PEOPLE & PLACE:

Dasymetric Mapping Using Arc/Info

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Introduction

To better understand patterns of human settlement, migration, and related economic activities, social scientists traditionally have relied on data gathered directly from individuals and their families. Such “census” data can provide information about the socioeconomic characteristics of people living in different geographic areas at different times. In the United States, complete census data are collected every 10 years from people residing in geographic units defined as census “blocks” and delineated by the Census Bureau to contain approximately 100 people each. These enumeration units are nested hierarchically within block groups, census tracts, counties, and states (Figure 1). It is difficult to analyze or display data at the block level; moreover, for reasons of privacy, population number is the only variable available for these smallest collection units. More detailed information about people and households is available only at higher levels of organization, starting with the block group.

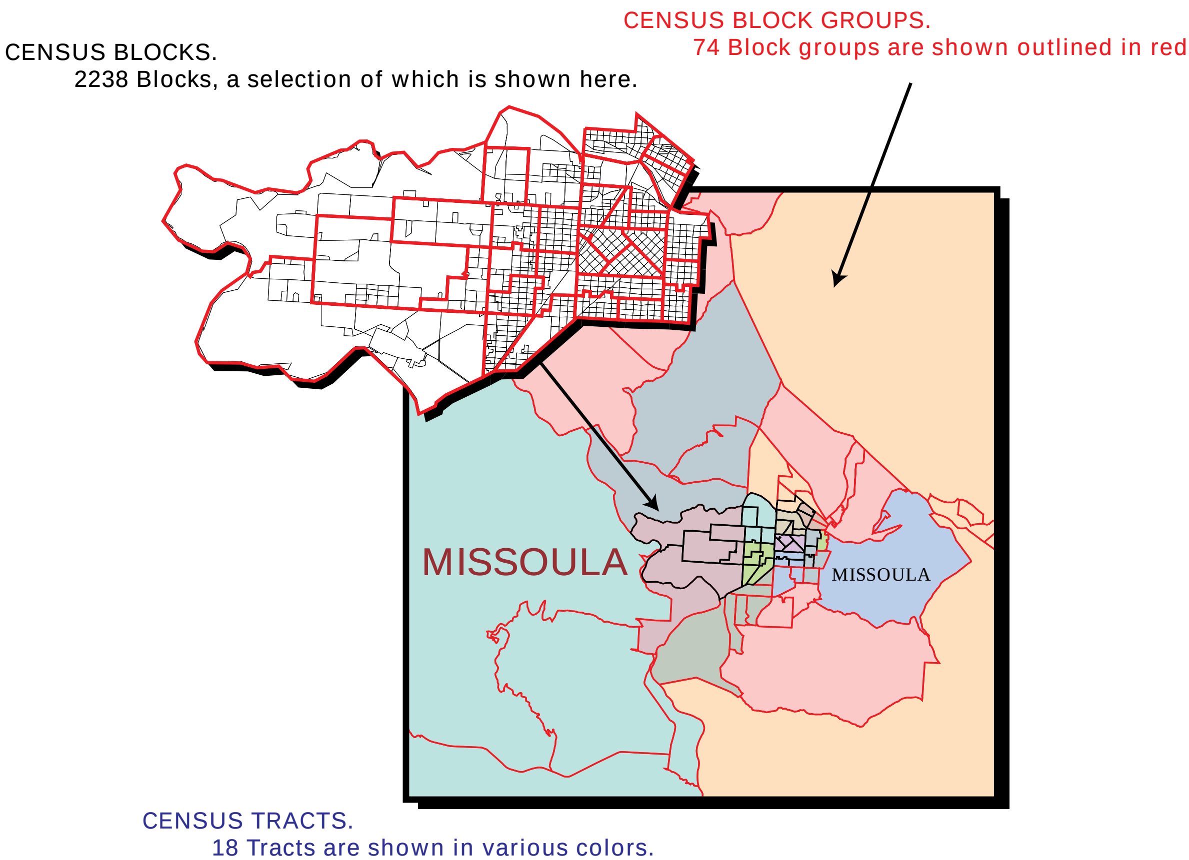

Figure 1: The hierarchical relationship among census blocks, block groups, and tracts is shown here for a portion of Missoula County, Montana. For the entire county, there are 74 block groups containing 2,238 blocks and falling within 18 census tracts.

Choropleth maps are the most common way to display census data, or any data for which the enumeration and mapping units are the same. For example, a choropleth map of human population density is readily made by dividing the number of people recorded in the enumeration unit (i.e. the census block or block group) by the size of that unit. Despite their simplicity, choropleth maps have limited utility for detailed spatial analysis of socioeconomic data, especially in western North America, where human populations are concentrated in relatively few towns and cities, found at lower elevations, and along major river corridors. Relatively large expanses of land are essentially uninhabited, especially in block groups or tracts that lie far away from urban areas. When population density, or any other socioeconomic variable, is mapped by choropleth techniques, the results often tell us more about the size and shape of the enumeration unit, than about the people actually living and working within them.

One way to circumvent these limitations is to transform the enumeration units into smaller and more relevant map units in a process known as dasymetric mapping. In this paper we describe an automated GIS application that uses Arc/Info to more precisely map human population density in Missoula County, Montana. The process is complex because population numbers from the 1990 Census were reassigned to new map units using a combination of variables. Patterns of land ownership were used to identify uninhabited areas in each census block group. Land cover, land use, and topographic classes that were used to further restrict the boundaries of inhabited areas. We emphasize that other socio-economic variables, such as median age of housing units, median income by ethnic group, or even births per 1000 women, could be mapped according to the same basic approach wherever adequate data exist.

Methods

Population data came from the 1990 U.S. Census; the mapping unit for population density was the census block group. Land ownership data were obtained as polygon coverages from the U.S. Forest Service, the U.S. Bureau of Land Management, and Plum Creek Timber Co.; their source scale was 1:100,000 or finer. Topography was derived from U.S. Geological Survey 7.5 minute digital elevation models (DEM's). Land cover was mapped from Landsat Thematic Mapper (TM) imagery using a two-stage classification procedure (Ma et al. MSa, b) and a 5 acre minimum mapping unit (MMU). Agricultural and urban land uses were manually labeled from the same Landsat TM imagery and at the same 5 acre MMU (Ma et al MSb).

These digital data were assembled into continuous (e.g., seamless) vector coverages in Arc/Info (ver. 7.0.4) running on an IBM RS/6000 UNIX workstation. Land cover, land use, land ownership, and DEM grids were intersected in the following sequence for each block group in the county (Figure 2). First, areas uninhabited by people were identified (Figure 2A) by selecting: 1) all census blocks with zero population; 2) all lands owned by the local, state or federal governments; 3) all corporate timberlands and 4) all water features. Next, four general land cover/land use classes were selected from the land cover data: urban, agriculture, forested, and open lands (Figure 2B). All urban and agriculture polygons were assumed to be populated and left

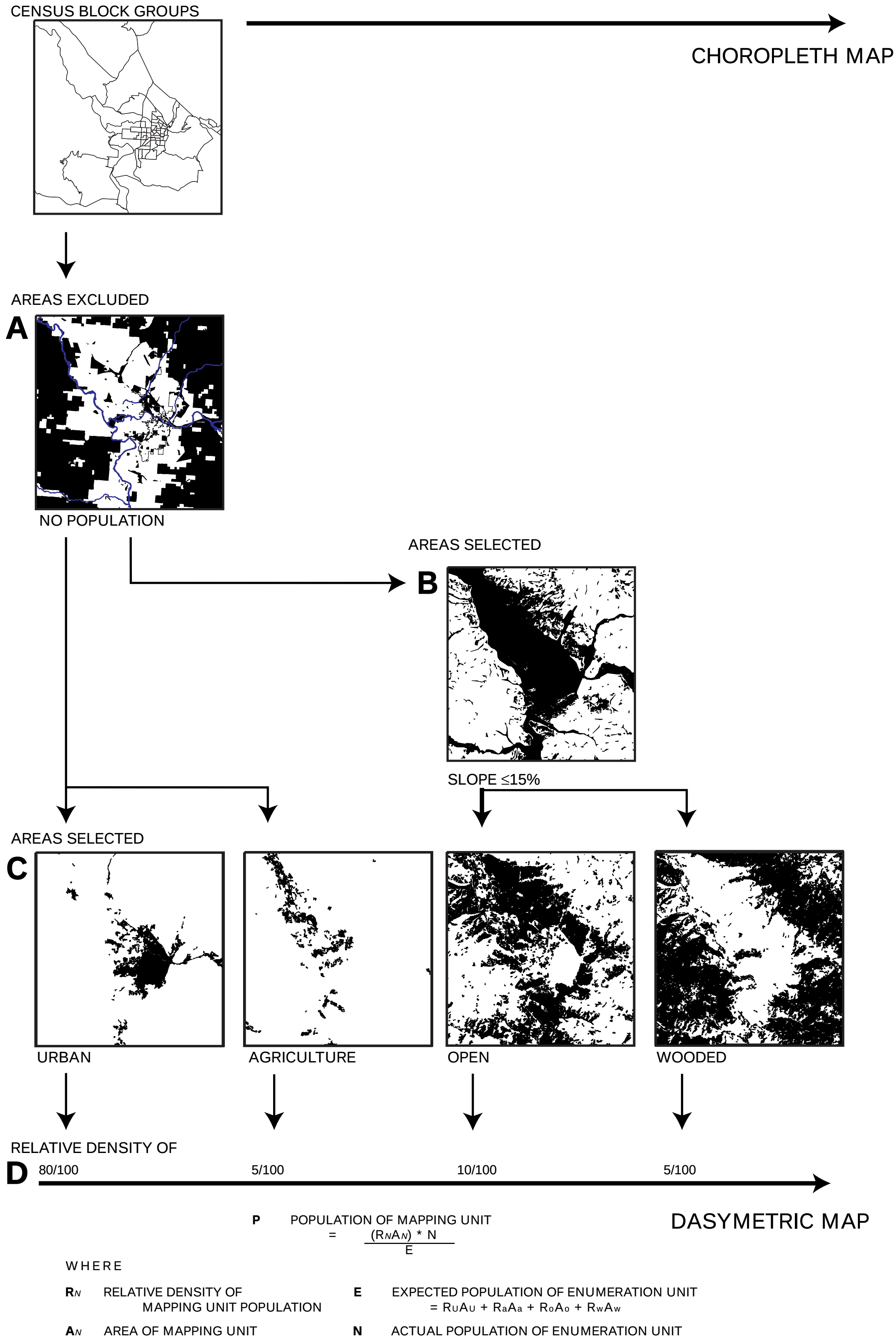

Figure 2: Filtering steps applied to each census block group to create a dasymetric map of population density. A) identify and remove all uninhabited lands by selecting 1) all census blocks in which no people were counted, 2) all lands owned by local, state, or federal governments, 3) all corporate timberlands, and 4) all water or wetland features; B) select four general land cover/use classes (urban, agriculture, forest, and open lands); C) further restrict open and forested lands to only those portions with slope less than or equal to 15%.

alone, whereas only those areas of forested or open land with a slope of less than or equal to 15% were "assigned" people (Figure 2C). Assuming that urban polygons contained more people per unit area than agriculture, wooded, or open polygons, we differentially allocated the recorded population for each census block group among these four types on a per unit area basis. A filtering routine was programmed into an AML to accomplish this task (Figure 2D): Urban polygons were given a relative weighting of 80% (80 people per 100 population), whereas open polygons were weighted at 10%, and agriculture and forested polygons at 5% each. After each step, islands in the polygons resulting from each sequential intersecting operation had to be identified and flagged. Finally, an attribute item for population density was added, and the database populated with the recalculated population density estimates.

Before an actual map could be made, we selected appropriate density classes based on examination of a frequency histogram of all the density values (Figure 3). The number of classes, the class breaks, and the use of colors to indicate the different classes were all determined manually from the distribution of data in the new mapping units. Finally, the Arc/Info polygons were exported as ungenerate files to a Macintosh platform and imported (using Avenza's MapPublisher) into Adobe Photoshop and Adobe Illustrator to create the final maps.

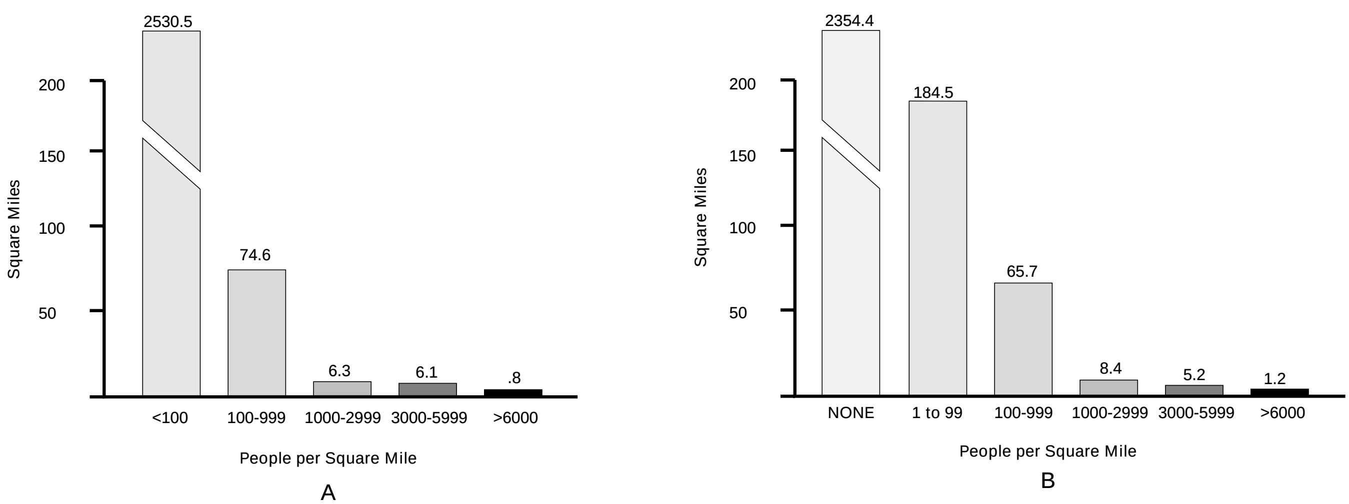

Figure 3: The amount of area in Missoula County in each population density class derived from A) the choropleth map, and B) the dasymetric map.

Results

Figure 4A shows a choropleth map of population density for a portion of the county around the city of Missoula. Because of the way the enumeration units have been drawn, and because topography, land ownership, and land cover affect the distribution of people in the Missoula valley, the predominant class is the lowest one ("Less than 100"). In fact, this class represents nearly 97% of the entire county, covering 2,531 sq. mi. (Figure 3A).

In contrast, the dasymetric population maps (Figures 4B and 5) identify a sixth class, with no population density ("None"), which covers 2,354 sq. mi or >90% of the county (Figure 3B). The "Less than 100" class represents only 185 sq. mi., or 7% of Missoula County, which is a far more accurate picture of population density than the 97% indicated by the choropleth map. Changes in class size for the higher density classes appear relatively small at this scale, indicating that most of the differences between the two mapping techniques result from the exclusion of unoccupied lands (A) and to a lesser extent slope restrictions (B). This finding alone indicates the importance of carefully excluding public and corporate lands where no people should be living.

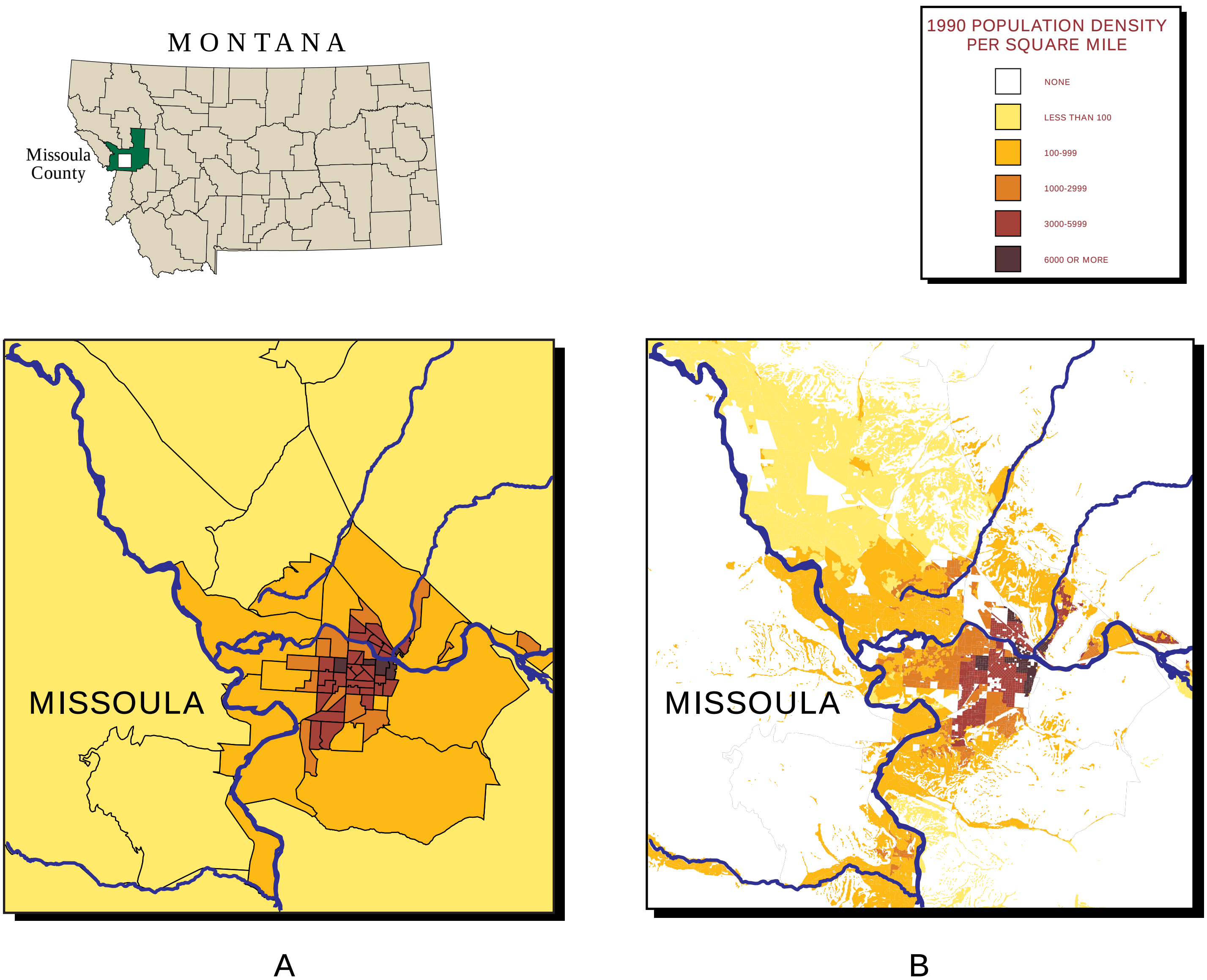

Figure 4: 1990 population density for a portion of Missoula County, Montana; A) Choropleth map, B) Dasymetric map.

Conclusions

In addition to population density, other socio-economic variables, such as income, gender, race, religion, occupation, housing units, etc., also can be mapped using dasymetric techniques. We are currently extending this work to a 40 county region in western Montana, northern Idaho, and northeastern Washington where we will map population density, median age of housing units (by decade) and median income. These results will enable land managers and public policy makers to examine settlement patterns over time and in relation to distances from water or forest or wilderness, and thereby better understand why people live where they do in the Rocky Mountain west. Finally, when coupled with other broad scale natural resource data that are becoming available in digital form, the database can serve as a predictive tool to identify areas most vulnerable to any negative consequences of future development or land use change. In other words, using these techniques, we are better able to ask and answer the fundamental questions: *Where is it? Why is it there?* and *How can we benefit from knowing that it's there?*

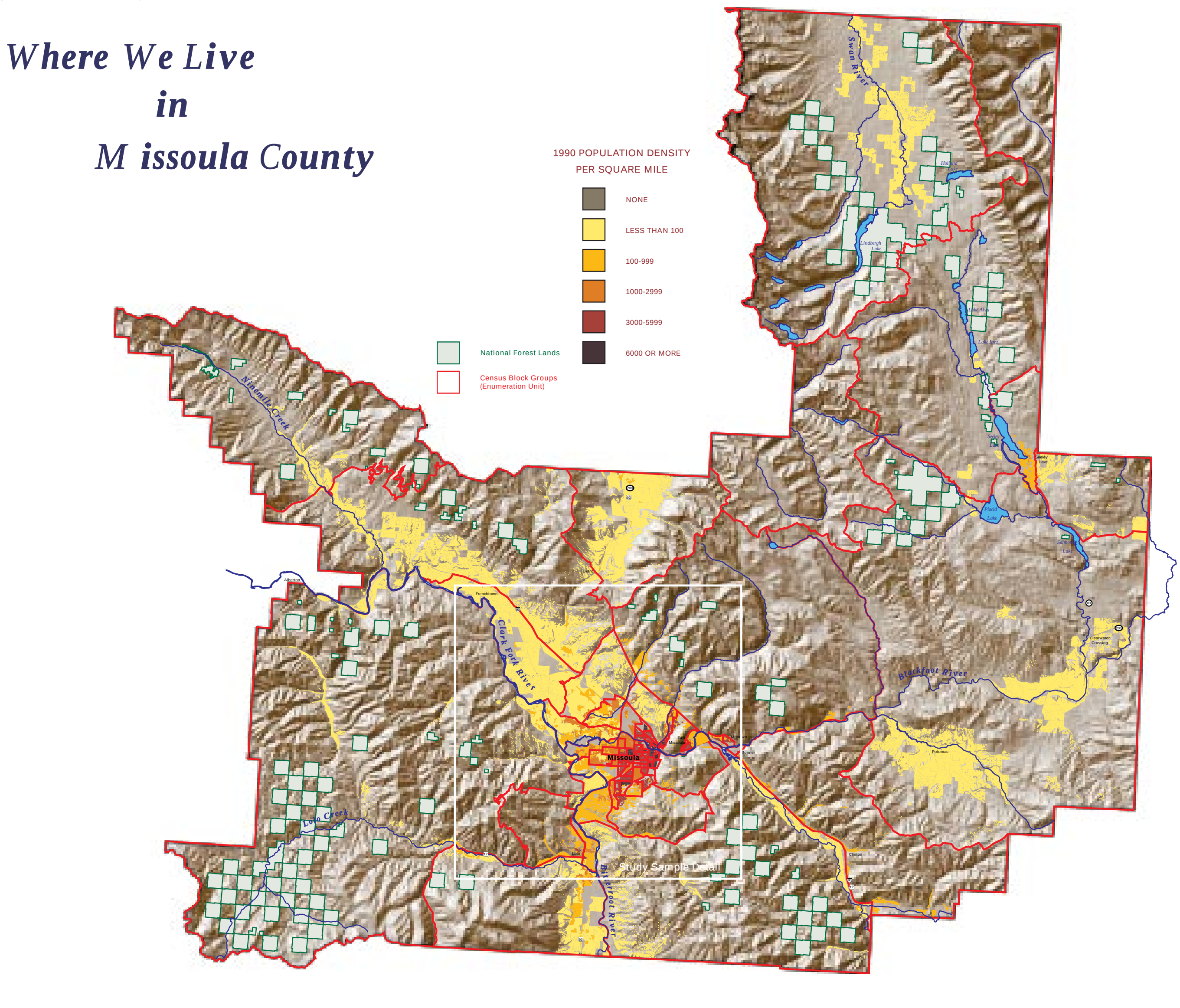

Figure 5: Dasymetric map of 1990 population density for Missoula County, Montana.