the loess prairie hills and blufflands and low prairie plains.

On the right side of the second node, LTA Types characterized by 'younger houses on average and relatively lower MFI' were the low prairie plains, prairie plains, and prairie/woodland dissected plains. Two of these 'younger house, low MFI' LTA Types – low prairie plains and prairie plains – had very small percentages of people with retirement income while the third type – prairie/woodland dissected plains – had higher retirement income.

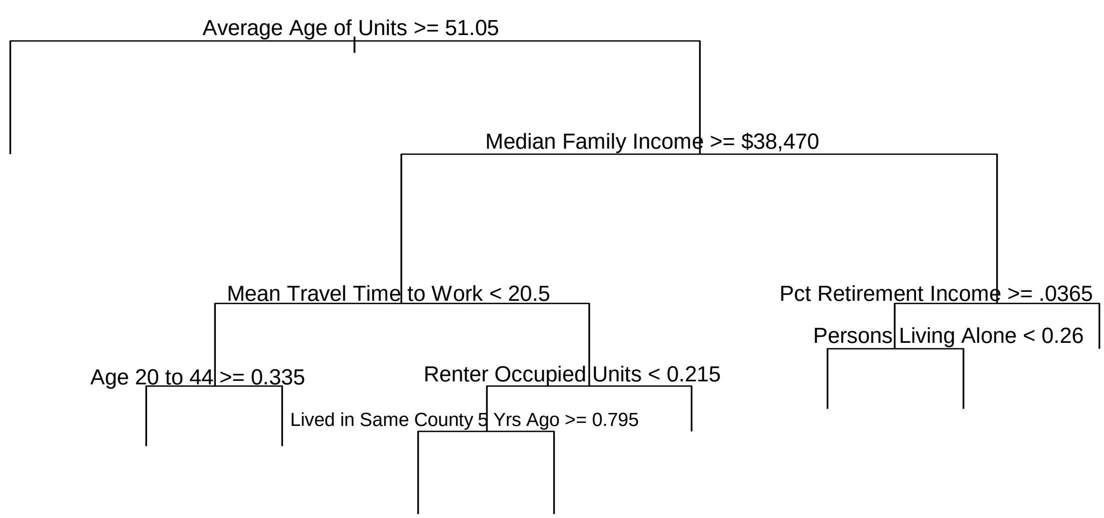


Figure 38. Till Plains (TP) LTA Types classification tree. Classification tree results are based on samples of block groups from each of the 8 TP LTA Types. Units for socio-economic variables on classification trees vary according to the substantive nature of the variables. Units may be: 1) Proportions of people in a block group in decimal form; 2) average or median monetary values; 3) average time in minutes; and 4) average or median age in years.

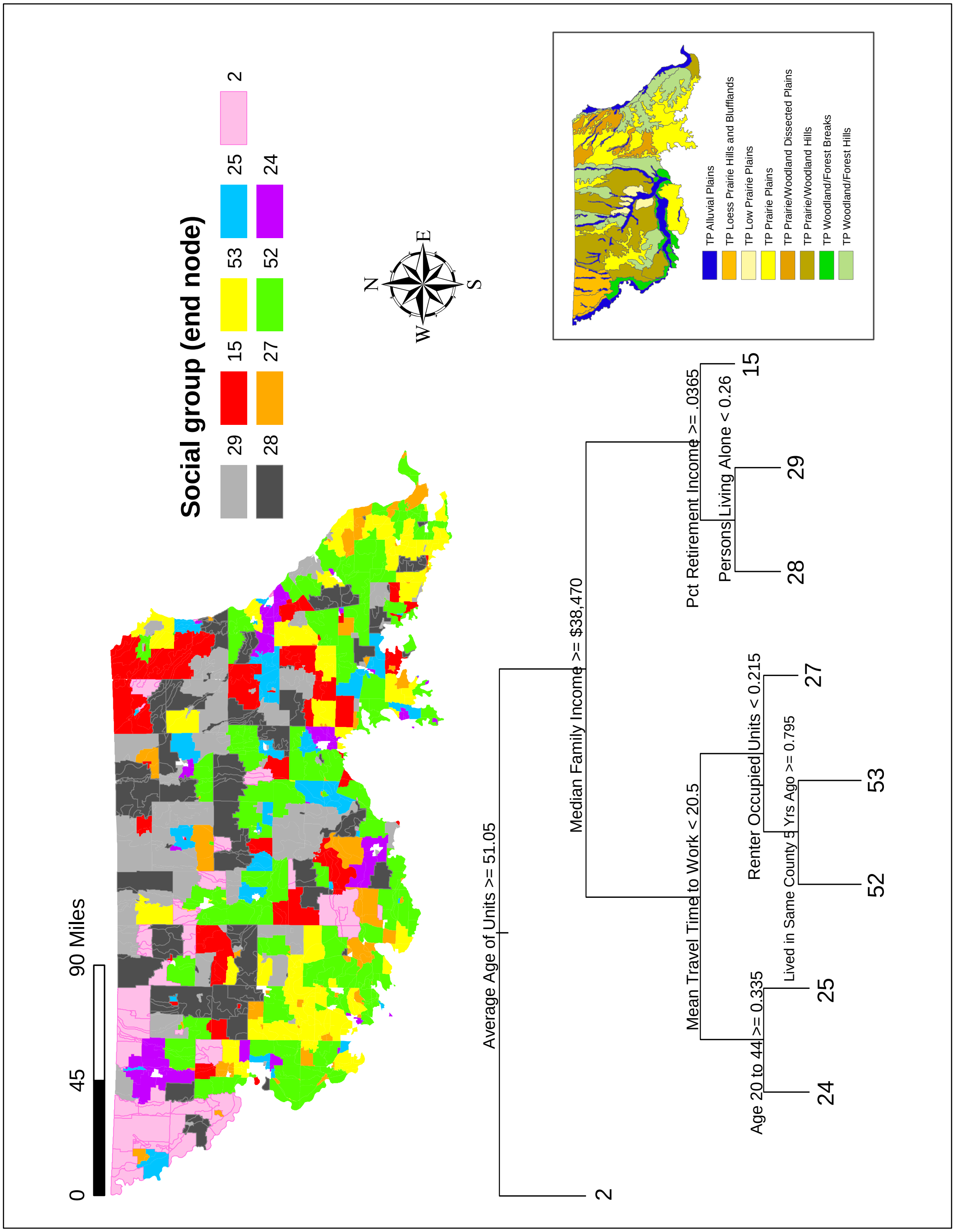
Table 13. CART table for Till Plains (TP) LTA Types

	Node Level				
LTA Type	1	2	3	4	5
TP Alluvial Plains	Avg age of units <51.05	Median family income >=$38,470	Avg commute time >=20.5	Renter occupied units <.215	Lived in same county 5 years ago >=.795
TP Loess Prairie Hills and Blufflands	Avg age of units >=51.05				
TP Loess Prairie Hills and Blufflands	Avg age of units <51.05	Median family income >=$38,470	Avg commute time <20.5	Age 20 to 44 >=.335	
TP Low Prairie Plains	Avg age of units <51.05	Median family income >=$38,470	Avg commute time <20.5	Age 20 to 44 <.335	
TP Low Prairie Plains	Avg age of units <51.05	Median family income <$38,470	% retirement income >=.0365	Persons living alone >=.26	
TP Prairie Plains	Avg age of units <51.05	Median family income <$38,470	% retirement income >=.0365	Persons living alone <.26	
TP Prairie/Woodland Dissected Plains	Avg age of units <51.05	Median family income <$38,470	% retirement income <.0365		
TP Prairie/Woodland Hills	n/a	n/a	n/a	n/a	n/a
TP Woodland/Forest Breaks	Avg age of units <51.05	Median family income >=$38,470	Avg commute time >=20.5	Renter occupied units >=.215	
TP Woodland/Forest Hills	Avg age of units <51.05	Median family income >=$38,470	Avg commute time >=20.5	Renter occupied units <.215	Lived in same county 5 years ago <.795

-Node level reflects the number of times a given block group has been sorted by a social variable on the classification tree. An end node was assigned an ecological unit designator (here, TP LTA Type) reflecting the ecological unit within which the majority of block groups at that end node are situated.
-The TP Prairie/Woodland Dissected Plains LTA Type was not included in the classification tree because it never represented the majority of block groups at an end node.
-Two end nodes had a majority of block groups in the same TP LTA Type (TP Loess Prairie Hills and Blufflands).

Figure 39 depicts the presence and spatial distribution of social groups for LTA Types in the Till Plains (TP). There are 8 LTA Types within the TP section. Several significant patterns emerge in the CART map for these LTA Types. First, the northwest corner of the Till Plains contains the vast majority of block groups identified at the root node of the classification tree as having an average house age of greater than 51 years. This parallels the social group identified as the root node for the TP subsections (Figure 26), where the average age of units was also the most prominent socio-economic variable. Secondly, at the second node of the classification tree, the six social groups that are differentiated according to higher median family incomes are geographically situated in the southern half of the Till Plains section. In addition, these social groups also are differentiated by the proportion of population that is between 20 to 44 years of age and a migration variable (lived in same county 5 yrs ago).

Social groups identified at the second node of the classification tree in terms of lower median family income (MFI) levels are further partitioned by amount of retirement income and persons living alone. The resultant three social groups (end nodes) on the right side of the tree are situated almost entirely in the northern half of the Till Plains section. The social group defined by end node 29 is also interesting because it represents higher retirement income block groups with higher proportions of people living alone.



A *social group* is a set of block groups (end node) distinguished according to one or more socio-economic attributes.

Figure 39. CART Map: Till Plains (TP) LTA Types.

Social diversity and fragmentation. Social homogeneity varied moderately among LTA Types in the Till Plains (Figure 16c and Figure 40). The loess prairie hills & blufflands LTA Type is the most socially homogeneous (SIDI = .655), whereas the alluvial plains LTA Type is the most socially heterogeneous (SIDI = .857).

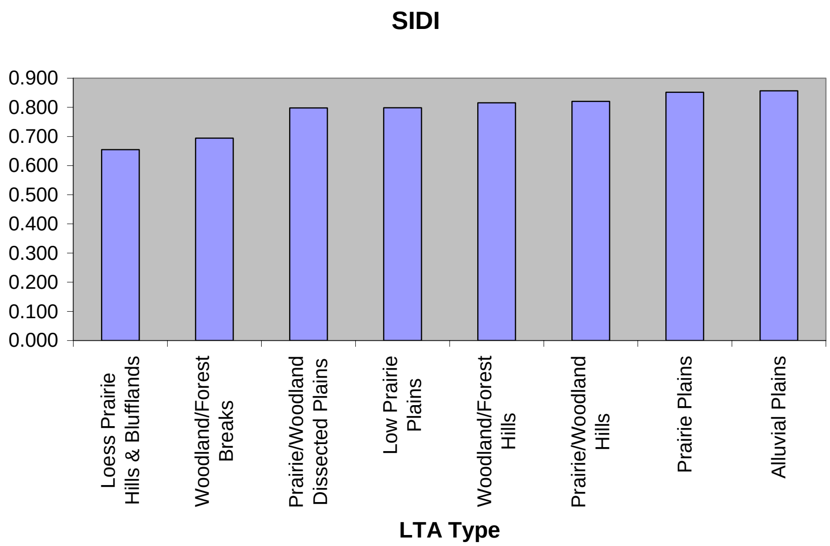


Figure 40. Simpson's diversity index for TP LTA Types (arranged from lower to higher)

Homogeneous LTA Types tend to be in the northern half of the Till Plains (loess prairie hills & blufflands) or in the prairie/woodland dissected plains in the east or woodland forest breaks in the west. These LTA Types exemplify pockets of prime farmland and timberland. However, there is higher heterogeneity in the prairie/woodland hills and woodland/forest hills LTA Types. Prairie plains and alluvial plains LTA Types have heterogeneous patterns, but this may result in part from their complex shapes.

Social fragmentation varied significantly across LTA Types in the Till Plains (Figure 17c and Figure 41). The loess prairie hills & blufflands displayed a clustered social pattern (PARA = 4.33), while the alluvial plains LTA Type had the most fragmented social pattern (PARA = 11.77). However, it is important to remember that the alluvial plains LTA Type boundaries are elongated and curved and may have influenced the PARA value for this LTA Type.

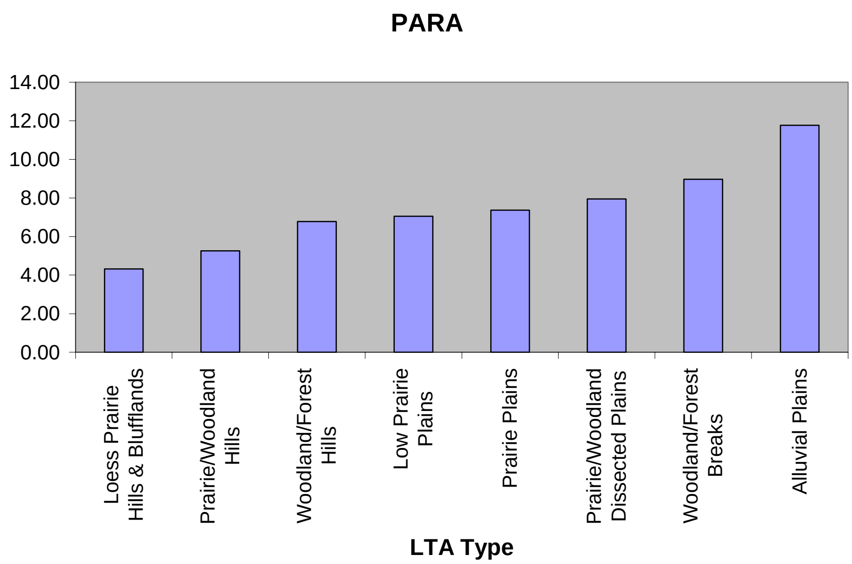


Figure 41. Perimeter-to-area ratio for TP LTA Types (arranged from lower to higher)

Patterns in fragmentation again seem to be heavily influenced by shape of LTA Types. The most curvilinear LTA Types (alluvial plains and woodland/forest breaks) have higher fragmentation levels while more rounded LTA Types (loess prairie hills & blufflands and the prairie woodland hills) displayed lower levels of fragmentation.

5 Discussion

5.1 Social profiles for ecological units

In describing social profiles for ecological units for this study, several important points need to be discussed. It was expected in an exploratory analysis such as this that certain socio-economic variables would vary in a statistically significant way across particular ecological units and others would not; and that some of these relationships and/or differences would be maintained across ECS levels while others would not. First, certain socio-economic variables reflect significant differences across ecological units. That is, people located in particular ecological units are concurrently differentiated in a non-random fashion by certain socio-economic variables. The set of housing variables exemplifies this phenomenon. Four of the five variables served to differentiate ecological sections, that is, displayed at least one significant difference among these ecological units. In Table 3, the focus variable *median house value* of $105,000 for Till Plains (TP) residents differed significantly from median house values in the other three sections, which ranged from $60,000 (MB) to $77,000 (OP).

At the same time, it was also found that certain social variables did not display any significant differences across ecological sections. For example, none of the five variables related to age (i.e., 0 to 9 through over 65) served to differentiate ecological sections in a statistically-significant way. Although this is not entirely unexpected, it was thought that certain age groups (e.g., people 'over 65') might perhaps vary significantly across some ecological units, particularly when the latter included retirement destinations and farming communities. It is also noteworthy that none of the income variables revealed significant differences across ecological sections. Perhaps the urban mask was strong enough to prevent the influence of higher income block groups (typically more prevalent in and around urban areas in contrast to lower-income rural areas) from producing significant results in the ANOVA tests.

As noted, the key purpose of the social profile is to make comparisons at a very broad ecological level. It could very well be that for many social variables, the section level is too broad to capture a number of perhaps important differences in social attributes of people living in those ecological units. In that regard, another key goal of this project has been to formulate a protocol that may be extended to more detailed levels of the ECS hierarchy – i.e., subsection, and/or landtype association (LTA) – as well as LTA Type (not a formal hierarchical level). It is probable that significant differences will emerge for some (or many) socio-economic variables at these more refined levels.

Several of the socio-economic variables that displayed statistically significant differences in ANOVA at the section level were also the prominent variables in the CART analysis. Less than 9th grade education (i.e., no high school) and median and average house value were examples of this pattern. Thus at the section level, the ANOVA results offer support for the CART procedures utilized in this analysis.

5.2 Prominent socio-economic attributes for ecological units

Attention now turns to the prominent socio-economic attributes of people in ecological units as identified in the CART analyses. Two important considerations relative to results here pertain to scale and urban presence. Scale is concerned with the ECS levels utilized in the CART analyses and the associated patterns of prominent variables that were identified at those levels. Urban presence refers to the effect of spatial proximity to urban areas on the identification of prominent socio-economic attributes.

No single socio-economic variable was found to be prominent at all ECS levels. The most prominent variable identified at the section level differs from variables at lower levels (Table 14).

Table 14. Prominent socio-economic variables revealed in CART analyses at section and subsection ECS levels and for LTA Type by section

	Prominent Variables		
ECS Level	Node Variable 1 (ROOT)	Node Variable 2	Node Variable 3
Section	No high school	Median house value	Pct public assistance income
Subsection			
Mississippi Basin	Average commute time	Specified owner occupied units	Farming, fishing, & forestry occupations
Osage Plains	Median household income		
Ozark Highlands	Median family income[a]	Graduate/professional degree	Minority
Till Plains	Average age of units[b]	Household income 50-100K	Poor persons
LTA Type			
Mississippi Basin	Minority	Poor persons	
Osage Plains	Average house value	Lived in same county 5 yrs ago	
Ozark Highlands	Median family income[a]	On farms	Pct wage or salary income
Till Plains	Average age of units[b]	Median family income	Average commute time

At the section level, less than 9th grade education (i.e., no high school) defined the root node of the classification tree. However, at other ECS levels, variables such as ‘mean travel time to work’ and ‘average age of housing units’ were the most prominent. With respect to the section level, it is noteworthy that a key variable relative to educational attainment served to differentiate Missourians ecologically at the broadest level; and that the Mississippi Basin was clearly the most representative section for lower relative educational achievement. Although not to be inferred from this study, lower educational attainment can be both a cause and an effect on many other social phenomena such as poverty, lack of sufficient and proficient health care, and a resulting lower quality of life (including, perhaps, ecological sustainability) for residents. Given that sections compose the coarsest scale of Missouri’s ECS hierarchy, this result suggests that a more detailed analysis linking education levels of people within Missouri to the specific ecological landscapes within which they live should be undertaken. A potential hypothesis of such an investigation may be that the extent of local participation in landscape conservation projects will vary with the educational level of people living within local landscapes.

Prominent socio-economic variables differ across ecological units at a given ECS level (e.g., OZ subsection vs. MB subsection). For example, the most prominent variable for OZ subsections is median family income, but for MB subsections it is mean travel time to work. This suggests that no socio-economic variable can effectively capture the social dimension for all ecological units within an ECS level.

However, some variables that are prominent at one ECS level are also prominent at another ECS level. The average age of housing units was most prominent in distinguishing between ecological units in the Till Plains subsections and LTA Types.

For OZ subsections and LTA Types, median family income was a prominent variable. Results suggest that ecological and spatial differences between subsections and LTA Types may not differ extensively insofar as they affect the ability to distinguish among social characteristics across ecological units. For OZ and TP, this may imply that analyses of subsections and LTA Types were redundant and analysis at one of these levels would be sufficient.

Because median family income is a prominent variable in distinguishing OZ subsections, it can reasonably be inferred that there are some OZ subsections and LTA Types with high family income and some with low income. Therefore, income inequality may prove to be an important focus of attention in investigating the social dimension of people living in the Ozark Highlands. Among other foci, it may be of interest to test whether there are real differences between those in poverty and those who are affluent in regards to their actions/behaviors within the ecological landscape.

Generally, when moving down the ECS hierarchy from section to LTA type, prominent socioeconomic attributes reveal more specific behaviors and socio-economic characteristics. For example, mean travel time to work and persons in a minority surface as additional prominent socio-economic attributes for MB subsections and LTA Types, respectively. At the subsection level, travel time to work may be interpreted as follows. Two sets of MB residents might be involved here: those persons who travel to work in the metropolitan area of Cape Girardeau and those who drive long distances to factories near the Mississippi River along the Missouri-Illinois border. Given the prevalence of jobs in Cape Girardeau and factory jobs in the eastern portions of the Mississippi Basin, driving times to work increase for those in MB farthest from these areas. In effect, the location of work serves to drive the sorting process which provides the basis for describing people distributed spatially across the ecological landscape. In addition, certain potential effects of this distribution could be hypothesized and investigated as well. For example, increased travel times exert pressure upon the ecological landscape in several ways including air pollution, noise pollution, and fragmentation of landscapes through increased road building to accommodate those who live far from the workplace. The above serves as one example of how moving down the ECS hierarchical levels (in this case, from section to subsection) can reveal more specific or localized socio-economic behaviors and characteristics for people situated in particular ecological landscapes.

Specific prominent variables were discovered that differentiate ecological units at a given ECS level when those units contain significant portions of metropolitan areas. The most prominent socio-economic variables for OP subsections and LTA Types were median household income and average house value, respectively. For both OZ subsections and LTA Types, median family income was most prominent. It should be noted that a northern portion of the Osage Plains section is encompassed by the metropolitan area of Kansas City and the northeast portion of the Ozark Highlands contains most of the St. Louis metropolitan area. Because median household income and average house value were prominent variables in OP, the implication is that OP contains both higher income-populations and higher-value housing and, conversely, lower-income populations and lower-value housing. Since urban areas contain diverse groups of people in terms of income levels and housing values, it can reasonably be assumed that prominent variables describing ecological units that encompass portions of metropolitan areas will be influenced by income and housing-related characteristics of people. This is significant because the urban mask applied to the social dataset was expected to remove most of the urban influences on the landscape – including income disparities across ecological units.

5.3 Socio-economic diversity and fragmentation in ecological units

The following discussion focuses on some important topics related to the composition and spatial distribution of social groups (end nodes) and the significance of these phenomena – i.e., social diversity and fragmentation – for ecological units.

First, certain landscape features (e.g., ruggedness) and the lack of significant human presence (i.e., remoteness) appear to be related to the homogeneity and diversity of ecological units. In some of the most remote ecological units (e.g., TP loess prairie hills and blufflands), social homogeneity is greatest. It is also very high for many rugged ecological units of the state other than those adjacent to urban areas (e.g., OZ9, OZ prairie plains and OZ igneous knobs). This suggests that the majority of people in these rugged and remote ecological units are similar with respect to certain socio-economic characteristics and hence, their actions and behaviors might be interpreted as being similar. Ecological units with socially homogeneous populations might imply a greater ease in implementation of conservation projects and collaborative planning, however; more research is needed to determine if this is true.

Even though there are homogeneous and clumped social groups in some ecological units, this may change in the near future. Missouri's current pattern of population growth includes people migrating to the open country and to ecological units (e.g., subsections) adjacent to socially homogenous and 'rugged' ones. Therefore, outsiders would be forced to become socially-integrated with long-time residents who may or may not accept these new in-migrants. As the population increases near or within these rugged subsections, it may benefit natural resource managers to continually monitor or profile these subsections in order to prepare for potential management and public relations challenges in the future. Surveys of landowners, such as the one conducted by the Initiative for Future Agriculture and Food Systems (IFAFS) project in partnership with the University of Missouri-Columbia, would aid in this effort.

At the same time, rugged ecological units outside of urban and suburban areas sometimes exhibit diverse and dispersed social patterns. For example, the Osage River hills (OZ6) is a very rugged ecological unit that contains no significant urban areas. However, its social diversity and fragmentation is quite high due to the presence of multiple social groups distributed widely across the landscape. This suggests another social phenomenon that is driving social diversification and fragmentation. In fact, another characteristic of OZ6 is the presence of the retirement and tourism industry, reflected in the development of retirement homes along the Lake of the Ozarks (and formation of different social groups). Because social diversity and fragmentation is high in OZ6 and because of the area's reputation as a retirement-destination setting unspoiled by a large urban presence, OZ6 acts as a counter-example to the observed pattern that rugged ecological units distanced from urban areas tend to contain homogeneous and clustered social patterns.

On the other hand, ecological units containing or encompassing urban areas and/or suburbs reflect higher social diversity and fragmentation values than do other non-urban ecological units. Subsections entirely encompassing urban areas (e.g., OZ1 and OZ12) generally have higher degrees of social diversity and fragmentation compared to rural and, in particular, rugged subsections. Diverse social patterns also emerged in ecological units characterized by a suburban presence (e.g., TP3, OZ rugged hills and forest breaks). This suggests that subsections which comprise either urban and/or suburban areas will reflect the presence of multiple social groups and dispersed spatial patterns of such groups, which amplify social diversity and fragmentation values.

The significance and resultant implications of patterns of social diversity and fragmentation in ecological units are extensive for this study. Socially homogeneous and clustered social patterns within ecological units are significant because they reflect social groups who are similar with respect to certain socio-economic attributes and are spatially contiguous as well. With additional research (e.g., surveys) it may be ascertained whether these people behave in the same way, especially in terms of interest in conservation education, participating in collaborative planning, and conducting management practices on the landscape. It is possible that larger groups with similar conservation attitudes, participation in the planning process, and uniformity in management practices may be expected in ecological units in which people are socially homogeneous and spatially clustered. At the same time, socially-diverse and fragmented ecological units are significant because they may indicate an increased complexity in obtaining returns from conservation education, collaborative planning, and natural resource management within them. Diverse and fragmented social patterns are indicative of different types of people in different places who may have different conservation goals and interests, varying degrees of social participation, and various philosophies for managing natural resources.

Ultimately, however, it is the variables that operate to define social groups (i.e., end nodes) that in reality dictate what implications can be drawn from the analyses. If the prominent variables selected by the CART analysis are not representative of characteristics of people within an ecological unit, then the diversity and fragmentation measures will also not represent the social dimension well. For example, social groups steeped in poverty more than likely exhibit many similar socio-economic characteristics such as income and education levels, house ownership or lack thereof, and other related attributes. Social groups defined exclusively by similar-aged houses (i.e., through the variable average age of units) may also reveal some things about the people but income, education level, and other characteristics cannot be as easily inferred from values of a housing attribute. While further analysis would have to be conducted, it seems safe to believe that those in poverty share many socio-economic characteristics and, therefore, also share some of the same attitudes and beliefs about conservation, collaborative planning, and natural resource management. Therefore, in interpreting the implications of diversity and fragmentation for Missouri's ecological units, attention must me paid to the prominent socio-economic variables that comprise a social group.

5.4 Miscellaneous concerns and future directions

This final section looks briefly at alternative data sources that may improve this study's relevance and interpretations of results. It then considers the advantages and limitations of the methods chosen for this study. A third focus concerns alternative methods that may be implemented in similar socio-ecological studies to improve the explanatory power of relationships that were uncovered between the socio-economic and ecological dimensions of Missouri landscapes.

Other data sources. While the ecological dataset for Missouri is solidified as a tool for describing and understanding the landscape in terms of a hierarchy of ecological units, the social dataset is less robust in describing and understanding the socio-economic dimension of the landscape. The U.S. Census of Population & Housing has been conducted every 10 years; thus socio-economic phenomena occurring in time intervals shorter than 10 years are not recorded in the Census. However, in 2010 the American Community Survey will be replacing the U.S. Census of Population & Housing and will be conducted every year for cities and areas with populations greater than 65,000 people. For towns with fewer than 65,000 people, the survey will be conducted every 3-5 years. The transition from the U.S. Census of Population and Housing to the American Community Survey will produce relatively few changes in the types of variables obtained from these surveys.

U.S. census data is utilized in many applications; however, other data sources and literature are also important. For more current economic information at the local level (i.e., counties and metropolitan/micropolitan areas), the Bureau of Economic Analysis

(BEA) within the U.S. Department of Commerce is an important resource. Information from the BEA at these levels includes personal income estimates and income estimates by occupation/industry and can be downloaded in table form for non-decennial years (i.e., years between successive rounds of the Census of Population and Housing). Another important dataset for linking to Missouri's ECS hierarchy of ecological units may be the Census of Agriculture delivered by the National Agricultural Statistics Service (NASS). This census produces farm-related information (e.g., # of farms and value of sales) every 5 years for congressional districts, counties, and zip codes and can effectively be linked to the ecological units in Missouri. Data distributed by various economic and agricultural agencies comprise new variables not included in the U.S. Census of Population and Housing or the American Community Survey.

Urban mask limitation. The urban mask applied in this study may not have been strong enough to mitigate the urban effects on the prominent socio-economic attributes and degrees of social diversity and fragmentation identified in study results. The purpose of performing an urban mask was to protect against bias in the random sampling procedure for selecting block groups for the CART analysis. A bias is introduced because over half of the block groups in the state are situated in urban areas. Because of this, a random sample of all block groups in Missouri would likely be divided evenly among block groups in urban areas and rural areas, the latter of which account for a large percentage of the state's ecological landscape. As a result, the prominent socio-economic attributes would reflect conditions within urban areas – locations in which the ecological dimension is less a factor in distinguishing between groups of people – to a far greater degree than is spatially warranted and prominent variables distinguishing among people in rural areas would be lacking. In attempting to reflect the social dimension in rural landscapes of Missouri while still accommodating some of the urban/suburban presence, block groups with 90% or greater urban population (i.e., urban block groups) were deleted from this analysis.

Certain prominent social variables selected in CART analyses would clearly seem to vary according to urban and rural differences (e.g., median household income and average house value). Urban/suburban regions generally contain people who are more affluent compared to those in rural areas of the state. Because this study's goal was to explore potential patterns between the social and ecological dimensions, and since urban areas are thought to distort these connections in ways touched upon above, the urban mask applied in this study may still need to be strengthened to further mask out suburban portions of ecological units that seem to be influencing the prominent socio-economic variable selection in the CART analyses. An urban mask of block groups with 10% or greater urban population (i.e., urban and 'mixed' block groups) may be a viable alternative to masking out the urban/suburban patterns (variables) hence leaving only the 'rural' block groups. This may eliminate the selection of prominent socio-economic attributes of people associated with urban/suburban areas (e.g., higher income and education levels). If this modification were adopted, it would be interesting to see which variables selected by CART analysis are prominent. However, special consideration would have to be given to those ecological units that, after a more pronounced urban mask, would be left with just a few block groups.

CART: Advantages and limitations. <u>The CART method adopted for this study has several advantages</u>. First, CART analyses were conducted at different levels of the ecological hierarchy – section, subsection, and LTA Type (technically not a formal level, but an aggregate of landtype associations [LTA], a finer level of ecological resolution). This allowed more detailed and localized information pertinent to specific landscapes to be obtained. A second advantage lies in forcing the classification trees to a size equal to that of the number of ecological units (e.g., sections, subsections). This allows a manageable number of classes and end nodes to be preserved in the classification trees. In addition, it also allows each ecological unit to be represented in the CART analysis.

However, the CART method selected for this study also has a few limitations, especially with respect to analysis of social diversity and fragmentation of ecological units. The first limitation involves the fact that for a given CART analysis at a given level of the ECS (e.g., Ozark Highlands subsections), a specific set of prominent variables for the classification tree will be yielded. The same will be true for all other CART analyses for ecological units at other ECS levels (e.g., Till Plains LTA Types). However, each classification tree will have its own structure reflecting its own distinctive set of prominent social variables. Thus, for example, a housing variable formed the root node for the Till Plains LTA Types classification tree, whereas an income variable formed the root node for the OZ subsections tree, which itself was comprised of many more variables than the TP tree. All of this complicates comparisons among ecological units at different levels of the ECS (each with its own tree and set of prominent variables) in relation to a social characteristic like diversity or fragmentation. For the OZ subsections will be socially diverse or fragmented with respect to the set of prominent variables that define the tree; and the same applies to the TP LTA Types with its own unique tree structure and set of prominent variables.

Secondly, in forcing the size of classification trees to equal that of the number of ecological units, a consistent number of classes (i.e., same tree size) were not maintained. With respect to the ecological unit of subsection, for example, since there are two OP subsections and 20 OZ subsections, the former had a classification tree with 2 end nodes while OZ subsections had a tree with 20 end nodes. This poses challenges in interpreting the social dimension and its associated spatial pattern of diversity and fragmentation for ecological units. Because FRAGSTATS analyses are class-dependent (i.e., SIDI and PARA values are dependent on the number of classes), cross-comparing social diversity and fragmentation of ecological units was not possible.

PARA limitations and alternative. When investigating social fragmentation of LTA Types, special consideration must be given to those LTA Types that are non-contiguous and dissected in shape. Perimeter-to-area ratio (PARA) is a good measure for analyzing social fragmentation of ecological units; however, ecological units must be relatively simple and uniform in shape in order for this measure to yield more accurate interpretations. With respect to PARA, the degree of fragmentation seems to depend on how curvilinear the ecological LTA Type boundary is rather than on the arrangement of social patterns within the LTA Type boundary. Each LTA Type boundary in OZ has curved features – especially the Alluvial Plains, which is distinguished by extremely coiled and elongated features (see Figure 35). It is also noteworthy that three of the four most fragmented LTA Types within OZ (excluding the alluvial plains) are ‘dissected plains’ LTA Types. The term ‘dissected’ suggests that ecological fragmentation is going to be higher in those LTA Types. This, in turn may influence the spatial distribution of social attributes, that is, social fragmentation. Therefore, in order to determine the spatial clustering or dispersion that actually defines the degree of social fragmentation, further analysis must be conducted due to the inconsistencies in ecological unit boundary shapes.

Because of these complications, another landscape measure – the shape index – may have more interpretive power. The shape index standardizes shapes into square-like dimensions in a way that would allow for cross-comparisons of social fragmentation in ecological units without the limitations inherent in the perimeter-to-area ratio (PARA). Future socio-ecological studies should investigate the utility of the shape index for describing the social fragmentation in ecological landscapes.

Alternative strategies for discovering prominent socio-economic variables.

Alternative strategies for discovering prominent socio-economic variables utilized in describing and distinguishing between ecological units of Missouri include: 1) changes in variables utilized in CART analysis; and the 2) application of discriminant analysis or other quantitative techniques.

Re-arranging the variables employed in CART analysis (e.g., selecting age variables only) or incorporating variables from alternate datasets (e.g., Census of Agriculture) may produce different prominent socio-economic variables. In utilizing particular CART variables, one might include only age attributes of people in one CART analysis and education attributes in another in order to acquire one prominent variable for each major socio-economic category. Another alternative would be to incorporate variables from economic or agricultural datasets mentioned below into the existing dataset utilized in this study. If variables from these latter datasets proved to be prominent variables, it would be important to include these datasets in future studies investigating the link between socio-economic and ecological dimensions of Missouri landscapes.

Discriminant analysis may provide additional insights into variables or groups of variables that serve to distinguish ecological units by social attributes. While the structure of the data is not visualized in discriminant analysis as it is in CART analysis, prominent variables are still selected and these could also form the basis for comparisons between CART and discriminant analysis techniques and results.

Synthesis of quantitative (statistical) and qualitative (survey) techniques. Combining qualitative techniques (e.g., surveys and interviews) with quantitative techniques (e.g., CART) would aid in uncovering causal relationships between the social and ecological dimensions of Missouri landscapes (Radeloff et al 2000). From this research, many hypotheses can be formed from correlations discovered between prominent socio-economic variables and the ecological units people live within. However, particular correlations and the variables themselves cannot be ascertained as being significant without further analyses (e.g., surveys and/or other qualitative approaches).

Jackson, Lee, & Sommer (2004) present an alternative method to this study's approach in which census data and surveys are employed together. The authors state that the qualitative method of 'surveying' carries more weight in uncovering causal relationships between the ecological and social dimensions of landscapes. In this article, an examination of policy effects on socio-economic systems within Washington State was performed utilizing surveys (i.e., longitudinal analyses or repeated surveys over an extended period of time). Their main conclusion was that aggregate data (such as that aggregated to the level of census block group) did not effectively or realistically capture local variation in terms of the effects of federal land management policies on socio-economic conditions. While one of the major drawbacks of longitudinal analysis is the amount of resources – both time and money -- that are required, its strength lies in producing conclusive evidence of the effects that landscape-related policy has on people in the landscape (Jackson, Lee, and Sommers 2004).

Longitudinal analysis (i.e., surveying over time) may be a future direction of this research because of its ability to test hypotheses generated from correlations found in exploratory analyses. This type of analysis may help establish the causal linkages between the prominent socio-economic attributes of people and the ecological units in which they reside (Radeloff et al 2000).

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7 Appendices

Appendix 1. Missouri's 4 sections, 31 subsections, and 25 LTA Types

ECS Level	Ecological Unit Code	Ecological Unit
Section	TP	Central Dissected Till Plains
	OP	Osage Plains
	MB	Mississippi River Alluvial Basin
	OZ	Ozark Highlands
Subsection	MB1	Black River Alluvial Plain
	MB2	Crowley's Ridge
	MB3	St. Francis River Alluvial Plain
	MB4	Mississippi River Alluvial Plain
	OP1	Scarped Osage Plains
	OP2	Cherokee Plains
	OZ1	Springfield Plain
	OZ2	Springfield Plateau
	OZ3	Elk River Hills
	OZ4	White River Hills
	OZ5	Central Plateau
	OZ6	Osage River Hills
	OZ7	Gasconade River Hills
	OZ8	Meramec River Hills
	OZ9	Current River Hills
	OZ10	St. Francois Knobs and Basins
	OZ11	Prairie Ozark Border
	OZ12	Outer Ozark Border
	OZ13	Inner Ozark Border
	OZ14	Black River Ozark Border
	OZ15	Missouri River Alluvial Plain
	OZ16	Mississippi River Alluvial Plain
	TP1	Missouri River Alluvial Plain
	TP2	Deep Loess Hills
	TP3	Loess Hills
	TP4	Grand River Hills
	TP5	Chariton River Hills
	TP6	Claypan Till Plains
	TP7	Wyaconda River Dissected Till Plains
	TP8	Mississippi River Hills
	TP9	Mississippi River Alluvial Plain

Appendix 1. Cont.

ECS Level	Ecological Unit
LTA Type	MB Alluvial Plains
	MB Crowley's Ridge Hills
	MB Sand Ridges & Hills
	OP Alluvial Plains
	OP Prairie Plains
	OP Prairie/Savanna Scarped & Dissected Plains
	OZ Alluvial Plains
	OZ Dolomite Glade/Woodlands
	OZ Igneous Knobs
	OZ Oak Savanna/Woodland (Dissected) Plains
	OZ Oak Woodland Dissected Plains & Hills
	OZ Oak Woodland/Forest Hills
	OZ Oak-Pine Hills
	OZ Pine-Oak Woodland Dissected Plain
	OZ Prairie Plains
	OZ Prairie/Savanna (Dissected) Plains
	OZ Rugged Hills & Forest Breaks
	TP Alluvial Plains
	TP Loess Prairie Hills and Blufflands
	TP Low Prairie Plains
	TP Prairie Plains
	TP Prairie/Woodland Dissected Plains
	TP Prairie/Woodland Hills
	TP Woodland/Forest Breaks
	TP Woodland/Forest Hills

Appendix 2. Missouri's 264 LTAs

	LTA Code	LTAs
Mississippi Basin (MB)	MB1a	Black River Silty Lowland
	MB1b	Ash Hill Low Sand Hills and Terraces
	MB1c	Otter Slough Silty Terrace
	MB1d	Mingo Silty Lowland
	MB1e	Castor River Silty Lowland
	MB1f	Advance Sand Plain
	MB2a	Crowley's Ridge Loess Woodland/Forest Hills
	MB2b	Crowley's Ridge Footslopes and Alluvial Plains
	MB3a	St. Francis River Floodplain
	MB3b	Campbell Dissected Silty Terrace
	MB3c	Kennett-Malden Prairie/Savanna Dissected Sand Ridge
	MB3d	Honey-Cypress Loamy Terrace
	MB4a	Parma Dissected Terrace
	MB4b	Ash Slough Dissected Terrace
	MB4c	Portageville Loamy Natural Levee
	MB4d	Little River Clayey Lowland
	MB4e	Sikeston Prairie/Savanna Sand Ridge
	MB4f	Blodgett Dissected Sand Plain
	MB4g	East Prairie Prairie/Savanna Dissected Sand Plain
	MB4h	Circle Ditch Bayou Clayey Lowland
	MB4i	St. Johns Bayou Clayey Lowland
	MB4j	St. James Bayou Clayey Lowland
	MB4k	Portageville Bayou Clayey Lowland
	MB4l	Mississippi River Holocene Alluvial Plain
Osage Plains (OP)	OP1a	Scarped Osage Plains Alluvial Plains
	OP1b	Jackson County Prairie/Woodland Scarped Plain
	OP1c	Belton High Prairie Plain
	OP1d	Outer Osage Prairie/Savanna Scarped Plain
	OP1e	Osage Prairie Plains
	OP1f	Inner Osage Prairie/Savanna Scarped Plain
	OP1g	Upper Blackwater Prairie/Woodland Dissected Plain
	OP1h	Windsor Prairie/Savanna Dissected Plain
	OP1i	Northern Pettis County Prairie Plain
	OP1j	Southern Pettis County Prairie Plain
	OP2a	South Grand Alluvial Plains
	OP2b	Four Rivers Alluvial Plains
	OP2c	South Grand Smooth Low Prairie Plains
	OP2d	Four Rivers Low Prairie Plains
	OP2e	Dry Wood Creek Prairie Plain
	OP2f	Little Dry Wood Creek Prairie/Savanna Dissected Plain
	OP2g	Milo Smooth Prairie Plain
	OP2h	Clear Creek Prairie/Savanna Dissected Plain
	OP2i	Lamar Smooth Prairie Plain
	OP2j	Blue Mound Prairie/Savanna Scarped Plain

*The number of LTAs by section is as follows: MB (24); OP (20); OZ (163); and TP (57).

Appendix 2. Cont.

	LTA Code	LTAs
Ozark Highlands (OZ)	OZ1a	Lockwood Smooth Prairie Plain
	OZ1b	Stockton Prairie/Savanna Dissected Plain
	OZ1c	Weaubleau Prairie/Savanna Dissected Plain
	OZ1d	Lost Creek Oak Savanna/Woodland Low Hills
	OZ1e	Shoal Creek Oak Savanna/Woodland Low Hills
	OZ1f	Spring River Prairie/Savanna Dissected Plain
	OZ1g	Springfield Karst Prairie Plain
	OZ1h	Upper Sac River Oak Savanna/Woodland Low Hills
	OZ1i	Little Sac River Oak Savanna/Woodland Low Hills
	OZ1j	James River Oak Savanna/Woodland Low Hills
	OZ1k	Finley River Oak Savanna/Woodland Low Hills
	OZ1l	Sparta Oak Savanna Plain
	OZ1m	Seymour Highland Oak Savanna/Woodland Dissected Karst Plain
	OZ2a	Southwest City Prairie Plain
	OZ2b	Southwest City Oak Savanna/Woodland Low Hills
	OZ3a	Big Sugar Creek Oak Woodland/Forest Hills
	OZ3b	Elk River Oak Woodland Dissected Plain
	OZ4a	White River Dolomite Glade/Oak Woodland Rugged Hills and Knobs
	OZ4b	Shell Knob Dolomite Glade/Oak Woodland Basin
	OZ4c	Bull Creek Dolomite Glade/Oak Woodland Breaks
	OZ4d	White River Dolomite Glade/Oak Woodland Breaks
	OZ4e	Forsyth Oak Woodland Dissected Plain
	OZ4f	Little North Fork Dolomite Glade/Oak Woodland Hills
	OZ4g	Upper Swan Creek Dolomite Glade/Oak Forest Breaks
	OZ4h	Gainesville Dolomite Glade/Oak Woodland Knobs
	OZ4i	Hercules Dolomite Glade/Oak Woodland Knobs
	OZ4j	Ava Oak Woodland Dissected Plain
	OZ4k	Gainesville Oak Woodland Hills
	OZ4l	Romance Oak Woodland Dissected Plain
	OZ4m	Bryant Creek Oak-Pine Woodland/Forest Hills
	OZ4n	Van Zant Oak Woodland Dissected Plain
	OZ4o	North Fork River Oak-Pine Woodland/Forest Hills
	OZ4p	North Fork Pine-Oak Woodland Dissected Plain
	OZ4q	Jenkins Oak Savanna/Woodland Basin
	OZ5a	Bolivar Prairie/Savanna Plain
	OZ5aa	Gasconade-Bourbeuse Oak Savanna/Woodland Plain
	OZ5b	Upper Pomme de Terre Oak Savanna/Woodland Dissected Plain
	OZ5bb	Bourbeuse-Meramec Oak Savanna/Woodland Plain
	OZ5c	Buffalo Prairie/Savanna Plain
	OZ5cc	Bourbeuse River Oak Woodland Dissected Plain
	OZ5d	Upper Niangua Oak Savanna/Woodland Dissected Plain

Appendix 2. Cont.

	LTA Code	LTAs
Ozark Highlands (OZ)	OZ5dd	Bourbeuse River Oak Woodland Hills
	OZ5e	Upper Gasconade Oak Woodland Dissected Plain
	OZ5f	Lebanon Prairie/Savanna Karst Plain
	OZ5g	Auglaize Prairie/Savanna Dissected Plain
	OZ5h	Tavern Creek Oak Savanna/Woodland Dissected Plain
	OZ5i	Dixon Prairie/Savanna Dissected Plain
	OZ5j	Linn Oak Woodland Dissected Plain
	OZ5k	Upper Gasconade Oak Savanna/Woodland Plain
	OZ5l	Cabool-Mountain Grove Oak Savanna/Woodland Plain
	OZ5m	Summersville Oak Savanna/Woodland Plain
	OZ5n	Mountain View Oak Savanna/Woodland Plain
	OZ5o	West Plains Oak Savanna/Woodland Plain
	OZ5p	Howell-Oregon Counties Oak Woodland Dissected Plain
	OZ5q	Alton Oak Savanna/Woodland Plain
	OZ5r	Ripley County Oak Woodland Dissected Plain
	OZ5s	Flatwoods Oak Savanna/Woodland Plain
	OZ5t	Licking Oak Savanna/Woodland Plain
	OZ5u	Big Piney Oak Woodland Dissected Plain
	OZ5v	Little Piney Oak Woodland Dissected Plain
	OZ5w	Salem Oak Savanna/Woodland Plain
	OZ5x	Upper Meramec Oak Woodland Dissected Plain
	OZ5y	Dry Fork Oak Woodland Dissected Plain
	OZ5z	Rolla Oak Savanna/Woodland Plain
	OZ6a	Lower Sac River Oak Woodland Hills
	OZ6b	Truman Lake Oak Woodland Hills
	OZ6c	Pomme de Terre Dolomite Glade/Woodland Hills
	OZ6d	Middle Osage River Oak Woodland Hills
	OZ6e	Niangua River Oak Woodland/Forest Breaks
	OZ6f	Lake Ozark Oak Woodland/Forest Breaks
	OZ6g	Lower Osage River Oak Woodland/Forest Hills
	OZ7a	Upper Gasconade Oak Woodland Hills
	OZ7b	Upper Gasconade Hills Oak Woodland Dissected Plain
	OZ7c	Roubidoux Creek Oak Woodland/Forest Hills
	OZ7d	Big Piney Hills Oak Woodland Dissected Plain
	OZ7e	Big Piney River Oak-Pine Woodland/Forest Hills
	OZ7f	Fort Wood Wood Oak Savanna/Woodland Plain
	OZ7g	Middle Gasconade River Oak Woodland/Forest Breaks
	OZ7h	Middle Gasconade River Oak Woodland Benchland
	OZ7i	Little Piney River Oak-Pine Woodland/Forest Hills
	OZ7j	Big Piney Pine-Oak Woodland Dissected Plain
	OZ7k	Lower Gasconade River Oak Woodland/Forest Hills

Appendix 2. Cont.

	LTA Code	LTAs
Ozark Highlands (OZ)	OZ8a	West Meramec River Oak Woodland/Forest Hills
	OZ8b	Cherryville Oak Savanna/Woodland Plain
	OZ8c	Huzzah-Courtois Oak Woodland Dissected Plain
	OZ8d	Meramec River Oak Forest Breaks
	OZ8e	Huzzah Oak Woodland/Forest Hills
	OZ8f	Courtois Oak-Pine Woodland/Forest Hills
	OZ8g	East Meramec Oak Woodland/Forest Hills
	OZ8h	Indian Prairie Oak Savanna/Woodland Plain
	OZ8i	Big River Oak Woodland/Forest Hills
	OZ8j	Clear Creek Pine-Oak Woodland Dissected Plain
	OZ8k	Potosi Oak Savanna/Woodland Plain
	OZ9a	Current River Pine-Oak Woodland Dissected Plain
	OZ9b	Current River Oak-Pine Woodland/Forest Hills
	OZ9c	Eleven Point River Oak-Pine Woodland/Forest Hills
	OZ9d	Black River Oak-Pine Woodland/Forest Hills
	OZ9e	Current River Oak Forest Breaks
	OZ9f	Jacks Fork River Oak-Pine Forest Breaks
	OZ9g	Eleven Point Oak-Pine Forest Breaks
	OZ9h	Black River Oak Forest Breaks
	OZ9i	Eminence Igneous Glade/Oak Forest Knobs
	OZ10a	St. Francois Igneous Glade/Oak Forest Knobs
	OZ10b	St. Francois Dolomite Glade/Oak Woodland Basins
	OZ10c	Roselle Oak Woodland Upland Igneous Plain
	OZ10d	St. Francois Oak-Pine Woodland/Forest Hills
	OZ11a	Tipton Upland Prairie Plain
	OZ11b	Upper Lamine Savanna/Woodland Dissected Plain
	OZ12a	Lower Lamine River Woodland/Forest Hills
	OZ12aa	Perry Oak Savanna/Woodland Dissected Plain
	OZ12b	Arrow Rock Prairie/Woodland Dissected Karst Plain
	OZ12bb	Benton Loess Woodland/Forest Hills
	OZ12c	Petite Saline Oak Savanna/Woodland Dissected Plain
	OZ12cc	Benton Hills Alluvial Plains and Footslopes
	OZ12d	Jamestown Oak Woodland/Forest Karst Hills
	OZ12e	Boonslick Oak Woodland/Forest Hills
	OZ12f	Harrisburg Oak Woodland/Forest Hills
	OZ12g	Rock Bridge Woodland/Forest Low Karst Hills
	OZ12h	Central Missouri Oak Woodland/Forest Hills
	OZ12i	Montgomery-Warren Oak Woodland/Forest Rugged Hills
	OZ12j	Mokane Mixed-Hardwood Woodland/Forest Low Strath Hills
	OZ12k	Holstein Mixed-Hardwood Woodland/Forest Low Strath Hills

Appendix 2. Cont.

	LTA Code	LTAs
Ozark Highlands (OZ)	OZ12l	Loutre River Alluvial Plain
	OZ12m	Central Missouri Oak Savanna/Woodland Dissected Plain
	OZ12n	Wildwood Loess Woodland/Forest Breaks
	OZ12o	Chesterfield Oak Savanna/Woodland Dissected Plain
	OZ12p	St. Louis County Prairie/Savanna Dissected Karst Plain
	OZ12q	Florissant Karst Prairie Plain
	OZ12r	St. Louis Karst Prairie Plain
	OZ12s	Lower Meramec Hills Alluvial Plain
	OZ12t	Lower Meramec Oak and Mixed-Hardwood Woodland/Forest Hills
	OZ12u	Lower Meramec Highlands Alluvial Plain
	OZ12v	Meramec Highlands Oak Woodland/Forest Rugged Hills
	OZ12w	St. Mary Oak and Mixed-Hardwood Forest Hills
	OZ12x	Brickey Limestone Glade/Mixed Hardwood Forest Rugged Hills
	OZ12y	Zell Platform Woodland/Forest Low Hills
	OZ12z	Cape Oak and Mixed-Hardwood Forest Hills
	OZ13a	Moniteau Creek Woodland/Forest Hills
	OZ13b	Upper Moreau River Oak Woodland Dissected Plain
	OZ13c	South Fork Moreau River Woodland/Forest Hills
	OZ13d	Osage-Gasconade River Oak Woodland/Forest Hills
	OZ13e	Osage County Loess Woodland/Forest Hills
	OZ13f	Hermann Oak Woodland/Forest Rugged Hills
	OZ13g	Lower Osage River Alluvial Plain
	OZ13h	Lower Gasconade River Alluvial Plain
	OZ13i	Franklin County Oak Woodland/Forest Low Hills
	OZ13j	Pacific Alluvial Plain
	OZ13k	Big River Dolomite Glade/Oak Woodland Low Hills
	OZ13l	Big River Alluvial Plain
	OZ13m	Rocky Ridge Oak and Oak-Pine Woodland/Forest Hills
	OZ13n	Kinsey Oak Woodland/Forest Hills
	OZ13o	Lamotte Sandstone Oak Woodland/Forest Basin
	OZ13p	East Bollinger Oak Woodland/Forest Hills
	OZ14a	Grandin Pine-Oak Woodland Dissected Plain
	OZ14b	Southeastern Oak Savanna/Woodland Plain
	OZ14c	Wappappello Oak-Pine Woodland/Forest Hills
	OZ14d	West Bollinger Oak-Pine Woodland/Forest Hills
	OZ15a	Lower Missouri River Alluvial Plain
	OZ15b	Marais Temps Clair Alluvial Plain
	OZ15c	West Alton Alluvial Plain
	OZ16a	Ozarks-Mississippi River Alluvial Plain
	OZ16b	Big Field Alluvial Plain
	OZ16c	Bois Brule Alluvial Plain

Appendix 2. Cont.

	LTA Code	LTAs
Till Plains (TP)	TP1a	Northwest Missouri River Alluvial Plain
	TP1b	Western Missouri River Alluvial Plain
	TP1c	Wakenda Missouri River Alluvial Plain
	TP1d	Missouri-Grand River Alluvial Plain
	TP2a	Northwest Missouri Deep Loess Alluvial Plains
	TP2b	Northwest Missouri Deep Loess Prairie Blufflands
	TP2c	Northwest Missouri Deep Loess Prairie Hills
	TP3a	Loess Hills Alluvial Plains
	TP3b	Missouri River Loess Woodland/Forest Breaks
	TP3c	Nodaway Loess Prairie Hills
	TP3d	Platte River Loess Prairie/Woodland Hills
	TP3e	Platte River Loess Prairie/Woodland Scarped Plain
	TP3f	Marshall Prairie Plain
	TP4a	Grand River Alluvial Plains
	TP4b	Upper Grand River Prairie/Woodland Hills
	TP4c	Cameron Upland Prairie Plain
	TP4d	Little Platte River Woodland/Forest Scarped Hills
	TP4e	Crooked River Woodland/Forest Scarped Hills
	TP4f	Shoal Creek Prairie/Woodland Scarped Plain
	TP4g	Gilman City Upland Prairie Plain
	TP4h	Trenton Woodland/Forest Scarped Hills
	TP4i	Weldon River Woodland/Forest Hills
	TP4j	Medicine Creek Prairie/Woodland Hills
	TP4k	Lower Grand River Lowland Prairie Plains
	TP5a	Chariton River Alluvial Plains
	TP5b	Locust Creek Woodland/Forest Hills
	TP5c	Unionville Upland Prairie Plain
	TP5d	Upper Chariton River Woodland/Forest Hills
	TP5e	Chariton River Prairie/Woodland Hills
	TP5f	Lower Chariton Woodland/Forest Hills
	TP6a	North Fork Salt River Alluvial Plain
	TP6b	Grand Prairie Prairie Plain
	TP6c	Audrain Flat Prairie Plain
	TP6d	Cuivre River Prairie Plain
	TP6e	North Fork Salt River Prairie Plain
	TP6f	Upper Salt River Prairie/Woodland Dissected Plain
	TP6g	Monroe City Flat Prairie Plain
	TP6h	North Fork Salt River Prairie/Woodland Dissected Plain
	TP7a	Northeast Missouri Alluvial Plains
	TP7b	Lancaster Prairie/Woodland Dissected Plain
	TP7c	Middle Fabius River Prairie Plains
	TP7d	Wyaconda River Prairie Plains
	TP7e	Fox River Prairie Plain
	TP7f	Wyaconda River Prairie/Woodland Dissected Plains
	TP7g	Fabius River Prairie/Woodland Dissected Plains
	TP7h	Mississippi River Woodland/Forest Hills
	TP7i	Fox River Prairie/Woodland Dissected Plains
	TP8a	Philadelphia Prairie Plain
	TP8b	North River Woodland/Forest Hills
	TP8c	Salt River Woodland/Forest Hills
	TP8d	Lincoln Hills Woodland/Forest Hills
	TP8e	Cuivre River Woodland/Forest Hills
	TP8f	St. Charles County Prairie/Woodland Low Hills
	TP9a	Alexandria Alluvial Plain
	TP9b	West Quincy Alluvial Plain
	TP9c	Ted Shanks Alluvial Plain
	TP9d	St. Charles/Lincoln Alluvial Plain

Appendix 3. Complete set of social profiles for ecological units at ECS levels of subsection and LTA Type

Appendix 3a. Social profile for ecological subsections in Missouri

	Mississippi Basin subsections				Osage Plains subsections		Till Plains subsections								
Social Variable	**MB1**	**MB2**	**MB3**	**MB4**	**OP1**	**OP2**	**TP1**	**TP2**	**TP3**	**TP4**	**TP5**	**TP6**	**TP7**	**TP8**	**TP9**
Population															
Total persons	20508	15244	15698	48813	147681	48581	21643	7913	123268	108553	40373	104898	25908	80155	11444
Density (persons per square mile)	27	42	44	21	43	20	20	13	35	17	15	27	14	39	30
Urban[a]	0.02	0.03	0.07	0.02	0.06	0.02	0.06	0.00	0.08	0.01	0.01	0.03	0.00	0.07	0.10
Age[a]															
0 to 9	0.12	0.11	0.12	0.13	0.14	0.13	0.13	0.10	0.13	0.13	0.13	0.14	0.14	0.14	0.13
10 to 19	0.15	0.15	0.15	0.14	0.16	0.15	0.15	0.15	0.16	0.16	0.14	0.16	0.15	0.15	0.14
20 to 44	0.32	0.32	0.32	0.33	0.33	0.31	0.32	0.29	0.32	0.30	0.30	0.32	0.30	0.32	0.34
45 to 64	0.25	0.26	0.25	0.25	0.25	0.26	0.25	0.26	0.25	0.25	0.26	0.25	0.24	0.25	0.25
Over 65	0.16	0.15	0.16	0.15	0.13	0.16	0.15	0.19	0.14	0.17	0.17	0.14	0.16	0.13	0.13
Race[a]															
White alone	0.95	0.98	0.95	0.92	0.97	0.98	0.98	0.99	0.97	0.99	0.99	0.97	0.99	0.97	0.97
Black alone	0.04	0.01	0.02	0.07	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.02
Minority Pop	0.06	0.02	0.06	0.09	0.04	0.03	0.03	0.01	0.03	0.02	0.02	0.03	0.02	0.04	0.04
Education[a]															
Less than 9th Grade	0.18	0.14	0.17	0.16	0.06	0.08	0.06	0.06	0.05	0.06	0.08	0.07	0.11	0.08	0.08
High school grad or GED	0.37	0.42	0.39	0.41	0.42	0.45	0.47	0.46	0.44	0.47	0.48	0.44	0.47	0.45	0.43
Bachelors degree	0.04	0.06	0.06	0.06	0.09	0.08	0.09	0.09	0.11	0.09	0.08	0.09	0.08	0.08	0.08
Occupation[a]															
Management, professional & related	0.21	0.22	0.22	0.22	0.28	0.28	0.30	0.35	0.30	0.29	0.29	0.29	0.29	0.26	0.24
Service	0.12	0.12	0.13	0.14	0.13	0.14	0.14	0.14	0.14	0.15	0.12	0.14	0.13	0.14	0.15
Sales and office	0.19	0.20	0.21	0.21	0.22	0.20	0.21	0.19	0.22	0.20	0.19	0.21	0.17	0.21	0.20
Farming, fishing, & forestry	0.04	0.04	0.05	0.06	0.02	0.03	0.03	0.04	0.02	0.04	0.03	0.03	0.04	0.02	0.03
Construction, extractions & maintenance	0.13	0.15	0.12	0.11	0.16	0.12	0.12	0.10	0.12	0.13	0.12	0.12	0.12	0.15	0.14
Production, transportation & material moving	0.31	0.27	0.27	0.27	0.20	0.23	0.20	0.18	0.20	0.19	0.24	0.21	0.24	0.23	0.24

Profiles for ecological subsections were generated from U.S. Census of Population & Housing data for block group statistical spatial units. ‘Urban’ block groups were deleted from this analysis (i.e., 90% or greater urban population).

[a] **–** Proportion of population within ecological unit boundary to which social variable applies
[b] – **Mean poverty ratio**: Index showing the average degree of poverty in an area. A poverty ratio of 2.0 reveals people who are living at twice the poverty line (Blodgett 2000).

Appendix 3a Cont.

	Mississippi Basin subsections				Osage Plains subsections		Till Plains subsections								
Social Variable	**MB1**	**MB2**	**MB3**	**MB4**	**OP1**	**OP2**	**TP1**	**TP2**	**TP3**	**TP4**	**TP5**	**TP6**	**TP7**	**TP8**	**TP9**
Income ($)															
Median household	26454	30047	26974	28620	41345	31134	35965	31332	41754	33992	31850	35861	29961	39509	39515
Average for households < $200k	31854	35554	32227	34758	45937	36280	39848	38103	45417	38815	36263	39864	35860	44015	44048
Median family	31333	33401	29980	33549	45833	36064	41411	35980	47093	38696	36452	40486	35152	44241	45318
Average family	38622	39739	37307	41305	52696	41407	49131	46148	53794	46194	44077	46155	42513	50171	50976
Per capita	13482	14180	13653	14540	17870	14525	17416	17052	18451	16146	15730	15996	14680	16829	17755
Mean poverty ratio[b]	2.15	2.27	2.07	2.18	2.47	2.30	2.44	2.33	2.52	2.37	2.30	2.40	2.26	2.49	2.46
Housing															
Renter occupied units[a]	0.23	0.17	0.25	0.27	0.15	0.19	0.23	0.30	0.19	0.18	0.17	0.18	0.18	0.16	0.22
Median year moved in	1992	1992	1992	1991	1993	1992	1990	1989	1991	1991	1991	1991	1990	1992	1992
Average age of units (yrs.)	32	31	35	35	33	38	46	55	41	43	41	35	44	31	36
Median house value ($)	48406	62524	45492	54281	85821	55920	58385	39755	75647	50771	47404	67107	48086	88936	74612
Average house value ($)	56364	71578	56492	61409	98772	68317	69592	46788	87894	62360	59900	77633	59143	101156	86576

Appendix 3a Cont.

	Ozark Highlands Subsections															
Social Variable	**OZ1**	**OZ2**	**OZ3**	**OZ4**	**OZ5**	**OZ6**	**OZ7**	**OZ8**	**OZ9**	**OZ10**	**OZ11**	**OZ12**	**OZ13**	**OZ14**	**OZ15**	**OZ16**
Population																
Total persons	262396	1161	19898	93280	224275	91681	44805	51948	29613	49843	19648	209244	136369	31672	20788	3929
Density (persons per square mile)	55	54	38	30	33	38	25	30	10	32	23	59	61	23	50	43
Urban[a]	0.05	0.00	0.00	0.02	0.03	0.01	0.02	0.03	0.00	0.05	0.04	0.08	0.05	0.01	0.09	0.05
Age[a]																
0 to 9	0.14	0.20	0.16	0.12	0.13	0.11	0.13	0.13	0.12	0.12	0.15	0.14	0.14	0.12	0.13	0.14
10 to 19	0.15	0.14	0.16	0.14	0.15	0.14	0.15	0.17	0.16	0.15	0.17	0.15	0.16	0.15	0.15	0.16
20 to 44	0.32	0.39	0.34	0.30	0.31	0.28	0.33	0.33	0.30	0.31	0.32	0.34	0.34	0.31	0.34	0.34
45 to 64	0.25	0.18	0.24	0.28	0.26	0.29	0.25	0.25	0.27	0.26	0.23	0.24	0.25	0.27	0.25	0.22
Over 65	0.14	0.10	0.11	0.16	0.14	0.18	0.14	0.13	0.15	0.16	0.12	0.12	0.12	0.16	0.14	0.13
Race[a]																
White alone	0.96	0.79	0.92	0.97	0.97	0.98	0.95	0.98	0.96	0.97	0.97	0.97	0.98	0.98	0.97	0.97
Black alone	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.02	0.00
Minority Pop	0.04	0.38	0.10	0.04	0.04	0.03	0.05	0.03	0.05	0.03	0.04	0.03	0.02	0.03	0.04	0.04
Education[a]																
Less than 9th Grade	0.07	0.18	0.09	0.10	0.11	0.09	0.11	0.14	0.14	0.14	0.12	0.08	0.11	0.15	0.09	0.12
High school grad or GED	0.42	0.32	0.41	0.42	0.41	0.43	0.41	0.39	0.41	0.38	0.42	0.41	0.41	0.38	0.39	0.47
Bachelors degree	0.08	0.02	0.05	0.07	0.07	0.07	0.08	0.05	0.06	0.05	0.09	0.11	0.07	0.06	0.11	0.08
Occupation[a]																
Management, professional & related	0.26	0.21	0.21	0.24	0.24	0.23	0.27	0.19	0.22	0.21	0.27	0.27	0.23	0.22	0.29	0.25
Service	0.13	0.16	0.13	0.15	0.14	0.16	0.15	0.18	0.15	0.19	0.14	0.14	0.14	0.14	0.13	0.11
Sales and office	0.22	0.15	0.20	0.22	0.21	0.25	0.20	0.20	0.18	0.20	0.21	0.24	0.24	0.19	0.24	0.24
Farming, fishing, & forestry	0.02	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.04	0.03	0.02	0.01	0.01	0.03	0.01	0.02
Construction, extractions & maintenance	0.12	0.11	0.13	0.14	0.14	0.15	0.14	0.17	0.14	0.14	0.14	0.14	0.15	0.13	0.14	0.13
Production, transportation & material moving	0.23	0.32	0.29	0.23	0.26	0.19	0.22	0.25	0.28	0.23	0.22	0.20	0.23	0.30	0.20	0.27

Appendix 3a Cont.

	Ozark Highlands Subsections															
Social Variable	**OZ1**	**OZ2**	**OZ3**	**OZ4**	**OZ5**	**OZ6**	**OZ7**	**OZ8**	**OZ9**	**OZ10**	**OZ11**	**OZ12**	**OZ13**	**OZ14**	**OZ15**	**OZ16**
Income ($)																
Median household	33788	21680	28445	28622	30538	31230	31446	32005	25157	28697	35514	42587	41268	29157	45217	39097
Average for households < $200k	38260	25342	32849	33027	35512	36374	36496	37169	30544	33553	40163	46554	44697	33731	49590	41321
Median family	38166	23936	32863	32356	35036	36046	36577	36437	29439	33360	41112	47093	45802	33266	51422	43215
Average family	45904	34161	41481	40604	42291	43587	42988	45075	35940	40830	46178	54450	52068	41444	61097	47850
Per capita	15891	11295	13811	14823	14835	15707	15180	14962	12761	14010	15145	18447	17543	14326	20937	15732
Mean poverty ratio[b]	2.34	1.72	2.11	2.16	2.23	2.28	2.28	2.22	2.03	2.18	2.37	2.53	2.54	2.20	2.58	2.43
Housing																
Renter occupied units[a]	0.18	0.42	0.22	0.17	0.16	0.14	0.19	0.15	0.17	0.18	0.16	0.15	0.14	0.16	0.17	0.17
Median year moved in	1993	1995	1995	1993	1993	1993	1992	1993	1993	1993	1993	1992	1992	1993	1992	1989
Average age of units (yrs.)	33	35	30	29	31	28	32	30	32	32	35	30	31	29	34	35
Median house value ($)	74810	50773	61819	68336	67734	77504	66161	63780	47507	57861	73382	94750	85794	55413	99608	94626
Average house value ($)	87305	59092	87010	84525	78166	95817	72623	73893	60976	75324	82890	108402	96307	68018	117688	95742

Appendix 3b. Social profile for ecological LTA Types in Missouri

	Mississippi Basin LTA Types			Osage Plains LTA Types			Till Plains LTA Types							
Social Variable	**MB Alluvial Plains**	**MB Crowley's Ridge Hills**	**MB Sand Ridges & Hills**	**OP Alluvial Plains**	**OP Prairie Plains**	**OP Prairie Savanna Scarped & Dissected Plains**	**TP Alluvial Plains**	**TP Loess Prairie Hills and Blufflands**	**TP Low Prairie Plains**	**TP Prairie Plains**	**TP Prairie Woodland Dissected Plains**	**TP Prairie Woodland Hills**	**TP Woodland Forest Breaks**	**TP Woodland Forest Hills**
Population														
Total persons	59397	10256	30642	8630	80050	109224	48553	17491	7415	150207	22533	114160	40198	123546
Density (persons per square mile)	21	40	41	18	28	43	20	12	15	25	14	22	47	27
Urban[a]	0.02	0.03	0.05	0.02	0.03	0.06	0.05	0.01	0.04	0.03	0.00	0.03	0.08	0.03
Age[a]														
0 to 9	0.12	0.11	0.12	0.13	0.13	0.13	0.13	0.11	0.12	0.13	0.14	0.13	0.13	0.13
10 to 19	0.15	0.15	0.14	0.15	0.15	0.16	0.15	0.16	0.15	0.16	0.15	0.15	0.15	0.15
20 to 44	0.33	0.32	0.32	0.31	0.32	0.32	0.31	0.31	0.28	0.31	0.31	0.30	0.32	0.31
45 to 64	0.25	0.26	0.26	0.25	0.26	0.25	0.25	0.25	0.25	0.25	0.24	0.25	0.26	0.26
Over 65	0.15	0.15	0.15	0.15	0.14	0.13	0.16	0.17	0.20	0.15	0.15	0.17	0.14	0.14
Race[a]														
White alone	0.92	0.99	0.95	0.98	0.97	0.97	0.98	0.99	0.99	0.97	0.98	0.98	0.97	0.98
Black alone	0.06	0.00	0.04	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.01
Minority Pop	0.08	0.02	0.06	0.03	0.03	0.04	0.02	0.01	0.01	0.03	0.02	0.02	0.03	0.03
Education[a]														
Less than 9th Grade	0.17	0.14	0.16	0.08	0.07	0.06	0.07	0.05	0.07	0.08	0.09	0.06	0.06	0.08
High school grad or GED	0.40	0.42	0.42	0.45	0.44	0.43	0.47	0.48	0.49	0.45	0.47	0.47	0.46	0.45
Bachelors degree	0.06	0.06	0.04	0.08	0.08	0.10	0.09	0.09	0.09	0.09	0.08	0.09	0.10	0.08
Occupation[a]														
Management, professional & related	0.22	0.22	0.21	0.28	0.28	0.28	0.29	0.31	0.27	0.29	0.28	0.31	0.28	0.27
Service	0.13	0.12	0.13	0.13	0.13	0.13	0.14	0.15	0.13	0.14	0.15	0.13	0.15	0.14
Sales and office	0.20	0.20	0.22	0.21	0.21	0.22	0.20	0.19	0.23	0.21	0.19	0.21	0.22	0.20
Farming, fishing, & forestry	0.05	0.04	0.04	0.03	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.04	0.02	0.03
Construction, extractions & maintenance	0.12	0.15	0.11	0.15	0.14	0.14	0.12	0.12	0.12	0.12	0.12	0.13	0.12	0.14
Production, transportation & material moving	0.28	0.27	0.28	0.20	0.22	0.20	0.21	0.21	0.21	0.21	0.23	0.19	0.20	0.22

Profiles for ecological LTA Types were generated from U.S. Census of Population & Housing data for block group statistical spatial units. 'Urban' block groups were deleted from this analysis (i.e., 90% or greater urban population).

[a] **–** Proportion of population within ecological unit boundary to which social variable applies
[b] – **Mean poverty ratio**: Index showing the average degree of poverty in an area. A poverty ratio of 2.0 reveals people who are living at twice the poverty line (Blodgett 2000).

Appendix 3b. Cont.

Social Variable	Mississippi Basin LTA Types			Osage Plains LTA Types			Till Plains LTA Types							
	MB Alluvial Plains	MB Crowley's Ridge Hills	MB Sand Ridges & Hills	OP Alluvial Plains	OP Prairie Plains	OP Prairie Savanna Scarped & Dissected Plains	TP Alluvial Plains	TP Loess Prairie Hills and Blufflands	TP Low Prairie Plains	TP Prairie Plains	TP Prairie Woodland Dissected Plains	TP Prairie Woodland Hills	TP Woodland Forest Breaks	TP Woodland Forest Hills
Income ($)														
Median household	27823	30248	28817	35244	34823	39983	35091	32745	32994	35787	30792	35704	42057	36912
Average for households < $200k	33842	35762	34166	40348	39834	44538	39309	38000	37865	40210	36185	40000	45601	41568
Median family	32550	33546	33348	40497	39523	44515	40484	38400	39031	40321	36447	40386	46615	41586
Average family	39840	40013	41942	46533	45303	51283	47556	45244	44802	46697	43593	47720	54035	48903
Per capita	14105	14296	14618	16081	15658	17469	16768	16159	15630	16095	15144	16706	18620	16849
Mean poverty ratio[b]	2.16	2.28	2.18	2.37	2.37	2.45	2.39	2.36	2.35	2.39	2.30	2.38	2.55	2.43
Housing														
Renter occupied units[a]	0.26	0.17	0.25	0.18	0.17	0.15	0.21	0.25	0.18	0.18	0.18	0.18	0.17	0.16
Median year moved in	1992	1992	1992	1992	1993	1993	1990	1990	1990	1991	1991	1991	1990	1992
Average age of units (yrs.)	35	31	33	39	36	33	44	51	43	39	41	42	40	35
Median house value ($)	51819	63614	54324	63354	69259	79784	55822	44549	43223	66048	48863	55870	75393	70683
Average house value ($)	59857	72984	60859	76130	82477	91906	66874	53955	59048	76789	60467	68065	87966	82568

Appendix 3b. Cont.

Social Variable	Ozark Highlands LTA Types										
	OZ Alluvial Plains	**OZ Dolomite Glade Woodlands**	**OZ Igneous Knobs**	**OZ Oak Savanna Woodland Dissected Plains**	**OZ Oak Woodland Dissected Plains & Hills**	**OZ Oak Woodland Forest Hills**	**OZ Oak-Pine Hills**	**OZ Pine-Oak Woodland Dissected Plain**	**OZ Prairie Plains**	**OZ Prairie Savanna (Dissected) Plains**	**OZ Rugged Hills & Forest Breaks**
Population											
Total persons	36822	142138	16492	277208	174107	186492	60988	24227	28432	189375	154317
Density (persons per square mile)	59	57	22	45	25	39	14	18	26	57	59
Urban[a]	0.11	0.04	0.04	0.04	0.01	0.04	0.00	0.01	0.03	0.06	0.06
Age[a]											
0 to 9	0.13	0.12	0.12	0.14	0.12	0.14	0.12	0.13	0.15	0.14	0.13
10 to 19	0.15	0.14	0.15	0.16	0.15	0.16	0.15	0.16	0.15	0.15	0.15
20 to 44	0.34	0.31	0.31	0.33	0.30	0.34	0.30	0.31	0.32	0.32	0.32
45 to 64	0.25	0.27	0.26	0.25	0.27	0.24	0.27	0.26	0.24	0.25	0.27
Over 65	0.14	0.16	0.15	0.13	0.16	0.12	0.16	0.14	0.14	0.14	0.14
Race[a]											
White alone	0.97	0.97	0.97	0.97	0.97	0.97	0.96	0.96	0.97	0.96	0.97
Black alone	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Minority Pop	0.04	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.05	0.04
Education[a]											
Less than 9th Grade	0.10	0.09	0.14	0.10	0.11	0.11	0.14	0.14	0.10	0.08	0.09
High school grad or GED	0.40	0.40	0.38	0.42	0.42	0.41	0.40	0.40	0.44	0.41	0.39
Bachelors degree	0.10	0.07	0.05	0.08	0.07	0.08	0.06	0.06	0.09	0.08	0.09
Occupation[a]											
Management, professional & related	0.28	0.23	0.21	0.24	0.24	0.25	0.21	0.22	0.28	0.25	0.25
Service	0.12	0.17	0.19	0.14	0.14	0.14	0.15	0.14	0.12	0.14	0.15
Sales and office	0.24	0.23	0.19	0.22	0.21	0.23	0.18	0.20	0.22	0.22	0.22
Farming, fishing, & forestry	0.01	0.01	0.03	0.02	0.03	0.02	0.04	0.03	0.03	0.02	0.02
Construction, extractions & maintenance	0.14	0.15	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.15
Production, transportation & material moving	0.21	0.21	0.23	0.24	0.24	0.22	0.27	0.28	0.22	0.25	0.20

Appendix 3b. Cont.

Social Variable	Ozark Highlands LTA Types										
	OZ Alluvial Plains	OZ Dolomite Glade Woodlands	OZ Igneous Knobs	OZ Oak Savanna Woodland Dissected Plains	OZ Oak Woodland Dissected Plains & Hills	OZ Oak Woodland Forest Hills	OZ Oak-Pine Hills	OZ Pine-Oak Woodland Dissected Plain	OZ Prairie Plains	OZ Prairie Savanna (Dissected) Plains	OZ Rugged Hills & Forest Breaks
Income ($)											
Median household	44303	33105	27846	34216	29223	38402	26942	25736	34862	32346	36830
Average for households < $200k	48152	37461	33139	38682	34368	42401	31785	31163	39258	36983	41605
Median family	49962	37155	32457	38644	33484	43294	31330	29901	39470	36738	41740
Average family	58203	45475	40284	45752	40676	50328	38750	38306	45461	44359	49338
Per capita	19942	16397	13848	15639	14573	17008	13458	13066	15571	15389	17235
Mean poverty ratio[b]	2.55	2.30	2.17	2.34	2.18	2.44	2.10	2.04	2.37	2.29	2.38
Housing											
Renter occupied units[a]	0.16	0.16	0.18	0.16	0.16	0.15	0.17	0.17	0.18	0.18	0.16
Median year moved in	1991	1994	1992	1993	1993	1992	1993	1993	1992	1993	1993
Average age of units (yrs.)	34	27	33	31	31	31	31	30	37	32	28
Median house value ($)	97593	79844	55720	76546	64230	79676	52277	52536	70791	70166	89454
Average house value ($)	112324	97413	73798	87849	76221	92179	64566	65112	86030	82362	104176