A SPATIAL EMERGY MODEL FOR ALACHUA COUNTY, FLORIDA

BY

JAMES DAVID LAMBERT

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1999

Dedicated
To
Marilyn M. Winston

ACKNOWLEDGEMENT

I would like to express my sincerest appreciation to my committee chairman, Dr. John F. Alexander, and to my other committee members, Dr. H.T. Odum, Dr. Earl M. Starnes, Dr. Lawrence D. Harris, and Dr. Paul D. Zwick for their support and patience over the years. Special appreciation is due Dr. Howard T. Odum who has changed my way of looking at the world forever. This work would not have been completed without the encouragement and support of my most significant, best friend, and fellow student, Marilyn Winston.

TABLE OF CONTENTS

Abstract of Dissertation Presented to the Graduate School
Of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

A SPATIAL EMERGY MODEL
FOR
ALACHUA COUNTY, FLORIDA

By

James David Lambert

August 1999

Chairman: John F. Alexander, Jr.
Major Department: College of Architecture

A spatial model of the distribution of energy flows and storages in Alachua County, Florida, was created and used to analyze spatial patterns of energy transformation hierarchy in relation to spatial patterns of human settlement. Emergy, the available energy of one kind previously required directly or indirectly to make a product or service, was used as a measure of the quality of the different forms of energy flows and storages. Emergy provides a common unit of measure for comparing the productive contributions of natural processes with those of economic and social processes—it is an alternative to using money for measuring value.

A geographic information system was used to create a spatial model and make maps that show the distribution and magnitude of different types of energy and emergy

flows and storages occurring in one-hectare land units. Energy transformities were used to convert individual energy flows and storages into emergy units.

Maps of transformities were created that reveal a clear spatial pattern of energy transformation hierarchy. The maps display patterns of widely-dispersed areas with lower transformity energy flows and storages, and smaller, centrally-located areas with higher transformities. Energy signature graphs and spatial unit transformities were used to characterize and compare the types and amounts of energy being consumed and stored according to land use classification, planning unit, and neighborhood categories. Emergy ratio maps and spatial unit ratios were created by dividing the values for specific emergy flows or storages by the values for other emergy flows or storages. Spatial context analysis was used to analyze the spatial distribution patterns of mean and maximum values for emergy flows and storages.

The modeling method developed for this study is general and applicable to all types of landscapes and could be applied at any scale. An advantage of this general approach is that the results of other studies using this method will be directly comparable with the results of this study. The results and conclusions of this study reinforce the hypothesis that an urban landscape will develop a predictable spatial pattern that can be described in terms of a universal energy transformation hierarchy.

INTRODUCTION

The primary goal of this study is to create a general type of spatial model of the distribution of energy flows and storages in urban and regional landscapes that can be used to study spatial patterns of the energy transformation hierarchy and energy signatures in relation to spatial patterns of human settlement. EMERGY (capitalized throughout this study to avoid confusion with the word ‘energy’) is used as a measure of the quality of the different forms of energy flows and storages that are included in the model. A secondary goal of the study is to demonstrate how recent advances in computer and information science technologies can be applied in a way that provides new insights into the spatial patterns of energy flow and storage.

The primary target audience for this study is urban and regional planners. However, anyone interested in how man-dominated landscapes are spatially organized to process and store both local, natural energy sources and imported, nonrenewable energy sources should be interested in the results. The specific spatial model presented in this study was implemented at a spatial resolution that makes it particularly useful for describing, quantifying, and studying patterns that occur within spatial units of urban systems. Although the focus for this study is on patterns of urban systems, the modeling methods presented in this study are intended to be general and applicable to all types of landscapes and most could be applied at any scale.

Theoretical Basis for the Study

This study is based on general and ecological systems theory developed over the past three decades by H.T. Odum and his associates (Odum, 1971; Odum, et.al., 1976, Odum, 1983, 1988, 1992; Hall, 1995; Odum,1996; Odum, et.al., 1998). A basic review of the concepts and principles of this theory that are most important and relevant to this study are presented in the following sections.

EMERGY Defined

In his latest book, *Environmental Accounting—EMERGY and Environmental Decision Making* (1996), H.T. Odum explains how the concept of EMERGY can be used as the basis for an environmental accounting approach that measures and evaluates the relative contributions to real wealth that are made by both environmental and economic processes. In this book, Odum (1996, p.6) defines real wealth as anything that ". . . is produced and maintained by work processes from the environment. . . ." He explains how real wealth can be measured in terms of EMERGY in the following paragraph.

> To build and maintain the storage of available resources, environmental work has to be done, requiring energy use and transformation. We can quantitatively evaluate the storage by the work done in its formation. Work of energy transformation can be measured by the availability of the energy that is used up. Thus, real wealth can be measured by the work previously done. EMERGY is a scientific measure of real wealth in terms of the energy required to do the work of production. (Odum, 1996, p. 7)

EMERGY is defined as the ". . . available energy of one kind previously required directly or indirectly to make a product or service . . ." (Odum, 1996, p.7). This study will use a variant of EMERGY, called solar EMERGY, as its primary unit of measure.

Solar EMERGY is defined by Odum (1996, p.8) as ". . . the available solar energy used up directly and indirectly to make a service or product. Its unit is the solar emjoule (abbreviated sej)." These straightforward definitions do not do nearly as much justice to the elegance of this concept as the following quote from Dr. Odum's book in which he presents the concept from the perspective of "common folk".

> A commonplace idea among people everywhere is that some things take more effort than others. Long before physical science made a narrow quantitative definition of energy, the word "energy" was used to refer to the work done. For example, it was said that a house took more energy to build than a chair. The universal idea among common folk was, and still is, that putting more energy into something generates more value. The concept of EMERGY is scientifically defined to give a quantitative measure to this ancient principle.
>
> Because of the way it is defined, the scientific use of "energy" does not coincide with the folk concept. The practical, operational scientific measure of energy is the heat generated when various forms of energy are converted. The scientific concept makes no allowance for different kinds of energy representing different levels of effort. The scientific concept rates a calorie of sunlight, electricity, nuclear fission, and human thinking as equal. In other words, the different levels of prior effort involved in generating different kinds of energy are ignored. . . . EMERGY is a measure that looks back upstream to record what energy went into the train of transformation processes. The computations recognize that each type of energy has a different upstream energy input which must be included in order to summarize all the energy of one type that is required to generate the output. (Odum, 1996, pp. 13-14)

With these concepts in mind, EMERGY was chosen for this study because it measures the work contributed by *both* nature and society to the production and storage of 'real wealth'. An advantage of using EMERGY for a study such as this is that the concept provides a method for comparing storages and flows related to natural processes with those of economic and social processes. EMERGY provides an alternative to using money for measuring the contributory value of an element of the system. Money does not work well for valuing the contribution of the 'free' energy sources from nature. The essential contributions from these free resources are often ignored, if not forgotten, in evaluations of economic systems because of the difficulties of valuing natural resources (Ahmad et al., 1989; Costanza, 1991; Uno and Bartelmus, 1998).

Energy Systems Diagrams

EMERGY analysis is based on diagramming the flows and storages of energy using a standard symbol language (Odum, 1983, 1996). These energy system diagrams are drawn based on an understanding of several energy-related characteristics of the system being modeled. These characteristics include: what the boundaries of the system are, what outside energy sources contribute to the system, how energy flows interact within a system, and what the flow pathways are between interactions and energy storage elements of a system being modeled. The diagrams are drawn according to a strict set of rules, defined and described by H.T. Odum (1983), so that the laws of thermodynamics are observed.

A simple example is shown in Figure 1-1. It has flows from two types of potential energy sources interacting in a productive process to create a storage or structure (real wealth). The first law of energy conservation is observed in the diagramming of the energy flows and storages (all of the energy entering the system is accounted for—none is created or destroyed). The diagram also illustrates the second law of thermodynamics by accounting for the fact that some energy loses its ability to do work in the production interaction process (leaving the system in the form of dispersed heat), and that all storages will naturally depreciate over time and must be maintained by productive processes.

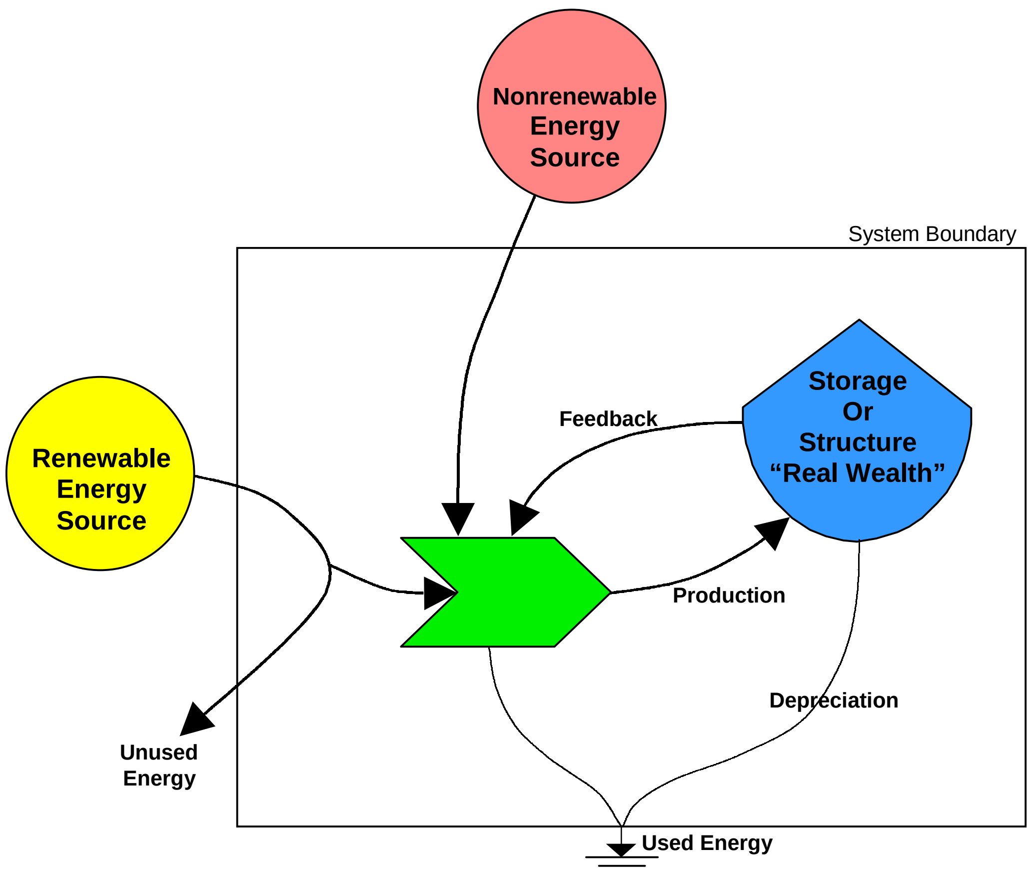


Figure 1-1: A simple energy system diagram showing two sources of potential energy interacting in a productive process that builds a storage or structure. This storage is "real wealth" as defined by Odum (1996). The diagram illustrates that, because of the second law of thermodynamics, much of the potential energy used in the productive process is used up (loses its ability to do work) and leaves the system in a more dispersed form (usually as heat). The storage also loses potential energy over time. Surviving systems will self organize to develop structure that has reinforcing feedback to the production process (Odum, 1983).

Transformity Defined

Transformities are used to calculate the EMERGY in a product or service. H.T. Odum describes the concept of transformity in the following quotes from his book.

> The quotient of a product's EMERGY divided by its energy is defined as its transformity (Odum, 1976, 1988). The units of transformity are emjoules per joule. . . . Solar transformity is the solar EMERGY required to make one joule of a service or product. Its units are solar emjoules per joule (sej/J). A product's solar transformity is its solar EMERGY divided by its energy.
>
> The more energy transformations there are contributing to a product, the higher is the transformity. This is because at each transformation, available energy is used up to produce a smaller amount of energy of another form. Thus, the EMERGY increases but the energy decreases, and therefore the EMERGY per unit energy increases sharply. . . . Goods and services that have required the most work to make and have the least energy have the highest transformities. Examples are human services and information . . .most energy transformations are controlled by inputs of high transformity, whose energy contribution is small but whose EMERGY contribution may be large. An example is the control of a forest by people . . . (Odum, 1996, p. 11)

Transformities, as defined above, can be used to distribute all forms of energy along a universal energy hierarchy based on the magnitude of transformity values (Odum, 1996). The concept of universal energy hierarchy is based on the second law of thermodynamics that states that available energy is degraded in any transformation process. The second law explains why we see hierarchy in all types of systems.

Odum (1996) points out that a familiar pattern seen in many types of systems can be described in terms of transformities—many units of lower transformity energy converge and interact through productive processes with other higher-transformity forms of energy to create even fewer units of other forms of energy with even higher transformities.

Spatial Distribution of Energy According to Tranformation Hierarchy

Odum and others (Odum and Brown, 1976; Constanza, 1975, Brown, 1980, Odum, 1983, 1996; Whitfield, 1994; Huang, 1998) have proposed that the spatial distribution of energy flows and storages tend to follow patterns based on the level of transformity for the flow or storage (illustrated in Figure 1-2).

For example, low transformity flows tend to be widely dispersed compared to higher transformity flows. In terms of the spatial arrangement of urban systems, these previous studies predict that a city center will have a higher energy flow transformity than the less developed suburbs surrounding the city center, and that rural areas outside the city will have the lowest transformity for flows.

In the case of storages, there are usually many smaller, lower transformity storages that are widely dispersed, and there are usually fewer of the larger, higher transformity storages. Once again, in terms of the urban spatial pattern, this observation suggests that a city center will have a higher storage transformity than suburbs. Because of the large inputs of high-transformity nonrenewable resources and human services that are required to develop and maintain all forms of urban structure, it is likely that the transformities for urban storages will be larger than those for natural structure in the surrounding areas.

Brown (1980, 1981) observed a hierarchical phenomenon in the sizes and distributions of cities in the regional landscape of Florida, and described the phenomenon in terms of energy and transformity hierarchies. Whitfield (1994) demonstrated this spatial phenomenon in his study of the energy distribution patterns of Jacksonville, Florida. Huang (1998) found similar patterns in a study of Taipei, Taiwan.

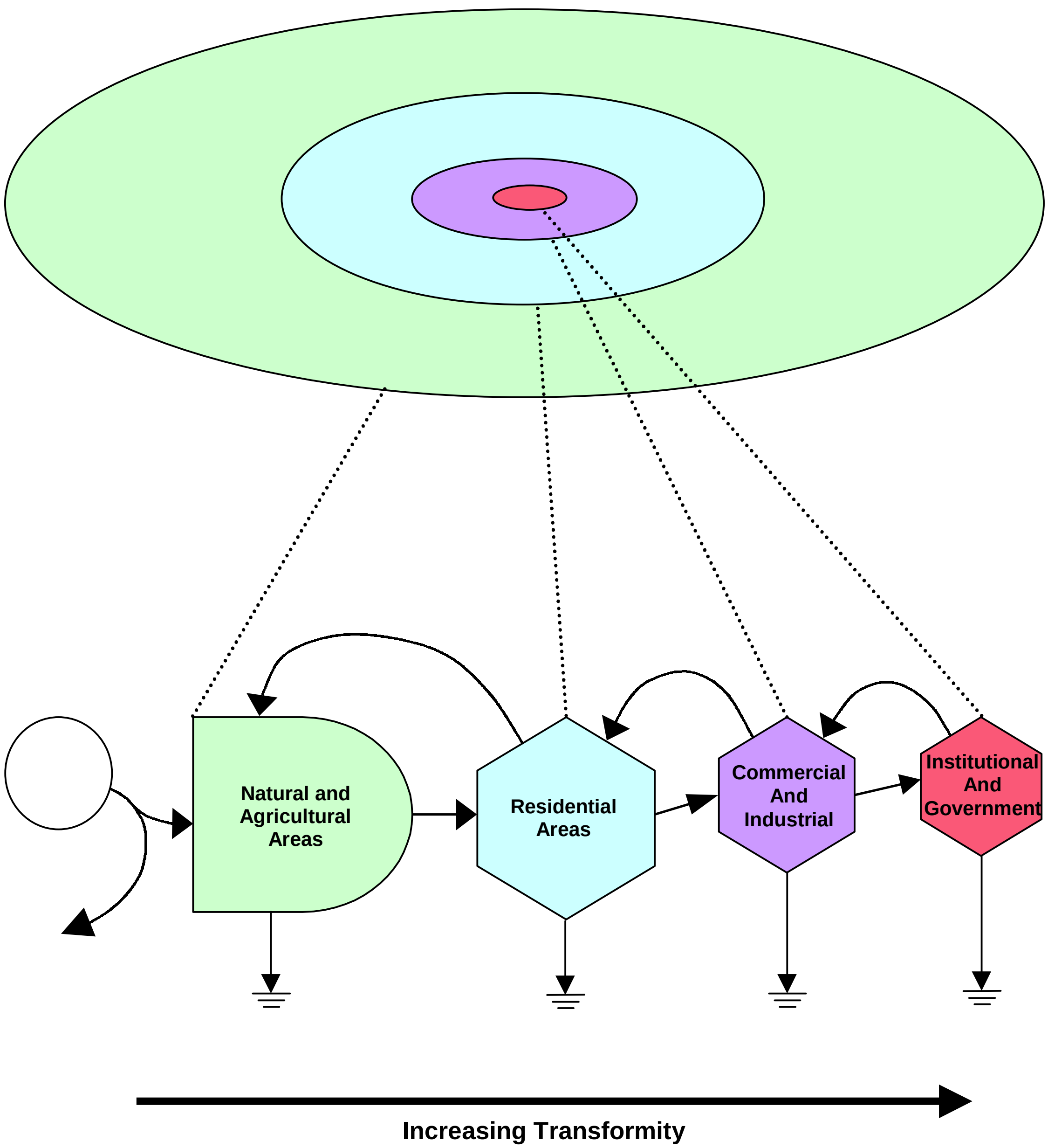


Figure 1-2: Conceptual diagram for the spatial arrangement of various elements of a regional landscape arranged in order of predicted transformity (adapted from Huang, 1998, and Brown, 1981).

Energy Signatures

Odum (1983) suggests that all systems self-organize to maximize power flow according to the energy sources that are available to the system. The term ‘energy signature’ has been used by Odum (1983) to describe the type and magnitude of energy flows to a particular system. The nature and magnitude of these energy sources helps determine the nature and magnitude of the productive processes and the storages that occur in the system. This concept can be applied to both ecological and economic systems. For instance, Twilley (1995) found that energy signatures could be used to predict the morphological structure and ecological processes of mangrove ecosystems, and Odum (1983) has used energy signatures to characterize the level of development of countries and regions.

These energy signatures are typically presented as bar graphs with the magnitudes of each of the various energy sources for the system accounted for in the same units of measure (for energy or EMERGY). Odum (1983) prefers that the sources be arranged from left to right on the graph in order of increasing transformity to improve understanding of the energy transformation hierarchy.

Whereas, the concept of energy signatures has been previously used to characterize total systems, it is proposed here that they could also be used to characterize distinct spatial units in the landscape. It is also proposed that the concept can logically be expanded to include the magnitude of storages that are within each spatial unit in the signature. An energy signature of areal land units that includes both energy flow and storage magnitudes (measured in units of the same kind—in this case, EMERGY) could be used as a multivariate land classification scheme that links classes with processes.

<u>Land Area Unit Model Diagram</u>

The unit model system diagram shown in Figure 1-3 is proposed as a general basis for spatial modeling of the EMERGY flows and storages in equal-size units of land area in an urban and/or regional system. The diagram shows how the EMERGY sources from outside the land area unit model system flow in and interact with other flows through production processes that maintain or build storages of EMERGY. This model does not attempt to model flows between different land area units—each unit is considered to be a separate unit model system with flows coming from unspecified points outside of the unit model system and going to unspecified points outside the unit system.

The spatial model created in this study is based on this diagram. In other words, the individual storage and flow components of the spatial model correspond to elements of the unit model system diagram. The diagrammatic elements that have corresponding components in the spatial model are numbered for cross-referencing in the text.

To create the spatial model, the magnitude of each energy flow into each land area unit and each energy storage within each unit was estimated based on the characteristics and features of each land area unit. The EMERGY associated with each energy flow or storage was calculated using the appropriate transformities for each type of energy flow or storage. Energy or EMERGY signatures for land area units are based on the magnitude of each flow and storage included in the diagram.

The horizontal dimension used in this study for the land area unit model was 100-meter squared (one-hectare). The vertical dimension of each land unit was 250 meters from the ground to the lower boundary and 100 meters from the ground to the upper boundary of the land area unit. The time dimension used in this study is one year.

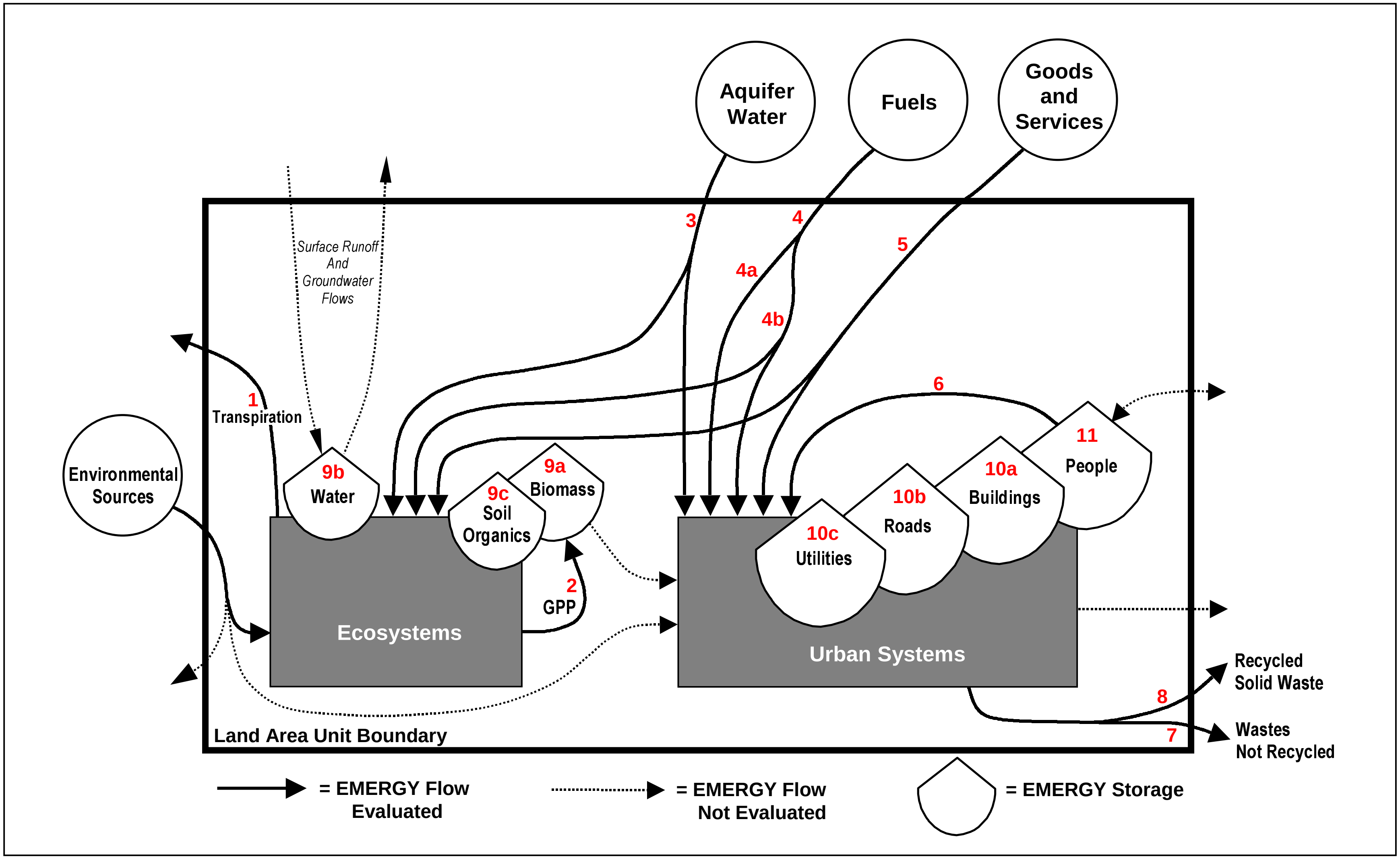


Figure 1-3: EMERGY flows and storages evaluated for each land area unit in the spatial model. Individual flow and storage elements have been numbered to provide cross-references in the text (see Figure 2-1). Note: GPP = gross primary production.

Technological Basis for the Study

Throughout much of modern civilization, the paper map has been the preeminent tool for studying and managing the spatial patterns of natural processes and human settlement. However, recent advances in computer technologies and in the field of geographic information sciences have resulted in the development of sophisticated geographic information systems (GIS) that offer a new paradigm for the study of spatial processes and patterns—the digital spatial model.

There has been dramatic growth in the use of GIS technology in the last decade. Most government agencies with land planning or management responsibilities have adopted the technology, and many have created, or are in the process of creating, GIS databases that describe the features of the land that they study, regulate, or manage. This phenomenon has resulted in the widespread public availability of government-developed GIS databases (Lambert and Zwick, 1997).

Typically these GIS databases have been created to support the very particular spatial information needs of the agency, but often they can be used for other purposes because of the general nature of the data. For example, GIS databases developed by property appraisers contain descriptive attributes and, most significantly, the location of buildings that can be used to precisely map the location of estimates for the storage of energy and EMERGY in urban structure.

Detailed municipal GIS databases that describe property, road, and utility structures form the basis of a new opportunity to examine the spatial distribution patterns of energy and EMERGY in more detail than has been possible using paper maps and traditional techniques. At the same time that the relevant digital spatial data have become available, the computer hardware with enough computational power to manipulate these large, complex databases is becoming less expensive. And finally, the capabilities of the GIS software have evolved to make working with large databases much more practical than in the recent past.

As previously stated, a secondary goal of this study is to demonstrate how recent advances in technology can be applied to the study of the spatial patterns and relations of energy flows and storages in landscapes. To a large degree, this study is made possible by the temporal convergence of three necessary ingredients—data, hardware, and software. It is hoped that by mixing these ingredients together with EMERGY theory that new insights will be revealed in the results.

Previous Studies of the Spatial Distribution of Energy in the Landscape

About two decades ago there were several studies conducted that used energy transformation hierarchy theory as a basis for studying urban and regional systems (Brown, 1973; DeBellevue, 1976; Littlejohn, 1973; Maltby, 1977; H.T. Odum, 1971; Regan, 1977; Sipe, 1977; Sipe, et.al., 1979; Steller, 1976; Zucchetto, 1975; Kangas, 1983). All of these studies used energy systems diagrams to model aspects of the urban system. Most of these studies used land use maps to estimate areas of different land uses. These area estimates were used to make estimates of energy flows and storages in the systems being studied.

Many textual references were made in these studies regarding the relationships between energy transformation hierarchy and the spatial patterns observed in the system being studied. However, if any maps were included, they were usually simple hand drawn diagrammatic maps that were used to document these relations or land use maps that were used to make the area calculations.

In 1981 an energy analysis workshop was conducted at the University of Florida to assess the research needs for developing a better understanding of the relationships between humanity and nature (Brown and Odum, 1981). Most of the primary research needs that were identified through this process were related to the need for a better understanding of how ecological and economic processes affect the spatial organization of landscapes.

There were several studies conducted about two decades ago that were specifically aimed at examining the spatial patterns of the distribution of energy flows and storages in regional landscapes as expressed in various embodied energy units. This body of research was the initial inspiration for this research work. All of these early studies used similar methods to estimate energy flows and storages per unit of area.

For instance, as part of the study ‘Carrying Capacity of Man and Nature in South Florida’ (Odum and Brown, 1976), Costanza(1975) studied the spatial distribution of land use subsystems in south Florida over the period from 1900 to 1973. He calculated the metabolism and structure for each subsystem by multiplying the energy flows and storages occurring in each subsystem by an energy quality factor and expressed the results in fossil fuel equivalents (FFE).

Costanza’s study used methods to measure areas of each land use that would be considered rather primitive when compared to today’s technological methods. First land use maps were prepared from air photos, then these maps were cut up into pieces and weighed to determine the area of each land use in each county. These rough area calculations were used to calculate subsystem energy flows and storages by multiplying the area times a generalized estimate of the flow or storage per unit area for each subsystem.

He produced coarse resolution regional maps showing the spatial distribution of incoming energies using isopleths, and spectral distribution graphs showing mean energy flow per unit area, referred to in this study as energy density. Energy flow per unit area was later referred to as power density (Odum, Brown, and Costanza, 1976).

Costanza (1979) utilized the data from this earlier research to build a spatial simulation model for south Florida. This model divided the south Florida region into 88 16 by 16-mile cells. This spatial model was linked to an energy diagram simulation model. According to Costanza, the model did a “fairly good job” of predicting the historical development of spatial patterns between 1900 and 1973.

Brown (1980) studied the hierarchical organization of urban and regional landscapes using embodied energy (expressed as coal equivalents, CE) as a basis for his calculations. He calculated the power density and volume of structure for 11 urban land uses. Urban power densities were calculated based on the embodied energy in the electricity and other primary fuels used, and on the embodied energy in goods and services. The power densities for natural ecological systems were measured by estimating the gross primary production of each type of system.

Brown calculated areas of land uses in his study areas in the same manner as Costanza, by cutting up land use maps and weighing the pieces. Estimates of direct energy use within urban land use classes were derived from representative samples of yearly energy consumption from utility records. These average figures were then multiplied by the number of acres of the corresponding land use class. Estimates of volume of structure per land use were also based on representative samples. Using a ratio of the embodied energy per dollar of assessed value of 20,000 Cal CE/$, Brown calculated an average figure for embodied energy in urban structure per acre of each category of land. Embodied energy in goods and services was assumed to be proportional to the consumption of direct energy (electricity and fuel). Brown used a ratio of 21,000 Cal CE/$ to calculate the embodied energy in goods and services.

Using these data, he produced a series of graphs that demonstrated the hierarchical distribution land use areas within his study areas and the phenomenon of increasing levels of embodied energy flows and storages with increasing complexity of land use. His study also demonstrated the hierarchical distribution of cities in Florida when measured by their total embodied energy flow and storage.

Alexander (1981) used a dynamic landscape simulation model of Flagler County, Florida to study the effects of regional development policies on settlement patterns. His model combined energy theory with thematic mapping methods developed by Ian McHarg (1969). The computer simulation model he used created simple maps using symbols (+, x,*,--, etc.) to plot out the spatial results. This is the first example (known to the author) where a computer-generated map was created that was based on energy transformation theory. Another early example of using computers to generate energy maps was a study by Richardson (1988) that used a simple, but general, dynamic simulation model to demonstrate how systems will self-organize spatially to maximize power flows from available sources.

A more recent study by Whitfield (1994) examined the spatial patterns of EMERGY flows and storages for Jacksonville, Florida. Whitfield evaluated the resource flows and storages for 17 different land uses in his study area. He used averaged figures for each land use to calculate the EMPOWER density, EMERGY storage, and transformity for each land use.

Whitfield's study includes a collection of graphs he called "resource use signatures" that show the amount of each resource flow by land use. Most significantly, he generated maps of the total EMERGY flows and storages for Jacksonville, as well as spatial profiles that he called "landscape signatures". These landscape signature graphs show the quantity of EMERGY flow or storage on the y-axis and the x-axis indicates the distance along a straight transect through the city. From these maps and profiles, the spatial pattern of resource use and structure in the study area is clearly evident.

In a recent study of energy hierarchies in the landscape, Huang (1998) studied the effects of the spatial convergence of energy on the evolution of spatial patterns of Taipei, Taiwan. He used a model (similar to Figure 1-2) to explain how Taipei is spatially organized to converge lower transformity energy flows from the natural and agricultural areas into areas of higher concentration, with the area of highest concentration (energy flow density) being at the urban center of the system. Huang (1998) observed that "…mutual non-linear interactions between population, area, and assets of each zone result in a self-organizing spatial system, from which an urban hierarchy evolves."

In this study, Huang estimated the magnitude of 14 different renewable and nonrenewable flows of energy and EMERGY for 1178 administrative districts in Taipei. He did not estimate energy stored in urban or natural structure, but implied that the level of urban structure develops in tandem with the level of energy density. Using the flow values estimated for each district, Huang used statistical analysis to cluster the districts into six energetic zones to simplify his model and describe the concept of energy convergence based on these zones.

Huang used the latest GIS technology to make maps and conduct analysis of spatial patterns. For instance, using the estimated flows, he generated maps of the individual flows, the combined renewable and nonrenewable flows, and EMERGY investment ratio maps. Several EMERGY indices were calculated for each of the energetic zones including: transformity of the zone, total zonal EMPOWER density, EMERGY investment ratio for the zone, and per capita EMERGY used in the zone.

Study Area

The area chosen for spatial modeling and study is Alachua County, Florida, USA. The map in Figure 1-4 shows where Alachua County is located in the State of Florida. The model is based on data from the years 1993 and 1994. According to the 1990 U.S. Census of Population (U.S. Census Bureau, 1992), the county had a population of 142,081 adults and 39,515 children. The county has a service-oriented economy with the largest employer being state and local government. There is very little industrial manufacturing, and only a small agricultural industry (cattle, vegetables, forestry).

The largest city in the county, Gainesville, is located in the center of the county, and there are several small towns distributed in a radial arrangement around Gainesville. Most (94%) of the population of the county works in the county, and most of the county's employers are located in the City of Gainesville. Gainesville is also the location of several regional shopping centers and regional hospitals and health service providers. The University of Florida is also located in Gainesville. The University exerts a strong influence on the spatial organization of the county in terms of the location of high-density housing, service providers, and road infrastructure.

The rural areas of the county are best described according to the eastern and western halves of the county. The eastern portion of the county is characterized by a fairly level landscape with many isolated small wetlands and several large lake, stream, and wetland systems. A large portion of the eastern half of the county is used for forestry production. There is relatively little population growth in this half of the county. In contrast, the western half of the county is characterized by upland forest types, pastures, and agricultural crop fields. There are no large lakes or wetlands in this half of the county. Compared to the eastern half of the county, the western half is experiencing dramatic residential development pressure radiating out from the City of Gainesville.

Alachua County was chosen because of the familiarity that the author has with the area. Familiarity was an important consideration for two reasons: first, because of the level of spatial detail obtainable by using one-hectare square areas for the land area unit spatial model; and second, because of the abstraction of this detail resulting from converting everything into energy and EMERGY terms. Although other potential study areas already had the spatial data that were required for this type of study, it was decided that it would be more advantageous to be very familiar with the detailed spatial patterns of the study area. Unfortunately, this decision meant that considerable effort had to be expended to develop several of the GIS databases (property parcels, buildings, roads, and land use classifications) that would be required to conduct the study.

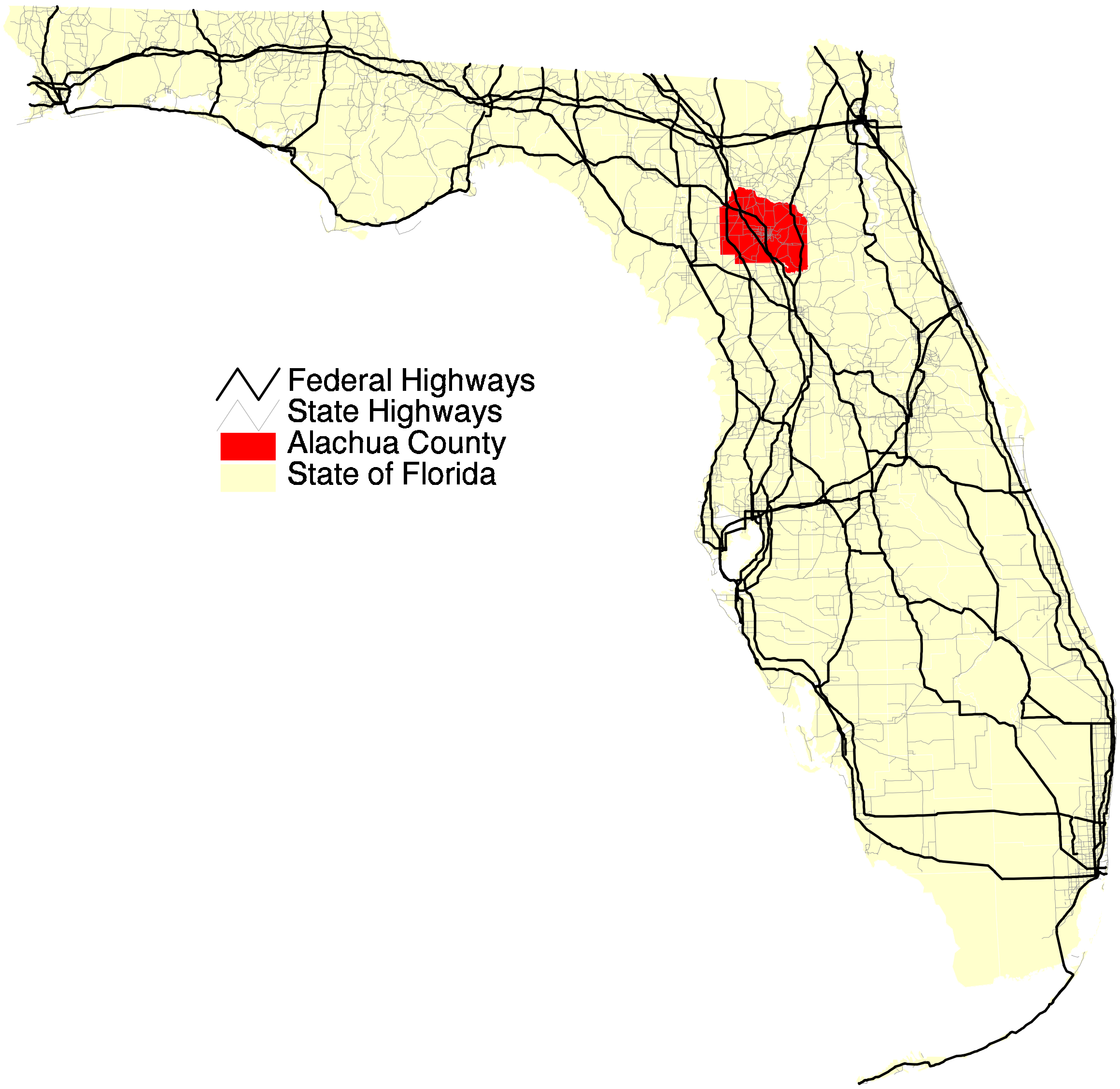


Figure 1-4: Location of the Alachua County study area.

Study Objectives

The primary objectives for this study are: 1) to develop a general theoretical approach for the spatial modeling of energy flows and storages in urban and regional landscapes; 2) to analyze the spatial patterns of energy transformation hierarchy and energy signatures in the study area using a specific implementation of the general model; and, 3) to demonstrate how GIS technologies and methods can be used to add new insight into spatial patterns of energy hierarchy by conducting analyses that would not be reasonable to do without GIS technology.

1) Develop a general theoretical method. The first objective is to develop a general method for the spatial modeling of energy flows and storages in an urban and regional landscape using energy transformation hierarchy theory and the land area unit diagram model as a theoretical basis.

The previous studies that were cited suggest that urban and regional systems may develop similar spatial patterns in terms of energy transformation hierarchies. However, the non-standard methods used in these studies can make direct quantitative comparisons of the results difficult. This study will demonstrate that the concept of a land area unit spatial model is a more general approach to modeling the spatial distribution of energy and EMERGY flows and storages.

2) Study the spatial patterns of energy hierarchy for the study area. The second primary objective is to study the spatial patterns of the energy transformation hierarchy in the Alachua County study area.

Because the target audience for this study is urban planners, the specific spatial model created for this study should be at a spatial resolution and scale that makes the results most useful from the viewpoint of the planner. The resolution of the spatial model should make it possible for planners to describe and study the energetic characteristics of the urban landscape in relation to more commonly used land area terms such as land use and zoning classifications and neighborhoods. The influence of prominent urban features, such as major roads or shopping centers, should be recognizable in the results.

3) Demonstrate the value added by using GIS technologies and methods. The third primary objective of the study is to demonstrate how GIS technologies and methods increase the potential for studying spatial relations in terms of energy hierarchy.

The availability of very detailed GIS databases of urban structural features and urban flows such as traffic counts and electricity usage makes very detailed spatial analysis possible. By using GIS analysis methods, patterns of energy distribution may be found in this detailed data that were not previously intuited. However, one may want to ask the question in the end as to whether or not the extra detail adds enough new insight to be worth the enormous effort required to manipulate the large amounts of data.

Organization of the Study

This study is organized around the creation, description, and use for analysis of a spatial EMERGY model of Alachua County, Florida. The model was created by using the values of descriptive attributes in several thematic GIS databases as the input for algorithms that estimate the flows and storages of energy and EMERGY. Detailed descriptions of the methods and algorithms used to create the model dominate the methods chapter of the study. In fact, the methods chapter was designed to be a ‘cookbook’ for others wishing to create similar models for other cities or regions.

A conscious effort was made to avoid as much GIS software-specific terminology in the methods chapter as possible. In other words, the methods were designed to not require a specific GIS software package for implementation—in fact, the procedures used should be available in most basic GIS software. However, some generic GIS terminology has been used for clarity. A familiarity with basic GIS methods will be required of someone wishing to create their own model using this approach.

The first section of the results chapter uses maps and basic statistics to describe the results for each of the individual components of the model. The model components are associated with a flow or storage that was represented in the land area unit model system diagram (Figure 1-3). An EMERGY and an energy map was made for each flow or storage represented in the model diagram. The model component maps represent energy flow density (joules/hectare/year), EMPOWER density (solar emjoules/hectare/year), energy storage density (joules/hectare), or EMERGY storage density, referred to in this study as "EMSTORAGE" (solar emjoules/hectare) for the component flow or storage.

In the second section of the results, appropriate energy and EMERGY component flows were added together to create "Total Energy density" and "Total EMPOWER density" maps. Transformity maps are presented that were created by dividing the "Total EMPOWER density" map values by the "Total Energy density" map values (solar emjoules/ joules). Similar maps were created for "Total" energy and EMERGY storage.

County-wide energy and EMERGY signature graphs are presented that were created by summing the all of the land area unit values for each of the component flows and storages. The county-wide signatures were created to characterize the whole study area as if the County were a single land area unit.

In the third section of the results, three comparative studies are presented that should be of particular interest to urban and regional planners. Comparisons of the energy and EMERGY characteristics (including energy and EMERGY signatures and transformities) are presented for land use classifications, planning units, and representative neighborhoods.

The fourth and fifth sections in the results present analyses that would be very difficult to conduct without using GIS technology. For instance, in the fourth section, EMERGY ratio maps were produced by dividing the values in one EMERGY component map by the values in another component map. Examples of the EMERGY ratio maps include the ratio of nonrenewable to renewable EMERGY—a possible index of environmental loading, and the ratio of EMERGY in urban structure to EMERGY in natural structure. In the fifth section, spatial context analyses were conducted that utilize the special capabilities of GIS technology. In the context analyses, the values of each land area unit were compared to the values of the contiguous units to generate several spatial context characterizations for each land area unit.

Finally, the last section of the results presents a version of the spatial model in which the land area units are one-square kilometer (compared to one-hectare). This version of the spatial model was created to be able to examine the effects of the size of the land area unit on the results, and to evaluate the usefulness of a more generalized model for planning applications.

METHODS

General Description of the Model

The spatial EMERGY model components. A general land area unit system diagram model describing the EMERGY flows and storages for each land area unit was presented in Figure 1-3. The spatial model that complements this diagram model includes both energy and EMERGY components that correspond to each of the diagram's storage and flow symbols. In the spatial model each component is modeled as a data set called a 'grid'. A grid is a spatial data set that divides the study area into equal-size, square land area units called 'cells'. Each cell contains a value corresponding to the magnitude of the flow or storage that the component grid represents.

The number of grids in the spatial model is directly related to the complexity of the diagrammatic model. For instance, urban structure can be represented by a single storage tank in the diagram and as a single component grid in the complementary spatial model. Or urban structure can be modeled more discretely with separate tanks in the diagram, and separate grids in the spatial model.

In the spatial model, a 'component grid' may be composed of the sum of two or more 'subcomponent grids.' For example, in the spatial model the 'urban built structure' component grid is the sum of the subcomponent grids representing the storages in the buildings, transportation infrastructure, and utility infrastructure.

A primary purpose of creating each of these subcomponent grids separately was to facilitate the processing of the original source GIS data layers. However, in this study subcomponent grids were also considered to be discrete elements of their associated component flow or storage that were potentially worthy of being used independently in planning analyses.

The concept of a subcomponent grid and it's related component grid in the spatial model is implicit. It may help to think of a subcomponent grid representing a storage as a compartment within a storage tank symbol in the diagram model, and a subcomponent grid representing a flow as one of the forks along a split flow symbol. Figure 2-1 illustrates these concepts.

Tables 2-1 and 2-2 list the component and subcomponent grids included in the spatial EMERGY model that was developed for this study. These tables include a cross reference to the numbers used in Figure 1-3 to identify the individual flow and storage elements in the land area unit diagram model that are included in the spatial model.

Any given component grid, or even a subcomponent grid, may also be the sum of one or more 'intermediate component grids'. The split flows shown in Figure 1-3 for water use (element #3), fuels used in buildings and agriculture (element #4b), and goods used (element # 5) were calculated using 'intermediate component grids'. Many intermediate component grids were created as intermediate steps in the creation of component or subcomponent grids. Unlike subcomponent grids, they exist, in this study, only to facilitate processing of original GIS data layers, and will not be considered explicitly in the general analysis of the model or any planning analyses. The intermediate component grids could, however, be used for more detailed analysis in future studies.

Table 2-1: Component and subcomponent (shown shaded) grids representing flows of energy and EMERGY that were included in the spatial model.

General Category	Description of Individual Flows Calculated	Figure 1-3 Item Number	Energy Component Grid Name	EMERGY Component Grid Name
Renewable Resources Used	Transpiration	1	renew_en	renew
Natural Systems Metabolism	Gross primary productivity	2	gpp_en	gpp
Water Used by Man	Water used for domestic, commercial, and agricultural purposes	3	wtruse_en	wtruse
Direct Use of Fuels and Electricity	Sum of use in buildings, grounds, agriculture, transportation	4	fuel_en	fuel
	Use for transportation	4a	trn_ful_en	trn_ful
	Use in buildings, grounds, and agriculture	4b	bag_ful_en	bag_ful
Goods/Services Consumption	Consumable and durable goods (and services) used	5	goods_en	goods
Human Services	'In situ' services from local people	6	service_en	service
Solid and Liquid Wastes	Solid/liquid wastes that are not recycled	7	waste_en	waste
Recycled Wastes	Recycled solid wastes	8	recycle_en	recycle

Table 2-2: Component and subcomponent (shown shaded) grids representing storage of energy and EMERGY that were included in the spatial model.

General Category	Description of Individual Storages Calculated	Figure 1-3 Item Number	Energy Component Grid Name	EMERGY Component Grid Name
Natural Systems Structure (includes agriculture, forestry, and urban forest)	Sum of biomass, surface and ground water, and organic matter in soils	9	natstr_en	natstr
	Biomass	9a	biostr_en	biostr
	Surface and groundwater	9b	wtrstr_en	wtrstr
	Organic matter in soil	9c	soilom_en	soilom
Urban System Structure	Sum of buildings, roads and utilities infrastructure	10	urbstr_en	urbstr
	Buildings	10a	bldg_en	bldg
	Roads	10b	road_en	road
	Utilities infrastructure	10c	util_en	util
People	Storage in humans	11	popstr_en	popstr

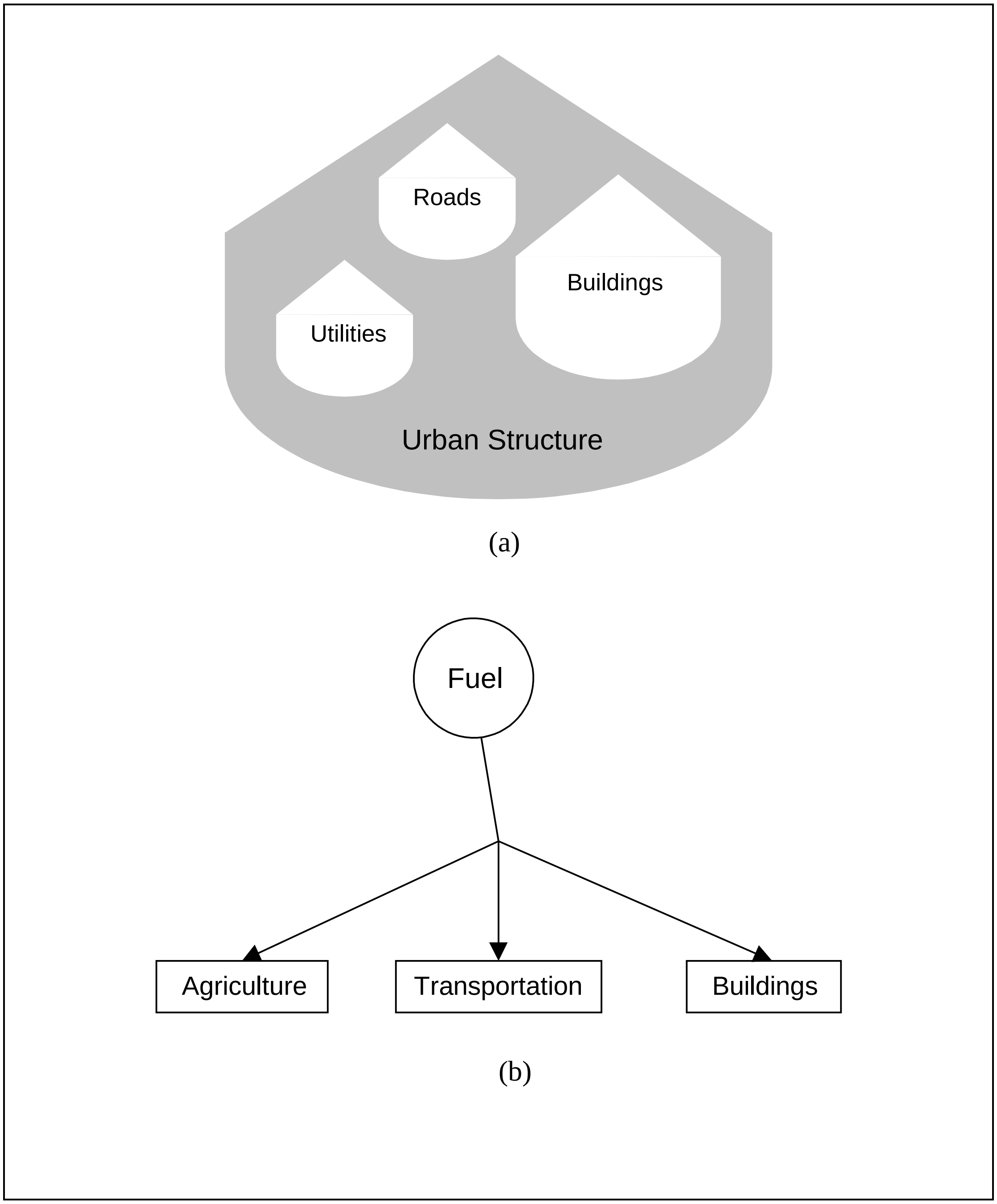


Figure 2-1: The relationship between a subcomponent grid and it's related component grid in the spatial model. One can think of a storage subcomponent grid as a compartment within a storage tank symbol (a), or a flow subcomponent grid as a split along a flow symbol line (b).

Size of Component Grid Cells. All of the grids in the model have a cell area of one hectare. Each square cell is 100 meters on each side. Each grid has 583 columns and 596 rows. This results in grids that have a total of 347,468 cells per grid. Only 252,581 cells have data associated with them because the area of the county does not fill the entire *square* grid. Each of the cells of each (sub)component grid is spatially coincident with cells in the other (sub)component grids.

Units of measure. The number associated with each grid cell in a (sub)component grid represents either the total energy or EMERGY stored or the total energy or EMERGY flow per year occurring in the geographic area of that cell.

The numbers for all component grids representing EMERGY storage are in units of solar emjoules per hectare (sej/ha) and are referred to as EMSTORAGE density values. The energy storage component grids are in units of joules per hectare (j/ha).

EMERGY flows are measured as the total annual flow of solar emjoules per hectare per year (sej/ha/yr). Energy flows are measured in units of joules per hectare per year (j/ha/yr).

EMPOWER has been defined as the EMERGY flow per unit of time and 'EMPOWER density' as the EMPOWER per unit of area (EMPOWER/area) (Odum, 1996). In this model, the numbers associated with each cell in each of the EMERGY flow component grids represent the 'component EMPOWER density' of each cell.

Geographic extent and time period. The spatial model covers the geographic extent of Alachua County, Florida. All calculations of EMERGY storage and flow were based on data from either 1993 or 1994. These years were chosen because of the availability of primary data and statistics. A single reference year for the model was not possible due to limitations imposed by data availability. All energy or EMERGY flow numbers only represent the total flow occurring for a period of one year, which occurred at some time during the two-year reference period. In some cases, calculations represent an average of data for the two years; in other cases, data were only available for one or the other of the two years. Materials with a turnover time of less than a year are calculated in the model as flows. Materials with longer turnover times are calculated as storage in the model.

Software and Hardware Used

GIS and imagery processing software. The primary GIS software used for this study was Arc/Info Version 7.1, a product of the Environmental Systems Research Institute, Inc. (ESRI), Redlands, California. Another ESRI software product called ArcView GIS Version 3.0 was also used extensively.

GIS software terminology. An effort was made to describe these methods in terms that do not require the reader to be familiar with GIS software-specific jargon. However, familiarity with a few terms is essential. In ESRI software terminology, a vector-type GIS data layer is called a ‘coverage.’ There are three basic categories of coverages based on the type of spatial feature that they represent: points, lines, or polygons. A raster-type GIS data layer is called a ‘grid’ (ESRI, 1996).

Computer hardware. Because of the intensive computer processing required for executing some of the steps in creating this model, a workstation computer (SUN Ultra1 Model 170 workstation, UNIX operating system) was used to create the model and perform the analyses. The initial development of the model required the use of approximately 6 gigabytes of disk storage. This large amount of disk storage was required primarily to facilitate the collection and processing o0f the raw GIS databases and for the manipulation of this raw data to create the final model. The model in its final form can be viewed and analyzed using far less expensive desktop PC computers.

Development of the GIS Database

The first major step in the development of the spatial EMERGY model was the development of a GIS database that would provide the type of information needed to estimate energy and EMERGY flows and storages listed in the previous tables. This required the collection, review, and processing of existing data, and subsequently, the creation of several new coverages.

Existing coverages. Over the past few years, many GIS databases have been created by various federal, state, and local government agencies in support of their specific missions. Many of these GIS databases for Florida have been collected and processed so that they have a standardized digital format (ESRI coverages) and map projection through the Florida Geographic Data Library (FGDL) project (Lambert and Zwick, 1997). In this study the FGDL map projection, described in Figure 2-2, was used for all existing and new coverages and grids. Approximately 100 GIS databases, including those available as a result of the FGDL project, were reviewed for their potential contribution to this study. Based on a review of the available databases, only a few were eventually used directly in the creation of the final model.

Projection	ALBERS EQUAL AREA
Datum	NAD27
Units	METERS
Spheroid	CLARKE1866
Parameters:	
1st standard parallel	24 0 0.000
2nd standard parallel	31 30 0.000
central meridian	- 84 0 0.000
latitude of projection's origin	24 0 0.000
false easting (meters)	400000.000
false northing (meters)	0.00000

Figure 2-2: Description of the map projection and coordinate system used for all coverages and grids in the GIS database and model.

Several of the databases that were not used directly still served important roles as ancillary, supporting data. For instance, municipal limits and boundaries of protected areas help one understand why a particular observed spatial pattern might have developed. There is also a potential for some of these databases to be used in the future for additional analyses.

New coverages. Based on the review of the existing databases, several new coverages had to be developed including parcels, buildings, and roads. The creation of these new coverages required a great deal of time and effort. However, they were indispensable inputs to the development of the model. The following sections briefly describe the methods used to develop these new coverages.

Property parcel coverage. The property parcel coverage was created by converting the Alachua County Property Appraiser's GIS database, in MapGrafix software format, into the Arc/Info GIS polygon coverage format. This effort required the development of a new software format conversion methodology (Lambert, 1996).

A property parcel coverage is a valuable primary data source for the development of this type of model because of the attribute data associated with each polygon feature. For instance, attributes associated with the built structures include dollar value of the structures, and the year they were built. Other attributes indicate the primary type of economic activity occurring on the parcel based on Florida Department of Revenue land use codes (FDOR, 1990) and total square footage of buildings. The property parcel coverage was also valuable as one of the intermediate data processing inputs for several of the final components of the model.

Building coverage. The creation of the building coverage was made possible by the creation of the property parcel coverage described above. The polygon centroids of those polygons in the parcel coverage that had a dollar value greater than zero for built structure were converted into a point-feature coverage.

The building coverage includes attribute data for all built structure on a property. For instance, there are attributes for the dollar value of miscellaneous structure such as fencing, driveways, etc. in addition to the primary building structures. Consequently, in some cases, point features may not represent buildings, but rather only other built structure. The attribution of the coverage allowed for consideration of these cases when calculating fuel use in buildings, etc., however, it was a complicating factor in the calculations, and may have introduced a few anomalies in some of the component grids.

All of the point features that were derived from polygons that were 10 acres or less in area, were assumed to approximate the location of the built structures accurately enough for the spatial resolution of the model. On the other hand, it was determined that the accuracy of the location of each of the point features that were derived from parcel polygons that were greater than 10 acres in size should be reviewed.

One objective of reviewing each of these point features was to identify those features with obviously anomalous locations, and to manually reposition the feature to a more likely location within the limits of it's originating polygon. Typical anomalous conditions included point features in the middle of lakes or wetlands. A second objective of this review was to identify, and reposition if necessary, those point features with dollar values greater than one million. A 1995 SPOT panachromatic satellite image

(10-meter resolution) was a used as an aid to reposition each point feature to its most probable location within its originating parcel polygon. All of this tedious work was necessary because the spatial accuracy of the building point coverage would be reflected in several of the final components of the model that would be derived from various attribute data associated with the building coverage.

Road coverage. A new road coverage had to be created because the existing coverages for roads were not spatially accurate enough for the model and did not have the descriptive and quantitative attributes needed to calculate estimated EMERGY flows and storages.

The initial spatial data for this new coverage was converted from several AutoCad digital format files that were created as part of the Alachua County Control Densification and Identification of Land Corners Project (Southern Resource Mapping Co., 1990). This relatively spatially-accurate digital map of the roads of Alachua County was derived from 1988-vintage aerial photography. New roads, built since 1988, were added to the coverage using the parcel coverage as a guide.

Attribute data for functional classification, number of lanes, and estimated average annual daily traffic was added to each road segment in the coverage (ADOT, 1995, and FDOT, 1995). These attribute data were necessary for the EMERGY storage and flow calculations as described in later sections.

Land use and cover coverage. A county-wide land use and cover coverage was created for this study by combining the pre-release version of the 1995 Suwannee River Water Management District (SRWMD) land use and cover coverage (SRWMD, 1995) with the 1990 St. John's River Water Management District (SJRWMD) (May, 1993) land use and cover coverage. Both coverages were derived from aerial photo interpretation, and are based on the Florida Land Use and Cover Classification System (FLUCCS) (FDOT, 1985). This resulted in a hybrid land use and cover coverage based on different dates. Fortunately, this did not affect the analysis appreciably because the small portion of the county not included in the SRWMD coverage was in the southeast portion of the County. This part of the County had not changed much since 1990 (based on a review of the 1990 data using the SPOT panachromatic satellite imagery for 1995 for comparison).

General Methods for Creating Component Grids

The general methods used to process the primary data coverages into the (sub)component grids of the spatial model are described in this section. Other (sub)component-specific methods are described in later sections.

Analytical Coverages

Each of the (sub)component grids created was actually derived from an 'analytical' coverage that was created to facilitate the calculations required in this study. These 'analytical' coverages are significantly modified versions of the existing or new 'raw' primary data coverages.

Every 'analytical coverage' has had several new data items added to its feature attribute table to facilitate the energy and EMERGY calculations. Each analytical coverage has also been 'overlaid' with a county-wide polygon coverage, called 'alanet100cov', which is comprised of 100-meter square polygons corresponding to the one-hectare cells in the final model. Other unique modifications to specific analytical coverages are described in later sections.

Each of the model's component grids was created by first making energy and EMERGY calculations based on attribute data contained in the analytical coverages, and then converting the analytical coverages into grids using methods developed for each type of coverage (i.e., point, line, polygon).

Figure 2-3 describes the general conversion steps that were used for all types of analytical coverages, and the following sections discuss specific methods for point, line, or polygon-type analytical coverages. The unique energy and EMERGY calculations and methods used to create each of the intermediate, subcomponent, or component grids in the model are described in later sections. The actual file names of each grid or coverage created in this study have been used in this report to facilitate the use of the GIS digital database (which will be published separately on CD-ROM) by other researchers.

(Sub)Component Grids from Point-feature Coverages

The following steps were used to convert all of the analytical coverages that were comprised of point features into the grids used in the model. The method was designed to convert these point coverages into grids that have individual cell values that represent the sum of all of the energy or EMERGY values (for a particular flow or storage) calculated for the point features found within the area of each one-hectare cell.

Step One
Overlay analytical coverage with 100-meter square polygons
of the 'alanet100cov' coverage to transfer the
unique 'id' for each polygon (found in the 'emgrid-id' attribute item)
to the spatially coincident features in the analytical coverage.

Step Two
Calculate the amount of energy and EMERGY
that is associated with each feature in the analytical coverage
using appropriate values in the feature attribute table.

Step Three
Create a 'summary data table'
that contains values for the total energy or EMERGY
of all point, line, or polygon features that is summarized by
the 'unique id' of each 100-meter-square polygon.

Step Four
Merge the 'summary data table' with the feature attribute table of the
'summary coverage' called 'emnet100cov' using the values in the
'emgrid-id' attribute items (the unique id of the 100-meter-square polygons)
of both tables as the relational values.

Step Five
Create the energy or EMERGY grid
using the POLYGRID Arc/INFO command
and the appropriate item in the 'emnet100cov' feature attribute table
as the data input source for the command.

Figure 2-3: General steps used to convert all analytical coverages into the intermediate, sub-component, or component grids.

Step 1: Each analytical point coverage was overlaid with a polygon coverage called 'alanet100cov' using the Arc/Info IDENTITY command (ESRI, 1996). This step only needs to be executed once for each of the analytical coverages.

The 'alanet100cov' coverage divides the entire county into 100-meter-square polygons that are spatially coincident with the grid cells in the final model. Each polygon in the 'alanet100cov' coverage has a unique identification number stored in an attribute item called 'emgrid-id'. As a result of the overlay operation, every point feature that falls within the area of any one the polygons in the 'alanet100cov' coverage, as illustrated in Figure 2-4, is attributed with the same unique identification number from the 'alanet100cov' coverage.

Step 2: The amount of each energy or EMERGY flow or storage associated with each point feature was calculated using the appropriate attribute items in the point feature attribute table. The specific calculations for each type of energy or EMERGY flow or storage are described later.

Step 3: The Arc/Info STATISTICS command (ESRI, 1996) was used to create a summary database table of the total energy or EMERGY of all point features found within each 100 meter-square polygon.

Step 4: This summary database table was then merged (using the unique number in the 'emgrid-id' attribute item as the relational item value) with the polygon attribute table of the 'emnet100cov' summary coverage using the Arc/Info JOINITEM command (ESRI, 1996).

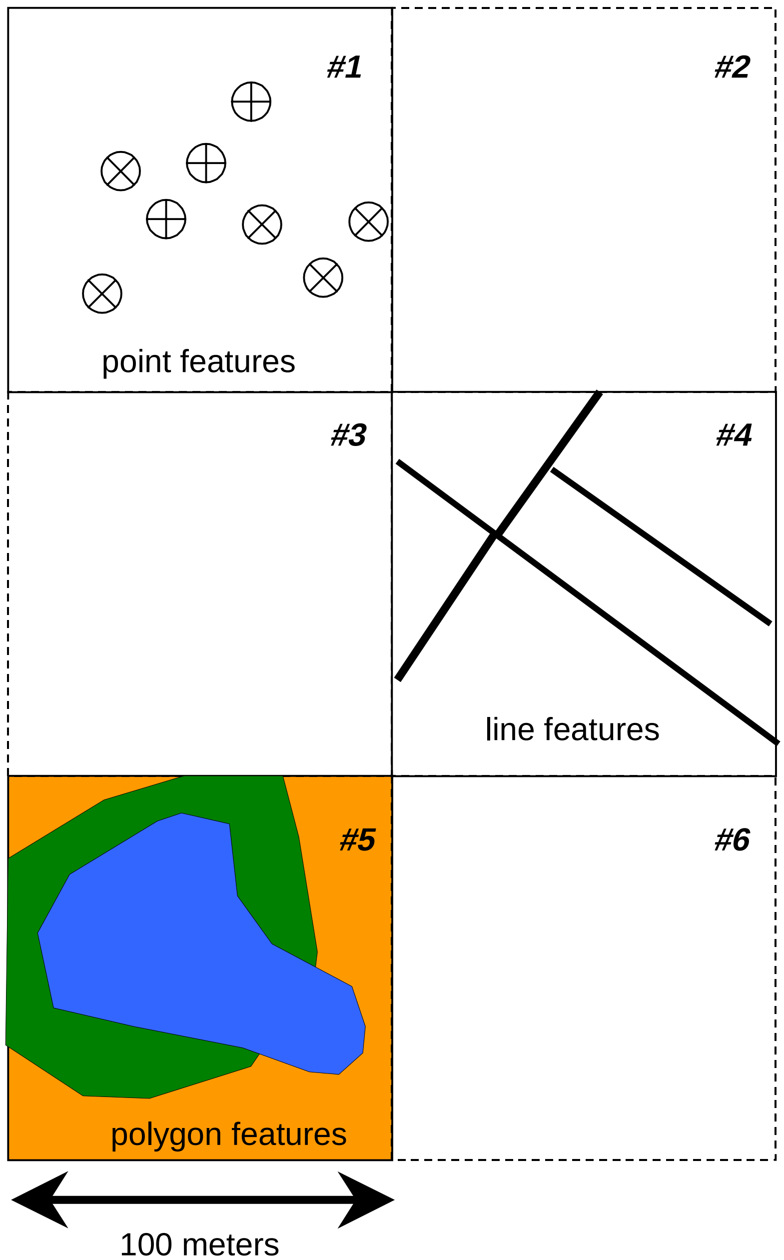


Figure 2-4: Each analytical coverage was overlaid with a polygon coverage that divides the entire county into 100 meter-square polygons. These polygons are spatially coincident with the grid cells in the final model. Each polygon in the 'alanet100cov' coverage has a unique identification number stored in an attribute item called 'emgrid-id'. As a result of the overlay operation, every point, line, or polygon feature that falls within the area of any one the polygons in the 'alanet100cov' coverage is attributed with the same unique identification number from the 'alanet100cov' coverage. As illustrated above, polygon and line features are split at the points of intersection with each of the 100-meter square polygons.

The ‘emnet100cov’ summary coverage has the same 100 meter-square polygons (which are spatially coincident with the grid cells in the final model) with the same unique numbers (in the ‘emgrid-id’ attribute) as the ‘alanet100cov’ coverage. The ‘emnet100cov’ summary coverage was used to store all of the final summarized energy and EMERGY data for each polygon.

Step 5: Each final intermediate, subcomponent, or component grid was created by executing the Arc/Info GRID function POLYGRID (ESRI, 1996) using the summarized values for energy or EMERGY flows or storages from the appropriate attribute items in the ‘emnet100cov’ summary coverage as the input source for the POLYGRID function. The values in the resulting grid represent the total energy or EMERGY of all of the point features within each 100 meter-square area.

(Sub)Component Grids from Line-feature Coverages

The following steps were used to convert all analytical coverages that were comprised of linear features into the grids used in the model. Similar to the previous method employed for conversion of point features, this technique was designed to convert line feature coverages into grids that have individual cell values that represent the sum of all of the energy or EMERGY values calculated for the linear features found within the area of each 100 meter-square cell.

Step 1: Each analytical line coverage was overlaid with the polygon coverage called ‘alanet100cov’ coverage using the Arc/Info IDENTITY command (ESRI, 1996). In contrast to performing this operation on point coverages, in which the point features do not get altered in any way other than receiving an additional attribute, this overlay operation significantly alters the structure and number of linear features. Essentially, all linear features are ‘split’ at each of the points where they intersect the border of any one of the 100-meter-square polygons in the ‘alanet100cov’ coverage (see Figure 2-4).

Each line feature in the modified analytical coverage retains the values for each of its attributes except for the ‘length’ attribute. The value of the ‘length’ attribute is recalculated to reflect the length of the feature that is within each 100 meter-square polygon. This step needs to be executed only once for each analytical coverage.

Step 2: As a result of step one, each of the split linear features has an ‘emgrid-id’ attribute item value indicating which of the 100 meter-square polygons in the ‘alanet100cov’ coverage it is located within.

The amount of energy or EMERGY flow or storage associated with each feature was then calculated using the appropriate attributes multiplied times the length of the segment of the feature that is contained within each of the polygons. The specific calculations for each type of energy or EMERGY flow or storage are described later.

Step 3: The Arc/Info STATISTICS command (ESRI, 1996) was used to create a summary database table of the total energy or EMERGY of all the line features found within each 100 meter-square polygon.

Step 4: This summary database table was then merged (using the unique number in the ‘emgrid-id’ attribute item as the relational item value) with the polygon attribute table of the ‘emnet100cov’ coverage using the Arc/Info JOINITEM command (ESRI, 1996).

Step 5: Each final intermediate, sub-component, or component grid was created by executing the Arc/Info GRID function POLYGRID (ESRI, 1996) using the summarized values for energy or EMERGY flows or storages from the appropriate attribute items in the ‘emnet100cov’ summary coverage as the input source. The values in the resulting energy or EMERGY grid represent the total energy or EMERGY of all of the linear features within each 100 meter-square area.

(Sub)Component Grids from Polygon-feature Coverages

The following steps were used to convert all analytical coverages that were comprised of polygon features into the grids used in the model. This technique was designed to convert polygon feature coverages into grids that have individual cell values that represent the sum of all of the energy or EMERGY values calculated for the polygon features found within the area of each 100 meter-square cell.

Step 1: Each analytical polygon coverage was overlaid with the polygon coverage called ‘alanet100cov’ coverage using the Arc/Info IDENTITY command (ESRI, 1996). In a manner similar to the ‘splitting’ of linear features, and in contrast to point feature coverages, each polygon in the coverage is ‘split’ along the borders of any one of the 100 meter-square polygons. This effect is illustrated in Figure 2-4.

Each resulting polygon feature retains the values for each of its attributes except for the ‘area’ attribute. The value of the ‘area’ attribute is recalculated to reflect the area of the feature that is within each 100 meter-square polygon. This step only needs to be executed once for each analytical coverage.

Step 2: As a result of step one, each of the split polygon features has an ‘emgrid-id’ attribute item value indicating which of the 100 meter-square polygons it is located within. The amount of energy or EMERGY flow or storage associated with each feature was then calculated using the appropriate attributes multiplied times the area of the feature that is contained within each of the 100 meter-square polygons. The specific calculations for each type of energy or EMERGY flow or storage are described later.

Step 3: The Arc/Info STATISTICS command (ESRI, 1996) was used to create a summary database table of the total energy or EMERGY of all the features found within each 100 meter-square polygon.

Step 4: This summary database table was then merged (once again, using the unique number in the ‘emgrid-id’ attribute item as the relational item value) with the polygon attribute table of the ‘emnet100cov’ coverage using the Arc/Info JOINITEM command (ESRI, 1996).

Step 5: Each final component grid was created by using the Arc/Info GRID function POLYGRID (ESRI, 1996) and the summarized values for energy or EMERGY flows or storages from the appropriate attribute items in the ‘emnet100cov’ summary coverage as the input source. The values in the resulting intermediate, sub-component, or component grid represent the total energy or EMERGY of all of the polygon features within each 100 meter-square area.

Specific Methods for Creating Flow Component Grids

The following sections describe the specific calculations and methods used to create each of the energy and EMERGY flow component and subcomponent grids for Alachua County that were listed in Table 2-1 and diagrammed in Figure 1-3.

Natural System Flows—Gross Primary Productivity

The renewable, environmental energies available to a system include sunlight, deep earth heat, tides, surface wind, physical and chemical energy of rain and rivers. Through photosynthesis, plants have the ability to efficiently capture and process these natural energy flows, thus play the role of the primary production component of the world's natural ecosystems. Science has devised many ways of measuring the value of the contributions made by the earth's vegetation, but one of the most basic ways of assessing the amount of work contributed by plants is to measure their gross primary productivity. Gross primary productivity is a measure of the total energy captured, or organic matter created, by green plants per unit surface and time. The proportion of this production that is left after respiration is called net primary production (Whittaker, 1970, E. P. Odum, 1971).

Gross primary productivity is a more appropriate measure to use for this study than net primary productivity because it still recognizes the value of production for the maintenance of structure, as in the case of 'climax' forests, when net production is often very low (Bernatzky, 1978, Waring and Schlesinger, 1985, Packham et al.., 1992, Tivy, 1993). Several studies similar to this one (Costanza, 1975, Brown, 1980, and Whitfield, 1994) have used gross primary productivity (GPP) for similar reasoning.

Unfortunately, GPP is difficult to measure except in laboratory experiments or by inference from net production (Whittaker and Marks, 1975). Consequently, data on GPP for ecosystems are very limited. A major effort to measure the primary productivity of the world's ecosystems was conducted in the 1970s called the International Biological Program (IBP) (National Academy of Sciences, 1975). The focus of this coordinated research effort was to measure net primary productivity (NPP) and biomass of the world's ecosystems (Lieth, 1975, Lieth, 1978). As a result of these efforts, many estimates of NPP and biomass have been published from which GPP can be extrapolated (Art and Marks, 1971, Rodin et al., 1975, Leith, 1975, Olson, 1975, Reichle, 1981). Similar efforts continue today in recognition of the importance of the role of global forest resources in the global carbon cycle (Apps and Price, 1996, Archibold, 1995).

Satoo (1982) pointed out that estimating GPP from NPP can, however, be difficult because it depends on respiration rates that vary in relation to both environmental and stand conditions. For instance, the proportion of GPP that is measured as NPP varies with temperature, season, and age of stand. Complicating the issue further, these early measurements are coming under scrutiny recently because they often only estimated aboveground biomass (Long et al., 1992). Despite these difficulties in measuring GPP accurately, it is conceptually an appropriate measure of the work contributed by the vegetative component of natural systems.

Whereas GPP is a measure of the work contributed by natural systems, it is not a measure of the amount of natural, renewable energies used in the production. Odum

(1983, 1996) suggests a method of deriving a reasonable measure of the EMERGY from renewable sources that is used by terrestrial ecosystems is to use the amount of water transpired by the ecosystem. The EMERGY in transpired water is in effect an integration of the EMERGY in sun, wind, and rain, and avoids double-counting of these inputs (Odum, 1996). In cases where additional EMERGY sources (which may be non-renewable) are significant to production, the EMERGY of these sources must be added as well to find the total EMERGY contributing to GPP. Transformities for the GPP of natural systems can be calculated by dividing the total EMERGY contributing to GPP by the energy in GPP.

Gross primary productivity (GPP) was used in this study as a measure of the work contributed by natural systems. The amount of water transpired by ecosystems was used as a measure of the amount of natural, renewable energies used in the work provided by these ecosystems (Odum 1983, 1996). Additional non-renewable EMERGY sources that were significant to production, were added to the total EMERGY contributing to GPP. Transformities for the GPP of natural systems were calculated by dividing the total EMERGY contributing to GPP by the energy in GPP. Calculations for important ecosystems in Alachua County (as they were classified by the land use and cover coverages) were done to determine energy in GPP, natural and cultural EMERGY flows contributing to GPP, and transformity of GPP for each ecosystem.

The ‘em_landcov’ analytical coverage. The coverage used to create this component of the spatial model was the analytical coverage called ‘em_landcov’. This coverage was created in an attempt to more precisely model the variation found in urbanized landscapes than would be possible with the original land use and cover coverage described earlier. For instance, the areas occupied by roads are not identified in the land use and cover coverage (except in cases of major four-lane or interstate roads). Consequently, a method was devised to ‘buffer’ (using the Arc/Info BUFFER command (ESRI, 1996)) the linear road coverage features (by a factor considering number of lanes and average lane width) so that these paved areas, which do contribute any GPP and do not use environmental flows in the same manner as natural systems, could be treated differently from the areas with natural systems. Following the same reasoning, the areas covered by the footprints of buildings were identified and buffered (according to the square footage of the building) so that these areas could also be treated differently from the natural systems.

Another characteristic of the original land use and cover coverage is that some land use classification categories, such as the residential, commercial, and industrial classes, do not refer to any type of land cover (or natural system). In these cases, assumptions were made about the type of natural systems found in these categories. Based on personal observation, the typical Alachua County low- and medium-density residential yard consists of large trees with an understory that has been cleared in a zone adjacent to the dwelling and replaced with turfgrass, ornamental shrubs, and flowers. This maintained zone of residential landscape is supported by a significant amount of non-renewable energy sources. In an effort to estimate the areal extent of these maintained landscape zones, the building footprints were buffered by an additional 10 meters.

Other land use classifications, such as high-density residential, commercial, etc., are assumed to have proportionately less vegetation in the maintained landscape zone than low- and medium-density residential land uses because of larger proportions of the area used for parking lots, etc.. In the cases of more intensive land use types, such as shopping malls and industrial sites, estimates of proportionately less vegetation were made and applied to the entire area of the land use.

Data processing steps. The following generalized data processing steps were used in creating the analytical coverage ‘em_landcov’ and the gross primary production components of the spatial EMERGY model (element # 2 in Figure 1-3).

Step 1: The roads coverage was buffered based on an algorithm whereby the number of lanes of each road segment was multiplied by 2.5 meters to calculate the buffer distance used for each segment. The resulting buffered road polygon is twice as wide as the buffer distance. For example, a 4 lane road is assigned a 10 meter buffer distance resulting in a 20 meter wide polygon representing the paved area of the road. The buffered road coverage was then unioned with the original land use and cover coverage.

Step 2: The point features in the ‘building’ coverage that had a total building and miscellaneous value of less than $10,000 were deleted from the building coverage. These features were not considered for buffering as building footprints because most of these features only represent miscellaneous ‘improvements’ rather than actual residential or commercial buildings (52,411 point features remained out of a total of 57,421 features in the building coverage).

The remaining point features were buffered according to the square footage of the building to create the building footprint coverage. Estimates of the square footage were made for buildings where data was not present (2,334 features) by dividing the total value of the building by 50 (assuming $50/sq.ft.). The buffer distance used to buffer point features is the radius of a circle. The radius of the building footprint buffer (resulting in a circle) was calculated based on square footage of the building using the following equation:

$$(.305 \text{ m/ft})(\text{sqrt}(\text{totsqfoot}/3.14)) = \text{buffer distance in meters}$$

Finally, the building footprint coverage was unioned with the intermediate land use and cover coverage that was previously unioned with the buffered roads.

Step 3: The building footprint coverage was buffered by 10 meters to represent the area of the managed landscape that surrounds the buildings. As noted earlier, this 10 meter buffer distance is based on field observations in Alachua County. In an effort to introduce a measure of the natural spatial variation that is found in the urban landscape, the actual size of these buffered areas were purposefully made slightly random by introducing a coarse ‘fuzzy tolerance’ into the buffering algorithm. The resulting coverage was unioned with the last version of the land use and cover coverage to yield the final analytical coverage, called ‘em_landcov’, that includes areas of buffered roads, building footprints, and maintained landscape.

Step 4: Additional attribute items were added to the ‘em_landcov’ feature attribute table in order to calculate the EMERGY flows occurring through each classified polygon in the ‘em_landcov’ coverage.

Estimates of GPP per hectare were made for representative ecosystems. These estimates were converted from flows per hectare to flows per meter-squared. Each land use or cover class was assigned a flow/m^2 /yr value according to the most closely corresponding value calculated for a representative ecosystem, or in the cases of some commercial and industrial classifications, by assigning a value that has been proportionately reduced by a factor to estimate the amount of vegetation typically present on that type of land use. The flow/m^2 /yr rate assigned to each polygon was multiplied times the area of the polygon so that the total flow for each cell could be summed.

Step 5: The coverage was then processed according to the methods described previously for converting polygonal feature coverages into the EMERGY and energy component grids, called 'GPP' and 'GPP_EN', for gross primary productivity of natural systems.

Natural System Flows—Renenewable Sources

Renewable environmental energy flows are the basis of all natural processes and contribute to all economic processes. Each area on the earth's surface has several types of natural energy sources that contribute renewable energy and EMERGY to the natural and economic systems of the area. Odum (1983, 1996) has pointed out that the combination, frequency, and quantity of these environmental energy sources is reflected in the character of both the area's ecosystems and economic systems.

In Alachua County, sun, wind, and rain are the predominant local sources of natural energy. Rainwater ends up either being used for transpiration by ecosystems or flowing into streams, lakes, and aquifers. In this study, the geopotential energy in runoff water and streams was assumed to be a minor source of natural energy because of the relatively flat landscape of the county.

A notable exception to this assumption is the Santa Fe River, which flows along the northern boundary of the county. However, due to technical limitations of the relevant coverages, this important feature could not be included in the present form of the model. The storage of water in streams, lakes, and aquifers is however included in the model and is discussed later.

Odum (1996, 1983) cautions against ‘double-counting’ in evaluating the total EMERGY contributed by geobiospheric processes (from sun, wind, rain, waves, land cycles, etc.) to local areas of natural systems. For instance, he points out that, from a global perspective, sun, wind, and rain are all coproducts of the same global climatic process. Hence, the EMERGY content of rainfall contains EMERGY from sun and wind. In order to avoid double-counting the EMERGY of geobiospheric sources, Odum has shown that for any local area the largest geobiospheric input of EMERGY should be used to account for the total contribution of EMERGY from these global processes.

In consideration of this principle, calculations for representative one-hectare areas within Alachua County were made and it was revealed that the largest geobiospheric input of EMERGY comes from chemical potential energy of rainfall. In this model, transpiration by ecosystems was considered to be the primary use of this rainfall within any given one-hectare cell of the model. The rainfall that is not used in transpiration either recycles through evaporation, or contributes to long-term groundwater and lake storages. The chemical potential energy of the rainwater that is used in the process of transpiration in ecosystems integrates the combined inputs of the energy in sunlight used and wind absorbed and thus represents the total amount of EMERGY used from renewable geobiospheric sources without double-counting. This procedure assumes land use and its erosion is the same EMPOWER or less than the global annual budget.

The coverage used to create this component of the spatial model was the analytical coverage called ’em_landcov’ that was also used for the creation of the gross primary production component grids.

Calculations made previously to determine the energy and EMERGY in gross primary production included estimates of the energy and EMERGY in transpiration for each of the ecosystems represented in the county. These calculated values for energy and EMERGY in transpiration were also used to create this component of the model.

The previous section described how building and road footprints were added to the ‘em_landcov’ analytical coverage to more precisely model the type and amount of natural systems present in any one-hectare cell. For these calculations, transpiration flow values were not assigned to the building and road footprint polygons. Instead, the amount of annual sunlight energy and EMERGY received by each building or road footprint polygon was used to assign a value to those polygons.

<u>Data Processing Steps.</u> The following data processing steps were used to create the RENEW_EN and RENEW component grids that represent the amount of renewable energy and EMERGY used (element # 1 in Figure 1-3).

Step 1: Additional attribute items were added to the ‘em_landcov’ feature attribute table to facilitate calculations for the amount of transpiration per unit of area for each type of ecosystem or land use, and the corresponding energy and EMERGY flows. Energy and EMERGY calculations were made for the building and road footprint polygons by multiplying the annual solar insolation rate for Gainesville, Florida ((5.95 E9 j(sej)/m2/yr)(Odum 1996)) by the area of the polygon.

Step 2: The coverage was then processed according to the methods described previously for converting polygon feature coverages into the energy and EMERGY component grids.

Urban System Flows—Water Consumption

This component grid models the energy and EMERGY in water used by humans for domestic, commercial, and agricultural purposes (see element # 3 in Figure 1-3 and note the split flow to urban and agricultural systems). Since water used in agriculture is transpired, there is a small amount of double counting of the EMERGY calculated for agricultural renewable resources use.

According to Marella (1992 , 1993), in Alachua County, an estimated 52.12 million gallons of groundwater per day (Mgd) were withdrawn from the Floridan aquifer in 1990, while only .36 Mgd were withdrawn from surface waters. Of this total for the county, an estimated 22.95 Mgd was withdrawn for public-supply use, and 14.75 Mgd of this was used at residences. Thirteen utility companies provided water to a total of 142,104 customers in 1990. About 88% of these customers were served by Gainesville Regional Utilities, and the rest were served by minor utilities in the smaller cities. Self-supply wells supplied the majority of the water needs of those outside of the public-supply service areas. Agriculture was the largest self-supplier, using an estimated 18.45 Mgd of water for crop irrigation and raising of livestock.

The creation of the final component grid representing the energy and EMERGY in water used by humans for domestic, commercial, and agricultural purposes required that several intermediate component grids be created. The ‘em_resbldgcov’ analytical coverage was used to estimate the quantities of water used for domestic purposes. The point features in the 'em_resbldgcov' analytical coverage are a subset of the original 'buildings' coverage, which represent residential buildings only. The point features in the 'em_combldgcov' analytical coverage (which include all other buildings not in the 'em_resbldgcov' coverage, i.e., commercial, institutional, agricultural, and industrial buildings) were used to estimate the quantities of water used for commercial, industrial, and institutional purposes. The use of these analytical point coverages was determined to be the most appropriate, and consistent, method of calculating and locating domestic, commercial, and industrial water use because most of the water is used inside of, or very close to, buildings. On the other hand, agricultural water use was estimated using the analytical polygon coverage called 'em_agwtrcov' because agricultural water use is often distributed over larger areas.

It was determined that different transformities should be used for public-water supply and self-supplied well water. The transformity for water supplied by public utilities has a higher transformity, assumed to be 665714 sej/j (Odum, 1996), than self-supplied well water, assumed to be 255242 sej/ j (Odum, 1996), because of the additional energies required to process the water and supply it to the end-user. Consequently, it was necessary to create a coverage of approximate municipal water service boundaries, called 'munwtrbnd', that would facilitate the calculations of EMERGY in water used based on whether or not the water was from a public water utility or a well.

Four sets of intermediate component grids (described in Table 2-3) were created and then 'added' together to create the final water use component grids.

Table 2-3: Intermediate grids that were used to calculate the total energy and EMERGY of water use in buildings and agriculture.

Intermediate Grids	**Description**
RES_WTR	EMERGY of domestic water used
RES_WTR_EN	energy of domestic water used
COM_WTR	EMERGY of Comm/Industrial/Institutional
COM_WTR_EN	energy of Comm/Industrial/Institutional use
BLD_WTR	Sum of RES_WTR and COM_WTR
BLD_WTR_EN	Sum of RES_WTR_EN and COM_WTR_EN
AGR_WTR	EMERGY of agricultural water used
AGR_WTR_EN	energy of agricultural water used

Note: The final EMERGY component grid called WTRUSE is the sum of BLD_WTR and AGR_WTR. The final energy component grid called WTRUSE_EN is the sum of BLD_WTR_EN and AGR_WTR_EN. The intermediate component grid called AGR_WTR represents the left fork of the split flow in element #3 of Figure 1-3. The intermediate component grid called BLD_WTR is the right fork of the same element. These intermediate component grids represent how the land area unit diagram can be made more or less complex depending on the need for detail. In other words, these intermediate component grids could be included as subcomponent grids if desired.

Data processing steps. The following generalized data processing steps were used in creating the intermediate grids used to create this component of the model.

Domestic water use intermediate component grid. The domestic water use grids, called RES_WTR and RES_WTR_EN were created as follows:

Step 1: The analytical point coverage called ‘em_resbldgcov’ was overlaid with the ‘munwtrbnd’ coverage to identify those buildings which were part of a municipal water service area.

Step 2: Additional attribute items were added to the ‘em_resbldgcov’ analytical coverage feature attribute table to facilitate calculations for estimates of the amount of water used (gallons) in each building, and the energy and EMERGY.

Step 3: The calculations for the amount of water used in each building were based on the assumption that within municipal water service areas the rate of water use was 104 gallons/day/person, and outside the service areas the rate was 162 gallons/day/person (Marella, 1992). The estimated building population data used in these calculations was calculated as part of the development of the population and service component grids. The following equations were used:

for public water supply;

gallons of water used = building population * 37,960
(note: 104 gal/person/day * 365 day/yr = 37,960 gal/per/yr)

energy (joules) = gallons * 8.35 lb/gal * 453.6 g/lb * 4.9 j/g

EMERGY (sej) = energy (j) * 665,714 sej/j

for well water supply;

gallons of water used = building population * 59,130
(note: 162 gal/person/day * 365 day/yr = 59,130 gal/per/yr)

energy (joules) = gallons * 8.35 lb/gal * 453.6 g/lb * 4.9 j/g

EMERGY (sej) = energy (j) * 255,242 sej/j

Step 4: The coverage was then processed according to the methods described previously for converting point feature coverages into the energy and EMERGY intermediate component grids for residential water use.

Commercial water use intermediate component grid. The commercial/industrial/institutional water use grids, called COM_WTR and COM_WTR_EN were created as follows:

Step 1: The analytical point coverage called ‘em_combldgcov’ was processed to identify those buildings in the municipal water service area.

Step 2: Additional attribute items were added to the ‘em_combldgcov’ coverage to facilitate calculations for estimates of the amount of water used (gallons) in each building, and the energy and EMERGY.

Step 3: The calculations for the amount of water used in each building were based an assumption that the total amount of water used in all commercial, industrial, and institutional buildings could be distributed proportionally according to the square footage of each building. The following calculations were used to determine the proportion of water use to be attributed to each square foot of building depending on whether the building had public-supplied or well water:

For public water supply;

Total water used = 8.2 Mgd (Marella, 1993)

8.2 Mgd * 365 days/yr = 2,993,000,000 gal/yr

2,993,000,000 gal/yr / 46,118,466 sq.ft. = 64.9 gal/sq.ft./yr

For well water supply;

Total water used = 2.29 Mgd (Marella, 1993)

2.29 Mgd * 365 day/yr = 835,850,000 gal/yr

835,850,000 g/y / 8,315,778 sq.ft = 100.5 gal/sq.ft./yr

The following equations were used to calculate the gallons of water used, and the energy and EMERGY of this water:

For municipal supply;

gallons of water used = square footage of building * 64.9 gal

energy (joules) = gallons * 8.35 lb/gal * 453.6 g/lb * 4.9 j/g

EMERGY (sej) = energy (j) * 665,714 sej/j

For well water supply;

gallons of water used = square footage of building * 100.5 gal

energy (joules) = gallons * 8.35 lb/gal * 453.6 g/lb * 4.9 j/g

EMERGY (sej) = energy (j) * 255,242 sej/j

Step 4: The coverage was then processed according to the methods described previously for converting point feature coverages into the energy and EMERGY intermediate component grids for commercial/industrial/ institutional water use.

Agricultural water use intermediate component grid. The agricultural water use grids, called AGR_WTR and AGR_WTR_EN were created as follows:

Step 1: The analytical polygon coverage called ‘em_agwtrcov’ was created to identify those areas of the county being used for various agricultural purposes. Those types of agriculture using significant amounts of irrigation water (vegetables and ornamentals) or water for livestock were identified and located.

Step 2: Additional attribute items were added to the ‘em_agwtrcov’ coverage to facilitate calculations for estimates of the amount of water used (gallons) by agriculture, and the energy and EMERGY.

Step 3: The estimates used here for the amount of water used per unit of area by agriculture are based on the average quantities used by typical crops and animals grown in Alachua County and predicted aggregated use are consistent with estimates for total county use made by Marella (1992). For all vegetable and field crops, tree crops, and intensive livestock operations, the water use rate was estimated to be 45 gallons/m2/year. For all ornamental nurseries the water use rate was estimated to be 360 gallons/m2/year. Water used was assumed to be from wells.

The following equations were used:

gallons of water used = area (m2) * 45 gal/m2/yr

or,

gallons of water used = area (m2) * 360 gal/m2/yr

energy (joules) = gallons * 8.35 lb/gal * 453.6 g/lb * 4.9 j/g

EMERGY (sej) = energy (j) * 255,242 sej/j

Step 4: The coverage was then processed according to the methods described previously for converting polygon feature coverages into the energy and EMERGY intermediate component grids for agricultural water use.

Urban System Flows—Fuels and Electricity

The EMERGY component grid, called FUEL, represents the total energy and EMERGY of fuel and electricity used within each cell of the model (element # 4 in Figure 1-3). It was created by adding together the transportation subcomponent grid (element # 4a in Figure 1-3), called TRN_FUL, and the buildings and agriculture subcomponent grid called BAG_FUL (element # 4b in Figure 1-3). The energy component grid called FUEL_EN was created by adding together the TRN_FUL_EN and BAG_FUL_EN subcomponent grids.

Urban System Flows—Transportation Subcomponent

A large proportion of any urban area's total fossil fuel consumption is used for transportation (Energy Information Administration, 1994). In addition to estimating the spatial distribution of this use, the amount of fossil fuel used for transportation per unit of area and time may serve as an indicator of the relative amount of materials (goods) that are being carried through a given location for ultimate consumption at another unspecified location.

The primary coverage used to create this component of the spatial model was the analytical coverage called 'em_roadcov'. To facilitate the estimation of motor fuel use, each road segment was assigned an estimate of the average annual daily traffic flow (AADT). Two sources of AADT data were used to create this database. The primary source was the Alachua County Department of Transportation Traffic Survey Database (Alachua County, 1995). This tabular database contains sample daily traffic counts for all of the major urban and rural county roads. These traffic counts were made at specific known locations along roads, such as intersections or crossroads. Therefore, for the purposes of this study, it was necessary to extrapolate these point measurements to estimates for the traffic flow that occurred along the corresponding linear segment of each road. The other source of AADT data was the Road Characteristics Inventory GIS Database maintained by the FDOT (FDOT, 1996). This spatial database had AADT estimates for linear road segments (although this database was also originally derived from point measurements).

Data processing steps. The following generalized data processing steps were used in creating this subcomponent of the model.

Step 1: Additional attribute items were added to the analytical coverage, called 'em_roadcov', to enable the calculation of the energy and EMERGY flows of motor fuels used in each road segment found within each one hectare cell of the model.

Step 2: The energy and EMERGY flows for each road segment were calculated by using the AADT and an assumed average fuel consumption rate for vehicles in 1993 (Energy Information Administration, 1994). The average fuel consumption rate was converted from miles per gallon units to liters per meter as shown below.

(1609.34 meters/mile)(20 mpg)/(3.7854 liters/gal) = 8503 meters/liter

$(8503 \text{ meters/liter})^{-1}$ = .000117605 liters/meter

The following equation was used to calculate the liters of fuel used per year along each road segment.

(Length, meters)(.000117605 liters/meter)(AADT)(365 days) = liters/yr/segment

Finally, these material flows were converted into energy and EMERGY flows using the energy factor and transformity of fossil fuels (Odum, 1996) and the equations shown below.

(liters/yr/segment)(4.52×10^7 J/liter) = energy, j/yr/segment

(energy, j) * (6.6×10^4 sej/J) = sej/yr/segment

Step 3: The coverage was then processed according to the methods described previously for converting linear feature coverages into the EMERGY and energy subcomponent grids, called TRN_FUL and TRN_FUL_EN, for fossil fuel use in transportation.

Urban System Flows—Buildings and Agriculture Subcomponent

This subcomponent grid represents the flow of energy and EMERGY in the electricity and fossil fuels used in all types of buildings and in agriculture (see element # 4b in Figure 1-3 and note the split flow going both to agriculture and building use).

Electricity consumption accounts for approximately 86% of all types of fuel use in buildings in Florida, fossil fuels (natural gas, fuel oils, and LPG) account for 14% of the residential site energy consumption (EIA, 1993), and electricity consumption accounts for approximately 76% of commercial site energy consumption (EIA, 1994).

In Alachua County, the majority of fossil fuel use in buildings occurs within the Gainesville Regional Utilities (GRU) natural gas service area. Knowing this, ideally this component grid should be created by first calculating the energy and EMERGY from the estimated use of electricity, using a transformity of 200,000 sej/j (Odum, 1996), and then calculating the energy and EMERGY of fossil fuels, using a transformity of 48,000 sej/j (for natural gas , which is the primary fossil fuel used in buildings in Alachua County) (Odum, 1996), and finally by adding the amounts of energy or EMERGY calculated for each of the flows together. However, there is a lack of data regarding the location of the approximately 20,000 GRU customers that received natural gas service in the 1992-93 era (GRU, 1996). Therefore, it was necessary to calculate the energy and EMERGY representing both electricity and fuel use in buildings by predicting the use of electricity in each building as if natural gas supplies were not available.

Although this method introduces some error, particularly in the calculations of EMERGY, the amount of error was deemed to be acceptable for the purposes of this study. One reason for this is that the primary uses for fossil fuels in residences are for space and water heating, and in the 'typical' Florida home fossil fuels only account for about 14% of total energy consumption (EIA, 1993). The majority of residential energy consumption occurs through the uses of electricity for appliances, lighting, and air conditioners, and these uses are also found in homes with natural gas service. Therefore, the effect on the estimates introduced by this assumption only apply to a minor percentage of the total energy and EMERGY flows, and only in those buildings with gas service.

In order to estimate the amount of electricity used in each building using the data available for this study, different usage rates were assigned according to the size and/or type of building. Residential buildings were calculated using one of two different usage-rates equations according to the square footage of the building. The reasoning for this was that a strictly linear equation that calculates the same number of kilowatt-hours per square foot for all sizes of buildings is not realistic. A more appropriate calculation was derived from the finding by the Energy Information Administration (EIA) that for residential buildings about 75% of the electricity consumed is used for appliances and water heating (EIA, 1993). These basic uses of electricity are found in homes of all sizes and dollar values. Thus, it is more appropriate to assume a base level of electricity use for all residential buildings and then calculate additional usage for heating and cooling based on square footage. Variability due to age of home (new homes are more energy efficient) and household income (poor households tend to have older, less efficient appliances) was not included in these calculations.

Various types of commercial and institutional buildings have different typical energy intensity (kWh/sq.ft.) characteristics that have been established by national and regional surveys (EIA, 1992, 1991). For this study, each non-residential building was assigned to an energy intensity class according to the type of commercial or institutional activity being conducted in the building. The estimated total electricity used in each building was then calculated by multiplying the appropriate energy intensity, according to that building's energy intensity class, times the square footage of the building.

To establish the acceptability of these assumptions, the individual building energy use estimates were summed for all of the buildings within the county and compared with the known amounts of all types of energy (in kWh units) supplied by all utilities in 1993 (GRU, 1996, BEBR, 1995). The method used predicts the total electricity/heating fuel energy use to within 4.7% of the actual amount of energy known to be supplied to all customers.

The creation of the final component grid representing the energy and EMERGY in electricity and other fuels used by humans for domestic, commercial, and agricultural purposes required that several intermediate component grids be created in a manner similar to the method used to create the water use component grid. Four of the intermediate grids were created using the analytical point coverages called ‘em_resbldgcov’ and ‘em_combldgcov’. The ‘em_resbldgcov’ coverage was used to estimate of the electricity used in residential buildings, and the ‘em_combldgcov’ coverage was used to estimate the electricity used in commercial, industrial, and institutional buildings. Agricultural fuel use was estimated using the analytical polygon coverage called ‘em_landcov’.

Four sets (an energy and an EMERGY grid in each set) of intermediate component grids were created and then ‘added’ together to create the final electricity and fuel use subcomponent grids. These intermediate grids are listed in Table 2-4.

The final EMERGY subcomponent grid, called ‘BAG_FUL’, is the sum of BLD_ELC and AGR_FUL, and the final energy component grid, called ‘BAG_FUL_EN’, is the sum of BLD_ELC_EN and AGR_FUL_EN.

<u>Data processing steps.</u> The following three sets of generalized data processing steps were used in creating the intermediate component grids that were used to create this subcomponent of the spatial EMERGY Model.

<u>Domestic electricity use intermediate component grid.</u> The residential electricity use intermediate component grids, were created as follows:

Step 1: Additional attribute items were added to the 'em_resbldgcov' analytical coverage to facilitate calculations for the amount of electricity used in each building, and the corresponding energy and EMERGY flows.

Step 2: The calculations for the amount of electricity used in each building were based on the assumptions about base levels of use that were discussed above. Residential buildings were divided into two groups for the calculations. The first group included all buildings with a total square footage of less than 1000 square feet and all multi-family residential buildings. The multi-family buildings were included based on the assumption that: although the total square footage of multi-family buildings was usually greater than 1000 square feet, that this total was most often comprised of individual residential units of less than 1000 square feet with base levels of usage comparable to individual dwellings.

The following equation was used to calculate the amount of electricity used in buildings of this group:

Electricity Used (kWh/year) = total square feet * 9 kWh/sq.ft./year

The second group includes all other residential buildings (those with more than 1000 square feet). The base level of electricity usage was estimated to be 10,000 kWh/year/building, and additional usage was estimated for heating and cooling uses based on the square footage of the building (EIA, 1993). The following equation was used for this group:

Electricity Used, kWh/year =
(10,000 kWh/year) + (total square feet * 2.25 kWh/sq.ft./year)

Table 2-4: Intermediate grids that were used to calculate the total energy and EMERGY of electricity and fuel use in buildings and agriculture.

Intermediate Grids	**Description**
RES_ELC	EMERGY of residential electricity used
RES_ELC_EN	energy of residential electricity used
COM_ELC	EMERGY of Commercial/ Industrial/ Institutional electricity used
COM_ELC_EN	energy of Commercial/ Industrial/ Institutional electricity used
BLD_ELC	Sum of RES_ELC and COM_ELC
BLD_ELC_EN	Sum of RES_ELC_EN and COM_ELC_EN
AGR_FUL	EMERGY of agricultural fuels used
AGR_FUL_EN	energy of agricultural fuels used

Note: The final EMERGY sub-component grid called BAG_FUL is the sum of BLD_ELC and AGR_FUL. The final energy sub-component grid called BAG_FUL_EN is the sum of BLD_ELC_EN and AGR_FUL_EN. The intermediate component grid called AGR_FUL represents the left fork of the split flow of element #4b in Figure 1-3. The intermediate component grid called BLD_ELC is the right fork of the split flow of element #4b.

Finally, the energy and EMERGY of the electricity used was calculated using the following equations:

Energy, j/year = (kWh/yr) * (860 kcal/kWh) * (4186 J/kcal)

EMERGY, sej/year = (energy, j/yr) * (200,000 sej/j)

Step 3: The coverage was then processed according to the methods described previously for converting point feature coverages into the EMERGY and energy intermediate component grids, called RES_ELC and RES_ELC_EN, for electricity use in residential buildings.

<u>Commercial electricity use intermediate component grid.</u> The commercial/ industrial/institutional electricity use intermediate component grids were created as follows:

Step 1: Additional attribute items were added to the 'em_combldgcov' analytical coverage to facilitate calculations for the amount of electricity used in each building, and the corresponding energy and EMERGY flows.

Step 2: The calculations for the amount of electricity used in each building were based on the application of different usage rates for different types of buildings. Electricity usage rates, in kWh per square foot, were assigned to each building type (using the Department of Revenue (DOR) use code associated with the building) according to average usage rates, which were determined by regional surveys conducted by the Energy Information Administration (EIA, 1991, 1992, 1994). The following equation was used, applying the appropriate usage rate, to calculate each building's annual electricity use:

Electricity Used (kWh/year) = total square feet * kWh/sq.ft./year

The energy and EMERGY of the electricity used was calculated using the following equations:

Energy, j/year = (kWh/yr) * (860 kcal/kWh) * (4186 J/kcal)

EMERGY, sej/year = (energy, j/yr) * (200,000 sej/j)

Step 3: The data layer was then processed according to the methods described previously for converting point feature coverages into the EMERGY and energy intermediate component grids, called COM_ELC and COM_ELC_EN, for electricity use in commercial, industrial, and institutional buildings.

Agricultural use intermediate component grid. Agricultural uses of fuel that were closely associated with a building, such as nursery and greenhouse production, were calculated in the commercial/industrial/ institutional use grid. The agricultural fuel use intermediate component grids, called AGR_FUL and AGR_FUL_EN, include fuels used for pasture and row crop production, and maintenance of residential lawns and gardens, and were created as follows:

Step 1: Additional attribute items were added to the ‘em_landcov’ analytical (polygon) coverage to facilitate calculations for the amount of electricity and fossil fuels used per unit of area for each type of agricultural land use, and the corresponding energy and EMERGY flows.

Step 2: Estimated fuel energy usage rates for each type of agricultural production were used that were based on previous calculations done to determine contributions to gross primary production in natural and agricultural systems and other data (Fluck, 1992, and 1992b). The following equations were used, applying the appropriate usage rates, to calculate the energy and EMERGY of the fuels used for the total area of each occurrence of an agricultural land use:

Energy, j/year = (j/m2/yr) * (area, m2)

EMERGY, sej/year = (sej/m2/yr) * (area, m2)

Step 3: The coverage was then processed according to the methods described previously for converting polygon feature coverages into the EMERGY and energy intermediate component grids, called AGR_FUL and AGR_FUL_EN, for fuel use in agriculture.

Urban System Flows—Goods Consumption

This component grid models the flows of energy and EMERGY of both consumable and durable goods consumed in residential, commercial, and institutional buildings and as a result of agricultural production (element #5 in Figure 1-3). The EMERGY of these goods implicitly includes the EMERGY of services to deliver them to the point of their consumption (Odum, 1996). This model does not try to track the flow of goods through wholesale and retail establishments. Durable goods (furniture, cars, equipment, etc.) are included in these calculations by combining estimates of annual depreciation of durable goods (in other words, annual consumption) with estimates of the amounts of consumable goods used annually in each building.

The creation of this component grid required that several intermediate component grids be created in a manner similar to the methods used to create the water use and fuel use component grids. Four of the intermediate grids were created using the analytical point coverages called ‘em_resbldgcov’ and ‘em_combldgcov’. The ‘em_resbldgcov’ coverage was used to estimate the goods consumed in residential buildings, and the ‘em_combldgcov’ coverage was used to estimate the goods consumed in commercial, industrial, and institutional buildings. Agricultural goods consumption was estimated using the analytical polygon coverage called ‘em_landcov’.

Four sets (an energy and an EMERGY grid in each set) of intermediate component grids were created and then ‘added’ together to create the final goods consumption component grid. These intermediate grids are described in Table 2-5. The final EMERGY component grid, called ‘GOODS’, is the sum of ‘BLD_GDS’ and ‘AGR_GDS’.

Data processing steps. The following three sets of generalized data processing steps were used in creating the intermediate grids used to create this component of the spatial EMERGY Model.

Domestic goods consumption intermediate component grid. The residential goods consumption grids, called RES_GDS and RES_GDS_EN were created as follows:

Step 1: The analytical point coverage called ‘em_resbldgcov’ was overlaid with the ‘em_census’ analytical coverage to add the data required to estimate the income of each individual single family residential-type building. Additional attribute items were added to the ‘em_resbldgcov’ coverage to facilitate calculations of energy and EMERGY flows.

Table 2-5: Intermediate grids that were used to calculate the total energy and EMERGY of goods consumption in residential, commercial/public buildings and agriculture.

Intermediate Grids	**Description**
RES_GDS	EMERGY of residential-based goods consumed
RES_GDS_EN	energy of residential-based goods consumed
COM_GDS	EMERGY of Commercial/Industrial/ Institutional-based goods consumption
COM_GDS_EN	energy of Commercial/Industrial/ Institutional-based goods consumption
BLD_GDS	Sum of RES_GDS and COM_GDS
BLD_GDS_EN	Sum of RES_GDS_EN and COM_GDS_EN
AGR_GDS	EMERGY of goods consumed in agricultural production
AGR_GDS_EN	energy of goods consumed in agricultural production

Note: The final EMERGY sub-component grid called GOODS is the sum of BLD_GDS and AGR_GDS. The final energy sub-component grid called GOODS_EN is the sum of BLD_GDS_EN and AGR_GDS_EN. The intermediate component grid called AGR_GDS represents the left fork of the split flow of element #5 in Figure 1-3. The intermediate component grid called BLD_GDS is the right fork of the split flow of element #5.

Step 2: The 1990 census data (U.S. Bureau of the Census, 1992) were processed to find the aggregate income for each census 'blockgroup'. The aggregate income was apportioned to each building by first determining the total square footage of all residential buildings in each blockgroup and then assigning each building a proportional amount of the blockgroup aggregate income according to the square footage of the building. The aggregate income figures provided by the census data were also adjusted to 1994 levels (BEBR, 1995). The following equation was used to estimate the income for each building:

Building Income ($/year) = ((blockgroup aggregate income, $/year) / (blockgroup total square feet)) * square feet of building

Step 3: The estimated dollar amount of goods consumed in each building was then calculated based on each building's income estimate using data from the U.S. Department of Labor (1995). This data represents the sum of national average estimated expenditures ($) for the following general categories: food at home, household supplies, apparel, amortized vehicle, entertainment, equipment, appliances and furnishings purchases, personal care supplies, and miscellaneous supplies. Each building was assigned a dollar value for goods consumption based on the income range of the building.

Step 4: The EMERGY of the annual goods consumption in each building was calculated using the value of 1.37 E12 sej/$ (Odum, 1996) in the following equation:

EMERGY, sej/year = (dollars of goods/yr) * (1.37 E12 sej/$)

The energy of the annual goods consumption in each building was calculated based on methods and data used by Brown (1980). In this case the assumption was made that the average cost of a pound of goods was $5 and each pound of goods contained 1500 kcal of energy. The following equation was used:

Energy, j/year = (dollars of goods/yr) * (300 kcal/$) * (4186 J/kcal)

Step 5: The coverage was then processed according to the methods described previously for converting point feature coverages into the EMERGY and energy intermediate component grids, called RES_GDS and RES_GDS_EN, for goods consumption in residential buildings.

Commercial goods consumption intermediate component grid. In this model the commercial/industrial/institutional goods consumption grids, called COM_GDS and COM_GDS_EN, are intended to estimate the amount of goods consumed annually on site in the process of conducting the particular type of business associated with each building. The calculations for estimating the amount of goods consumed in each building were based on the application of different consumption rates, in dollars of goods consumed per square foot of building per year, for the different types of businesses associated with each of the buildings. These consumable and durable goods would typically include office supplies, and amortized depreciation of office furniture, appliances, and industrial equipment. These grids are not intended to represent goods in stock, that are intended for wholesale or retail sale to other consumers. In other words, goods are mapped at their point of consumption. These intermediate component grids were created as follows:

Step 1: Additional attribute items were added to the ‘em_combldgcov’ analytical coverage to facilitate calculations of energy and EMERGY flows in commercial/industrial/institutional buildings.

Step 2: Goods consumption rates, in dollars per square foot per year, were assigned to each building type using the Department of Revenue (DOR) use code associated with the building. These rates were calculated for commercial businesses according to an estimated percentage of gross annual sales expended on goods (both consumable and amortized durable goods) during a year for each type of business (USDOC, 1996a, 1996b, 1996c).

Data on county-wide annual gross sales for each type of business (BEBR, 1993, and 1995) was multiplied by the estimated percentage of gross sales representing goods consumed in conducting each type of business. This total expenditure on goods was then divided by the total square footage of all corresponding buildings to get the estimated rate of goods consumption per square foot for those buildings associated with each type of business.

Annual goods expenditures by schools, colleges and local/state/federal government were based on an estimated percentage of gross annual government expenditures in each category (BEBR, 1995). Gross annual expenditures in each category were multiplied by the appropriate percentage rate representing goods consumed and then divided by the aggregate total square footage of the appropriate type of buildings.

The following equation was used, applying the appropriate consumption rate, to calculate the annual goods consumption occurring in each building:

Goods consumed ($/year) = total square feet * dollars/sq.ft./year

Step 3: To be consistent with the calculations used for domestic goods consumption, the energy and EMERGY of the annual goods consumption in each commercial/institutional building was calculated using the same assumptions and the following equations:

EMERGY, sej/year = (dollars of goods/yr) * (1.37 E12 sej/$)

Energy, j/year = (dollars of goods/yr) * (300 kcal/$) * (4186 J/kcal)

Step 4: The coverage was then processed according to the methods described previously for converting point feature coverages into the EMERGY and energy intermediate component grids called, COM_GDS and COM_GDS_EN, representing goods consumption in commercial/institutional buildings.

Agricultural goods consumption intermediate component grid. In this model the intermediate component grids called AGR_GDS and AGR_GDS_EN are intended to estimate the amount of goods consumed annually in the process of pasture and row crop production, and maintenance of residential lawns and gardens. Consumption of goods that are closely associated with a building, such as nursery and greenhouse production, was calculated in the commercial/ institutional intermediate component grid. These grids were created as follows:

Step 1: Additional attribute items were added to the 'em_landcov' analytical (polygon) coverage to facilitate calculations for the amount of goods consumed per unit of area for each type of agricultural land use, and the corresponding energy and EMERGY flows.

Step 2: Estimated goods consumption rates for each type of agricultural production were used. These rates were based on previous calculations done to determine contributions to gross primary production in natural and agricultural systems and other data (Fluck, 1992, and 1992b).

The following equations were used, applying the appropriate usage rates, to calculate the energy and EMERGY of the goods consumed for the total area of each occurrence of an agricultural land use:

Energy, j/year = (j/m2/yr) * (area, m2)

EMERGY, sej/year = (sej/m2/yr) * (area, m2)

Step 3: The coverage was then processed according to the methods described previously for converting polygon feature coverages into the EMERGY and energy intermediate component grids called, AGR_GDS and AGR_GDS_EN, for goods consumption in agricultural production.

Urban System Flows—Human Services

This component grid models the energy and EMERGY of in-situ human services (those services provided within the area of each grid cell). It does not include the EMERGY from services that was implicitly included in the previous calculations for the EMERGY of goods consumed (see element #6 in Figure 1-3).

The creation of this component grid presented a significant challenge since, unlike buildings, people do not stay in the same location all day. The general approach taken for this study was to estimate the percentages of time people spend while at home, work or school, and while ‘shopping’, and then spatially distribute the corresponding services according to appropriate locations.

Based on this general approach, several intermediate component grids were created to facilitate the spatial distribution of these services. Six sets (an energy and an EMERGY grid in each set) of intermediate component grids were created and then ‘added’ together to create the final human services component grid. These intermediate grids are listed in Table 2-6. The final EMERGY component grid, called ‘SERVICE’, is the sum of the BLD_SRV and AGR_SRV intermediate component grids, and the final energy component grid, called ‘SERVICE_EN’, is the sum of the BLD_SRV_EN and AGR_SRV_EN intermediate component grids.

All of the intermediate grids, except for the agricultural services grid, were created using the analytical point coverages called ‘em_resbldgcov’ and ‘em_combldgcov’. The ‘em_resbldgcov’ coverage was used to estimate of the services provided while people were at their residences. The ‘em_combldgcov’ coverage was used to estimate the services provided while people were at workplaces, schools, or were shopping. The use of these analytical point coverages was determined to be the most appropriate method of calculating and locating most human services because most people spend the majority of their time in and around buildings.

The analytical polygon coverage called ‘em_landcov’ was used to calculate the agricultural services because these services tend to be spatially dispersed.

<u>Data processing steps.</u> The following generalized data processing steps were used in creating the intermediate grids used to create this component of the spatial EMERGY model.

Table 2-6: Intermediate grids that were used to calculate the total energy and EMERGY of human services.

Intermediate Grids	Description
RES_SRV	EMERGY of services occurring in residential buildings
RES_SRV_EN	energy of services in residential buildings
WRK_SRV	EMERGY of human services occurring in school and work buildings
WRK_SRV_EN	energy of services in school/work buildings
SHP_SRV	EMERGY of human services occurring in buildings as a result of shopping
SHP_SRV_EN	energy of services while shopping
COM_SRV	WRK_SRV + SHP_SRV
COM_SRV_EN	WRK_SRV_EN + SHP_SRV_EN
BLD_SRV	RES_SRV + COM_SRV
BLD_SRV_EN	RES_SRV_EN + COM_SRV_EN
AGR_SRV	EMERGY of human services provided to agricultural production
AGR_SRV_EN	energy of services in agricultural production

Note: The final EMERGY component grid, called 'SERVICE', is the sum of the BLD_SRV and AGR_SRV intermediate component grids, and the final energy component grid, called 'SERVICE_EN', is the sum of the BLD_SRV_EN and AGR_SRV_EN intermediate component grids.

Services-at-home intermediate component grid. In this study, the assumption was made that people spend 67% of each 24-hour day at home. The intermediate component grids, called RES_SRV and RES_SRV_EN, representing EMERGY and energy of services provided at home were created as follows:

Step 1: The analytical point coverage called 'em_resbldgcov' was overlaid with the 'em_census' data layer to add the data required to estimate the population of each individual residential-type building.

The census data (U.S. Bureau of the Census, 1992) were processed to identify two population classes: the total number of adults (over 18 years old) and the total number of children. Since the census data represent the total population, by age class, for an area called a 'census block', these population numbers had to be distributed proportionately across all of the buildings, represented as point features, which were found in each block.

This apportioning of the population was accomplished by first determining the number of 'residential units' occurring in each building (the number of units in multi-family buildings is an attribute in the property parcel coverage) and the total number of units occurring in each census block.

Then, a calculation was performed for each building as follows: the total number of people (in each age class) of the corresponding census block was divided by the total number of residential units in that block; this number was then multiplied by the number of residential units in the building. The result of these calculations was an estimate of each building's population of both adults and children (people under 18 years old).

Step 2: Additional attribute items were added to the 'em_resbldgcov' coverage to facilitate calculations for the energy in services. The energy in human services from adults and children occurring in each residential building were calculated using the following equations:

Energy in adult services, j/yr/bldg = (# of adults) * (2500 kcal/day)
* (365 days/year) * (4186 j/kcal) * (.67)

Energy in child services, j/yr/bldg = (# of children) * (2500 kcal/day)
* (365 days/year) * (4186 j/kcal) * (.67)

Total energy in services, j/yr/bldg = (Adult Services, j/yr/bldg)
+ (Child Services, j/yr/bldg)

Step 3: Additional attribute items were also added to the ‘em_resbldgcov’ coverage to facilitate calculations for the EMERGY in services from humans based on different transformities according to level of education (Odum, 1996). For adults, the average proportion of high school and college-educated persons (U.S. Census Bureau, 1992) was used to calculate the EMERGY of services using two different transformities. All services from children use the same transformity. The following equations were used:

for college-educated adults;

EMERGY, sej/yr/bldg = ((# adults) * (.25)) (2500 kcal/day)
* (365 days/year) * (4186 j/kcal) * (.67, %time) * (7.33 E7 sej/j)

for high school-educated adults;

EMERGY, sej/yr/bldg = ((# adults) * (.75)) (2500 kcal/day)
* (365 days/year) * (4186 j/kcal) * (.67, %time) * (2.46 E7 sej/j)

for children;

EMERGY, sej/yr/bldg = (# children) (2500 kcal/day) * (365 days/year)
* (4186 j/kcal) * (.67, %time) * (8.90 E6 sej/j)

for the total EMERGY;

Total EMERGY, sej/yr/bldg = EMERGY from college-educated adults
+ EMERGY from high-school educated adults
+ EMERGY from children

Step 4: The ‘em_resbldgcov’ analytical coverage was then processed according to the methods described previously for converting point feature coverages into the EMERGY and energy intermediate component grids, called RES_SRV and RES_SRV_EN, for residential human services.

Services-at-work/school intermediate component grid. In this study, the assumption was made that people spend 25% of each day at work or school. The analytical point coverage called ‘em_combldgcov’ was used to create this intermediate component grid. This coverage contains all of the buildings that were not classified as residential. The intermediate component grids, called WRK_SRV and WRK_SRV_EN, representing EMERGY and energy of services provided at work or school were created as follows:

Step 1: Additional attribute items were added to the ‘em_combldgcov’ coverage to facilitate an estimate of the average daytime population of each building. These calculations were based on estimates of the number of employees, or students, per square foot of each building type according to the Department of Revenue Use Code. These estimates were calculated by dividing the total number of employees/students for each type of business/school (BEBR, 1993) by the total square footage of all of the buildings in each type of business/school. The average daytime building population was calculated as follows:

Building Population = (employees or students/sq.foot) * (sq. feet of building)

Step 2: Additional attribute items were added to the 'em_combldgcov' coverage to facilitate calculations for the energy in human services. Only the building population of primary and secondary schools were used for the calculation of children's services. The energy in human services from adults and children occurring in each building were calculated using the following equations:

Energy in adult services, j/yr/bldg = (# of adults) * (2500 kcal/day) * (365 days/year) * (4186 j/kcal) * (.25)

Energy in child services, j/yr/bldg = (# of children) * (2500 kcal/day) * (365 days/year) * (4186 j/kcal) * (.25)

Total energy in services, j/yr/bldg = (Adult Services, j/yr/bldg) + (Child Services, j/yr/bldg)

Step 3: Additional attribute items were also added to the 'em_combldgcov' coverage to facilitate calculations for the EMERGY in services from humans at work/school. These calculations are also based on different transformities according to level of education as was done for services occurring at residences. Different types of buildings were assumed to have different percentages of college and high school educated adults, and children depending on whether the building was associated with professional services, manufacturing, etc. The following equations (which are essentially the same ones used for residential services, except for the percentage of time and the varying percentages of college and high school-educated adults) were used:

for college-educated adults;

EMERGY, sej/yr/bldg = ((# adults) * (%college)) (2500 kcal/day)
* (365 days/year) * (4186 j/kcal)
* (.25, %time) * (7.33 E7 sej/j)

for high school-educated adults;

EMERGY, sej/yr/bldg = ((# adults) * (%high school) (2500 kcal/day)
* (365 days/year) * (4186 j/kcal)
* (.25, %time) * (2.46 E7 sej/j)

for all children;

EMERGY, sej/yr/bldg = (# children) (2500 kcal/day) * (365 days/year)
* (4186 j/kcal) * (.25, %time) * (8.90 E6 sej/j)

for the total EMERGY;

Total EMERGY, sej/yr/bldg = EMERGY from college-educated adults
+ EMERGY from high-school educated adults
+ EMERGY from children

Step 4: The ‘em_combldgcov’ analytical coverage was then processed according to the methods described previously for converting point feature coverages into the EMERGY and energy intermediate component grids, called WRK_SRV and WRK_SRV_EN, for human services provided while at work or school.

<u>‘Shopping’ intermediate component grid.</u> In this study, the assumption was made that people spend an average of 8% of each day ‘shopping’ at retail or service establishments. This works out to about 2 hours per day, and implicitly includes time spent driving to and from these ‘shopping’ places. This intermediate grid was created in an attempt to recognize that people spend time at locations other than work and home.

The energy and EMERGY in human services provided by people while shopping at these locations was estimated in the intermediate component grids called SHP_SRV and SHP_SRV_EN. These grids were created as follows:

Step 1: Additional attribute items were added to the analytical point coverage called ‘em_combldgcov’ to facilitate the calculations. Only those buildings that were assumed to be associated with the retail or service industries were qualified for inclusion in these calculations. The square footage of each shopping-qualified building was divided by the total square footage of all qualified buildings to determine the percentage each building represents of the total county-wide qualified building square footage.

Step 2: The primary calculations used to create this grid are based on two assumptions: first, it was assumed that every person, including children, spends 8% of their time shopping, and second, it was assumed that the percentage of the total shopping time of all people in the county that occurs in each qualified building was proportional to the percentage that building represents of the total county-wide shopping-qualified building square footage. The total population of the county, 142,081 adults and 39,515 children, was based on U.S. Census Bureau data (1990). Based on these assumptions, the following equations were used to calculate the energy in shopping services:

Energy in adult services, j/yr/bldg = (% of total shopping sq. footage)
* (total number of adults in county) * (.08, %time)
* (2500 kcal/day)* (365 days/year) * (4186 j/kcal)

Energy in child services, j/yr/bldg = (% of total shopping sq. footage)
* (total number of children in county) * (.08, %time)
* (2500 kcal/day)* (365 days/year) * (4186 j/kcal)

Total energy in services, j/yr/bldg = (Adult Services, j/yr/bldg)
+ (Child Services, j/yr/bldg)

Step 3: Additional attribute items were also added to the ‘em_combldgcov’ coverage to facilitate calculations for the EMERGY in services from humans while shopping. These calculations are based on the assumptions about education levels used previously for the residential services intermediate component grid. The following equations were used:

for college-educated adults;

EMERGY, sej/yr/bldg = (% of total shopping sq. footage)
* (# of college educated adults in county)
* (.08, %time) * (2500 kcal/day) * (365 d/year)
* (4186 j/kcal) * (7.33 E7 sej/j)

for high school-educated adults;

EMERGY, sej/yr/bldg = (% of total shopping sq. footage)
* (# of high school educated adults in county)
* (.08, %time)* (2500 kcal/day) * (365 d/year)
* (4186 j/kcal) * (2.46 E7 sej/j)

for children;

EMERGY, sej/yr/bldg = (% of total shopping sq. footage)
* (# of children in county) * (.08, %time)
* (2500 kcal/day) * (365 days/year)
* (4186 j/kcal) * (8.90 E6 sej/j)

for the total EMERGY;

Total EMERGY, sej/yr/bldg = EMERGY from college-educated adults
+ EMERGY from high school educated adults
+ EMERGY from children

Step 4: The ‘em_daypopcov’ analytical coverage was then processed according to the methods described previously for converting point feature coverages into the

EMERGY and energy intermediate component grids, called SHP_SRV and SHP_SRV_EN, for human services provided while shopping.

Agricultural services intermediate component grid. Human services related to agricultural production, which were closely associated with a building, such as nursery and greenhouse production, were calculated in the intermediate component grid for work/school services. This grid includes services that are more appropriately modeled as occurring over areal rather than point locations. These services include those provided to pasture, forestry, and row crop production, and maintenance of residential lawns and gardens. The intermediate component grids are called AGR_SRV and AGR_SRV_EN and were created as follows:

Step 1: Additional attribute items (were added to the ‘em_landcov’ polygon coverage to facilitate calculations for the amount of human services provided per unit of area for each type of agricultural land use, and the corresponding energy and EMERGY flows.

Step 2: Estimated service rates for each type of agricultural production were used based on previous calculations done to determine contributions to gross primary production in natural and agricultural systems.

The following equations were used, applying the appropriate usage rates, to calculate the energy and EMERGY of the services provided for the total area of each occurrence of an agricultural land use:

Energy, j/year = (j/m2/yr) * (area, m2)

EMERGY, sej/year = (sej/m2/yr) * (area, m2)

Step 3: The coverage was then processed according to the methods described previously for converting polygon feature coverages into the EMERGY and energy intermediate component grids, called AGR_SRV and AGR_SRV_EN, for human services provided in agricultural production.

Urban System Flows—Wastes Not Recycled

This component grid models the flows of energy and EMERGY of the solid and liquid wastes that were generated in residential, commercial, and institutional buildings that were not recycled (see element #7 in Figure 1-3).

Data from several sources (FDEP, 1995, USEPA, 1997, and TIA, 1991) on the municipal solid waste (MSW) stream for Alachua County (for the period of July 1994 to June 1995) was summarized and used as the basis for estimates of municipal solid waste (MSW) flows being generated at the sites of various types of buildings. Land-filled MSW was categorized into: general wastes (urban or rural), yard wastes (urban or rural), and construction debris. Liquid waste estimates were based on a percentage of water consumed using data calculated previously for the water use component grid.

The creation of this component grid required that several intermediate component grids be created in a manner similar to the method used to create previous component grids. Separate solid and liquid waste intermediate component grids were created using different methods. The ‘em_resbldgcov’ coverage was used to estimate the solid and liquid wastes generated in residential buildings, and the ‘em_combldgcov’ coverage was used to estimate the solid and liquid wastes generated in commercial, industrial, and

Table 2-7: Intermediate grids that were used to calculate the total energy and EMERGY of municipal solid wastes (MSW) and liquid waste flows that were not recycled.

Intermediate Grids	Description
RES_MSW	EMERGY of MSW originating in residential buildings
RES_MSW_EN	energy of MSW originating in residential buildings
RES_LWS	EMERGY of liquid wastes originating in residential buildings
RES_LWS_EN	energy of liquid wastes originating in residential buildings
COM_MSW	EMERGY of MSW originating in commercial/institutional buildings
COM_MSW_EN	energy of MSW originating in commercial/institutional buildings
COM_LWS	EMERGY of liquid wastes originating in commercial/institutional buildings
COM_LWS_EN	energy of liquid wastes originating in commercial/institutional buildings
BLD_MSW	RES_MSW + COM_MSW
BLD_MSW_EN	RES_MSW_EN + COM_MSW_EN
BLD_LWS	RES_LWS + COM_LWS
BLD_LWS_EN	RES_LWS_EN + COM_LWS_EN

institutional, and agricultural buildings. Four sets (an energy and an EMERGY grid in each set) of intermediate component grids were created and then ‘added’ together to create the final waste component grid. The intermediate grids are described in Table 2-7. The final EMERGY component grid, called ‘WASTE’, is the sum of ‘BLD_MSW’ and ‘BLD_LWS’.

Data processing steps. The following three sets of generalized data processing steps were used in creating the solid and liquid waste intermediate component grids.

Domestic solid waste intermediate component grid. The residential solid waste intermediate component grids, called RES_MSW and RES_MSW_EN were created as follows:

Step 1: Additional attribute items were added to the ‘em_resbldgcov’ coverage to facilitate calculations of material, energy and EMERGY flows for each of the three categories of wastes (general, yard, and construction debris).

Step 2: The calculations for the flow of ‘general waste’ materials that are landfilled are based on the assumption that the total county-wide residential general wastes (the sum of urban and rural general waste material tonnage) can be distributed proportionately to each building according to that buildings proportion of the total residential population. Based on this assumption, the following equation was used to find the annual amount of general wastes to be apportioned to each person associated with each building:

general waste, lbs./person/year = 48,830,000 lb/yr / 177,578 persons
= 274.98 lbs/person/yr

Using this estimate, the total amount of general land filled wastes for each building was calculated (using the estimated building population calculated previously for the human services component grid) as follows:

general waste, lbs./building/year = 274.98 lbs/p/yr * building population

Using an estimate of 1500 kcal/lb of general wastes (a figure also used for goods consumption calculations) and 2.0 E6 sej/J as the transformity for the typical mix of household general wastes (based on data that indicates general wastes are composed of lots of paper, packaging, and food wastes (USEPA, 1997)), the energy and EMERGY of these materials was calculated using the following equations:

Energy, J/building/year = (total lbs/building/yr) * (1500 kcal/lb) * (4186 J/kcal)

EMERGY, sej/building/year = (J/building/yr) * (2.0 E6 sej/J)

Step 3: The calculations for the flow of 'yard waste' materials are based on the assumption that the total county-wide 'urban residential' yard wastes can be distributed equally to each 'urban residential' building. Likewise, it was assumed that the total county-wide 'rural residential' yard wastes can be distributed equally to each 'rural residential' building. Based on these assumptions, the following equations were used (based on the summarized MSW data) to calculate the annual amount of the total yard wastes to apportion to each type of building:

for urban residential buildings;

yard waste, lbs./building/yr = 19,214,000 lbs/yr / 35,350 buildings
= 543.54

for rural residential buildings;

yard waste, lbs./building/yr = 2,134,000 lbs/yr / 13,651 buildings = 156.33

Using an estimate of 6,651,554 J/lb (= 3.5 kcal/g * 454 g/lb * 4186 j/kcal) of yard wastes and 1.0 E5 sej/J as the transformity of yard wastes, the energy and EMERGY of these materials was calculated using the following equations:

Energy, J/building/year = (yard wastes, lbs/building/yr) * 6,651,554 J/lb

EMERGY, sej/building/year = (J/building/yr) * (1.0 E5 sej/J)

Step 4: The calculations for the flow of ‘construction debris’ materials are based on the assumption that the total county-wide residential construction debris wastes (the sum of urban and rural general waste material tonnage--which was 19,394,000 lbs) can be distributed proportionately to each newly constructed residential building according to that buildings proportion of the total square footage of all newly constructed buildings (which was 3,548,573 square feet). Newly constructed residential buildings were defined as those buildings (in the ‘em_respopcov’ coverage) with a value of ‘1994’ in the ‘yearbuilt’ attribute of the coverage. Based on these assumptions, the following equations were used to calculate the annual amount of the total construction debris wastes to apportion to each building:

construction debris, lbs./yr = 19,394,000 lbs/yr
* (total square feet of building / 3,548,573 square feet)

Using an estimate of 6,651,554 J/lb (= 3.5 kcal/g * 454 g/lb * 4186 j/kcal) of construction debris (a conservative estimate based on the energy in wood) and 2.0 E5 sej/J as the transformity of construction debris, the energy and EMERGY of these materials was calculated using the following equations:

Energy, J/building/year = (constr. debris, lbs/building/yr) * 6,651,554 J/lb

EMERGY, sej/building/year = (J/building/yr) * (2.0 E5 sej/J)

Step 5: Finally, the calculated values for energy and EMERGY of general wastes, yard wastes, and construction debris wastes were added together to get the total solid waste flow for each building. The coverage was then processed according to the methods described previously for converting point feature coverages into the energy and EMERGY intermediate component grids for solid waste generation flows in residential buildings.

<u>Commercial/institutional solid waste intermediate component grid.</u> The commercial/institutional solid waste intermediate component grids, called DAY_MSW and DAY_MSW_EN were created as follows:

Step 1: Additional attribute items were added to the 'em_combldgcov' coverage to facilitate calculations of material, energy and EMERGY flows for each of the three categories of wastes (general, yard, construction debris).

Step 2: The calculations for the flow of 'general waste' materials are based on the assumption that the total county-wide commercial/industrial general wastes (the sum of commercial and institutional general waste material tonnage--which was 121,130,000 lbs/yr) can be distributed proportionately to each building according to that buildings proportion of the total square footage of all commercial and institutional buildings (which was 46,825,001 square feet). Based on these assumptions, the following equations were used to calculate the annual amount of the total general wastes to apportion to each building:

general wastes, lbs./yr = 121,130,000 lbs/yr
* (total sq. feet of building / 46,825,001 sq. feet)

The energy and EMERGY of these materials was calculated using the same equations used for residential general wastes.

Step 3: The calculations for the flow of ‘yard waste’ materials are based on the assumption that the sum of the total county-wide ‘commercial’ and ‘institutional’ yard wastes can be distributed equally to each building. Based on these assumptions, the following equations were used to calculate the annual amount of the total yard wastes to apportion to each type of building:

yard waste, lbs./bldg./yr = 21,350,000 lbs/yr / 4,465 buildings = 4781.63

The energy and EMERGY of these materials was calculated using the same equations used for residential yard wastes.

Step 4: The calculations for the flow of ‘construction debris’ materials are based on the same assumptions of proportional distribution as those used for residential construction debris wastes calculations. Based on these assumptions and summarized MSW data, the following equation was used to calculate the annual amount of the total construction debris wastes to apportion to each building:

construction debris, lbs./yr = 39,378,000 lbs/yr
* (total square feet of building / 1,574,276 sq. feet)

The energy and EMERGY of these materials was calculated using the same equations used for residential construction debris wastes.

Step 5: Finally, the calculated values for energy and EMERGY of general wastes, yard wastes, and construction debris wastes were added together to get the total solid waste flow for each building. The coverage was then processed according to the methods described previously for converting point feature coverages into the energy and EMERGY intermediate component grids for solid waste generation flows in commercial/ institutional buildings.

Domestic and commercial/institutional liquid waste intermediate component grids. According to Marella (1994), about 70% of the water withdrawn for public supply ends up at domestic wastewater treatment facilities. Both the residential liquid waste intermediate component grids, called RES_LWS and RES_LWS_EN, and the commercial/institutional liquid waste intermediate component grids, called DAY_LWS and DAY_LWS_EN were created as follows:

Step 1: Additional attribute items were added to the ‘em_resbldgcov’ and the ‘em_combldgcov’ coverages to facilitate calculations of energy and EMERGY flows.

Step 2: The energy and EMERGY of water used in each building was previously calculated to create the water use intermediate component grids. The following equations were used to calculate the energy and EMERGY flows of wastewater for each building:

Energy, J/building/year = (water use, J/building/yr) * .70

EMERGY, sej/building/year = (water use, sej/building/yr) * .70

Step 3: The coverage was then processed according to the methods described previously for converting point feature coverages into the energy and EMERGY intermediate component grids for wastewater generation flows in both residential and commercial/institutional buildings.

<u>Urban System Flows—Goods Recycled</u>

This component grid models the flows of energy and EMERGY of recycled solid wastes (recycling of liquid wastes is not included) that were generated in residential, commercial, and institutional buildings (see element #8 in Figure 1-3).

Data from several sources (FDEP, 1995, USEPA, 1997, and TIA, 1991) on the amount of the municipal solid waste (MSW) stream for Alachua County that was recycled during the period of July 1994 - June 1995 was summarized and used as the basis for estimates of recycled MSW flows being generated at the sites of various types of buildings. The recycled solid waste data were summarized into the same three categories used for the MSW calculations: general wastes, yard wastes, and construction debris.

The creation of this component grid required that two intermediate component grids be created in a manner similar to the method used to create previous component grids. The 'em_resbldgov' coverage was used to estimate the recycled solid wastes flows from each residential building, and the 'em_combldgcov' coverage was used to estimate the recycled solid wastes flows from commercial, industrial, and institutional, and agricultural buildings. The intermediate component grids, described in Table 2-8, were created and then 'added' together to create the final recycled solid waste component grids called 'RECYCLE' and 'RECYCLE_EN'.

Data processing steps. The following generalized data processing steps were used in creating the recycled solid waste intermediate component grids.

Domestic recycled solid waste intermediate component grid. The residential intermediate component grids, called RES_REC and RES_REC_EN were created as follows:

Step 1: Additional attribute items were added to the 'em_resbldgcov' coverage to facilitate calculations of material, energy and EMERGY flows.

Step 2: The calculations for the flows of recycled 'general waste' materials (in lbs./yr) are based on the same proportional distribution assumptions and methods used for the calculation of general waste flows from residential buildings used to create the 'RES_MSW' intermediate component grid. The energy and EMERGY flow calculations were also based on the same energy per pound and transformity assumptions used for the MSW grids. Using the summarized data, the following equations were used to find the annual amount of recycled general solid waste materials energy and EMERGY to be apportioned to each building:

recycled general solid waste, lbs./person/year =
38,332,000 lb/yr / 177,578 persons = 215.86 lbs/p/yr

recycled general solid waste, lbs./building/year =
215.86 lbs/p/yr * building population

Energy, J/building/year = (total lbs/bldg./yr) * (1500 kcal/lb) * (4186 J/kcal)

EMERGY, sej/building/year = (J/building/yr) * (2.0 E6 sej/J)

Step 3: The calculations for the flow of recycled 'yard waste' materials are also based on the methods used for the RES_MSW intermediate component grid. The following equations were used to calculate the annual amount of the total yard wastes to apportion to each type of building, and the energy and EMERGY of these flows:

for urban residential buildings;

recycled yard waste, lbs./building/yr = 19,214,000 lbs/yr / 35,350 bldgs.
= 543.54

for rural residential buildings;

recycled yard waste, lbs./building/yr = 2,134,000 lbs/yr / 13,651 buildings
= 156.33

Energy, J/building/year = (yard wastes, lbs/building/yr) * 6,651,554 J/lb

EMERGY, sej/building/year = (J/building/yr) * (1.0 E5 sej/J)

Step 4: The calculations for the flow of recycled construction debris materials are also based on the assumptions and methods used for the RES_MSW intermediate component grid. The following equations were used to calculate the annual amount of the total recycled construction debris wastes to apportion to each type of building, and the energy and EMERGY of these flows:

construction debris, lbs./yr = 19,394,000 lbs/yr
* (total square feet of building / 3,548,573 sq. feet)

Energy, J/building/year = (construction debris, lbs/bldg/yr) * 6,651,554 J/lb

EMERGY, sej/building/year = (J/building/yr) * (2.0 E5 sej/J)

Table 2-8: Intermediate grids that were used to calculate the total energy and EMERGY of recycled solid wastes.

Intermediate Grids	**Description**
RES_REC	EMERGY of recycled solid wastes originating in residential buildings
RES_REC_EN	energy of recycled solid wastes originating in residential buildings
COM_REC	EMERGY of recycled solid wastes originating in commercial/institutional buildings
COM_REC__EN	energy of recycled solid wastes originating in commercial/institutional buildings

NOTE: The final EMERGY component grid, called 'RECYCLE', is the sum of the RES_REC and COM_REC intermediate component grids, and the final energy component grid, called 'RECYCLE_EN', is the sum of the RES_REC_EN and COM_REC_EN intermediate component grids.

Step 5: Finally, the calculated values for energy and EMERGY of recycled general wastes, yard wastes, and construction debris wastes were added together to get the total recycled solid waste flows for each building. The coverage was then processed according to the methods described previously for converting point feature coverages into the energy and EMERGY intermediate component grids for recycled solid waste flows in residential buildings.

Commercial/industrial/institutional recycled solid waste intermediate component grid. The commercial/industrial/institutional recycled solid waste intermediate component grids, called DAY_REC and DAY_REC_EN were created as follows:

Step 1: Additional attribute items were added to the 'em_combldgcov' coverage to facilitate calculations of material, energy and EMERGY flows for each of the three categories of wastes.

Step 2: The calculations for the flows of recycled 'general waste' materials (in lbs./yr) are based on the same proportional distribution assumptions and methods used for the calculation of general waste flows from commercial/institutional buildings used to create the 'DAY_MSW' intermediate component grid. The energy and EMERGY flow calculations were also based on the same energy per pound and transformity assumptions used for the MSW grids.

Using the summarized data, the following equations were used to find the annual amount of recycled general solid waste materials energy and EMERGY to be apportioned to each building:

recycled general wastes, lbs./building/yr = 99,816,000 lbs/yr
* (total square feet of bldg. / 46,825,001 square feet)

The energy and EMERGY of these materials was calculated using the same equations used for residential recycled general wastes.

Step 3: The calculations for the flow of recycled 'yard waste' materials are also based on the assumptions and methods used for the DAY_MSW intermediate component grid. The following equations were used to calculate the annual amount of the total yard wastes to apportion to each type of building, and the energy and EMERGY of these flows:

recycled yard waste, lbs./building/yr =
21,350,000 lbs/yr / 4,465 buildings = 4781.63

Energy, J/building/year = (yard wastes, lbs/building/yr) * 6,651,554 J/lb

EMERGY, sej/building/year = (J/building/yr) * (1.0 E5 sej/J)

Step 4: The calculations for the flow of recycled construction debris materials are also based on the same assumptions and methods used for the DAY_MSW intermediate component grid. The following equations were used to calculate the annual amount of the total recycled construction debris wastes to apportion to each type of building, and the energy and EMERGY of these flows:

recycled construction debris, lbs./yr = 39,378,000 lbs/yr
* (total square feet of bldg. / 1,574,276 square feet)

Energy, J/building/year = (construction debris, lbs/bldg/yr) * 6,651,554 J/lb

EMERGY, sej/building/year = (J/building/yr) * (2.0 E5 sej/J)

Step 5: Finally, the calculated values for energy and EMERGY of recycled general wastes, yard wastes, and construction debris wastes were added together to get the total recycled solid waste flows for each building. The coverage was then processed according to the methods described previously for converting point feature coverages into the energy and EMERGY intermediate component grids for recycled solid waste flows in commercial, industrial, and institutional buildings.

Specific Methods for Creating Storage Component Grids

The following sections describe the specific calculations and methods used to create each of the energy and EMERGY storage intermediate component, sub-component, and component grids in the model that were listed in Table 2-2.

Natural System Structure

The EMERGY component grid, called NATSTR, represents the total natural system structure found within each cell of the model. It was created by adding together the biomass sub-component grid called BIOSTR (element #9a in Figure 1-3), the water storage sub-component grid called WTRSTR (element #9b in Figure 1-3), and the soil organic matter sub-component grid called SOILOM (element #9c in Figure 1-3). The energy component grid, called NATSTR_EN, was created by adding together the biomass sub-component grid called BIOSTR_EN, the water storage sub-component grid called WTRSTR_EN, and the soil organic matter sub-component grid called SOILOM_EN.

Natural System Structure—Biomass Subcomponent

The total energy and EMERGY in biomass was the first subcomponent of natural system structure calculated for the model (element #9a in Figure 1-3). The amount of water transpired by ecosystems was used as a measure of the amount of natural, renewable energies used in creating the biomass structure (Odum 1983, 1996). Additional non-renewable EMERGY sources, that were significant to production, were added to get the total EMERGY contributing to natural structure. Transformities for the biomass structure of ecosystems were calculated by dividing the total EMERGY used to build the structure by the energy in biomass. Calculations for 15 representative ecosystems in Alachua County (as they were classified by the land use and cover coverage) were done to determine energy in biomass, natural and cultural EMERGY flows contributing, and the transformity for the structure of each ecosystem.

The primary coverage used to create this sub-component of the spatial model was the coverage called ‘em_landcov’. This analytical coverage was modified to identify areas of roads, building footprints, and intensively managed areas. The general steps involved in developing the ‘em_landcov’ analytical coverage are described in the methods section for the GPP (gross primary production) component grid.

Data processing steps. The following generalized data processing steps were used in creating this sub-component of the spatial EMERGY model.

Step 1: Additional attribute items were added to the ‘em_landcov’ analytical coverage to facilitate calculations of biomass/unit area in each polygon, and the corresponding storage of energy and EMERGY.

Step 2: In order to calculate the energy and EMERGY in biomass storage for each classified polygon in the modified land use and cover database, the calculations made for the representative ecosystems were converted from storage amounts per hectare to storage amounts per square meter. Each land use or cover class was assigned a storage/m^2 value according to the most closely corresponding value calculated for a representative ecosystem, or, in the cases of some commercial and industrial classifications, by assigning a value that has been proportionately reduced by a factor to estimate the amount of vegetation typically present on that type of land use.

The appropriate ratio for energy/m2 or EMERGY/m2 was multiplied by the area of each polygon in the modified land use coverage and the reduction factor (where appropriate) to obtain the total energy and EMERGY using the following equations:

Energy, j/ = (j/m2) * (area, m2) * (reduction factor, %)

EMERGY, sej = (sej/m2) * (area, m2) * (reduction factor, %)

Step 3: The coverage was then processed according to the methods described previously for converting polygonal feature coverages into the EMERGY and energy subcomponent grids, called BIOSTR and BIOSTR_EN, for storages in natural systems.

Natural System Structure—Water Storage Subcomponent

The water stored in lakes, wetlands, streams, and groundwater is an essential part of most ecosystems. This subcomponent grid is represented by element #9b in Figure 1-3. Two sets of intermediate grids (listed in Table 2-9) were created, one representing surface water storage and the other groundwater storage, and then added together to get the

Table 2-9: Intermediate grids that were used to calculate the total energy and EMERGY of water storage in lakes, wetlands, and aquifers.

Intermediate Grids	Description
GRN_WTR	EMERGY of groundwater storages
GRN_WTR_EN	energy of groundwater storages
SRF_WTR	EMERGY of surface water storages
SRF_WTR_EN	energy of surface water storages

Note: The final spatial EMERGY model sub-component grid, called ‘WTRSTR’, is the sum of the GRN_WTR and SRF_WTR intermediate component grids, and the final energy component grid, called ‘WTRSTR_EN’, is the sum of the GRN_WTR_EN and SRF_WTR_EN intermediate component grids.

final subcomponent grids for the energy and EMERGY in both surface and ground water. As shown in the diagram (Figure 1-3), intercell exchanges of water were not modeled.

The primary coverage used to create this component of the spatial model was the analytical coverage called 'em_hydcov'. This polygon coverage was created by first selecting out the lake and wetland polygons from the 'land use' coverage, and then combining these polygons with those from a coverage created by buffering the 'streams' line coverage. In order to calculate the volume of water stored in each polygon representing a water feature, average depths for each type of feature were assigned.

An average depth of 3.0 meters was used for all major lakes, and .30 meters was used for all streams (Fernald and Patton, 1984). An average annual depth for each type of wetland (according to the land use codes) was also assigned (Myers and Ewell, 1990). Most types of forested wetlands and wet prairies were assigned an average annual depth of .3 meters. Cypress swamps were assigned .4 meters and 'lake swamps' were assigned .7 meters depth. Areas of emergent aquatic vegetation were assigned a depth of 1.0 meter. The calculations for groundwater storage are based on a generalization that assumes a consistent quantity per unit of land area of usable, and accessible, groundwater. The quantity/area ratio used is based on an average accessible depth of 250 meters (Fernald and Patton, 1984) and an average bedrock porosity of 10% (Odum, 1992a). The transformity used for both surface and groundwater storages was 41,000 sej/joule (Odum, 1996).

Data processing steps. The following generalized data processing steps were used in creating the intermediate grids used to create this subcomponent of the spatial EMERGY model.

<u>Surface water storage intermediate component grid.</u> The surface water storage intermediate component grids, called SRF_WTR and SRF_WTR_EN were created as follows:

Step 1: Additional attribute items were added to the 'em_hydcov' analytical coverage to enable the calculation of the energy and EMERGY stored in each polygon.

Step 2: Each polygon was assigned an average surface water depth according to the land use code as described above. The amount of energy and EMERGY in the surface water storage was calculated using the following equations:

Energy, j = (area, m2) * (depth,m) * (1,000,000 g/m3) * (5.0 J/g)

EMERGY, sej = (Energy, j) * (41,000 sej/j)

Step 3: The coverage was then processed according to the methods described previously for converting polygonal feature coverages into the EMERGY and energy intermediate component grids, called SRF_WTR and SRF_WTR_EN, for surface water storages.

<u>Groundwater storage intermediate component grid.</u> The groundwater storage intermediate component grids, called GRN_WTR and GRN_WTR_EN were created as follows:

Step 1: Additional attribute items were added to the coverage, called 'em_hydcov', to enable the calculation of the energy and EMERGY stored in each polygon.

Step 2: Every polygon was assumed to have the same amount of groundwater storage potential per unit of area. Using an average depth of 250 meters, and 10%

average porosity for limestone (Fernald and Patton, 1984 and Odum, 1992), it was estimated that each square meter of land would have 25 cubic meters of accessible groundwater stored in the aquifer. The amount of energy and EMERGY in groundwater was calculated by using the following equations:

(25 m3/m2) * (1 E6 g/m3) * (5.0 j/g , Gibbs free energy)
= 125,000,000 j/m2

Energy, j = (area, m2) * 125,000,000 j/m2

EMERGY, sej = (Energy, j) * (41,000 sej/j)

Step 3: The coverage was then processed according to the methods described previously for converting polygonal feature coverages into the EMERGY and energy intermediate component grids, called GRN_WTR and GRN_WTR_EN, for groundwater storages.

Natural System Structure—Organic Matter in Soils Subcomponent

Organic matter in soils is the third subcomponent of natural structure included in this model (element #9c in Figure 1-3). The spatial distribution of soil types was provided by the Soil Survey Geographic (SSURGO) GIS database produced by the U.S. Department of Agriculture’s Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) (NRCS, 1995). The attribute data for each soil type was based on the Alachua County Soil Survey (USDA, 1985).

The primary coverage used to create these energy and EMERGY sub-components of the spatial model was the analytical coverage called ‘em_soilcov’. In highly developed urban areas a considerable portion of the land area is covered by roads, buildings, parking lots, etc.. Normally, the shallow soils under these man-made structures have little or no organic matter. The original SSURGO database generally does not identify areas covered by roads and buildings.

In an attempt to more accurately model the impact of urban development on this element of natural structure, the original soils coverage was 'unioned' with the footprints of buildings and roads. The areas within these footprints were considered to have no organic matter that was available to natural systems. In some urban areas the effect of deleting the areas of buildings and roads can be a significant factor in the calculations. The volume calculations used for determining the amount of organic matter in each soil type are based on an assumption of a .5 meter soil depth.

Data processing steps. The following generalized data processing steps were used in creating this subcomponent of the spatial EMERGY model.

Step 1: The 'em_soilcov' coverage was processed to add attributes for percentage organic matter and bulk density for each soil type. The coverage was then unioned with the buffered buildings and roads coverage using similar methods described earlier (in the methods section for GPP) for creation of the 'em_landcov' analytical coverage.

Step 2: The energy and EMERGY (using a transformity of 63,000 sej/J (Odum, 1996)) stored in organic matter was then calculated for each polygon using the following equations:

energy, j = (% org. matter)(bulk density, g/cm3)(5.4 kcal/g)(1 E6 cm3/m3)
(.5 m deep)(4186 J/kcal)(area, m2)

EMERGY, sej = (energy, J)(6.3 E4 sej/J)

Step 3: The coverage was then processed according to the methods described previously for converting polygonal feature coverages into the EMERGY and energy subcomponent grids, called SOILOM and SOILOM_EN.

Urban System Structure

The EMERGY component grid, called URBSTR, represents the total urban man-made structure found within each cell of the model. It was created by adding together the buildings subcomponent grid called BLDG (element #10a in Figure 1-3), the roads subcomponent grid called ROAD (element #10b), and the utilities infrastructure subcomponent grid called UTIL(element #10c). The energy component grid, called URBSTR_EN, was created by adding together the buildings subcomponent grid called BLDG_EN, the roads subcomponent grid called ROAD_EN, and the utilities infrastructure subcomponent grid called UTIL_EN. The methods used to create each of these subcomponent grids are described below.

Urban System Structure—Buildings Subcomponent

Buildings are often the most prominent 'unnatural' features of man-dominated landscapes. The amount of EMERGY stored in buildings per unit of area serves, when added to the EMERGY storage of urban infrastructure (roads and utilities), as a comparative indicator of the degree to which humans have invested EMERGY in order to create urban structure in any given area. Urban structure also provides a conduit for, and attracts EMERGY flows to an area (Odum, 1996).

The primary coverage used to create this subcomponent of the spatial model was the point coverage called 'buildings'. Since the 'buildings' coverage was derived from the parcel coverage, it has most of the same attribute items. These attributes seemed to initially offer two options for calculating the EMERGY stored in buildings. The first option was to use the total square footage of the building multiplied by the EMERGY per square foot of the building (which might be based on separate evaluations of the EMERGY in the basic materials, other goods, and construction services which are added together). The second option was to use the appraised dollar value of each building multiplied by the EMERGY per dollar ratio for the index year of 1993.

Roudebush (1992) calculated the EMERGY per square foot of two built-environment alternatives (essentially two types of construction techniques). His detailed evaluations of the EMERGY inputs required for these two construction alternatives generated a ratio of 2.35 e13 sej/square foot for one alternative versus 2.1 e13 sej/square foot for the other alternative. His research showed that there is a variation in EMERGY per square foot found between construction alternatives, and he concluded that one of the evaluated alternatives would have less of an environmental impact than the other. Roudebush did not, however, extrapolate these results to predict a generalized ratio for EMERGY per square foot of any built structure.

Whereas, the most accurate method of assigning total EMERGY values to each building would be based on a complete evaluation of each construction alternative, the database available for this study does not include these details, and an evaluation of all construction types would not be feasible for this study. Based on personal communication with appraisers at the Alachua Country Property Appraiser's Office, it was determined that the methods employed to establish a building's appraised dollar value for taxation purposes included calculations that consider construction type, and current condition of the structure. Consequently, the dollar value attribute in the building database does reflect, to some degree, the variety of construction types through the variation of appraised dollar values per square foot.

It is recognized that all buildings have an inherent turnover time. However, for these calculations, it was assumed that the dollar figures assigned by the property appraiser represent the currently depreciated status of the structure. In other words, annual depreciation was either assumed to be cancelled out by regular annual maintenance, or to be reflected in the lower assessed value of a structure that has not been maintained.

Additionally, when the results of calculations (for a sample of the building data) using Roudebush's (1992) sej/square foot ratio values (multiplied times the square footage of the building) were compared to calculations using the EMERGY per dollar ratio (multiplied times the dollar value of the building), the resulting total EMERGY values for this sample of building data were of the same magnitude. Although this informal comparison does not completely validate the method of using EMERGY per dollar ratios to calculate total EMERGY stored in buildings, it does suggest that this method will generate reasonable approximations. Therefore, the EMERGY per dollar ratio alternative method was used to create this component of the model.

The 'buildings' coverage has attribute items for the appraised dollar value of both buildings and other miscellaneous structural improvements such as driveways, fences, and pools found on a property. For the purposes of this study the dollar value of buildings was added to the dollar value of miscellaneous improvements. The sum of these two values was used to calculate the EMERGY in built structures using the EMERGY per dollar ratio. The dollar value of land was not included.

Brown's (1980) estimates of the chemical potential energy in the basic materials (concrete, and wood) used to construct buildings are used for the estimates of energy in building structure. Brown's estimates were for total pounds per acre of wood and concrete in buildings for various land use types. In order to be able to use these estimates with the square footage data in the building database, the data were converted to proportions of wood to concrete. These proportions were used to estimate the pounds/square foot and the energy/square foot for each type of building.

Data processing steps. The following generalized data processing steps were used in creating the energy and EMERGY sub-component grids.

Step 1: A copy of the point coverage 'buildings' was made and any attribute items that were not going to be used for the calculations were eliminated from the database to increase computer processing speed. Additional attribute items were added to the new coverage, called 'em_bldgcov', to enable the calculation of the energy and EMERGY stored in each building.

Step 2: The EMERGY for each building was calculated by multiplying the appraised total dollar value of each building (which includes it's miscellaneous improvements like paving, fences, etc.) times the EMERGY per dollar ratio for 1993 of 1.37 e12 sej/$ (Odum, 1996) using the following equation:

$$\text{EMERGY, sej} = (\text{Building Value, \$})(1.37 \times 10^{12} \text{ sej/\$})$$

Step 3: Each point feature in the building coverage was assigned a generalized structural energy intensity type (depending on the type of building) with a corresponding value of energy per square foot. The energy of each building was calculated, based on the assigned structural energy intensity ratio, using the following equation:

energy, j = (area, sq.ft.)(energy, J/sqft.)

Step 4: The coverage was then processed according to the methods described previously for converting point feature coverages into EMERGY and energy subcomponent grids, called BLDG and BLDG_EN, for storage in buildings.

<u>Urban System Structure—Roads Subcomponent</u>

Roads are another prominent feature in man-dominated landscapes. They represent a major EMERGY investment to build structure that will facilitate the flow of both local and imported goods and services (Odum, 1996).

The primary coverage used to create this subcomponent grid of the spatial EMERGY model was the line coverage called 'em_roadcov'. Descriptive attribute data was added to this analytical coverage to facilitate calculations of the energy and EMERGY stored in the structure of roads. The 'functional classification' of each road segment was assigned based on the Florida Department of Transportation (FDOT) Functional Classification System (FDOT, 1993). This classification system is used by the FDOT to establish construction standards, and consequently to estimate the costs of construction and maintenance for each class of roads. The data for the functional classification and number of lanes for each road was obtained from both the Alachua

County Department of Transportation (ADOT) plan for county and city roads (ADOT, 1995b) and the FDOT Road Characteristics Inventory (RCI) GIS database (FDOT, 1995).

For the purposes of this study, a simplifying assumption was made whereby, it was assumed that the annual depreciation of roads was offset by inputs of annual maintenance, thereby canceling out the annual depreciation of the storage.

A large proportion of the cost of building a road is derived from the construction services used to build the road, and maintenance is primarily service-oriented (FDOT, 1994 and CUTR, 1994). It was assumed that an EMERGY evaluation of the materials used to build the roads (asphalt, concrete, steel, etc.) would also reveal that a large proportion of the EMERGY in the materials would be from the services involved in manufacturing and transportation to the site.

Based on these assumptions, it was assumed that the EMERGY in road structure could be reasonably estimated from the total cost (excluding land acquisition) of building a mile of each type (by functional classification) of road. Estimated construction costs ($) per mile for each class of road were derived from various reports (FDOT, 1994, CUTR, 1994) and converted to dollar per meter per lane values for this study.

The energy stored in road infrastructure was calculated from an estimate of the amount of materials in the road. Whitfield (1994) and Brown (1980) made assumptions for the chemical potential energy in the basic materials used to build roads that are also used in this study.

<u>Data processing steps.</u> The following generalized data processing steps were used in creating this subcomponent of the spatial EMERGY model.

Step 1: Additional attribute items were added to the coverage, called 'em_roadcov' to enable the calculation of the energy and EMERGY stored in each road segment.

Step 2: The EMERGY for each road segment was calculated by assigning the appropriate $/meter/lane values to each road segment according to the it's functional classification, and by using the EMERGY per dollar ratio for 1993 of 1.37 e12 sej/$ (Odum, 1996) in the following equation:

Length(meters) * $/meter/lane * lanes * EMERGY/$(sej/$) = EMERGY(sej)

Step 3: The energy stored in road infrastructure was calculated assuming 15 lbs/sq.ft. and 3000 kcal/lb for asphalt, and 54 lb/sq.ft. and 30 kcal/lb of rock subbase (Brown, 1980) in the following equations:

(3000 kcal/lb) * (4186 J/kcal) * (15 lb/sq.ft.) = 188,370,000 J/sq.ft.

(30 kcal/lb) * (4186 J/kcal) * (54 lb/sq.ft.) = 6,781,320 J/sq.ft.

(188,370,000 J/sq.ft.) + (6,781,320 J/sq.ft) = 195151320 J/sq.ft.

(1.95 E8 J/ft2) * (10.76 ft2./m2) = 2,099,828,203 or 2.1 E9 J/m2

Assuming 3.66 meters as the width of a road lane, the energy of each road segment in the coverage was calculated by the following formula:

(3.66 m) * (length of segment in meters) * (no. of lanes) * (2.1 E9 J/m2)

Step 4: The coverage was then processed according to the methods described previously for converting linear feature coverages into the EMERGY and energy subcomponent grids, called ROAD and ROAD_EN, for storage in road structures.

Urban System Structure—Utility Infrastructure Subcomponent

The utility distribution infrastructure built to provide electricity, water, gas, and phone services to homes and businesses is the third subcomponent of urban structure in this model. It is important to note that this subcomponent grid only represents the distribution system, it does not include power generation plants, water or wastewater plants, etc.. These elements of the system are included in the 'buildings' subcomponent grid. Electric distribution and phone lines are found throughout the study area, but gas and water service lines are limited to the urban areas of Alachua County.

The development of this subcomponent grid was complicated by the fact that many different utility companies are involved in providing various services to different parts of the county. For instance, the county's residents are served by three major electric utility companies and several minor electric cooperatives. However, the dominant utility in the county is Gainesville Regional Utilities, Inc. (GRU) which provides electric and water service to the largest percentage of the county's residents (approximately 63,000 electric and 44,000 water customers in 1993) (GRU, 1996).

GRU was the only utility company that had any GIS databases of their facilities that were available for use in this study, and they only provided the author with the electric distribution system database. Consequently, a method had to be developed for estimating the dollar values and geographic distribution of the other utility infrastructure not covered by the GRU electric system database.

The solution to this dilemma was to create the analytical line coverage called 'em_utilcov'. This coverage was created to represent the county-wide primary electric distribution line system. It is comprised of a combination of the actual data provided by

GRU for primary distribution lines within their service area, and proxy data (derived from the ‘em_roadcov’ analytical coverage) for primary distribution lines in those areas outside of the GRU service area. Through personal observation, it was found that the great majority of electric distribution lines in rural areas tend to coincide spatially with roads. Therefore, it was determined that for the purposes of this study, rural paved and graded roads could serve as indicators of the presence of a primary electric distribution lines.

This electric distribution line system coverage (em_utilcov) was used to geographically distribute the total dollar value of all of the components of the GRU electric distribution system proportionately throughout those lines in the GRU service area. The dollars/meter figures calculated for the GRU system were also used to assign dollar values to the representative distribution lines (created from the roads) in the areas outside the GRU service area.

Since no coverages were available for the gas and water distribution system, the total value of gas and water distribution lines was also distributed proportionately along those electric distribution lines that were within gas and/or water service areas. Unfortunately, there was no data readily available for telephone lines, therefore this sub-component grid does not include telephone service infrastructure.

<u>Data processing steps.</u> The following generalized data processing steps were used in creating this subcomponent of the spatial EMERGY model.

Step 1: Additional attribute items were added to the ‘em_utilcov’ analytical coverage to enable the calculation of the energy and EMERGY stored in each segment of utility infrastructure. The electric distribution line system was overlaid with the GRU

gas service area and the municipal water service area coverages to identify those lines that would represent multiple types of utility infrastructure. The municipal water service areas coverage, called ‘munwtrbnd’, included the GRU water service area and all areas within the municipal limits of all of the small towns providing water service in the County. Each utility line segment was then assigned a class according to the type(s) of infrastructure that it represented. There were four classes: electric only, electric and water, electric and gas, and electric/gas/water.

Step 2: The total dollar value of the GRU electric distribution system (GRU, 1996) was divided by the total length of the lines within the GRU service area only to estimate a $/meter (length) ratio for electric infrastructure.

Water and gas ratios were calculated in the same manner and added to the electrical distribution values for those line segments in the ‘em_utilcov’ coverage that were part of municipal water or gas service areas.

An appropriate ‘total utility infrastructure cost per meter ratio’ was assigned to each line features segment in the ‘em_utilcov‘ coverage according to whether or not the segment represented: 1) electricity distribution infrastructure only, or 2) electricity and gas, or 3) electricity, gas, and water distribution infrastructure.

The dollar value of each line segment was then calculated by multiplying the appropriate ‘total utility infrastructure cost per meter ratio’, according to the combination of utility infrastructures the line represented, times the length of the line:

Dollar value of segment = Length(meters) * $/meter

Step 3: The energy and EMERGY of the utility infrastructure was calculated by using the EMERGY/dollar ratio for 1993 of 1.37 E12 sej/$ (Odum, 1996), and by assuming a transformity of 1.37 E8 sej/j:

Dollars/segment * EMERGY/$,sej/$ = EMERGY,sej/segment

Energy, j/segment = EMERGY,sej/segment / 1.37 E8 sej/j

Step 4: The coverage was then processed according to the methods described previously for converting linear feature coverages into the EMERGY and energy sub-component grids, called UTIL and UTIL_EN, for utility structure.

Urban System Structure—People

Population distribution pattern data layers are commonly used in GIS analysis (Kaiser et al., 1995). This component grid models the average amount and location of energy and EMERGY stored in the people in each grid cell (element #11 in Figure 1-3). It is different from the human services component grid because it models the average energy or EMERGY storage that might be found at any given time in a given location during the index year as opposed to the total amount of energy or EMERGY flow from services at that location during the index year.

The methods used for the creation of this component grid are very similar to those described earlier for the creation of the human services component grid called SERVICE. As with the human services component grid, the spatial distribution of the total population was modeled based on assumed percentages of time spent while at home, work or school, and 'shopping'.

Several intermediate component grids (Table 2-10) were created to facilitate the spatial distribution of the population. Four sets (an energy and an EMERGY grid in each set) of intermediate component grids were created and then 'added' together to create the final population component grid.

The final EMERGY component grid, called 'POPSTR', is the sum of the RES_POP and COM_POP intermediate component grids, and the final energy component grid, called 'POPSTR_EN', is the sum of the RES_POP_EN and COM_POP_EN intermediate component grids.

Data processing steps. The following generalized data processing steps were used in creating the intermediate component grids which were used to create this component of the spatial EMERGY model.

Residential population intermediate component grid. As was done with the human services component grid, the assumption was made that people spend 67% of each day in residential-type buildings. As a result of calculations made for human services, the analytical point coverage called 'em_resbldgcov' already includes data for the estimated population (of both adults and children (people under 18 years old)) for each individual residential-type building. The following steps were used to create the RES_POP and RES_POP_EN intermediate component grids:

Step 1: Additional attribute items were added to the 'em_resbldgcov' coverage to facilitate calculations for the energy stored in the human population of each building. The energy stored in humans was calculated using the following equations:

Table 2-10: Intermediate grids that were used to calculate the total energy and EMERGY stored in the human population of Alachua County.

Intermediate Grids	Description
RES_POP	EMERGY of humans in residential buildings
RES_POP_EN	energy of humans in residential buildings
WRK_POP	EMERGY of humans in school/work buildings
WRK_POP_EN	energy of humans in school/work buildings
SHP_POP	EMERGY of humans in buildings shopping
SHP_POP_EN	Energy of humans while shopping
COM_POP	WRK_POP + SHP_POP
COM_POP_EN	WRK_POP_EN + SHP_POP_EN

NOTE: The final EMERGY component grid, called 'POPSTR', is the sum of the RES_POP and COM_POP intermediate component grids, and the final energy component grid, called 'POPSTR_EN', is the sum of the RES_POP_EN and COM_POP_EN intermediate component grids.

Energy stored in adult building population, j/bldg =
(# of adults) * (150 lb/adult) * (.4, dry wt.) * (.454 lb/kg)
* (1000 g/kg) * (7 kcal/g) * (4186 j/kcal) * (.67, %time)

Energy stored in children building population, j/bldg =
(# of children) * (60 lb/adult) * (.4, dry wt.) * (.454 lb/kg)
* (1000 g/kg) * (7 kcal/g) * (4186 j/kcal) * (.67, %time)

Total energy stored in population, j/bldg =
(Adults, j/bldg) + (Children, j/bldg)

Step 2: Additional attribute items were also added to the 'em_resbldgcov' coverage to facilitate calculations for the EMERGY stored in humans. These calculations are made according to level of education and the corresponding estimates of the amount of EMERGY supporting each person per year at that level of education (Odum, 1996). An average age of 9 years was assumed for children and 30 years was assumed for adults. The following equations were used:

for college-educated adults;

EMERGY, sej/bldg = ((# adults in building) * (.25, %college educated))
* (30 years) * (28.0 E16 sej/person-year) * (.67, %time)

for high school-educated adults;

EMERGY, sej/bldg = ((# adults in building)
* (.25, %high school educated)) * (30 years)
* (9.4 E16 sej/person-year) * (.67, %time)

for children;

EMERGY, sej/bldg = (#children in building) * (9 years)
* (3.4 E16 sej/person-year) * (.67, %time)

Total EMERGY, sej/bldg = EMERGY from college-educated adults
+ EMERGY from high-school educated adults
+ EMERGY from children

Step 3: The 'em_resbldgcov' analytical coverage was then processed according to the methods described previously for converting point feature coverages into the EMERGY and energy intermediate component grids, called RES_POP and RES_POP_EN, for the human population found in residential buildings.

Work/school population intermediate component grid. To be consistent with the corresponding human services component grid, the assumption was made that people spend 25% of each day in work or school buildings. As a result of the calculations made for human services, the analytical point coverage called 'em_combldgcov' already had data for the estimated population of college and high school-educated adults and children for each building.

The WRK_POP and WRK_POP_EN intermediate component grids were created using the same basic assumptions, steps, and equations used for the residential population intermediate component grid. The major exception is that the percentage of time used was 25%, the children were assumed to have an average age of 12 years, and the percentages of college and high school-educated adults varied with the type of building.

'Shopping' intermediate component grid. The SHP_POP and SHP_POP_EN intermediate component grids were created using only those buildings in the 'em_combldgcov' which were assumed to be associated with the retail or service industries. The purpose of these calculations is to add the average energy and EMERGY of the 'customers' in these buildings to the energy and EMERGY of the employee population of these same buildings (which was previously calculated in the work/school intermediate population component grid). As was done for the 'shopping' services intermediate component grid, the percentage each building represents of the total county-wide qualified building square footage was used to distribute 8 % of the total energy and EMERGY of the total county population proportionately to each qualified building. These intermediate component grids were created as follows:

Step 1: Additional attribute items were added to the analytical point coverage called 'em_combldgcov' to facilitate the calculation of the energy and EMERGY in the shopping population.

Step 2: First, the EMERGY of the total county population was found by calculating the sum of the EMERGY of all population classes (all education levels) for all of the buildings in the 'em_resbldgcov' analytical coverage. A value of 5.82 E23 sej was calculated for the EMERGY of the total population.

Next, 8% of this total population amount was distributed proportionately to the shopping-qualified buildings, in the 'em_combldgcov' analytical coverage, according to the percentage of the total county-wide shopping area the building represents. Consideration of the education levels is implicit in these calculations since the county-wide value is the sum of calculations made using different education levels. The following equation was used for each building:

EMERGY, sej/bldg = (% of total shopping sq. footage)
* (5.82 E23 sej) * (.08)

Step 3: The energy in the shopping population was calculated by estimating an average transformity for a high school-educated adult using the following equations:

Energy stored in average adult =
(150 lb/adult) * (.4, dry wt.) * (.454 lb/kg) * (1000 g/kg)
* (7 kcal/g) * (4186 j/kcal) = 7.98 E8 j/person

EMERGY stored in average adult =
(30 years) * (9.4 E16 sej/person-year) = 2.82 E18 sej/person

Transformity = (2.82 E18 sej/person) / (7.98 E8 j/person) = 3.53 E8 sej/j

Using this estimated average transformity, the energy in the shopping population of each qualified building was calculated using the previously calculated EMERGY value in the following equation:

Energy stored in 'shopping' pop., j/bldg = (EMERGY, sej) / (3.53 E8 sej/j)

Step 4: The 'em_combldgcov' analytical coverage was then processed according to the methods described previously for converting point feature coverages into the EMERGY and energy intermediate component grids, called SHP_POP and SHP_POP_EN, for the shopping population.

General Methods for Creating Analytical Grids

The intermediate, subcomponent, or component grids that were created using the previous methods can be thought of as primary data that can be further manipulated or processed for input to various types of spatial analysis procedures. In a manner similar to the processing of the primary data coverages (such as parcels, buildings, and roads) used to create the analytical coverages, the model grids can be further processed to create analytical grids.

The analytical grids created may be simple derivatives of the original grids in which the cell values are converted into different units, or they may be created by applying simple algorithms to combinations of the model grids. A simple example would be the addition of several grids to create summary analytical grids representing total flows or storages. A more complex analytical method might require input from both component grids and ancillary data grid(s) (such as population density, current zoning, future land use, or spatial proximity) to output an analytical grid with values representing a new type of eco-energetic index or classification.

Logarithm Grids

Upon examination of the final spatial EMERGY model grids, it was found that the individual grid cell data values range from 0 (meaning there is no energy or EMERGY flow or storage in the cell) to approximately 100,000,000,000,000,000,000 (1.0×10^{20} or 1.0 E20). Excluding the ‘0’ values and a few cells with uniquely high values, most of the cell-value numbers range from approximately 1.0 E14 to 1.0 E20. The magnitude of these numbers often made it awkward to work with the grids in the model. For example, some of the GIS software being used does not readily convert these numbers to exponential notation for display and map legends.

In an attempt to simplify the model results and to improve comprehension by both the author and the reader, the common logarithm (base 10) was computed for each number in each cell of each grid. The final spatial EMERGY model consists of 51 energy and 51 EMERGY intermediate, subcomponent, or component grids, therefore, this procedure resulted in the creation of an additional 51 energy and 51 EMERGY analytical grids representing the flows and storages as logarithm values. The cell values represent either the logarithm of the total energy or EMERGY stored or the logarithm of the total energy or EMERGY flow per year occurring in the geographic area of each one hectare cell. The numbers for all analytical grids representing EMERGY storages are in units of logarithm of solar emjoules per hectare (log-sej/ha). The energy storage component grids are in units of logarithm of joules per hectare (log-j/ha). EMERGY flows are measured as the logarithm of the total annual flow of solar emjoules per hectare per year (log-sej/ha/yr). Energy flows are measured in units of logarithm of joules per hectare per year (log-j/ha/yr).

Total EMERGY Consumption and Total EMERGY Storage

EMPOWER is defined as the EMERGY flow per unit of time and ‘EMPOWER Density’ as the EMPOWER per unit of area (EMPOWER/area) (Odum, 1996). In this model, the numbers associated with each cell in each of the EMERGY flow (sub)component grids represent the ‘(Sub)Component EMPOWER Density’ of each cell. In other words, the numbers represent the EMPOWER density for each particular type of flow. For instance, the values in the ‘goods’ subcomponent grid represent the ‘EMPOWER density of goods consumption’. Similarly, the numbers associated with each cell in each of the EMERGY storage (sub)component grids represent the ‘(Sub)Component EMSTORAGE Density’.

The cell values of several of the component grids that represent flows of EMERGY were added together to create a ‘Total EMERGY Consumption’ analytical grid. The values in this grid represent ‘Total Consumption EMPOWER density’ for each grid cell.

In this model, the values in the ‘Total EMERGY Consumption’ analytical grid are the sum of the EMERGY in renewable resources used (as measured by transpiration—

element #1 in Figure 1-3), water used in buildings and agriculture (element #3 in Figure 1-3), all fuels used (including transportation, building, and agricultural use—element #4 in Figure 1-3), all goods used (and EMERGY in services associated with the goods—element #5 in Figure 1-3), and in-situ human services (element #6 in Figure 1-3).

To prevent ‘double-counting’ of EMERGY flows, the component grids representing gross primary productivity (the ‘gpp’ grid), waste generation (the ‘waste’ grid), and waste recycling (the ‘recycle’ grid) are not included in this summation.

In order to be able to calculate the transformity of ‘Total EMERGY Consumption’, the component grids that represent flows of energy that are complementary to the EMERGY component grids used to create the ‘Total EMERGY Consumption’ grid were also added together--the result is a ‘Total Energy Consumption’ analytical grid.

The component grids that represent all of the storages of EMERGY were added together to create a ‘Total EMERGY Storage’ analytical grid (sum of values for elements 9a, 9b, 9c, 10a, 10b, 10c, and 11 in Figure 1-3). The values in this grid represent ‘Total EMSTORAGE density’ for each grid cell.

It is important to emphasize that every one of the storages included in the land area unit model diagram is included in this summation. The ‘Urban Structure’ and ‘Natural Structure’ component grids were created similarly—by adding the related subcomponent grids to calculate values for ‘Total Urban Structure EMSTORAGE Density’ and ‘Total Natural Structure EMSTORAGE Density’ for each cell. In fact, the cell values in this analytical grid were actually created by adding the EMSTORAGE density values in the urban structure, natural structure, and people component grids.

To be able to calculate a transformity for the ‘Total EMERGY in Storage’, the component grids that represent all of the storages of energy were also added together to create a ‘Total Energy Storage’ analytical grid. After adding the component grids together, the common logarithm (base 10) was computed for each number in each cell of each ‘Total’ grid to create logarithm analytical ‘Total Density’ grids.

In results sections of this text, the ‘Total EMERGY Consumption’ analytical grid is referred to as the ‘Total EMPOWER Density’ analytical grid. The ‘Total EMERGY Storage’ analytical grid is referred to as the ‘Total EMSTORAGE Density’ analytical grid.

Transformity Grids

By dividing each cell value in the ‘Total EMERGY Consumption’ analytical grid by the value in the spatially coincident cell of the ‘Total Energy Consumption’ analytical grid, another analytical grid was created representing the transformity of the ‘Total EMERGY Consumption’ for each grid cell in the spatial model.

The transformity analytical grid for the ‘Total EMSTORAGE’ was calculated by dividing the ‘Total EMSTORAGE Density’ values in the grid by the ‘Total Energy Storage Density’ values in the ‘Total Energy Consumption’ grid. The units of the cell values in the transformity analytical grids are in solar emjoules/joule (sej/j).

Other Analytical Grids

In a manner similar to adding the component grids that represent flows or storages of EMERGY together to get ‘Total Density’ analytical grids, other combinations of component grids can be added together to produce analytical grids that can be used for further analysis. After adding the grids together, the common logarithm (base 10) was computed for each number in each cell of each analytical grid to create logarithm analytical grids for display purposes.

For instance, in this study the ‘Resource Use’ analytical grid was created by adding together the component EMPOWER density grids representing: the renewable resources used (the ‘renew’ component grid—element #1 in Figure 1-3), the water used by man (the ‘wtruse’ component grid—element #3 in Figure 1-3), the direct use of fuels and electricity (the ‘fuel’ component grid—element #4 in Figure 1-3), and the goods consumed (the ‘goods’ component grid—element # 5 in Figure 1-3). Notably, the ‘Resource Use’ analytical grid does not include the EMPOWER contributed by the in-situ human services (from the ‘service’ component grid—element #6 in Figure 1-3), but does include both renewable (element #1) and nonrenewable flows (elements #3, #4, and #5 in Figure 1-3) of EMERGY.

An analytical grid representing the total nonrenewable EMERGY flows, called ‘nonrenew’, was also created. This grid includes the sum of all of the flows included in the ‘Resource Use’ analytical grid except for the renewable resource flows contributed by the ‘renew’ component grid (i.e., elements #3, #4, and #5 in Figure 1-3).

To illustrate the potential value of creating both component and subcomponent grids in the model, another analytical grid was created, called ‘nonren_trn’, representing the amount of nonrenewable resources used without including the contribution of the flows from fuel used for transportation (from the ‘trn_ful’ subcomponent grid—element #4a in Figure 1-3). The cell values in this analytical grid represent the sum of the values from the ‘wtruse’ and ‘goods’ component grids, and the ‘bag_ful’ subcomponent grid (sum of the values for elements #3, #5, and #4b). Except for the contribution of EMERGY in the fuels used in agriculture (which were calculated on an area basis), this analytical grid represents nonrenewable flows occurring through buildings.

Using the Model for Analysis

Due to the generally quantitative nature of the model created for this study, the (sub)component grids could potentially be used for many types of studies and analyses. The following sections describe the general methods used for the analyses chosen for this study. In addition to the general statistical and data summary analyses that were used to help describe and better understand the characteristics of the model results, three comparative studies were conducted that may be of particular interest to researchers and practitioners in the urban and regional planning discipline.

Maps and Histograms

Maps of each of the component and subcomponent EMERGY and energy grids were produced using their corresponding logarithm analytical grids. As explained previously, it was determined that the extremely large ranges of the values in the (sub)component grids made presenting the results in logarithm form more comprehensible. The logarithm values of the maps are displayed in various colors corresponding to ranges of logarithm values (e.g. 16.00 – 16.49, 16.50 – 16.99, etc.).

Histograms were created for each (sub)component logarithm analytical grid to plot the number of grid cells that have values that fall within each log value range (using the same ranges that were used for plotting the corresponding logarithm analytical component map). Similar histograms were also created for the ‘Total Consumption EMPOWER’, ‘Total Energy Consumption’, ‘Total EMSTORAGE’, and ‘Total Energy Storage’ density logarithm analytical grids.

Histograms were also created for the ‘Total Consumption EMPOWER’ and ‘Total EMSTORAGE’ transformity analytical grids to plot the number of grid cells that have values within ranges of transformity ratios (sej/j).

County-wide (Sub)Component EMERGY Signatures

Another set of histograms, called ‘County-wide Component EMERGY Signatures’, were created by calculating the log of the sum of the values for all of the cells in each of the (sub)component grids. The histograms display the log of total county-wide EMERGY flow or storage for each (sub)component of the model. Four histograms were created corresponding to sets of (sub)component EMPOWER grids, energy flow grids, EMSTORAGE grids, and energy storage grids.

Calculations were also made to determine the percentages of the total county-wide annual EMPOWER (sej/county/yr) and total county-wide EMSTORAGE (sej/county) that were contributed by each of the (sub)component grids that were included in the ‘Total EMERGY Consumption’ and ‘Total EMSTORAGE’ analytical grids.

Comparative Studies

Three comparative studies were conducted in which basic statistics, maps, and EMERGY component signatures were generated for land use classifications, planning units, and representative neighborhoods.

Land use classifications. The Florida Land Use and Cover Classification System (FLUCCS) (FDOT, 1985) is commonly used by planners in Florida for describing and classifying land. With this in mind, the 1995 land use and cover GIS database (described earlier) was used to generate basic statistics and EMERGY signatures according to the land use classifications in the FLUCCS.

In this study, the magnitudes of EMERGY flows and storages, the mean densities of these flows and storages, the transformities were calculated for the land areas associated with each land classification code according to the land use and cover polygon coverage. These calculations were performed for both the more detailed ‘level 3’ classifications and the aggregated ‘level 2’ classifications.

Maps were generated of the log of the annual total EMPOWER (total consumption EMPOWER) and EMSTORAGE density based on the mean values calculated for each ‘level 2’ land use classification to facilitate comparison with the corresponding maps produced using the actual values in the model component grids. Maps of the transformities calculated for each ‘level 2’ land use classification were also generated.

In the Alachua County land use and cover GIS database, there are 163 ‘level 3’ land use classes and the 36 ‘level 2’ classes. These large numbers of classes result in large lists of statistics that are difficult to digest. To facilitate further analysis and to possibly improve comprehension of the results, a more aggregated land use classification scheme was created that only has 10 classes. This new scheme is similar to the ‘level 1’ classification scheme used for the FLUCCS except that the more generalized ‘residential’ classification in the FLUCCS was expanded to include the more specific ‘low-density’, ‘medium-density’, and ‘high-density’ residential classes.

Based on the new aggregated classification scheme, component EMERGY signatures were created for each classification by calculating the log of the sum of the values for all of the cells in each of the (sub)component grids. The signature histograms display the log of total EMERGY flow or storage for each (sub)component of the model that occurs within the area of each aggregated land use classification category.

Planning units. Four ‘planning units’ were defined for this study to facilitate comparison of the EMPOWER and EMSTORAGE characteristics of the different planning units. The ‘City of Gainesville’ planning unit was defined spatially by the city limits. The ‘Urban Services Area’ planning unit was defined by drawing a polygon around the areas contiguous to Gainesville that receive city utility services. The ‘Other Incorporated Areas’ planning unit includes those areas within the legal limits of the following small towns: Alachua, High Springs, Newberry, Archer, Micanopy, Hawthorne, Waldo, and La Crosse. All other areas belong to the ‘Alachua County’ planning unit.

Using the same approach used for the land classification study, the magnitudes of EMERGY flows and storages, the mean densities of these flows and storages, the transformities were calculated for the land areas associated with each planning unit.

Component EMERGY signatures were created for each planning unit by calculating the log of total EMERGY flow or storage for each (sub)component of the model that occurs within the area of each planning unit.

Neighborhoods. Four representative neighborhoods were chosen for this study to facilitate comparison of the EMPOWER and EMSTORAGE characteristics of the different types of residential development. In order to facilitate comparison, a 70 hectare representative 'sample' area was selected within each neighborhood.

The 'Millhopper Ranchettes' neighborhood was chosen to represent the typical 5-acre ranchette development that are found along the suburban fringe in Alachua County. 'The Hammock' subdivision was chosen to represent 'up-scale' developments with larger homes and 1 to 2-acre lots.

The 'Northwood Oaks' subdivision was chosen to represent typical neighborhoods in Gainesville on .25 to .3-acre lots. The 'Florida Park' neighborhood was chosen to represent the more densely-populated neighborhoods found near the University of Florida and downtown Gainesville.

Using the same methods used for the land classification and planning unit studies, the magnitudes of EMERGY flows and storages, the mean densities of these flows and storages, the transformities were calculated for the 70-hectare sampled land areas associated with each neighborhood.

Component EMERGY signatures were created for each planning unit by calculating the log of total EMERGY flow or storage for each (sub)component of the model that occurs within the area of each planning unit.

EMERGY Ratio Analysis

Several of the many possible EMERGY ratios were calculated for this study. The calculation of the ratios is accomplished simply by dividing the values in each cell of one component, or analytical, grid by the values in each spatially coincident cell of another component/analytical grid. For the ratio grids created in this study, this arithmetic operation results in a ratio grid with the values in each cell being a unit-less ratio number. This is because component/analytical EMPOWER grids are divided only by other EMPOWER component/analytical grids, and EMSTORAGE grids are divided only by other EMSTORAGE grids.

EMPOWER ratio grids were calculated for the following: nonrenewable use (NR) to renewable use EMERGY flows (NR/R)(sum of the values for Figure 1-3 elements #3, #4, and #5 divided by the value of element #1), nonrenewable-less-transportation fuels use (NR-T) to renewable use EMERGY flows (NR-T/R)(sum of the values for Figure 1-3 elements #3, #4b, and #5 divided by the value of element #1), in-situ human services (S) to nonrenewable use (NR) EMERGY flows (S/NR)(the value of element #6 in Figure 1-3 divided by the sum of the values for elements #3, #4, and #5), and in-situ human services (S) to resource use (RU) EMERGY flows (S/RU)(the value of element #6 in Figure 1-3 divided by the sum of the values for elements #1,#3, #4, and #5).

EMSTORAGE ratio grids were calculated for the following: urban structure (U) to natural system structure (N) EMERGY storages (U/N)(the sum of the values of elements #10a, #10b, and #10c in Figure 1-3 divided by the sum of the values for elements #9a, #9b, and #9c), urban structure (U) to biomass (B) EMERGY storages

(U/B)(the sum of the values of elements #10a, #10b, and #10c in Figure 1-3 divided by the value for element #9a), population (P) to urban structure (U) EMERGY storages (P/U)(the value for element #11 in Figure 1-3 divided by the sum of the values of elements #10a, #10b, and #10c), and population (P) to biomass (B) EMERGY storages (P/B)(the value for element #11 in Figure 1-3 divided by the value of element #10a).

County-wide EMERGY ratio maps were produced for each of the EMPOWER and EMSTORAGE ratio grids. Using methods similar to those described for the comparative studies, ratios were calculated for the land areas associated with each aggregated land use classification, planning unit, and neighborhood.

Spatial Context Analysis

Spatial context analysis was performed to examine several relations between the values of individual cells and the values of surrounding cells. Contextual indices were designed and calculated in an attempt to better understand spatial distribution patterns of EMPOWER density and EMSTORAGE density.

Surrounding cells that are included in quantitative comparisons with a central cell are defined as being in the 'neighborhood' of the central cell. Three neighborhood-types were used for this study: the one-cell-, three-cell-, and five-cell-radius neighborhoods. Only those adjacent cells whose cell-center is within 100 meters (the dimensions of one cell) of the cell-center of the central cell belong to the one-cell-radius neighborhood of a particular cell. Three- and five-cell-radius neighborhoods are defined and calculated in the same manner as the one-cell-radius neighborhoods.

Three different contextual indices were calculated for each of the three neighborhood types: log of the mean density values of the cells in the neighborhood, log of the maximum density value of the cells within the neighborhood, and the percentage of the maximum neighborhood value that the value of the central cell represents. Each of the three contextual indices was calculated for each of the three neighborhood types for both the total annual EMPOWER density analytical grid (representing total EMERGY consumption—sum of elements # 1, #3, #4, #5, and #6 in Figure 1-3) and the total EMSTORAGE density analytical grid (sum of elements #9a, #9b, #9c, #10a, #10b, #10c, and #11 in Figure 1-3). Maps and histograms were produced of the results.

One-Kilometer Cell-Size Model

The cell-size of the spatial EMERGY model created for this study was chosen to reveal detail and patterns of distribution and variation within land use classifications, planning units, and neighborhoods. This level of spatial resolution may not be required for a spatial EMERGY model to be useful for studies of larger regions (such as state, country, or global studies). Additionally, the spatial accuracy of the data that is often available for larger regions may dictate that a larger cell size be used for the development of the component grids.

To simulate how a coarser resolution model would look compared to the one-hectare model presented in this study, the values in several of the analytical grids were aggregated into one-kilometer cell size analytical grids. The values in each cell of the one-kilometer analytical grids are the log of the sum of the values of those one-hectare cells that are spatially coincident with each one-kilometer cell.

RESULTS

The GIS Database

An extensive GIS database of Arc/Info coverages was compiled for this study. Many existing coverages were reviewed for their potential contributions of primary data that could be used to create the spatial EMERGY model. As a result of this review, it was determined that some of the existing primary data coverages could be used as inputs with little additional processing. At the same time, it was also determined that several new primary data coverages would have to be created either because there was no existing coverage of the type needed, or because the existing data did not meet the spatial accuracy or attribute content requirements of this study.

Using the existing or new primary data coverages, several analytical coverages were also created by overlaying primary data coverages with the 100-meter square polygons of the 'alanet100cov' coverage, and adding appropriate attribute items to the feature attribute tables to allow for calculations of energy and EMERGY flows and storages. These analytical coverages were necessary for creating the component, sub-component, and intermediate component grids of the spatial EMERGY model.

The following sections contain brief descriptions of the new primary data coverages and analytical coverages created for this study, a simple map of the features in each coverage, and a descriptive list of the items in each coverage feature attribute table.

New Primary Data Coverages

Property parcels. The property parcel polygon coverage (Figure 3-1) was created by converting the Alachua County Property Appraiser's GIS database, which was in MapGrafix software format, into Arc/INFO GIS software format (Lambert, 1996). This conversion process required about 6 months of full-time work on the part of the author. There are 86,846 polygons in the coverage representing the boundaries of individual land ownership (as of December, 1995) in Alachua County. Figure 3-2 describes the items in the polygon attribute table for the coverage.

Department of Revenue (DOR) land use codes were assigned to each parcel, by the Alachua County Tax Appraiser's office, to serve as a basis for taxation based on the primary use of the property parcel and/or the use of the buildings on the property (DOR, 1990). Table 3-1 lists the descriptions of each of the DOR codes, the number of instances of parcel polygon features assigned each code number, and the total square footage of the buildings in each classification code.

DOR codes were used in several of the energy and EMERGY calculations. For instance, the codes were used as the basis for determining the type of parcel or building a coverage feature represents. The parcel/building type was then used to assign the corresponding flow or storage rates values to each of these features for use in appropriate equations. Other important attributes that were used in the calculations included the total square footage of the building, and the dollar value of the building and miscellaneous improvements. Table 3-1 is presented here to provide a cross-reference for subsequent tables and calculations that are based on the DOR codes.

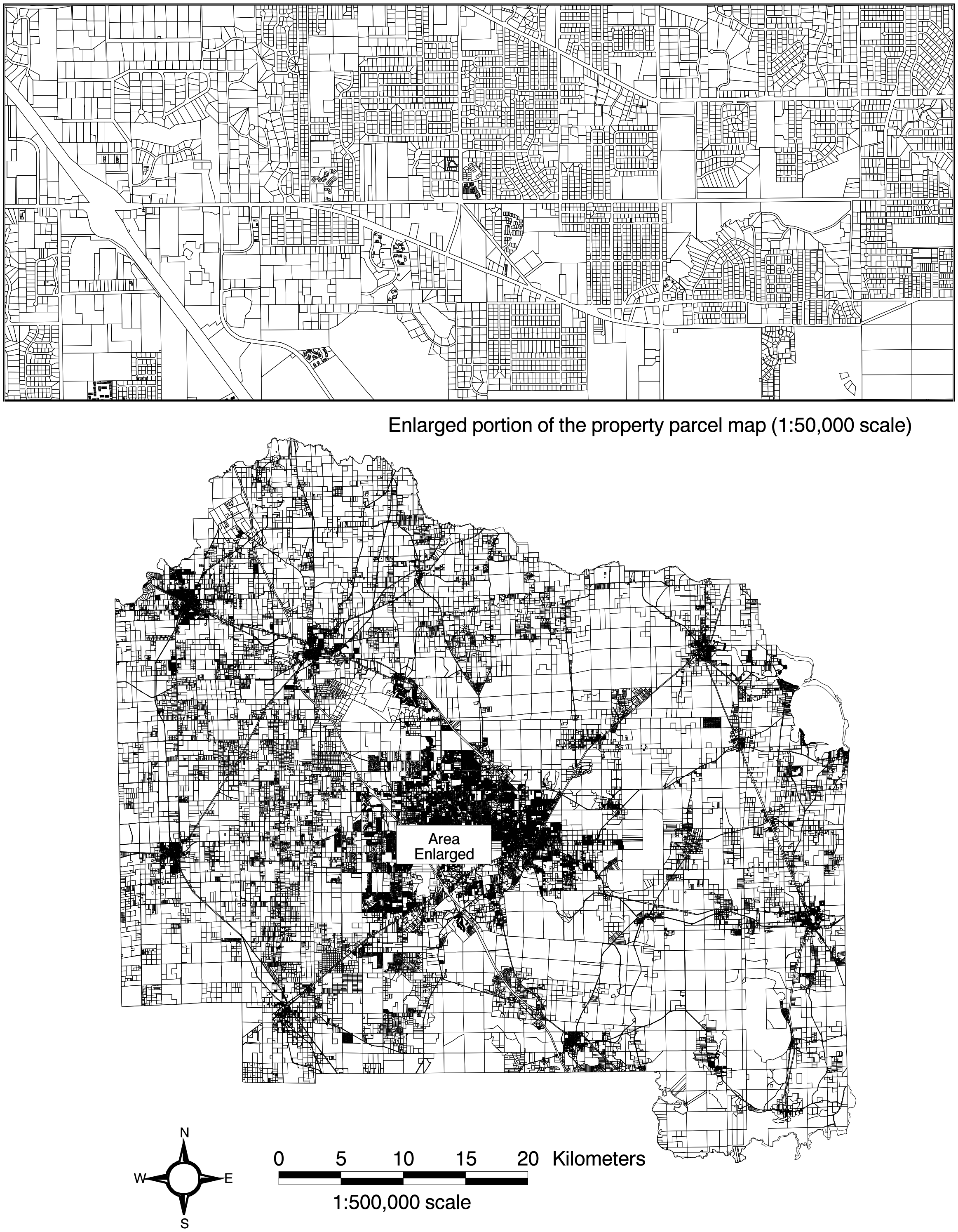


Figure 3-1: Map of the polygon coverage of property parcels for Alachua County.

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	AREA	4	12	F	3	area of polygon, m2
5	PERIMETER	4	12	F	3	perimeter of polygon, m
9	ALAPAVE1#	4	5	B	-	software item
13	ALAPAVE1-ID	4	5	B	-	software item
17	SECTWNRNG	13	13	C	-	section, township, range
30	OLNAME	40	40	C	-	owner last name
70	OFNAME	30	30	C	-	owner first name
100	CITYCODE	8	5	F	0	city land use code (incomplete)
108	DORCODE	8	5	F	0	DOR land use code (complete)
116	LUSE	8	5	F	0	county land use code (incomplete)
124	MUSE	8	5	F	0	county major use code
132	HMST_CODE	8	3	F	0	homestead exemption code
140	HMST_AMT	8	10	F	0	homestead exemption amount, $
148	TR_ACRES	8	10	F	2	area according to deed, acres
156	ACRES	8	10	F	2	area according to appraiser GIS
164	TJUSTVALUE	8	12	F	0	total just value, $
172	TLANDVALUE	8	12	F	0	total land value, $
180	TBLDGVALUE	8	12	F	0	total building value, $
188	MISCVALUE	8	12	F	0	miscellaneous structure value, $
196	TOTVALUE	8	12	F	0	total value, $
204	TAXVALUE	8	12	F	0	assessed value, $
212	SALEDATE	8	8	C	-	last sale date
220	SALEVALUE	8	10	F	0	last sale value, $
228	SALE_VACIM	1	1	C	-	appraiser code
229	QUALIFIED	1	1	C	-	appraiser code
230	TOTSQFOOT	8	12	F	0	total square footage, ft2
238	HTSQFOOT	8	12	F	0	heated square footage, ft2
246	YEARBLT	8	5	F	0	year built
254	BEDROOMS	8	4	F	0	number of bedrooms
262	BATHS	8	5	F	1	number of bathrooms
270	NUM_BLDGS	8	5	F	1	total number of buildings
278	ZONE1	6	6	C	-	zoning code (incomplete)
284	ZONE2	6	6	C	-	zoning code (incomplete)
290	LUSE1	8	8	C	-	county land use code (incomplete)
298	LUSE2	8	8	C	-	county land use code (incomplete)
306	PCITY	15	15	C	-	city association
321	PARCEL_ID	13	13	C	-	parcel identification number
334	PARCEL_IDTYPE	7	7	C	-	polygon type (used in conversion)
341	PARCEL_IDGROUP	1	1	C	-	multiple polygon parcel?
342	LABEL_SOURCE	1	1	C	-	used in database conversion
343	POLY_TYPE	7	7	C	-	used in database conversion
350	POLY_ACRES	4	12	F	2	coverage polygon area, m2

Figure 3-2: ‘Property Parcels’ coverage polygon feature attribute table.

Table 3-1: Description of Department of Revenue (DOR) Codes used in the 'buildings' and 'property parcels' coverages. The table also lists the number of instances and total square footage of all of the buildings in each classification.

DOR Code	Description	No. of Instances	Total Square Footage
0	Vacant Residential	42	19470
100	Single Family Residential	41063	84807662
200	Mobile Home Residential	4477	5441880
300	Multi-Family Residential (10 or more units)	321	17833161
400	Residential Condominiums	1106	1212655
600	Retirement Homes (not classified institutional)	4	247073
700	Misc. Residential (boarding homes, etc.)	1152	187275
800	Multi-Family Residential (less than 10 units)	1689	5033998
900	Undefined Residential	18	38522
1000	Vacant Commercial	4	14108
1100	Stores, One Story	529	3480536
1200	Mixed Use - Store and Office	100	495076
1300	Department Stores	3	295530
1400	Supermarkets	17	298165
1500	Regional Shopping Centers	10	1371463
1600	Community Shopping Centers	136	3591552
1700	Office and Non-Professional Services, One Story	512	2505447
1800	Office and Non-Professional Services, Multi-Story	51	719524
1900	Professional Services	212	1691523
2000	Airports, bus terminals	2	79650
2100	Restaurants, Cafeterias	92	471342
2200	Drive-In Restaurants	79	229516
2300	Financial Institutions	50	451266
2400	Insurance Company Offices	11	462002
2500	Repair Service Shops, Laundries, mobile home sales	93	386852
2600	Repair Service Shops, Laundries, mobile home sales	65	244012
2700	Repair Service Shops, Laundries, mobile home sales	143	1148567
2800	Parking Lots and Mobile Home Parks	135	357905
2900	Wholesale Outlets	54	584396
3000	Florists, Greenhouses	12	59008
3200	Theatres	2	46146
3300	Nightclubs, bars	45	270591
3400	Bowling Alleys, etc.	4	136860
3500	Tourist Attractions, Fairgrounds	3	16285
3600	Camps	8	136084
3700	Race Tracks	1	27081
3800	Golf Courses	7	117081
3900	Hotels, Motels	52	2120923
4000	Vacant Industrial	1	236
4100	Light Manufacturing	115	2340608
4200	Heavy Industrial and Manufacturing	6	491714
4300	Lumber Yards and Sawmills	8	62219
4400	Packing Plants, Fruit and Vegetable	1	160
4500	Canneries and Distilleries	2	41216
4569	Canneries and Distilleries	1	1728
4600	Food Processing	2	43705
4700	Mineral Processing, Cement and Gravel Plants	5	44532

Table 3-1 -- continued.

DOR Code	Description	No. of Instances	Total Square Footage
4800	Warehousing and Distribution Terminals	328	3200857
4900	Open Storage, Junk Yards, Fuel Storage	17	75865
5100	Cropland, soil capability class I	151	306770
5200	Cropland, soil capability class II	482	937196
5300	Cropland, soil capability class III	15	20128
5400	Timberland - site index 90 and above	126	250745
5500	Timberland - site index 80 to 89	309	571482
5600	Timberland - site index 70 to 79	94	150889
5700	Timberland - site index 60 to 69	1	60
5900	Timberland - site index not classified	84	190208
6000	Grazing Land, soil capability Class I	228	734421
6100	Grazing Land, soil capability Class II	583	1443921
6200	Grazing Land, soil capability Class III	99	217326
6300	Grazing Land, soil capability Class IV	19	56947
6400	Grazing Land, soil capability Class V	7	13441
6500	Grazing Land, soil capability Class VI	118	209464
6600	Orchard Groves	138	338200
6700	Poultry, bees, etc.	4	29142
6800	Dairies, Feed Lots	142	402494
6900	Ornamentals, Misc. Agriculture	84	162133
7100	Churches	386	1916038
7300	Privately owned Hospitals	4	486441
7600	Mortuaries, cemeteries	15	64410
7635	Crematorium	1	1713
7900	Cultural Organizations, facilities	3	15368
8200	Parks and Recreational Areas	17	50133
8300	Public County Schools	42	921707
8400	Colleges	876	13329334
8500	Hospitals	6	185401
8600	County (other than recreation, college, hospital)	28	745187
8700	State (other than recreation, college, hospital)	34	402381
8800	Federal (not military, recreation, hospital)	11	769961
8900	Municipal (not recreation, college, hospital)	129	608800
9100	Utilities	37	766812
9200	Mining	1	392
9400	Right of Way	4	2478
9600	Waste Disposal	1	736
9700	Outdoor Recreation	16	17954
9900	Acreage not zoned agricultural	1	2700

Buildings. The creation of the building point coverage (Figure 3-3) was described earlier in the methods chapter. Essentially, the polygon centroids of those polygons in the parcel coverage that had a dollar value greater than zero for built structure were converted into point features. There are 57,421 point features in the building coverage. Figure 3-4 describes the point feature attribute table for the coverage.

Some of these point features were repositioned to more accurately represent the location of the built structure on each parcel. This was done because the spatial accuracy of the building point coverage would be reflected in several of the final components of the model that would be derived from various attribute data associated with the building coverage.

It is important to emphasize that, in some cases, the point features in this coverage represent other types of privately-owned built structures (such as fencing, driveways, and other structural improvements to a parcel) other than, or in addition to, the buildings on a particular parcel. Every effort has been made to consider this factor in the calculations associated with buildings, however, some anomalies may exist in the final results because of this characteristic of the coverage. Another characteristic of the building coverage that is important to note is that, in some cases, a single point feature represents multiple buildings on a parcel. This is particularly the case for those point features representing multi-family housing. Fortunately, there are attributes in the building coverage's feature attribute table that identify the number of buildings associated with each feature. These data allowed for consideration of this characteristic in the calculations of energy and EMERGY flows and storages associated with buildings.

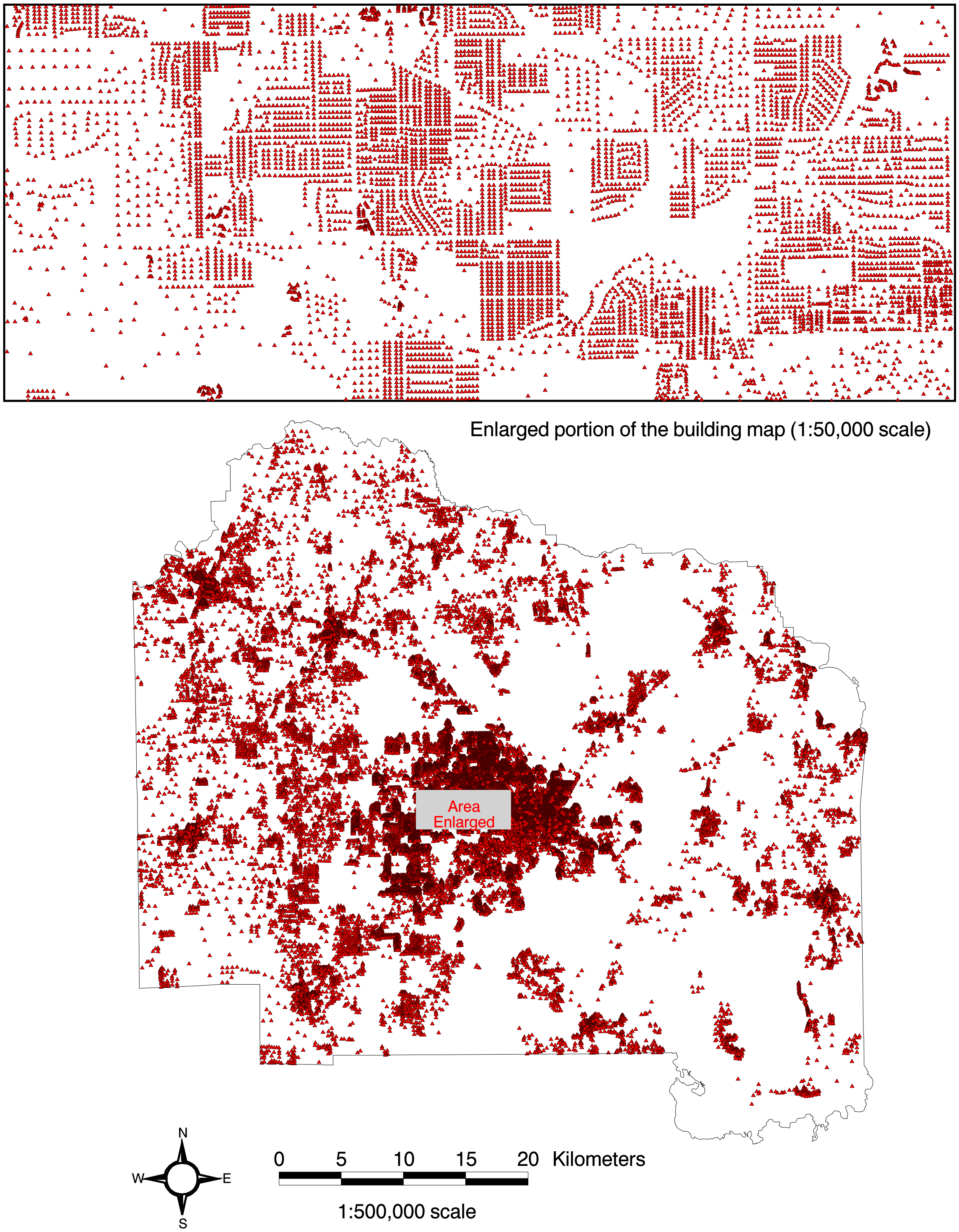


Figure 3-3: Map of the point coverage of buildings in Alachua County.

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	AREA	8	18	F	5	software item
9	PERIMETER	8	18	F	5	software item
17	ALLBLDGS#	4	5	B	-	software item
21	ALLBLDGS-ID	4	5	B	-	software item
25	PARCEL_ID	13	13	C	-	parcel identification number
38	SECTWNRNG	13	13	C	-	section, township, range
51	OLNAME	40	40	C	-	owner last name
91	OFNAME	30	30	C	-	owner first name
121	CITYCODE	8	5	F	0	city land use code (incomplete)
129	DORCODE	8	5	F	0	DOR land use code (complete)
137	LUSE	8	5	F	0	county land use code (incomplete)
145	MUSE	8	5	F	0	county major use code
153	HMST_CODE	8	3	F	0	homestead exemption code
161	HMST_AMT	8	10	F	0	homestead exemption amount, $
169	TR_ACRES	8	10	F	2	area according to deed, acres
177	ACRES	8	10	F	2	area according to appraiser GIS
185	TJUSTVALUE	8	12	F	0	total just value, $
193	TLANDVALUE	8	12	F	0	total land value, $
201	TBLDGVALUE	8	12	F	0	total building value, $
209	MISCVALUE	8	12	F	0	miscellaneous structure value, $
217	BLDG_MISC	8	12	F	0	sum of tbldgvalue and miscvalue
225	BLDG_MISC_EST	1	1	C	-	miscvalue estimated? Y/N
226	TOTVALUE	8	12	F	0	total value, $
234	TAXVALUE	8	12	F	0	assessed value, $
242	SALEDATE	8	8	C	-	last sale date
250	SALEVALUE	8	10	F	0	last sale value, $
258	SALE_VACIM	1	1	C	-	appraiser code
259	QUALIFIED	1	1	C	-	appraiser code
260	TOTSQFOOT	8	12	F	0	total square footage, ft2
268	HTSQFOOT	8	12	F	0	heated square footage, ft2
276	YEARBLT	8	5	F	0	year built
284	BEDROOMS	8	4	F	0	number of bedrooms
292	BATHS	8	5	F	1	number of bathrooms
300	NUM_BLDGS	8	5	F	1	total number of buildings
308	ZONE1	6	6	C	-	zoning code (incomplete)
314	ZONE2	6	6	C	-	zoning code (incomplete)
320	LUSE1	8	8	C	-	county land use code (incomplete)
328	LUSE2	8	8	C	-	county land use code (incomplete)
336	PCITY	15	15	C	-	city association
351	FREQ_FLAG	1	1	C	-	item used in database development
352	CHECK_FLAG	1	1	C	-	item used in database development
353	UF_FLAG	1	1	C	-	item used in database development

Figure 3-4: ‘Buildings’ coverage point feature attribute table.

Roads. The roads coverage (Figure 3-5) was converted from several AutoCad digital format files that were created as part of the Alachua County Control Densification and Identification of Land Corners Project (Southern Resource Mapping Co., 1990). New roads, built since 1988, were added to the coverage using the parcel coverage as a guide. There are 21,355 line features in the coverage. Figure 3-6 describes the line feature attribute table for the coverage.

Attribute data for functional classification, number of lanes, and estimated average annual daily traffic were added to each road segment in the coverage to facilitate calculations of energy and EMERGY flows and storages associated with roads (ADOT, 1995, and FDOT, 1995).

Land use and cover. The land use and cover coverage (Figure 3-7) was created by combining 1995 and 1990 land use and cover coverages (SRWMD, 1995, May, 1993). There are 18,480 polygon features in the year-hybrid coverage. Figure 3-6 describes the polygon feature attribute table for the coverage.

Table 3-2 provides a cross-reference for subsequent tables and calculations that are based on the Florida Land Use and Cover Classification System (FLUCCS) (FDOT, 1985) codes used in this coverage. The total County-wide areas associated with each code, the percentage of the County covered by each code, and the number of instances are summarized in Table 3-2. In Figure 3-8, the codes have been aggregated to more generalized types to illustrate an apparent area-based hierarchy of land use and cover. FLUCCS codes were used in several of the calculations as the basis for determining the type of land use or cover a feature represents and to assign the corresponding flow or storage rate values to each of these features for use in appropriate equations.

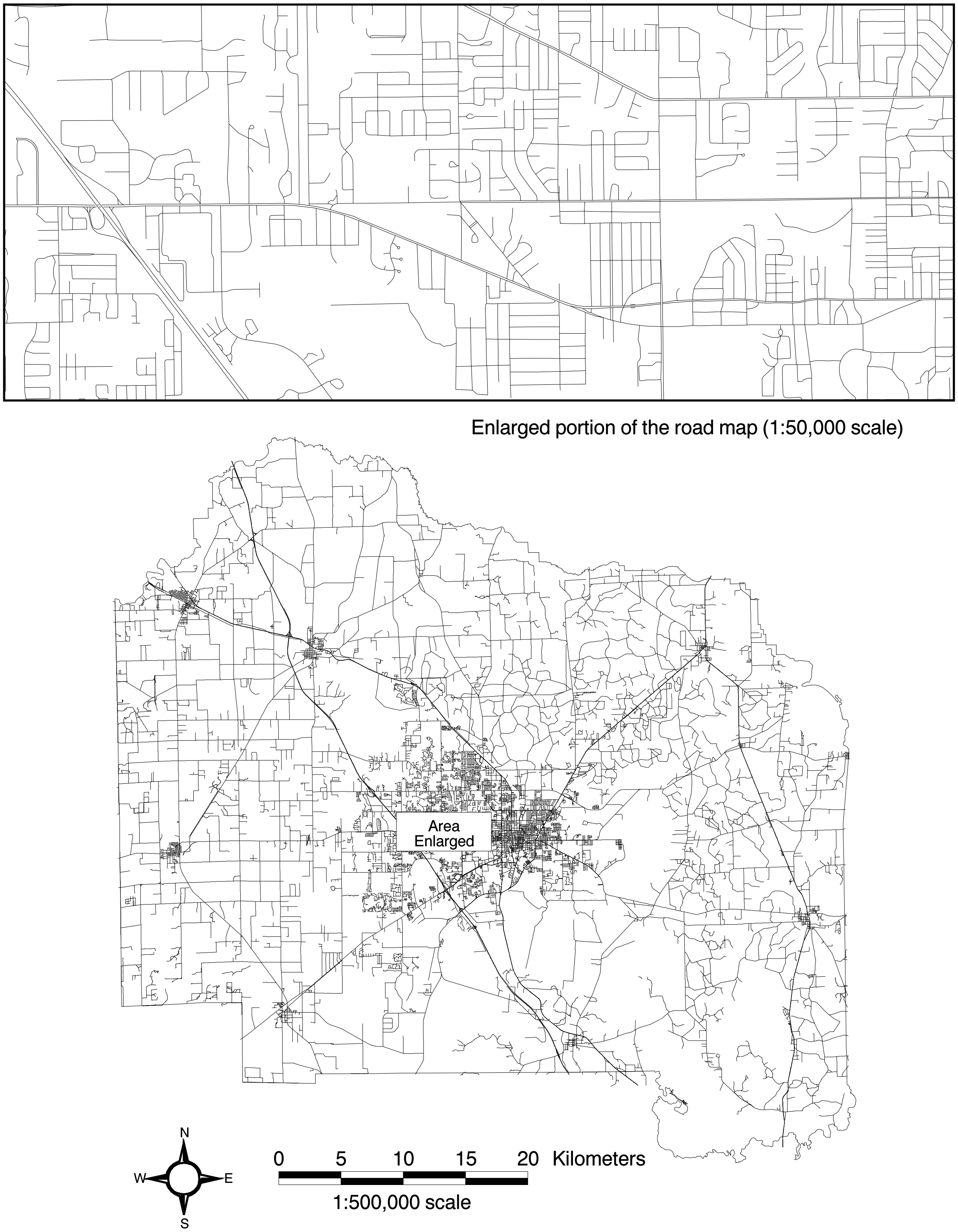


Figure 3-5: Map of the line coverage of roads in Alachua County.

(a)

Roads Coverage

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	FNODE#	4	5	B	-	software item
5	TNODE#	4	5	B	-	software item
9	LPOLY#	4	5	B	-	software item
13	RPOLY#	4	5	B	-	software item
17	LENGTH	8	18	F	5	length in meters
25	JDL_ROADS_1#	4	5	B	-	software item
29	JDL_ROADS_1-ID	4	5	B	-	software item
33	DXF_LAYER	16	16	C	-	AutoCAD layer name
49	FNAME	38	38	C	-	road name
87	FUNCLASS	2	2	I	-	FDOT functional classification
89	NO_LANES	1	1	I	-	number of lanes
90	AADT	6	6	I	-	average annual daily traffic, #
96	AADT_SOURCE	3	3	C	-	source of the AADT data
99	LINESOURCE	3	3	C	-	source of the line feature
102	MAP_ANNO	1	1	C	-	used for map annotation methods
103	DBL_LINE	1	1	C	-	is road symbolized by two lines?
104	EDITFLAG	3	3	C	-	used in database development

(b)

Land Use and Cover Coverage

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	AREA	8	18	F	5	area of polygon, m2
9	PERIMETER	8	18	F	5	perimeter of polygon, m
17	LANDUSE95#	4	5	B	-	software item
21	LANDUSE95-ID	4	5	B	-	software item
25	LUCODE	4	4	I	-	FLUCCS land use code
29	HECTARES	4	12	F	4	area of polygon in hectares

Figure 3-6: Descriptions of the feature attribute tables for the ‘Roads’ line coverage (a) and the ‘Land Use and Cover’ polygon coverage (b).

Enlarged portion of the landuse and cover map (1:50,000 scale)

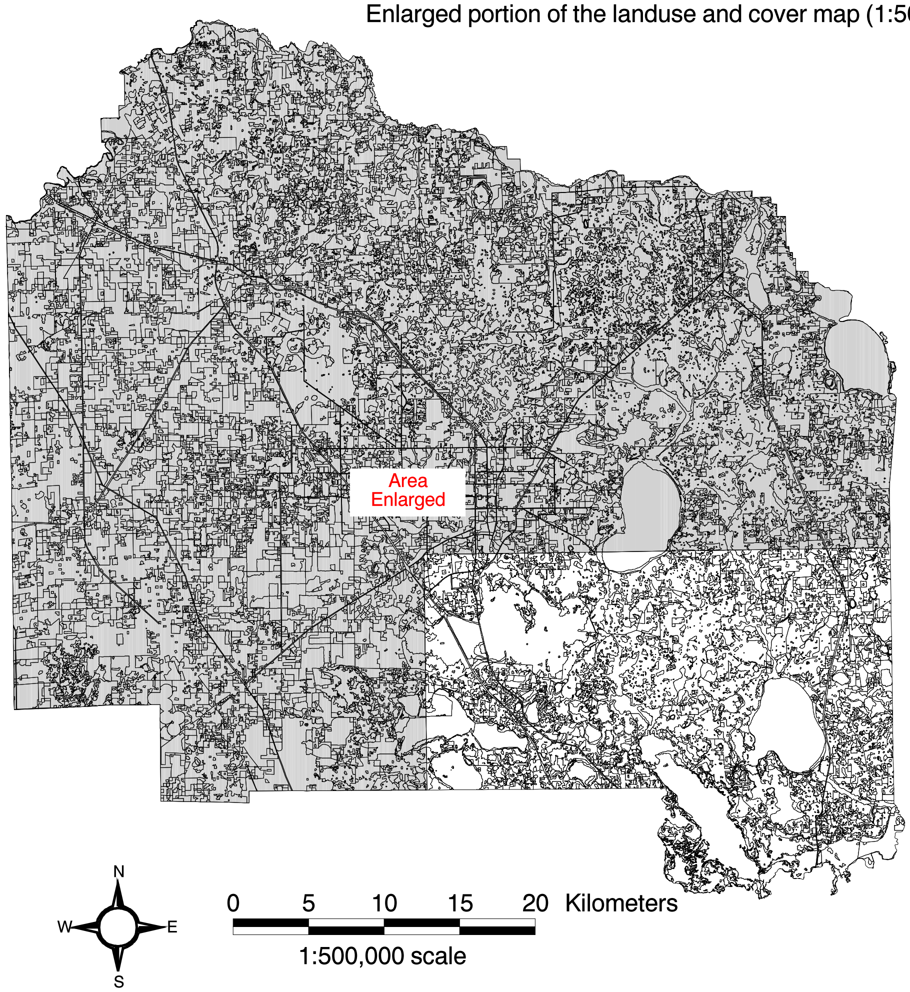


Figure 3-7: Map of the polygon coverage of landuse and cover for Alachua County that was modified for this study. The gray-shaded polygons are from the Suwannee River Water Management District 1995 landuse/cover database (SRWMD, 1995). The unshaded polygons are from the St. Johns River Water Management District 1990 landuse/cover database (May, 1993).

Table 3–2: Description of the Level 3 Florida Land Use and Cover Classification Codes (FDOT, 1985) used in the polygon coverage of land use and cover . This table provides an essential cross-reference for several subsequent tables of calculation results that use the codes presented here. For each code, summary statistics are presented for the total county-wide area (in hectares) in each classification, the percentage of the total County-wide area covered by each classification, and the number of polygons assigned to each classification.

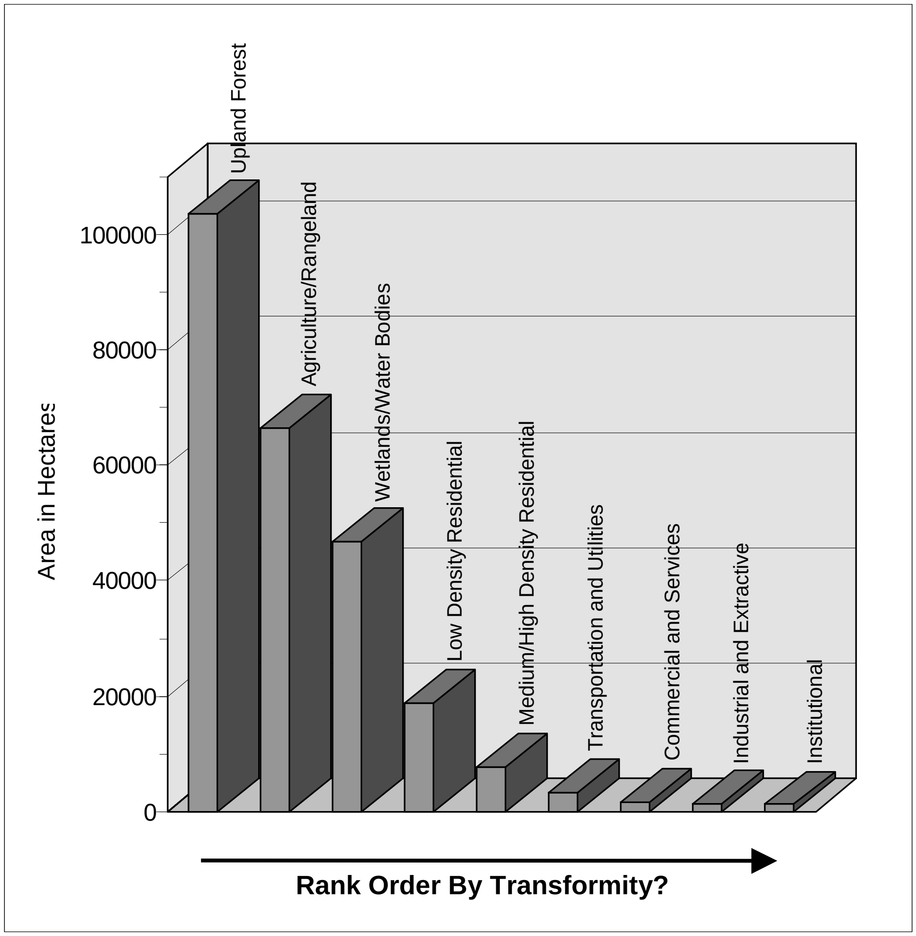
Level 3 Code	Description	Co.-wide hectares	% of Co.-wide area	No. of Polygons
1100	Residential, low density	1987.1	0.7915	345
1110	single family	1387.6	0.5527	55
1120	mobile homes	23.9	0.0095	11
1130	mixed units (single/mobile)	1683.4	0.6705	107
1140	ranchettes - single family	3773.3	1.5029	1355
1150	ranchettes - mobile homes	1224.5	0.4877	601
1160	ranchettes - mixed units	8763.3	3.4904	811
1200	Residential, med. density	471.7	0.1879	16
1210	single family	2289.1	0.9118	58
1220	mobile homes	218.3	0.0869	14
1230	mixed units (single/mobile)	3432.6	1.3672	76
1300	Residential, high density	170.1	0.0678	14
1310	single family	171.6	0.0683	10
1320	mobile homes	104.2	0.0415	13
1330	multiple dwelling, low rise	520.5	0.2073	70
1340	multiple dwelling, high rise	262.1	0.1044	24
1350	mixed units (single/mobile)	39.8	0.0158	2
1400	Commercial and Services	1091.8	0.4349	273
1411	shopping centers	243.5	0.0970	24
1423	junk yards	45.3	0.0180	16
1424	farmers markets	2.2	0.0009	1
1452	motels	44.7	0.0178	14
1453	travel trailer parks	7.6	0.0030	1
1454	campgrounds	40.8	0.0163	2
1460	oil and gas storage	3.9	0.0015	2
1470	mixed commercial/services	11.8	0.0047	3
1480	cemeteries	120.7	0.0481	44
1490	commercial construction	9.4	0.0037	1
1500	Industrial	9.5	0.0038	1
1516	grain processing	1.1	0.0005	1
1521	sawmills	33.2	0.0132	2
1527	woodyards	3.8	0.0015	1
1550	light industrial	446.6	0.1779	71
1551	boat building	24.9	0.0099	1
1552	electronics industry	21.9	0.0087	1
1555	container manufacturing	3.9	0.0015	1
1560	heavy industrial	16.3	0.0065	3
1565	heavy industrial	13.6	0.0054	2
1570	chemical processing	7.7	0.0031	1
1600	Extractive	13.5	0.0054	1
1611	strip mines, clays	2.9	0.0012	1
1614	strip mines, phosphate	495.2	0.1972	2
1620	sand and gravel pits	50.5	0.0201	9
1631	rock quarries, limerock	112.1	0.0447	2
1660	holding ponds	117.5	0.0468	31
1670	inactive strip mines	75.6	0.0301	3

Table 3-2 – continued.

Level 3 Code	Description	Co.-wide hectares	% of Co.-wide area	No. of Polygons
1700	Institutional	115.1	0.0459	20
1710	educational facilities	807.0	0.3214	53
1720	religious facilities	87.6	0.0349	59
1741	hospitals	53.5	0.0213	6
1756	govt. maintenance yards	41.6	0.0166	8
1765	municipal prisons	21.7	0.0087	3
1770	other institutional	63.2	0.0252	5
1800	Recreational	18.9	0.0075	4
1820	golf courses	364.9	0.1453	13
1831	auto race tracks	93.0	0.0370	2
1850	parks	16.5	0.0066	3
1851	city parks	2.5	0.0010	1
1860	community recreation	122.5	0.0488	22
1890	other recreation	107.7	0.0429	12
1900	Open Land	57.1	0.0227	7
1910	undeveloped in urban area	114.2	0.0455	32
1920	inactive w/streets only	101.3	0.0404	13
1923	inactive (non-forested)	174.1	0.0693	24
1924	inactive (forested > 10%)	320.3	0.1276	39
2110	Agriculture (improved pasture)	40779.0	16.2424	1354
2120	unimproved pasture	517.3	0.2060	72
2130	woodland pasture	5042.8	2.0086	475
2140	row crops	11602.4	4.6213	395
2150	field crops	478.4	0.1906	34
2160	field crops	36.7	0.0146	4
2200	tree crops	8.9	0.0035	1
2210	citrus groves	60.0	0.0239	10
2220	fruit orchards	12.7	0.0050	4
2224	blueberries	345.6	0.1377	24
2230	other groves	10.2	0.0040	2
2231	pecans	604.8	0.2409	91
2240	other tree crops	10.0	0.0040	4
2300	feeding operations	8.1	0.0032	4
2310	cattle feeding	19.8	0.0079	1
2320	poultry feeding	40.5	0.0161	10
2410	tree nurseries	118.3	0.0471	7
2420	sod farms	3.2	0.0013	1
2430	ornamental nurseries	86.4	0.0344	16
2450	floriculture	1.5	0.0006	1
2510	horse farms	100.8	0.0402	13
2520	dairies	61.4	0.0244	6
2530	kennels	10.5	0.0042	3
2540	aquaculture	41.0	0.0163	10
2590	other specialty farms	59.9	0.0239	4
2600	other open lands, rural	47.9	0.0191	13
2610	fallow crop land	14.5	0.0058	4
2620	old fields	1302.2	0.5187	169
3100	Rangeland (herbaceous)	14.9	0.0059	6
3200	shrub and brushland	117.4	0.0467	18
3290	other shrub and brush	3912.9	1.5585	368
3300	mixed rangeland	185.4	0.0738	28
4110	Upland Forest (mesic flatwoods)	1478.7	0.5890	114
4120	longleaf sandhill	270.2	0.1076	11
4140	pine-mesic oak	104.2	0.0415	9
4190	plantation woodlands	291.2	0.1160	3
4200	upland hardwood forest	292.4	0.1165	18
4210	oak sandhill	653.1	0.2601	15

Table 3-2 – continued.

Level 3 Code	Description	Co.-wide hectares	% of Co.-wide area	No. of Polygons
4230	oak - pine - hickory	815.5	0.3248	40
4250	temperate hardwoods	16674.7	6.6416	900
4310	beech-magnolia	202.6	0.0807	4
4340	hardwood - conifer mixed	20334.9	8.0995	835
4400	tree plantations	9111.1	3.6290	115
4410	pine plantations	42227.9	16.8195	826
4430	forest regeneration	10463.5	4.1676	383
5100	Water (streams)	72.4	0.0288	20
5120	streams	13.7	0.0055	1
5200	lakes	5961.4	2.3744	168
5210	lakes, > 500 acres	4113.9	1.6386	4
5220	lakes, 100-500 acres	371.6	0.1480	3
5230	lakes, 10-100 acres	353.0	0.1406	25
5240	lakes, < 10 acres	212.3	0.0846	297
5300	reservoirs	16.1	0.0064	43
5330	reservoirs, 10-100 acres	49.0	0.0195	6
5340	reservoirs, <10 acres	296.6	0.1182	444
6100	Wetlands	14.1	0.0056	3
6110	bay swamps	326.4	0.1300	21
6120	shrub swamps	3.5	0.0014	2
6140	shrub swamps	303.9	0.1210	56
6150	bottomland hardwood forest	1281.3	0.5104	51
6170	mixed wetland hardwoods	298.9	0.1191	37
6200	wetland coniferous forest	50.1	0.0199	13
6210	cypress	2223.0	0.8854	577
6220	pond pine	957.7	0.3815	201
6300	wetland forested mixed	14693.6	5.8525	3450
6310	hydric hammock	187.6	0.0747	3
6410	freshwater marshes	8535.7	3.3998	1253
6420	freshwater marshes	3.1	0.0013	1
6430	wet prairies	1321.1	0.5262	70
6440	emergent aquatic vegetation	2344.6	0.9339	202
6450	submergent aquatic vegetation	73.0	0.0291	5
6460	aquatic vegetation	1934.5	0.7705	359
6530	ephemeral ponds	675.2	0.2689	83
6600	cutover wetlands	151.1	0.0602	96
7400	Barren land (disturbed)	18.9	0.0075	6
7410	other disturbed land	41.1	0.0164	7
7420	borrow areas	34.5	0.0137	9
8111	Transportation (comm.airport)	346.7	0.1381	1
8113	private airport	26.4	0.0105	3
8120	railroads	15.7	0.0063	1
8140	roads and highways	382.1	0.1522	4
8141	interstate highways	274.2	0.1092	1
8142	divided highways (state/federal)	718.4	0.2861	10
8143	two-lane highways	177.4	0.0706	12
8147	other highways	378.2	0.1507	10
8170	transmission lines	117.9	0.0470	4
8180	auto parking (rest areas)	1.0	0.0004	1
8200	communications	2.6	0.0010	2
8310	Utilities (electric plant)	2.7	0.0011	3
8311	electric power plant	113.5	0.0452	1
8312	electric power plant	13.2	0.0052	2
8315	electric sub stations	21.8	0.0087	9
8320	electric transmission lines	397.4	0.1583	22
8330	water supply plants	17.4	0.0069	3
8340	sewage treatment plants	104.8	0.0417	10
8350	solid waste disposal	164.0	0.0653	5



Aggregated Land Use/Cover Categories	Level 3 FLUCCS Codes included in category	County-wide Area (hectares)
Upland Forest/Recreation	1800 - 1899, 4000 - 4999	103646
Agriculture/Rangeland/Open Land	1900 - 3999	66518
Wetlands and Water Bodies	5000 - 6999	46841
Low Density Residential	1000 - 1199	18843
Medium/High Density Residential	1200 - 1399	7680
Transportation and Utilities	7000 - 9000	3279
Commercial and Services	1400 - 1499	1622
Industrial and Extractive	1500 - 1699	1450
Institutional	1700 - 1799	1190

Figure 3-8: Chart showing the area (in hectares) of aggregated land use and cover types in Alachua County (circa 1994). These statistics were derived from the modified land use and cover coverage used for this study (May, 1993, and SRWMD, 1995). The graph may correspond to the rank order of the transformity of each land use.

Analytical Coverages

This section presents descriptions of the analytical coverages that were used to create the component, subcomponent, and intermediate component grids of the spatial EMERGY model.

Every ‘analytical coverage’ has had several new data items added to it’s feature attribute table to facilitate the energy and EMERGY calculations. This section documents the data structure of those attribute items to facilitate future research using these methods. Each analytical coverage has also been ‘overlaid’ with a county-wide polygon coverage that is comprised of 100 meter square polygons corresponding to the one-hectare cells in the final model. Each of the model’s component grids was created by first making energy and EMERGY calculations based on attribute data contained in the analytical coverages, and then converting the coverages into grids using a standard conversion method developed for each type of coverage.

Em_landcov. The em_landcov analytical polygon coverage was created by overlaying the original ‘land use and cover’ coverage with a buffered building coverage, a maintained landscape zone coverage, and a buffered roads coverage. A small portion of the coverage is shown in Figure 3-9. Unfortunately, the very high density of features in this coverage makes it impractical to create a usable map of the entire county at the scale required for this document.

As described earlier in the methods section, the areal extent of maintained landscape zones around buildings was estimated by buffering the building footprints an additional 10 meters. In an effort to introduce a measure of the natural spatial variation

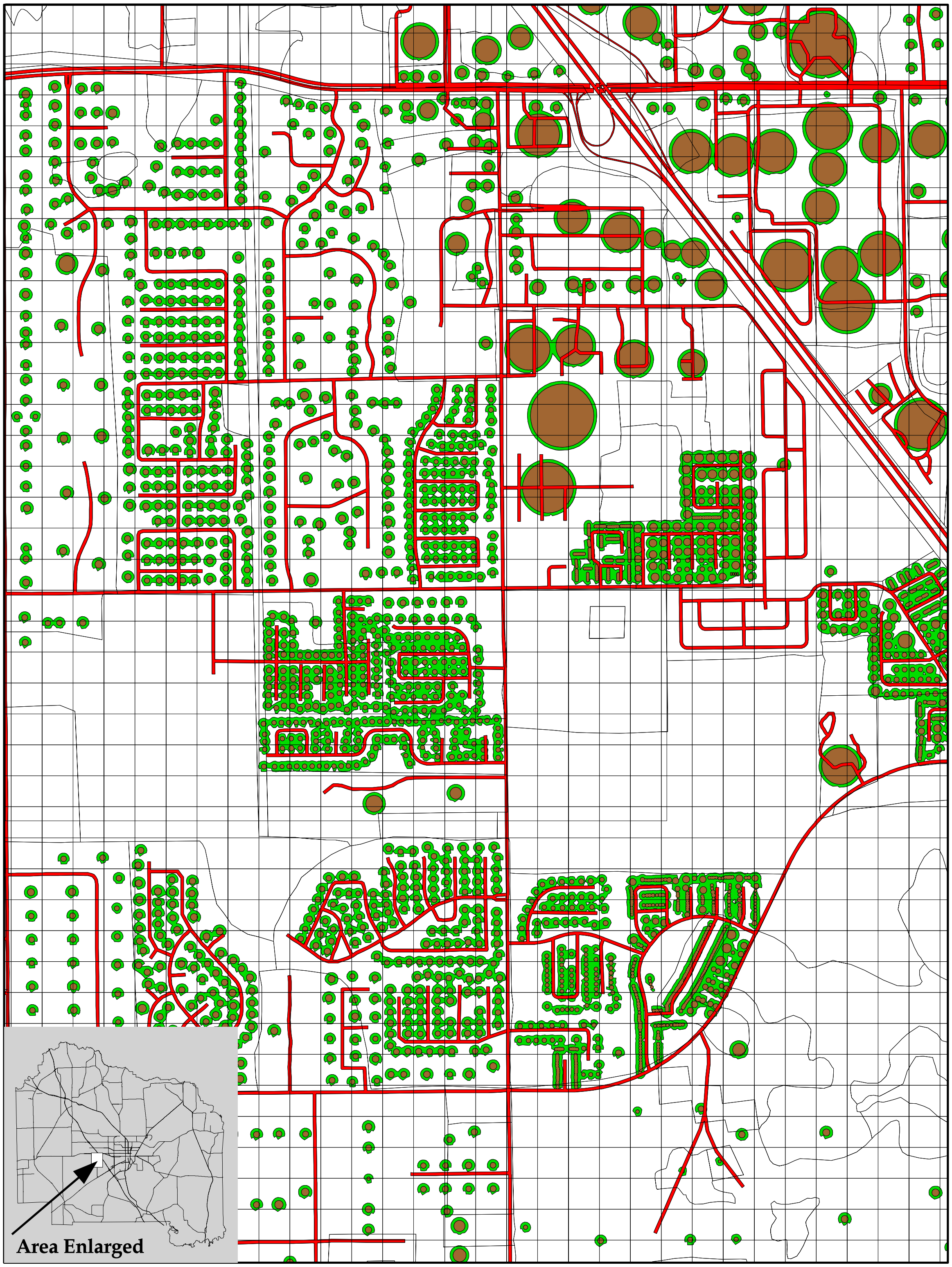


Figure 3-9: A small portion of the 'em_landcov' analytical polygon coverage. This coverage was created by combining the original landuse and cover coverage with polygons representing roads (in red), building footprints (in brown), and maintained landscape areas (in green). This map is drawn at 1:20,000 scale.

that is found in the urban landscape, the actual size of these buffered areas was purposefully made slightly random by introducing a coarse ‘fuzzy tolerance’ into the buffering algorithm. The result, which can be seen in Figure 3-9, is that the buffered areas are not exact circles.

Upon review, this method appears to work very well for residential areas comprised of 1/4 to 2-acre lots. The 10 meter buffer distance simulates the personally observed phenomenon in Alachua County that larger residential lots have proportionately larger natural, unmaintained areas of native vegetation. These small ‘pockets of nature’ that exist within the urban setting are important to urban wildlife. These ‘pockets of nature’ were reclassified for the purposes of this analysis as mixed hardwood-pine forests. This method helps model the ‘real world’ variation in the amount and type of vegetative cover that occurs between the one hectare cells within a single land use classification.

Unfortunately, the maintained landscape zone concept does not work as well for the more intensive land use types such as shopping malls and industrial sites. In these cases estimates of proportionately less vegetation were made and applied to the entire area of the land use.

In some cases, residential land uses (and even some other uses) are not identified in the original land use and cover coverage. For instance, several thousand individual rural homes that are under forest canopy or in large pastures are not classified as residential. But, the amount of, and type of, vegetation in close proximity to these homes is often significantly different than that of the assigned land use classification. The managed landscape zone and building footprints that were added to the original data help to adjust several subsequent calculations to account for this phenomenon, and more accurately reflect the nature of the landscapes surrounding these rural residences.

A significant, and troublesome, idiosyncrasy of the building coverage is that, in some cases, collections of buildings are represented by a single point feature. This anomaly in the building database usually only occurs with apartment complexes or mobile home parks that are owned by a single individual. The aggregated total square footage of all of the buildings is, however, documented in the property record. Hence the buffer distance (determined by square footage) that is used to create the building footprint for these single points representing multiple buildings may be very large to account for the multiple buildings. In a few cases, this results in inappropriately modeling an entire hectare cell as covered by a building footprint.

This analytical coverage was used to calculate the energy and EMERGY in gross primary production and structure of natural and agricultural systems, and to calculate the use of natural renewable sources of energy, and the use of fuels, goods, and services for agricultural, forestry, and home garden/landscape land uses. It is a very large coverage with 754,177 polygons. Figure 3-10 describes the polygon feature attribute table for the coverage. The ‘em_landcov’ analytical coverage provided the data for the calculations leading to the creation of the following grids:

Component Grids:

	RENEW	RENEW_EN
	GPP	GPP_EN

Sub-Component Grids:

	BIOSTR	BIOSTR_EN

Intermediate Component Grids:

	AGR_FUL	AGR_FUL_EN
	AGR_GDS	AGR_GDS_EN
	AGR_SRV	AGR_SRV_EN

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	AREA	8	18	F	5	area of polygon
9	PERIMETER	8	18	F	5	perimeter of polygon
17	EM_LANDCOV#	4	5	B	-	software item
21	EM_LANDCOV-ID	4	5	B	-	software item
25	LUCODE	4	4	I	-	FLUCCS land use code
29	URBZONENUM	1	1	I	-	Overlay analysis code
30	URBANZONE	1	1	C	-	(footprint or lawn)
31	APP_B_NOTE	4	4	C	-	reference to Appendix B notes
35	REDX_FACTOR	4	6	F	2	natural system reduction factor
39	NATSYS_BASIS	24	24	C	-	natural system basis description
63	ENVSRC_E11SEJ_M2	4	6	F	2	renewable flow/use by lucode
67	TOT_ENVSRC_J	8	18	F	0	calculated env. source use, j
75	TOT_ENVSRC_SEJ	8	18	F	0	calculated env. source use, sej
83	CULT_E11SEJ_M2	4	6	F	2	cultural source rate, sej
87	TOT_CULT_SEJ	8	18	F	0	calculated flow/use, sej
95	GPPEN_E7J_M2	4	6	F	2	gross primary production rate, j
99	TOT_GPPEN_J	8	18	F	0	calculated GPP in joules
107	GPP_TRANSFORMITY	4	6	B	-	GPP transformity sej/j
111	GPPEM_E11SEJ_M2	4	6	F	2	GPP EMERGY rate, e11 sej/m2
115	TOT_GPPEM_SEJ	8	18	F	0	calculated EMERGY in GPP, sej
123	BIOSTEN_E7J_M2	4	6	F	2	energy in structure/m2 for lucode
127	TOT_BIOSTEN_J	8	18	F	0	calculated energy in structure
135	BIOSTRANSFORMITY	4	6	B	-	calculated transformity
139	BIOSEM_E11SEJ_M2	4	6	F	2	EMERGY in structure/m2
143	TOT_BIOSTEM_SEJ	8	18	F	0	calculated EMERGY, sej
151	EMGRID-ID	6	6	I	-	spatial summary item
157	HECTARES	4	12	F	2	hectares for the polygon
161	AGRFLOW_FLAG	1	1	C	-	agricultural land use (y/n)
162	AGR_FUEL_J_M2	4	12	F	0	fuel use rate for agr. type
166	AGR_FUEL_J	4	12	F	0	calculated energy in fuel used
170	AGR_FUEL_SEJ_M2	8	20	F	0	EMERGY in fuel used rate
178	AGR_FUEL_SEJ	8	20	F	0	calculated EMERGY in fuel
186	AGR_SRV_J_M2	4	12	F	0	services used rate for type
190	AGR_SRV_J	4	12	F	0	calculated energy in services
194	AGR_SRV_SEJ_M2	8	20	F	0	EMERGY in services used rate
202	AGR_SRV_SEJ	8	20	F	0	calculated EMERGY in services
210	AGR_GDS_J_M2	4	12	F	0	goods used rate for type
214	AGR_GDS_J	4	12	F	0	calculated energy in goods used
218	AGR_GDS_SEJ_M2	8	20	F	0	EMERGY in goods used rate
226	AGR_GDS_SEJ	8	20	F	0	calculated EMERGY in goods\

Figure 3-10: Description of the polygon feature attribute table for the ‘em_landcov’ analytical coverage.

Em_resbldgcov. The em_resbldgcov analytical point coverage (Figure 3-11) was created by reselecting only those features in the 'buildings' coverage that were classified as *residential* type buildings (including single and multi-family, and mobile homes). The coverage has 49001 point features. Figure 3-12 describes the point feature attribute table for the coverage.

Attribute data about population and income were added to each of the point features by overlaying the coverage with a modified U.S. Census Bureau TIGER/Line file coverage called 'em_censuscov'. The em_censuscov analytical polygon coverage (Figure 3-13) contains original 1990, and 1994 adjusted, population counts for census blocks and income data for each census blockgroup (U.S. Bureau of the Census, 1992). The population and income data were redistributed proportionately to the point features within each block or blockgroup as described previously in the methods section.

The method used to apportion the area-aggregated population data to point features usually resulted in non-integer values being assigned to each building point feature. This result was determined to be acceptable since subsequent calculations would summarize the data derived from the population counts for each 100-meter square cell.

Municipal water service information was added to each point feature by overlaying the point coverage with a polygon coverage of service area boundaries (Figure 3-11). Although the Gainesville Regional Utilities water service area was known precisely, the municipal boundaries of minor cities had to be used to approximate other service areas. These service area boundaries allowed for a distinction to be made, in the energy and EMERGY calculations for water usage, between the use of municipal and well water.

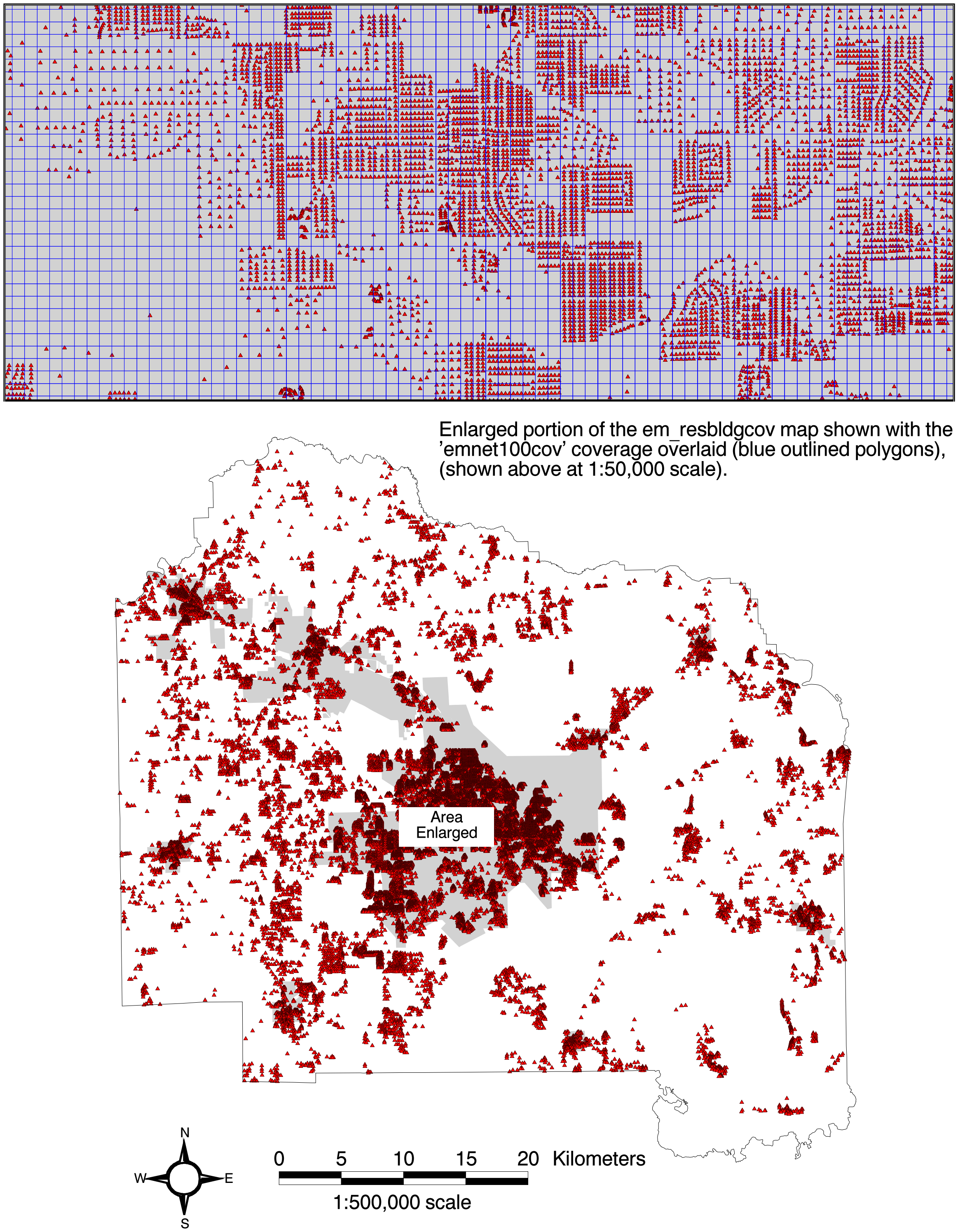


Figure 3-11: Map of the point coverage of residential-type buildings in Alachua County called 'em_resbldgcov'. The gray-shaded areas represent the municipal water service areas (using the ancillary data coverage called 'munwtrbnd').

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	AREA	8	18	F	5	area of polygon
9	PERIMETER	8	18	F	5	perimeter of polygon
17	EM_RESBLDGCOV#	4	5	B	-	software item
21	EM_RESBLDGCOV-ID	4	5	B	-	software item
25	PARCEL_ID	13	13	C	-	tax appraiser unique id
38	OLNAME	40	40	C	-	owner last name
78	OFNAME	30	30	C	-	owner first name
108	DORCODE	8	5	F	0	Dept. of Revenue Use Code
116	LUSE	8	5	F	0	Alachua Co. landuse code
124	TBLDGVALUE	8	12	F	0	total building value, $
132	MISCVALUE	8	12	F	0	misc. assets value, $
140	BLDG_MISC	8	12	F	0	total + misc. value, $
148	BLDG_MISC_EST	1	1	C	-	bldg_misc estimated for study?
149	TOTSQFOOT	8	12	F	0	total square footage of building
157	TOTSQFOOT_EST	1	1	C	-	totsqfoot estimated for study?
158	HTSQFOOT	8	12	F	0	heated square footage of building
166	YEARBLT	8	5	F	0	year building was built
174	BEDROOMS	8	4	F	0	number of bedrooms
182	BATHS	8	5	F	1	number of bathrooms
190	NUM_BLDGS	8	5	F	1	number of buildings for feature
198	UF_FLAG	1	1	C	-	Univ. of Florida building?
199	EMGRID-ID	6	6	I	-	spatial summary item
205	TRACTBLK	13	13	C	-	Census tract and block number
218	BLDG_POP_UNITS	3	3	I	-	building population units
221	NO_BLDG_IN_BLK	4	5	B	-	number of buildings in block
225	NO_UNITS_IN_BLK	8	18	F	6	number of units in block
233	FIPS	3	3	C	-	FIPS code
236	TRACT	6	6	C	-	Census tract number
242	BLOCK	4	4	C	-	Census block number
246	TOTAL_BLK_POP	4	8	B	-	total people in block
250	TOTAL_BLK_VOTERS	4	8	B	-	total voters in block
254	BLKGRP	10	10	C	-	Census block-group number
264	CENSUS_FLAG	1	1	C	-	Census flag
265	BLDG_POP_TOTAL	4	8	F	2	calculated total population
269	BLDG_POP_VOTERS	4	8	F	2	calculated voter population
273	BLDG_POP_CHILD	4	8	F	2	calculated child population
277	VPOP_J	4	12	F	0	calculated energy stored in voters
281	CPOP_J	4	12	F	0	calculated energy in children
285	TOTPOP_J	4	12	F	0	vpop_j + cpop_j, total energy, j
289	TOTPOP67_J	4	12	F	0	67% of totpop_j
293	CPOP_SEJ	8	20	F	0	calc'd EMERGY in children
301	VPOP_COL_SEJ	8	20	F	0	calc'd EMERGY in college educated
309	VPOP_HS_SEJ	8	20	F	0	calc'd EMERGY in high school ed.
317	TOTPOP_SEJ	8	20	F	0	cpop_sej+vpop_col_sej+vpop_hs_sej
325	TOTPOP67_SEJ	8	20	F	0	67% of totpop_sej
333	VSRV_J	4	12	F	0	calc'd energy of voter services
337	CSRV_J	4	12	F	0	calc'd energy of child services
341	TOTSRV_J	4	12	F	0	vsrv_j + csrv_j
345	VSRV_COL_SEJ	8	24	F	0	EMERGY in college ed. services
353	VSRV_HS_SEJ	8	24	F	0	EMERGY in high school ed. services
361	CSRV_SEJ	8	24	F	0	EMERGY in children services
369	TOTSRV_SEJ	8	24	F	0	vsrv_col_sej+vsrv_hs_sej+csrv_sej
377	MUNWATER_NAME	30	30	C	-	municipal water service provider
407	MUNWATER_FLAG	1	1	C	-	municipal water service?
408	GAL_WATER_USED	4	12	F	1	gallons of potable/well water used
412	MUNWATER_J	4	12	F	0	energy in municipal water used
416	MUNWATER_SEJ	8	20	F	0	EMERGY in municipal water used
424	WELLWATER_J	4	12	F	0	energy in well water used
428	WELLWATER_SEJ	8	20	F	0	EMERGY in well water used
436	TOT_WATER_J	4	12	F	0	munwater_j + wellwater_j
440	TOT_WATER_SEJ	8	20	F	0	munwater_sej + wellwater_sej
448	WASTEWATER_J	4	12	F	0	energy in wastewater generated
452	WASTEWATER_SEJ	8	20	F	0	EMERGY in wastewater generated
460	BLOCKGRP	10	10	C	-	Census Blockgroup (BG) number
470	BG_MED_INCOME89	8	9	F	0	median household income in 1989
478	BG_AGG_INCOME89	8	15	F	0	BG aggregated household incomes
486	BG_BLDG_FREQ	4	5	B	-	BG building frequency
490	BG_TOTSQFOOT	8	18	F	0	total bldg. square footage in BG
498	BLDG_INCOME89	8	9	F	0	calc'd building income in 1989
506	BLDG_INCOME93	8	12	F	0	adjusted building income in 1993
514	GOODS_DOLLARS	4	12	F	2	estimated goods consumed, $
518	GOODS_J	4	12	F	0	calc'd energy in goods consumed
522	GOODS_SEJ	8	20	F	0	calc'd EMERGY in goods consumed
530	GOODS_TRANS	4	12	F	0	calc'd transformity of goods used
534	ELEC_KWH	4	12	F	0	estimated kwh's electricity used
538	ELEC_J	4	12	F	0	calc'd energy in electricity used
542	ELEC_SEJ	8	20	F	0	calc'd EMERGY in electricity used
550	MSW_URBAN	1	1	C	-	urban municipal solid waste (MSW)?
551	MSW_GEN_LBS	4	12	F	1	estimated general MSW, lbs.
555	MSW_GEN_J	4	12	F	0	calc'd energy in general MSW
559	MSW_GEN_SEJ	8	20	F	0	calc'd EMERGY in general MSW
567	MSW_YRD_LBS	4	12	F	1	estimated yardwaste MSW, lbs
571	MSW_YRD_J	4	12	F	0	calc'd energy in yardwaste MSW
575	MSW_YRD_SEJ	8	20	F	0	calc'd EMERGY in yardwaste MSW
583	MSW_CD_LBS	4	12	F	1	estimated construction debris MSW
587	MSW_CD_J	4	12	F	0	calc'd energy in construction MSW
591	MSW_CD_SEJ	8	20	F	0	calc'd EMERGY in construction MSW
599	MSW_TOT_J	4	12	F	0	msw_gen_j + msw_yrd_j + msw_cd_j
603	MSW_TOT_SEJ	8	20	F	0	msw_gen_sej+msw_yrd_sej+msw_cd_sej
611	REC_GEN_LBS	4	12	F	1	est. recycled general wastes, lbs
615	REC_GEN_J	4	12	F	0	energy in recycled gen. wastes
619	REC_GEN_SEJ	8	20	F	0	EMERGY in recycled gen. wastes
627	REC_YRD_LBS	4	12	F	1	est. recycled yard wastes, lbs
631	REC_YRD_J	4	12	F	0	energy in recycled yard wastes
635	REC_YRD_SEJ	8	20	F	0	EMERGY in recycled yard wastes
643	REC_CD_LBS	4	12	F	1	est. recycled constr. wastes, lbs
647	REC_CD_J	4	12	F	0	energy in recycled constr. wastes
651	REC_CD_SEJ	8	20	F	0	EMERGY in recycled constr. wastes
659	REC_TOT_J	4	12	F	0	rec_gen_j + rec_yrd_j + rec_cd_j
663	REC_TOT_SEJ	8	20	F	0	rec_gen_sej+rec_yrd_j+rec_cd_sej

Figure 3-12: Description of the point feature attribute table for the 'em_resbldgcov' analytical coverage.

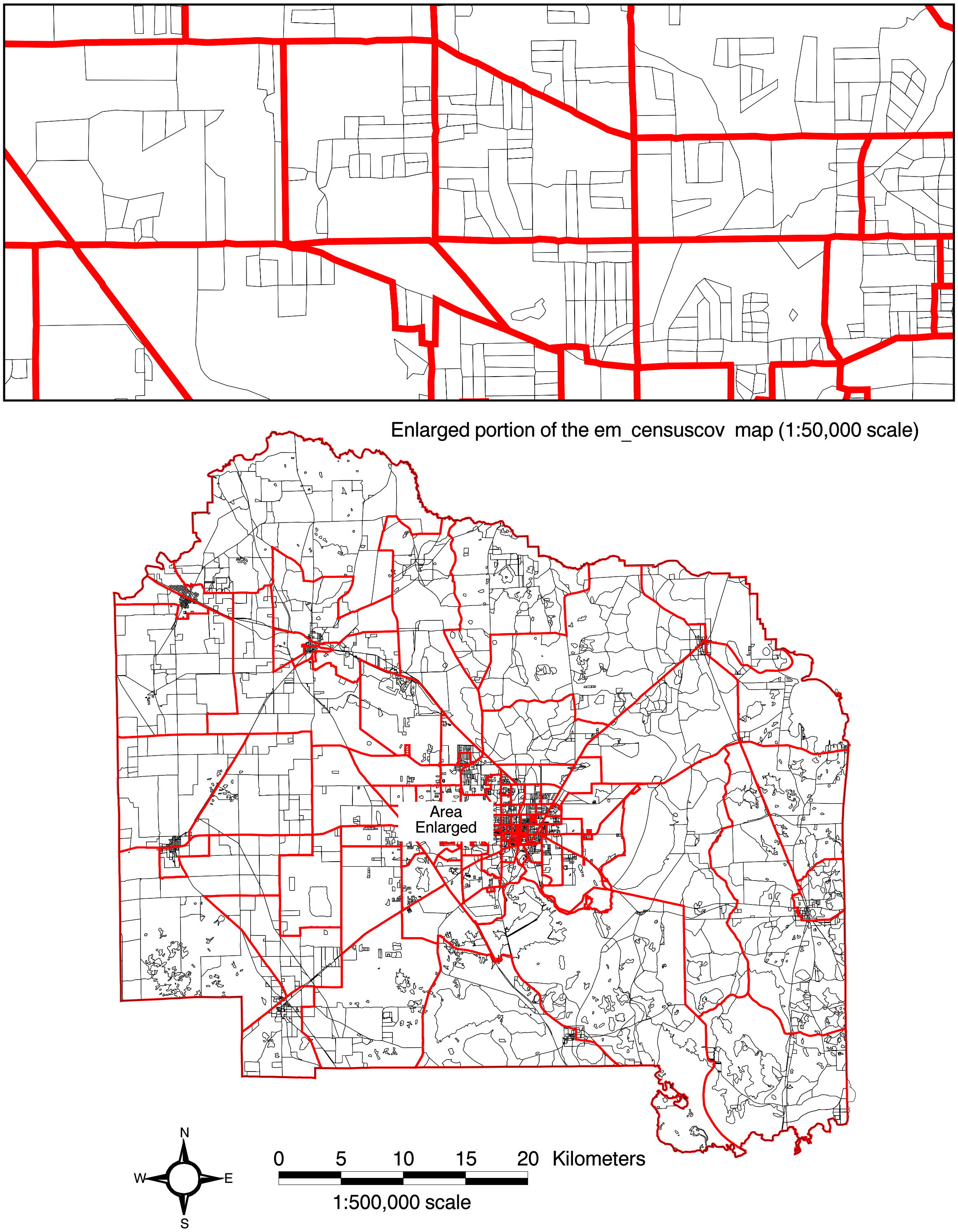


Figure 3-13: Map of the analytical polygon coverage of census blocks (thin, black lines) and blockgroups (thicker, red lines) for Alachua County called 'em_censuscov'.

The em_resbldgcov analytical coverage was used to calculate (for residential buildings only) the EMERGY and energy in the population while at their residences, services provided by people in residential buildings, goods consumed in the residential buildings, electricity (and other fuels) used in the buildings, municipal and well water consumed, wastewater and solid wastes generated, and solid wastes recycled from goods consumed in the buildings.

This coverage provided the data for the calculations leading to the creation of the following grids in the model:

Intermediate Component Grids:

RES_POP	RES_POP_EN
RES_SRV	RES_SRV_EN
RES_GDS	RES_GDS_EN
RES_ELC	RES_ELC_EN
RES_WTR	RES_WTR_EN
RES_LWS	RES_LWS_EN
RES_MSW	RES_MSW_EN
RES_REC	RES_REC_EN

Em_combldgcov. The em_combldgcov analytical point coverage (Figure 3-14) was created by reselecting only those features in the 'buildings' coverage that were NOT classified *residential* (those with DOR codes between 0 and 900, see Table 3-1). In other words, all commercial, institutional, agricultural, and industrial buildings are included in this coverage. The coverage has 7,214 point features. Figure 3-15 describes the point feature attribute table for this coverage.

Municipal water service areas information was added by overlaying the coverage with service area boundaries as described earlier for the em_resbldgcov coverage.

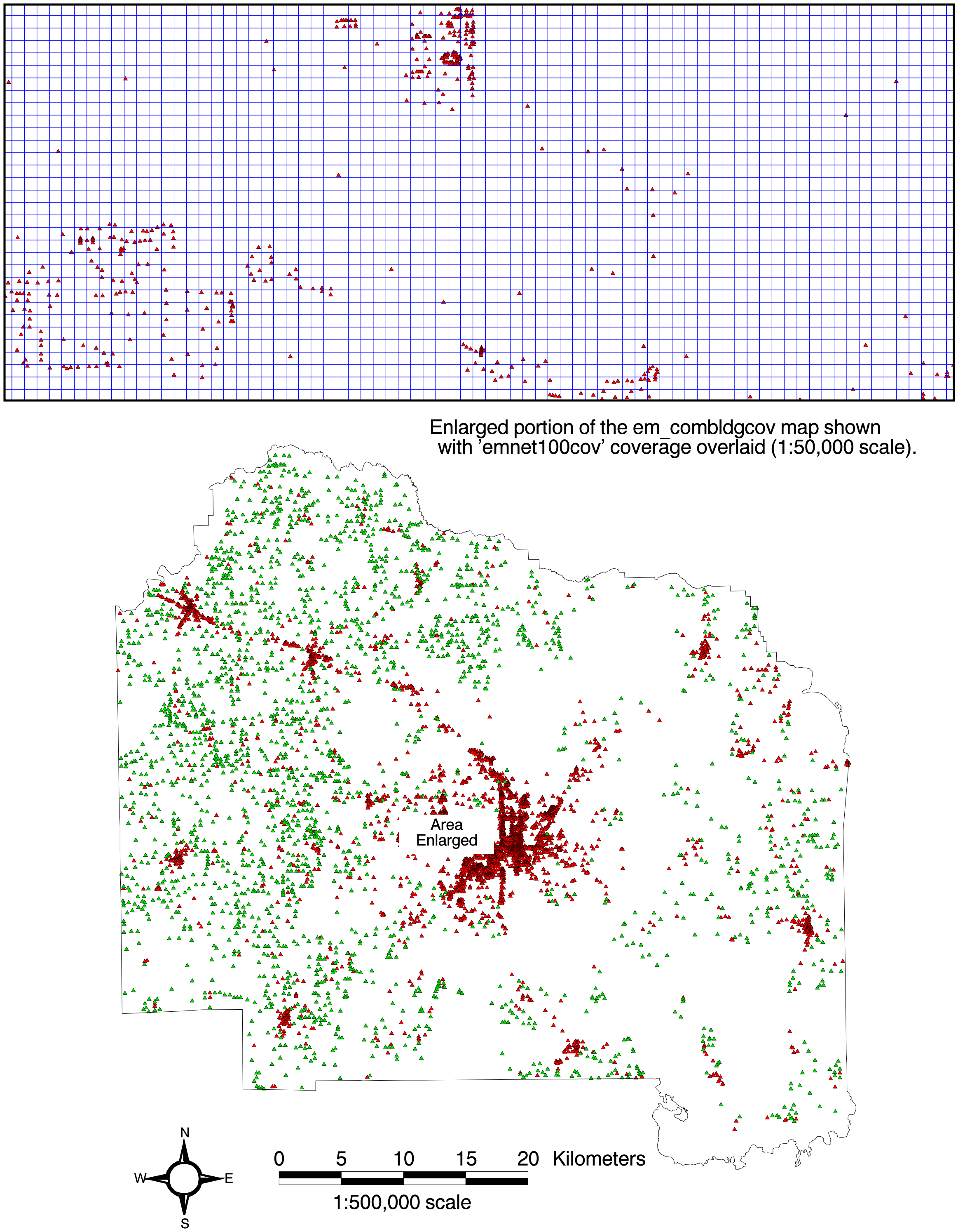


Figure 3-14: Map of the analytical point coverage of commercial, agricultural, industrial, and institiutional buildings in Alachua County called 'em_combldgcov'. Agricultural buildings are shown in green, and all other types are shown in red.

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	AREA	8	18	F	5	area of polygon
9	PERIMETER	8	18	F	5	perimeter of polygon
17	EM_COMBLDGCOV#	4	5	B	-	software item
21	EM_COMBLDGCOV-ID	4	5	B	-	software item
33	PARCEL_ID	13	13	C	-	tax appraiser unique id
46	OLNAME	40	40	C	-	owner last name
86	OFNAME	30	30	C	-	owner first name
116	CITYCODE	8	5	F	0	city land use code
124	DORCODE	8	5	F	0	Dept. of Revenue use code
132	LUSE	8	5	F	0	county land use code
140	TJUSTVALUE	8	12	F	0	total just value, $
148	TLANDVALUE	8	12	F	0	total land value, $
156	TBLDGVALUE	8	12	F	0	total building value, $
164	MISCVALUE	8	12	F	0	total misc. assets value, $
172	BLDG_MISC	8	12	F	0	total bldg + misc. assets value
180	BLDG_MISC_EST	1	1	C	-	bldg_misc estimated for study?
181	TOTSQFOOT	8	12	F	0	total square footage of building
189	TOTSQFOOT_EST	1	1	C	-	totsqfoot estimated?
190	HTSQFOOT	8	12	F	0	heated square footage of building
198	YEARBLT	8	5	F	0	year building was built
206	BEDROOMS	8	4	F	0	number of bedrooms
214	BATHS	8	5	F	1	number of baths
222	NUM_BLDGS	8	5	F	1	number of buildings for feature
230	UF_FLAG	1	1	C	-	Univ. of Florida building?
231	EMGRID-ID	6	6	I	-	spatial summary item
237	DELETE_FLAG	1	1	C	-	special processing flag
238	EMP_PER_SQFT	8	7	F	1	estimated employees/sq.ft.
246	WORK_POP_TOTAL	4	8	F	2	estimated total number employees
250	WORK_APOP_J	4	12	F	0	calc'd energy in adult employees
254	WORK_CPOP_J	4	12	F	0	calc'd energy in child students
258	TOT_WORKPOP_J	4	12	F	0	work_apop_j + work_cpop_j
262	COLL_PERCENT	4	4	F	2	percent of pop. college educated
266	HS_PERCENT	4	4	F	2	percent of pop. highschool educ'd
270	ELEM_PERCENT	4	4	F	2	percent of pop. elementary educ'd
274	WK_APOP_COL_SEJ	8	24	F	0	EMERGY in college ed. employees
282	WK_APOP_HS_SEJ	8	24	F	0	EMERGY in highschool ed. employees
290	WK_CPOP_SEJ	8	24	F	0	ERERGY in children/students
298	TOT_WKPOP_SEJ	8	24	F	0	total EMERGY in emp./student pop.
306	SHOP_FLAG	1	1	C	-	building with retail trade?
307	SHOP_PERCENT	4	12	F	10	percent of co-wide retail space
311	SHOP_POP_J	4	12	F	0	energy in shopping population
315	SHOP_POP_SEJ	8	24	F	0	EMERGY in shopping population
323	TOT_POP_J	4	12	F	0	tot_workpop_j + shop_pop_j
327	TOT_POP_SEJ	8	24	F	0	tot_wkpop_sej + shop_pop_sej
335	WK_ASRV_J	4	12	F	0	calc'd energy in adult services
339	WK_CSRV_J	4	12	F	0	calc'd energy in student services
343	TOT_WKSRV_J	4	12	F	0	wk_asrv_j + wk_csrv_j
347	WK_ASRVC_SEJ	8	24	F	0	EMERGY in college-level services
355	WK_ASRVH_SEJ	8	24	F	0	EMERGY in hs-level services
363	WK_CSRV_SEJ	8	24	F	0	EMERGY in student services
371	TOT_WKSRV_SEJ	8	24	F	0	wk_asrvc_sej+wk_asrvh_sej+wk_csrv_
379	SHP_ASRV_J	4	12	F	0	energy in shopping adult services
383	SHP_CSRV_J	4	12	F	0	energy in shopping child services
387	TOT_SHPSRV_J	4	12	F	0	shp_asrv_j + shp_csrv_j
391	SHP_ASRVC_SEJ	8	24	F	0	EMERGY in college-level services
399	SHP_ASRVH_SEJ	8	24	F	0	EMERGY in hs-level services
407	SHP_CSRV_SEJ	8	24	F	0	EMERGY in children services
415	TOT_SHPSRV_SEJ	8	24	F	0	shp_asrvc_sej + shp_asrvh_sej + shp_csrv_sej
423	TOT_DAYSRV_J	4	12	F	0	tot_wksrv_j + tot_shpsrv_j
427	TOT_DAYSRV_SEJ	8	24	F	0	tot_wksrv_sej + tot_shpsrv_sej
435	MUNWATER_NAME	30	30	C	-	municipal water service provider
465	MUNWATER_FLAG	1	1	C	-	municipal water service available?
466	GAL_WATER_USED	4	12	F	1	gallons of potable/well water used
470	MUNWATER_J	4	12	F	0	energy in municipal water used
474	MUNWATER_SEJ	8	20	F	0	EMERGY in municipal water used
482	WELLWATER_J	4	12	F	0	energy in well water used
486	WELLWATER_SEJ	8	20	F	0	EMERGY in well water used
494	TOT_WATER_J	4	12	F	0	munwater_j + wellwater_j
498	TOT_WATER_SEJ	8	20	F	0	munwater_sej + wellwater_sej
506	WASTEWATER_J	4	12	F	0	energy in wastewater generated
510	WASTEWATER_SEJ	8	20	F	0	EMERGY in wastewater generated
518	GOODS_DOLLARS	4	12	F	2	estimated goods consumed, $
522	GOODS_J	4	12	F	0	energy in goods consumed, j
526	GOODS_SEJ	8	20	F	0	EMERGY in goods consumed
534	ELEC_KWH	4	12	F	0	estimated electricity used, kwh
538	ELEC_J	4	16	F	0	energy in electricity used
542	ELEC_SEJ	8	20	F	0	EMERGY in electricity used
557	MSW_GEN_J	4	12	F	0	energy in general wastes
561	MSW_GEN_SEJ	8	20	F	0	EMERGY in general wastes
569	MSW_YRD_LBS	4	12	F	1	estimated yard wastes, lbs.
573	MSW_YRD_J	4	12	F	0	energy in yard wastes
577	MSW_YRD_SEJ	8	20	F	0	EMERGY in yard wastes
585	MSW_CD_LBS	4	12	F	1	estimated construction debris, lbs
589	MSW_CD_J	4	12	F	0	energy in construction debris
593	MSW_CD_SEJ	8	20	F	0	EMERGY in construction debris
601	MSW_TOT_J	4	12	F	0	msw_gen_j + msw_yrd_j + msw_cd_j
605	MSW_TOT_SEJ	8	20	F	0	msw_gen_sej+msw_yrd_sej+msw_cd_sej
613	REC_GEN_LBS	4	12	F	1	estimated recycled general wastes
617	REC_GEN_J	4	12	F	0	energy in recycled general wastes
621	REC_GEN_SEJ	8	20	F	0	EMERGY in recycled general wastes
629	REC_YRD_LBS	4	12	F	1	estimated recycled yard wastes
633	REC_YRD_J	4	12	F	0	energy in recycled yard wastes
637	REC_YRD_SEJ	8	20	F	0	EMERGY in recycled yard wastes
645	REC_CD_LBS	4	12	F	1	estimated recycled constr. debris
649	REC_CD_J	4	12	F	0	energy in recycled constr. debris
653	REC_CD_SEJ	8	20	F	0	EMERGY in recycled constr. debris
661	REC_TOT_J	4	12	F	0	rec_gen_j + rec_yrd_j + rec_cd_j
665	REC_TOT_SEJ	8	20	F	0	rec_gen_sej+rec_yrd_sej+rec_cd_sej

Figure 3-15: Description of the point feature attribute table for the 'em_combldgcov' analytical coverage.

Census data on number of employees per square foot were added to the coverage using calculations based on data from the Bureau of Economic and Business Research (BEBR, 1993). The methods used to apportion these employee data to the appropriate point features usually resulted in non-integer values being assigned to each building. This result was determined to be acceptable since subsequent calculations would summarize the data derived from the population counts for each 100-meter square cell.

It is important to emphasize that this analytical coverage contains point features representing buildings (and other structural improvements such as fencing, etc.) associated with agricultural enterprises. This is particularly evident when one examines the western half of the county and finds many point features (shown in green in Figure 3-14) that might seem out of place in such a rural area if this coverage only contained commercial, industrial, and institutional buildings.

It was found that, in some cases, these agriculturally-classified features actually represent both residences and utilitarian buildings. These cases are limited to those property parcels that have DOR codes between 5100 and 6500 (see Table 3-1). These codes were assigned by the Property Appraiser's office to parcels where the predominant use was for either crops, timber, or grazing. There were 2,316 instances of point features with these codes.

In most cases, other attributes of each feature record made it possible (although complicated at times) for this database anomaly to be taken into consideration for the energy and EMERGY flow and storage calculations. There may, however, be some cases in which this characteristic of the coverage has introduced some errors into various results.

This coverage was used to calculate the EMERGY and energy in the working/studying population, services provided by people while at work, school, or shopping, goods consumed in the course of conducting business, electricity (and other fuels) used in these types of buildings, municipal and well water consumed, wastewater and solid wastes generated, and solid wastes recycled.

This coverage provided the data for the calculations leading to the creation of the following grids in the model:

Intermediate Component Grids:

COM_POP	COM_POP_EN
SHP_POP	SHP_POP_EN
WRK_POP	WRK_POP_EN
COM_SRV	COM_SRV_EN
SHP_SRV	SHP_SRV_EN
WRK_SRV	WRK_SRV_EN
COM_GDS	COM_GDS_EN
COM_ELC	COM_ELC_EN
COM_WTR	COM _WTR_EN
COM_LWS	COM_LWS_EN
COM_MSW	COM_MSW_EN
COM_REC	COM_REC_EN

Em_agwtrcov. The em_agwtrcov analytical polygon coverage (Figure 3-16) was derived from the 'land use' coverage by reselecting only those features with agricultural land use codes. The resulting coverage was then unioned with the 'alanet100cov' coverage. It was used to calculate the energy and EMERGY in water used for agricultural irrigation. The coverage has 321,413 polygon features. Figure 3-17 describes the polygon feature attribute table for the coverage.

This coverage provided the data for the calculations leading to the creation of the following grids in the model:

Intermediate Component Grids:

AGR_WTR	AGR_WTR_EN

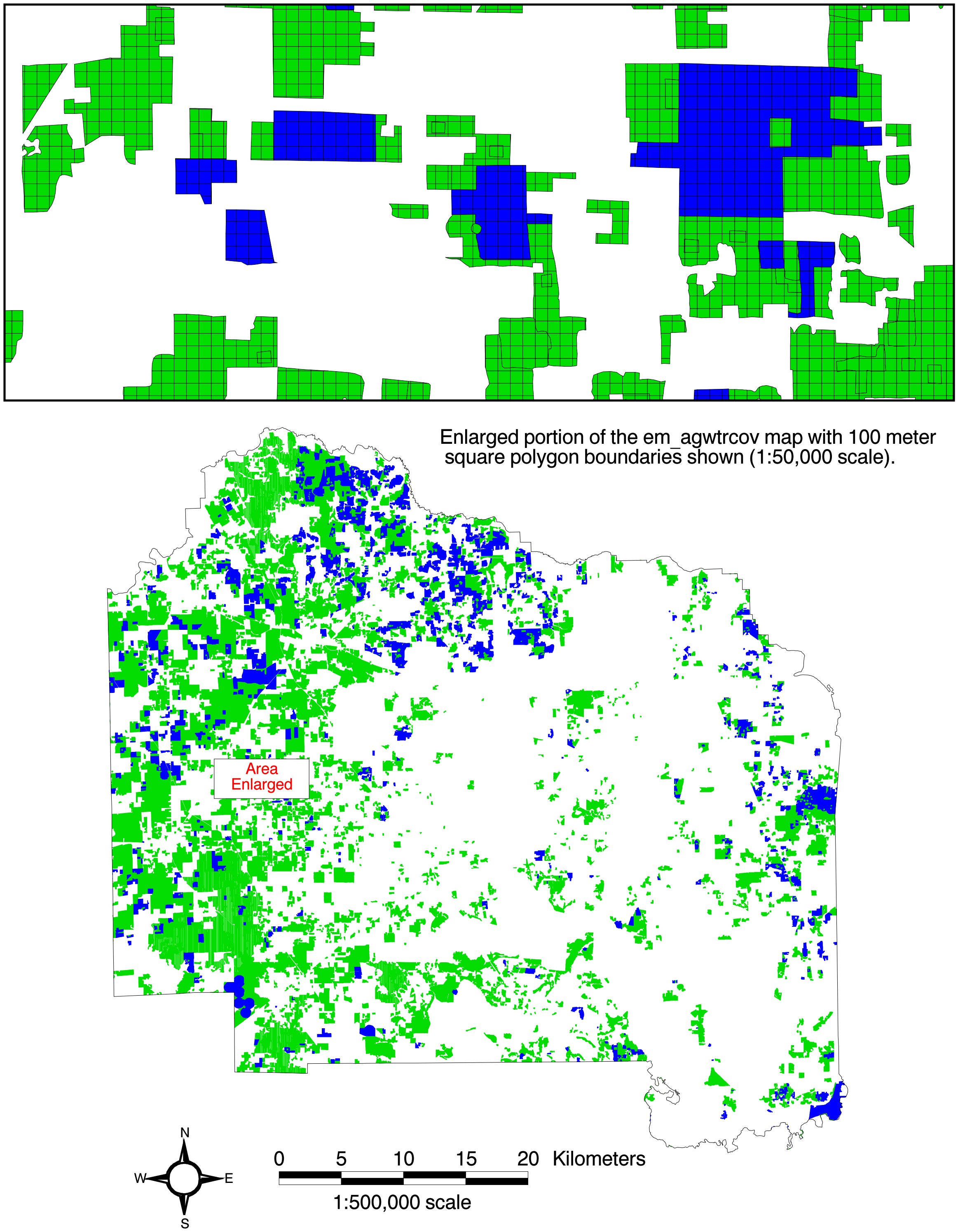


Figure 3-16: Map of the analytical polygon coverage called 'em_agwtrcov'. Polygons representing all types of agricultural landuses were extracted from the landuse and cover coverage. The blue-shaded polygons represent landuse types where irrigation is used, and all other agricultural uses are shown in green.

(a)

‘Em_agwtrcov’ Analytical Coverage

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	AREA	8	18	F	5	area of polygon
9	PERIMETER	8	18	F	5	perimeter of polygon
17	EM_AGWTRCOV#	4	5	B	-	software item
21	EM_AGWTRCOV-ID	4	5	B	-	software item
25	LUCODE	4	4	I	-	landuse type code
29	IRR_FLAG	1	1	C	-	irrigated land type?
30	GAL_PER_M2_YR	3	3	I	-	water use rate (gallons/m2)
33	AGWATER_J	4	12	F	0	calculated energy in joules
37	AGWATER_SEJ	8	20	F	0	calculated EMERGY in sej
45	EMGRID-ID	6	6	I	-	spatial summary item

(b)

‘Em_hydcov’ Analytical Coverage

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	AREA	8	18	F	5	area of polygon
9	PERIMETER	8	18	F	5	perimeter of polygon
17	EM_HYDCOV#	4	5	B	-	software item
21	EM_HYDCOV-ID	4	5	B	-	software item
25	LUCODE	4	4	I	-	landuse code (lake,wetland,etc.)
29	EMGRID-ID	6	6	I	-	spatial summary item
35	SW_DEPTH	4	4	F	1	surface water depth
39	WTRSTREN_J	4	16	F	0	calculated energy in both surface and groundwater
43	WTRSTR_SEJ	8	20	F	0	calculated EMERGY
51	SURFWTREN_J	4	16	F	0	calculated energy in surface water
55	SURFWTR_SEJ	8	20	F	0	calculated EMERGY in surface water
63	GRNDWTREN_J	4	16	F	0	calculated energy in groundwater
67	GRNDWTR_SEJ	8	20	F	0	calculated EMERGY in groundwater

Figure 3-17: Descriptions of the polygon feature attribute tables for the ‘em_agwtrcov’ , and the ‘em_hydcov’ analytical coverages.

Em_hydcov. The 'em_hydcov' analytical polygon coverage (Figure 3-18) was created by selecting lakes and wetlands from the 'land use and cover' coverage and overlaying it with a buffered stream coverage. The resulting coverage was then unioned with the 'alanet100cov' coverage. It was used to calculate the energy and EMERGY in water stored in lakes, rivers, wetlands, and the aquifer. The coverage has 346,432 polygon features. Figure 3-17 describes the polygon feature attribute table for the coverage.

This coverage provided the data for the calculations leading to the creation of the following grids in the model:

Intermediate Component Grids:

GRN_WTR	GRN_WTR_EN
SRF_WTR	SRF_WTR_EN

Em_soilcov. This analytical polygon coverage (Figure 3-19) was created by overlaying the SSURGO soils coverage (NRCS, 1995) with buffered buildings and roads coverages and the 'alanet100cov' coverage. The areas covered by the building and road footprints were considered to have no available organic matter for the purpose of the calculations. The coverage was used to calculate the energy and EMERGY stored in soil organic matter. There are 728,829 polygons in the coverage. Figure 3-20 describes the polygon feature attribute table for the 'em_soilcov' coverage.

This coverage provided the data for the calculations leading to the creation of the following grids in the model:

Sub-Component Grids:

SOILOM	SOILOM_EN

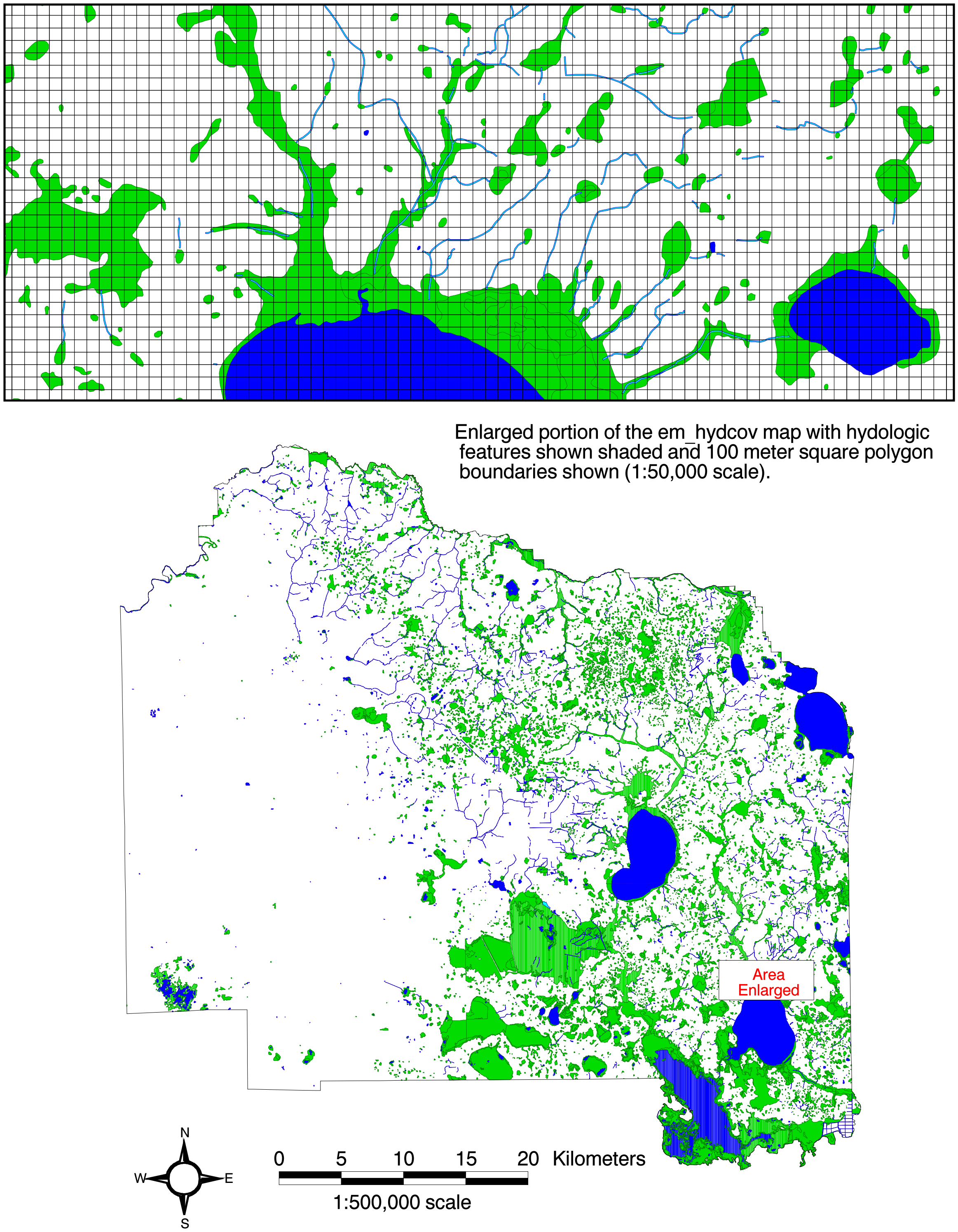


Figure 3-18: Map of the analytical polygon coverage of hydrologic features called 'em_hydcov'. Lakes and streams are shown in blue and wetlands are in green.

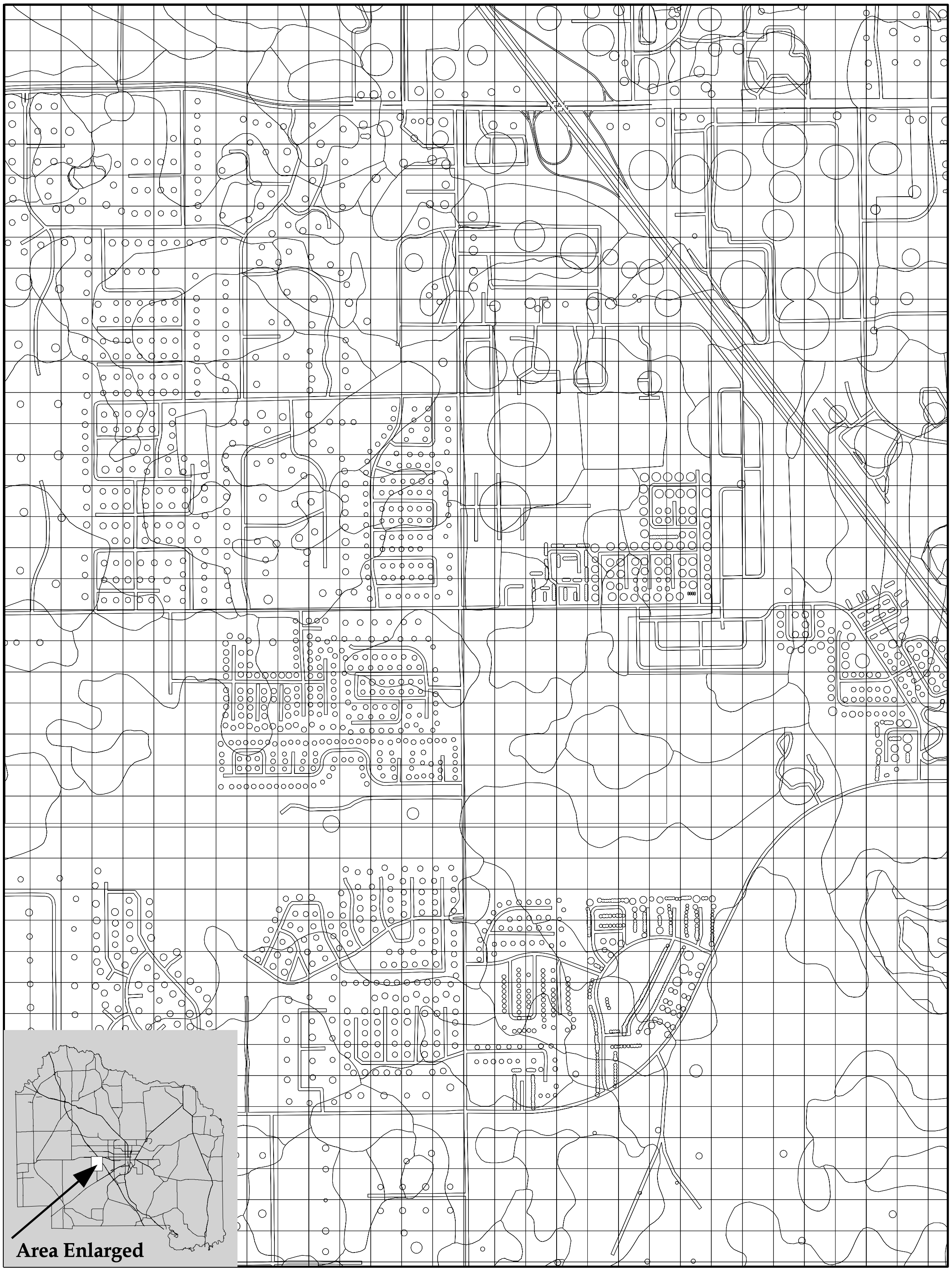


Figure 3-19: A small portion of the ’em_soilcov’ analytical polygon coverage. This coverage was created by combining the original soils coverage with polygons representing road and building footprints. (This map is 1:20,000 scale).

(a)

‘Em_soilcov’ Analytical Coverage

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	AREA	8	18	F	5	area of polygon
9	PERIMETER	8	18	F	5	perimeter of polygon
17	EM_SOILCOV#	4	5	B	-	software item
21	EM_SOILCOV-ID	4	5	B	-	software item
25	MUID_REL	2	2	I	-	soil map unit ID
27	MUNAME	60	60	C	-	soil map unit name
87	EM_TYPE	1	1	C	-	assigned type for calculations
88	BULK_DENSITY	4	4	F	2	bulk density of soil type
92	AVG_PCT_OM	4	8	F	4	average percent organic matter
96	EMGRID-ID	6	6	I	-	spatial summary item
102	SOIL_SEJ	8	20	F	0	calculated EMERGY, sej
110	SOILEN_J	8	20	F	0	calculated energy, joules
118	ROAD_PRINT	1	1	C	-	area of road structure? (y/n)
119	BLDG_PRINT	1	1	C	-	area of building footprint? (y/n)

(b)

‘Em_bldgcov’ Analytical Coverage

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	AREA	8	18	F	5	area of polygon in m2
9	PERIMETER	8	18	F	5	perimeter of polygon, m
17	EM_BLDGCOV#	4	5	B	-	software item
21	EM_BLDGCOV-ID	4	5	B	-	software item
25	BLDG_MISC	9	9	I	-	total $ value of building and misc. assets
34	BLDG_MISC_EST	1	1	C	-	estimated (Y/N)
35	YEARBLT	4	4	I	-	construction Date (Year)
39	YEARBLT_EST	1	1	C	-	estimated (Y/N)
40	BLDG_SEJ93	8	24	F	0	sej per dollar ratio
48	SEJPERDOLLAR93	8	14	F	0	sej value calculated
56	EMGRID-ID	6	6	I	-	spatial summary item
62	TOTSQFOOT	8	12	F	0	total sq. feet of structure
70	TOTSQFOOT_EST	1	1	C	-	estimated (Y/N)
71	EN_BLDG_CLASS	3	3	C	-	(RESidential, COMmercial, or INStitutional)
74	ENERGY_J	8	18	F	0	joules calculated based on building class

Figure 3-20: Descriptions of the feature attribute tables for the ‘em_soilcov’ (a), and ‘em_bldgcov’ (b) analytical coverages.

Em_bldgcov. The 'em_bldgcov' analytical point coverage has the same point features as the 'buildings' primary data coverage (see Figure 3-3), but attribute items have been added to facilitate calculations of the EMERGY and energy stored in all buildings and miscellaneous built structure. Where attribute data were missing (in the original buildings coverage) for the total dollar value of the buildings and miscellaneous assets, estimates were made (and noted as estimates in the feature attribute table) based on average dollars per square foot ratios for other buildings of the same type. The coverage has 57,421 point features. Figure 3-20 describes the point feature attribute table for the coverage.

This coverage provided the data for the calculations leading to the creation of the following grids in the model:

Sub-Component Grids:
BLDG BLDG_EN

Em_roadcov. The 'em_roadcov' analytical line coverage has the same line features as the 'roads' primary data coverage (see Figure 3-5), but attribute items have been added to facilitate calculations of the EMERGY and energy stored in road structure and the EMERGY and energy flows of fuels used in transportation. The coverage has 77,539 arc features. Figure 3-21 describes the line feature attribute table for the coverage.

This coverage provided the data for the calculations leading to the creation of the following grids in the model:

Sub-Component Grids:
ROAD ROAD_EN
TRN_FUL TRN_FUL_EN

(a)

'Em_roadcov' Analytical Coverage

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	FNODE#	4	5	B	-	software item
5	TNODE#	4	5	B	-	software item
9	LPOLY#	4	5	B	-	software item
13	RPOLY#	4	5	B	-	software item
17	LENGTH	8	18	F	5	length in meters
25	EM_ROADCOV#	4	5	B	-	software item
29	EM_ROADCOV-ID	4	5	B	-	software item
33	FUNCLASS	2	2	I	-	functional class code
35	NO_LANES	1	1	I	-	number of lanes in segment
36	AADT	6	6	I	-	avg. annual daily traffic
42	AADT_SOURCE	3	3	C	-	AADT data reference source
45	LINESOURCE	3	3	C	-	reference source of line feature
48	DBL_LINE	1	1	C	-	road shown as dbl line?
49	EMGRID-ID	4	5	B	-	spatial summary item
53	AADT_CALC	6	6	I	-	estimated AADT number
59	LITERS_PER_YR	4	12	F	2	calculated liters/year of fuel
63	TRANSEN_J	8	18	F	2	calculated joules of fuel used
71	TRANS_SEJ	8	24	F	2	calculated sej of fuel used
79	DOL_PER_M_LAN	4	12	F	2	dollars/meter/lane by funclass
83	ROAD_DOLLARS	4	12	F	2	calculated dollars per segment
87	ROAD_SEJ93	8	24	F	0	calculated sej per segment
95	ROADEN_J	8	18	F	0	calculated joules per segment

(b)

'Em_utilcov' Analytical Coverage

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	ITEM DESCRIPTION/UNITS
1	FNODE#	4	5	B	-	software item
5	TNODE#	4	5	B	-	software item
9	LPOLY#	4	5	B	-	software item
13	RPOLY#	4	5	B	-	software item
17	LENGTH	8	18	F	5	length in meters
25	EM_UTILCOV#	4	5	B	-	software item
29	EM_UTILCOV-ID	4	5	B	-	software item
33	CNTYELEC_FLAG	2	2	I	-	functional class of road
35	GRUELEC_FLAG	4	4	C	-	GRU type of distribution line
39	UF_FLAG	1	1	C	-	Univ. of Florida area? (y/n)
40	GRUWAT_FLAG	1	1	C	-	GRU water service area? (y/n)
41	GRUGAS_FLAG	1	1	C	-	GRU gas service area? (y/n)
42	CNTYWAT_FLAG	1	1	C	-	Other city water service area?
43	UTIL_TYPE	4	4	C	-	calculated utility type code
47	EMGRID-ID	6	6	I	-	spatial summary item
53	UTIL_DOLLARS	4	12	F	2	estimated dollar value of line
57	UTILEN_J	4	12	F	0	calculated energy in structure
61	UTIL_SEJ	8	18	F	0	calculated EMERGY in structure

Figure 3-21: Descriptions of the feature attribute tables for the 'em_roadcov' (a), and 'em_utilcov' (b) analytical coverages.

Em_utilcov. The em_utilcov analytical line coverage (Figure 3-22) was created to represent the County-wide utilities distribution line system. It is comprised of a combination the line features from a coverage provided by Gainesville Regional Utilities (GRU) for primary electric distribution lines within their service area, and proxy line features derived from the 'roads' coverage representing distribution lines in those areas outside of the GRU service area.

All line features that were within the GRU gas and approximated metropolitan water service areas were given attributes indicating that these features represent more than just electric distribution lines. Thus, any given line feature represents one of the following combinations of utilities infrastructure: electric only, electric and water, electric and gas, or electric, water, and gas.

The coverage was used to estimate the energy and EMERGY in electric, gas, and water utilities infrastructure. The coverage has 70,996 arc features. Figure 3-21 describes the line feature attribute table for the coverage.

This coverage provided the data for the calculations leading to the creation of the following grids:

Sub-Component Grids:
UTIL UTIL_EN

Summary Coverage

The 'emnet100cov' summary polygon coverage has the same 100 meter-square polygons and the same unique polygon identification numbers (stored in the 'emgrid-id' item of the feature attribute table) as the 'alanet100cov' coverage that was used to overlay each of the analytical coverages. These 100 meter-square polygons are spatially

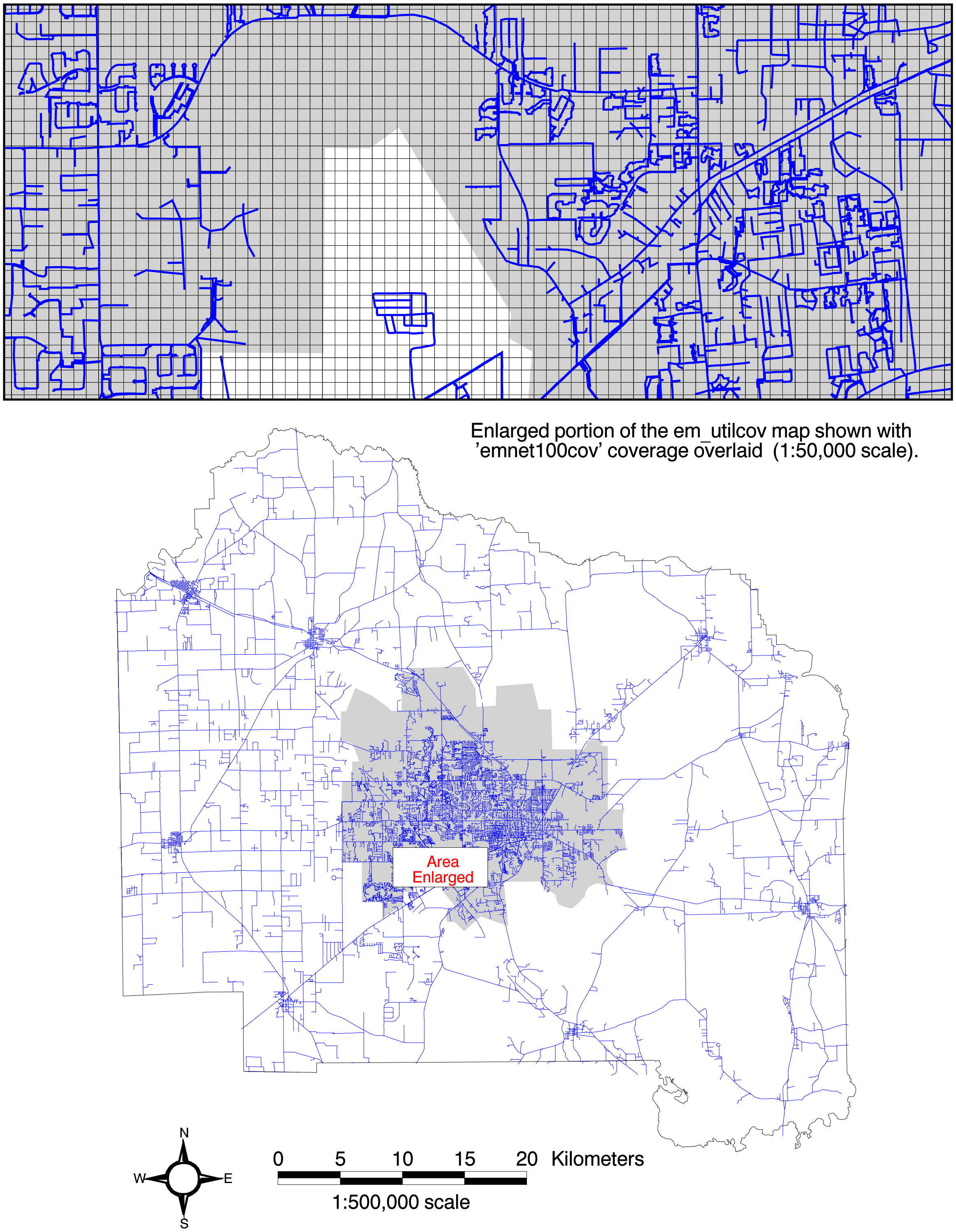


Figure 3-22: Map of the analytical line coverage of utility infrastructure in Alachua County called 'em_utilcov'. This analytical coverage was derived from two sources: the GRU electric facilities GIS database (within the extent of the area shown shaded in gray) and the 'em_roadcov' coverage for areas outside the GRU service area.

coincident with the cells of each of the intermediate, subcomponent, and component grids in the final model. The feature attribute table for the 'emnet100cov' summary coverage was used to store all of the final summarized energy and EMERGY data for each 100 meter-square polygon. Figure 3-23 lists each of the items in the feature attribute table and notes the intermediate, subcomponent, or component grid that was created using each item. The table also includes items that record the number of individual features that were present in each of the 100-meter square polygon for each of the analytical coverages. All of the final intermediate, subcomponent, or component grids were created by using the summarized values for energy or EMERGY flows or storages from the appropriate attribute items in the 'emnet100cov' summary coverage as the input source for the Arc/Info POLYGRID function.

In addition to being a necessary intermediate product in the creation of the grid format model, the 'emnet100cov' summary coverage is essentially a single coverage form of the final multiple grid spatial EMERGY model. Hence, one might, at first thought, question the need for the creation of the many individual grids. However, in practice the use of this polygon coverage for spatial analysis and display is hampered by the fact that very large coverages (in terms of computer file size and number of features) take much longer to process and display on today's computers than do grids. Additionally, some of the spatial analysis methods used in this study, which will be discussed later, are significantly more difficult to perform on coverages than on grids. The format of the 'summary coverage' feature attribute table is, however, a very convenient format for importing data into other database, spreadsheet, and statistical analysis computer programs.

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	DESCRIPTION/GRID CREATED
1	AREA	4	12	F	3	area of the polygon, m2
5	PERIMETER	4	12	F	3	perimeter of the polygon, m2
9	EMNET100COV#	4	5	B	-	software item
13	EMNET100COV-ID	4	5	B	-	software item
17	EMGRID-ID	6	6	I	-	spatial summary item
23	TRANS_FREQ	4	5	B	-	no. of features in ‘em_roadcov’
27	TRANS_SEJ	8	24	F	0	TRN_FUL
35	TRANSEN_FREQ	4	5	B	-	no. of features in ‘em_roadcov’
39	TRANSEN_J	8	18	F	0	TRN_FUL_EN
47	BLDG_FREQ	4	5	B	-	no. of features in ‘em_bldgcov’
51	BLDG_SEJ93	8	24	F	0	BLDG
59	BLDGEN_FREQ	4	5	B	-	no. of features in ‘em_bldgcov’
63	BLDGEN_J	8	18	F	0	BLDG_EN
71	ROAD_FREQ	4	5	B	-	no. of features in ‘em_roadcov’
75	ROAD_SEJ93	8	24	F	0	ROAD
83	ROADEN_FREQ	4	5	B	-	no. of features in ‘em_roadcov’
87	ROADEN_J	8	18	F	0	ROAD_EN
95	RENEW_FREQ	4	5	B	-	no. of features in ‘em_landcov’
99	RENEWEN_J	8	18	F	0	RENEW_EN
107	RENEW_SEJ	8	20	F	0	RENEW
115	EMLAND_FREQ	4	5	B	-	no. of features in ‘em_landcov’
119	TRANSPIRE_SEJ	8	18	F	0	EMERGY in transpiration only
127	TOT_CULT_SEJ	8	18	F	0	EMERGY in cultural land inputs
135	TOT_GPPEN_J	8	18	F	0	GPP_EN
143	TOT_GPPEM_SEJ	8	18	F	0	GPP
151	TOT_BIOSTEN_J	8	18	F	0	BIOSTR_EN
159	TOT_BIOSTEM_SEJ	8	18	F	0	BIOSTR
167	SOIL_FREQ	4	5	B	-	no. of features in ‘em_soilcov’
171	SOILEN_J	8	18	F	0	SOILOM_EN
179	SOIL_SEJ	8	20	F	0	SOILOM
187	RES_POP_FREQ	4	5	B	-	no. of features in ‘em_resbldgcov’
191	RES_POPEN_J	8	18	F	0	RES_POP_EN
199	RES_POP_SEJ	8	24	F	0	RES_POP
207	COM_POP_FREQ	4	5	B	-	no. of features in ‘em_combldgcov’
211	WORK_POPEN_J	8	18	F	0	WRK_POP_EN
219	WORK_POP_SEJ	8	24	F	0	WRK_POP
227	SHOP_POPEN_J	8	18	F	0	SHP_POP_EN
235	SHOP_POP_SEJ	8	24	F	0	SHP_POP
243	COM_POPEN_J	8	18	F	0	COM_POP_EN
251	COM_POP_SEJ	8	24	F	0	COM_POP
259	TOT_POPEN_J	8	18	F	0	POPSTR_EN
267	TOT_POP_SEJ	8	24	F	0	POPSTR
275	RES_SRV_FREQ	4	5	B	-	no. of features in ‘em_resbldgcov’
279	RES_SRVEN_J	8	18	F	0	RES_SRV_EN
287	RES_SRV_SEJ	8	20	F	0	RES_SRV
295	COM_SRV_FREQ	4	5	B	-	no. of features in ‘em_combldgcov’
299	WORK_SRVEN_J	8	18	F	0	WRK_SRV_EN
307	WORK_SRV_SEJ	8	24	F	0	WRK_SRV
315	SHOP_SRVEN_J	8	18	F	0	SHP_SRV_EN
323	SHOP_SRV_SEJ	8	24	F	0	SHP_SRV
331	COM_SRVEN_J	8	18	F	0	COM_SRV_EN
339	COM_SRV_SEJ	8	24	F	0	COM_SRV
347	BLD_SRVEN_J	8	18	F	0	BLD_SRV_EN
355	BLD_SRV_SEJ	8	24	F	0	BLD_SRV
363	RES_WTRUSE_FREQ	4	5	B	-	no. of features in ‘em_resbldgcov’
367	RES_WTREN_J	8	18	F	0	RES_WTR_EN
375	RES_WTR_SEJ	8	20	F	0	RES_WTR
383	COM_WTRUSE_FREQ	4	5	B	-	no. of features in ‘em_combldgcov’
387	COM_WTREN_J	8	18	F	0	COM_WTR_EN
395	COM_WTR_SEJ	8	20	F	0	COM_WTR
403	BLD_WTREN_J	8	18	F	0	BLD_WTR_EN
411	BLD_WTR_SEJ	8	20	F	0	BLD_WTR
419	AGR_WTRUSE_FREQ	4	5	B	-	no. of features in ‘em_agwtrcov’
423	AGR_WTREN_J	8	18	F	0	AGR_WTR_EN
431	AGR_WTR_SEJ	8	20	F	0	AGR_WTR
439	TOT_WTREN_J	8	18	F	0	WTRUSE_EN
447	TOT_WTR_SEJ	8	20	F	0	WTRUSE
455	COM_LWST_FREQ	4	5	B	-	no. of features in ‘em_combldgcov’

Figure 3-23: Description (including grids created from each item) of the polygon feature attribute table for the ‘emnet100cov’ summary coverage.

COLUMN	ITEM NAME	WIDTH	OUTPUT	TYPE	N.DEC	DESCRIPTION/GRID CREATED
459	COM_LWSTEN_J	8	18	F	0	COM_LWS_EN
467	COM_LWST_SEJ	8	20	F	0	COM_LWS
475	RES_LWST_FREQ	4	5	B	-	no. of features in 'em_resbldgcov'
479	RES_LWSTEN_J	8	18	F	0	RES_LWS_EN
487	RES_LWST_SEJ	8	20	F	0	RES_LWS
495	TOT_LWSTEN_J	8	18	F	0	BLD_LWS_EN
503	TOT_LWST_SEJ	8	20	F	0	BLD_LWS
511	RES_GDS_FREQ	4	5	B	-	no. of features in 'em_resbldgcov'
515	RES_GDSEN_J	8	18	F	0	RES_GDS_EN
523	RES_GDS_SEJ	8	20	F	0	RES_GDS
531	COM_GDS_FREQ	4	5	B	-	no. of features in 'em_combldgcov'
535	COM_GDSEN_J	8	18	F	0	COM_GDS_EN
543	COM_GDS_SEJ	8	20	F	0	COM_GDS
551	BLD_GDSEN_J	8	18	F	0	BLD_GDS_EN
559	BLD_GDS_SEJ	8	20	F	0	BLD_GDS
567	RES_ELEC_FREQ	4	5	B	-	no. of features in 'em_resbldgcov'
571	RES_ELECEN_J	8	18	F	0	RES_ELC_EN
579	RES_ELEC_SEJ	8	20	F	0	RES_ELC
587	COM_ELEC_FREQ	4	5	B	-	no. of features in 'em_combldgcov'
591	COM_ELECEN_J	8	18	F	0	COM_ELC_EN
599	COM_ELEC_SEJ	8	20	F	0	COM_ELC
607	BLD_ELECEN_J	8	18	F	0	BLD_ELC_EN
615	BLD_ELEC_SEJ	8	20	F	0	BLD_ELC
623	AGR_FLOW_FREQ	4	5	B	-	no. of features in 'em_landcov'
627	AGR_FUELEN_J	8	18	F	0	AGR_FUL_EN
635	AGR_FUEL_SEJ	8	20	F	0	AGR_FUL
643	AGR_SRVEN_J	8	18	F	0	AGR_SRV_EN
651	AGR_SRV_SEJ	8	20	F	0	AGR_SRV
659	AGR_GDSEN_J	8	18	F	0	AGR_GDS_EN
667	AGR_GDS_SEJ	8	20	F	0	AGR_GDS
675	TOT_ELECEN_J	8	18	F	0	BAG_FUL_EN
683	TOT_ELEC_SEJ	8	20	F	0	BAG_FUL
691	TOT_SRVEN_J	8	18	F	0	SERVICE_EN
699	TOT_SRV_SEJ	8	24	F	0	SERVICE
707	WTRSTR_FREQ	4	5	B	-	no. of features in 'em_hydcov'
711	SURFWTREN_J	8	18	F	0	SRF_WTR_EN
719	SURFWTR_SEJ	8	20	F	0	SRF_WTR
727	GRNDWTREN_J	8	18	F	0	GRN_WTR_EN
735	GRNDWTR_SEJ	8	20	F	0	GRN_WTR
743	WTRSTREN_J	8	18	F	0	WTRSTR_EN
751	WTRSTR_SEJ	8	20	F	0	WTRSTR
759	RES_MSW_FREQ	4	5	B	-	no. of features in 'em_resbldgcov'
763	RES_MSWEN_J	8	18	F	0	RES_MSW_EN
771	RES_MSW_SEJ	8	20	F	0	RES_MSW
779	RES_RECEN_J	8	18	F	0	RES_REC_EN
787	RES_REC_SEJ	8	20	F	0	RES_REC
795	COM_MSW_FREQ	4	5	B	-	no. of features in 'em_combldgcov'
799	COM_MSWEN_J	8	18	F	0	COM_MSW_EN
807	COM_MSW_SEJ	8	20	F	0	COM_MSW
815	COM_RECEN_J	8	18	F	0	COM_REC_EN
823	COM_REC_SEJ	8	20	F	0	COM_REC
831	TOT_MSWEN_J	8	18	F	0	BLD_MSW_EN
839	TOT_MSW_SEJ	8	20	F	0	BLD_MSW
847	TOT_RECEN_J	8	18	F	0	RECYCLE_EN
855	TOT_REC_SEJ	8	20	F	0	RECYCLE
863	WASTE_J	8	18	F	0	WASTE_EN
871	WASTE_SEJ	8	20	F	0	WASTE
879	UTIL_FREQ	4	5	B	-	no. of features in 'em_utilcov'
883	UTILEN_J	8	18	F	0	UTIL_EN
891	UTIL_SEJ	8	24	F	0	UTIL
899	FUELEN_J	8	18	F	0	FUEL_EN
907	FUEL_SEJ	8	24	F	0	FUEL
915	GOODSEN_J	8	18	F	0	GOODS_EN
923	GOODS_SEJ	8	24	F	0	GOODS
931	NATSTREN_J	8	18	F	0	NATSTR_EN
939	NATSTR_SEJ	8	24	F	0	NATSTR
947	URBSTREN_J	8	18	F	0	URBSTR_EN
955	URBSTR_SEJ	8	24	F	0	URBSTR

Figure 3-23 --continued.

The Spatial EMERGY Model

The final spatial EMERGY model consists of 51 energy and 51 EMERGY intermediate, sub-component, or component grids. All of these grids have 252,581 cells that have data associated with them. The cell values represent either the total energy or EMERGY stored or the total energy or EMERGY flow per year occurring in the geographic area of each one-hectare cell.

The numbers in each of the cells of all of the grids representing EMERGY storages are in units of solar emjoules per hectare (sej/ha) and, in this study, are referred to as the 'Component EMSTORAGE Density' of each cell. The energy storage component grids are in units of joules per hectare (j/ha) representing the 'Component Energy Storage Density' of each cell. EMERGY flows are measured as the total annual flow of solar emjoules per hectare per year (sej/ha/yr) and represent the 'Component EMPOWER Density' for each cell. Energy flows are measured in units of joules per hectare per year (j/ha/yr) and represent the 'Component Energy Flow Density'. All calculations of energy and EMERGY storages and flows were based on data from either 1993 or 1994.

Logarithm analytical grids were created for each of the final intermediate, subcomponent, and component grids using methods described previously. This was done in an attempt to simplify the model results so that they would be more easily comprehended by both the author and the reader, and to make the results easier to display and process--given the limitations of the GIS software being used. This procedure resulted in the creation of an additional 51 energy and 51 EMERGY analytical grids representing the flows and storages as logarithm values.

The numbers for these logarithm analytical grids representing EMERGY storages are in units of logarithm of solar emjoules per hectare (log sej/ha), and will be referred to in this study as the 'Component Log EMSTORAGE Density'. The energy storage component grids are in units of logarithm of joules per hectare (log j/ha) representing the 'Component Log Energy Storage Density'. EMERGY flows are measured as the logarithm of the total annual flow of solar emjoules per hectare per year (log sej/ha/yr) representing the 'Component Log EMPOWER Density' for each cell. Finally, the energy flows are measured in units of logarithm of joules per hectare per year (log j/ha/yr) and represent the 'Component Log Energy Flow Density'.

Table 3-3 contains a comprehensive list of the names and descriptions of all of the intermediate component, subcomponent, and component energy and EMERGY grids created, and the complementary logarithm analytical grids created for each component grid. The original component grids, taken collectively, are the spatial EMERGY model. The complementary set of logarithm analytical grids, also taken collectively, represent a derivative form (logarithmic) of the spatial EMERGY model.

In the following sections, maps of the subcomponent, and component energy and EMERGY grids in the model will be presented using the logarithm analytical grids for presentation of the model results.

Table 3-3: List and description of the intermediate (**I**), sub-component (**S**), and component (**C**) grids created for the model.

TYPE	GRID NAME	DESCRIPTION
I	agr_ful	EMERGY of fuels used in agricultural production
I	agr_ful_en	energy of fuels used in agricultural production
I	agr_ful_log	log of agr_ful
I	agr_fulen_log	log of agr_ful_en
I	agr_gds	EMERGY of goods consumed for agricultural production
I	agr_gds_en	energy of goods consumed for agricultural production
I	agr_gds_log	log of agr_gds
I	agr_gdsen_log	log of agr_gds_en
I	agr_srv	EMERGY of services provided for agricultural production
I	agr_srv_en	energy of services provided for agricultural production
I	agr_srv_log	log of agr_srv
I	agr_srven_log	log of agr_srv_en
I	agr_wtr	EMERGY of water used in agricultural production
I	agr_wtr_en	energy of water used in agricultural production
I	agr_wtr_log	log of agr_wtr
I	agr_wtren_log	log of agr_wtr_en
S	bag_ful	EMERGY of fuels and electricity used in all buildings and agricultural production
S	bag_ful_en	energy of fuels and electricity used in all buildings and agricultural production
S	bag_ful_log	log of bag_ful
S	bag_fulen_log	log of bag_ful_en
S	biostr	EMERGY of biomass
S	biostr_en	energy of biomass
S	biostr_en_log	log of biostr_en
S	biostr_log	log of biostr
I	bld_elc	EMERGY of electricity used in all buildings
I	bld_elc_en	energy of electricity used in all buildings
I	bld_elc_log	log of bld_elc
I	bld_elcen_log	log of bld_elc_en
I	bld_gds	EMERGY of goods consumed in all buildings
I	bld_gds_en	energy of goods consumed in all buildings
I	bld_gds_log	log of bld_gds
I	bld_gdsen_log	log of bld_gds_en
I	bld_srv	EMERGY of services provided in all buildings
I	bld_srv_en	energy of services provided in all buildings
I	bld_srv_log	log of bld_srv
I	bld_srven_log	log of bld_srv_en
I	bld_wtr	EMERGY of water used in all buildings
I	bld_wtr_en	energy of water used in all buildings
I	bld_wtr_log	log of bld_wtr
I	bld_wtren_log	log of bld_wtr_en
S	bldg	EMERGY stored in structure of all buildings
S	bldg_en	energy stored in structure of all buildings
S	bldg_en_log	log of bldg_en
S	bldg_log	log of bldg
I	com_elc	EMERGY of electricity used in comm./ind./inst. buildings
I	com_elc_en	energy of electricity used in comm./ind./inst. buildings
I	com_elc_log	log of com_elc
I	com_elcen_log	log of com_elc_en
I	com_gds	EMERGY of goods consumed in comm./ind./inst. buildings
I	com_gds_en	energy of goods consumed in comm./ind./inst. buildings
I	com_gds_log	log of com_gds
I	com_gdsen_log	log of com_gds_en

Table 3-3 -- continued.

TYPE	GRID NAME	DESCRIPTION
I	com_pop	EMERGY stored in people in comm./ind./inst. buildings
I	com_pop_en	energy stored in people in comm./ind./inst. buildings
I	com_pop_log	log of com_pop
I	com_popen_log	log of com_pop_en
I	com_srv	EMERGY of services provided in comm./ind./inst. buildings
I	com_srv_en	energy of services provided in comm./ind./inst. buildings
I	com_srv_log	log of com_srv
I	com_srven_log	log of com_srv_en
I	com_wtr	EMERGY of water used in comm./ind./inst. buildings
I	com_wtr_en	energy of water used in comm./ind./inst. buildings
I	com_wtr_log	log of com_wtr
I	com_wtren_log	log of com_wtr_en
C	fuel	EMERGY of fuels and electricity used in all buildings, agricultural production, and transportation
C	fuel_en	energy of fuels and electricity used in all buildings, agricultural production, and transportation
C	fuel_en_log	log of fuel_en
C	fuel_log	log of fuel
C	goods	EMERGY of goods consumed in all buildings and agricultural production
C	goods_en	energy of goods consumed in all buildings and agricultural production
C	goods_en_log	log of goods_en
C	goods_log	log of goods
C	gpp	EMERGY of gross primary production
C	gpp_en	energy of gross primary production
C	gpp_en_log	log of gpp_en
C	gpp_log	log of gpp
I	grn_wtr	EMERGY stored in ground water (aquifers)
I	grn_wtr_en	energy stored in ground water (aquifers)
I	grn_wtr_log	log of grn_wtr
I	grn_wtren_log	log of grn_wtr_en
C	natstr	EMERGY stored in biomass, surface and ground water, and organic matter in soils
C	natstr_en	energy stored in biomass, surface and ground water, and organic matter in soils
C	natstr_en_log	log of natstr_en
C	natstr_log	log of natstr
C	popstr	EMERGY stored in human population of all buildings
C	popstr_en	energy stored in human population of all buildings
C	popstr_en_log	log of popstr_en
C	popstr_log	log of popstr
C	renew	EMERGY of environmental sources used
C	renew_en	energy of environmental sources used
C	renew_en_log	log of renew_en
C	renew_log	log of renew
I	res_elc	EMERGY of electricity used in residential buildings
I	res_elc_en	energy of electricity used in residential buildings
I	res_elc_log	log of res_elc
I	res_elcen_log	log of res_elc_en
I	res_gds	EMERGY of goods consumed in residential buildings
I	res_gds_en	energy of goods consumed in residential buildings
I	res_gds_log	log of res_gds
I	res_gdsen_log	log of res_gds_en
I	res_pop	EMERGY stored in human population of residential buildings
I	res_pop_en	energy stored in human population of residential buildings
I	res_pop_log	log of res_pop
I	res_popen_log	log of res_pop_en

Table 3-3 -- continued.

TYPE	GRID NAME	DESCRIPTION
I	res_srv	EMERGY of services provided in residential buildings
I	res_srv_en	energy of services provided in residential buildings
I	res_srv_log	log of res_srv
I	res_srven_log	log of res_srv_en
I	res_wtr	EMERGY of water consumed in residential buildings
I	res_wtr_en	energy of water consumed in residential buildings
I	res_wtr_log	log of res_wtr
I	res_wtren_log	log of res_wtr_en
S	road	EMERGY stored in transportation infrastructure
S	road_en	energy stored in transportation infrastructure
S	road_en_log	log of road_en
S	road_log	log of road
C	servic_en_log	log of service_en
C	service	EMERGY of all services provided on site
C	service_en	energy of all services provide on site
C	service_log	log of service
I	shp_pop	EMERGY stored in shopping population
I	shp_pop_en	energy stored in shopping population
I	shp_pop_log	log of shp_pop
I	shp_popen_log	log of shp_pop_en
I	shp_srv	EMERGY of services provided by shopping
I	shp_srv_en	energy of services provided by shopping
I	shp_srv_log	log of shp_srv
I	shp_srven_log	log of shp_srv_en
S	soilom	EMERGY stored in soil organic matter
S	soilom_en	energy stored in soil organic matter
S	soilom_en_log	log of soilom_en
S	soilom_log	log of soilom
I	srf_wtr	EMERGY stored in surface waters
I	srf_wtr_en	energy stored in surface waters
I	srf_wtr_log	log of srf_wtr
I	srf_wtren_log	log of srf_wtr_en
S	trn_ful	EMERGY of fuels used in transportation
S	trn_ful_en	energy of fuels used in transportation
S	trn_ful_log	log of trn_ful
S	trn_fulen_log	log of trn_ful_en
C	urbstr	EMERGY stored in all buildings, roads, and utility infrastructure
C	urbstr_en	energy stored in all buildings, roads, and utility infrastructure
C	urbstr_en_log	log of urbstr_en
C	urbstr_log	log of urbstr
S	util	EMERGY stored in utility infrastructure
S	util_en	energy stored in utility infrastructure
S	util_en_log	log of util_en
S	util_log	log of util
I	wrk_pop	EMERGY stored in employees at work
I	wrk_pop_en	energy stored in employees at work
I	wrk_pop_log	log of wrk_pop
I	wrk_popen_log	log of wrk_pop_en
I	wrk_srv	EMERGY of services provide at place of employment
I	wrk_srv_en	energy of services provide at place of employment
I	wrk_srv_log	log of wrk_srv
I	wrk_srven_log	log of wrk_srv_en

Table 3-3 -- continued.

TYPE	GRID NAME	DESCRIPTION
S	wtrstr	EMERGY stored in surface and ground water
S	wtrstr_en	energy stored in surface and ground water
S	wtrstr_en_log	log of wtrstr_en
S	wtrstr_log	log of wtrstr
C	wtruse	EMERGY of water used for domestic, commercial, and agricultural purposes
C	wtruse_en	energy of water used for domestic, commercial, and agricultural purposes
C	wtruse_en_log	log of wtruse_en
C	wtruse_log	log of wtruse
I	res_msw	EMERGY of municipal solid wastes (MSW) originating in residential buildings
I	res_msw_en	energy of MSW originating in residential buildings
I	res_msw_log	log of res_msw
I	res_mswen_log	log of res_msw_en
I	res_lws	EMERGY of liquid wastes (LWS) originating in residential buildings
I	res_lws_en	energy of LWS originating in residential buildings
I	res_lws_log	log of res_lws
I	res_lwsen_log	log of res_lws_en
I	com_msw	EMERGY of MSW originating in comm./inst./ind. buildings
I	com_msw_en	energy of MSW originating in comm./inst./ind. buildings
I	com_msw_log	log of com_msw
I	com_mswen_log	log of com_msw_en
I	com_lws	EMERGY of LWS originating in comm./inst./ind. buildings
I	com_lws_en	energy of LWS originating in comm./inst./ind. buildings
I	com_lws_log	log of com_lws
I	com_lwsen_log	log of com_lws_en
I	bld_msw	sum of res_msw and com_msw
I	bld_msw_en	sum of res_msw_en and com_msw_en
I	bld_msw_log	log of bld_msw
I	bld_mswen_log	log of bld_msw_en
I	bld_lws	sum of res_lws and com_lws
I	bld_lws_en	sum of res_lws_en and com_lws_en
I	bld_lws_log	log of bld_lws
I	bld_lwsen_log	log of bld_lws_en
C	waste	sum of bld_msw and bld_lws
C	waste_en	sum of bld_msw_en and bld_lws_en
C	waste_log	log of waste
C	waste_en_log	log of waste_en
I	res_rec	EMERGY of recycled MSW originating in residential buildings
I	res_rec_en	energy of recycled MSW originating in residential buildings
I	res_rec_log	log of res_rec
I	res_recen_log	log of res_rec_en
I	com_rec	EMERGY of recycled MSW originating in comm./inst./ind. buildings
I	com_rec_en	energy of recycled MSW originating in comm./inst./ind. buildings
I	com_rec_log	log of com_rec
	com_recen_log	log of com_rec_en
C	recycle	sum of res_rec and com_rec
C	recycle_en	sum of res_rec_en and com_rec_en
C	recycle_log	log of recycle
C	recycl_en_log	log of recycle_en

EMERGY Flow Components

The logarithm analytical component grids for each of the energy and EMERGY flow component grids of the spatial EMERGY model are used to graphically display the final model results. A standard set of log value ranges has been used to present the results for each component to facilitate comparisons between the component grids.

This approach has the advantage of making it easier to visually compare the patterns and values of one component with another. However, in some cases, the standard set of log value ranges (e.g., 16.00 – 16.49, 16.50 – 16.99, 17.00 – 17.49, etc.) is not sufficiently finely divided for the reader to fully appreciate the variation in values that actually exists in the data. Because of the relative complexity of the model results, it was decided that this limitation was not as important as using a standardized legend for the presentation of all component grid results.

Gross primary productivity component. The creation of the gross primary productivity (GPP) component grid (element #2 in Figure 1-3) was based on two related sets of calculations. First, estimates of GPP per hectare were made for representative ecosystems. These calculations include inputs from both natural and cultural sources (such as fertilizer, labor, machinery used--where appropriate). Transformities for the GPP of each ecosystem type were also calculated. These calculations are in Table 3-4.

In the second set of calculations, each level 3 land use or cover class was assigned a ‘natural system basis’ (NSB) that relates the class to the most closely corresponding general ecosystem type. In the cases of some commercial and industrial classifications, the NSB-based flow values have been proportionately reduced by a factor intended to estimate the amount of vegetation typically present on that type of land use classification. It is important to remember that those areas that were classified as building or road footprints were (logically) not assigned a GPP flow value. As previously described in the methods section, those areas around buildings that were assumed to be significantly altered from the original land use and cover type and were assigned a 'maintained lawn and garden' land use type for their NSB. The results of the detailed calculations for each land use and cover class, including the estimated reduction factors applied, can be found in Table 3-5. (Descriptions for the level 3 land use and cover codes can be found in Table 3-2.) Using these calculated values, the component grids were created by assigning the appropriate EMERGY and energy flow rates for each land use and cover class to the polygons in the 'em_landcov' analytical coverage.

A map of the logarithm analytical EMERGY component grid called 'gpp_log' is shown in Figure 3-24 and a histogram of the number of cells in this EMERGY component grid that have values within each range of log values is shown in Figure 3-25. This map shows that for about 75% of the area of the County, the EMERGY flow rate for GPP falls within the range of 15 to 15.49 log sej/ha/yr. A slightly higher range of log values (15.5 to 16) was calculated for some urban areas and agricultural fields due to the contribution of EMERGY due to cultural inputs.

A map of the logarithm analytical energy component grid called 'gpp_en_log' is shown in Figure 3-26 and a histogram of the number of cells in this energy component grid that have values within each range of log values is shown in Figure 3-27. The map shows slightly higher energy flow rates in areas of upland forests, wetlands, and some agricultural fields.

Table 3-4: EMERGY, energy, and calculated transformities of gross primary production (GPP) for ecosystem types used in this study and EMERGY of the environmental sources and cultural inputs contributing to GPP.

Ecosystem	Environ. Sources Used E14 sej/ha/yr	Cultural Inputs E14 sej/ha/yr	Energy in GPP E11 J/ha/yr	Transformity of GPP sej / J	EMERGY in GPP E14 sej/ha/yr	Note
Pasture	13.1	9.0	4.9	4519	22.1	1
Row crops	19.7	57.6	7.3	10546	77.3	2
Rangeland	6.6	.3	1.5	4656	6.9	3
Pine Flatwoods	13.1	0	8.6	1520	13.1	4
Pine Plantations	13.1	.4	10.2	1325	13.5	5
Forest Regeneration	13.1	.7	10.2	1350	13.8	6
Hardwood Forests	16.4	0	15.9	1033	16.4	7
Hardwood/ Pine Forests	14.8	0	11.5	1287	14.8	8
Dry Forests	5.6	0	3.7	1523	5.6	9
Forested Wetlands	16.4	0	15.4	1064	16.4	10
Cypress Domes	9.0	0	8.5	1056	9.0	11
Wet Prairies	9.0	0	7.3	1227	9.0	12
Freshwater Marshes	9.0	0	6.1	1473	9.0	13
Lakes and Ponds	36.9	0	3.1	12058	36.9	14
Residential Lawn/ Garden	13.1	124.0	7.3	18690	137.1	15

Table 3-4 -- continued.

Notes

A transformity of 1.8 E4 sej/J was assumed for the transformity of transpired water (Odum, 1996) for all calculations associated with this table.

1) Energy in GPP for improved pasture assuming a GPP of 4.0 gC/m2/d:
(4.0 g C/m2/day)(365 d/yr) (8 kcal/g C)(4186 J/kcal)(10,000 m2/ha)
= 4.89 E11 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration is based on Beard (1985):
(.004 m/day)(10,000 m2/ha) (365 day/yr) (1.0 E6 g/m3)(5.0 J/g)(1.8 E4 sej/J)
= 1.31 E15 sej/ha/yr
Cultural inputs of EMERGY based on data from Guttierrez(1978) and transformities from Odum(1996):
Fertilizers: (Nitrogen/Phosphorus/Potassium)
(30 lbN/ac/yr)(2.47 ac/ha)(.454 kg/lb)(E3 g/kg)(4.6 E9 sej/g) = 1.55 E14 sej/ha/yr
(30 lb P/ac/yr)(2.47 ac/ha)(.454 kg/lb)(E3 g/kg)(17.8 E9 sej/g) =5.99 E14 sej/ha/yr
(30 lb K/ac/yr)(2.47 ac/ha)(.454 kg/lb)(E3 g/kg)(1.74 E9 sej/g)= 5.85 E13 sej/ha/yr
Fuels and electricity:
(1500 kcal/ac/yr Fuel)(2.47 ac/ha)(4186 J/kcal)(6.6 E4 sej/J) = 1.02 E12sej/ha/yr
(930kcal/ac/yr Elec.)(2.47 ac/ha)(4186 J/kcal)(2.0 E5sej/J) = 1.92 E12 sej/ha/yr
Machinery:
(6.65 E4 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal)= 2.75 E13sej/ha/yr
Labor:
(1.47 E5 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal)= 6.08 E13sej/ha/yr
Total Cultural inputs of EMERGY = 9.04 E14 sej/ha/yr
Total EMERGY inputs: (1.31 E15 sej/ha/yr) + (9.04 E14 sej/ha/yr)
= 2.21 E15 sej/ha/yr
In comparison, Costanza(1975) and Brown(1980) used data from DeBellevue (et. al., 1975, and 1976) to estimate GPP/subsystem metabolism at:
(5.1 E6 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 2.11 E15 sej/ha/yr
Note: A ratio of 40,000 solar kcal / coal kcal (Odum, 1996) was used to translate any data in Coal Equivalents (CE) (Costanza (1975) , Brown (1980)).
Transformity for GPP (using energy from GPP of 4 gC/m2/day):
(2.21 E15 sej/ha/yr) / (4.89 E11 J/ha/yr) = 4519 sej/J
EMERGY in GPP: (4.89 E11 J/ha/yr)(4519 sej/J) = 2.21 E15 sej/ha/yr

2) Energy in GPP for vegetable rowcrops assuming average of 8 gC/m2/day for vegetable growing season and 4 gC/m2/day from pasture for remaining part of the year based on watermelon production in Alachua County (Smith and Taylor, 1995):
(6.0 g C/m2/day)(365 d/yr) (8 kcal/g C)(4186 J/kcal)(10,000 m2/ha)
= 7.33 E11 J/ha/yr

Table 3-4 -- continued.

Environmental inputs of EMERGY estimated from transpiration (assuming average 6mm/day rate):
(.006 m/day)(10,000 m2/ha) (365 day/yr) (1.0 E6 g/m3)(5.0 J/g)(1.8 x E4 sej/J)
= 1.97 E15 sej/ha/yr
Cultural inputs of EMERGY based on data from Ware and McCollum (1975) and Smith and Taylor (1991, 1995) and transformities from Odum(1996):
Fertilizers: (Nitrogen/Phosphorus/Potassium)
(150 lbN/ac/yr)(2.47 ac/ha)(.454 kg/lb)(E3 g/kg)(4.6 E9 sej/g) = 7.74 E14 sej/ha/yr
(150 lb P/ac/yr)(2.47 ac/ha)(.454 kg/lb)(E3 g/kg)(17.8 E9 sej/g) = 2.99E15sej/ha/yr
(150 lb K/ac/yr)(2.47 ac/ha)(.454 kg/lb)(E3 g/kg)(1.74 E9 sej/g) = 2.93E14sej/ha/yr
Labor (13.5 hr/ac), (using transformity for labor as 8.9 E6 sej/J):
(13.5 hr/ac/yr)(2.47 ac/ha)(150kcal/hr)(4186 J/kcal)(8.9 E6 sej/J)
= 1.86 E14 sej/ha/yr
Fuels (10 gal/ac/yr):
(10 gal/ac/yr)(2.47 ac/ha)(1.7 E8 J/gal)(6.6 E4 sej/J) = 2.77 E14 sej/ha/yr
Other Goods/Services required for preharvest production ($365/ac):
(365 $/ac/yr)(2.47 ac/ha)(1.37 E12 sej/$) = 1.24 E15 sej/ha/yr
Total Cultural inputs of EMERGY = 5.76 E15 sej/ha/yr
Total EMERGY inputs: (1.97 E15 sej/ha/yr) + (5.76 E15 sej/ha/yr)
= 7.73 E15 sej/ha/yr
In comparison, Costanza (1975) using data from DeBellevue (1975) based on sugar cane estimated:
(3.3 E6 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 1.36 E15 sej/ha/yr
Transformity for GPP:
(7.73 E15 sej/ha/yr) / (7.33 x E11 J/ha/yr) = 10546 sej/J

3) The GPP estimate for rangeland is based on data from several sources. Abrahamson and Hartnett (1990) estimated that dry prairies (similar to some types of 'rangeland') would have GPP values that were about 21% of pine flatwoods. Based on their prediction, the GPP of dry prairies would be 1.21 gC/m2/day. This value is remarkably similar to the 1.2 gC/m2/day measured for 'old fields' by Golley (1965):
(1.2 g C/m2/day)(365 d/yr) (8 kcal/g C)(4186 J/kcal)(10,000 m2/ha)
= 1.47 E11 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration:
(.002 m/day)(10,000 m2/ha) (365 day/yr) (1.0 E6 g/m3)(5.0 J/g)(1.8 E4 sej/J)
= 6.57 E14 sej/ha/yr
Cultural inputs of EMERGY (Guttierrez, 1978) including fuels,machinery, and labor:
(66,500 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal)= 2.75 E13 sej/ha/yr
Total EMERGY inputs:
(6.57 E14 sej/ha/yr) + (2.75 E13 sej/ha/yr) = 6.85 E14 sej/ha/yr
Transformity of GPP:
(6.85 E14 sej/ha/yr) / (1.47 E11 J/ha/yr) = 4656 sej/J

Table 3-4 -- continued.

EMERGY of GPP: (1.47 E11 J/ha/yr)(4656 sej/J) = 6.85 E14 sej/ha/yr
For comparison, Costanza (1975) calculated a higher value:
(4.0 E6 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 1.65 E15 sej/ha/yr

4) The energy in GPP estimate for pine flatwoods is based on data from several sources which were then averaged. Golkin and Ewel (1984) measured the GPP for pine flatwoods in north central Florida at 2100 gC/m2/yr (5.75 gC/m2/day) :
(2100 gC/m2/yr)(8 kcal/g C)(4186 J/kcal)(10,000 m2/ha) = 7.03 E11 J/ha/yr
Costanza(1975) referred to Bayley, Burns, and Cowles (1974) who found GPP rates of 8.3 gC/m2/day for pine plantations:
(3030 gC/m2/yr)(8 kcal/g C)(4186 J/kcal)(10,000 m2/ha) = 1.02 E12 J/ha/yr
Average of the above estimates:
(7.03 E11 J/ha/yr) + (1.02 E12 J/ha/yr) / 2 = 8.62 E11 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration:
(.004 m/day)(10,000 m2/ha) (365 day/yr)(1.0 E6 g/m3)(5.0 J/g)(1.8 E4 sej/J)
= 1.31 E15 sej/ha/yr
Transformity of GPP:
(1.31 E15 sej/ha/yr) / (8.62 E11 J/ha/yr) = 1520 sej/J
EMERGY in GPP = 1.31 E15 sej/ha/yr
In comparison, Costanza (1975) based his final calculations on averages which included unusually high productivity estimates:
(6.4 E6 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 2.64 E15 sej/ha/yr

5) The energy in GPP for 20 year old 'pine plantations' is based on Bayley, Burns, and Cowles(1974) :
(3030 gC/m2/yr)(8 kcal/g C)(4186 J/kcal)(10,000 m2/ha) = 1.02 E12 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration:
(.004 m/day)(10,000 m2/ha) (365 day/yr) (1.0 E6 g/m3)(5.0 J/g)(1.8 E4 sej/J)
= 1.31 E15 sej/ha/yr
Cultural inputs of EMERGY estimated from Duryea and Edwards (1987) based on one-time site preparation and planting costs of $150/ac, and $5/year management costs (allocated over 20 years = $12.50/ac/yr):
($12.5/acre/yr)(2.47 ac/ha)(1.37 E12 sej/$) = 4.23 E13 sej/ha/yr
Transformity of GPP:
(1.31 E15 sej/ha/yr)+ (4.23 E13 sej/ha/yr) / (1.02 E12 J/ha/yr) = 1325 sej/J
EMERGY in GPP = 1.35 E15 sej/ha/yr

6) The energy in GPP for 'forest regeneration' (assuming a 10 year old pine plantations) is based on Bayley, Burns, and Cowles(1974) :
(3030 gC/m2/yr)(8 kcal/g C)(4186 J/kcal)(10,000 m2/ha) = 1.02 E12 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration:
(.004 m/day)(10,000 m2/ha) (365 day/yr) (1.0 E6 g/m3)(5.0 J/g)(1.8 E4 sej/J)
= 1.31 E15 sej/ha/yr

Table 3-4 -- continued.

Cultural inputs of EMERGY estimated from Duryea and Edwards (1987) based on one-time site preparation and planting costs of \$150/ac, and \$5/year management costs (allocated over 10 years = \$20/ac/yr):
(\$20/acre/yr)(2.47 ac/ha)(1.37 E12 sej/\$) = 6.77 E13 sej/ha/yr
Transformity of GPP:
(1.31 E15 sej/ha/yr)+ (6.77 E13 sej/ha/yr) / (1.02 E12 J/ha/yr) = 1350 sej/J
EMERGY in GPP = 1.38 E15 sej/ha/yr

7) The energy in GPP estimate for hardwood forests is based on Costanza (1975) (which Costanza based on estimates made by H.T. Odum for tropical rain forests that were adjusted for 9 month growing season).
(13.0 gC/m2/day)(365 days/yr)(8kcal/g C)(4186 J/kcal)(10000 m2/ha)
= 1.59 E12 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration:
(.005 m/day)(10,000 m2/ha) (365 day/yr)
(1.0 E6 g/m3)(5.0 J/g)(1.8 E4 sej/J) = 1.64 E15 sej/ha/yr
Transformity of GPP:
(1.64 E15 sej/ha/yr) / (1.59 E12 J/ha/yr) = 1033 sej/J
EMERGY in GPP = 1.64 E15 sej/ha/yr
In comparison, Costanza (1975) , using a transformity equivalent to 2000 sej/J calculated:
(7.7 E6 CE/ac/yr)((2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 3.18 E15 sej/ha/yr

8) The energy in GPP estimate for Hardwood/conifer mixed forest is assumed to be based on the average of the GPP estimates for pine flatwoods and hardwood forests:
((13.0 gC/m2/day) + (5.75 gC/m2/day))/ 2 = 9.38 gC/m2/day
(9.38 gC/m2/day)(365 days/yr)(8kcal/g C)(4186 J/kcal)(10000 m2/ha)
= 1.15 E12 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration (also based on average of pine and hardwood forests):
(.0045 m/day)(10,000 m2/ha) (365 day/yr)(1.0 E6 g/m3)(5.0 J/g)(1.8 E4 sej/J)
= 1.48 E15 sej/ha/yr
Transformity of GPP: (1.48 E15 sej/ha/yr) / (1.15 E12 J/ha/yr) = 1287 sej/J
EMERGY in GPP = 1.48 E15 sej/ha/yr

9) The energy in GPP estimate for Dry Forests (sandhills, high pine, etc.) is based on Brown et. al. (1984b, using data from Lugo, 1978):
(3.0 g C/m2/day)(365 d/yr) (8 kcal/g C)(4186 J/kcal)(10,000 m2/ha)
= 3.67 E11 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration (also based on average of pine and hardwood forests):
(.0017 m/day)(10,000 m2/ha) (365 day/yr)(1.0 E6 g/m3)(5.0 J/g)(1.8 E4 sej/J)
= 5.59 E14 sej/ha/yr

Table 3-4 -- continued.

Transformity of GPP:
(5.59 E14 sej/ha/yr) / (3.67 E11 J/ha/yr) = 1523 sej/J
EMERGY in GPP = 5.59 E14 sej/ha/yr

10) The energy in GPP estimate for forested wetlands is based on Brown et. al. (1984, and 1984b) and Ewel (1990) :
(12.6 gC/m2/day)(365 days/yr)(8kcal/g C)(4186 J/kcal)(10000 m2/ha)
= 1.54 E12 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration:
(.005 m/day)(10,000 m2/ha) (365 day/yr)(1.0 E6 g/m3)(5.0 J/g)(1.8 E4 sej/J)
= 1.64 E15 sej/ha/yr
Transformity of GPP: (1.64 E15 sej/ha/yr) / (1.54 E12 J/ha/yr) = 1064 sej/J
EMERGY in GPP = 1.64 E15 sej/ha/yr
In comparison, Costanza (1975) , using a transformity equivalent to 2000 sej/J calculated:
(7.3 E6 CE/ac/yr)((2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal)= 3.02 E15 sej/ha/yr

11) Energy in GPP estimated for cypress domes (based on Ewel (1990)):
(6.97 gC/m2/day)(365 days/yr)(8kcal/g C)(4186 J/kcal)(10000 m2/ha)
= 8.52 E11 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration(based on Odum (1992)):
(1.0 E4 m3/ha/yr)(1.0 E6 g/m3)(5.0 J/g)(1.80 E4 sej/J) = 9.0 E14 sej/ha/yr
Transformity for GPP: (9.0 E14 sej/ha/yr) / (8.52 E11 J/ha/yr) = 1056 sej/J
EMERGY in GPP: 9.0 E14 sej/ha/yr
In comparison, Costanza (1975) and Brown (1980) calculated EMERGY in GPP using a figure of 11 gC/m2/day for GPP for cypress domes:
(7.3 E6 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 3.14 E15 sej/ha/yr

12) The GPP and structure estimates for wet prairies are based data from Costanza (1975, after Carter, et.al., 1973):
(6.0 gC/m2/day)(365 days/yr)(8kcal/g C)(4186 J/kcal)(10000 m2/ha)
= 7.33 E11 J/ha/yr
Environmental inputs of EMERGY estimated from transpiration (based on Odum (1992)):
(1.0 E4 m3/ha/yr)(1.0 E6 g/m3)(5.0 J/g)(1.80 E4 sej/J) = 9.0 E14 sej/ha/yr
Transformity for GPP:
(9.0 E14 sej/ha/yr) / (7.33 E11 J/ha/yr) = 1227 sej/J
EMERGY in GPP: 9.0 E14 sej/ha/yr

13) Energy in GPP estimated for freshwater marshes based on data from Odum (1996, for salt marsh in northwest Florida):
(5.0 gC/m2/day)(365 days/yr)(8kcal/g C)(4186 J/kcal)(10000 m2/ha)
= 6.11 E11 J/ha/yr

Table 3-4 -- continued.

Environmental inputs of EMERGY estimated from transpiration based on Odum (1992):
(1.0 E04 m3/ha/yr)(1.0 E6 g/m3)(5.0 J/g)(1.80 E4 sej/J) = 9.0 E14 sej/ha/yr
Transformity for GPP: (9.0 E14 sej/ha/yr) / (6.11 E11 J/ha/yr) = 1473 sej/J
EMERGY in GPP: 9.0 E14 sej/ha/yr

14) Energy in GPP is estimated for lakes and ponds based on data from Costanza (1975, after Bayley and Odum, 1973):
(2.5 gC/m2/day)(365 days/yr)(8kcal/g C)(4186 J/kcal)(10000m2/ha)
=3.06E11J/ha/yr
Environmental inputs of EMERGY estimated from chemical potential energy of water (assuming average 1.8 m depth of lakes (Gottgens and Montague(1987)):
(1.8m)(10000 m2/ha)(1 E6 g/m3)(5 J/g)(4.1 x E4 sej/J/ha) = 3.69 x E15 sej/ha
Transformity for GPP: (3.69 E15 sej/ha/yr) / (3.06 E11 J/ha/yr) = 12,058 sej/J
EMERGY in GPP : (3.06 E11 sej/ha/yr)(12058 sej/J) = 3.69 E15 sej/ha/yr
For comparison, Costanza (1975) found for GPP:
(1.4 E6 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 5.79 E14 sej/ha/yr

15) Energy in GPP for residential lawns/gardens assuming a GPP of 6.0 gC/m2/d:
(6.0 g C/m2/day)(365 d/yr) (8 kcal/g C)(4186 J/kcal)(10,000 m2/ha)
= 7.33 E11 J/ha/yr
Environmental inputs of EMERGY based on Beard (1985):
(.004 m/day)(10,000 m2/ha) (365 day/yr) (1.0 E6 g/m3)(5.0 J/g)(1.8 E4 sej/J)
= 1.31 E15 sej/ha/yr
Cultural inputs of EMERGY based on data from Hensley (1994) and transformities from Odum(1996):
(120 lbN/ac/yr)(2.47 ac/ha)(.454 kg/lb)(E3 g/kg)(4.6 E9 sej/g) = 6.19 E14 sej/ha/yr
(30 lb P/ac/yr)(2.47 ac/ha)(.454 kg/lb)(E3 g/kg)(17.8 E9 sej/g) = 5.99 E14 sej/ha/yr
(60 lb K/ac/yr)(2.47 ac/ha)(.454 kg/lb)(E3 g/kg)(1.74 E9 sej/g) = 1.17 E14 sej/ha/yr
Total fertilizers: 1.34 E15 sej/ha/yr
Fuels (assume 50 gal/ac/yr):
(50 gal/ac/yr)(2.47 ac/ha)(3.7854 liters/gal)(4.72 E7 J/liter)(6.6 E4 sej/J)
= 1.46 E15 sej/ha/yr
Labor (assuming 12 minutes/1000 sq ft./wk (Hensley, 1994))
(using transformity for labor as 8.9 E6 sej/J (Odum, 1996)):
(.012 min/ft2/wk)(43560 ft2/ac)(2.47 ac/ha)(52 wk/yr)/60 min/hr = 1119 hr/ha/yr
(1119 hr/ha/yr)(150kcal/hr)(4186 J/kcal)(8.9 E6 sej/J) = 6.25 E15 sej/ha/yr
Other Goods/Services (assume $1000/ac/yr):
(1000$/ac/yr)(2.47 ac/ha)(1.37 E12 sej/$) = 3.38 E15 sej/ha/yr
Total Cultural inputs of EMERGY = 1.24 E16 sej/ha/yr
Total inputs: (1.31 E15 sej/ha/yr) + (1.24 E16 sej/ha/yr)= 1.37 E16 sej/ha/yr
Transformity for GPP: (1.37 E16 sej/ha/yr) / (7.33 E11 J/ha/yr) = 18690 sej/J
EMERGY in GPP = 1.37 E16 sej/ha/yr

Table 3-5: Estimated EMERGY and energy in gross primary production (GPP) of natural systems and transformity of GPP assigned to each modified level 3 land use and cover code in the 'em_landcov' analytical coverage with environmental sources and cultural inputs contributing to GPP.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Environ. Sources Used, E11 sej/m2/yr [4]	Cultural Inputs, E11 sej/m2/yr [5]	Energy in GPP, E7 J/m2/yr [6]	Transformity of GPP [7]	EMERGY in GPP, E11 sej/m2/yr [8]	Table 3-4 Note [9]
11001	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
11002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
11101	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
11102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
11201	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
11202	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
11301	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
11302	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
11401	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
11402	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
11501	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
11502	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
11601	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
11602	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
12001	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
12002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
12101	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
12102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
12201	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
12202	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
12301	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
12302	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
13001	lawn/garden	0.70	0.92	8.68	5.11	18690	9.60	15
13002	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
13101	lawn/garden	0.70	0.92	8.68	5.11	18690	9.60	15
13102	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
13201	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
13202	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
13301	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
13302	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
13401	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
13402	lawn/garden	0.20	0.26	2.48	1.46	18690	2.74	15
13501	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
13502	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
14001	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
14002	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
14111	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
14112	lawn/garden	0.05	0.07	0.62	0.37	18690	0.69	15
14231	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
14232	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
14241	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
14242	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
14521	lawn/garden	0.20	0.26	2.48	1.46	18690	2.74	15
14522	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
14531	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
14541	hardwood/pine forests	0.80	1.18	0.00	9.20	1287	1.18	8
14542	lawn/garden	0.70	0.92	8.68	5.11	18690	9.60	15
14601	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15

Table 3-5 -- continued.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Environ. Sources Used, E11 sej/m2/yr [4]	Cultural Inputs, E11 sej/m2/yr [5]	Energy in GPP, E7 J/m2/yr [6]	Transformity of GPP [7]	EMERGY in GPP, E11 sej/m2/yr [8]	Table 3-4 Note [9]
14602	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
14701	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
14702	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
14801	lawn/garden	0.80	1.05	9.92	5.84	18690	10.97	15
14802	lawn/garden	0.80	1.05	9.92	5.84	18690	10.97	15
14901	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
14902	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
15001	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
15002	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
15161	hardwood/pine forests	0.10	0.15	0.00	1.15	1287	0.15	8
15211	hardwood/pine forests	0.10	0.15	0.00	1.15	1287	0.15	8
15212	hardwood/pine forests	0.05	0.07	0.00	0.58	1287	0.07	8
15271	hardwood/pine forests	0.10	0.15	0.00	1.15	1287	0.15	8
15272	hardwood/pine forests	0.05	0.07	0.00	0.58	1287	0.07	8
15501	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
15502	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
15511	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
15512	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
15521	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
15522	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
15551	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
15552	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
15601	lawn/garden	0.05	0.07	0.62	0.37	18690	0.69	15
15602	lawn/garden	0.05	0.07	0.62	0.37	18690	0.69	15
15651	lawn/garden	0.05	0.07	0.62	0.37	18690	0.69	15
15652	lawn/garden	0.05	0.07	0.62	0.37	18690	0.69	15
15701	lawn/garden	0.05	0.07	0.62	0.37	18690	0.69	15
15702	lawn/garden	0.05	0.07	0.62	0.37	18690	0.69	15
16001	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16002	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16111	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16141	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16142	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16201	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16202	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16311	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16312	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16601	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16701	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
16702	pine flatwoods	0.01	0.01	0.00	0.09	1520	0.01	4
17001	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
17002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
17101	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
17102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
17201	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
17202	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
17411	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
17412	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
17561	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
17562	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
17651	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
17652	pasture	1.00	1.31	0.90	4.90	4519	2.21	1

Table 3-5 -- continued.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Environ. Sources Used, E11 sej/m2/yr [4]	Cultural Inputs, E11 sej/m2/yr [5]	Energy in GPP, E7 J/m2/yr [6]	Transformity of GPP [7]	EMERGY in GPP, E11 sej/m2/yr [8]	Table 3-4 Note [9]
17701	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
17702	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18001	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18201	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18202	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18311	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
18312	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
18501	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18502	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18511	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18512	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18601	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18602	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18901	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
18902	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
19001	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
19002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
19101	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
19102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
19201	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
19202	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
19231	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
19232	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
19241	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
19242	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
21101	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
21102	lawn/garden	0.80	1.05	9.92	5.84	18690	10.97	15
21201	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
21202	lawn/garden	0.80	1.05	9.92	5.84	18690	10.97	15
21301	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
21302	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
21401	rowcrops	1.00	1.97	5.76	7.30	10546	7.73	2
21402	lawn/garden	0.80	1.05	9.92	5.84	18690	10.97	15
21501	rowcrops	1.00	1.97	5.76	7.30	10546	7.73	2
21502	lawn/garden	0.80	1.05	9.92	5.84	18690	10.97	15
21601	rowcrops	1.00	1.97	5.76	7.30	10546	7.73	2
22001	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22101	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22201	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22202	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22211	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22241	rowcrops	1.00	1.97	5.76	7.30	10546	7.73	2
22242	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22301	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22311	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22312	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
22401	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
23001	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
23002	pasture	1.00	1.31	0.90	4.90	4519	2.21	1

Table 3-5 -- continued.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Environ. Sources Used, E11 sej/m2/yr [4]	Cultural Inputs, E11 sej/m2/yr [5]	Energy in GPP, E7 J/m2/yr [6]	Transformity of GPP [7]	EMERGY in GPP, E11 sej/m2/yr [8]	Table 3-4 Note [9]
23101	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
23102	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
23201	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
23202	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
24101	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
24102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
24201	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
24301	rowcrops	1.00	1.97	5.76	7.30	10546	7.73	2
24302	rowcrops	1.00	1.97	5.76	7.30	10546	7.73	2
24501	rowcrops	1.00	1.97	5.76	7.30	10546	7.73	2
25101	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
25102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
25201	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
25202	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
25301	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
25302	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
25401	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
25402	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
25901	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
25902	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
26001	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
26002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
26101	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
26201	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
26202	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
31001	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
31002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
32001	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
32002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
32901	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
32902	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
33001	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
33002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
41101	pine flatwoods	1.00	1.31	0.00	8.60	1520	1.31	4
41102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
41201	dry forests	1.00	0.56	0.00	3.70	1523	0.56	9
41202	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
41401	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
41402	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
41901	pine flatwoods	1.00	1.31	0.00	8.60	1520	1.31	4
41902	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
42001	dry forests	1.00	0.56	0.00	3.70	1523	0.56	9
42002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
42101	dry forests	1.00	0.56	0.00	3.70	1523	0.56	9
42102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
42301	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8
42302	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
42501	hardwood forests	1.00	1.64	0.00	15.90	1033	1.64	7
42502	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
43101	hardwood forests	1.00	1.64	0.00	15.90	1033	1.64	7
43102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
43401	hardwood/pine forests	1.00	1.48	0.00	11.50	1287	1.48	8

Table 3-5 -- continued.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Environ. Sources Used, E11 sej/m2/yr [4]	Cultural Inputs, E11 sej/m2/yr [5]	Energy in GPP, E7 J/m2/yr [6]	Transformity of GPP [7]	EMERGY in GPP, E11 sej/m2/yr [8]	Table 3-4 Note [9]
43402	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
44001	pine plantations	1.00	1.31	0.04	10.20	1325	1.35	5
44002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
44101	pine plantations	1.00	1.31	0.04	10.20	1325	1.35	5
44102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
44301	forest regeneration	1.00	1.31	0.07	10.20	1350	1.38	6
44302	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
44601	forest regeneration	1.00	1.31	0.07	10.20	1350	1.38	6
51001	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
51002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
51201	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
52001	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
52002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
52101	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
52102	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
52201	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
52301	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
52302	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
52401	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
52402	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
53001	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
53002	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
53301	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
53302	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
53401	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
53402	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
55001	lakes/ponds	1.00	3.69	0.00	3.10	12058	3.69	14
61001	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
61101	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
61102	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
61201	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
61202	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
61301	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
61401	wet prairies	1.00	0.90	0.00	7.30	1227	0.90	12
61402	wet prairies	1.00	0.90	0.00	7.30	1227	0.90	12
61501	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
61502	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
61701	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
61702	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
62001	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
62101	cypress domes	1.00	0.90	0.00	8.50	1056	0.90	11
62102	cypress domes	1.00	0.90	0.00	8.50	1056	0.90	11
62201	pine flatwoods	1.00	1.31	0.00	8.60	1520	1.31	4
62202	pine flatwoods	1.00	1.31	0.00	8.60	1520	1.31	4
63001	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
63002	forested wetlands	1.00	1.64	0.00	15.40	1064	1.64	10
63101	hardwood forests	1.00	1.64	0.00	15.90	1033	1.64	7
64101	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
64102	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
64201	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
64301	wet prairies	1.00	0.90	0.00	7.30	1227	0.90	12
64302	wet prairies	1.00	0.90	0.00	7.30	1227	0.90	12

Table 3-5 -- continued.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Environ. Sources Used, E11 sej/m2/yr [4]	Cultural Inputs, E11 sej/m2/yr [5]	Energy in GPP, E7 J/m2/yr [6]	Transformity of GPP [7]	EMERGY in GPP, E11 sej/m2/yr [8]	Table 3-4 Note [9]
64401	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
64402	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
64501	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
64601	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
64602	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
65001	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
65301	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
65302	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
66001	freshwater marshes	1.00	0.90	0.00	6.10	1473	0.90	13
74001	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
74002	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
74101	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
74102	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
74201	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
81101	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81111	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81112	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
81131	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81132	lawn/garden	1.00	1.31	12.40	7.30	18690	13.71	15
81201	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81401	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81402	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81411	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81412	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81421	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81422	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81431	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81432	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81471	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81472	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
81701	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
81702	rangeland	1.00	0.66	0.03	1.50	4656	0.69	3
81801	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
81802	lawn/garden	0.50	0.66	6.20	3.65	18690	6.86	15
82001	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
82002	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
83101	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
83102	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
83111	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
83112	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
83121	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
83122	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
83151	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
83152	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
83201	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
83202	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
83301	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
83302	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
83401	lawn/garden	0.30	0.39	3.72	2.19	18690	4.11	15
83402	lawn/garden	0.10	0.13	1.24	0.73	18690	1.37	15
83501	pasture	0.10	0.13	0.09	0.49	4519	0.22	1
83502	pasture	0.10	0.13	0.09	0.49	4519	0.22	1
88801	pasture	1.00	1.31	0.90	4.90	4519	2.21	1
88802	pasture	1.00	1.31	0.90	4.90	4519	2.21	1

Table 3-5 -- continued.

Notes

1) The first four numbers in the modified land use and cover code in the 'em_landcov' coverage are based on the level 3 land use/cover codes that are described in Table 3-2. The fifth number in the modified code was created to identify those polygons representing:

a) areas of buffered buildings and roads,
   - identified by a value of '3' in the fifth number of the code (and not included in this table because all of the values are logically equal to 0 (no biomass)),

b) areas assumed to be significantly altered from the original land use and cover type to a 'maintained lawn and garden' type,
   - identified by a value of '2' in the fifth number of the code

c) areas not altered from the assigned land use and cover type,
   - identified by a value of '1'in the fifth number of the code.

2) Each land use and cover code was assigned a natural system basis (NSB) for the estimate of biomass. The NSB correlates with the general ecosystem types found in Table 3-4.

3) Estimated reduction factor used to reduce the estimated flows of energy and EMERGY indicated by the NSB for each code (e.g. some land uses have proportionately less vegetation than their NSB type).

4) EMERGYin the environmental sources used (based on transpiration) for gross primary production.

5) EMERGY in the cultural inputs (such as fertilizer, labor, machinery used up, etc.) contributing to the gross primary production.

6) Calculated annual energy in GPP (E7 J/m2/yr) after multiplying the reduction factor by the NSB value from Table 3-4.

7) Transformity from NSB found in Table 3-4.

8) Calculated annual EMERGY in GPP (E11 sej/m2) after multiplying the reduction factor by the NSB value from Table 3-4.

9) Reference to notes in Table 3-4 that have the detailed calculations for the energy and EMERGY flows of each NSB.

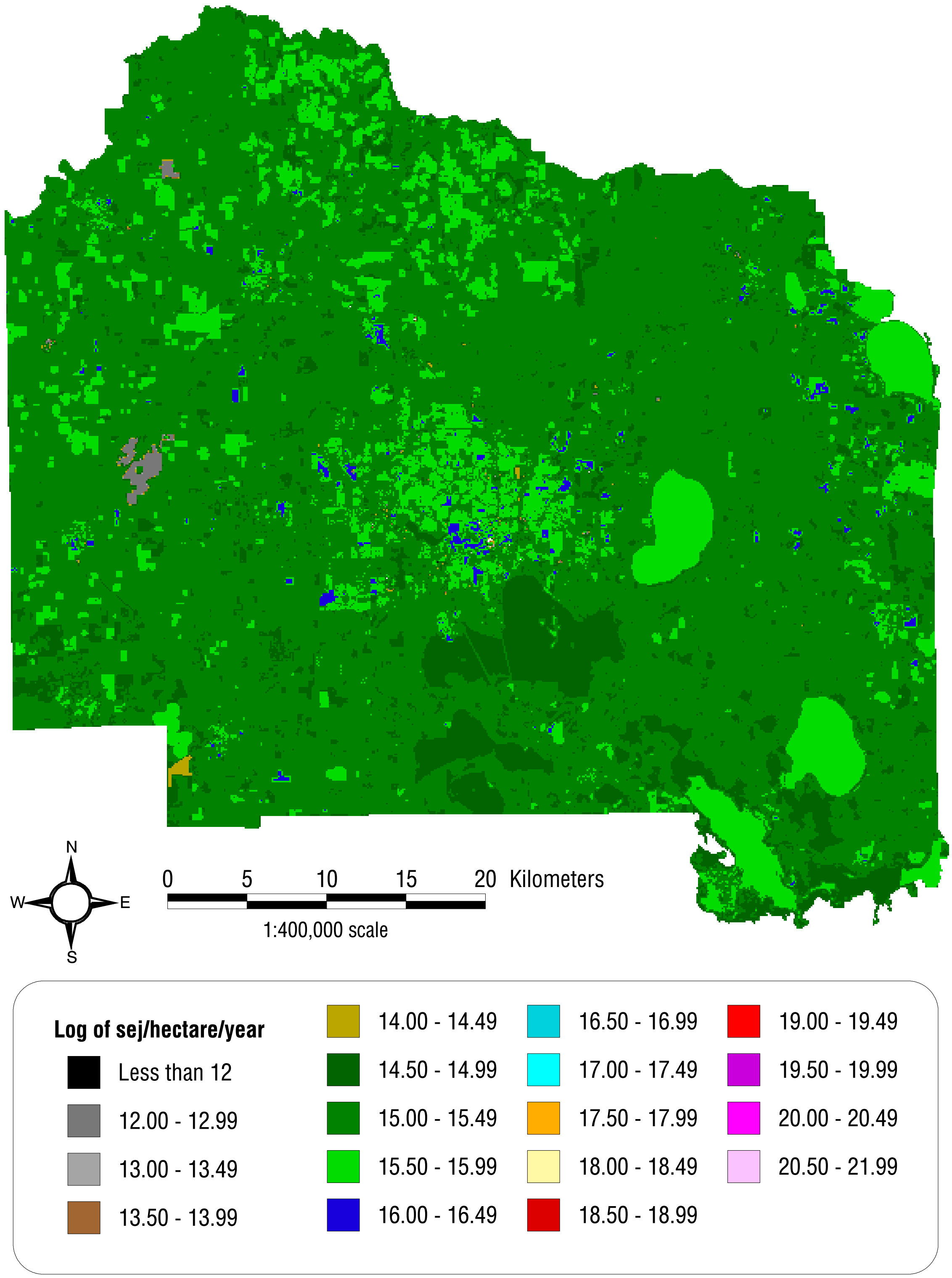


Figure 3-24: Map of the logarithm analytical EMERGY component grid called 'gpp_log'. This grid represents the log of the annual EMPOWER density (log sej/ha/yr) for the gross primary productivity (GPP) of natural systems.

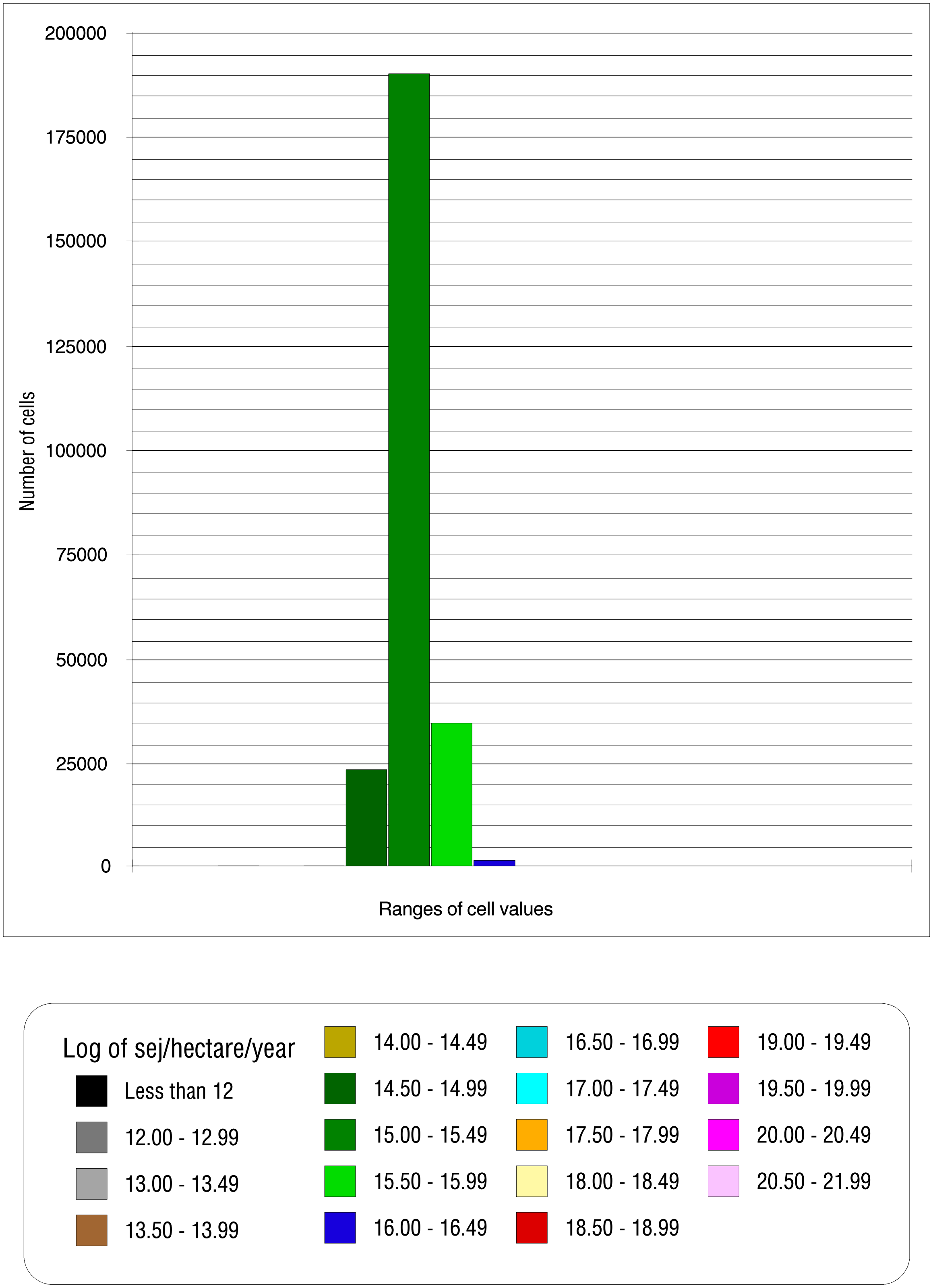


Figure 3-25: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called 'gpp_log'.

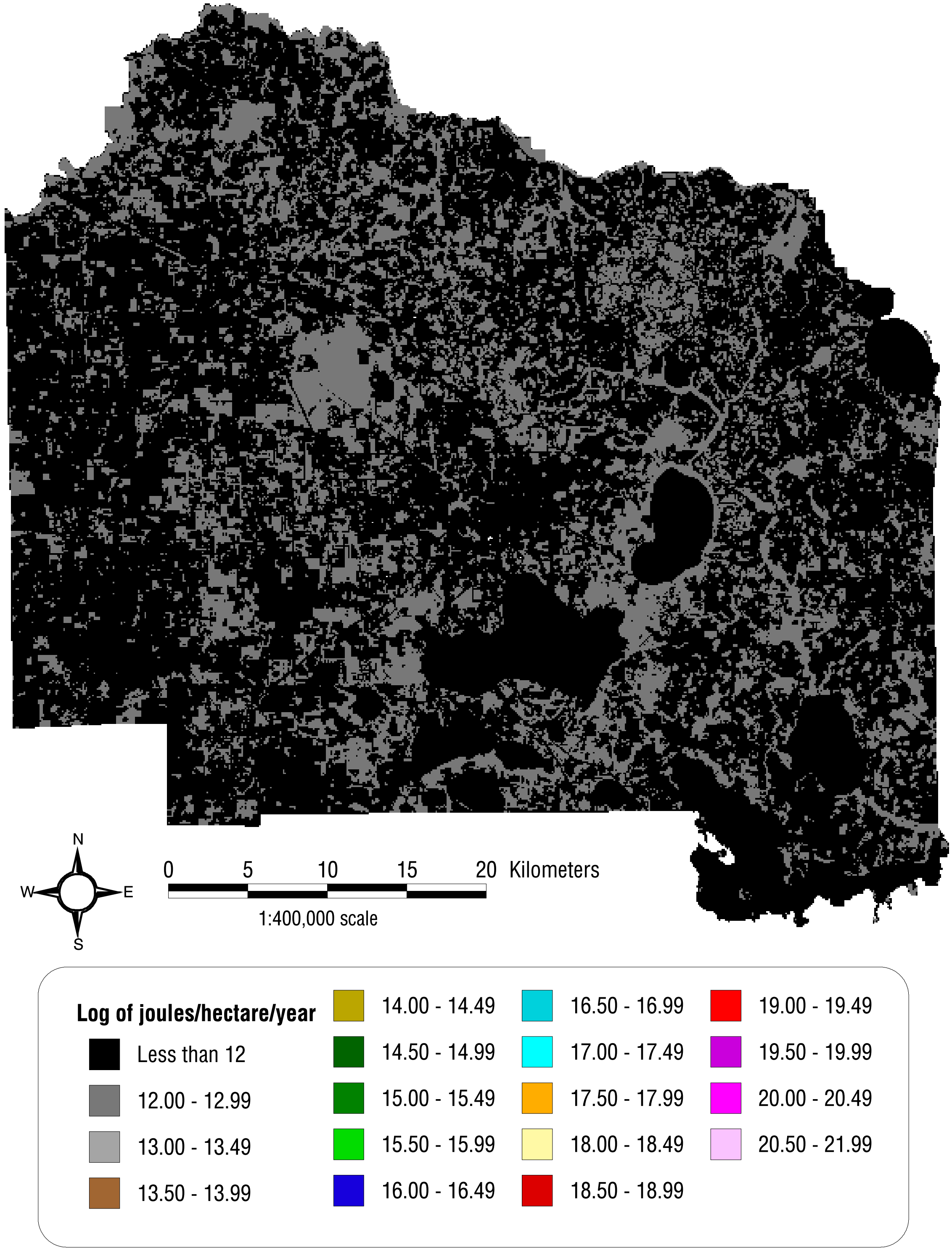


Figure 3-26: Map of the logarithm analytical energy component grid called 'gpp_en_log'. This grid represents the log of the annual energy flow density (log j/ha/yr) of the gross primary productivity (GPP) of natural systems.

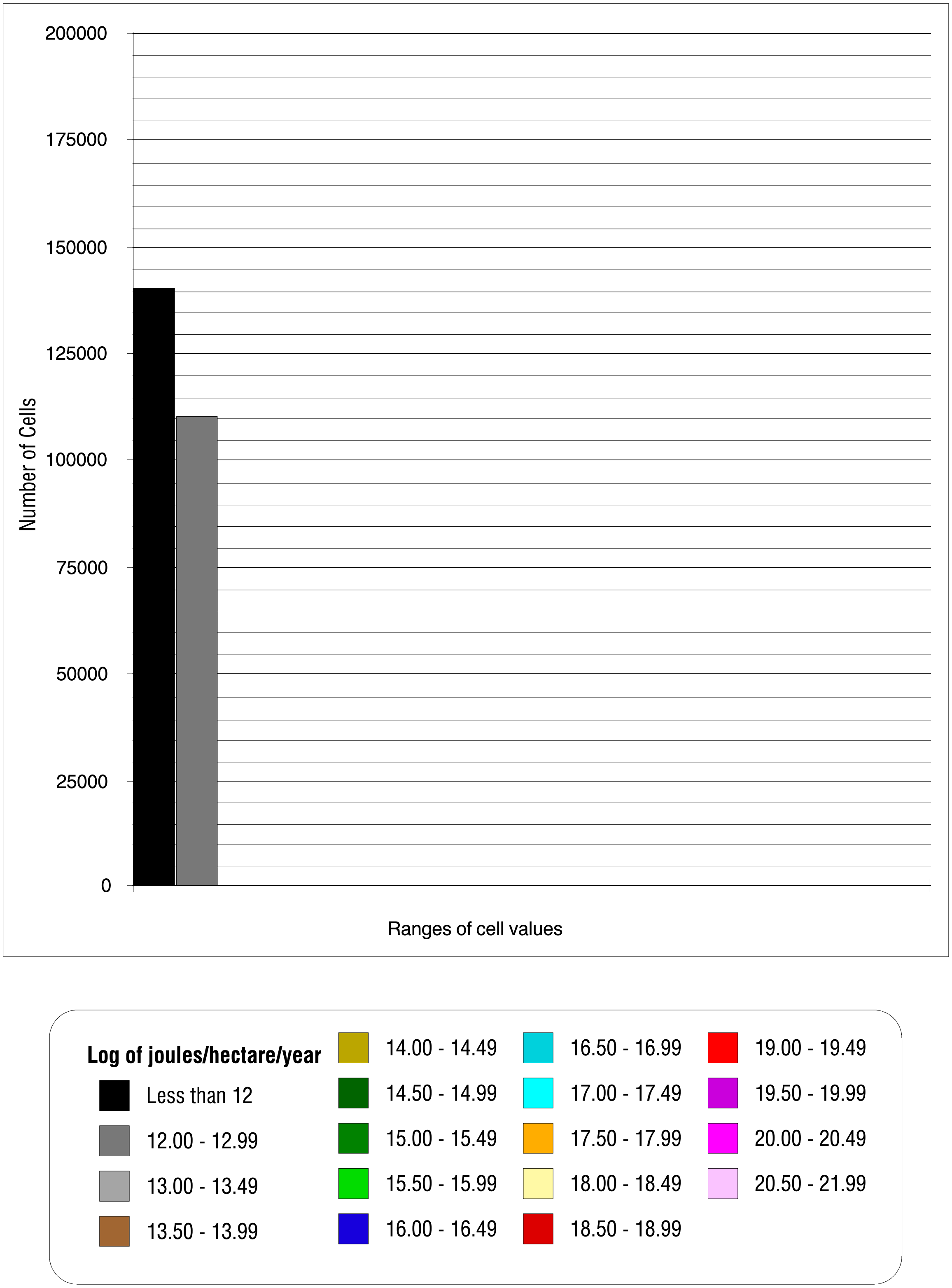


Figure 3-27: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'gpp_en_log'.

Renewable resources component. The analytical coverage called ‘em_landcov’ was also used to create this component. The calculations used to determine the energy and EMERGY in gross primary productivity include estimates of the energy and EMERGY in transpiration. These transpiration values were used to assign values for those areas not covered by building or road footprints. In these ‘footprint’ polygons the energy and EMERGY of the annual solar insolation rate was used (5.95 E9 j(sej)/m2/yr) to assign the ‘renewable resources used’ flow rates.

A map of the logarithm analytical EMERGY component grid called ‘renew_log’ is shown in Figure 3-28 (see element #1 in Figure 1-3). This map shows that for about 83% of the area of the County (compared to 75% for the GPP component), the EMERGY flow rate for ‘renewable resources used’ falls within the range of 15 to 15.49 log sej/ha/yr. A larger percentage of the County falls into this range than in the case of the GPP component because cultural inputs, with high EMERGY input contributions, are not included in this component. A histogram of the number of cells in this EMERGY component grid that has values within each range of log values is shown in Figure 3-29. The map of the logarithm analytical energy component grid called ‘renew_en_log’ is shown in Figure 3-30 and a histogram of cell value distribution is shown in Figure 3-31. The energy map displays a counter-intuitive pattern of energy flows. The pattern shows higher flows (only slightly over log 12 j/ha/yr) occurring in urban areas and along roads. This pattern, enhanced by chance by the standard legend, can be explained by the use of solar insolation values for building and road footprints that are higher than the typical energy flow values calculated for transpiration. Because the transformity of solar insolation is only 1 sej/joule, the EMERGY grid does not display this pattern.

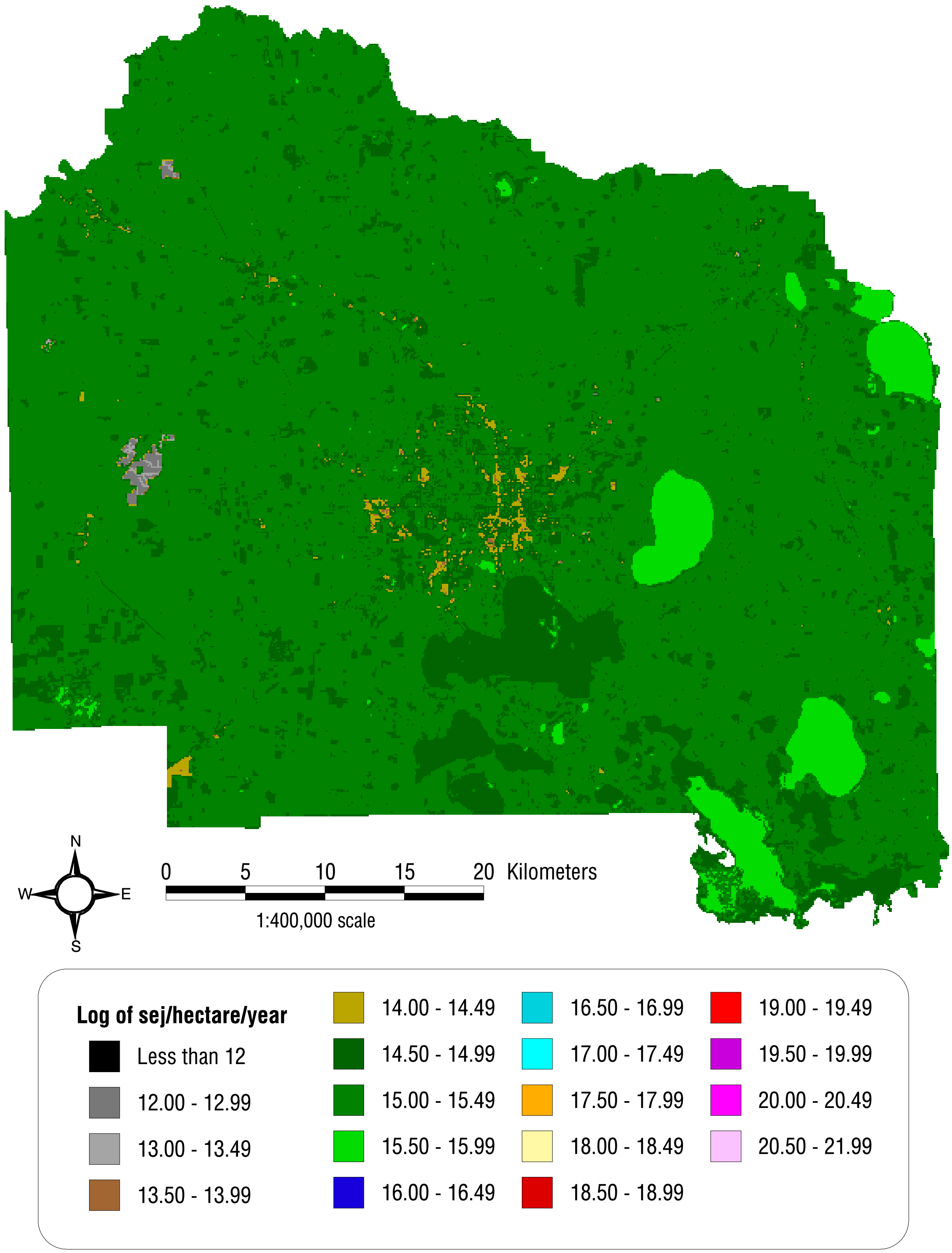


Figure 3-28: Map of the logarithm analytical EMERGY component grid called 'renew_log'. This grid represents the log of the annual EMPOWER density (log sej/ha/yr) of the renewable resources used (based on transpiration).

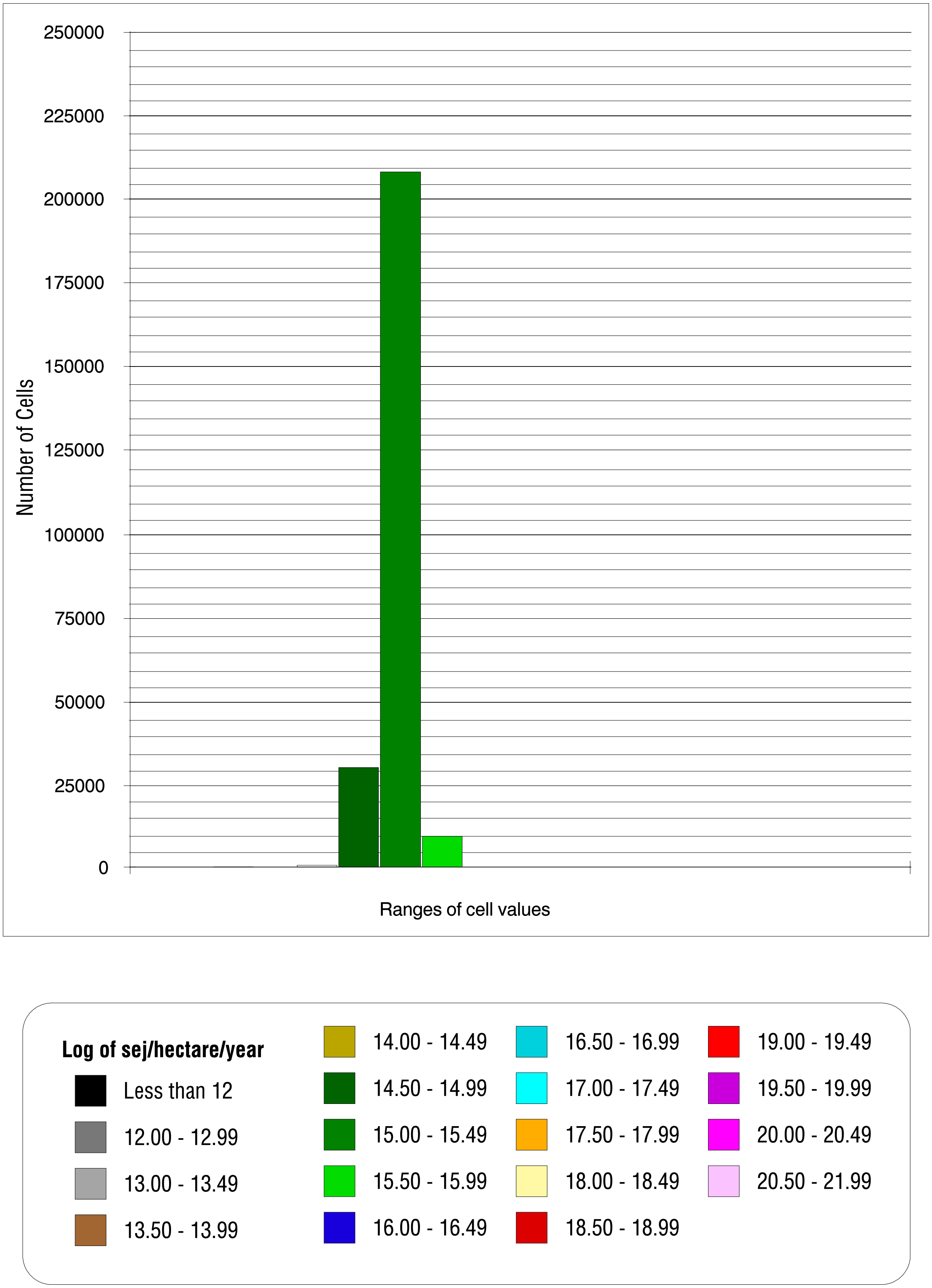


Figure 3-29: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called 'renew_log'.

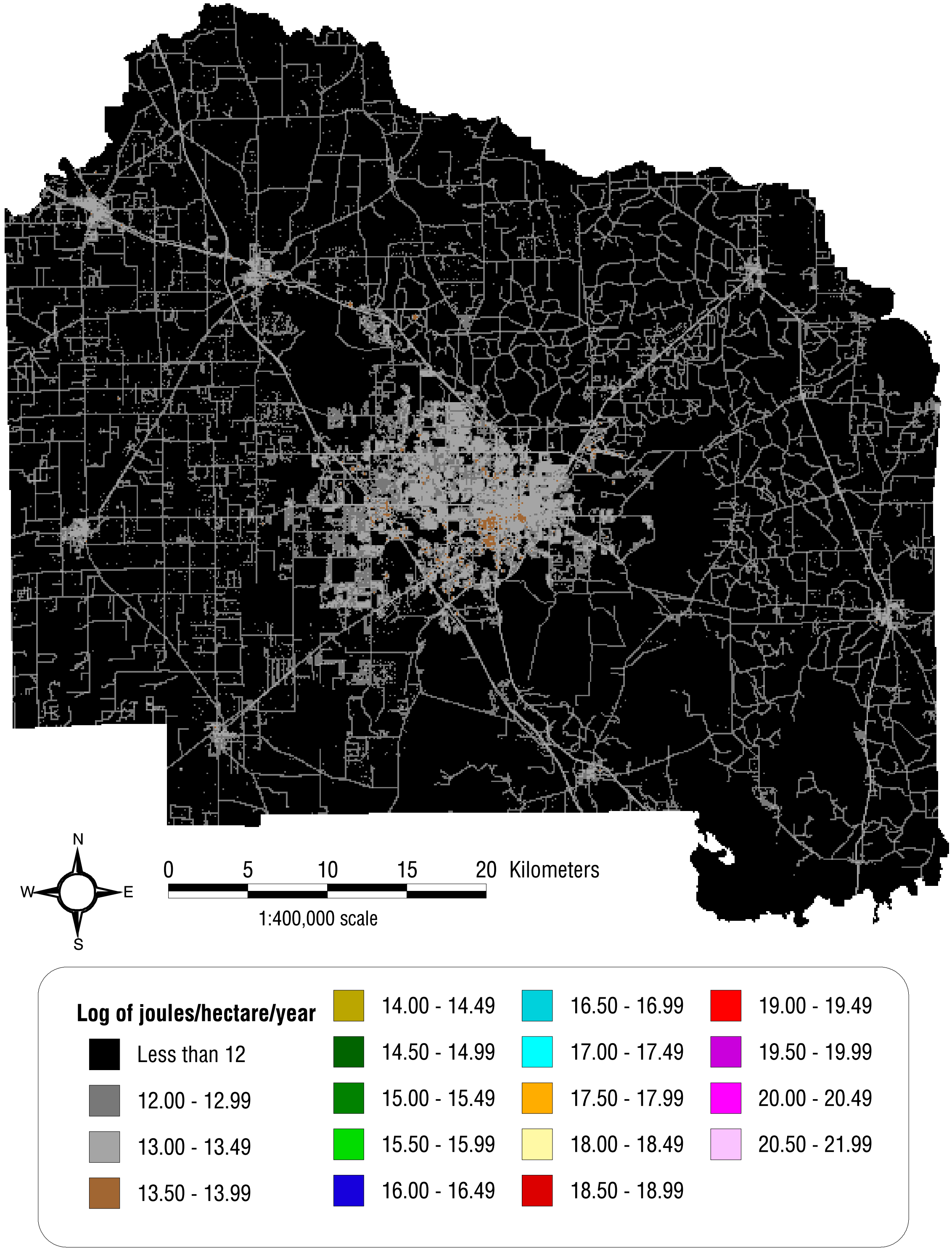


Figure 3-30: Map of the logarithm analytical energy component grid called 'renew_en_log'. This grid represents the log of the annual energy flow density (log j/ha/yr) of the renewable resources used (based on transpiration).

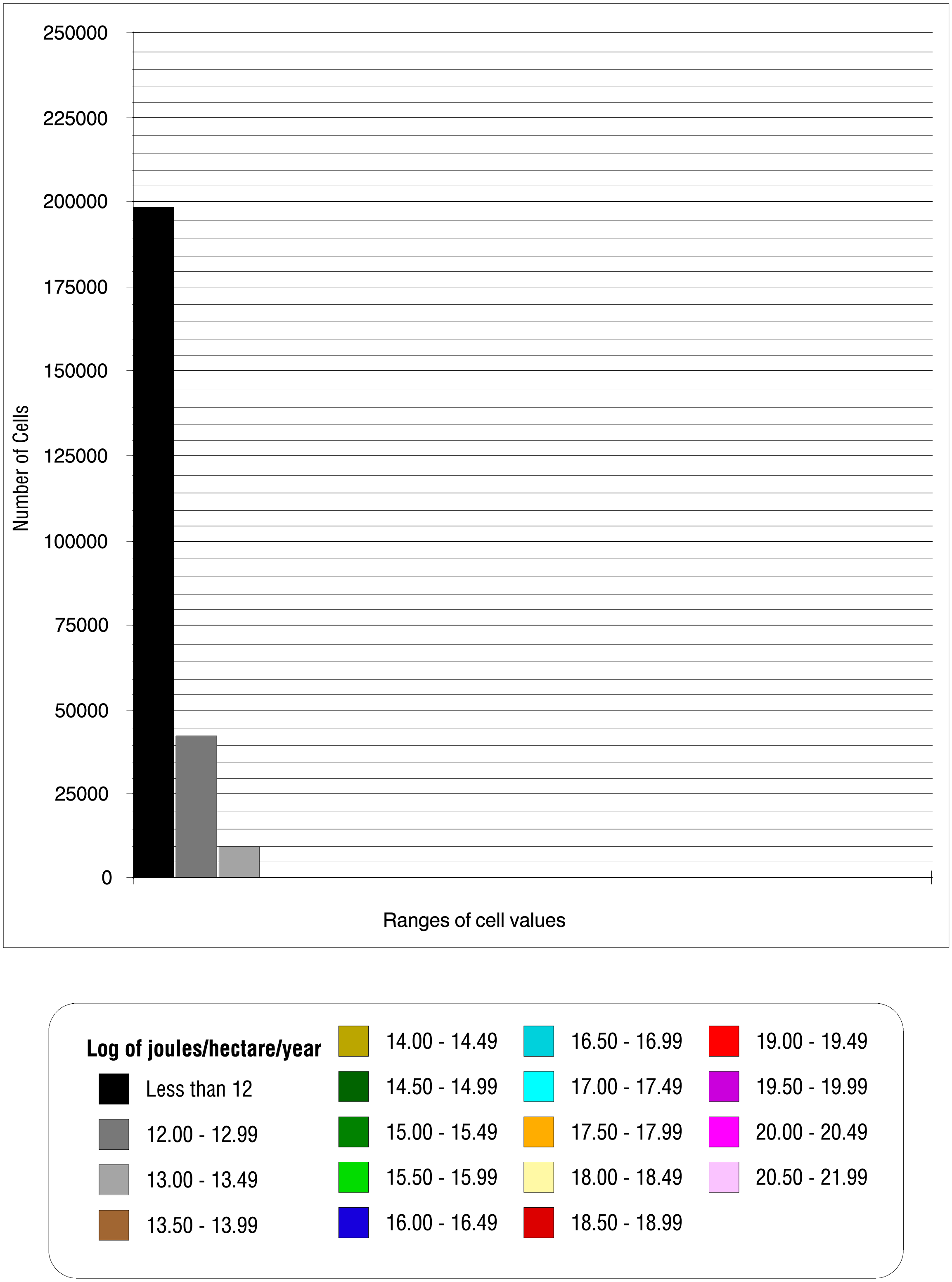


Figure 3-31: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'renew_en_log'.

Water use component. A map of the logarithm analytical EMERGY component grid called 'wtruse_log' is shown in Figure 3-32, and a histogram of cell value distribution for this EMERGY component grid is shown in Figure 3-33. This component of the model represents the energy and EMERGY flow density of the water used by man for domestic, commercial, and agricultural irrigation purposes (element #3 in Figure 1.3).

The patterns observed in this map reflect the methods used to create the water consumption component grids. Water use was calculated based on usage associated with buildings and agricultural crops. Typical EMERGY flow density values for agricultural crop areas range from 14.5 to 15.5 log sej/ha/yr. EMERGY flow density values for urban areas range from 15.5 to 17 log sej/ha/yr with the highest values being associated with the more intensive land uses.

The cell distribution histogram illustrates an intuitive spatial pattern for this component. There are many cells in the component grid with relatively lower values (primarily associated with agricultural crops), and an increasingly smaller number of cells associated with each increasingly higher EMERGY value range. As would be expected, the highest values are associated with high-density residential, commercial, and institutional land uses.

The map of the logarithm analytical energy component grid called 'wtruse_en_log' is shown in Figure 3-34 and a histogram of cell value distribution by standard legend value range is shown in Figure 3-35. The pattern displayed in the energy map also reflects the methods used to create the energy component grid. Because all of the values in this energy component grid are less than 12 log joules/ha/yr, the standard legend does not display the actual variation that exists in the energy flow data values.

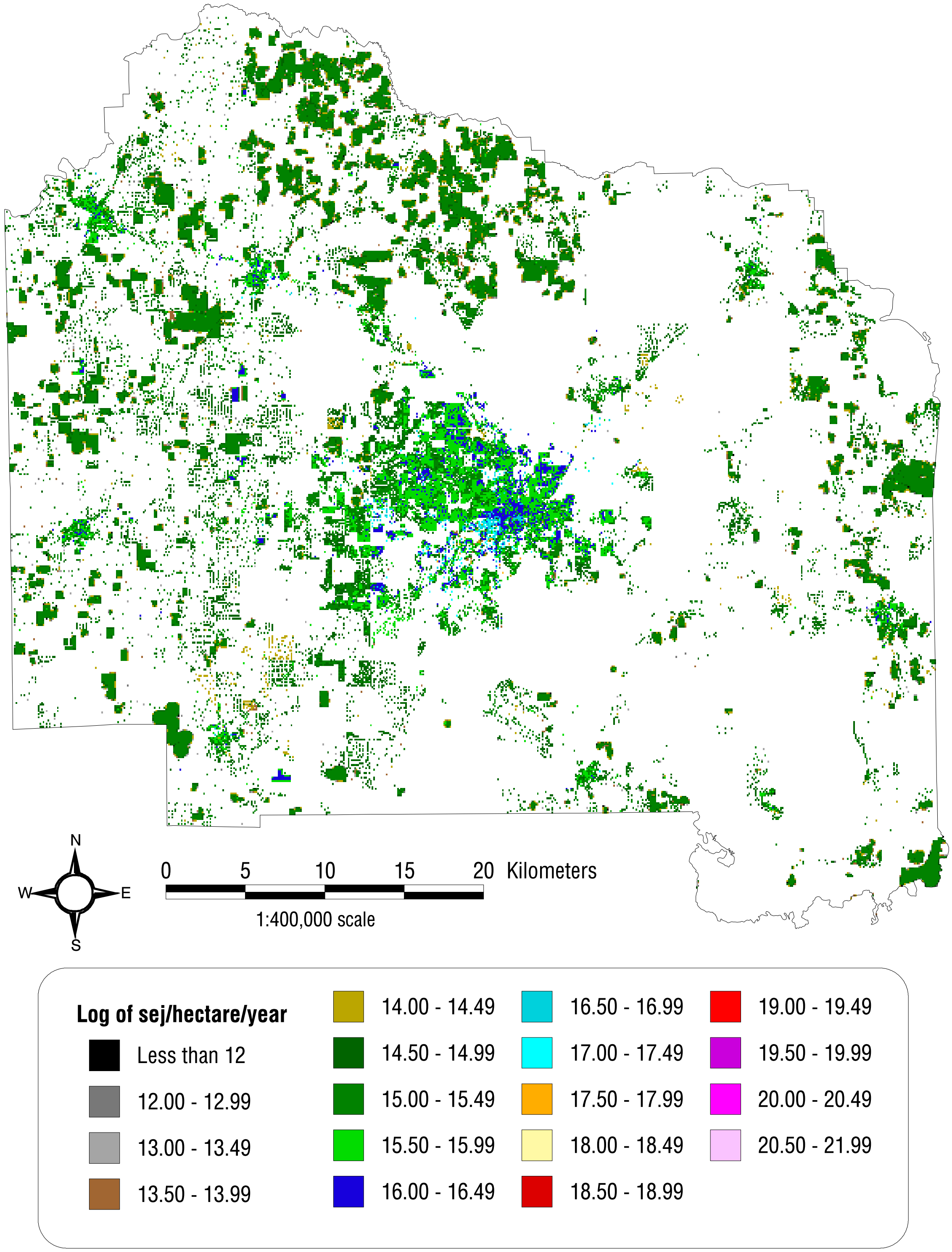


Figure 3-32: Map of the logarithm analytical EMERGY component grid called 'wtruse_log'. This grid represents the log of the annual EMPOWER density (log sej/ha/yr) of the water used by man for domestic, commercial, and agricultural irrigation purposes.

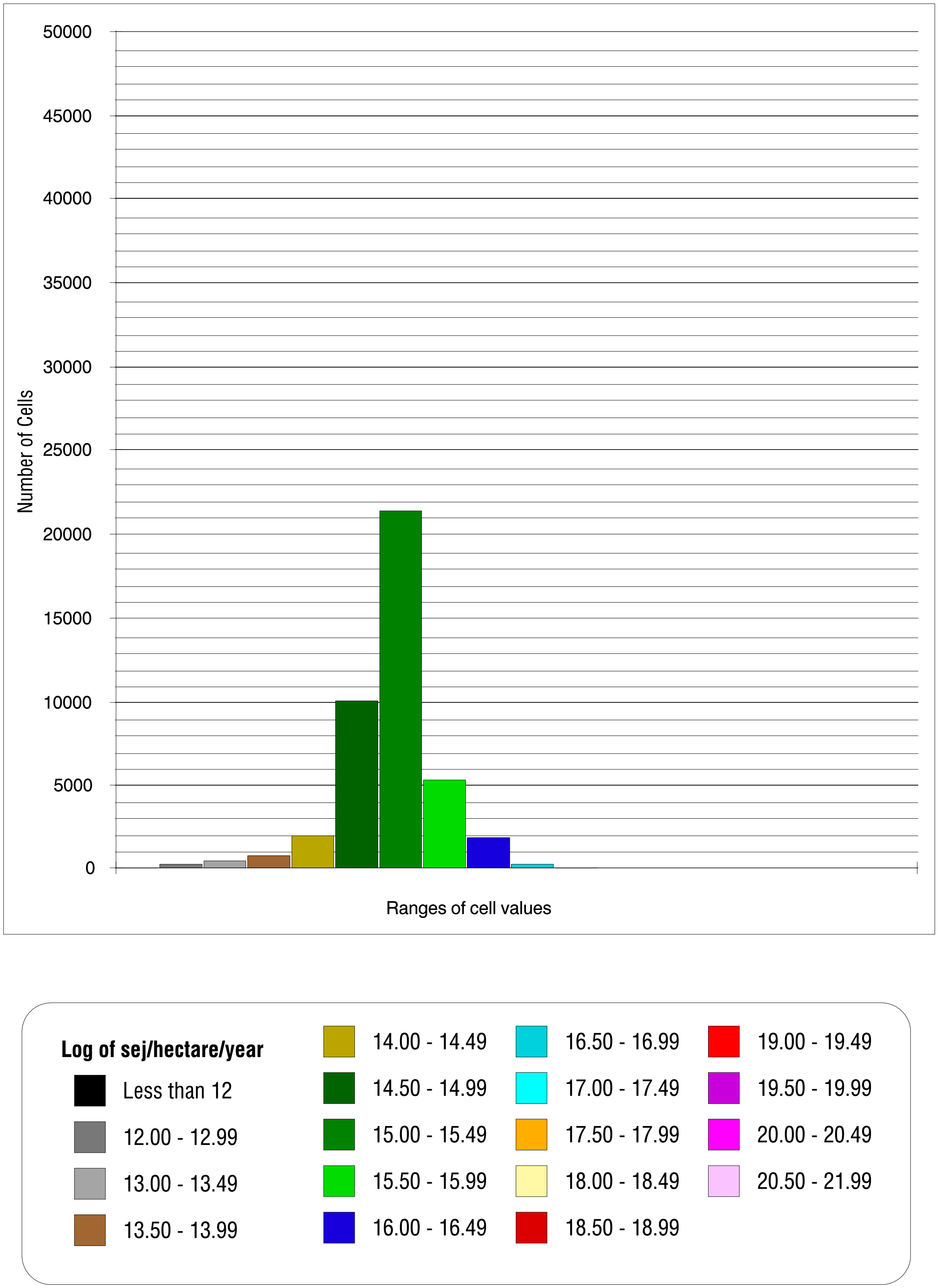


Figure 3-33: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called 'wtruse_log'.

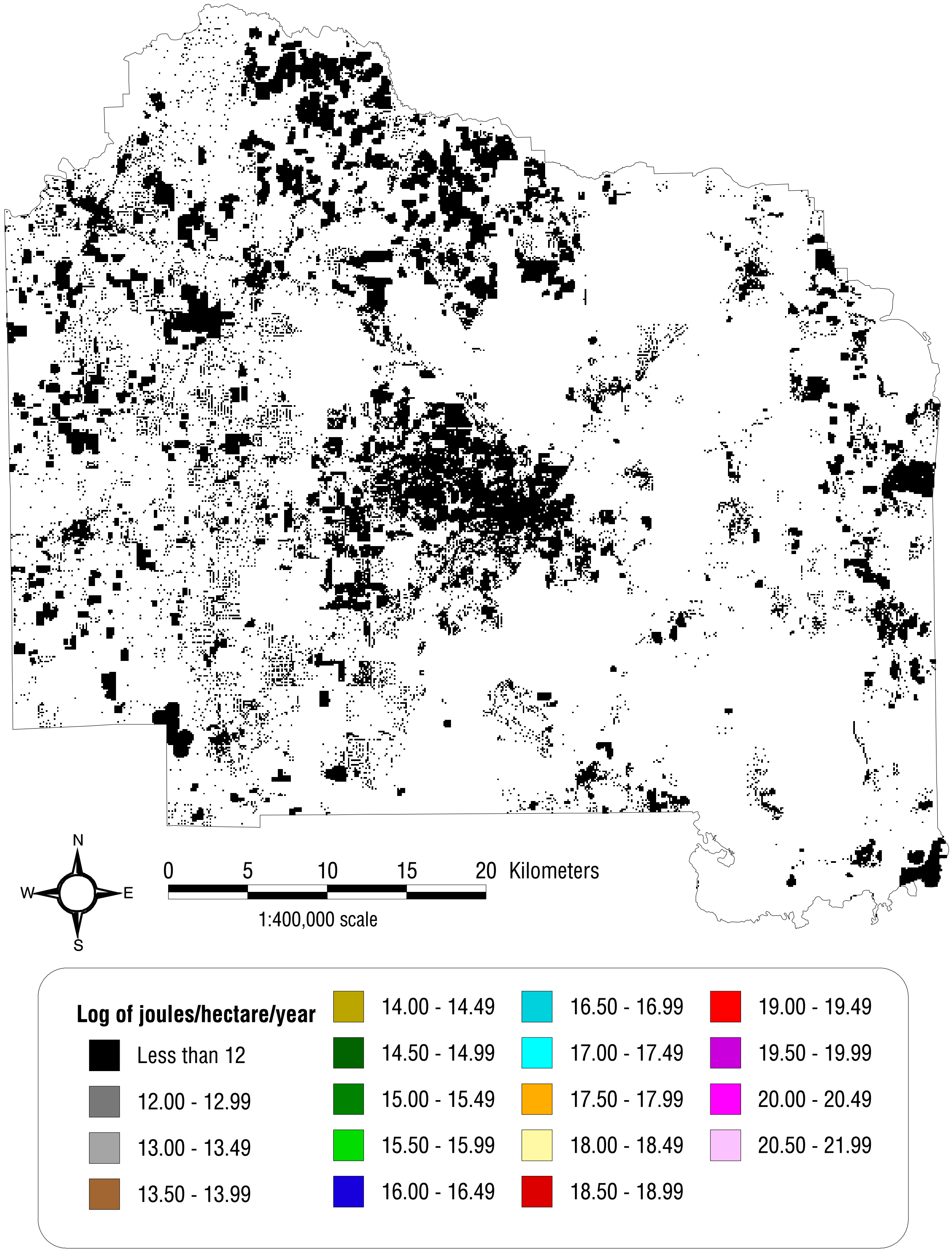


Figure 3-34: Map of the logarithm analytical energy component grid called 'wtruse_en_log'. This grid represents the log of the annual energy flow density (log j/ha/yr) of the water used by man for domestic, commercial, and agricultural irrigation purposes.

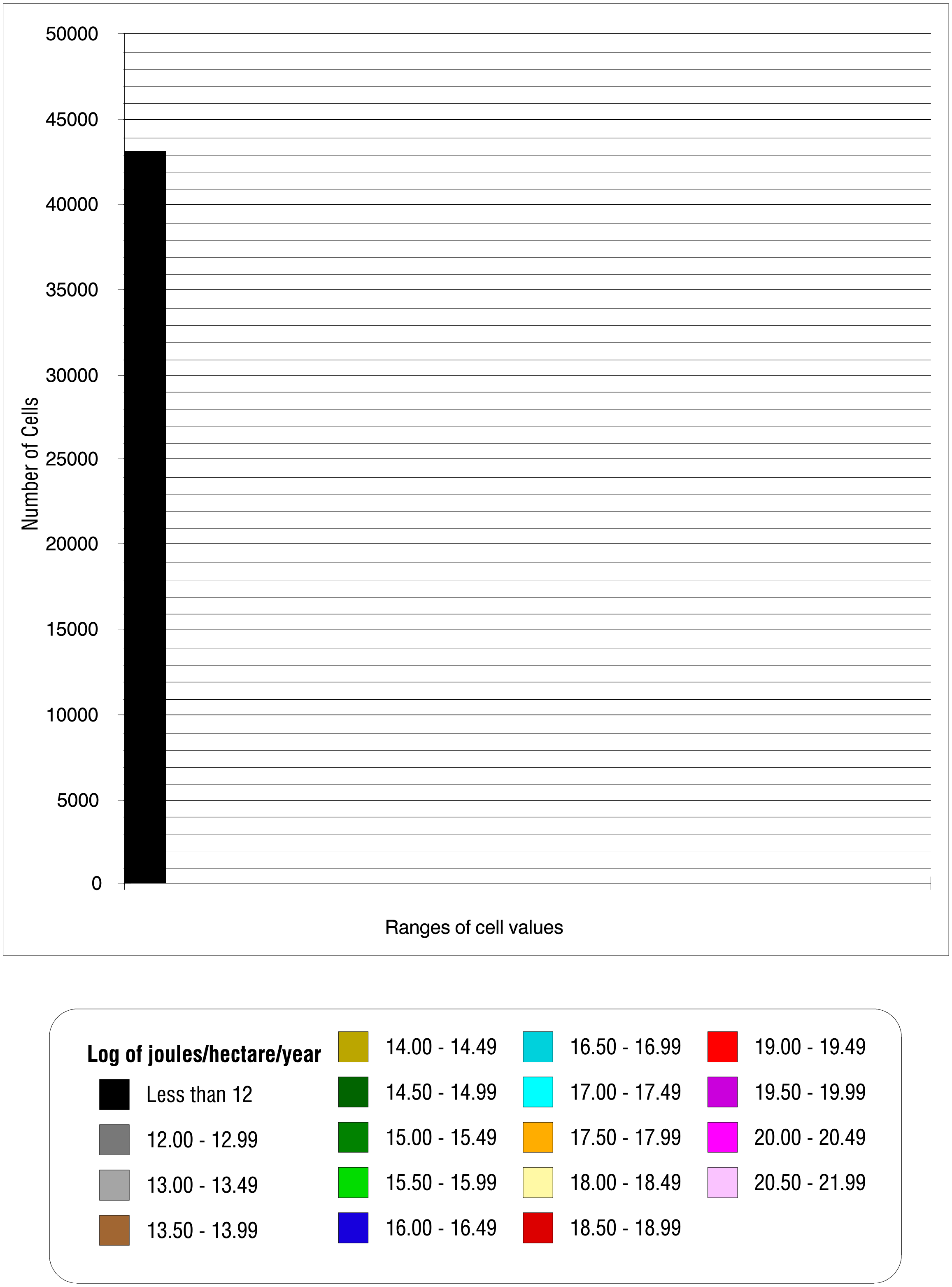


Figure 3-35: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'wtruse_en_log'.

Transportation fuel use subcomponent. A map of the logarithm analytical EMERGY subcomponent grid called ‘trn_ful_log’ is shown in Figure 3-36, and a histogram of cell value distribution for this EMERGY subcomponent grid is shown in Figure 3-37. This subcomponent of the model represents the energy and EMERGY flow density of fuel used for transportation (element # 4a in Figure 1-3).

The patterns observed in the EMERGY map of transportation fuel use reflect the pattern of transportation infrastructure in the County. The cell distribution histogram shows a wide range of values for this subcomponent grid reflecting the wide range of traffic counts for the roads. It is easy to identify both major and minor roads from the pattern shown in the EMERGY subcomponent map.

The map of the logarithm analytical energy subcomponent grid called ‘trnful_en_log’ is shown in Figure 3-38 and a histogram of cell value distribution by standard range of log values is shown in Figure 3-39. The pattern displayed in the energy map also reflects the pattern of roads, however, because most of the values in this energy subcomponent grid are less than 12 log joules/ha/yr, the standard legend does not display the actual variation that exists in the energy flow data values.

Building and Agriculture Fuel Use Subcomponent. This subcomponent of the model represents the energy and EMERGY flow density of fuels used in buildings and for agricultural production (element #4b in Figure 1-3). Commercial, institutional, agricultural, and industrial building fuel use was based on the use of electricity according to the rates listed in Table 3-6, and agricultural production fossil fuel use was based on the rates in Table 3-7. The map of the logarithm analytical EMERGY subcomponent grid called ‘bag_ful_log’ is shown in Figure 3-40, and a histogram of cell value distribution for this EMERGY subcomponent grid is shown in Figure 3-41. As would be expected, the patterns observed in the EMERGY component map show large areas of relatively low EMERGY flow density associated with agricultural production and much higher densities associated with urban land uses. The map of the logarithm analytical energy subcomponent grid, ‘bagful_en_log’, is shown in Figure 3-42 and a histogram of cell value distribution by standard range of log values is shown in Figure 3-43.

<u>Fuel use component.</u> This component of the model represents the energy and EMERGY flow density of fuels used in transportation, buildings, and for agricultural production (element #4 in Figure 1-3). Essentially, it is just the sum of the two previous subcomponent fuel use grids. The map of the logarithm analytical EMERGY component grid called ‘fuel_log’ is shown in Figure 3-44, and a histogram of cell value distribution for the EMERGY component grid is shown in Figure 3-45.

As expected, many of the same patterns can be observed in the EMERGY component map that were seen in the two subcomponent maps that were combined to make this component. However, the addition of the subcomponent grids highlights those areas where both large flows from transportation and building use intersect. The histogram displays a wide range of values from less than 12 to 18 log sej/ha/yr. But, significantly, one has to look at the map to see that there are a few important cells with values in the range of 18 to 19 log sej/ha/yr (and a high value of 19.25 log sej/ha/yr) corresponding to the Shands Medical complex. The map of the logarithm analytical energy component grid called ‘fuel_en_log’ is shown in Figure 3-46 and a histogram of cell value distribution by standard range of log values is shown in Figure 3-47.

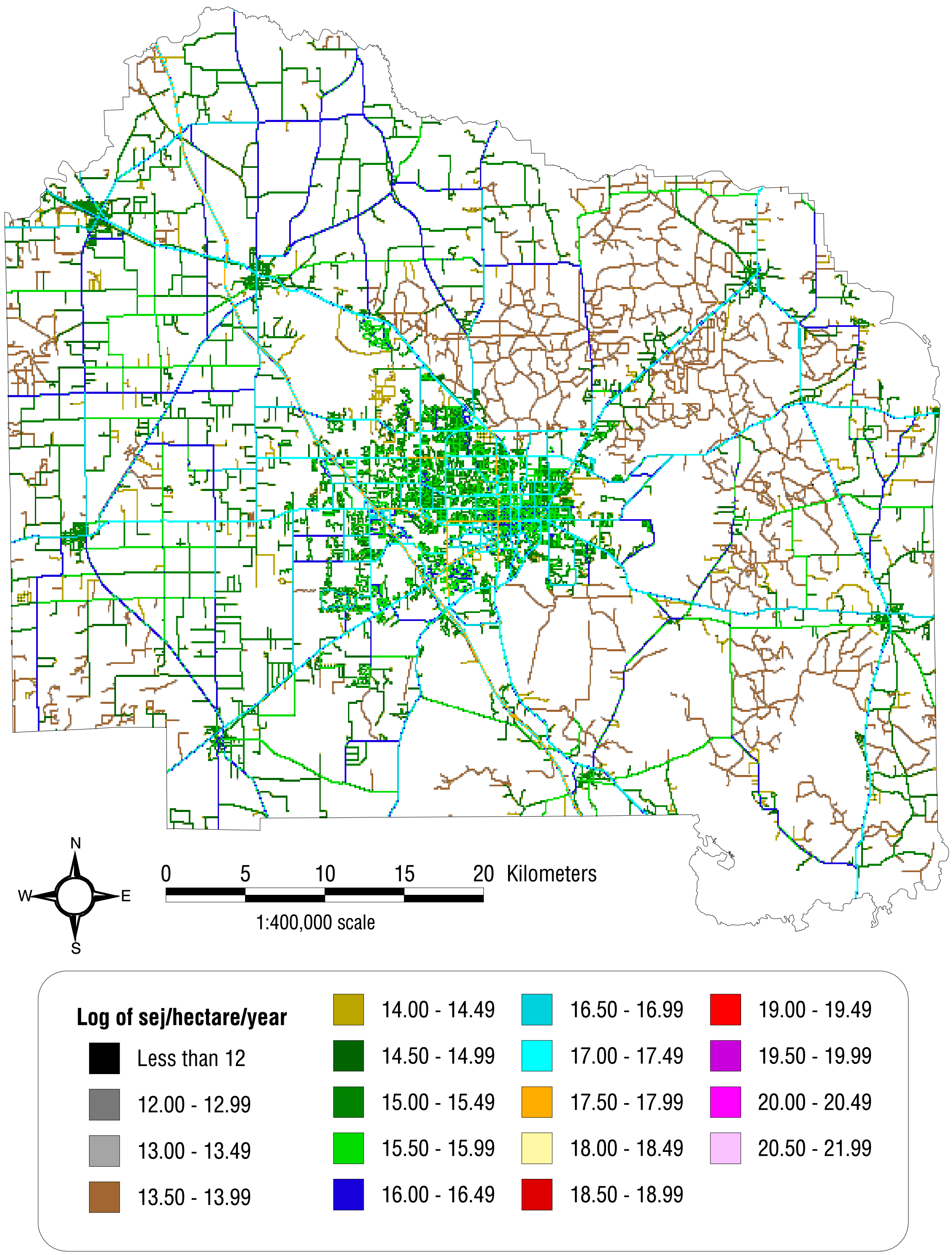


Figure 3-36: Map of the logarithm analytical EMERGY sub-component grid called 'trn_ful_log'. This grid represents the log of the annual EMPOWER density (log sej/ha/yr) of the fuels used for transportation.

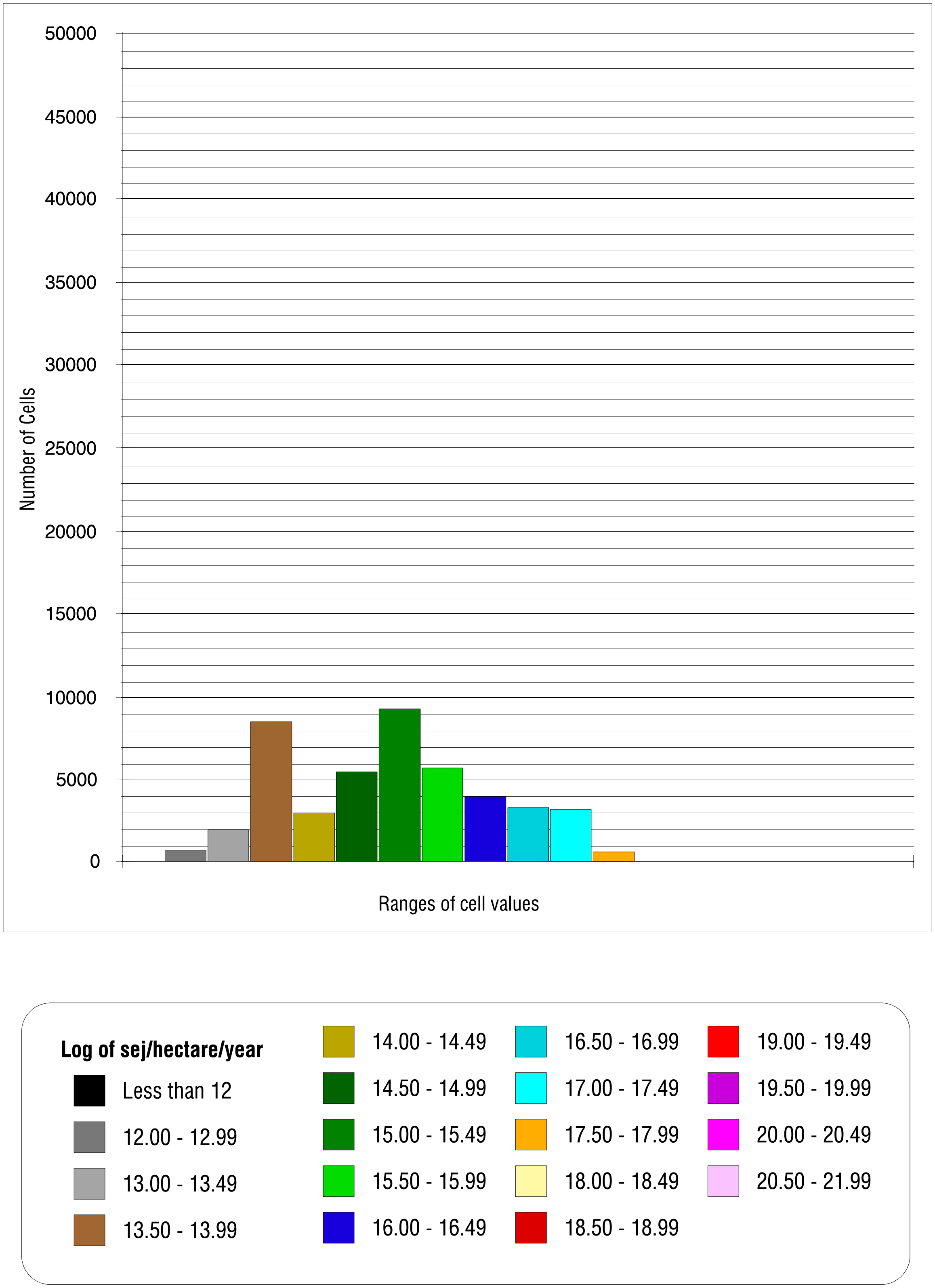


Figure 3-37: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY sub-component grid called ’trn_ful_log’.

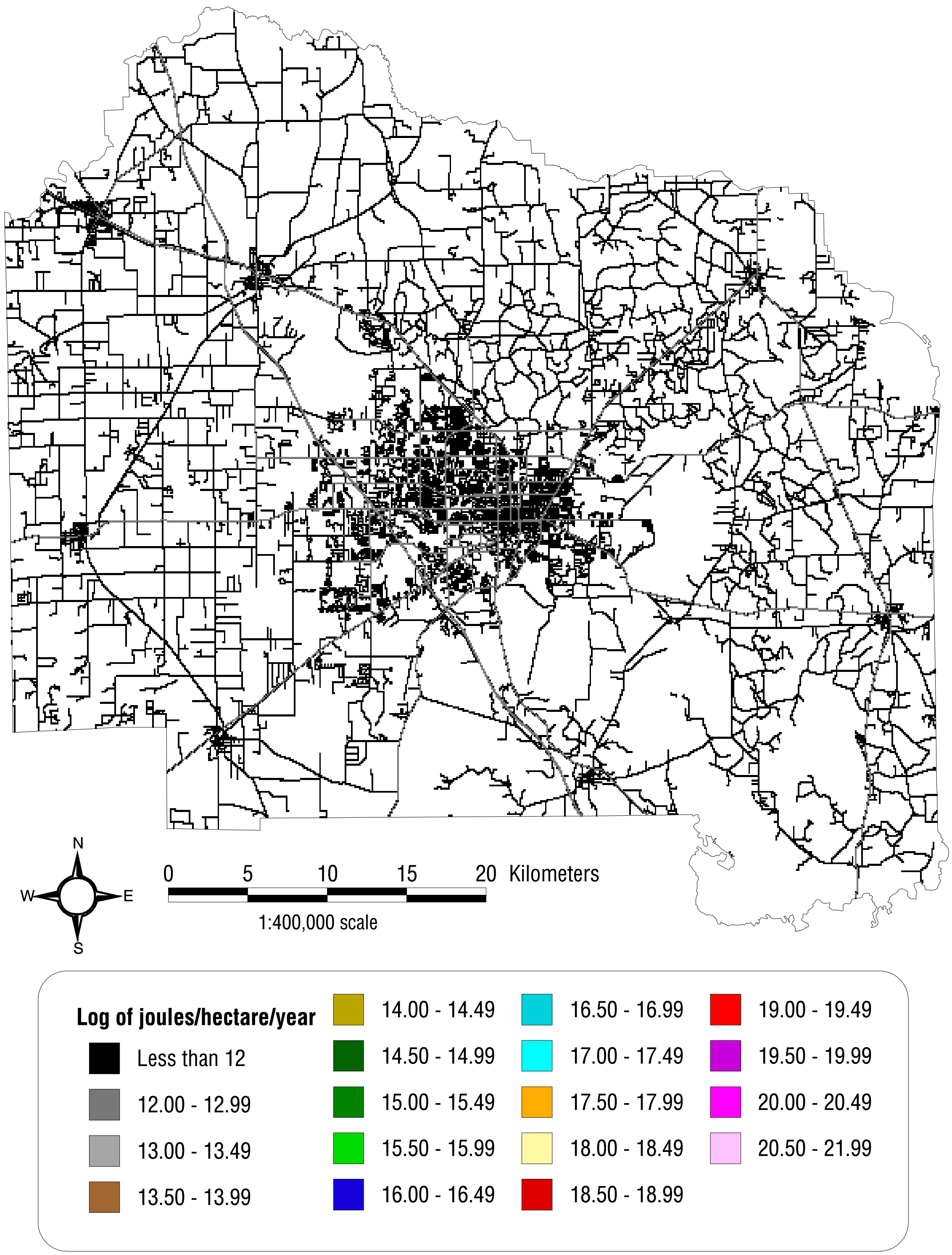


Figure 3-38: Map of the logarithm analytical energy sub-component grid called 'trn_fulen_log'. This grid represents the log of the annual energy flow density (log j/ha/yr) of the fuels used for transportation.

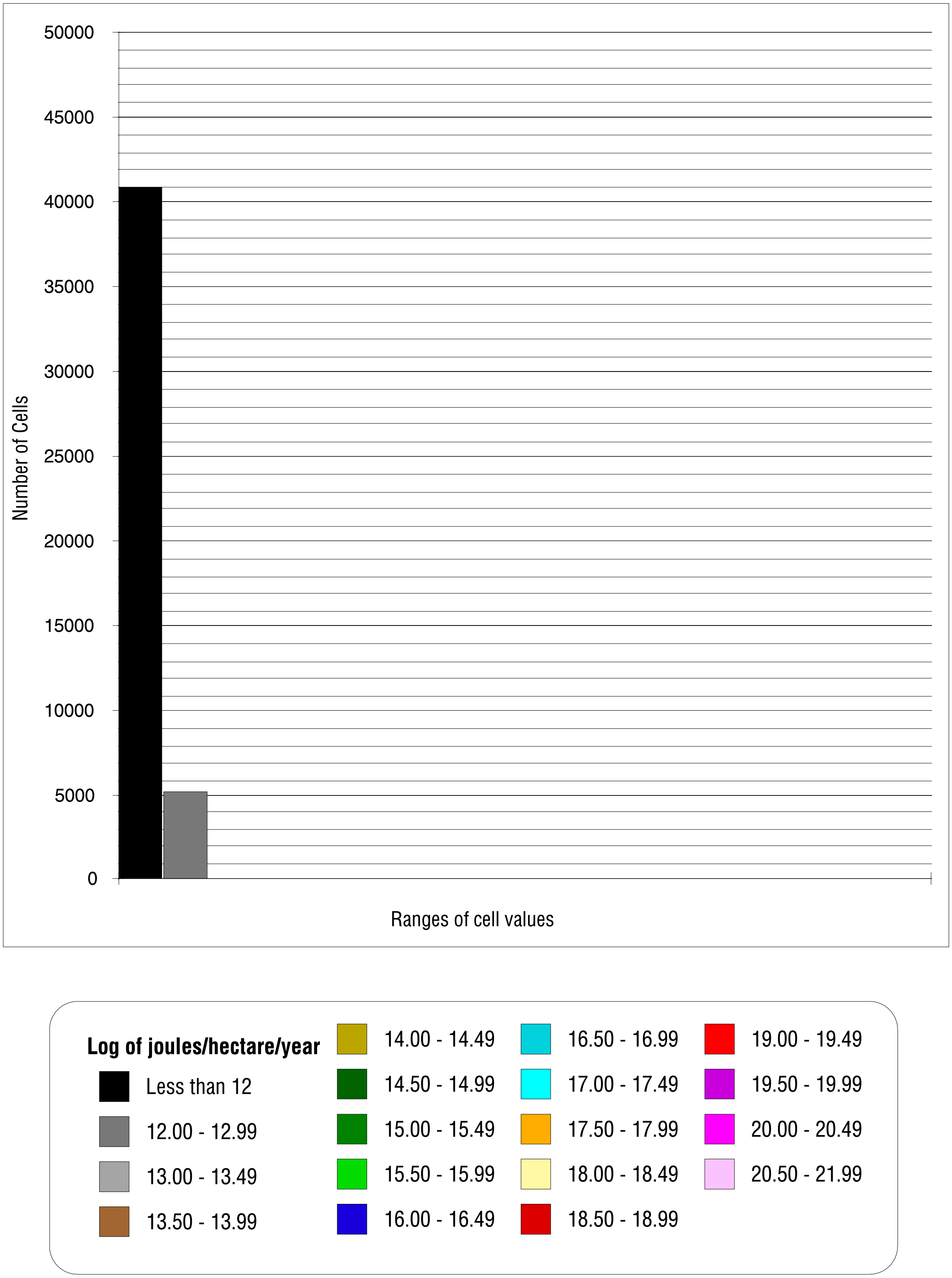


Figure 3-39: Histogram of the distribution of grid cell values found in the logarithm analytical energy sub-component grid called 'trn_fulen_log'.

Table 3-6: Estimated annual rates of electricity consumption assigned to commercial, institutional, agricultural, and industrial building features in the 'em_combldgcov' analytical coverage with summaries of the number of instances, total square footage, and total Kwh/year used for each Department of Revenue (DOR) code.

DOR Code [1]	Description	No. of Instances [2]	Total Square Footage[2]	KwH/ sq.ft./ year used [3]	Total Kwh per year [2]
1000	Vacant Commercial	4	14108	21	296268
1100	Stores, One Story	529	3480536	21	73091256
1200	Mixed Use - Store and Office	100	495076	21	10396596
1300	Department Stores	3	295530	21	6206130
1400	Supermarkets	17	298165	50.7	15116965.5
1500	Regional Shopping Centers	10	1371463	21	28800723
1600	Community Shopping Centers	136	3591552	21	75422592
1700	Office and Non-Professional Services, One Story	512	2505447	34	85185198
1800	Office and Non-Professional Services, Multi-Story	51	719524	34	24463816
1900	Professional Services	212	1691523	34	57511782
2000	Airports, bus terminals	2	79650	28.8	2293920
2100	Restaurants, Cafeterias	92	471342	62.1	29270338.2
2200	Drive-In Restaurants	79	229516	62.1	14252943.6
2300	Financial Institutions	50	451266	34	15343044
2400	Insurance Company Offices	11	462002	34	15708068
2500	Repair Service Shops, Laundries, mobile home sales	93	386852	21	8123892
2600	Repair Service Shops, Laundries, mobile home sales	65	244012	21	5124252
2700	Repair Service Shops, Laundries, mobile home sales	143	1148567	21	24119907
2800	Parking Lots and Mobile Home Parks	135	357905	9	3221145
2900	Wholesale Outlets	54	584396	21	12272316
3000	Florists, Greenhouses	12	59008	21	1239168
3200	Theatres	2	46146	21	969066
3300	Nightclubs, bars	45	270591	21	5682411
3400	Bowling Alleys, etc.	4	136860	21	2874060
3500	Tourist Attractions, Fairgrounds	3	16285	21	341985
3600	Camps	8	136084	9	1224756
3700	Race Tracks	1	27081	21	568701
3800	Golf Courses	7	117081	21	2458701
3900	Hotels, Motels	52	2120923	41.6	88230396.8
4000	Vacant Industrial	1	236	9	2124
4100	Light Manufacturing	115	2340608	87.1	203866956.8
4200	Heavy Industrial and Manufacturing	6	491714	94.3	46368630.2
4300	Lumber Yards and Sawmills	8	62219	94.3	5867251.7
4400	Packing Plants, Fruit and Vegetable	1	160	87.1	13936
4500	Canneries and Distilleries	2	41216	87.1	3589913.6
4569	Canneries and Distilleries	1	1728	87.1	150508.8
4600	Food Processing	2	43705	87.1	3806705.5
4700	Mineral Processing, Cement and Gravel Plants	5	44532	87.1	3878737.2
4800	Warehousing and Distribution Terminals	328	3200857	10.3	32968827.1
4900	Open Storage, Junk Yards, Fuel Storage	17	75865	9	682785
5100	Cropland, soil capability class I	151	306770	9	2760930
5200	Cropland, soil capability class II	482	937196	9	8434764
5300	Cropland, soil capability class III	15	20128	9	181152

Table 3-6 -- continued.

DOR Code [1]	Description	No. of Instances [2]	Total Square Footage[2]	KwH/ sq.ft./ year used [3]	Total Kwh per year [2]
5400	Timberland - site index 90 and above	126	250745	9	2256705
5500	Timberland - site index 80 to 89	309	571482	9	5143338
5600	Timberland - site index 70 to 79	94	150889	9	1358001
5700	Timberland - site index 60 to 69	1	60	9	540
5900	Timberland - site index not classified	84	190208	9	1711872
6000	Grazing Land, soil capability Class I	228	734421	9	6609789
6100	Grazing Land, soil capability Class II	583	1443921	9	12995289
6200	Grazing Land, soil capability Class III	99	217326	9	1955934
6300	Grazing Land, soil capability Class IV	19	56947	9	512523
6400	Grazing Land, soil capability Class V	7	13441	9	120969
6500	Grazing Land, soil capability Class VI	118	209464	9	1885176
6600	Orchard Groves	138	338200	9	3043800
6700	Poultry, bees, etc.	4	29142	9	262278
6800	Dairies, Feed Lots	142	402494	9	3622446
6900	Ornamentals, Misc. Agriculture	84	162133	9	1459197
7100	Churches	386	1916038	9	17244342
7300	Privately owned Hospitals	4	486441	66.5	32348326.5
7600	Mortuaries, cemetaries	15	64410	21	1352610
7635	Crematorium	1	1713	21	35973
7900	Cultural Organizations, facilities	3	15368	21	322728
8200	Parks and Recreational Areas	17	50133	9	451197
8300	Public County Schools	42	921707	17.5	16129872.5
8400	Colleges	876	13329334	17.5	233263347.2
8500	Hospitals	6	185401	66.5	12329166.5
8600	County (other than recreation, college, hospital)	28	745187	28.8	21461385.6
8700	State (other than recreation, college, hospital)	34	402381	28.8	11588572.8
8800	Federal (other than military, recreation, hospital)	11	769961	28.8	22174876.8
8900	Municipal (other than recreation, college, hospital)	129	608800	28.8	17533440
9100	Utilities	37	766812	28.8	22084185.6
9200	Mining	1	392	9	3528
9400	Right of Way	4	2478	9	22302
9600	Waste Disposal	1	736	28.8	21196.8
9700	Outdoor Recreation	16	17954	9	161586
9900	Acreage not zoned agricultural	1	2700	9	24300

Notes

1) Each building feature has a DOR code assigned by the Alachua County Property Appraiser's office based on a coding scheme dictated by the Florida Department of Revenue (FDOR, 1990).

2) Total number of building features and square footage summarized from the 'em_combldgcov' analytical coverage database.

3) Estimates are based on data from Energy Information Administration (EIA, 1991, EIA, 1992, EIA, 1994).

Table 3-7: Estimated annual usage rates for the energy and EMERGY in the fuels used by various types of agricultural production and for maintenance of residential landscapes.

Type of Agricultural production	**energy use rate, j/m2/year**	**EMERGY use rate, sej/m2/year**
Residential lawn and garden	2.21 E6	1.46 E11
Pasture	2,511	2.94 E8
Rangeland	250	2.94 E7
Rowcrops	4.2 E5	2.77 E10
Pine plantations	0	0
Forest regeneration	0	0

Note: These rates are based on calculations documented in the notes section of Table 3-4 and other data (Fluck, 1992, and 1992b).

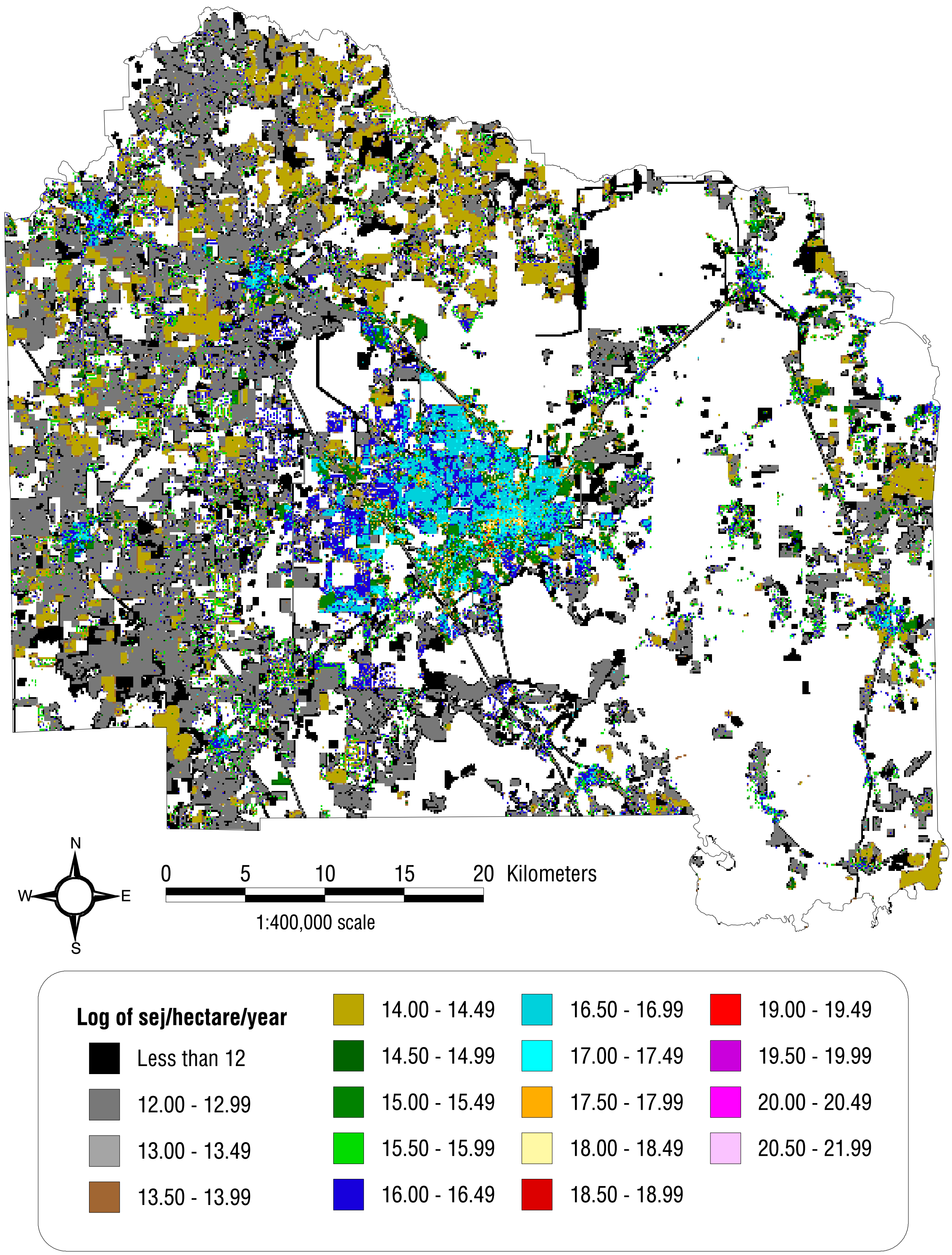


Figure 3-40: Map of the logarithm analytical EMERGY sub-component grid called 'bag_ful_log'. This grid represents the log of the annual EMPOWER density (log sej/ha/yr) of the fuels used in all buildings and for agricultural production.

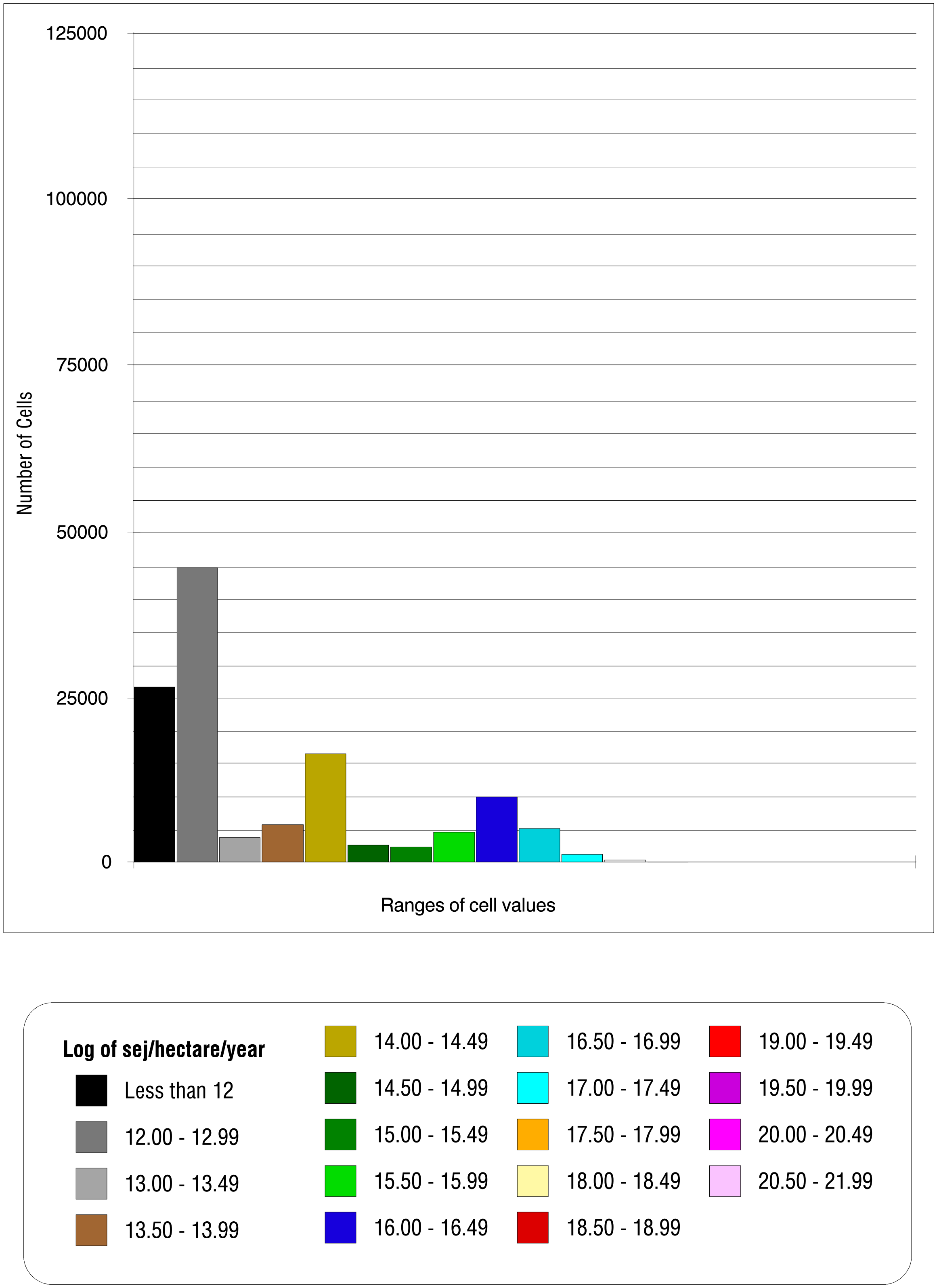


Figure 3-41: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY sub-component grid called 'bag_ful_log'.

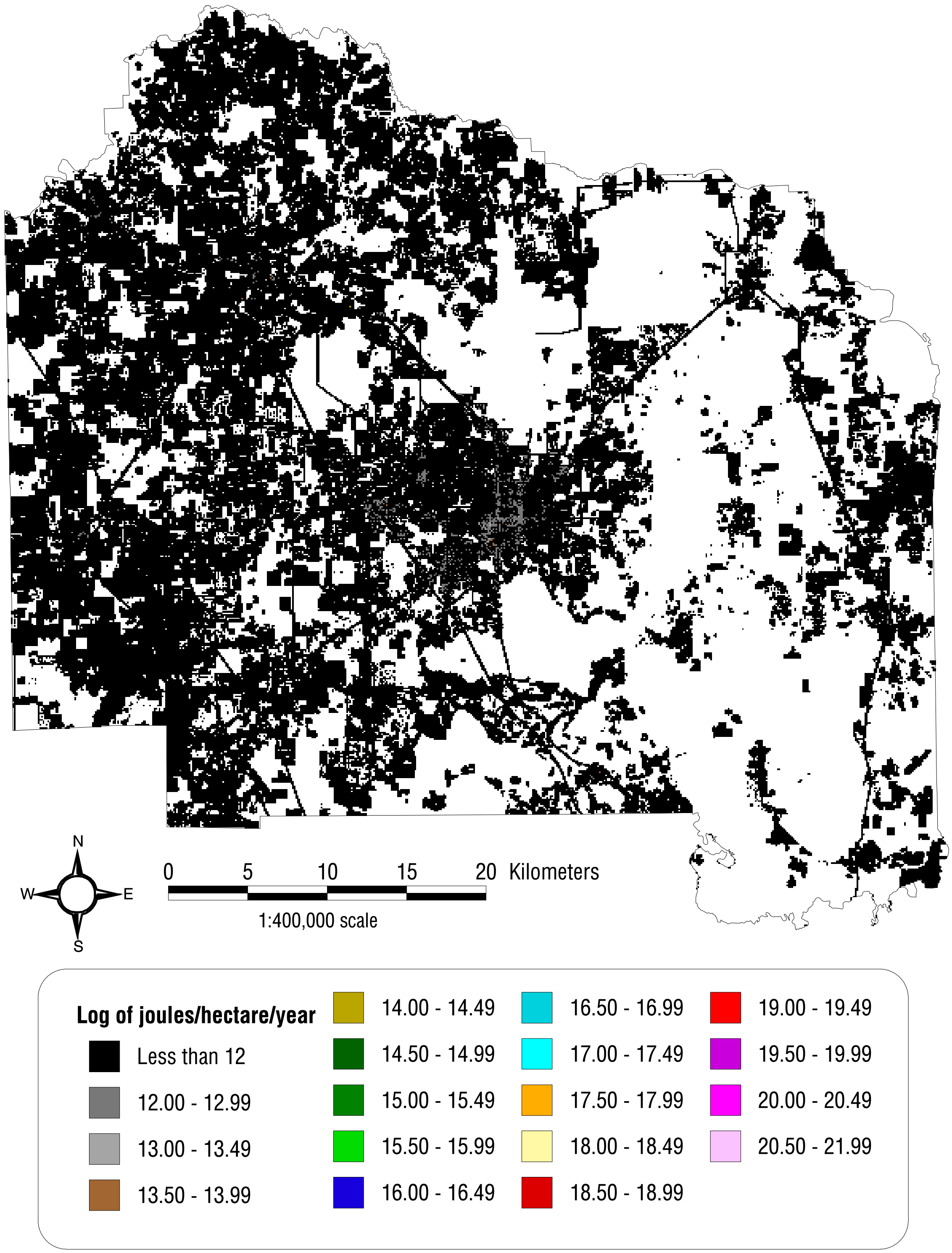
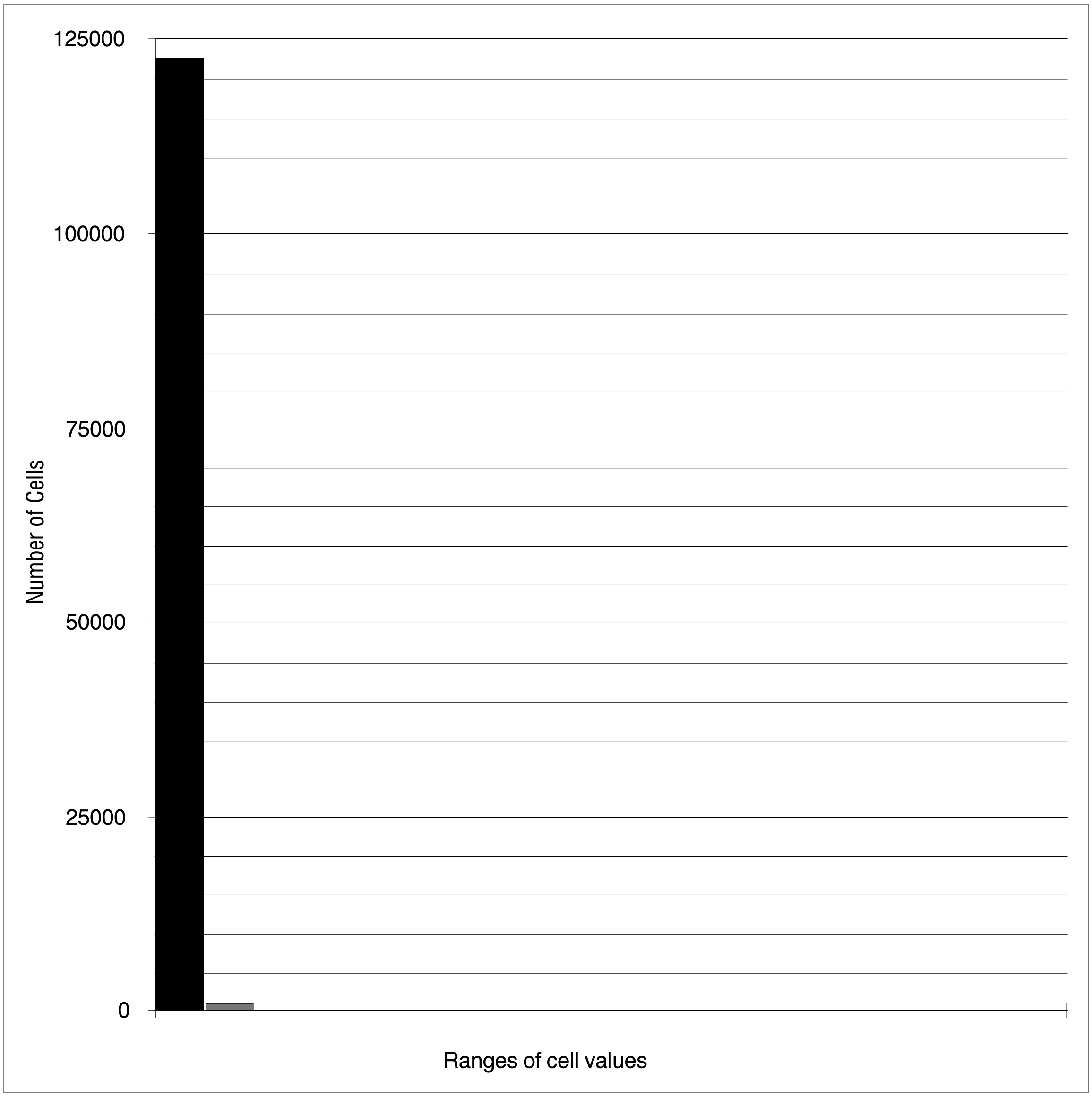


Figure 3-42: Map of the logarithm analytical energy sub-component grid called 'bag_fulen_log'. This grid represents the log of the annual energy flow density (log j/ha/yr) of the fuels used in all buildings and for agricultural production.



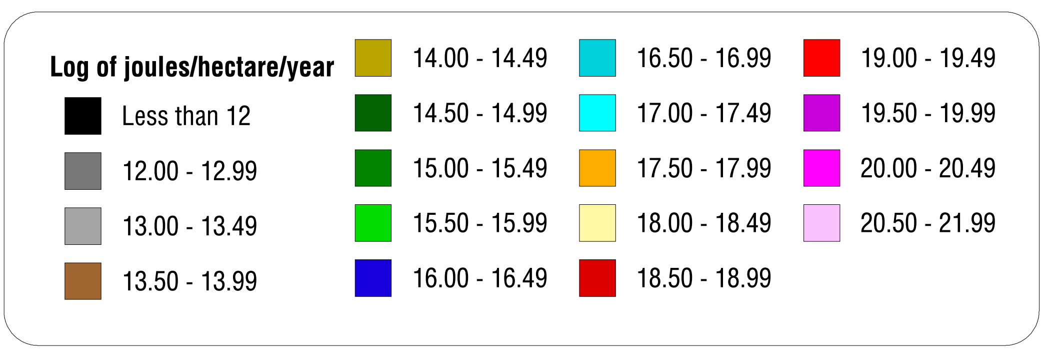


Figure 3-43: Histogram of the distribution of grid cell values found in the logarithm analytical energy sub-component grid called 'bag_fulen_log'.

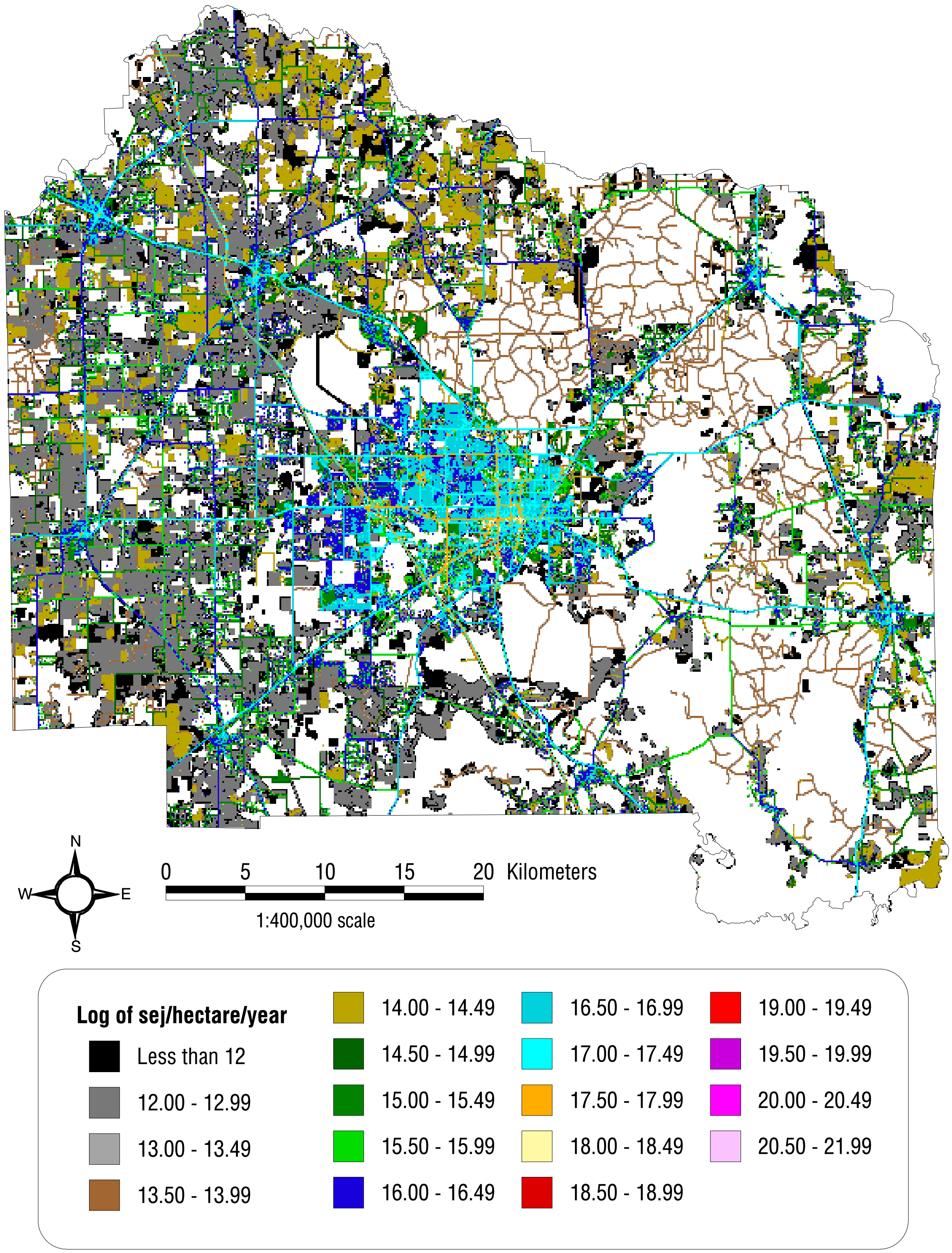


Figure 3-44: Map of the logarithm analytical EMERGY component grid called 'fuel_log'. This grid represents the log of the annual EMPOWER density (log sej/ha/yr) of all fuels used in all buildings and for transportation and agricultural production.

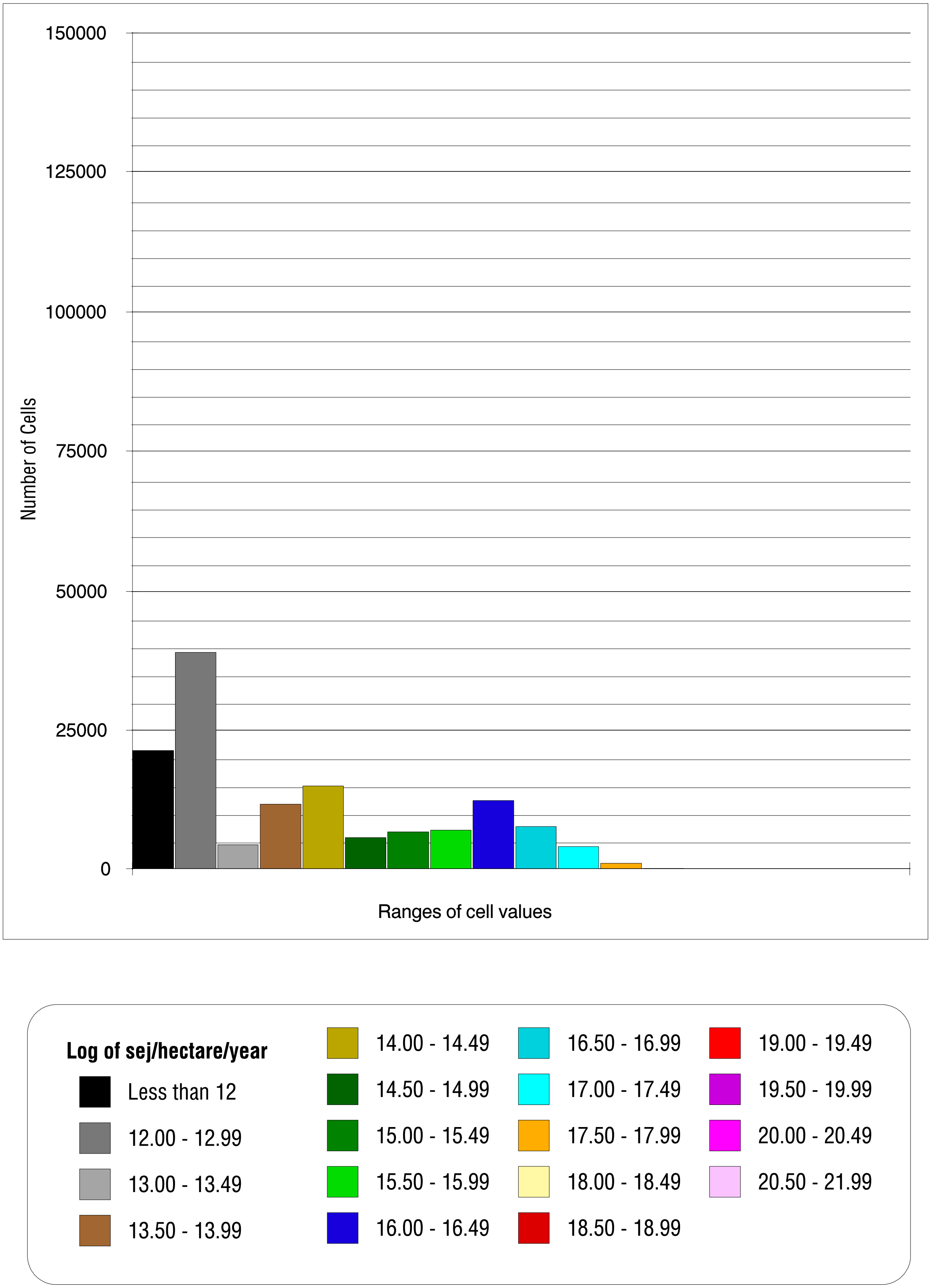


Figure 3-45: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called ’fuel_log’.

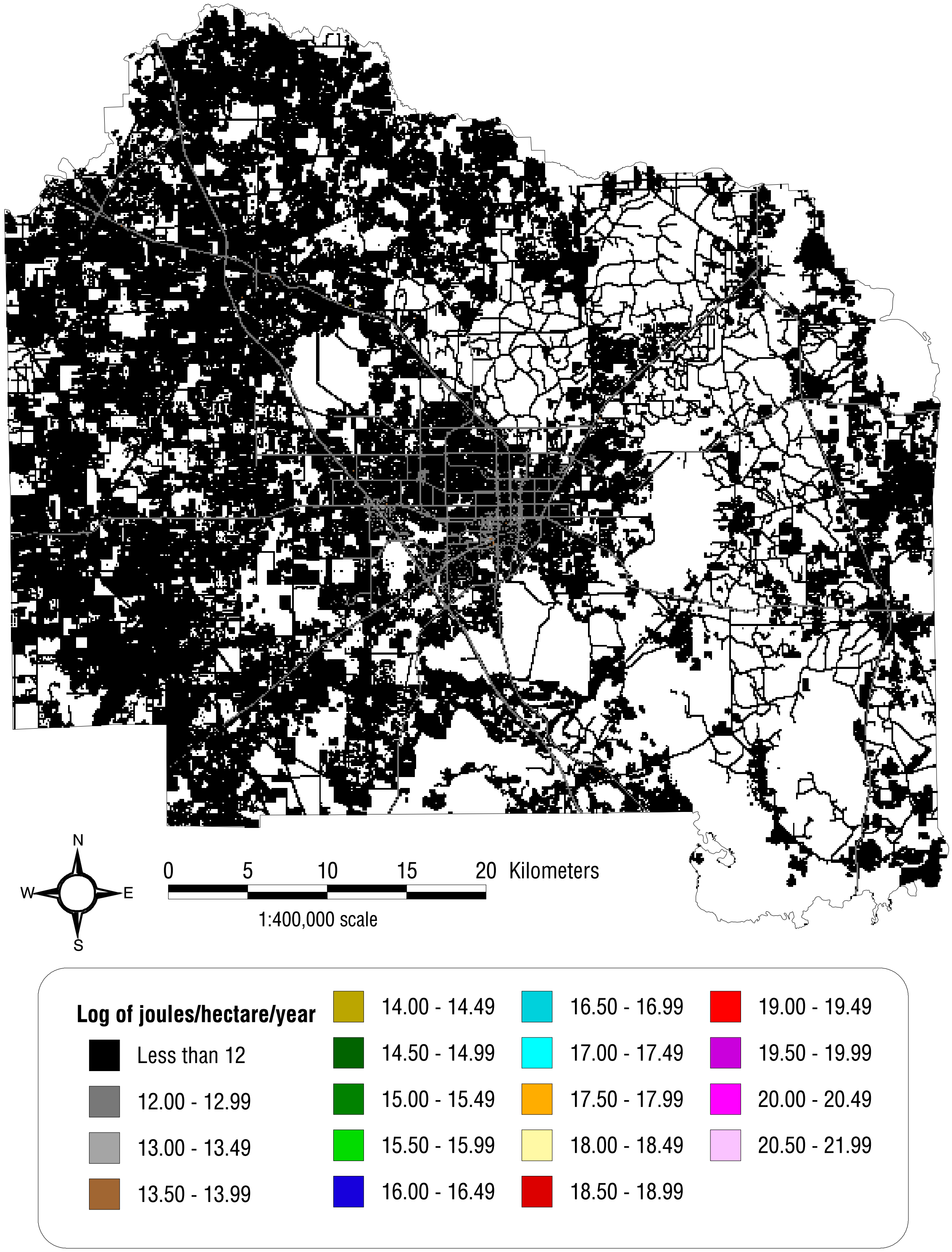
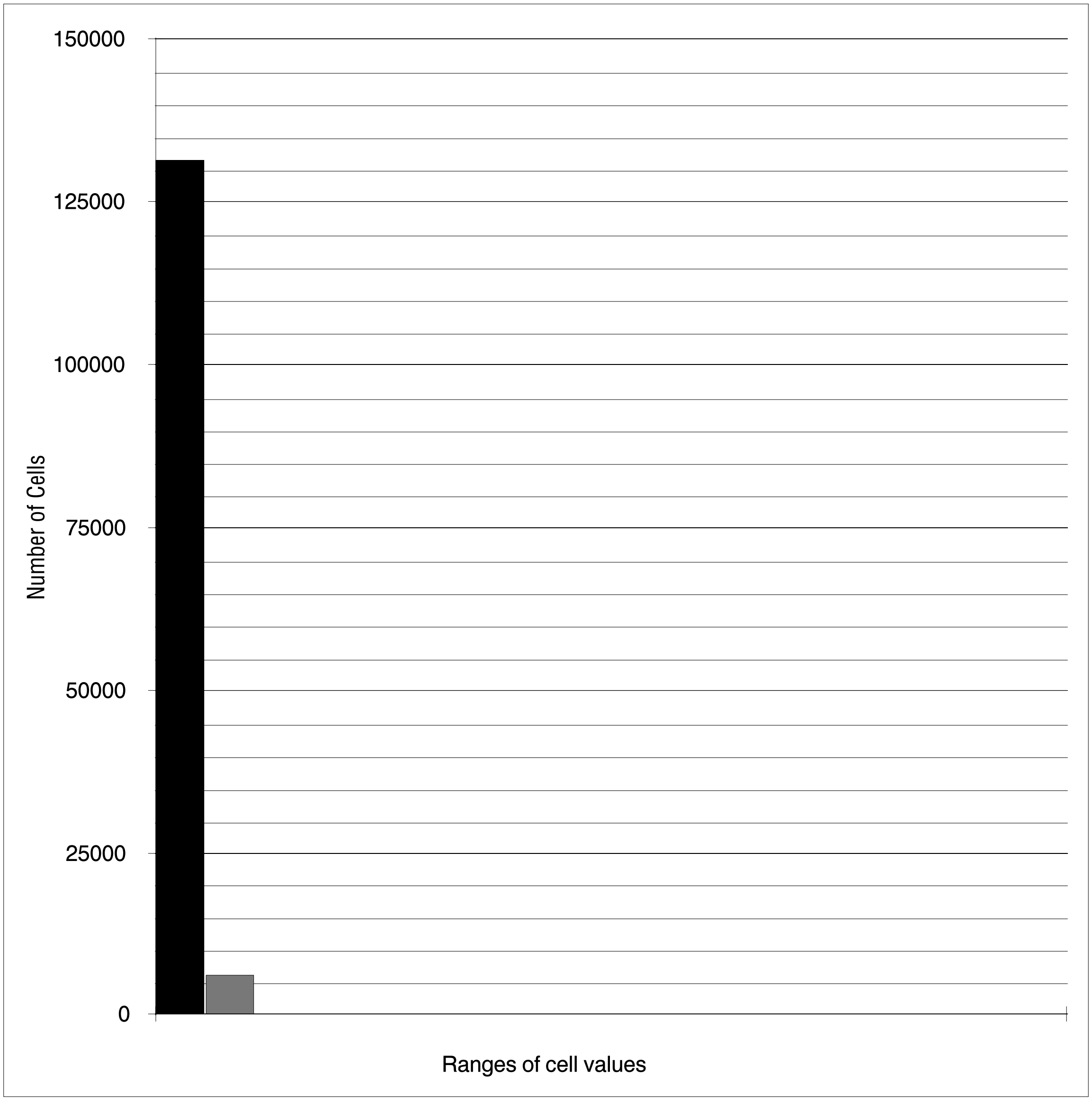


Figure 3-46: Map of the logarithm analytical energy component grid called 'fuel_en_log'. This grid represents the log of the annual energy flow density (log j/ha/yr) of all fuels used in all buildings and for transportation and agricultural production.



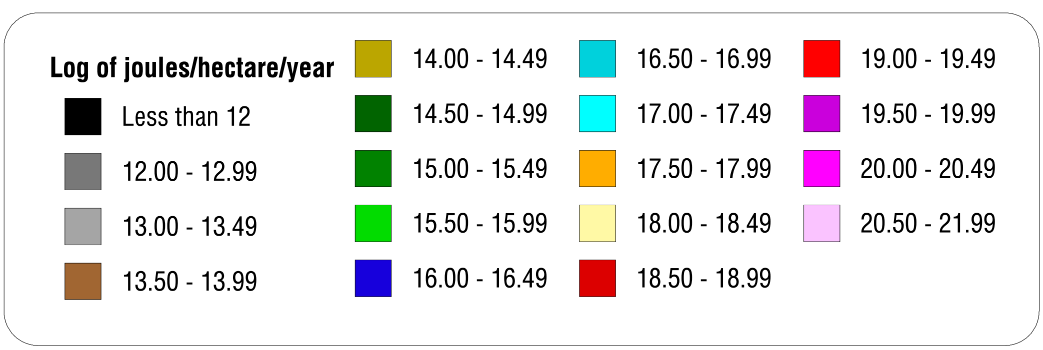


Figure 3-47: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'fuel_en_log'.

Goods consumption component. This component of the model represents the energy and EMERGY flow density of the consumable and durable goods consumption in all types of buildings and agricultural production (element #5 in Figure 1-3). Residential goods consumption was estimated based on average annual expenditures for goods by income range (U.S. Department of Labor, 1995) and the results are listed in Table 3-8. These estimates of annual expenditures represent the sum of national average estimated expenditures ($) for the following general categories: food at home, household supplies, apparel, amortized vehicle, entertainment, equipment, appliances and furnishings purchases, personal care supplies, and miscellaneous supplies.

Goods consumption for commercial and institutional buildings was estimated based on percentages of annual gross sales or expenditures and estimated dollar/square foot rates for general categories of businesses and institutions listed in Table 3-9. Based on these estimated annual rates of goods consumption by category, rate values were assigned to each commercial, institutional, and industrial building feature in the 'em_combldgcov' analytical coverage according to the Department of Revenue (DOR) code of the feature. Table 3-10 lists the rates calculated for each DOR code and summaries of the number of instances, total square footage, and total consumption for each DOR code. Table 3-11 lists the estimated annual rates for the energy and EMERGY in the goods consumed by various types of agricultural production and for the maintenance of residential landscapes.

A map of the logarithm analytical EMERGY component grid called 'goods_log' is shown in Figure 3-48, and a histogram of cell value distribution for this EMERGY component grid is shown in Figure 3-49.

The patterns observed in this map reflect the methods used to create the goods consumption component grids (in other words, flow values are associated with buildings and agricultural areas). EMERGY flow density values for rural and agricultural crop areas were found to have a wide range of values--from 12 to 16 log sej/ha/yr. However, the values of the majority of the cells in agricultural areas are in the range of 14.5 to 15 log sej/ha/yr). Some of this wide variation can be explained by the fact that in some cases only a small portion of a polygon in the 'em_landcov' analytical coverage ends up falling within a one-hectare cell.

EMERGY flow density values for urban residential areas range from 16.5 to 17.5 log sej/ha/yr. The highest values in the County are associated with institutional and commercial land uses and range from 17.5 to 19.5 log sej/ha/yr (with the very highest values being associated with the Shands Medical Center complex).

The cell distribution histogram for this EMERGY component grid displays two increasingly familiar patterns. First, a relatively large percentage of the cells in the component grid have relatively lower flow density values (primarily those associated with rural areas and agricultural crops). And second, there is an increasingly smaller number of cells associated with each increasingly higher EMERGY flow density value range.

The map of the logarithm analytical energy component grid called 'goods_en_log' is shown in Figure 3-50 and a histogram of cell value distribution is shown in Figure 3-51. As with some of the previous energy component maps, all of the values in this energy component grid are less than 12 log joules/ha/yr, hence the standard legend does not display the actual variation that exists in the energy flow data values.

Table 3-8: Estimated average annual expenditures for goods by income range used to assign goods consumption estimates to each residential building according to the estimated building income. These estimates were compiled from various data from the U.S. Department of Labor (1995). These total estimates for annual expenditures represent the sum of national average estimated expenditures ($) for the following general categories: food at home, household supplies, apparel, amortized vehicle, entertainment, equipment, appliances and furnishings purchases, personal care supplies, and miscellaneous supplies.

Building Income Range, $	**Estimated annual expenditure for goods, $**
less than 5000	5,277 [1]
5000 – 9999	6,271
10000 – 14999	7,582
15000 – 19999	9,092
20000 – 29999	10,242
30000 – 39999	13,159
40000 – 49999	15,302
50000 – 69999	18,069
70000 and up	25,469

Notes

1) This figure is greater than income due to goods consumed that were contributed from government assistance programs, etc..

Table 3-9: Estimated percentages of annual gross sales or expenditures and estimated rates (dollars/sq.ft.) of annual goods consumption ($) for general categories of businesses and institutions (based on data from USDOC, 1996a, 1996b, 1996c).

General category of business	**Estimated percentage of annual gross sales or expenditures**	**Estimated dollars of goods consumed annually per square foot of building**
Professional Services	10	5
Miscellaneous and General Classification	15	10
Consumer Services	30	15
Retail Stores and Shopping Centers	10	20
Schools, Colleges, and Government	10	25
Manufacturing	25	30
Wholesale Distributors	10	50
Grocery Stores	5	60
Restaurants	35	70
Hospitals	15	110

Table 3-10: Estimated annual rates of goods consumption (based on percentage of the gross sales or expenditures for all buildings in the class) assigned to commercial, institutional, and industrial building features in the 'em_combldgcov' analytical coverage (with summaries of the number of instances, total square footage, and total consumption for each Department of Revenue (DOR) code).

DOR Code [1]	Description	No. of Instances [2]	Total Square Footage [2]	% of annual gross sales/ expenditures [3]	goods consumed, $ /sq. foot/yr [3]	Total Annual Goods Consumed,$ [3]
1000	Vacant Commercial	4	14108	10	20	282160
1100	Stores, One Story	529	3480536	10	20	69610720
1200	Mixed Use - Store and Office	100	495076	10	20	9901520
1300	Department Stores	3	295530	10	20	5910600
1400	Supermarkets	17	298165	5	60	17889900
1500	Regional Shopping Centers	10	1371463	10	20	27429260
1600	Community Shopping Centers	136	3591552	10	20	71831040
1700	Office and Non-Professional Services, One Story	512	2505447	10	5	12527235
1800	Office and Non-Professional Services, Multi-Story	51	719524	10	5	3597620
1900	Professional Services	212	1691523	10	5	8457615
2000	Airports, bus terminals	2	79650	15	10	796500
2100	Restaurants, Cafeterias	92	471342	35	70	32993940
2200	Drive-In Restaurants	79	229516	35	70	16066120
2300	Financial Institutions	50	451266	10	5	2256330
2400	Insurance Company Offices	11	462002	10	5	2310010
2500	Repair Service Shops, Laundries, mobile home sales	93	386852	30	15	5802780
2600	Repair Service Shops, Laundries, mobile home sales	65	244012	30	15	3660180
2700	Repair Service Shops, Laundries, mobile home sales	143	1148567	30	15	17228505
2800	Parking Lots and Mobile Home Parks	135	357905	15	10	3579050
2900	Wholesale Outlets	54	584396	10	50	29219800
3000	Florists, Greenhouses	12	59008	15	10	590080
3200	Theatres	2	46146	15	10	461460
3300	Nightclubs, bars	45	270591	35	70	18941370
3400	Bowling Alleys, etc.	4	136860	15	10	1368600
3500	Tourist Attractions, Fairgrounds	3	16285	15	10	162850
3600	Camps	8	136084	15	10	1360840
3700	Race Tracks	1	27081	15	10	270810
3800	Golf Courses	7	117081	35	25	2927025
3900	Hotels, Motels	52	2120923	15	10	21209230
4000	Vacant Industrial	1	236	25	30	7080
4100	Light Manufacturing	115	2340608	25	30	70218240
4200	Heavy Industrial and Manufacturing	6	491714	25	30	14751420
4300	Lumber Yards and Sawmills	8	62219	25	30	1866570
4400	Packing Plants, Fruit and Vegetable	1	160	25	30	4800
4500	Canneries and Distilleries	2	41216	25	30	1236480
4569	Canneries and Distilleries	1	1728	25	30	51840
4600	Food Processing	2	43705	25	30	1311150
4700	Mineral Processing, Cement and Gravel Plants	5	44532	25	30	1335960
4800	Warehousing and Distribution Terminals	328	3200857	25	30	96025710
4900	Open Storage, Junk Yards, Fuel Storage	17	75865	15	10	758650

Table 3-10 -- continued.

DOR Code [1]	Description	No. of Instances [2]	Total Square Footage [2]	% of annual gross sales/ expenditures [3]	goods consumed, $ /sq. foot/yr [3]	Total Annual Goods Consumed,$ [3]
6600	Orchard Groves	138	338200	15	10	3382000
6700	Poultry, bees, etc.	4	29142	15	10	291420
6800	Dairies, Feed Lots	142	402494	15	10	4024940
6900	Ornamentals, Misc. Agriculture	84	162133	15	10	1621330
7100	Churches	386	1916038	10	5	9580190
7300	Privately owned Hospitals	4	486441	15	110	53508510
7600	Mortuaries, cemetaries	15	64410	15	10	644100
7635	Crematorium	1	1713	15	10	17130
7900	Cultural Organizations, facilities	3	15368	10	5	76840
8200	Parks and Recreational Areas	17	50133	10	5	250665
8300	Public County Schools	42	921707	10	25	23042675
8400	Colleges	876	13329334	10	25	333233350
8500	Hospitals	6	185401	15	110	20394110
8600	County (other than recreation, college, hospital)	28	745187	10	25	18629675
8700	State (other than recreation, college, hospital)	34	402381	10	25	10059525
8800	Federal (other than military, recreation, hospital)	11	769961	10	25	19249025
8900	Municipal (other than recreation, college, hospital)	129	608800	10	25	15220000
9100	Utilities	37	766812	10	25	19170300

Notes

1) Each building feature has a DOR code assigned by the Alachua County Property Appraiser's office based on a coding scheme dictated by the Florida Department of Revenue (FDOR, 1990).

2) Total number of building features and square footage summarized from the 'em_combldgcov' analytical coverage database.

3) Annual total goods consumed in all commercial, institutional, and industrial buildings (all categories) is estimated at $1,108,606,835. The total square footage for all buildings was 49,306,986 sq. ft.. The average consumption rate for all buildings is estimated at $22.48/sq.ft./year. For each code , an estimated percentage of the total annual gross sales (or expenditures in the case of institutions) (USDOC, 1996a, 1996b, 1996c, BEBR, 1993 and 1995) was used as the total annual consumption for all buildings assigned that code. This total consumption was distributed according to square footage of each building using the following equation:
Goods consumed, $/sq.ft./yr. = total goods consumed, $/yr. / total square footage

Table 3-11: Estimated annual rates for the energy and EMERGY in the goods consumed by various types of agricultural production and for the maintenance of residential landscapes.

Type of agricultural production	**energy use rate, j/m2/year**	**EMERGY use rate, sej/m2/year**
Residential lawn and garden	3.53 E5	1.5 E12
Pasture	1.62 E4	8.13 E10
Rangeland	1620	8.13 E9
Row crops	8.08 E4	4.06 E11
Pine plantations	0	0
Forest regeneration	0	0

Note: These rates are based on calculations documented in the ‘notes’ section of Table 3-4 and other data (Fluck, 1992, and 1992b).

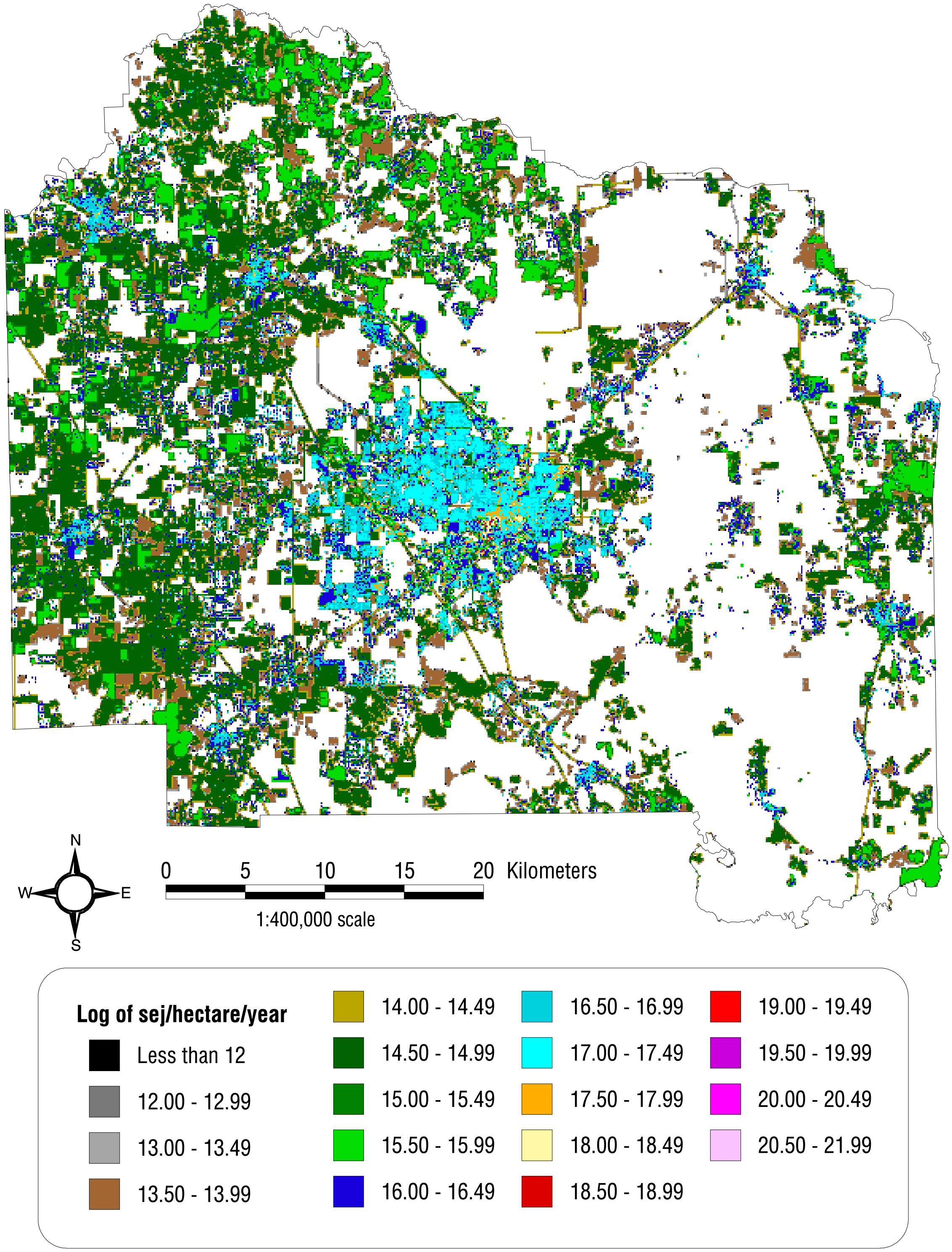


Figure 3-48: Map of the logarithm analytical EMERGY component grid called 'goods_log'. This grid represents the log of the annual EMPOWER density (log sej/ha/yr) of the consumable and durable goods used.

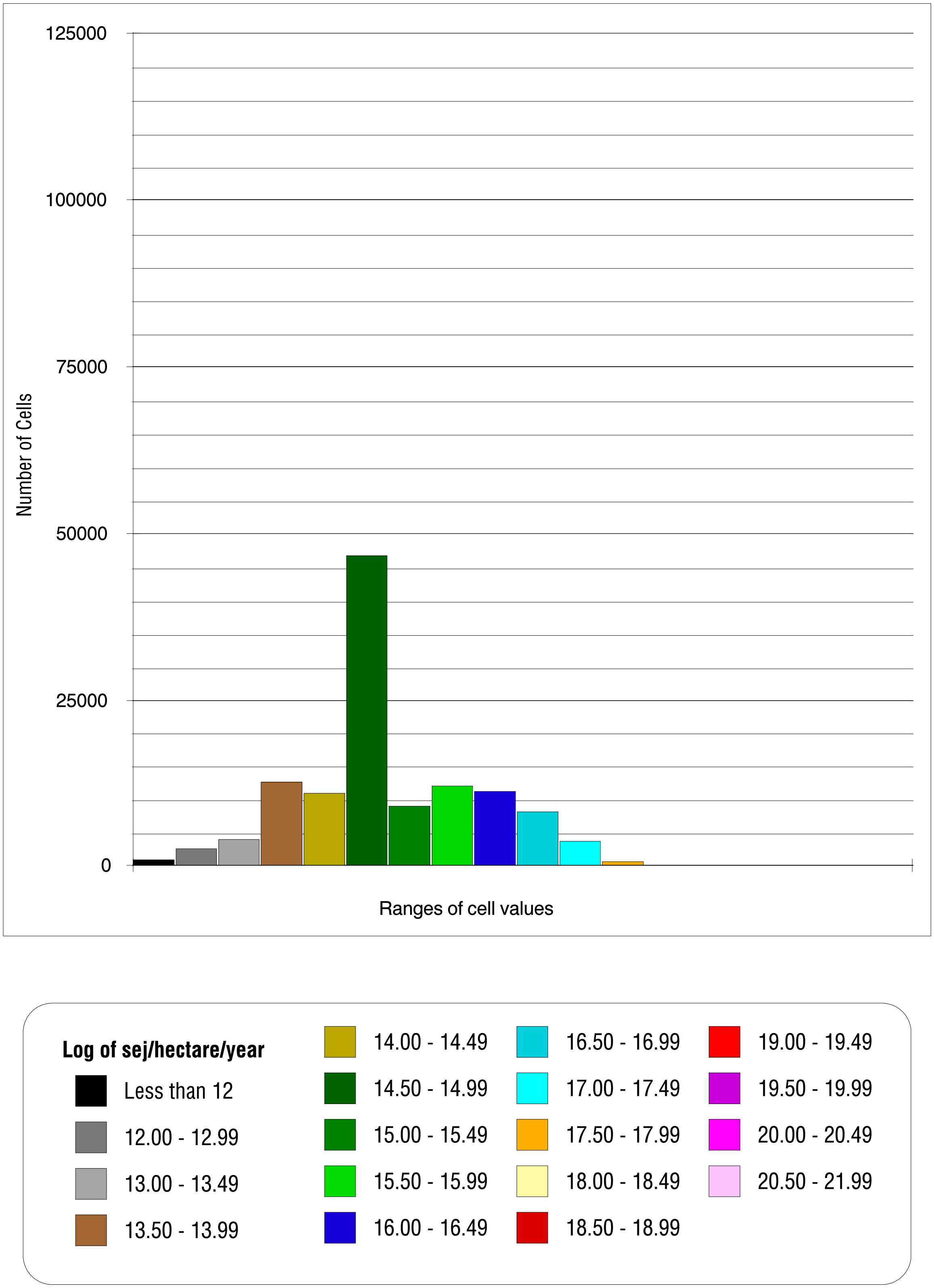


Figure 3-49: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called 'goods_log'.

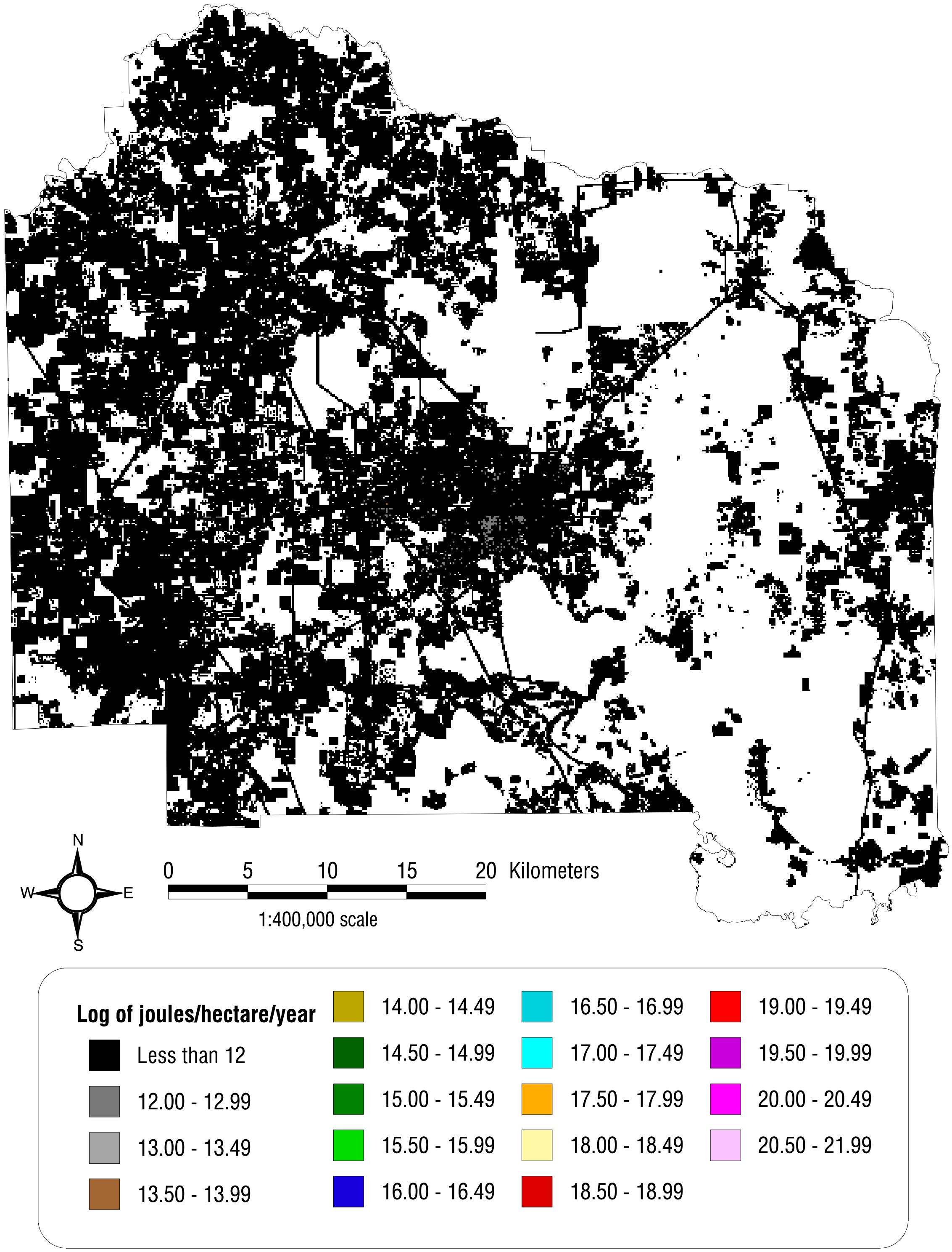


Figure 3-50: Map of the logarithm analytical energy component grid called 'goods_en_log'. This grid represents the log of the annual energy flow density (log j/ha/yr) of the consumable and durable goods used.

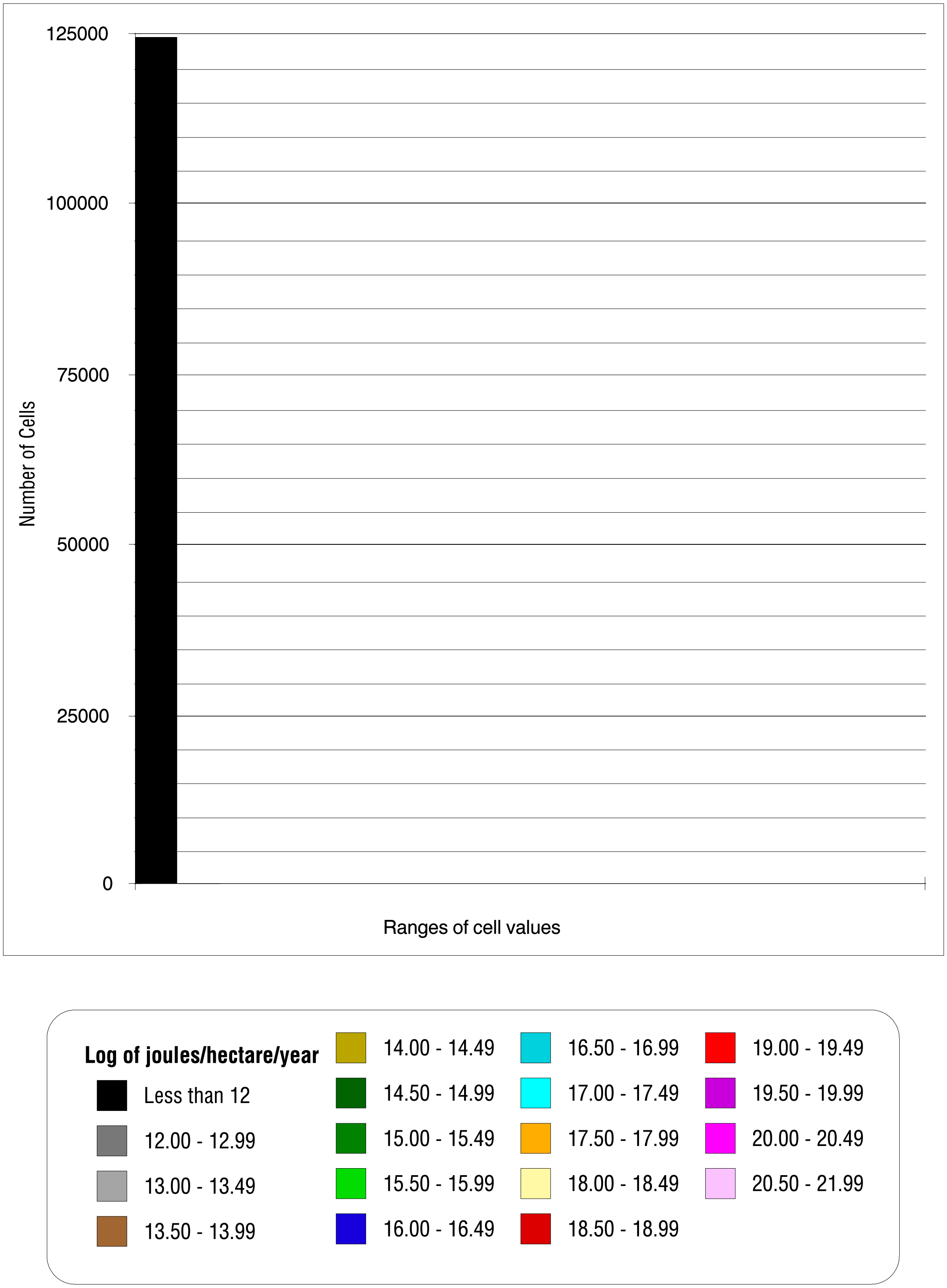


Figure 3-51: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'goods_en_log'.

Human services component. This component of the model represents the energy and EMERGY flow density of the human services provided by the residents of the County (element #6 in Figure 1-3). It does not include the EMERGY of services that is implicitly included in the flow of goods consumption.

Since people move around the landscape, estimates of the percentage of time that people spend at home, at work, and shopping were included in the calculations. Since most people spend most of their time in and around buildings, estimates of population per building were important inputs to the calculations used to create this component grid.

For residential building population estimates, the U.S. Census data was distributed proportionally to residential buildings (U.S. Bureau of the Census, 1992). For commercial, industrial, and institutional buildings, the total number of employees that were associated with each industry or institutional classification were proportionally distributed to the appropriate types of buildings. Table 3-12 lists the estimates of the square feet per employee/student for each DOR code that were used to assign a number of employees/students to each commercial, institutional, and industrial buildings.

Services provided in support of agricultural production are more appropriately distributed over land areas according to flow density rates rather than being assigned to building point features. Table 3-13 lists the estimated annual flow density rates for the energy and EMERGY in human services used by various types of agricultural production and for maintenance of residential landscapes.

A map of the logarithm analytical EMERGY component grid called 'service_log' is shown in Figure 3-52, and a histogram of cell value distribution for this EMERGY component grid is shown in Figure 3-53.

Like several of the previous component grids, the patterns observed in this map also reflect the methods used to create the grid. EMERGY flow density values for agricultural and forest areas were found to have a range of values from 13 to 14.5 log sej/ha/yr with the majority of these areas in the range of 13.5 to 14 log sej/ha/yr.

EMERGY flow density values for rural residential areas range from 16.5 to 17.5 log sej/ha/yr, and urban residential areas range from 17.5 to 18.5 log sej/ha/yr (reflecting the higher densities of homes in urban developments). Most institutional and commercial land uses have densities ranging from 18.5 to 19.5 log sej/ha/yr. Once again the highest flow density values, ranging from 19.5 to 20.5 log sej/ha/yr, are associated with the Shands Medical Center complex.

The cell distribution histogram for this EMERGY component grid shows two 'peaks' in the cell distribution pattern. The first 'peak' of the graph accounts for about 80% of the cells in the component grid that have values (some cells have a value equal to zero). These cells are grouped around the 13 to 14.5 log sej/ha/yr range and are primarily associated with rural. The values for the cells in the second smaller 'peak' range from 17 to 19.5 sej/ha/yr, and exhibit the pattern of an increasingly smaller number of cells associated with each increasingly higher EMERGY flow density value range.

The map of the energy component grid called 'service_en_log' is shown in Figure 3-54 and a histogram of cell value distribution is shown in Figure 3-55. Once again, the standard legend does not reveal the variation in the data because the values are so low.

Table 3-12: Estimates of total number of employees/students, and square feet per employee/student, for each Department of Revenue (DOR) code that were used to assign a number of employees/students to each commercial, institutional, and industrial building feature in the 'em_combldgcov' analytical coverage (with summaries of the number of instances, total square footage, and percentage of total retail/service).

DOR Code [1]	No. of Instances [2]	Total Square Footage [2]	Number of Employees/ Students [3]	Sq. ft./ Employee [4]	Retail or Service? [5]	Percent of Total Retail / Service [5]
1000	4	14108	23.5	600.0	Y	0.000
1100	529	3480536	5800.9	600.0	Y	16.926
1200	100	495076	825.1	600.0	Y	2.408
1300	3	295530	492.6	600.0	Y	1.437
1400	17	298165	496.9	600.0	Y	1.450
1500	10	1371463	2285.8	600.0	Y	6.669
1600	136	3591552	5985.9	600.0	Y	17.466
1700	512	2505447	9177.5	273.0	Y	12.184
1800	51	719524	2635.6	273.0	Y	3.499
1900	212	1691523	5619.7	301.0	Y	8.226
2000	2	79650	170.0	468.5	Y	0.387
2100	92	471342	3217.4	146.5	Y	2.292
2200	79	229516	1566.7	146.5	Y	1.116
2300	50	451266	1064.3	424.0	Y	2.194
2400	11	462002	1502.0	307.6	Y	2.247
2500	93	386852	184.1	2101.0	Y	1.881
2600	65	244012	116.1	2101.0	Y	1.187
2700	143	1148567	546.7	2101.0	Y	5.585
2800	135	357905	540.0	662.8	N	0.000
2900	54	584396	2096.9	278.7	N	0.000
3000	12	59008	179.0	329.7	Y	0.287
3200	2	46146	80.0	576.8	Y	0.224
3300	45	270591	1847.0	146.5	Y	1.316
3400	4	136860	136.9	1000.0	Y	0.666
3500	3	16285	16.3	1000.0	Y	0.079
3600	8	136084	70.0	1944.0	N	0.000
3700	1	27081	20.0	1354.0	N	0.000
3800	7	117081	80.0	1463.5	Y	0.569
3900	52	2120923	537.0	3949.6	N	0.000
4000	1	236	1.0	236.0	N	0.000
4100	115	2340608	3764.9	621.7	N	0.000
4200	6	491714	698.0	704.5	N	0.000
4300	8	62219	646.8	96.2	N	0.000
4400	1	160	1.0	160.0	N	0.000
4500	2	41216	82.4	500.0	N	0.000
4569	1	1728	3.5	500.0	N	0.000
4600	2	43705	87.4	500.0	N	0.000
4700	5	44532	33.0	1349.5	N	0.000
4800	328	3200857	306.0	10460.0	N	0.000
4900	17	75865	15.0	5057.0	N	0.000
5100	151	306770	57.0	5379.0	N	0.000
5200	482	937196	174.2	5379.0	N	0.000
5300	15	20128	3.7	5379.0	N	0.000
5400	126	250745	46.6	5379.0	N	0.000
5500	309	571482	106.2	5379.0	N	0.000
5600	94	150889	28.1	5379.0	N	0.000
5700	1	60	0.0	5379.0	N	0.000

Table 3-12 -- continued.

DOR Code [1]	No. of Instances [2]	Total Square Footage [2]	Number of Employees/ Students [3]	Sq. ft./ Employee [4]	Retail or Service? [5]	Percent of Total Retail / Service [5]
5900	84	190208	35.4	5379.0	N	0.000
6000	228	734421	136.5	5379.0	N	0.000
6100	583	1443921	268.4	5379.0	N	0.000
6200	99	217326	40.4	5379.0	N	0.000
6300	19	56947	10.6	5379.0	N	0.000
6400	7	13441	2.5	5379.0	N	0.000
6500	118	209464	38.9	5379.0	N	0.000
6600	138	338200	62.9	5379.0	N	0.000
6700	4	29142	5.4	5379.0	N	0.000
6800	142	402494	74.8	5379.0	N	0.000
6900	84	162133	30.1	5379.0	N	0.000
7100	386	1916038	870.1	2202.0	Y	9.318
7300	4	486441	6005.4	81.0	N	0.000
7600	15	64410	70.0	920.0	N	0.000
7635	1	1713	1.9	920.0	N	0.000
7900	3	15368	76.8	200.0	Y	0.075
8200	17	50133	250.7	200.0	Y	0.244
8300	42	921707	27109.0	34.0	N	0.000
8400	876	13329334	49997.5	266.6	N	0.000
8500	6	185401	2288.9	81.0	N	0.000
8600	28	745187	4307.4	173.0	N	0.000
8700	34	402381	1622.5	248.0	N	0.000
8800	11	769961	3104.7	248.0	N	0.000
8900	129	608800	3519.1	173.0	N	0.000
9100	37	766812	1039.0	738.0	N	0.000
9200	1	392	1.0	392.0	N	0.000
9400	4	2478	10.0	248.0	N	0.000
9600	1	736	1.0	736.0	N	0.000
9700	16	17954	72.4	248.0	N	0.000
9900	1	2700	1.0	2700.0	N	0.000

Notes

1) Each building feature has a DOR code assigned by the Alachua County Property Appraiser's office based on a coding scheme dictated by the Florida Department of Revenue (FDOR, 1990).

2) Total number of building features and square footage summarized from the 'em_combldgcov' analytical coverage database.

3) Estimated total number of employees/students working/studying in buildings assigned to each DOR code based on data from BEBR (1993).

4) In a few cases the numbers have been rounded off, or adjusted to compensate for logical inconsistencies in the data from BEBR (1993).

5) For retail or service buildings only, and for each DOR code:
Percent = total sq.ft. of bldgs. within code / total sq. ft. of all ret./serv. bldgs.

Table 3-13: Estimated annual rates for the energy and EMERGY in human services used by various types of agricultural production and for maintenance of residential landscapes.

Type of Agricultural production	**energy use rate, j/m2/year**	**EMERGY use rate, sej/m2/year**
Residential lawn and garden	7.03 E4	6.25 E11
Pasture	683	6.08 E9
Rangeland	68	6.08 E8
Rowcrops	2093	1.86 E10
pine plantations	475	4.23 E9
Forest regeneration	760	6.77 E9

Note: These rates are based on calculations that are documented in the 'notes' section of Table 3-4.

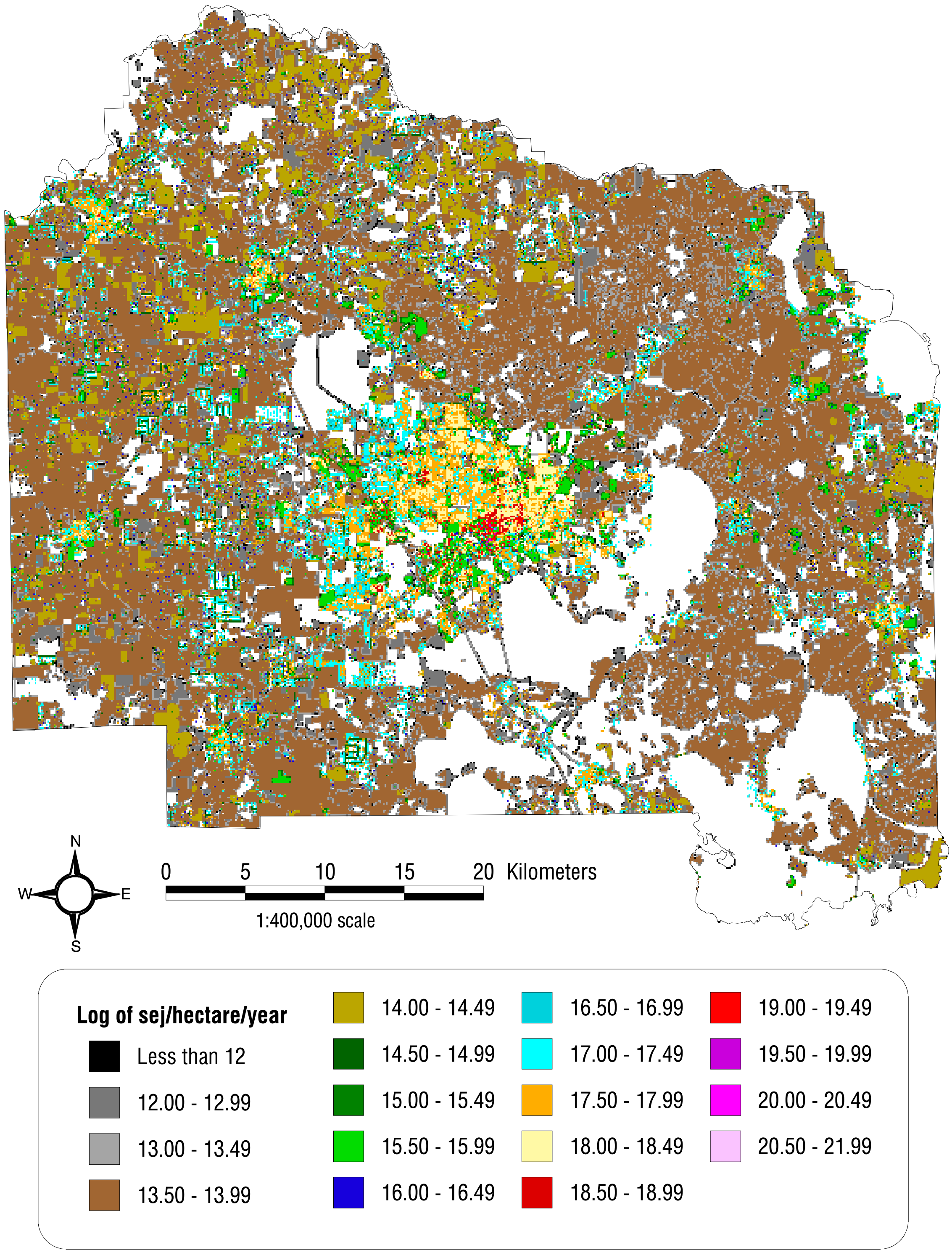


Figure 3-52: Map of the logarithm analytical EMERGY component grid called 'service_log'. This grid represents the log of the annual EMPOWER density (log sej/ha/yr) of all human services.

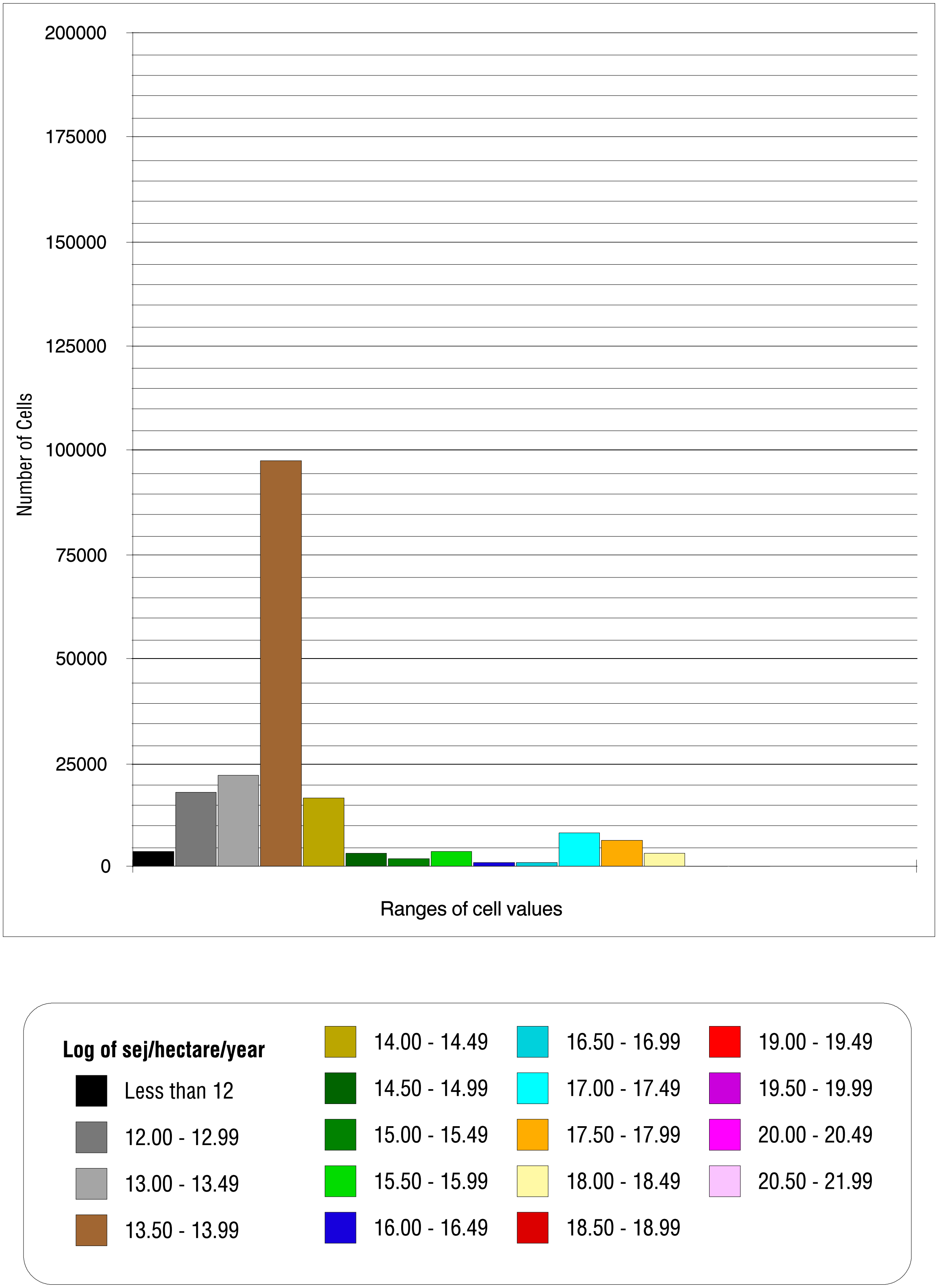


Figure 3-53: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called 'service_log'.

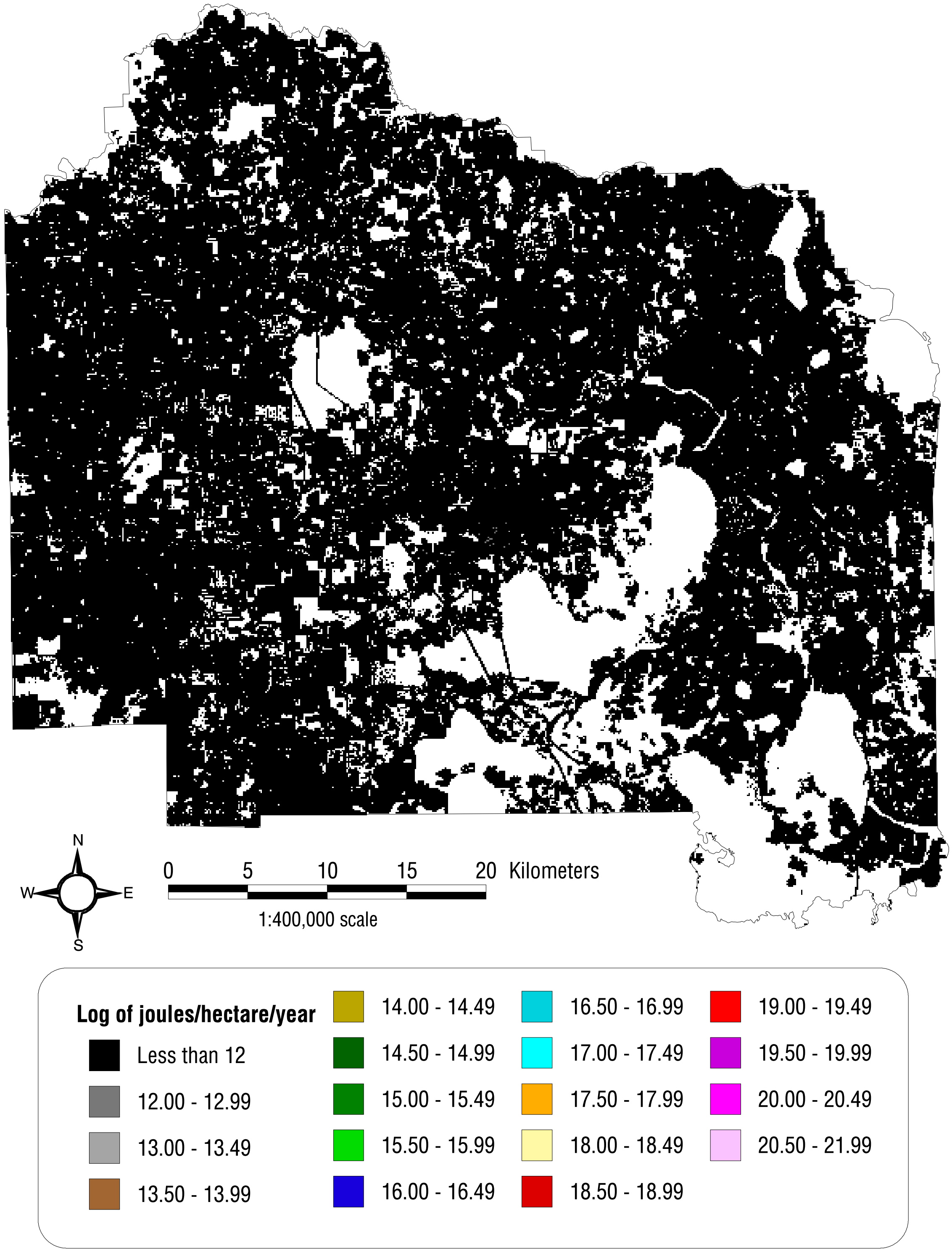


Figure 3-54: Map of the logarithm analytical energy component grid called 'servic_en_log'. This grid represents the log of the annual energy flow density (log j/ha/yr) of all human services.

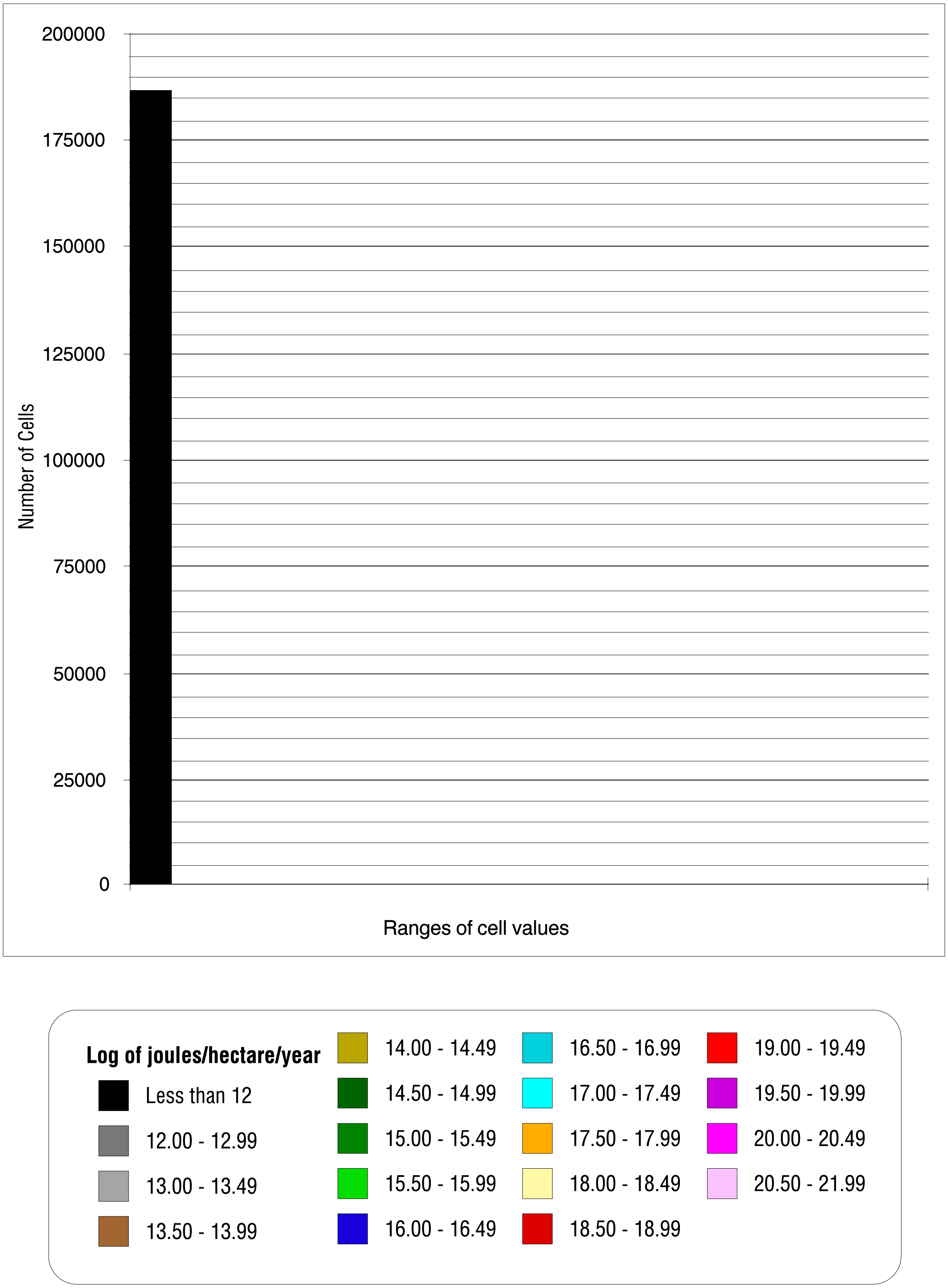


Figure 3-55: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'servic_en_log'.

Waste flow component. This component represents the energy and EMERGY flow density of both solid and liquid wastes generated in residential, commercial, and institutional buildings, and not recycled (element #7 in Figure 1-3). Data from several sources (FDEP, 1995, USEPA, 1997, and TIA, 1991) were summarized in Table 3-14 and used to estimate the total annual county-wide flows of municipal solid wastes (MSW) for different categories of buildings. The category of 'urban residential' is the sum of MSW flows from residential buildings in all incorporated areas of the county. Due to the manner in which MSW data are reported, the category of 'commercial' includes most of the larger (10 or more units) apartment complexes. The University of Florida's solid waste generation accounts for about 85% of the institutional waste (TIA, 1991). Municipal solid waste stream data were summarized in Table 3-14 into three categories: 'general wastes' (sum of paper, glass, metals, plastics, textiles, wood, and food wastes) , 'yard wastes' (grass clippings, trimmings), and 'construction debris'. This categorization facilitated calculations in which different transformities were used for each of the different categories of materials. The map of the logarithm analytical EMERGY component grid called 'waste_log' is shown in Figure 3-56, and a histogram of cell value distribution for the EMERGY component grid is shown in Figure 3-57.

The EMERGY flow map and histogram reflect a pattern corresponding to building density and land use intensity. The histogram displays a range of values from 14.5 to 19 log sej/ha/yr, and the now familiar pattern of many cells associated with the lower values and fewer cells with increasingly higher values. The map of the energy component grid called 'waste_en_log' is shown in Figure 3-58 and a histogram of cell value distribution by standard range of log values is shown in Figure 3-59.

Table 3-14: Summarized data on the municipal solid waste (MSW) stream for Alachua County during the period of July 1994 - June 1995 that was used as the basis for estimates of unrecycled solid waste flows (FDEP, 1995, USEPA, 1997, and TIA, 1991).

	Urban Residential MSW (tons)	Rural Residential MSW (tons)	Commercial MSW (tons)	Institutional MSW (tons)	County-Wide Total (tons)
General Wastes Landfilled	12,722	11,693	55,257	5,308	84,980
Yard Waste Landfilled	9,607	1,067	8,540	2,135	21,349
Construction Debris Landfilled	6,171	3,526	17,632	2,057	29,386
Total MSW Landfilled	28,500	16,286	81,429	9,500	135,715
Total Recycled MSW.	25,160	14,377	71,885	8,387	119,809
Estimated Total MSW stream	53,660	30,663	153,314	17,887	255,524
% of County-Wide Total	21%	12%	60%	7%	100%

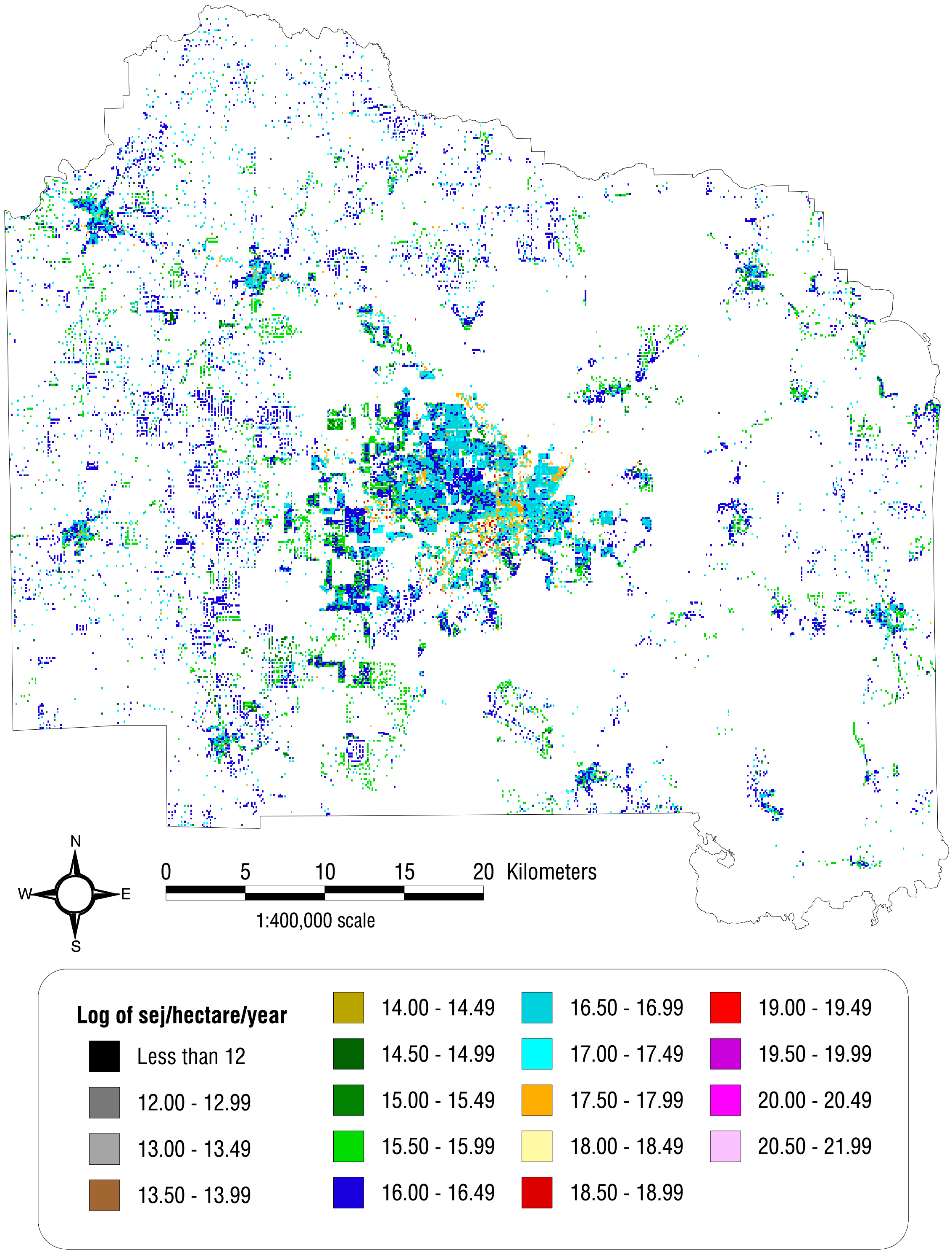


Figure 3-56: Map of the logarithm analytical EMERGY component grid called 'waste_log'. This grid represents the log of the annual EMPOWER density (log sej/ha/yr) of both the solid and liquid wastes generated in all buildings.

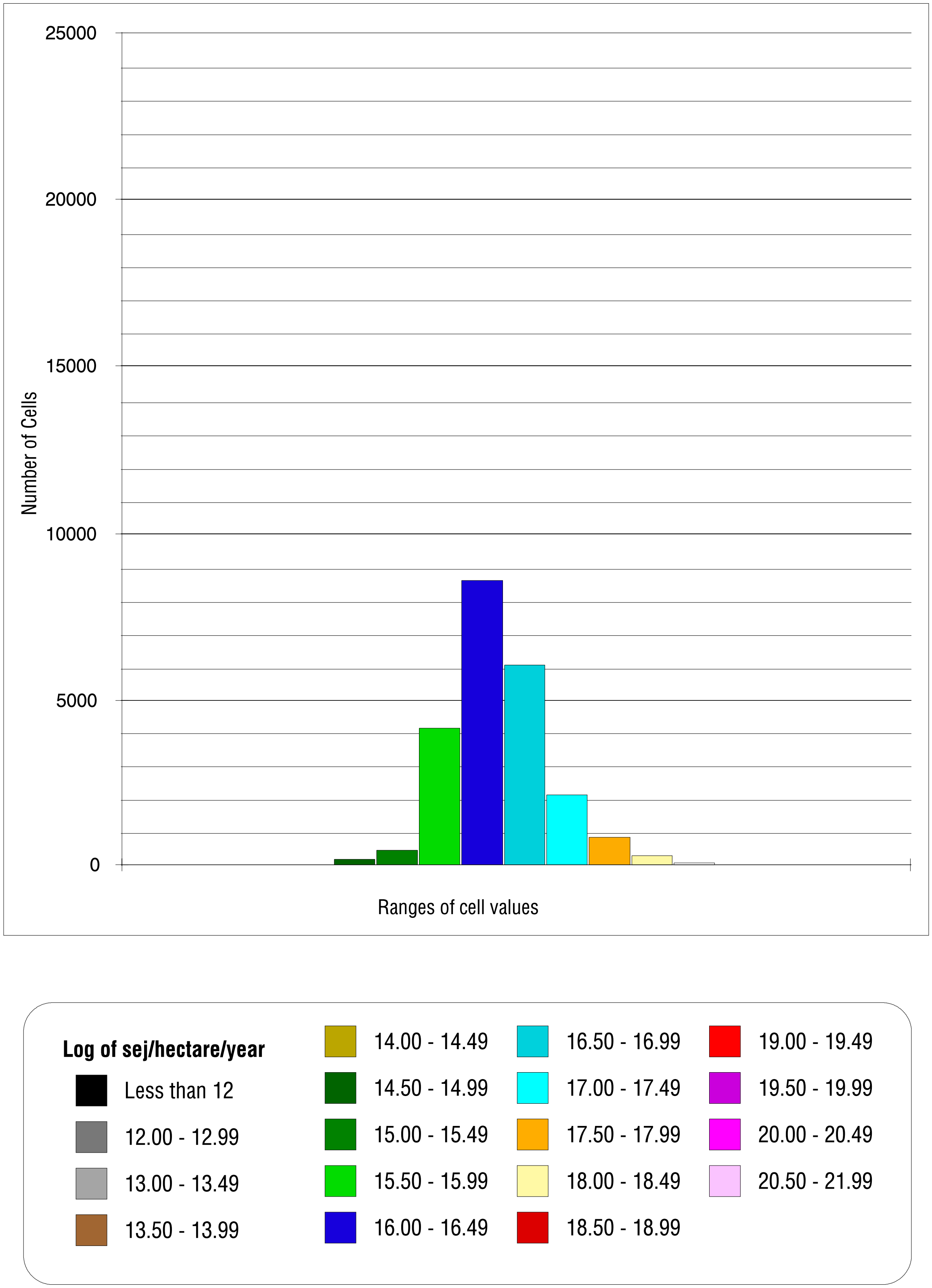


Figure 3-57: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called 'waste_log'.

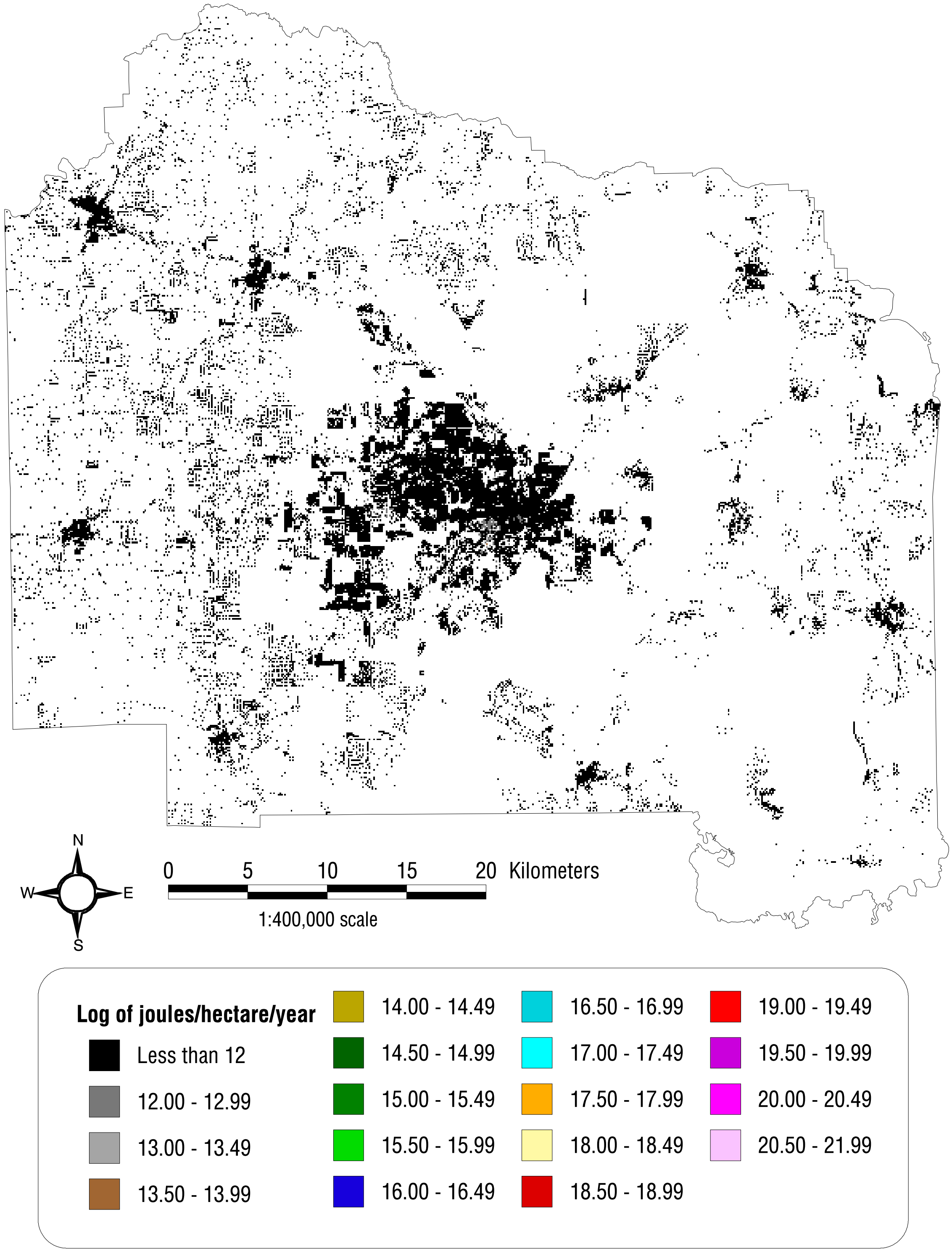


Figure 3-58: Map of the logarithm analytical energy component grid called 'waste_en_log'. This grid represents the log of the annual energy flow density (log j/ha/yr) of both the solid and liquid wastes generated in all buildings.

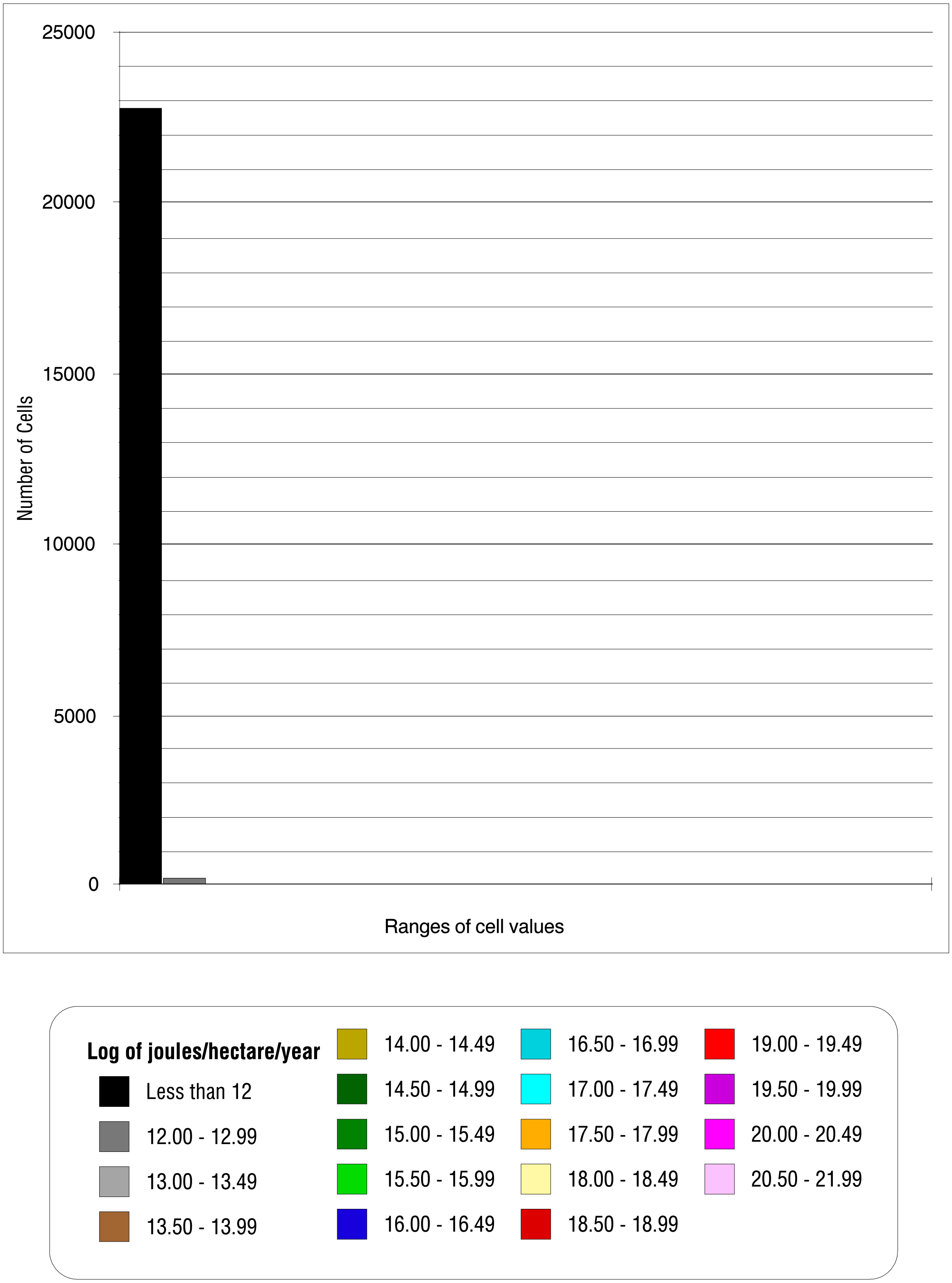


Figure 3-59: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'waste_en_log'.

Recycled waste flow component. This component represents the energy and EMERGY flow density of recycled solid wastes generated in residential, commercial, and institutional buildings (element #8 in Figure 1-3). Recycling of liquid wastes is not included in this component grid. Data from the same set of sources used for the MSW calculations (FDEP, 1995, USEPA, 1997, and TIA, 1991) were summarized in Table 3-15 and used to estimate the total annual County-wide recycling of municipal solid wastes (MSW) for different categories of buildings and waste. The recycling rate for both 'yard wastes' and 'construction debris' was assumed to be 50% of the total flow. Thus the estimated annual flow rate (tons/year) numbers for these categories are the same in both Table 3-14 and Table 3-15.

The map of the logarithm analytical EMERGY component grid called 'recycle_log' is shown in Figure 3-60, and a histogram of cell value distribution for the EMERGY component grid is shown in Figure 3-61. Like the waste flow map, the EMERGY flow map of recycling and the associated histogram reflect a pattern corresponding to building density and land use intensity. For instance, 67% of the total waste and recycle flows are associated with commercial and institutional buildings that are concentrated in relatively small areas. Consequently, areas that are characterized by these land uses display very high waste and recycling flow densities ranging from 17.5 to 19 log sej/ha/yr. Lower density residential areas fall into the range of 15.5 to 16 log sej/ha/yr and medium density urban residential areas range form 16 to 17 log sej/ha/yr.

The map of the energy component grid called 'recycle_en_log' is shown in Figure 3-62 and a histogram of cell value distribution by standard range of log values is shown in Figure 3-63.

Table 3-15: Summarized data on the municipal solid waste (MSW) stream for Alachua County during the period of July 1994 - June 1995 that were used as the basis for estimates of recycled wastes (FDEP, 1995, USEPA, 1997, and TIA, 1991).

	Urban Residential MSW (tons)	Rural Residential MSW (tons)	Commercial MSW (tons)	Institutional MSW (tons)	County-Wide Total (tons)
General Wastes Recycled	9,382	9,784	45,713	4,195	69,074
Yard Waste Recycled	9,607	1,067	8,540	2,135	21,349
Construction Debris Recycled	6,171	3,526	17,632	2,057	29,386
Total Recycled MSW	25,160	14,377	71,885	8,387	119,809
Total MSW Landfilled	28,500	16,286	81,429	9,500	135,715
Estimated Total MSW stream	53,660	30,663	153,314	17,887	255,524
% of County-Wide Total	21%	12%	60%	7%	100%

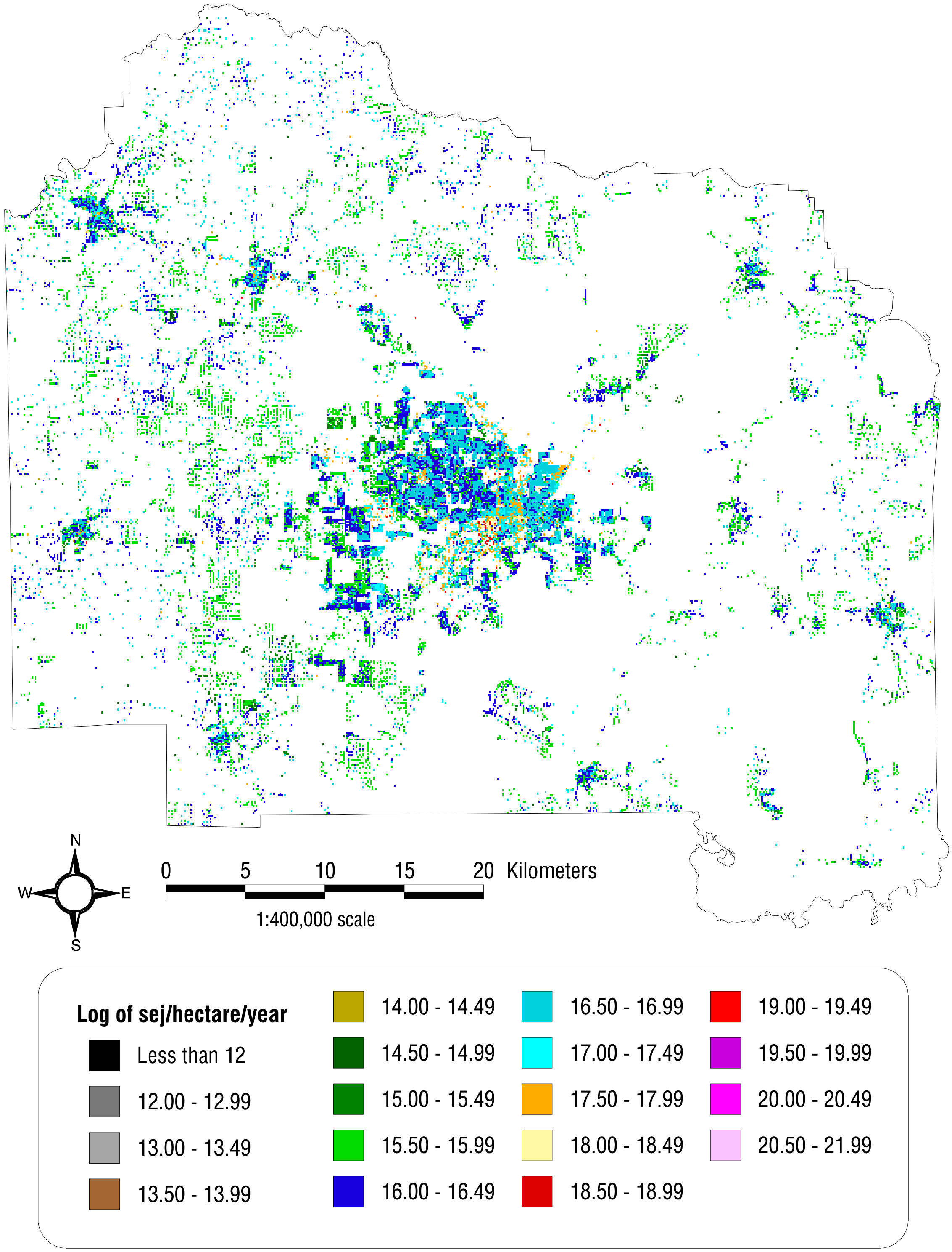


Figure 3-60: Map of the logarithm analytical EMERGY component grid called 'recycle_log. This grid represents the log of the annual EMPOWER density (log sej/ha/yr) of the solid wastes generated in all buildings that was recycled.

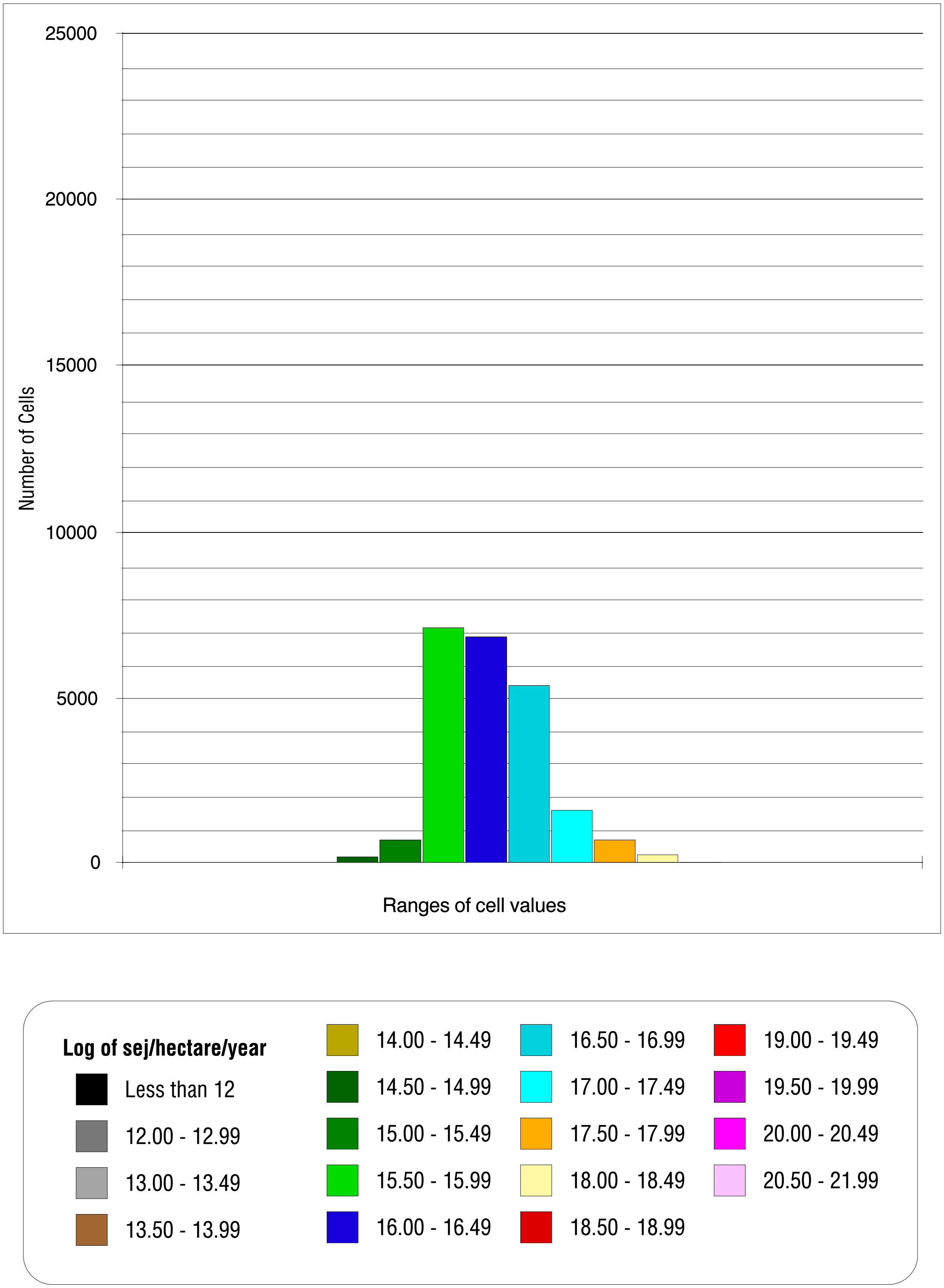


Figure 3-61: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called ’recycle_log.

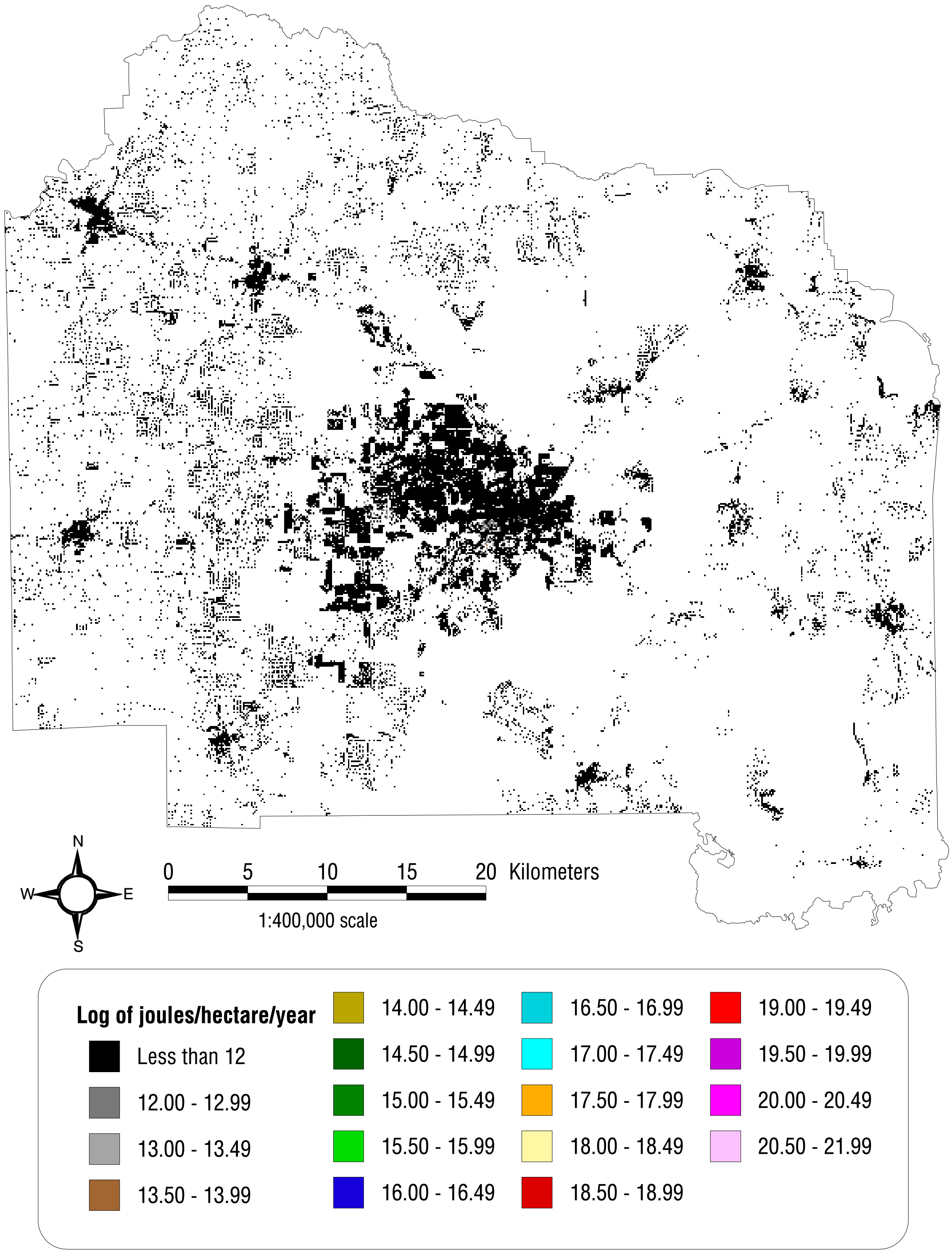
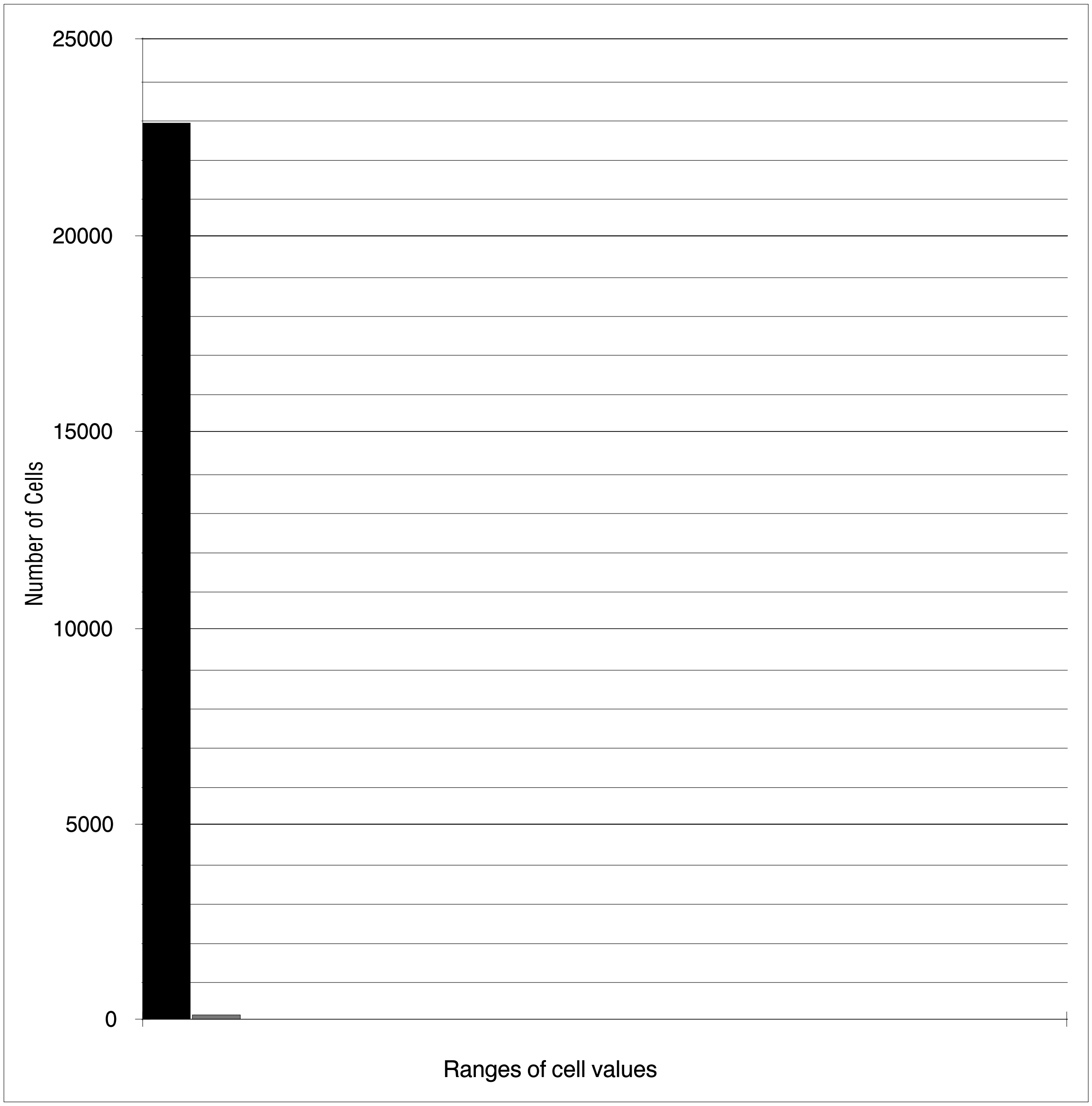


Figure 3-62: Map of the logarithm analytical energy component grid called 'recycl_en_log'. This grid represents the log of the annual energy flow density (log j/ha/yr) of the solid wastes generated in all buildings that was recycled.



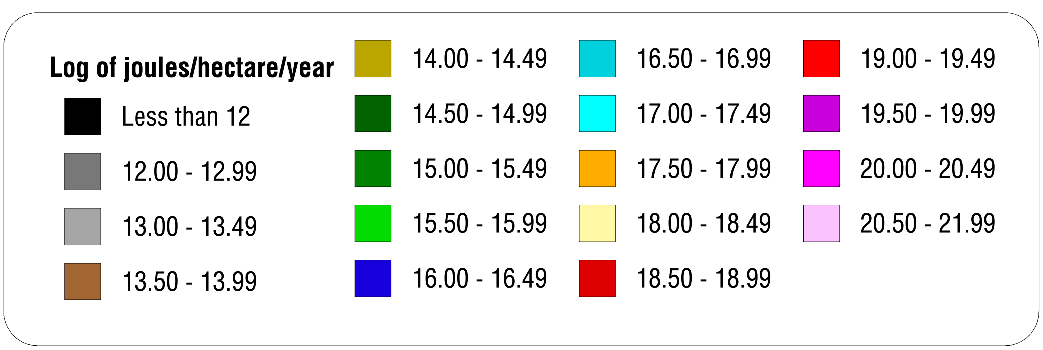


Figure 3-63: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'recycl_en_log'.

EMERGY Storage Components

The logarithm analytical component grids for each of the energy and EMERGY storage component grids of the spatial EMERGY model are used to graphically display the final model results. The same standard set of log value ranges has been used to present the results for each storage component that was used to present the results for the energy and EMERGY flow components in order to facilitate comparisons of the values and patterns in the maps and histograms.

The natural systems structure component is comprised of three subcomponent grids: the biomass storage, surface and groundwater storage, and the storage in organic matter of soils subcomponents. These subcomponent grids are presented first to help the reader understand the patterns displayed in the natural systems storage component of the model.

Biomass Storage Subcomponent. The total energy and EMERGY in biomass is the first subcomponent of the natural system structure component in the model (element #9a in Figure 1-3). The creation of the biomass storage subcomponent grid was based on two related sets of calculations. First, the EMERGY contributing to the production of the biomass was calculated by adding the EMERGY of renewable sources (from transpiration, element #1) to the EMERGY of nonrenewable sources (that were significant to production, elements #3, #4, and #5) using data from Table 3-4. Transformities for biomass were calculated by dividing the total EMERGY used to build the structure by the energy in the biomass. Calculations were done for representative ecosystems in Alachua County. The results of these calculations are found in Table 3-16.

In the second set of calculations, each level 3 land use or cover class was assigned a 'natural system basis' (NSB) that relates the class to the most closely corresponding general ecosystem type in Table 3-16. Each land use class was assigned a storage/m^2 value according to the NSB, or, in the cases of commercial and industrial classifications, by assigning a value that has been proportionately reduced by a factor to estimate the amount of biomass typically found on those types of land use. Building and road footprint polygons were assigned zero values for all calculations. Areas significantly altered from the original land use and cover type were assigned a 'maintained lawn and garden' land use type for their NSB. The results of the calculations for each land use and cover class, including the estimated reduction factors applied, can be found in Table 3-17. Descriptions for the level 3 land use and cover codes can be found in Table 3-2.

A map of the logarithm analytical EMERGY component grid called 'biostr_log' is shown in Figure 3-64 and a histogram of the number of cells in this EMERGY component grid that have values within each range of log values is shown in Figure 3-65.

The cell distribution histogram reveals that the values in the EMERGY map are fairly evenly distributed throughout the range of 15 to 17.5 log sej/ha. Because of the contributions from nonrenewable sources, the EMERGY storage value ranges for some urban areas of the county tend to be slightly higher than some natural areas.

A map of the logarithm analytical energy component grid called 'biostr_en_log' is shown in Figure 3-66 and a histogram of the number of cells in this energy component grid that have values within each range of log values is shown in Figure 3-67. The map shows slightly higher energy storage values in areas of upland forests than in lakes, wetlands, and agricultural fields.

Table 3-16: EMERGY, energy, and calculated transformities of natural system structure for ecosystem types used in this study.

Ecosystem	**Energy in biomass structure E11 J/ha**	**Transformity of biomass structure sej / J**	**EMERGY in biomass structure E14 sej/ha**	**Note**
Pasture	1.7	13,077	22.1	1
Rowcrops	.9	82,409	77.3	2
Rangeland	7.5	4,548	34.2	3
Pine Flatwoods	32.4	12,130	393.0	4
Pine Plantations	27.0	10,017	271.0	5
Forest Regeneration	13.5	10,205	138.0	6
Hardwood Forests	67.0	33,223	2230.0	7
Hardwood - Pine Forests	50.2	20,219	1020.0	8
Dry Forests	25.1	15,590	391.0	9
Forested Wetlands	56.8	20,211	1150.0	10
Cypress Domes	56.8	11,091	630.0	11
Wet Prairies	33.5	13,432	45.0	12
Freshwater Marshes	9.4	5,616	52.6	13
Lakes and Ponds	1.2	31,538	36.9	14
Residential Lawn/Garden	13.3	103,008	1370.0	15

Table 3-16 -- continued.

Notes

All of the following calculations of transformities of biomass in each ecosystem use data from the notes in Table 3-4 (that contain the values and calculations for the annual flows of energy and EMERGY--refer to the same note numbers in that table).

1) The energy in biomass structure estimate is based on data from Guttierrez(1978) and Ruelke (1976), (average dry wt. *with roots):*
(7000 lb/ac/yr)(.454 kg/lb)(2.47 ac/ha)(4000 kcal/kg)(4186 J/kcal)= 1.69 E11 J/ha
Transformity of biomass structure (assuming one year turnover time) *(including non-renewable sources such as fuel and labor, etc., and using the data from Table 3.1):*
(2.21 E15 sej/ha/yr) / (1.69 E11 J/ha) = 13,077 sej/J
EMERGY in biomass structure:
(1.69 E11 J/ha)(13,077 sej/J) = 2.21 E15 sej/ha
In comparison, Costanza (1975) calculated 1.02 E16 sej/ha for subsystem structure (including capital structures, which are included elsewhere in this study).

2) The energy in biomass structure estimate is based on the assumption of 16,000 lb/acre crop dry weight (for an average vegetable crop's biomass including vegetation, roots, and fruit based on average yields of watermelons and cabbage in Florida (Ware and McCollum, 1975)) for one growing season and .2 kg/m2 dry biomass from pasture during the remaining part of the year.
(16,000 lb/ac)(.454 kg/lb)(.2 dry) (2.47 ac/ha) = 3588 kg/ha
(.56 kg/m2)(10000 m2/ha)(4000 kcal/kg)(4186 J/kcal) = 9.38 E10 J/ha
Transformity of biomass structure (assuming one year turnover time)
(7.73 E15 sej/ha/yr) / (9.38 E10 J/ha/yr) = 82409 sej/J
(7.73 E15 sej/ha/yr) / (5.59 E6 g/ha) = 1.38 E9 sej/g
In comparison, Odum and Arding (1991 p.102) calculated a transformity for vegetables as 2.6 E5 sej/J. Odum (1996) lists 8.3 E4 sej/J for corn and 1.43 E9 sej/g for corn.
EMERGY in biomass structure: (9.38 E10 J/ha)(82409 sej/J) = 7.73 E15 sej/ha

3) The energy in biomass structure is based on an average of estimates from Costanza (1975), Gutierrez (1978), and Whittaker and Likens (1975).
(4.5 kg/m2)(10000 m2/ha)(4000 kcal/kg)(4186 J/kcal) = 7.53 E11 J/ha
Transformity of biomass structure (assuming a 5 year turnover time calculated by assuming an area weighted average of turnover times for grassland and pine forests ((.3 x 30 yr) + (.7 x 1 yr) / 2) = 4.85 yrs.).
(5 yr)(6.85 E14 sej/ha/yr) / (7.53 E11 J/ha) = 4548 sej / J
EMERGYin biomass structure: (7.53 E11 J/ha)(4548 sej/J) = 3.42 E15 sej/ha
For comparison, Costanza (1975) calculated for 'grassy scrub':
(16.5 E6 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 6.82 E15 sej/ha/yr

Table 3-16 -- continued.

4) The energy in the biomass structure estimate for pine flatwoods is based on data for harvest of an average 30 year old natural pine flatwoods (Walker, 1995). Because this estimate is based on stem harvest only, the figure is divided by .75 to increase the estimate to include roots, litter, branches, and needles (Waring and Schlesinger, 1985):
((3000 cubic feet / acre)/.75)(2.47 ac/ha)(.028 m3/ft3) = 276.6 m3/ha
(276.6 m3/ha)(.7 E3 kgdry/m3) = 193,648 kg/ha
(193,648 kg/ha)(4000 kcal/kg)(4186 J/kcal) = 3.24 E12 J/ha
Transformity of biomass structure (assuming a 30 year turnover time)
(30 yr)(1.31 E15 sej/ha/yr) / (3.24 E12 J/ha) = 12,130 sej / J
EMERGYin biomass structure: (3.24 E12 J/ha)(12,130 sej/J) = 3.93 E16 sej/ha
For comparison, Costanza (1975) calculated:
(80.1 E6 CE/ac/yr)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 3.31 E16 sej/ha/yr

5) The energy in the biomass structure estimate for the structure of 20 year old pine plantations is based on Walker (1995). Because this estimate is based on stem harvest only, the figure is divided by .75 to increase the estimate to include roots, litter, branches, and needles (Waring and Schlesinger, 1985).
((2500 cubic feet / acre)/.75)(2.47 ac/ha)(.028 m3/ft3) = 230.5 m3/ha
(230.5 m3/ha)(.7 E3 kgdry/m3) = 161,350 kg dry/ha
(161,350 kg/ha)(4000 kcal/kg)(4186 J/kcal) = 2.70 E12 J/ha
Transformity of biomass structure, assuming a 20 year turnover time,
and adding EMERGY in cultural inputs over 20 years:
($250/acre/20yr)(2.47 ac/ha)(1.37 E12 sej/$) = 8.46 E14 sej/ha
(20 yr)(1.31 E15 sej/ha/yr) + (8.46 E14 sej/ha) / (2.70 E12 J/ha) = 10,017 sej / J
EMERGYin biomass structure: (2.7 E12 J/ha)(10,017 sej/J) = 2.71 E16 sej/ha

6) The energy in the biomass structure estimate for the structure of 10 year old pine plantations is assumed to be half that of a mature plantation (Walker, 1995). Because this estimate is based on stem harvest only, the figure is divided by .75 to increase the estimate to include roots, litter, branches, and needles (Waring and Schlesinger, 1985):
((1250 cubic feet / acre)/.75)(2.47 ac/ha)(.028 m3/ft3) = 115.25 m3/ha
(115.25 m3/ha)(.7 E3 kgdry/m3) = 80,675 kg dry/ha
(80,675 kg/ha)(4000 kcal/kg)(4186 J/kcal) = 1.35 E12 J/ha
Transformity of biomass structure, assuming a 10 year turnover time,
and adding EMERGY in cultural inputs over 20 years:
($200/acre/10yr)(2.47 ac/ha)(1.37 E12 sej/$) = 6.77 E14 sej/ha
(10 yr)(1.31 E15 sej/ha/yr) + (6.77 E14 sej/ha) / (1.35 E12 J/ha) = 10,205 sej /J
EMERGYin biomass structure: (1.35 E12 J/ha)(10,205 sej/J) = 1.38 E16 sej/ha

7) The energy in biomass structure estimate for hardwood forests (hammocks) is based on averaged global data from Whittaker and Likens (1975) for temperate evergreen forests:

Table 3-16 -- continued.

(40 kg/m2)(10000 m2/ha)(4000 kcal/kg)(4186 J/kcal) = 6.70 E12 J/ha
Transformity of biomass structure, assuming a 70 year turnover time,
(70 yr)(3.18 E15 sej/ha/yr) / (6.70 E12 J/ha) = 33,223 sej / J
In comparison, Odum (1996) lists 3.23 E4 sej/J for rainforest wood.
EMERGYin biomass structure: (6.7 E12 J/ha)(33,223 sej/J) = 2.23 E17 sej/ha
In comparison, Costanza (1975) found:
(235.9 E6 CE/ac/yr)((2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal)= 9.76 E16 sej/ha/yr

8) The energy in biomass structure estimate for hardwood/conifer mixed forests is based on the average of hardwood and pine forests.
(30 kg/m2)(10000 m2/ha)(4000 kcal/kg)(4186 J/kcal)= 5.02 E12 J/ha
Transformity of biomass structure, assuming a 70 year turnover time:
(70 yr)(1.45 E15 sej/ha/yr) / (5.02 E12 J/ha) = 20,219 sej / J
EMERGYin biomass structure: (5.02 E12 J/ha)(20,219 sej/J) = 1.02 E17 sej/ha

9) The energy in biomass structure estimate for dry forests is based on averages from Olson (1975):
(15 kg/m2)(10000 m2/ha)(4000 kcal/kg)(4186 J/kcal) = 2.51 E12 J/ha
Transformity of biomass structure, assuming a 70 year turnover time:
(70 yr)(5.59 E14 sej/ha/yr) / (2.51 E12 J/ha) = 15,590 sej / J
EMERGYin biomass structure: (2.51 E12 J/ha)(15,590 sej/J) = 3.91 E16 sej/ha

10) The energy in biomass structure estimate is based on data fromswamps in north-central Florida (Nessel and Bayley, 1984) and theDismal Swamp (Day, 1984).
(339,000 kg/ha)(4000 kcal/kg)(4186 J/kcal) = 5.68 E12 J/ha
Transformity of biomass structure, assuming a 70 year turnover time:
(70 yr)(1.64 E15 sej/ha/yr) / (5.68 E12 J/ha) = 20,211 sej / J
EMERGYin biomass structure: (5.68 E12 J/ha)(20,211 sej/J) = 1.15 E17 sej/ha

11) The energy in biomass structure estimate is based on data from swamps in north-central Florida (Nessel and Bayley, 1984) and the Dismal Swamp (Day, 1984):
(339,000 kg/ha)(4000 kcal/kg)(4186 J/kcal) = 5.68 x E12 J/ha
Transformity for biomass (assuming 70 year old stand):
(70 yr)(9.0 E14 sej/ha/yr)/ (5.68 E12 J/ha) = 11,091 sej/J
EMERGY in biomass: (5.68 E12 J/ha)(11091 sej/J) = 6.30 E16 sej/ha
In comparison, Costanza (1975) and Brown (1980) calculated:
(214.5 E6 CE/ac)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 8.87 E16 sej/ha

12) The energy in biomass estimate is based on data from Kushlan (1990):
(2 kg/m2)(10000 m2/ha)(4000 kcal/kg)(4186 J/kcal) = 3.35 E11 J/ha
Transformity for biomass (assuming 5 year turnover):
(5 yr)(9.0 E14 sej/ha/yr)/ (3.35 E11 J/ha) = 13,432 sej/J
EMERGY in biomass: (3.35 E11 J/ha)(13432 sej/J) = 4.5 E15 sej/ha

Table 3-16 -- continued.

13) Energy in above-ground biomass structure (Odum, 1996 and Kushlan, 1990):
(1.0 kg/m2)(10000 m2/ha)(4000 kcal/kg)(4186 J/kcal) = 1.67 E11 J/ha
Transformity for aboveground biomass structure (assume 1 year turnover time):
(9.0 E14 sej/ha/yr) / (1.67 E11 J/ha) = 5389 sej/J
Solar EMERGY in aboveground biomass structure:
(1.67 E11 J/ha)(5389 sej/J) = 9.0 E14 sej/ha
Energy in underground biomass structure (Odum, 1996) (assume 5 year turnover time):
(4.6 kg/m2)(10000 m2/ha)(4000 kcal/kg)(4186 J/kcal) = 7.70 E11 J/ha
Transformity for underground biomass structure
((5 yr)(9.0 E14 sej/ha/yr)) / (7.7 E11 J/ha) = 5844 sej/J
EMERGY in belowground biomass structure:
(7.7 E11 J/ha)(5844 sej/J) = 4.5 E15 sej/ha
EMERGY in total biomass structure (using average of above and below-ground transformities which is 5616 sej/J):
((1.67 E11 J/ha) + (7.70 E11 J/ha))(5616 sej/J) = 5.26 E15 sej/ha

14) Energy in biomass structure is based on studies of Alachua County lakes by Gottgens and Montague(1987):
(.7 kg/m2)(10000 m2/ha)(4000 kcal/kg)(4186 J/kcal) = 1.17 x E11 J/ha
Transformity for biomass structure (assuming one year turnover):
(1 yr) (3.69 E15 sej/ha/yr) / (1.17 x E11 J/ha) = 31,538 sej / J
EMERGY in biomass structure:
(1.17 x E11 J/ha)(31538 sej/J) = 3.69 E15 sej/ha
For comparison, Costanza (1975) found:
(1.74 E6 CE/ac)(2.47 ac/ha)(40,000 kcal/CE)(4186 J/kcal) = 7.2 E14 sej/ha/yr

15) The energy in biomass structure estimate for residential lawns and gardens is based on personal observations:
(8 kg/m2)(10000 m2/ha)(4000 kcal/kg)(4186 J/kcal)= 1.33 E12 J/ha
Transformity of biomass structure (assuming 10 year turnover time as an average of trees and shrubs/lawn):
(10 yr)(1.37 E16 sej/ha/yr) / (1.33 E12 J/ha) = 1.03 E5 sej/J
EMERGY in biomass structure:
(1.33 E12 J/ha)(1.03 E5 sej/ha) = 1.37 E17 sej/ha

Table 3-17: Estimated EMERGY and energy stored in biomass of natural systems and transformity of biomass structure assigned to each modified land use and cover code in the 'em_landcov' analytical coverage.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Energy in Biomass E7J/m2 [4]	Transformity of Biomass [5]	EMERGY in Biomass E11sej/m2 [6]	Table 3-16 Note (NSB calculations) [7]
11001	hardwood/pine forests	1.00	50.20	20219	102.00	8
11002	residential lawn/garden	1.00	13.30	103008	137.00	15
11101	hardwood/pine forests	1.00	50.20	20219	102.00	8
11102	residential lawn/garden	1.00	13.30	103008	137.00	15
11201	hardwood/pine forests	1.00	50.20	20219	102.00	8
11202	residential lawn/garden	1.00	13.30	103008	137.00	15
11301	hardwood/pine forests	1.00	50.20	20219	102.00	8
11302	residential lawn/garden	1.00	13.30	103008	137.00	15
11401	hardwood/pine forests	1.00	50.20	20219	102.00	8
11402	residential lawn/garden	1.00	13.30	103008	137.00	15
11501	hardwood/pine forests	1.00	50.20	20219	102.00	8
11502	residential lawn/garden	1.00	13.30	103008	137.00	15
11601	hardwood/pine forests	1.00	50.20	20219	102.00	8
11602	residential lawn/garden	1.00	13.30	103008	137.00	15
12001	hardwood/pine forests	1.00	50.20	20219	102.00	8
12002	residential lawn/garden	1.00	13.30	103008	137.00	15
12101	hardwood/pine forests	1.00	50.20	20219	102.00	8
12102	residential lawn/garden	1.00	13.30	103008	137.00	15
12201	hardwood/pine forests	1.00	50.20	20219	102.00	8
12202	residential lawn/garden	1.00	13.30	103008	137.00	15
12301	hardwood/pine forests	1.00	50.20	20219	102.00	8
12302	residential lawn/garden	1.00	13.30	103008	137.00	15
13001	residential lawn/garden	0.70	9.31	103008	95.90	15
13002	residential lawn/garden	0.50	6.65	103008	68.50	15
13101	residential lawn/garden	0.70	9.31	103008	95.90	15
13102	residential lawn/garden	0.50	6.65	103008	68.50	15
13201	residential lawn/garden	0.50	6.65	103008	68.50	15
13202	residential lawn/garden	0.50	6.65	103008	68.50	15
13301	residential lawn/garden	0.50	6.65	103008	68.50	15
13302	residential lawn/garden	0.30	3.99	103008	41.10	15
13401	residential lawn/garden	0.30	3.99	103008	41.10	15
13402	residential lawn/garden	0.20	2.66	103008	27.40	15
13501	residential lawn/garden	0.50	6.65	103008	68.50	15
13502	residential lawn/garden	0.50	6.65	103008	68.50	15
14001	residential lawn/garden	0.30	3.99	103008	41.10	15
14002	residential lawn/garden	0.10	1.33	103008	13.70	15
14111	residential lawn/garden	0.10	1.33	103008	13.70	15
14112	residential lawn/garden	0.05	0.67	103008	6.85	15
14231	residential lawn/garden	0.10	1.33	103008	13.70	15
14232	residential lawn/garden	0.10	1.33	103008	13.70	15
14241	residential lawn/garden	0.10	1.33	103008	13.70	15
14242	residential lawn/garden	0.10	1.33	103008	13.70	15
14521	residential lawn/garden	0.20	2.66	103008	27.40	15
14522	residential lawn/garden	0.10	1.33	103008	13.70	15
14531	residential lawn/garden	0.50	6.65	103008	68.50	15
14541	hardwood/pine forests	0.80	40.16	20219	81.60	8
14542	residential lawn/garden	0.70	9.31	103008	95.90	15
14601	residential lawn/garden	0.10	1.33	103008	13.70	15
14602	residential lawn/garden	0.10	1.33	103008	13.70	15
14701	residential lawn/garden	0.30	3.99	103008	41.10	15

Table 3-17 -- continued.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Energy in Biomass E7J/m2 [4]	Transformity of Biomass [5]	EMERGY in Biomass E11sej/m2 [6]	Table 3-16 Note (NSB calculations) [7]
14702	residential lawn/garden	0.10	1.33	103008	13.70	15
14801	residential lawn/garden	0.80	10.64	103008	109.60	15
14802	residential lawn/garden	0.80	10.64	103008	109.60	15
14901	residential lawn/garden	0.10	1.33	103008	13.70	15
14902	residential lawn/garden	0.10	1.33	103008	13.70	15
15001	residential lawn/garden	0.10	1.33	103008	13.70	15
15002	residential lawn/garden	0.10	1.33	103008	13.70	15
15161	hardwood/pine forests	0.10	5.02	20219	10.20	8
15211	hardwood/pine forests	0.10	5.02	20219	10.20	8
15212	hardwood/pine forests	0.05	2.51	20219	5.10	8
15271	hardwood/pine forests	0.10	5.02	20219	10.20	8
15272	hardwood/pine forests	0.05	2.51	20219	5.10	8
15501	residential lawn/garden	0.10	1.33	103008	13.70	15
15502	residential lawn/garden	0.10	1.33	103008	13.70	15
15511	residential lawn/garden	0.10	1.33	103008	13.70	15
15512	residential lawn/garden	0.10	1.33	103008	13.70	15
15521	residential lawn/garden	0.50	6.65	103008	68.50	15
15522	residential lawn/garden	0.50	6.65	103008	68.50	15
15551	residential lawn/garden	0.10	1.33	103008	13.70	15
15552	residential lawn/garden	0.10	1.33	103008	13.70	15
15601	residential lawn/garden	0.05	0.67	103008	6.85	15
15602	residential lawn/garden	0.05	0.67	103008	6.85	15
15651	residential lawn/garden	0.05	0.67	103008	6.85	15
15652	residential lawn/garden	0.05	0.67	103008	6.85	15
15701	residential lawn/garden	0.05	0.67	103008	6.85	15
15702	residential lawn/garden	0.05	0.67	103008	6.85	15
16001	pine flatwoods	0.01	0.32	12130	0.39	4
16002	pine flatwoods	0.01	0.32	12130	0.39	4
16111	pine flatwoods	0.01	0.32	12130	0.39	4
16141	pine flatwoods	0.01	0.32	12130	0.39	4
16142	pine flatwoods	0.01	0.32	12130	0.39	4
16201	pine flatwoods	0.01	0.32	12130	0.39	4
16202	pine flatwoods	0.01	0.32	12130	0.39	4
16311	pine flatwoods	0.01	0.32	12130	0.39	4
16312	pine flatwoods	0.01	0.32	12130	0.39	4
16601	pine flatwoods	0.01	0.32	12130	0.39	4
16701	pine flatwoods	0.01	0.32	12130	0.39	4
16702	pine flatwoods	0.01	0.32	12130	0.39	4
17001	residential lawn/garden	1.00	13.30	103008	137.00	15
17002	residential lawn/garden	1.00	13.30	103008	137.00	15
17101	residential lawn/garden	1.00	13.30	103008	137.00	15
17102	residential lawn/garden	1.00	13.30	103008	137.00	15
17201	residential lawn/garden	1.00	13.30	103008	137.00	15
17202	residential lawn/garden	1.00	13.30	103008	137.00	15
17411	residential lawn/garden	1.00	13.30	103008	137.00	15
17412	residential lawn/garden	0.50	6.65	103008	68.50	15
17561	residential lawn/garden	0.50	6.65	103008	68.50	15
17562	residential lawn/garden	0.30	3.99	103008	41.10	15
17651	pasture	1.00	1.70	13077	2.21	1
17652	pasture	1.00	1.70	13077	2.21	1
17701	residential lawn/garden	1.00	13.30	103008	137.00	15
17702	residential lawn/garden	1.00	13.30	103008	137.00	15
18001	residential lawn/garden	1.00	13.30	103008	137.00	15

Table 3-17 -- continued.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Energy in Biomass E7J/m2 [4]	Transformity of Biomass [5]	EMERGY in Biomass E11sej/m2 [6]	Table 3-16 Note (NSB calculations) [7]
18002	residential lawn/garden	1.00	13.30	103008	137.00	15
18201	residential lawn/garden	1.00	13.30	103008	137.00	15
18202	residential lawn/garden	1.00	13.30	103008	137.00	15
18311	pasture	1.00	1.70	13077	2.21	1
18312	pasture	1.00	1.70	13077	2.21	1
18501	residential lawn/garden	1.00	13.30	103008	137.00	15
18502	residential lawn/garden	1.00	13.30	103008	137.00	15
18511	residential lawn/garden	1.00	13.30	103008	137.00	15
18512	residential lawn/garden	1.00	13.30	103008	137.00	15
18601	residential lawn/garden	1.00	13.30	103008	137.00	15
18602	residential lawn/garden	1.00	13.30	103008	137.00	15
18901	residential lawn/garden	1.00	13.30	103008	137.00	15
18902	residential lawn/garden	1.00	13.30	103008	137.00	15
19001	rangeland	1.00	7.50	4548	3.42	3
19002	residential lawn/garden	1.00	13.30	103008	137.00	15
19101	hardwood/pine forests	1.00	50.20	20219	102.00	8
19102	residential lawn/garden	1.00	13.30	103008	137.00	15
19201	hardwood/pine forests	1.00	50.20	20219	102.00	8
19202	residential lawn/garden	1.00	13.30	103008	137.00	15
19231	rangeland	1.00	7.50	4548	3.42	3
19232	residential lawn/garden	1.00	13.30	103008	137.00	15
19241	hardwood/pine forests	1.00	50.20	20219	102.00	8
19242	residential lawn/garden	1.00	13.30	103008	137.00	15
21101	pasture	1.00	1.70	13077	2.21	1
21102	residential lawn/garden	0.80	10.64	103008	109.60	15
21201	rangeland	1.00	7.50	4548	3.42	3
21202	residential lawn/garden	0.80	10.64	103008	109.60	15
21301	rangeland	1.00	7.50	4548	3.42	3
21302	residential lawn/garden	1.00	13.30	103008	137.00	15
21401	rowcrops	1.00	0.90	82409	7.73	2
21402	residential lawn/garden	0.80	10.64	103008	109.60	15
21501	rowcrops	1.00	0.90	82409	7.73	2
21502	residential lawn/garden	0.80	10.64	103008	109.60	15
21601	rowcrops	1.00	0.90	82409	7.73	2
22001	residential lawn/garden	1.00	13.30	103008	137.00	15
22002	residential lawn/garden	1.00	13.30	103008	137.00	15
22101	residential lawn/garden	1.00	13.30	103008	137.00	15
22102	residential lawn/garden	1.00	13.30	103008	137.00	15
22201	residential lawn/garden	1.00	13.30	103008	137.00	15
22202	residential lawn/garden	1.00	13.30	103008	137.00	15
22211	residential lawn/garden	1.00	13.30	103008	137.00	15
22241	rowcrops	1.00	0.90	82409	7.73	2
22242	residential lawn/garden	1.00	13.30	103008	137.00	15
22301	residential lawn/garden	1.00	13.30	103008	137.00	15
22311	residential lawn/garden	1.00	13.30	103008	137.00	15
22312	residential lawn/garden	1.00	13.30	103008	137.00	15
22401	residential lawn/garden	1.00	13.30	103008	137.00	15
23001	pasture	1.00	1.70	13077	2.21	1
23002	pasture	1.00	1.70	13077	2.21	1
23101	pasture	1.00	1.70	13077	2.21	1
23102	pasture	1.00	1.70	13077	2.21	1
23201	pasture	1.00	1.70	13077	2.21	1
23202	pasture	1.00	1.70	13077	2.21	1

Table 3-17 -- continued.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Energy in Biomass E7J/m2 [4]	Transformity of Biomass [5]	EMERGY in Biomass E11sej/m2 [6]	Table 3-16 Note (NSB calculations) [7]
24101	residential lawn/garden	1.00	13.30	103008	137.00	15
24102	residential lawn/garden	1.00	13.30	103008	137.00	15
24201	pasture	1.00	1.70	13077	2.21	1
24301	rowcrops	1.00	0.90	82409	7.73	2
24302	rowcrops	1.00	0.90	82409	7.73	2
24501	rowcrops	1.00	0.90	82409	7.73	2
25101	pasture	1.00	1.70	13077	2.21	1
25102	residential lawn/garden	1.00	13.30	103008	137.00	15
25201	pasture	1.00	1.70	13077	2.21	1
25202	pasture	1.00	1.70	13077	2.21	1
25301	residential lawn/garden	1.00	13.30	103008	137.00	15
25302	residential lawn/garden	1.00	13.30	103008	137.00	15
25401	pasture	1.00	1.70	13077	2.21	1
25402	pasture	1.00	1.70	13077	2.21	1
25901	pasture	1.00	1.70	13077	2.21	1
25902	pasture	1.00	1.70	13077	2.21	1
26001	pasture	1.00	1.70	13077	2.21	1
26002	residential lawn/garden	1.00	13.30	103008	137.00	15
26101	pasture	1.00	1.70	13077	2.21	1
26201	rangeland	1.00	7.50	4548	3.42	3
26202	residential lawn/garden	1.00	13.30	103008	137.00	15
31001	rangeland	1.00	7.50	4548	3.42	3
31002	residential lawn/garden	1.00	13.30	103008	137.00	15
32001	rangeland	1.00	7.50	4548	3.42	3
32002	residential lawn/garden	1.00	13.30	103008	137.00	15
32901	rangeland	1.00	7.50	4548	3.42	3
32902	residential lawn/garden	1.00	13.30	103008	137.00	15
33001	rangeland	1.00	7.50	4548	3.42	3
33002	residential lawn/garden	1.00	13.30	103008	137.00	15
41101	pine flatwoods	1.00	32.40	12130	39.30	4
41102	residential lawn/garden	1.00	13.30	103008	137.00	15
41201	dry forests	1.00	25.10	15590	39.10	9
41202	residential lawn/garden	1.00	13.30	103008	137.00	15
41401	hardwood/pine forests	1.00	50.20	20219	102.00	8
41402	residential lawn/garden	1.00	13.30	103008	137.00	15
41901	pine flatwoods	1.00	32.40	12130	39.30	4
41902	residential lawn/garden	1.00	13.30	103008	137.00	15
42001	dry forests	1.00	25.10	15590	39.10	9
42002	residential lawn/garden	1.00	13.30	103008	137.00	15
42101	dry forests	1.00	25.10	15590	39.10	9
42102	residential lawn/garden	1.00	13.30	103008	137.00	15
42301	hardwood/pine forests	1.00	50.20	20219	102.00	8
42302	residential lawn/garden	1.00	13.30	103008	137.00	15
42501	hardwood forests	1.00	67.00	33223	223.00	7
42502	residential lawn/garden	1.00	13.30	103008	137.00	15
43101	hardwood forests	1.00	67.00	33223	223.00	7
43102	residential lawn/garden	1.00	13.30	103008	137.00	15
43401	hardwood/pine forests	1.00	50.20	20219	102.00	8
43402	residential lawn/garden	1.00	13.30	103008	137.00	15
44001	pine plantations	1.00	27.00	10017	27.10	5
44002	residential lawn/garden	1.00	13.30	103008	137.00	15
44101	pine plantations	1.00	27.00	10017	27.10	5
44102	residential lawn/garden	1.00	13.30	103008	137.00	15

Table 3-17 -- continued.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Energy in Biomass E7J/m2 [4]	Transformity of Biomass [5]	EMERGY in Biomass E11sej/m2 [6]	Table 3-16 Note (NSB calculations) [7]
44301	forest regeneration	1.00	13.50	10205	13.80	6
44302	residential lawn/garden	1.00	13.30	103008	137.00	15
44601	forest regeneration	1.00	13.50	10205	13.80	6
51001	lakes/ponds	1.00	1.20	31538	3.69	14
51002	residential lawn/garden	1.00	13.30	103008	137.00	15
51201	lakes/ponds	1.00	1.20	31538	3.69	14
52001	lakes/ponds	1.00	1.20	31538	3.69	14
52002	residential lawn/garden	1.00	13.30	103008	137.00	15
52101	lakes/ponds	1.00	1.20	31538	3.69	14
52102	residential lawn/garden	1.00	13.30	103008	137.00	15
52201	lakes/ponds	1.00	1.20	31538	3.69	14
52301	lakes/ponds	1.00	1.20	31538	3.69	14
52302	residential lawn/garden	1.00	13.30	103008	137.00	15
52401	lakes/ponds	1.00	1.20	31538	3.69	14
52402	residential lawn/garden	1.00	13.30	103008	137.00	15
53001	lakes/ponds	1.00	1.20	31538	3.69	14
53002	residential lawn/garden	1.00	13.30	103008	137.00	15
53301	lakes/ponds	1.00	1.20	31538	3.69	14
53302	residential lawn/garden	1.00	13.30	103008	137.00	15
53401	lakes/ponds	1.00	1.20	31538	3.69	14
53402	residential lawn/garden	1.00	13.30	103008	137.00	15
55001	lakes/ponds	1.00	1.20	31538	3.69	14
61001	forested wetlands	1.00	56.80	20211	115.00	10
61101	forested wetlands	1.00	56.80	20211	115.00	10
61102	forested wetlands	1.00	56.80	20211	115.00	10
61201	forested wetlands	1.00	56.80	20211	115.00	10
61202	forested wetlands	1.00	56.80	20211	115.00	10
61301	forested wetlands	1.00	56.80	20211	115.00	10
61401	wet prairies	1.00	33.50	13432	4.50	12
61402	wet prairies	1.00	33.50	13432	4.50	12
61501	forested wetlands	1.00	56.80	20211	115.00	10
61502	forested wetlands	1.00	56.80	20211	115.00	10
61701	forested wetlands	1.00	56.80	20211	115.00	10
61702	forested wetlands	1.00	56.80	20211	115.00	10
62001	forested wetlands	1.00	56.80	20211	115.00	10
62101	cypress domes	1.00	56.80	11091	63.00	11
62102	cypress domes	1.00	56.80	11091	63.00	11
62201	pine flatwoods	1.00	32.40	12130	39.30	4
62202	pine flatwoods	1.00	32.40	12130	39.30	4
63001	forested wetlands	1.00	56.80	20211	115.00	10
63002	forested wetlands	1.00	56.80	20211	115.00	10
63101	hardwood forests	1.00	67.00	33223	223.00	7
64101	freshwater marshes	1.00	9.40	5616	5.26	13
64102	freshwater marshes	1.00	9.40	5616	5.26	13
64201	freshwater marshes	1.00	9.40	5616	5.26	13
64301	wet prairies	1.00	33.50	13432	4.50	12
64302	wet prairies	1.00	33.50	13432	4.50	12
64401	freshwater marshes	1.00	9.40	5616	5.26	13
64402	freshwater marshes	1.00	9.40	5616	5.26	13
64501	freshwater marshes	1.00	9.40	5616	5.26	13
64601	freshwater marshes	1.00	9.40	5616	5.26	13
64602	freshwater marshes	1.00	9.40	5616	5.26	13
65001	freshwater marshes	1.00	9.40	5616	5.26	13

Table 3-17 -- continued.

Modified Land Use and Cover Code [1]	Natural System Basis (NSB) for Estimates [2]	Multiply NSB values by a Factor of: [3]	Energy in Biomass E7J/m2 [4]	Transformity of Biomass [5]	EMERGY in Biomass E11sej/m2 [6]	Table 3-16 Note (NSB calculations) [7]
65301	freshwater marshes	1.00	9.40	5616	5.26	13
65302	freshwater marshes	1.00	9.40	5616	5.26	13
66001	freshwater marshes	1.00	9.40	5616	5.26	13
74001	rangeland	1.00	7.50	4548	3.42	3
74002	rangeland	1.00	7.50	4548	3.42	3
74101	rangeland	1.00	7.50	4548	3.42	3
74102	rangeland	1.00	7.50	4548	3.42	3
74201	rangeland	1.00	7.50	4548	3.42	3
81101	pasture	1.00	1.70	13077	2.21	1
81111	pasture	1.00	1.70	13077	2.21	1
81112	residential lawn/garden	0.50	6.65	103008	68.50	15
81131	pasture	1.00	1.70	13077	2.21	1
81132	residential lawn/garden	1.00	13.30	103008	137.00	15
81201	pasture	1.00	1.70	13077	2.21	1
81401	pasture	1.00	1.70	13077	2.21	1
81402	pasture	1.00	1.70	13077	2.21	1
81411	pasture	1.00	1.70	13077	2.21	1
81412	pasture	1.00	1.70	13077	2.21	1
81421	pasture	1.00	1.70	13077	2.21	1
81422	pasture	1.00	1.70	13077	2.21	1
81431	pasture	1.00	1.70	13077	2.21	1
81432	pasture	1.00	1.70	13077	2.21	1
81471	pasture	1.00	1.70	13077	2.21	1
81472	pasture	1.00	1.70	13077	2.21	1
81701	rangeland	1.00	7.50	4548	3.42	3
81702	rangeland	1.00	7.50	4548	3.42	3
81801	residential lawn/garden	0.50	6.65	103008	68.50	15
81802	residential lawn/garden	0.50	6.65	103008	68.50	15
82001	pasture	1.00	1.70	13077	2.21	1
82002	pasture	1.00	1.70	13077	2.21	1
83101	residential lawn/garden	0.30	3.99	103008	41.10	15
83102	residential lawn/garden	0.10	1.33	103008	13.70	15
83111	residential lawn/garden	0.30	3.99	103008	41.10	15
83112	residential lawn/garden	0.10	1.33	103008	13.70	15
83121	residential lawn/garden	0.30	3.99	103008	41.10	15
83122	residential lawn/garden	0.10	1.33	103008	13.70	15
83151	residential lawn/garden	0.30	3.99	103008	41.10	15
83152	residential lawn/garden	0.10	1.33	103008	13.70	15
83201	pasture	1.00	1.70	13077	2.21	1
83202	pasture	1.00	1.70	13077	2.21	1
83301	residential lawn/garden	0.30	3.99	103008	41.10	15
83302	residential lawn/garden	0.10	1.33	103008	13.70	15
83401	residential lawn/garden	0.30	3.99	103008	41.10	15
83402	residential lawn/garden	0.10	1.33	103008	13.70	15
83501	pasture	0.10	0.17	13077	0.22	1
83502	pasture	0.10	0.17	13077	0.22	1
88801	pasture	1.00	1.70	13077	2.21	1
88802	pasture	1.00	1.70	13077	2.21	1

Table 3-17 -- continued.

Notes

1) The modified landuse and cover code in the ‘em_landcov’ coverage was created to identify those polygons representing:

a) areas of buffered buildings and roads,
- identified by a value of ‘3’ in the fifth number of the code (and not included in this table because all of the values are logically equal to 0 (no biomass)),

b) areas assumed to be significantly altered from the original landcove type to maintained lawn and garden,
- identified by a value of ‘2’ in the fifth number of the code

c) areas not altered from the assigned landuse and cover type,
- identified by a value of ‘1’in the fifth number of the code.

2) Each landuse and cover code was assigned a natural system basis (NSB) for the estimate of biomass. The NSB correlates with the general ecosystem types found in Table 3-16.

3) Estimated reduction factor used to reduce the estimated amounts of energy and EMERGY in biomass indicated by the NSB for each code.

4) Calculated energy in biomass (E7 J/m2) after multiplying the reduction factor by the NSB value from Table 3-16.

5) Transformity from NSB found in Table 3-16.

6) Calculated EMERGY in biomass (E11 sej/m2) after multiplying the reduction factor by the NSB value from Table 3-16.

7) Reference to notes in Table 3-16 which have the detailed calculations for the energy and EMERGY for each NSB.

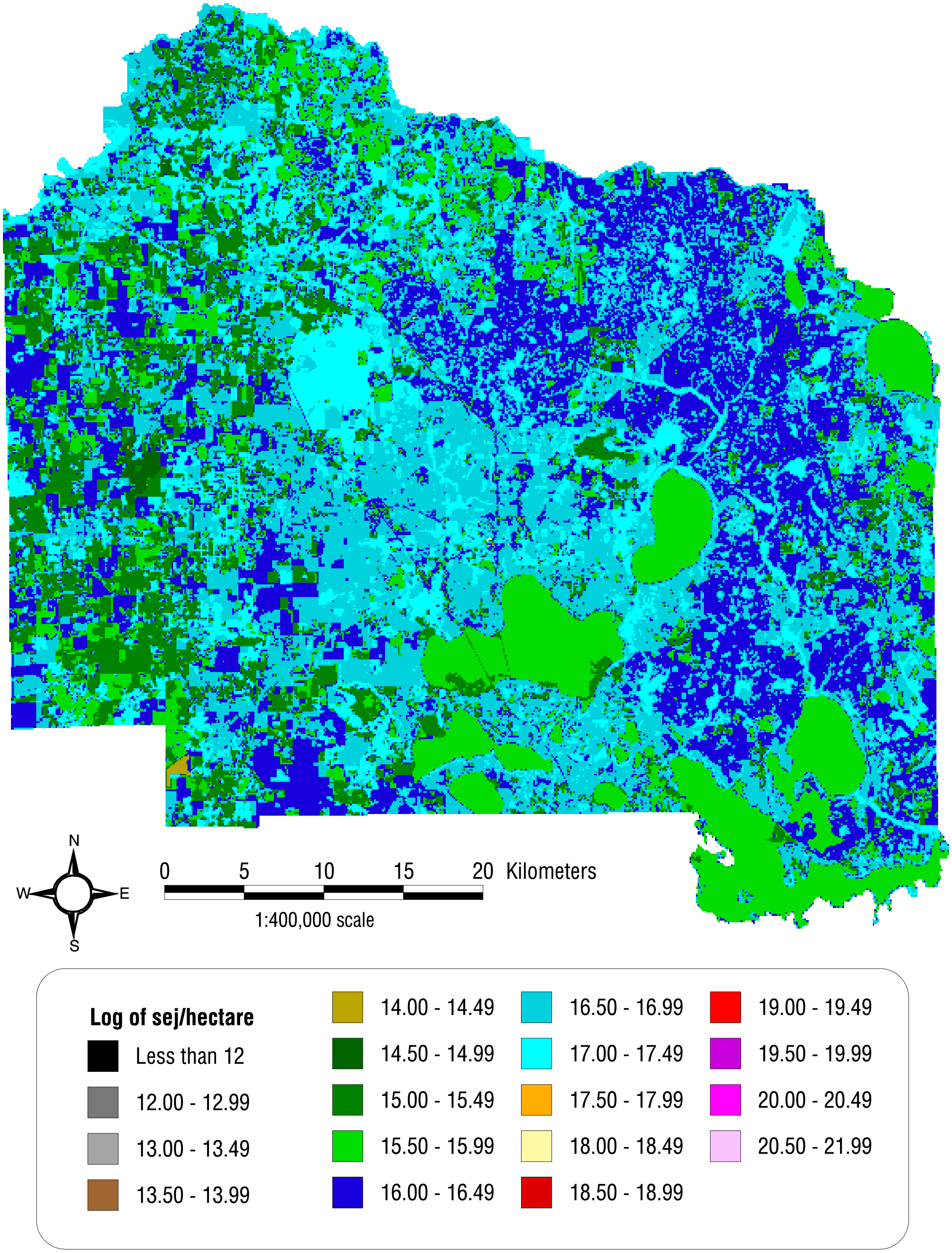


Figure 3-64: Map of the logarithm analytical EMERGY sub-component grid called 'biostr_log'. This grid represents the log of the EMSTORAGE density (log sej/ha) of the biomass in natural systems.

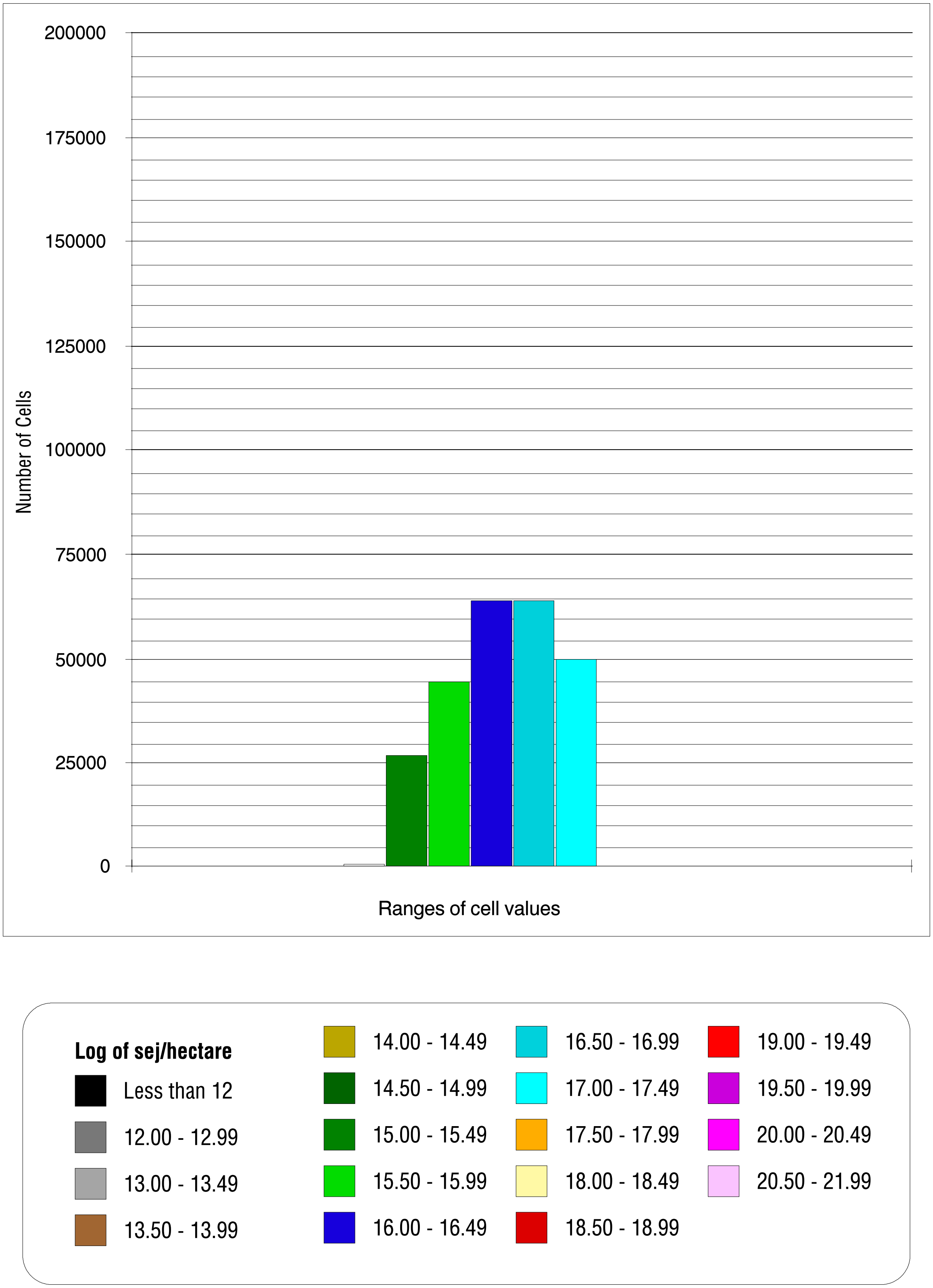


Figure 3-65: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY sub-component grid called 'biostr_log'.

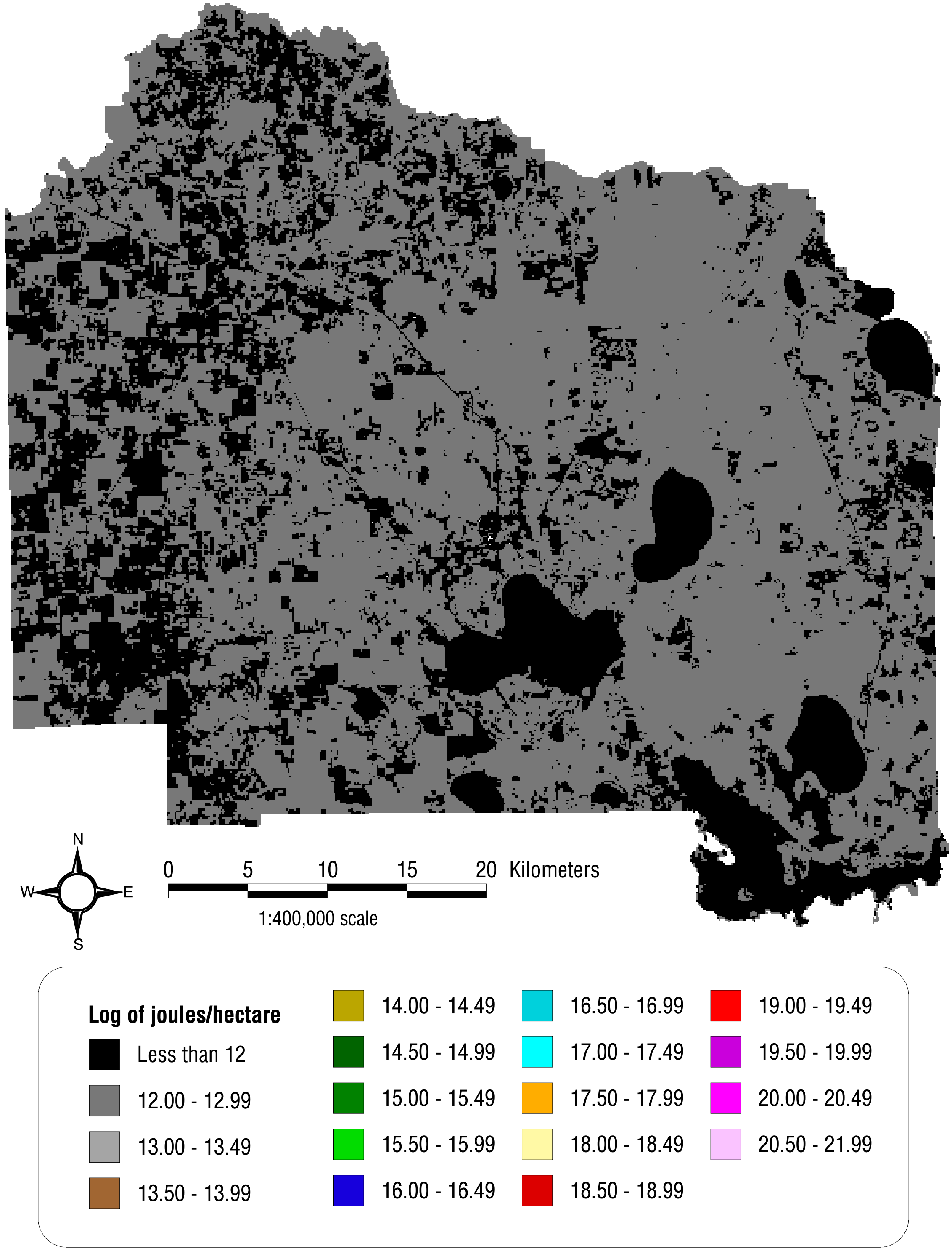
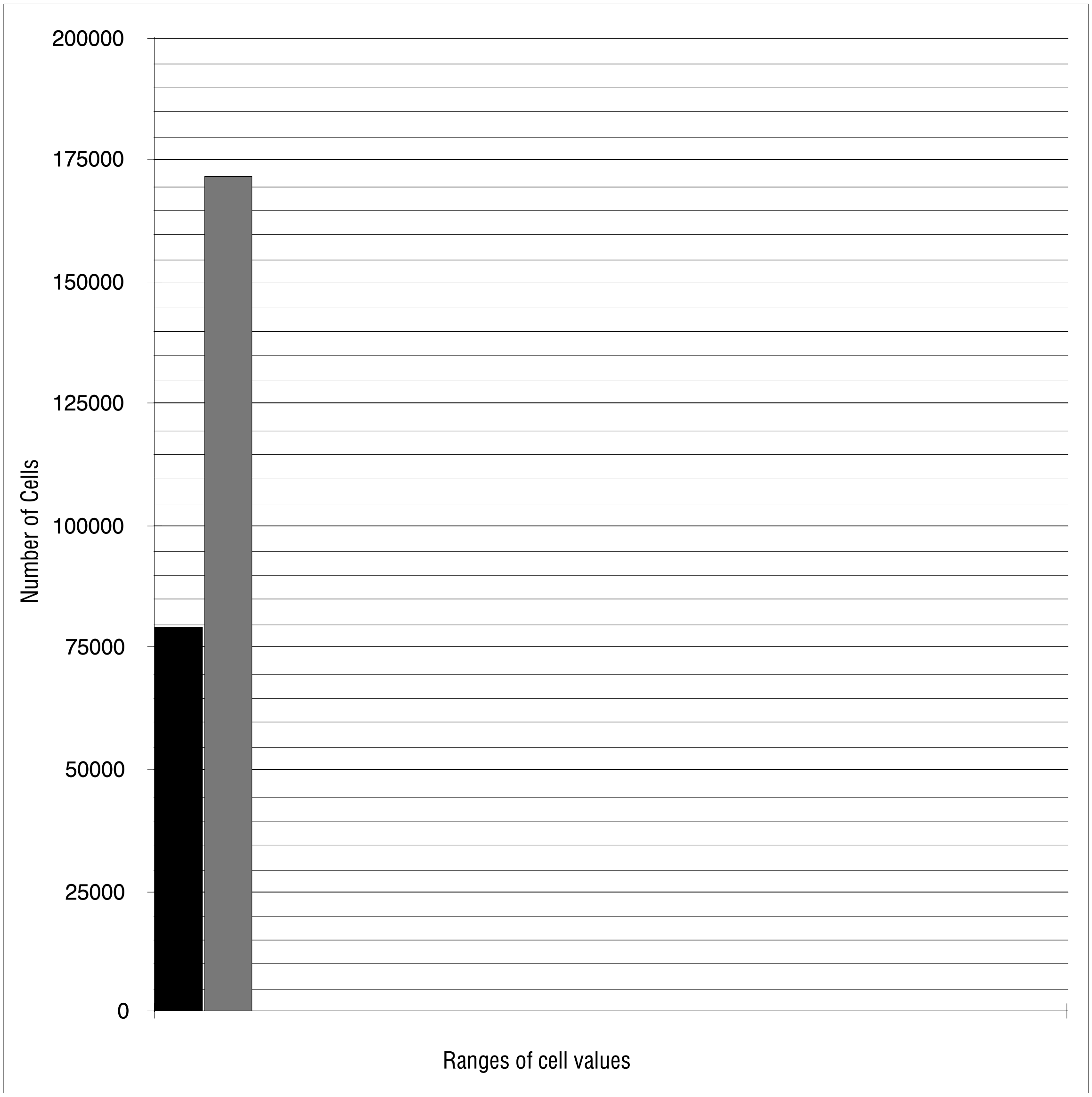


Figure 3-66: Map of the logarithm analytical energy sub-component grid called 'biostr_en_log'. This grid represents the log of the energy storage density (log j/ha) of the biomass in natural systems.



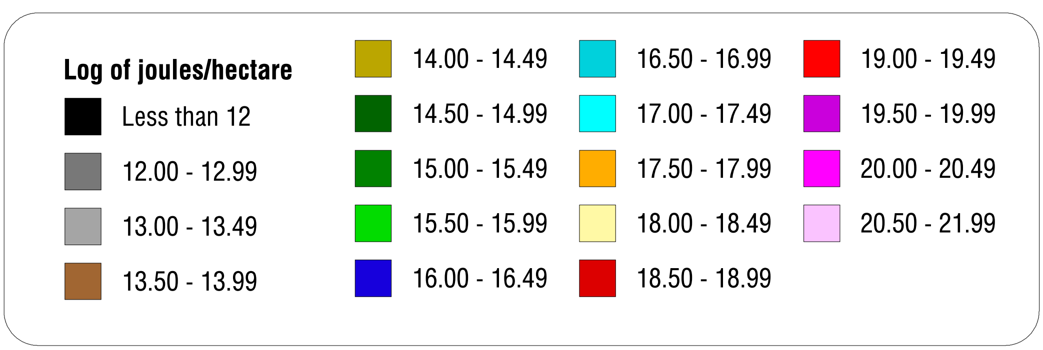


Figure 3-67: Histogram of the distribution of grid cell values found in the logarithm analytical energy sub-component grid called ’biostr_en_log’.

<u>Water storage subcomponent.</u> The total energy and EMERGY in stored water is the second subcomponent of the natural system structure component of the model (element #9b in Figure 1-3). This subcomponent grid was created by adding the two intermediate component grids representing surface water storage and groundwater storage. Although there is recognizable detail in the 'surface water storage' intermediate component grid, when the two grids are added together, these surface water feature details disappear. The calculations for groundwater storage assume that the same amount of groundwater is available throughout the county, thus the values in the EMERGY subcomponent grid all fall within the same range.

A map of the logarithm analytical EMERGY component grid called 'wtrstr_log' is shown in Figure 3-68 and a histogram of the number of cells within each range of log values is shown in Figure 3-69. As noted above, the cell distribution histogram reveals that the values in the EMERGY map are within the range of 16.5 to 17 log sej/ha. A map of the logarithm analytical energy component grid called 'wtrstr_en_log' is shown in Figure 3-70, and the associated histogram is shown in Figure 3-71.

<u>Organic matter storage subcomponent.</u> The total energy and EMERGY stored in the organic matter in soils is the third subcomponent of natural system structure in this model (element #9c in Figure 1-3). The Alachua County Soil Survey map was used to calculate the amount of soil organic matter present in the top half-meter of soil. Using the same approach used for creating the biomass storage subcomponent grid, the areas of building and road 'footprints' were assigned zero values for the quantity of organic matter available. A map of the logarithm analytical EMERGY component grid called 'soilom_log' is shown in Figure 3-72 and a histogram of the number of cells within each

range of log values is shown in Figure 3-73. The cell distribution histogram reveals that approximately 80% of the values in the EMERGY map are within the range of 16.5 to 17.5 log sej/ha, with the lower values in that range found in the western edge of the county that is characterized by very sandy soil types. On the other hand, some wetland areas display higher values, in the range of 17.5 to 18.5 log sej/ha, as a result of large storages of peat. The map of the logarithm analytical energy component grid called 'soilom_en_log' is shown in Figure 3-74, and the associated histogram is shown in Figure 3-75. Once again, the value ranges in the standard legend are found to be inadequate for displaying the level of detail that is actually present in the energy subcomponent grid.

Natural structure component. This component represents total energy and EMERGY in natural system structure. The component grid was created by adding the biomass, water storage, and soil organic matter storage subcomponent grids (elements #9a, #9b, and #9c). A map of the logarithm analytical EMERGY component grid called 'natstr_log' is shown in Figure 3-76 and it's associated histogram is shown in Figure 3-77. The cell distribution histogram reveals that the values in the EMERGY map fall within the range of 16.5 to 18.5 log sej/ha. However, about 65% of the cells have values in the 17 to 17.5 log sej/ha range. This is due primarily to the values contributed by the soil organic matter subcomponent. In fact, 80% of the EMERGY storage values in the biomass subcomponent grid are below 17 log sej/ha. Therefore, some of the detailed patterns seen in the biomass subcomponent map are obscured in this component. A map of the logarithm analytical energy component grid called 'natstr_en_log' is shown in Figure 3-78, and the associated histogram is shown in Figure 3-79.

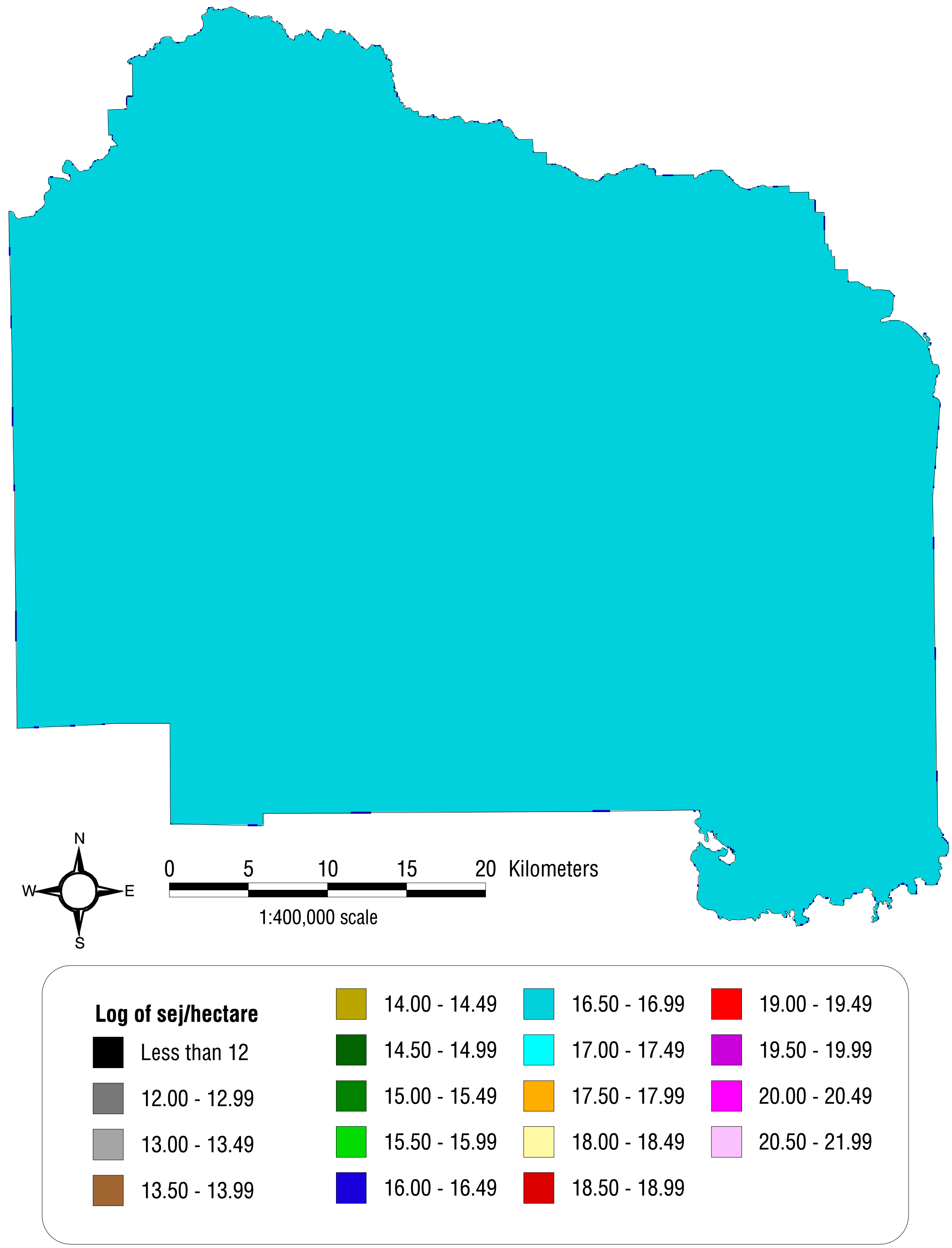
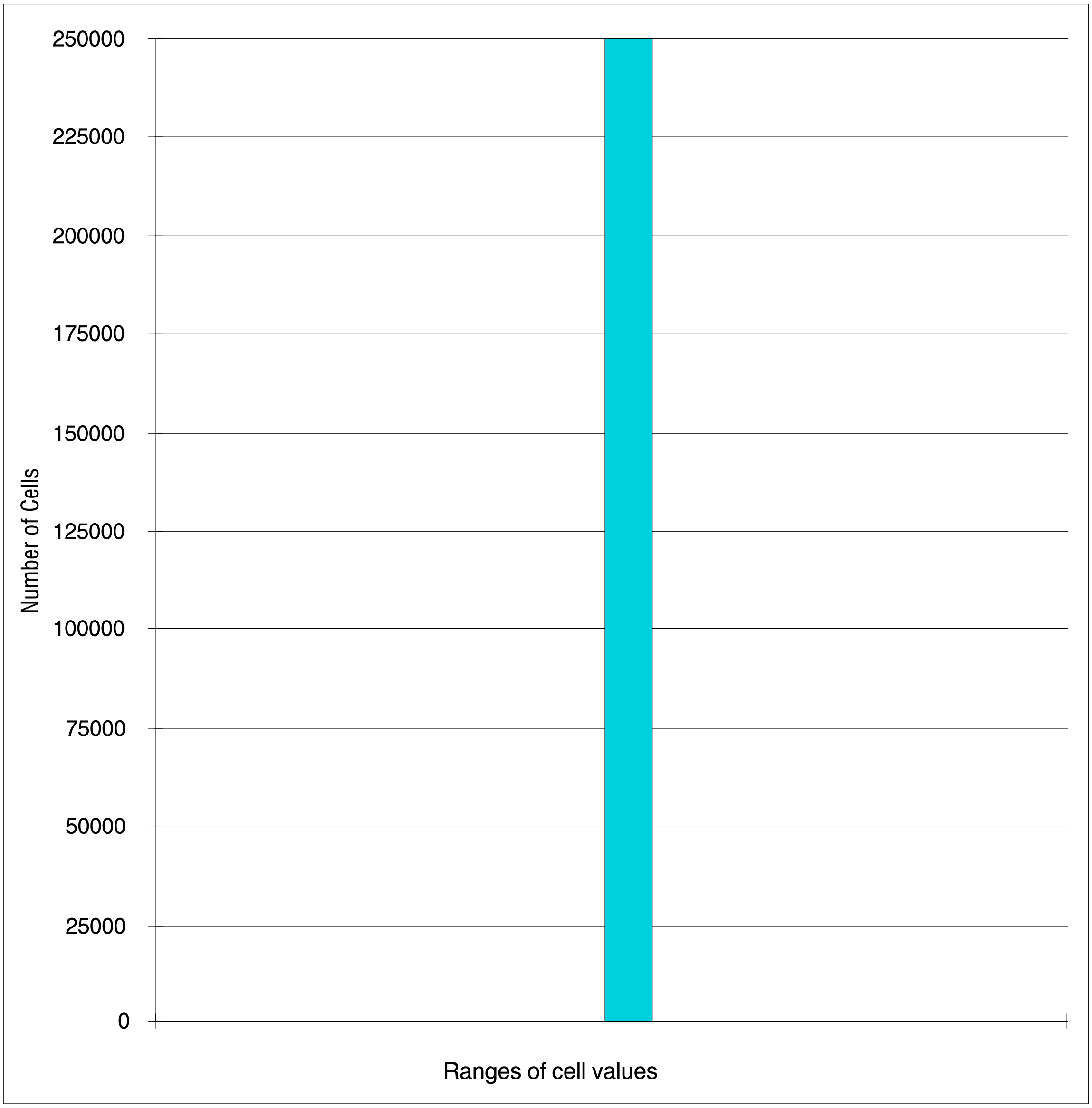


Figure 3-68: Map of the logarithm analytical EMERGY sub-component grid called 'wtrstr_log'. This grid represents the log of the EMSTORAGE density (log sej/ha) of the surface water and groundwater storages.



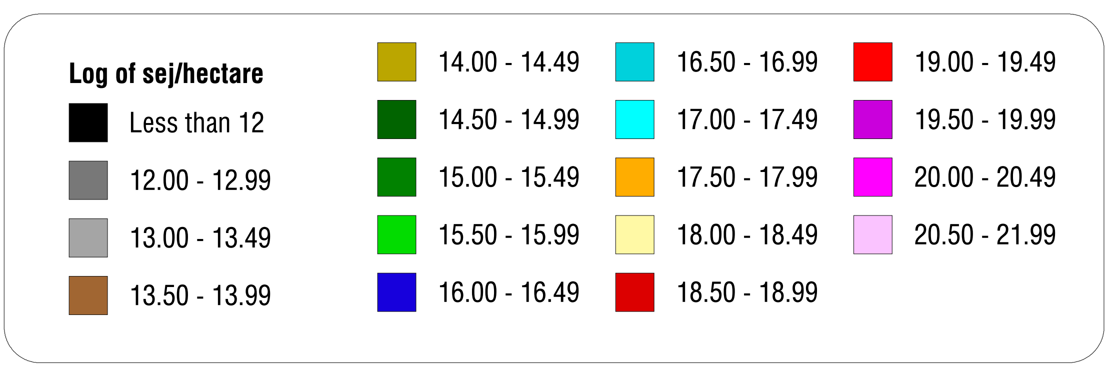


Figure 3-69: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY sub-component grid called 'wtrstr_log'.

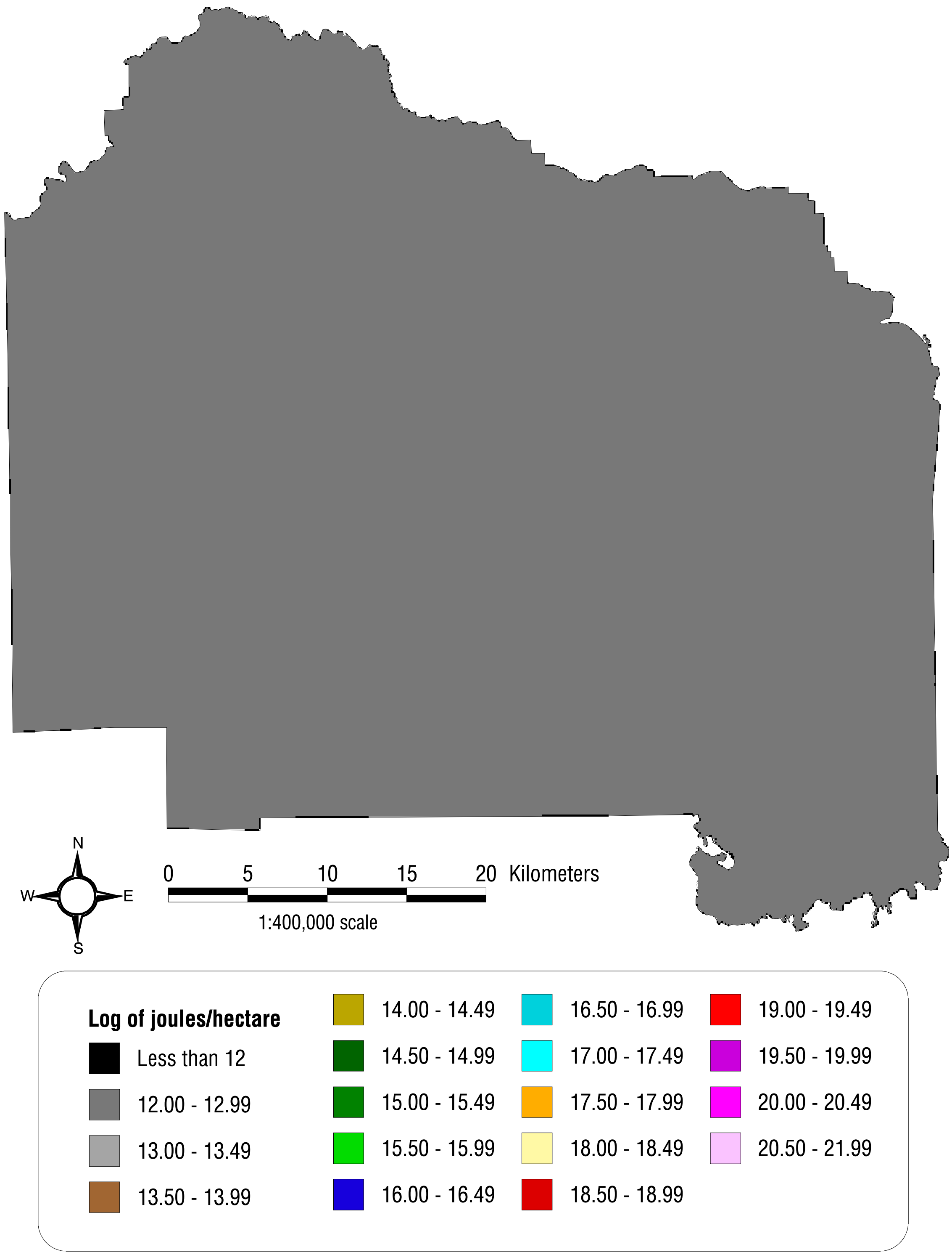


Figure 3-70: Map of the logarithm analytical energy sub-component grid called 'wtrstr_en_log'. This grid represents the log of the energy storage density (log j/ha) of the surface water and groundwater storages.

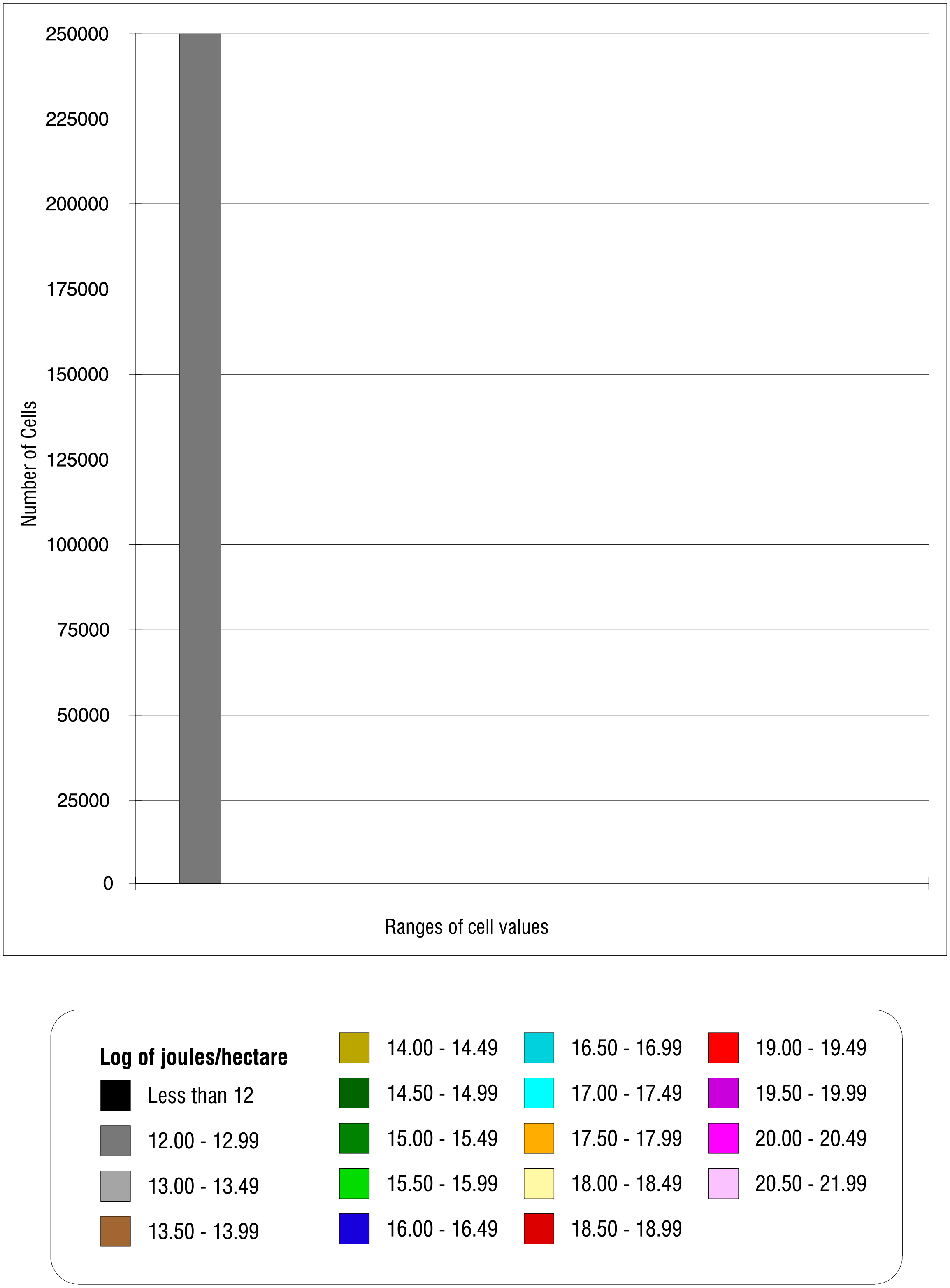


Figure 3-71: Histogram of the distribution of grid cell values found in the logarithm analytical energy subcomponent grid called 'wtrstr_en_log'.

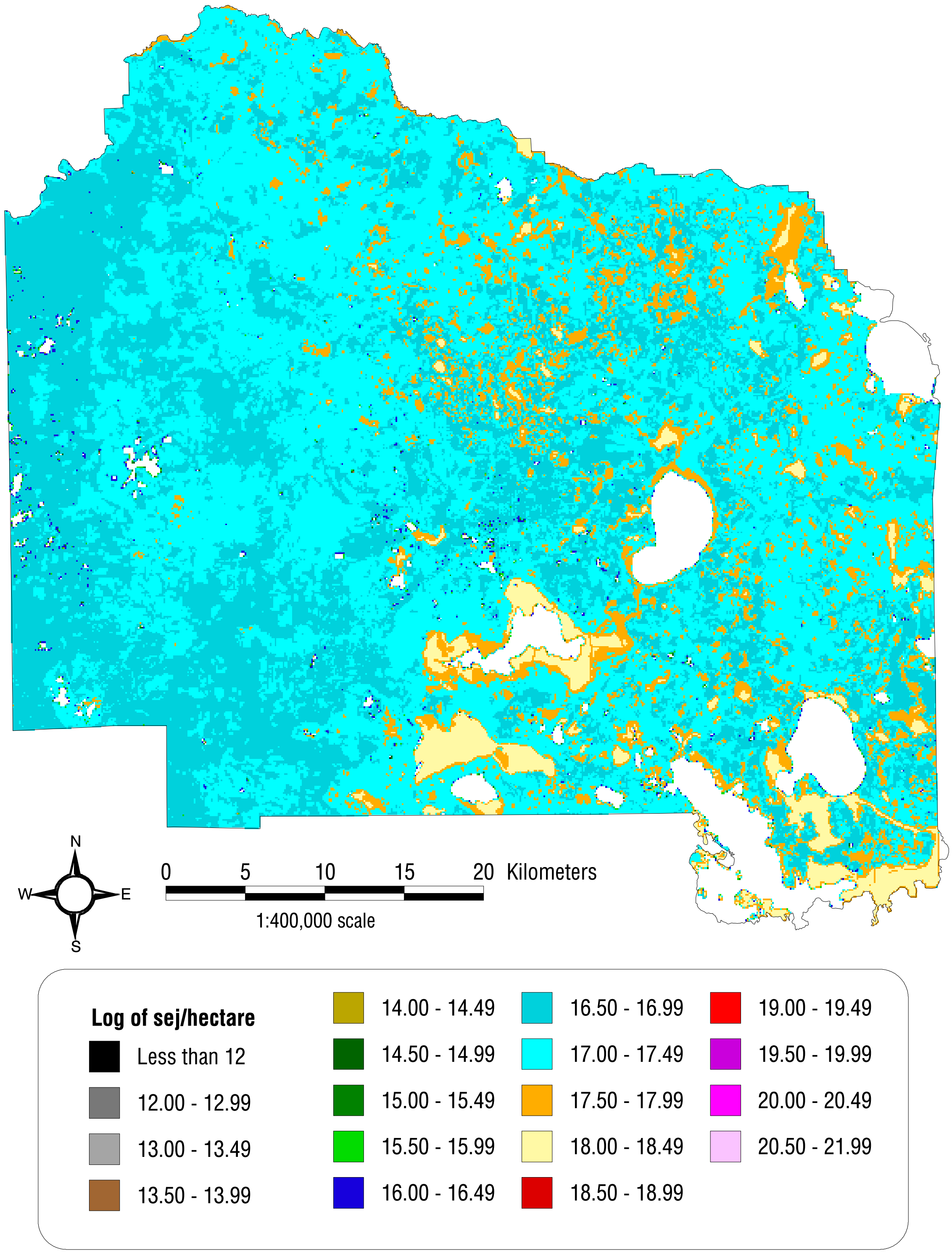


Figure 3-72: Map of the logarithm analytical EMERGY sub-component grid called 'soilom_log'. This grid represents the log of the EMSTORAGE density (log sej/ha) of the organic matter stored in soils.

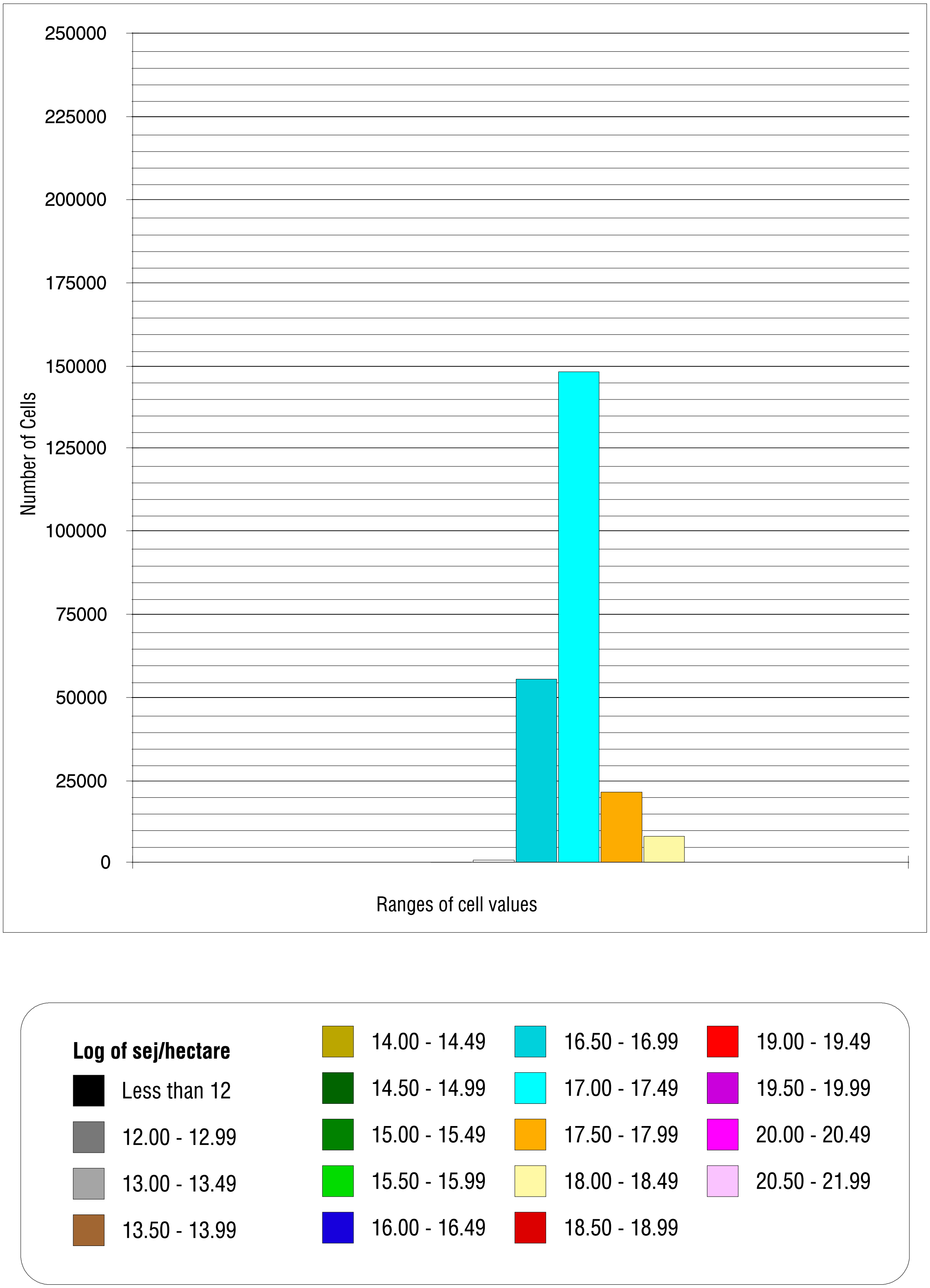


Figure 3-73: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY subcomponent grid called 'soilom_log'.

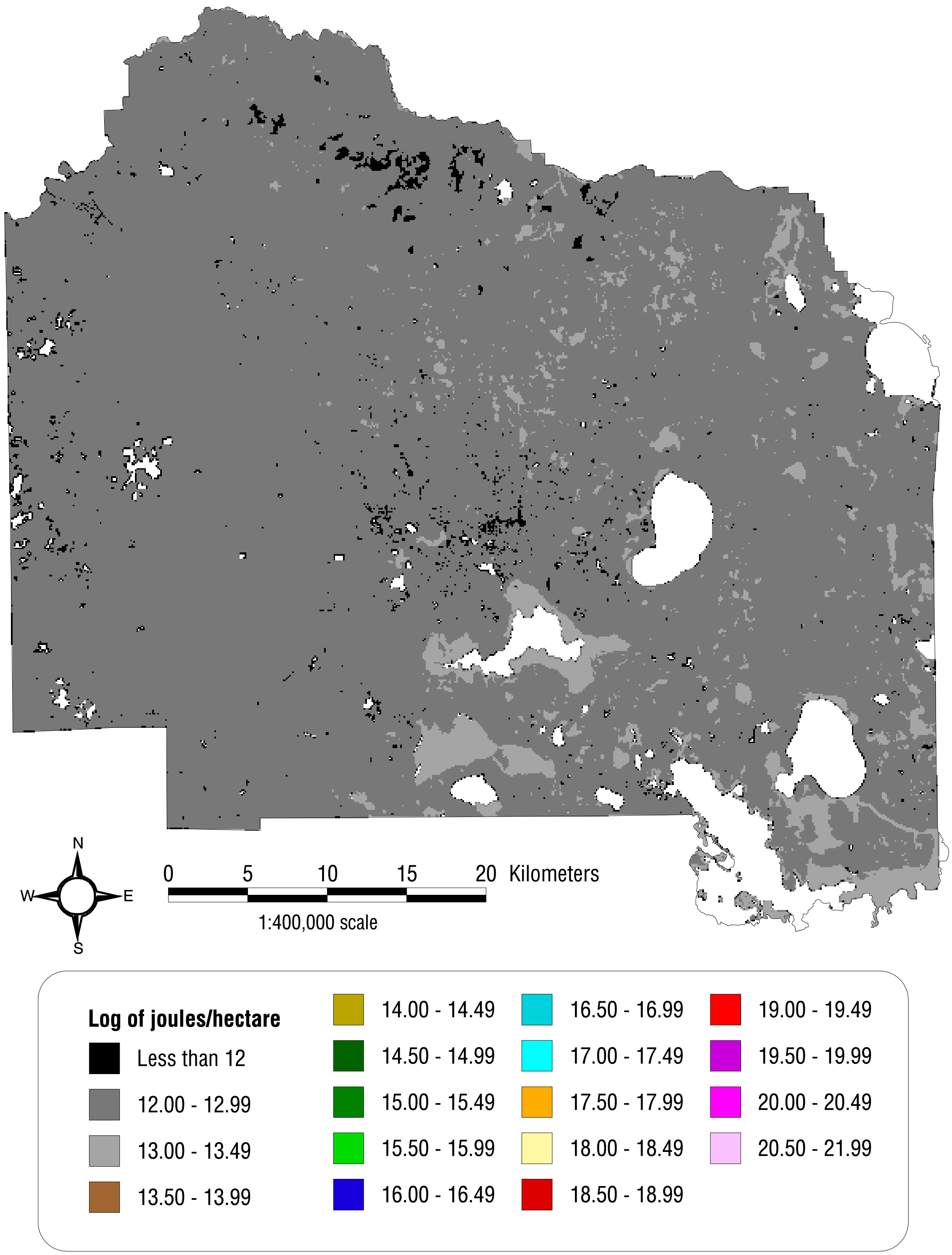


Figure 3-74: Map of the logarithm analytical energy sub-component grid called 'soilom_en_log'. This grid represents the log of the energy storage density (log j/ha) of the organic matter stored in soils.

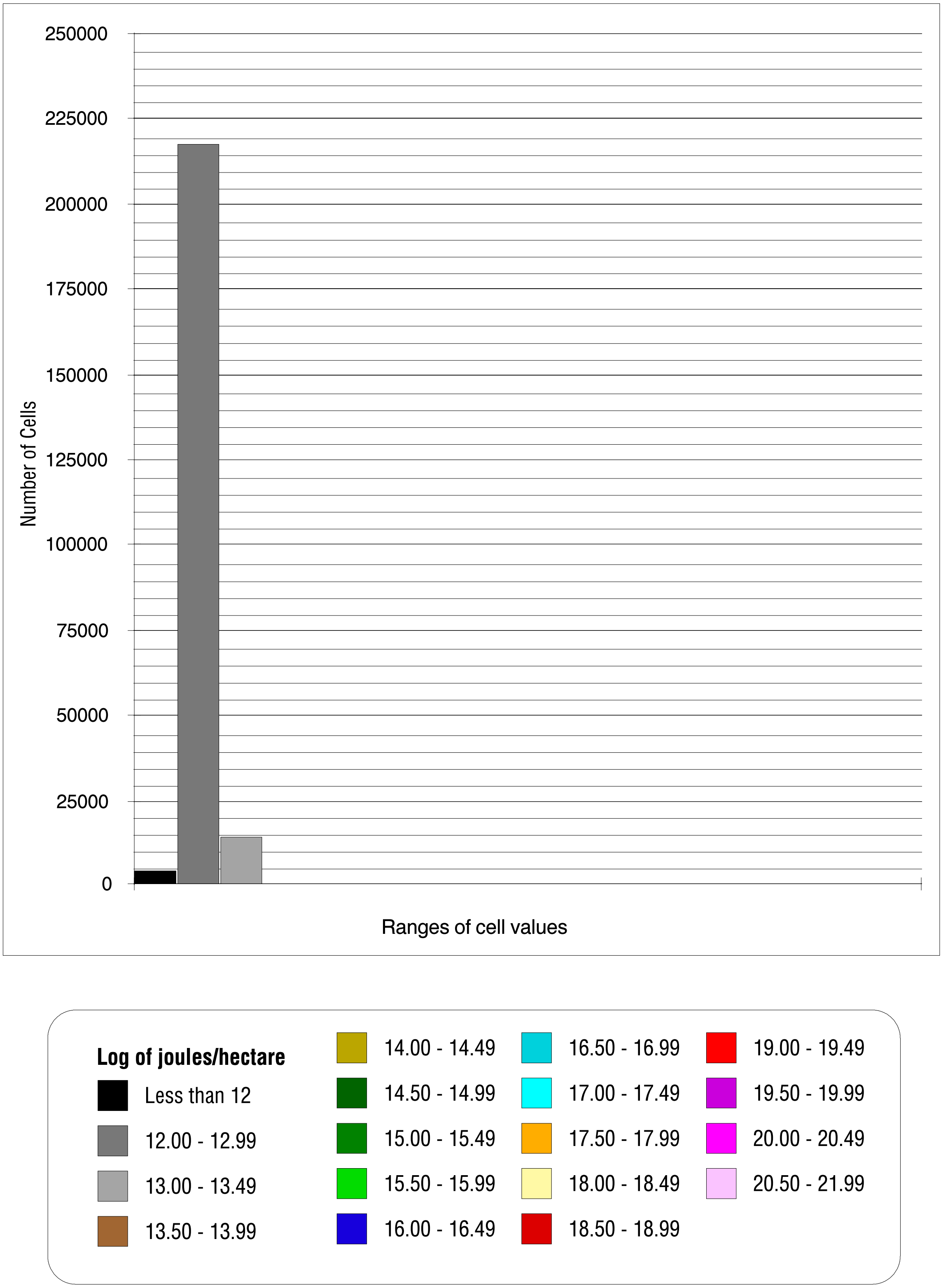


Figure 3-75: Histogram of the distribution of grid cell values found in the logarithm analytical energy subcomponent grid called 'soilom_en_log'.

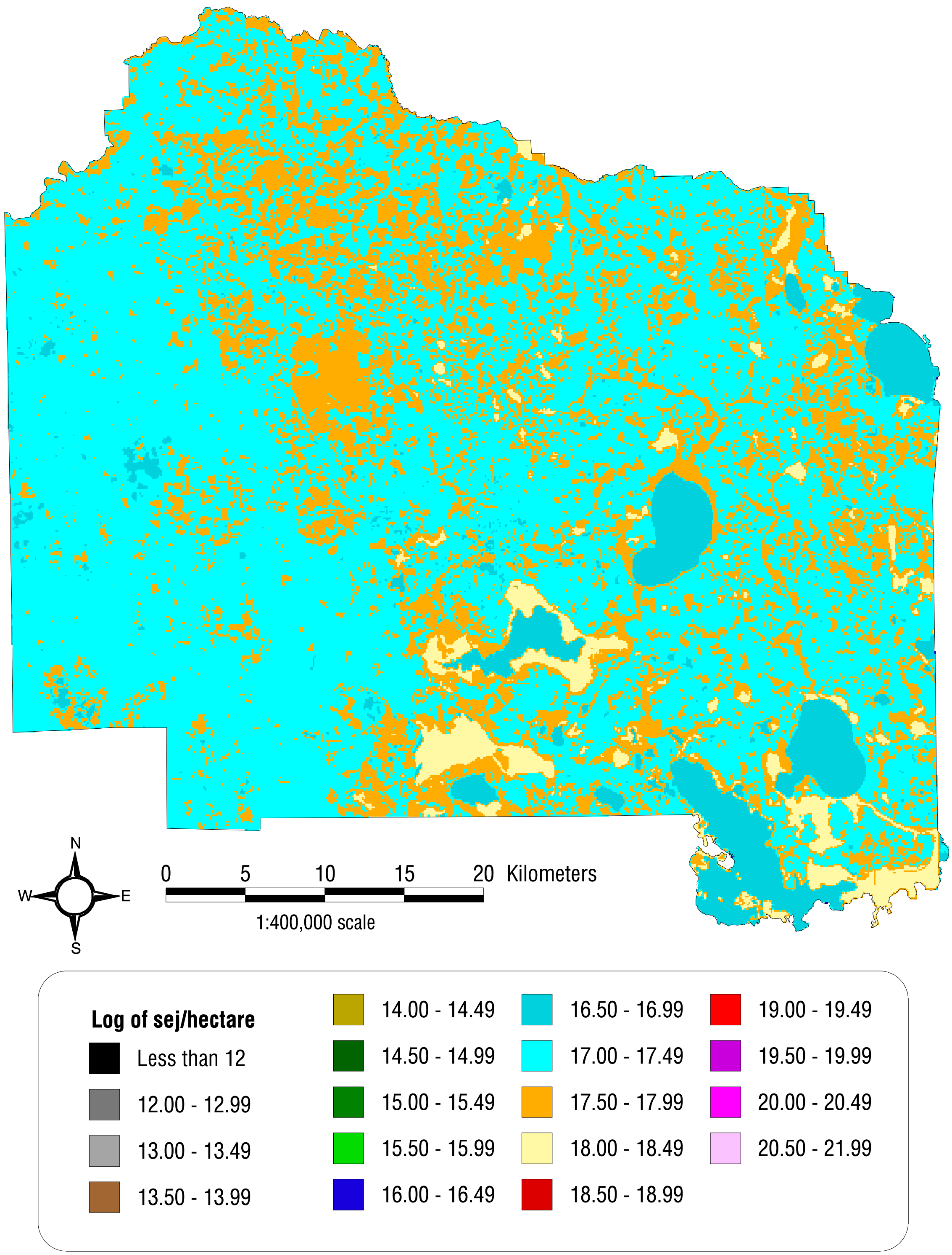


Figure 3-76: Map of the logarithm analytical EMERGY component grid called 'natstr_log'. This grid represents the log of the EMSTORAGE density (log sej/ha) of natural system structure (including storages of biomass, surface and ground water, and soil organics).

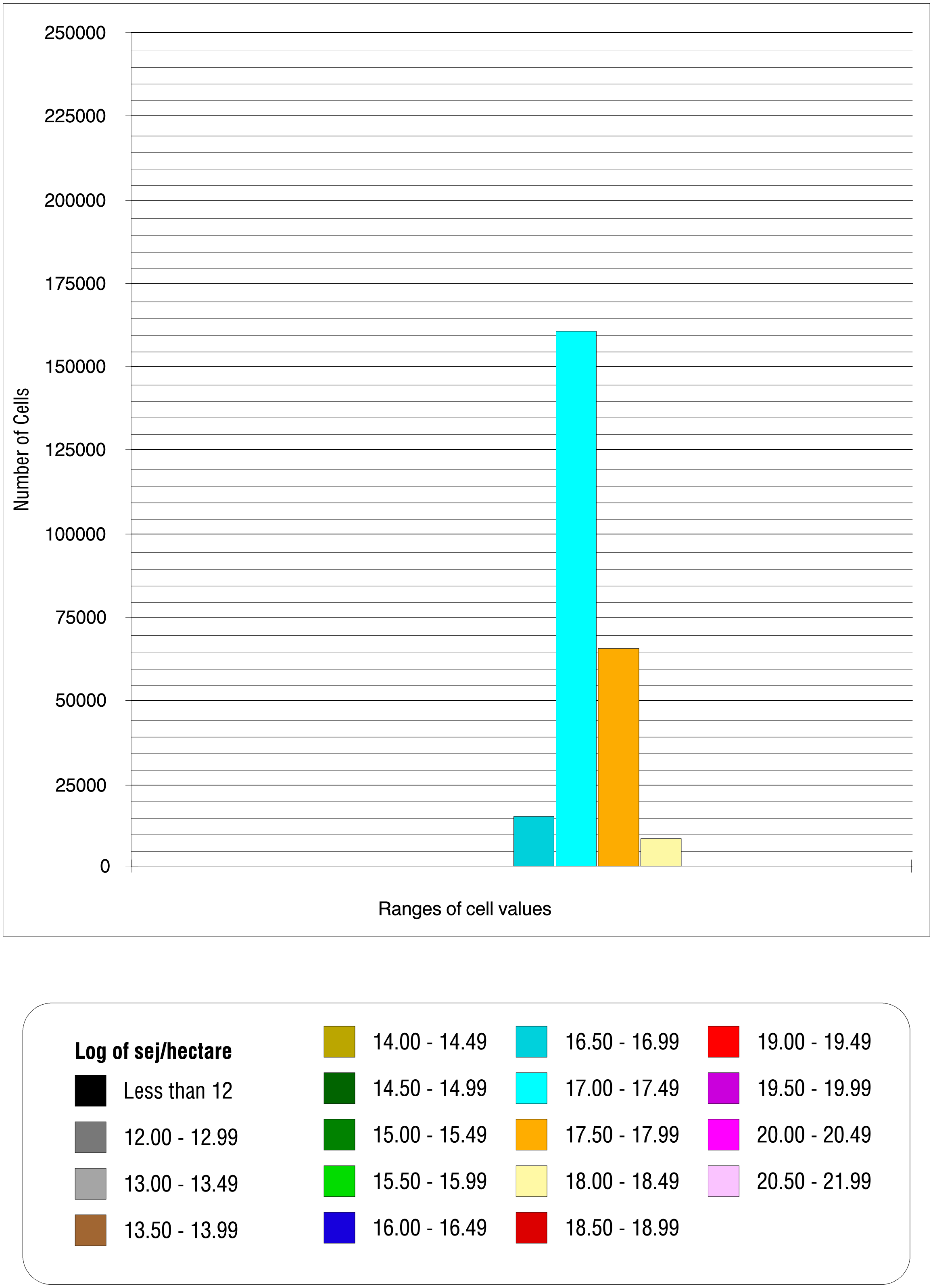


Figure 3-77: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called ’natstr_log’.

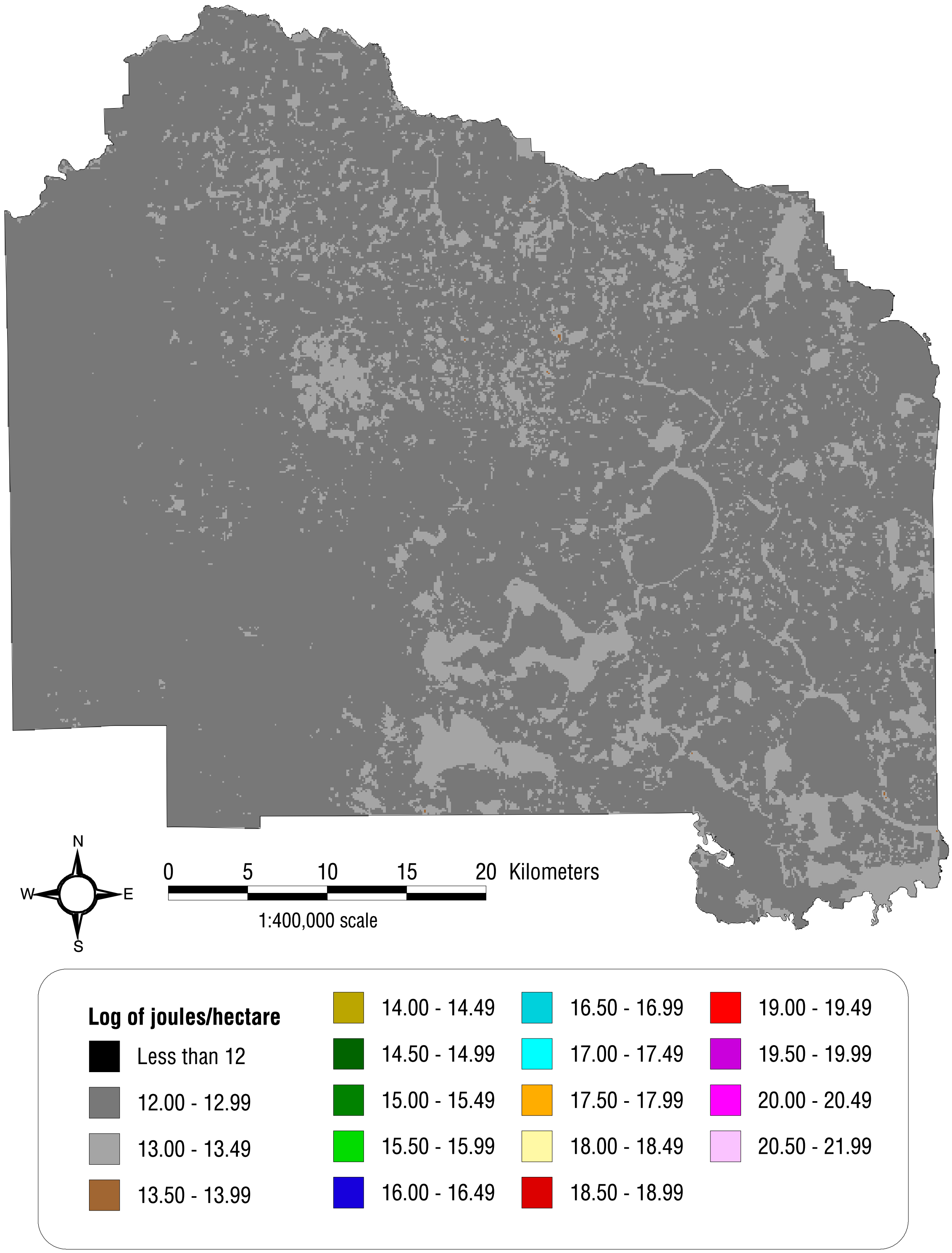


Figure 3-78: Map of the logarithm analytical energy component grid called 'natstr_en_log'. This grid represents the log of the energy storage density (log j/ha) of natural system structure (including storages of biomass, surface and ground water, and soil organic matter).

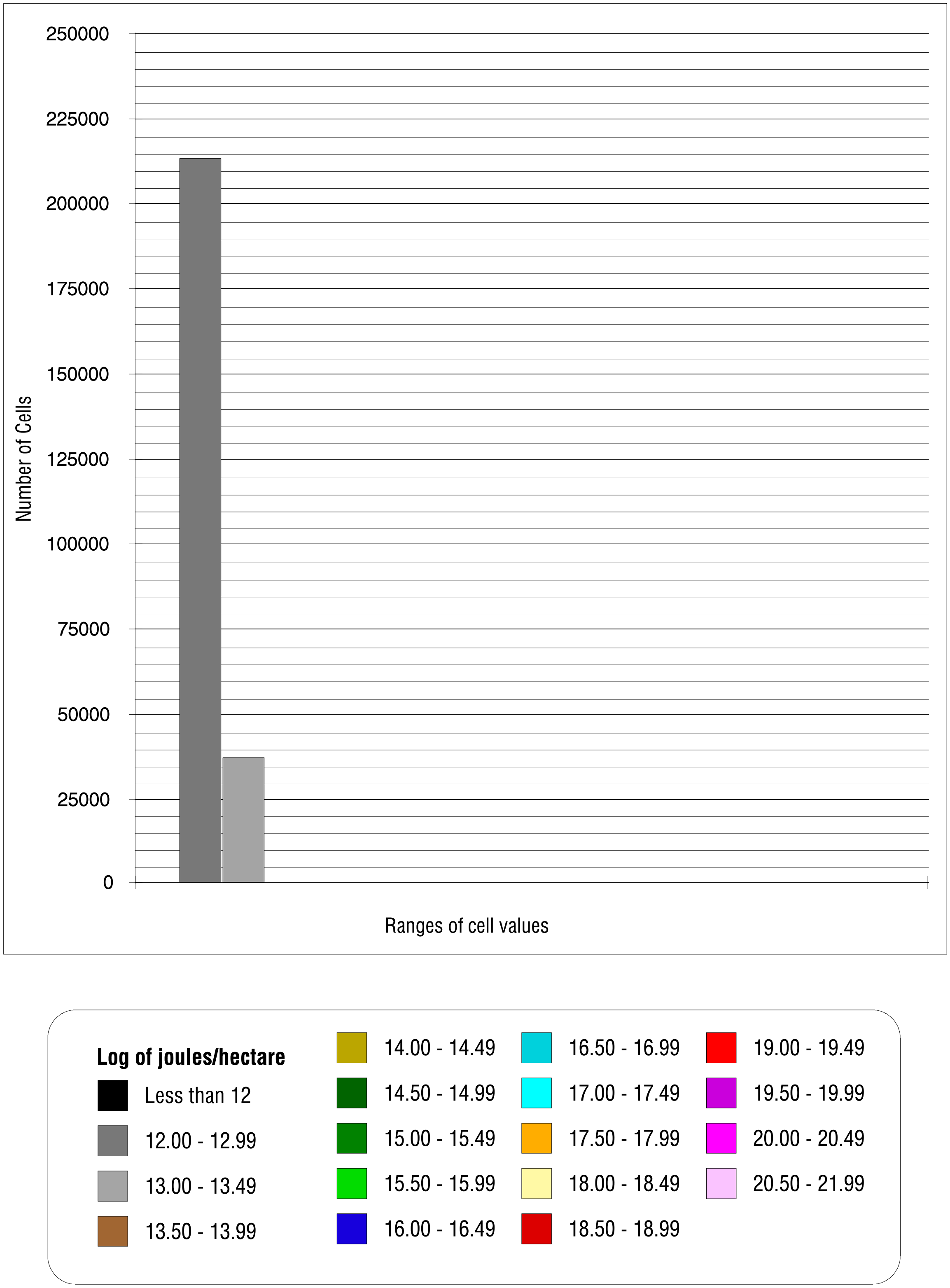


Figure 3-79: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'natstr_en_log'.

Building storage subcomponent. The total energy and EMERGY stored in buildings is the first subcomponent of the urban system structure component of the model (element #10a in Figure 1-3). The energy in building structures was estimated using Brown's estimates (1980) of energy in building structures and by assigning proportional amounts of construction materials used to categories of buildings. The figures and calculations used for these estimates are found in Table 3-18. As discussed in the methods section, the EMERGY of building structure was based on the EMERGY per dollar ratio for the index year.

A map of the logarithm analytical EMERGY component grid called 'bldg_log' is shown in Figure 3-80 and a histogram of the number of cells within each range of log values is shown in Figure 3-81. The cell distribution histogram reveals that most of the values in the EMERGY map in low-density residential and rural areas are within the range of 15 to 17 log sej/ha with about 60% of the cells in this range having values between 16.5 and 17 log sej/ha. Medium-density residential areas are characterized by values in the 17 to 18 log sej/ha range. Only about 3% of the cells have values greater than 18 log sej/ha. Notably, these high value cells are found in the area of the University of Florida campus, in the downtown Gainesville government building complex area, and in the major commercial and shopping areas. The highest values, in the range of 19.5 to 20.5 log sej/ha, are found in the Shands Medical Center complex area. A map of the logarithm analytical energy component grid called 'bldg_en_log' is shown in Figure 3-82, and the associated histogram is shown in Figure 3-83.

Road infrastructure subcomponent. The total energy and EMERGY stored in roads is the second subcomponent of the urban system structure component of the model (element #10b in Figure 1-3). EMERGY in road structures was based on estimates of road construction costs for each FDOT functional classification (using data from FDOT (1994) and CUTR (1994)) that are listed in Table 3-19. Calculations of the energy in road structure were based on estimates for the chemical potential energy in the materials used to build the roads.

A map of the logarithm analytical EMERGY component grid called ‘road_log’ is shown in Figure 3-84 and a histogram of the number of cells within each range of log values is shown in Figure 3-85. As expected, the pattern displayed in the EMERGY map reflects the pattern of the road infrastructure. Approximately 54% of the values in the EMERGY map are within the range of 16.5 to 17 log sej/ha. These values are associated with residential and secondary roads. About 13% of the cells have values in the 17 to 17.5 sej/ha range. This range corresponds to the primary road system and some high-density land use areas. A map of the logarithm analytical energy component grid called ‘road_en_log’ is shown in Figure 3-86, and its histogram is shown in Figure 30-87.

<u>Utility infrastructure subcomponent.</u> The total energy and EMERGY stored in utility infrastructure is the third subcomponent of the urban system structure component of the model (element #10c in Figure 1-3). Calculations used to create this subcomponent grid were based on estimates of the dollar value per meter of distribution lines according to the class of utility infrastructure. Table 3-20 lists the estimates used for these calculations.

A map of the logarithm analytical EMERGY component grid called ‘util_log’ is shown in Figure 3-88 and a histogram of the number of cells within each range of log values is shown in Figure 3-89. The pattern observed in the EMERGY component map reflects the fact that road line features were used to estimate the location of utility distribution lines in the areas of the County that are outside the GRU service area. The cell distribution histogram reveals that 92% of the cells have values between 16 and 17.5 sej/ha, and that 67% of the values in the EMERGY map are within the narrower range of 16.5 to 17 log sej/ha. A map of the logarithm analytical energy component grid called 'util_en_log' is shown in Figure 3-90, and the associated cell distribution histogram is shown in Figure 3-91.

Urban structure component. This component represents the total energy and EMERGY in urban systems structure. The component grid was created by adding the buildings, roads, and utility infrastructure subcomponent grids (elements #10a, #10b, and #10c in Figure 1-3).

A map of the logarithm analytical EMERGY component grid called 'urbstr_log' is shown in Figure 3-92 and a histogram of the number of cells within each range of log values is shown in Figure 3-93. The patterns observed in the map reflect the addition of the three subcomponent grids. Rural structural features, such as dirt roads and agricultural buildings, are included in this component (even though it is called the 'urban' structure component). Cells characterized only by these rural features have values between 14 and 16 sej/ha. Cells characterized primarily by road structure usually fall within 16.5 and 17.5 sej/ha. Medium-density residential areas have cell values between 17 and 18 sej/ha, commercial and industrial areas typically fall within the 18 to 19 sej/ha range, and the highest values, 18.5 to 20.5 sej/ha, are found within the main campus area of the University. A map of the logarithm analytical energy component grid called 'urbstr_en_log' is shown in Figure 3-94, and it's histogram is shown in Figure 3-95.

Table 3-18: Estimates of energy in building structure by type and proportional amounts of construction materials used.

Building Type	Proportion of Wood/ Concrete	Energy in wood E7J/sq.ft.	Energy in concrete E7J/sq.ft.	Total energy E7J/sq.ft	Note
Single Family Residential	.38	17.70	.93	18.6	1
Multi-Family Residential	.41	19.10	.89	20.0	2
Commercial	.32	14.90	1.28	16.2	3
Industrial	.19	8.85	1.53	10.4	4
Multi-story Commercial and Institutional	.12	5.60	1.66	7.3	5

<u>Notes</u>

All data derived from Brown(1980).

1) Energy in Wood = (.38)(70 lb/ft2)(454 g/lb)(3.5 kcal/g)(4186 J/kcal)
   Energy in Concrete = (.62)(180 lb/ft2)(20 kcal/lb)(4186 J/kcal)
2) Energy in Wood = (.41)(70 lb/ft2)(454 g/lb)(3.5 kcal/g)(4186 J/kcal)
   Energy in Concrete = (.59)(180 lb/ft2)(20 kcal/lb)(4186 J/kcal)
3) Energy in Wood = (.32)(70 lb/ft2)(454 g/lb)(3.5 kcal/g)(4186 J/kcal)
   Energy in Concrete = (.68)(225 lb/ft2)(20 kcal/lb)(4186 J/kcal)
4) Energy in Wood = (.19)(70 lb/ft2)(454 g/lb)(3.5 kcal/g)(4186 J/kcal)
   Energy in Concrete = (.81)(225 lb/ft2)(20 kcal/lb)(4186 J/kcal)
5) Energy in Wood = (.12)(70 lb/ft2)(454 g/lb)(3.5 kcal/g)(4186 J/kcal)
   Energy in Concrete = (.88)(225 lb/ft2)(20 kcal/lb)(4186 J/kcal)

Table 3-19: Estimated construction costs for building a mile of road by FDOT functional classification. The estimates are based on data from FDOT (1994) and CUTR (1994).

FDOT Functional Classification	Estimated Construction Costs ($/mile)	$/meter/lane	Source
Interstate	2,059,200	319.88	FDOT, 1994
Urban Principal Arterial	1,760,000	273.40	FDOT, 1994
Rural Principal Arterial	1,531,200	237.86	FDOT, 1994
Urban Minor Arterial	1,760,000	273.40	FDOT, 1994
Rural Minor Arterial	1,531,200	237.40	FDOT, 1994
Urban/Rural Major Collector	700,000	217.48	ADOT, 1995
Urban/Rural Minor Collector	700,000	217.48	ADOT, 1995
Urban/Rural Local	700,000	217.48	ADOT, 1995
Graded/Limerock	10,000	3.11	Estimated

Table 3-20: Estimated dollar value per meter of distribution line according to class of utility infrastructure.

Infrastructure Class	Dollar Value, $/meter
Electric Only	241.61
Electric and Water	374.79
Electric and Gas	258.60
Electric, Water, and Gas	391.78

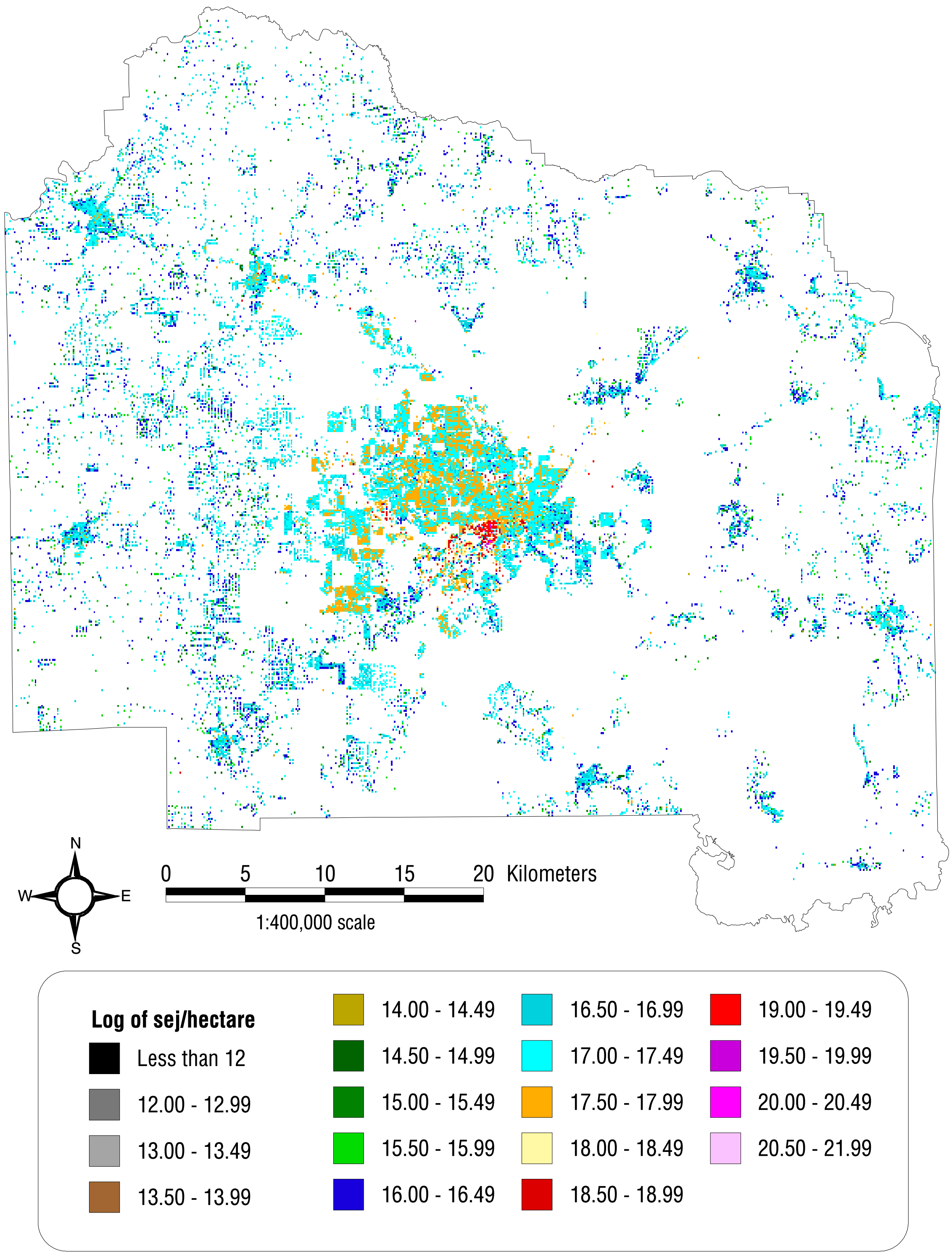


Figure 3-80: Map of the logarithm analytical EMERGY subcomponent grid called 'bldg_log'. This grid represents the log of the EMSTORAGE density (log sej/ha) of all buildings (including residential, institutional, and commercial) and miscellaneous built structures.

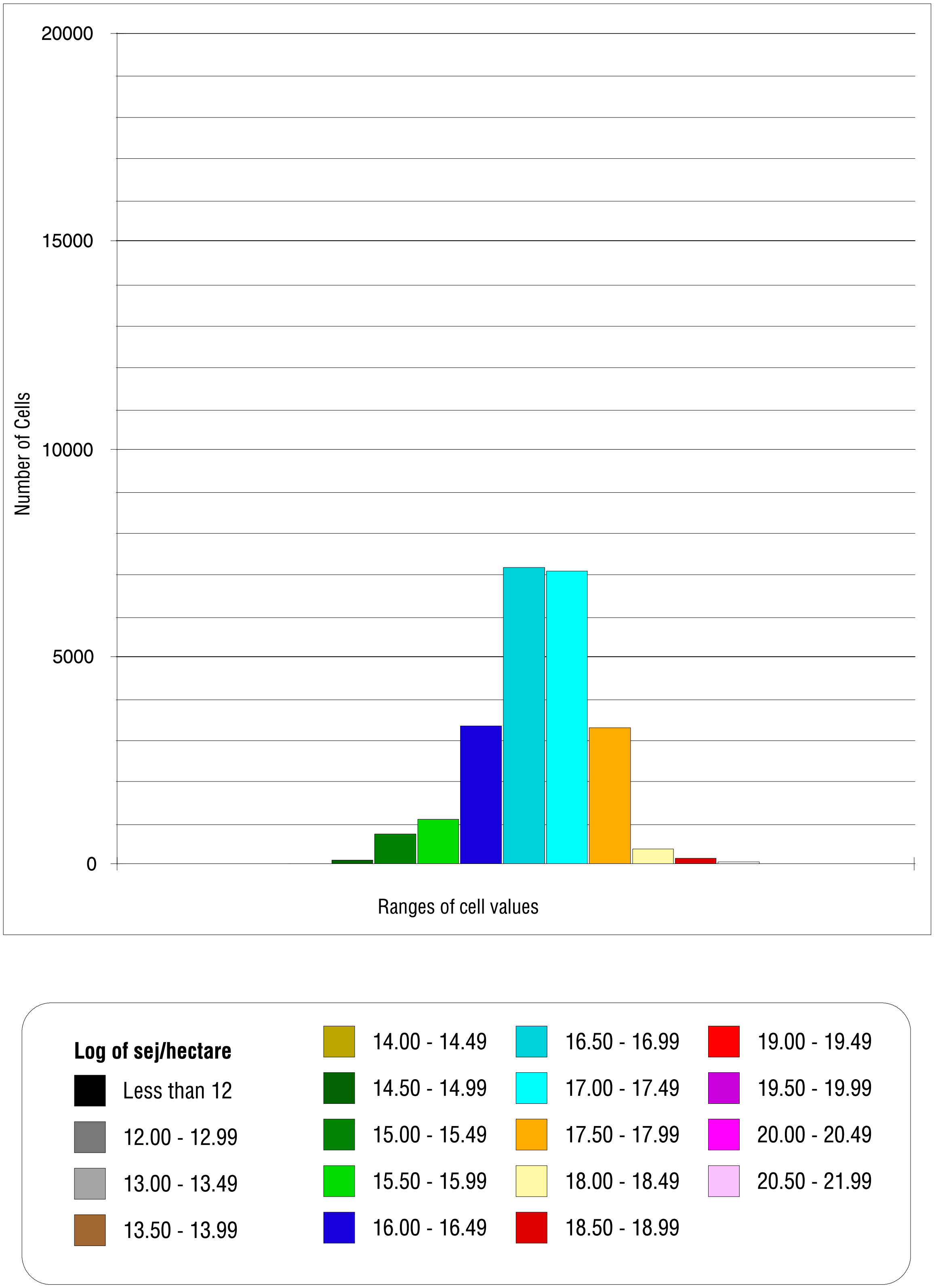


Figure 3-81: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY subcomponent grid called 'bldg_log'.

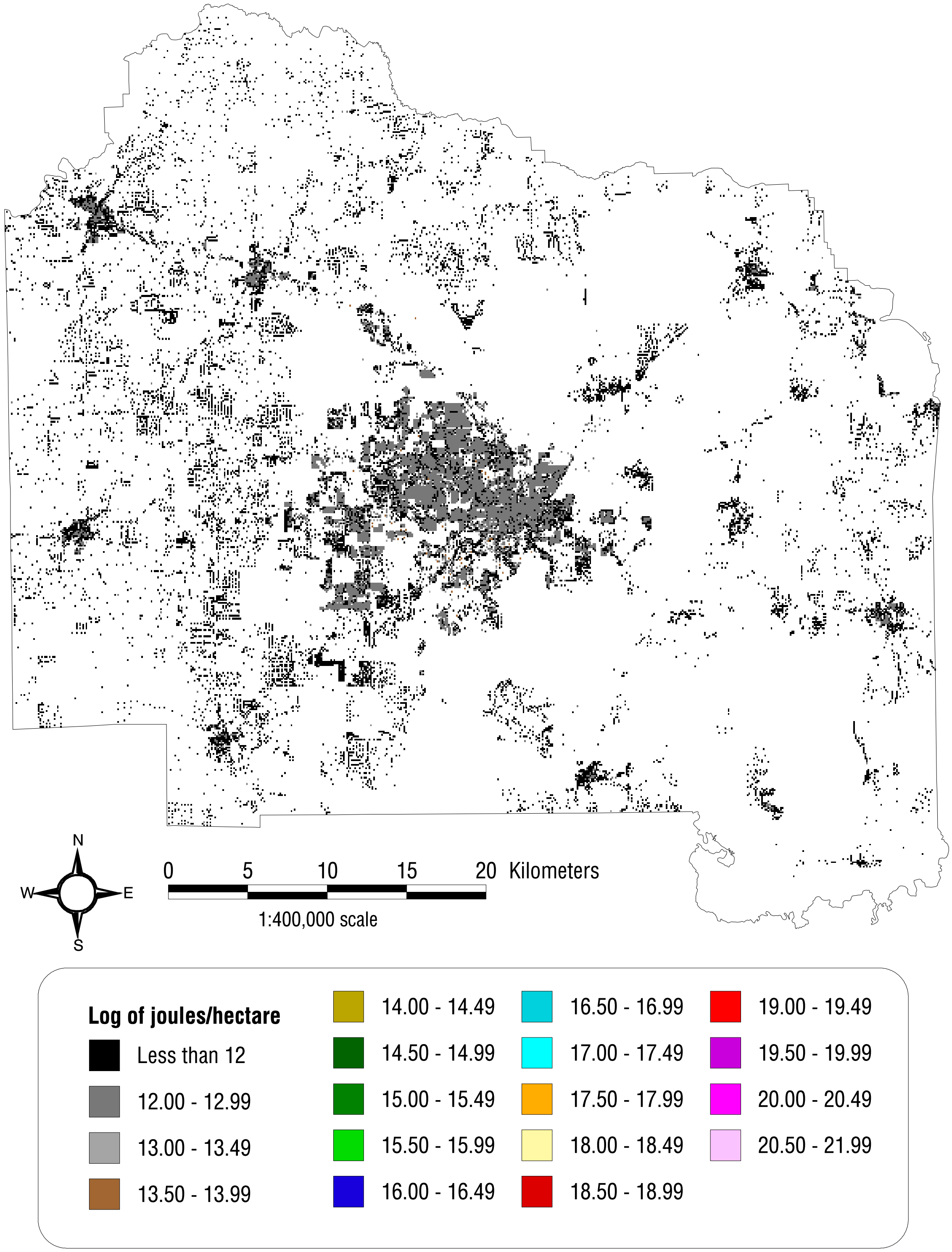


Figure 3-82: Map of the logarithm analytical energy subcomponent grid called 'bldg_en_log'. This grid represents the log of the energy storage density (log j/ha) of all buildings (including residential, institutional, and commercial) and miscellaneous built structures.

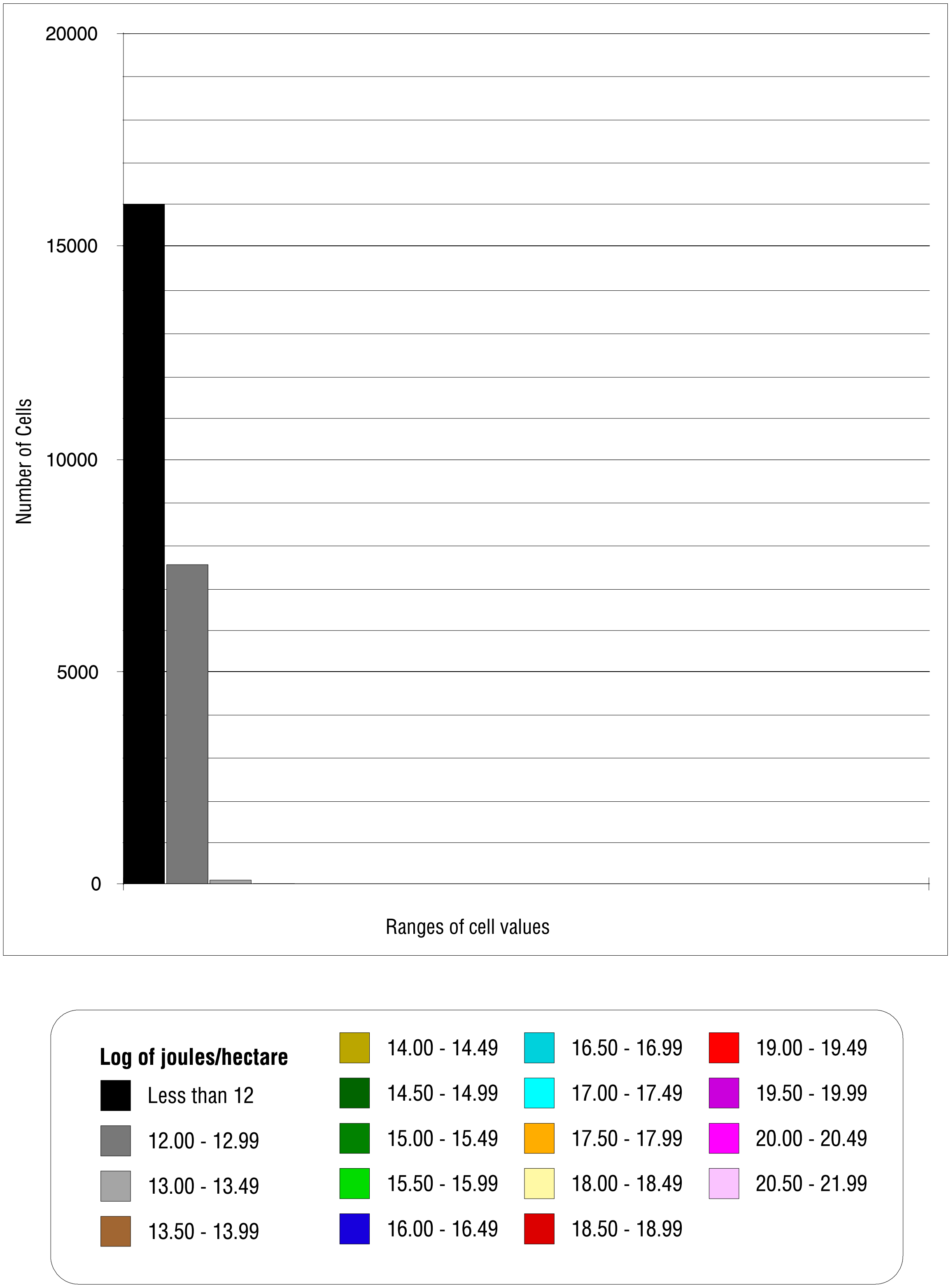


Figure 3-83: Histogram of the distribution of grid cell values found in the logarithm analytical energy subcomponent grid called 'bldg_en_log'.

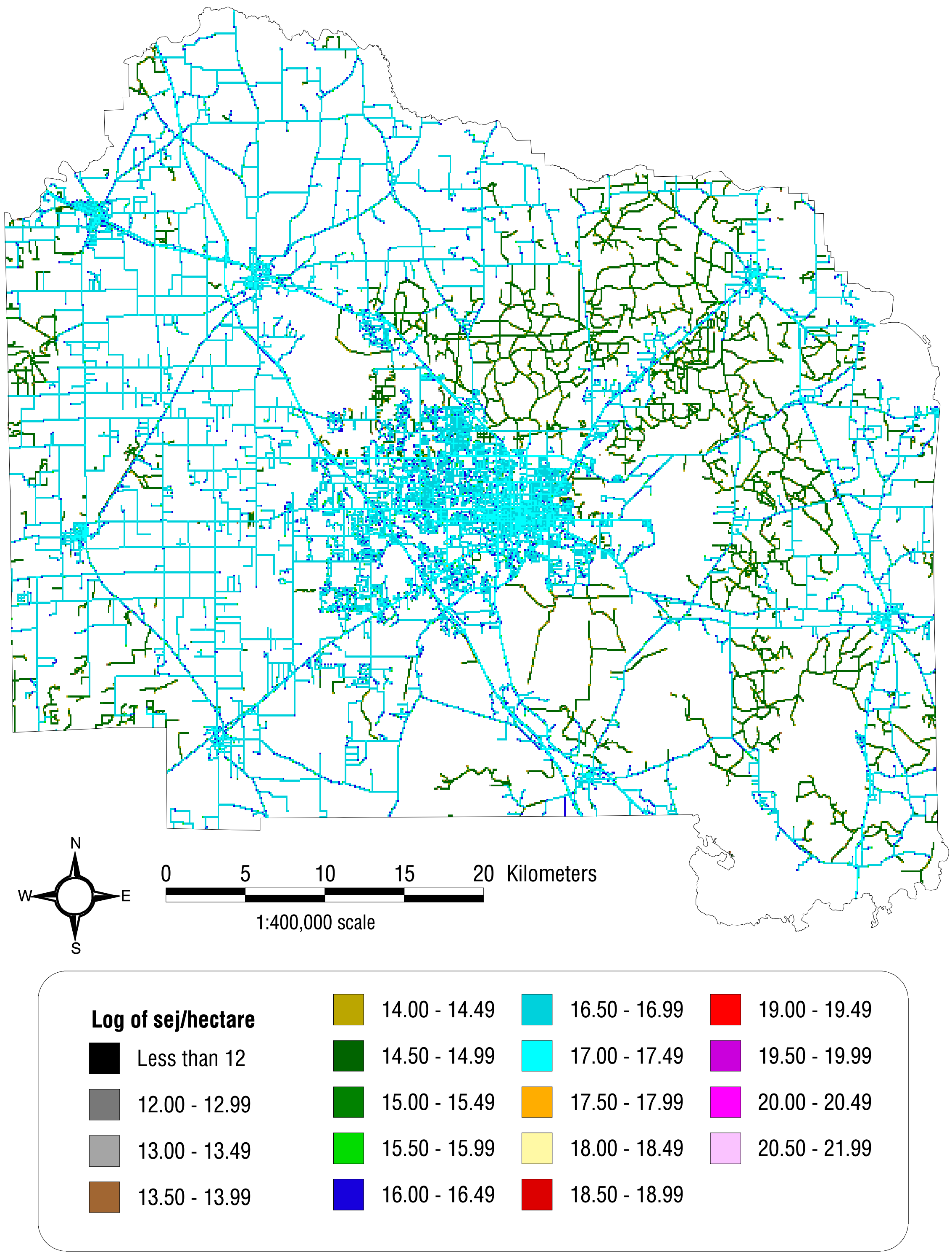


Figure 3-84: Map of the logarithm analytical EMERGY subcomponent grid called 'road_log'. This grid represents the log of the EMSTORAGE density (log sej/ha) of all road structures.

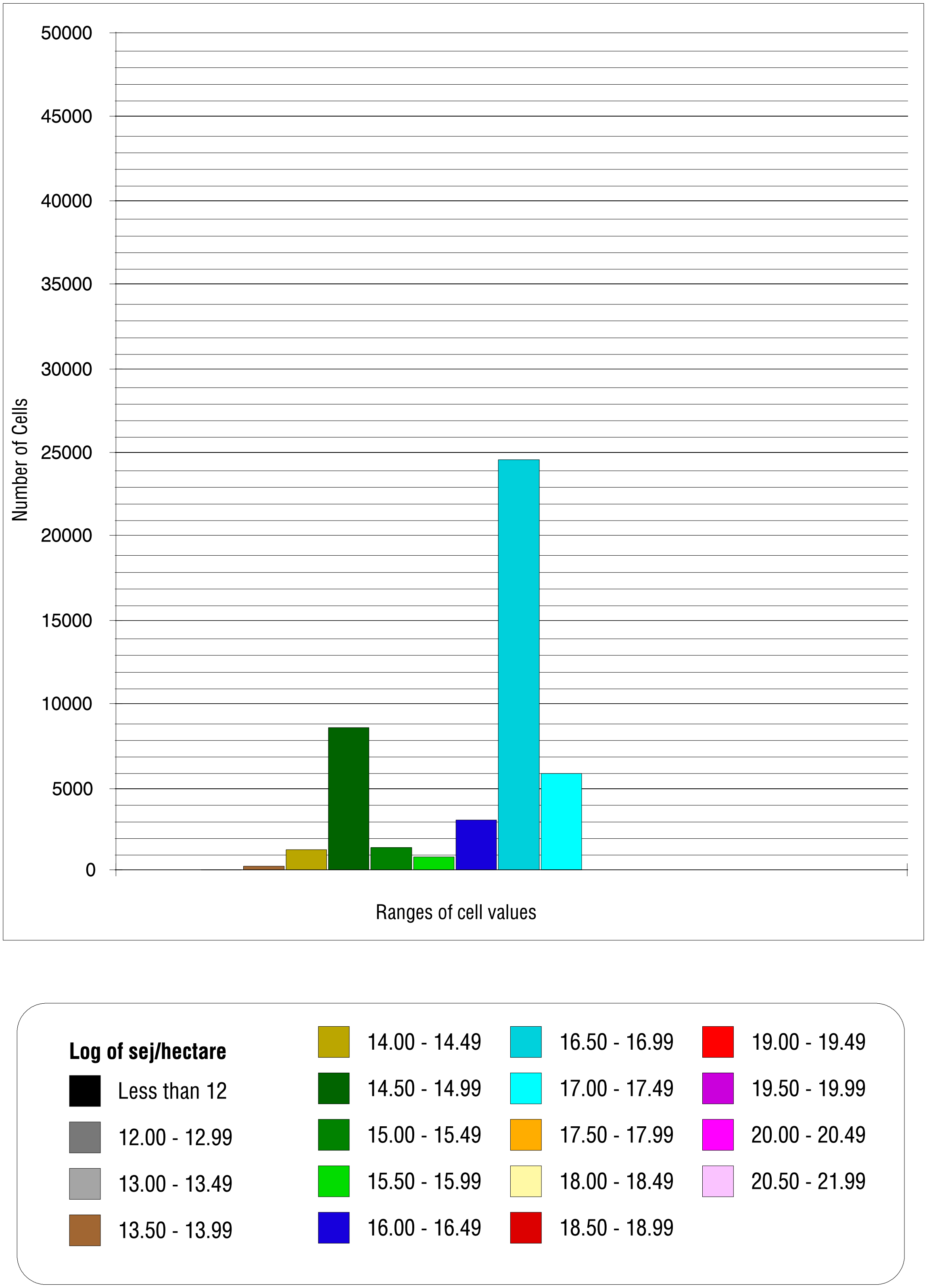


Figure 3-85: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY subcomponent grid called ’road_log’.

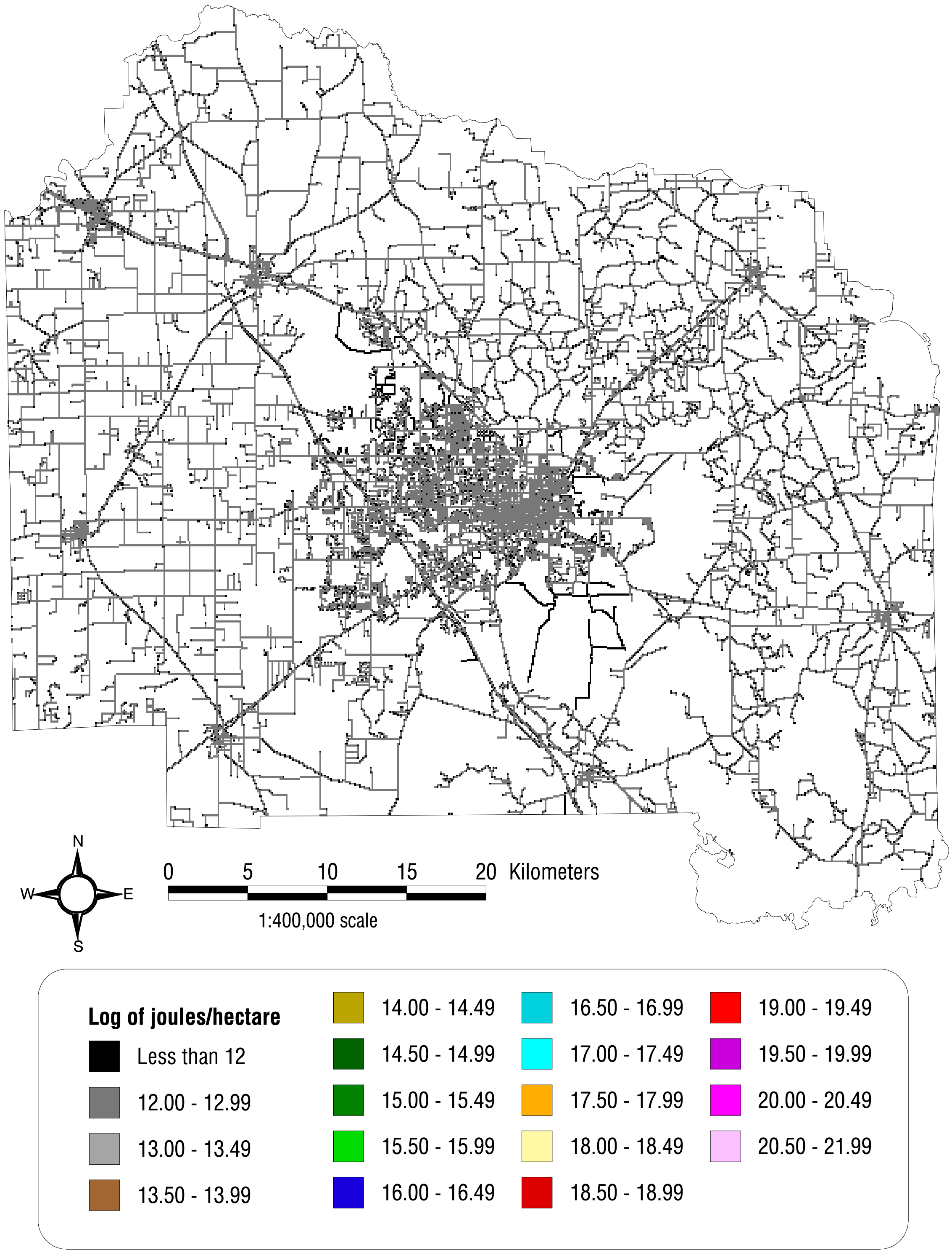


Figure 3-86: Map of the logarithm analytical energy subcomponent grid called 'road_en_log'. This grid represents the log of the energy storage density (log j/ha) of all road structures.

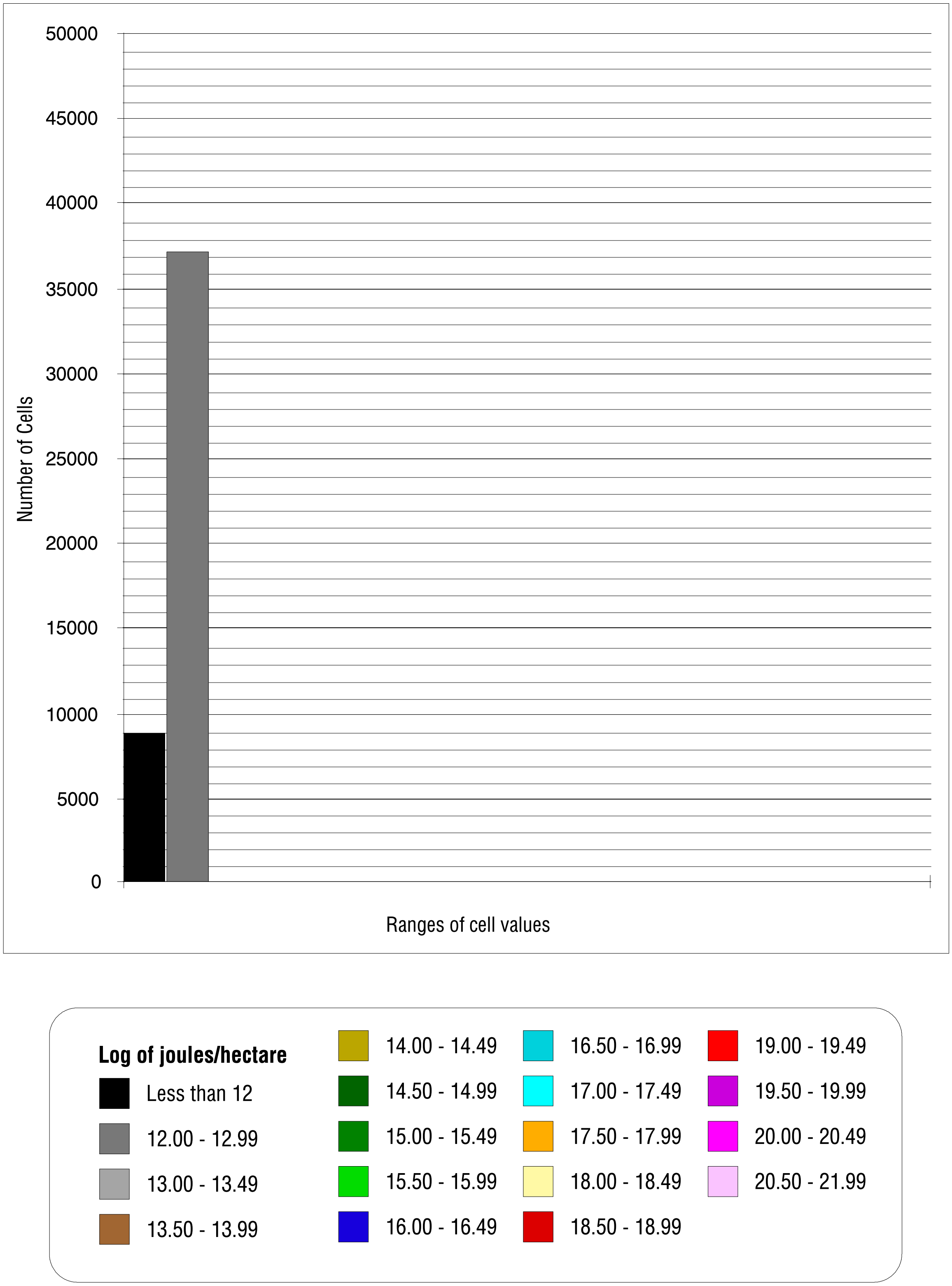


Figure 3-87: Histogram of the distribution of grid cell values found in the logarithm analytical energy subcomponent grid called 'road_en_log'.

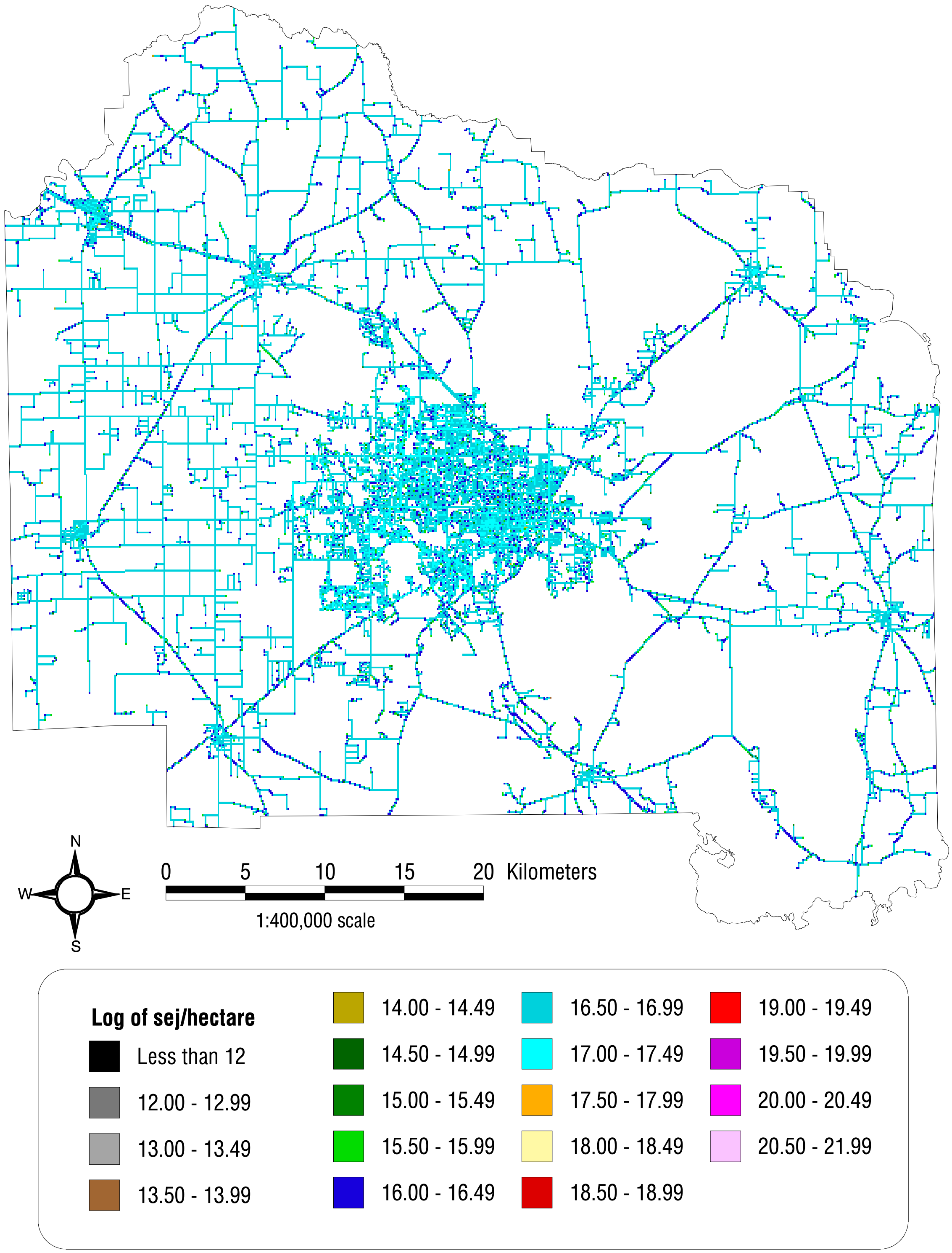


Figure 3-88: Map of the logarithm analytical EMERGY subcomponent grid called 'util_log'. This grid represents the log of the EMSTORAGE density (log sej/ha) of the utilities infrastructure.

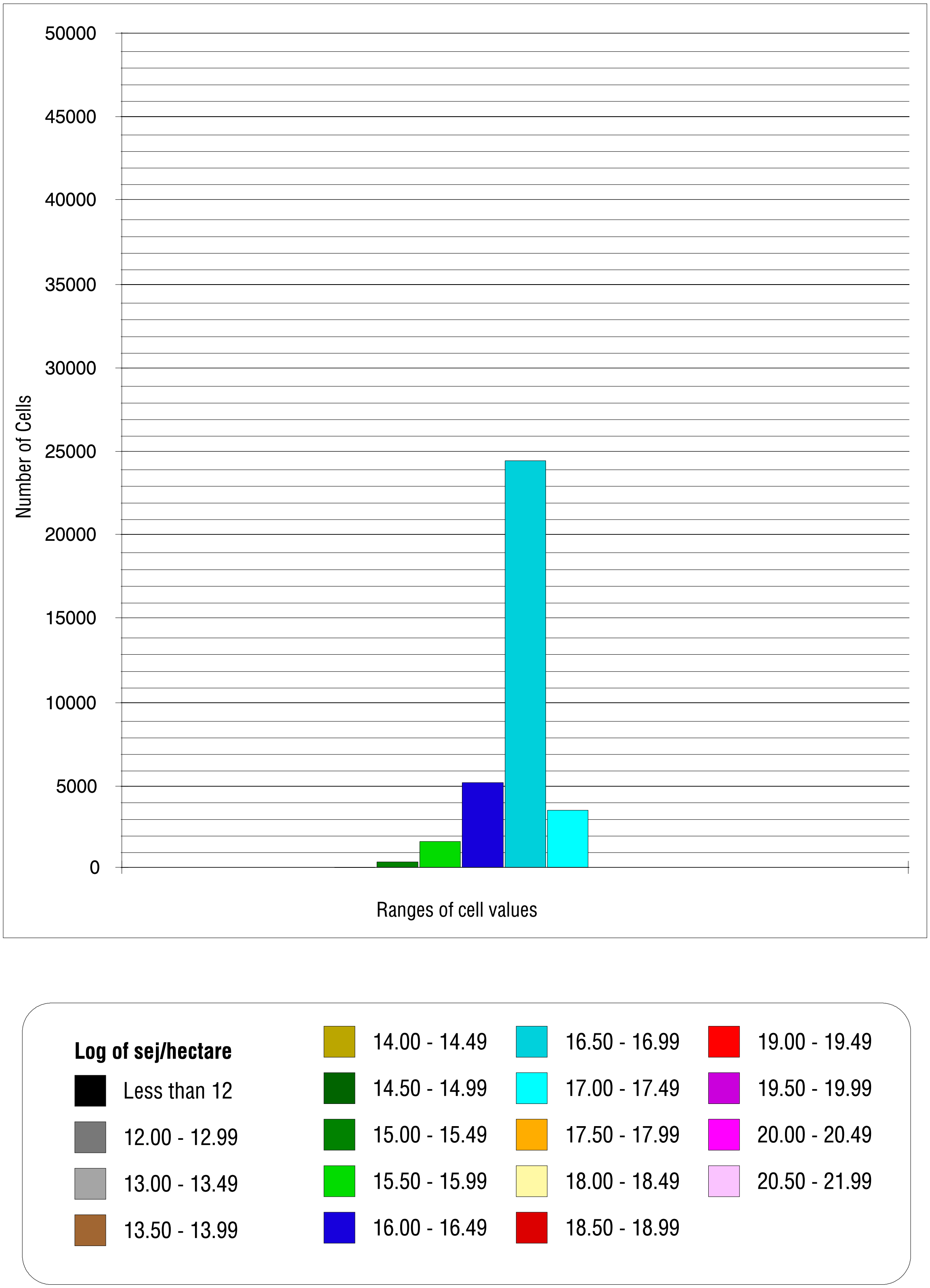


Figure 3-89: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY subcomponent grid called ’util_log’.

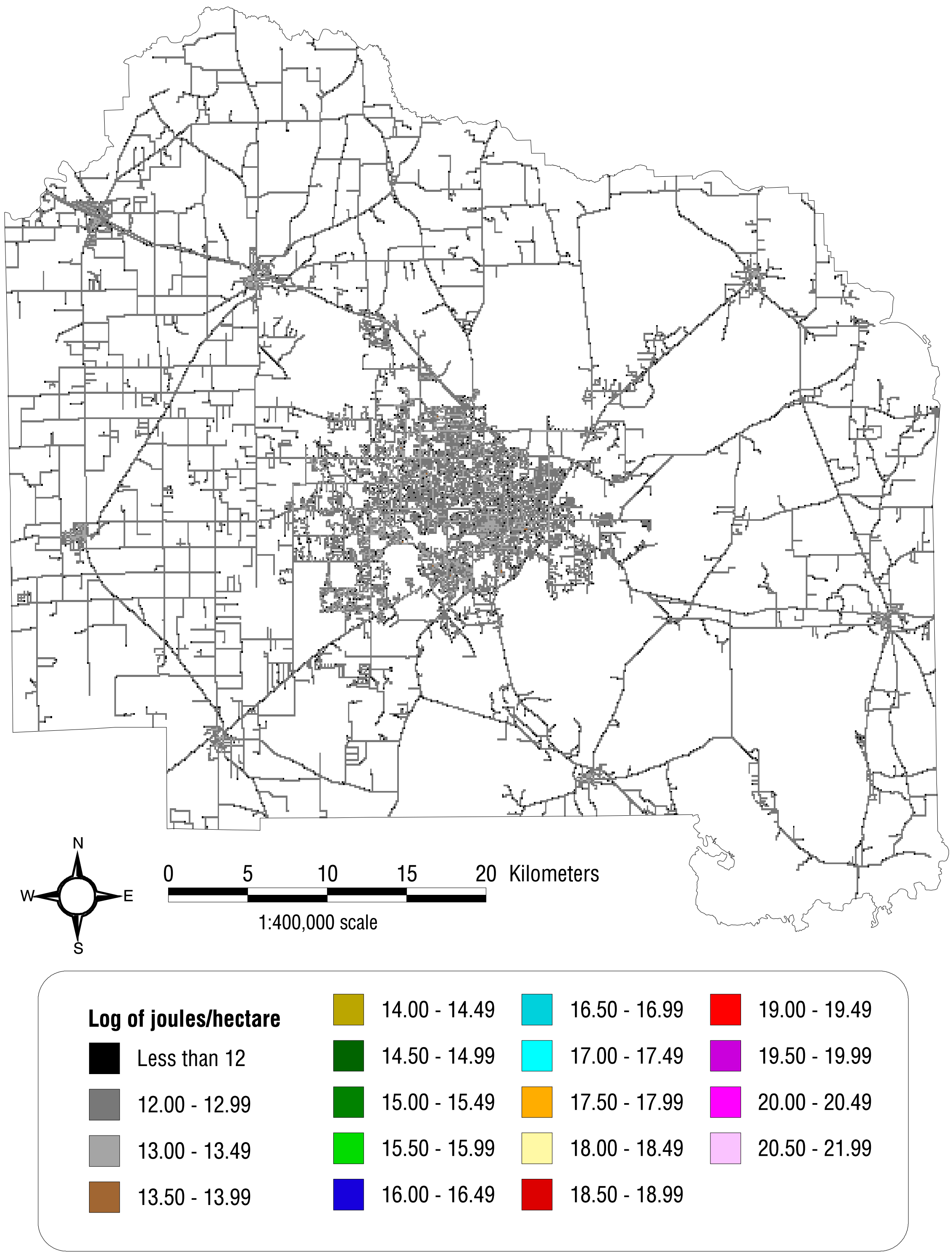


Figure 3-90: Map of the logarithm analytical energy subcomponent grid called 'util_en_log'. This grid represents the log of the energy storage density (log j/ha) of the utilities infrastructure.

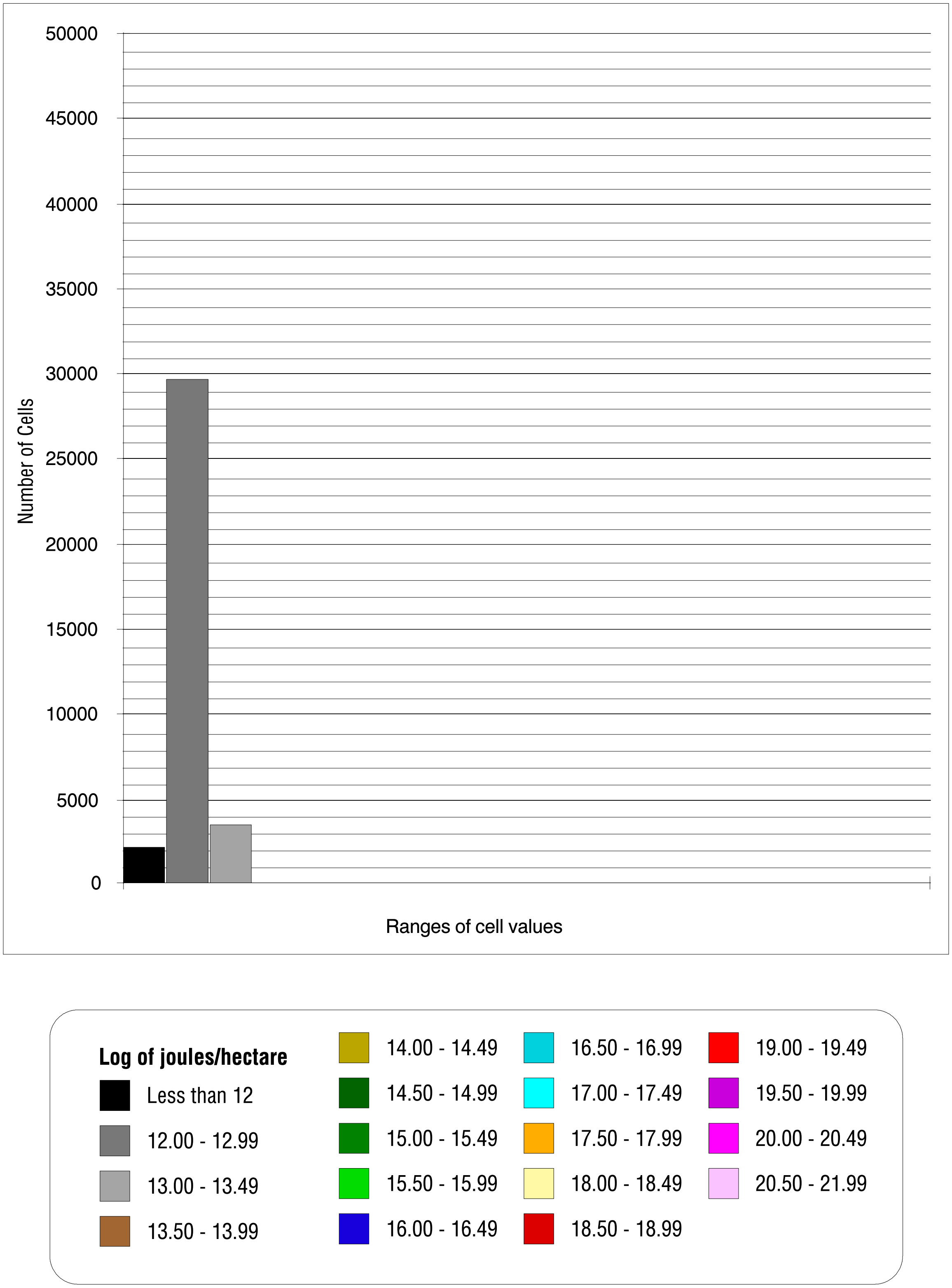


Figure 3-91: Histogram of the distribution of grid cell values found in the logarithm analytical energy subcomponent grid called 'util_en_log'.

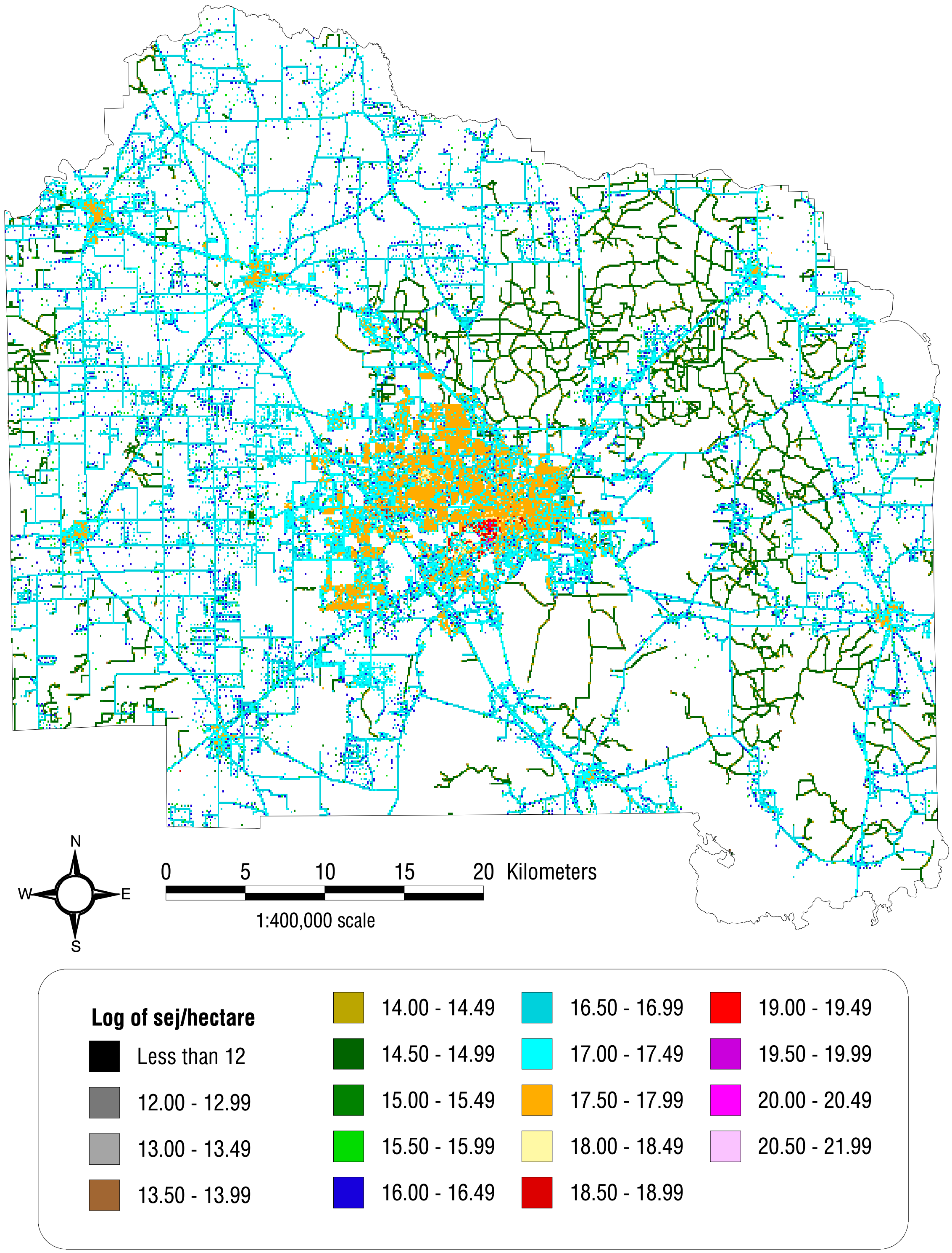


Figure 3-92: Map of the logarithm analytical EMERGY component grid called 'urbstr_log'. This grid represents the log of the EMSTORAGE density (log sej/ha) of urban system structure (including buildings, roads, and utilities infrastructure).

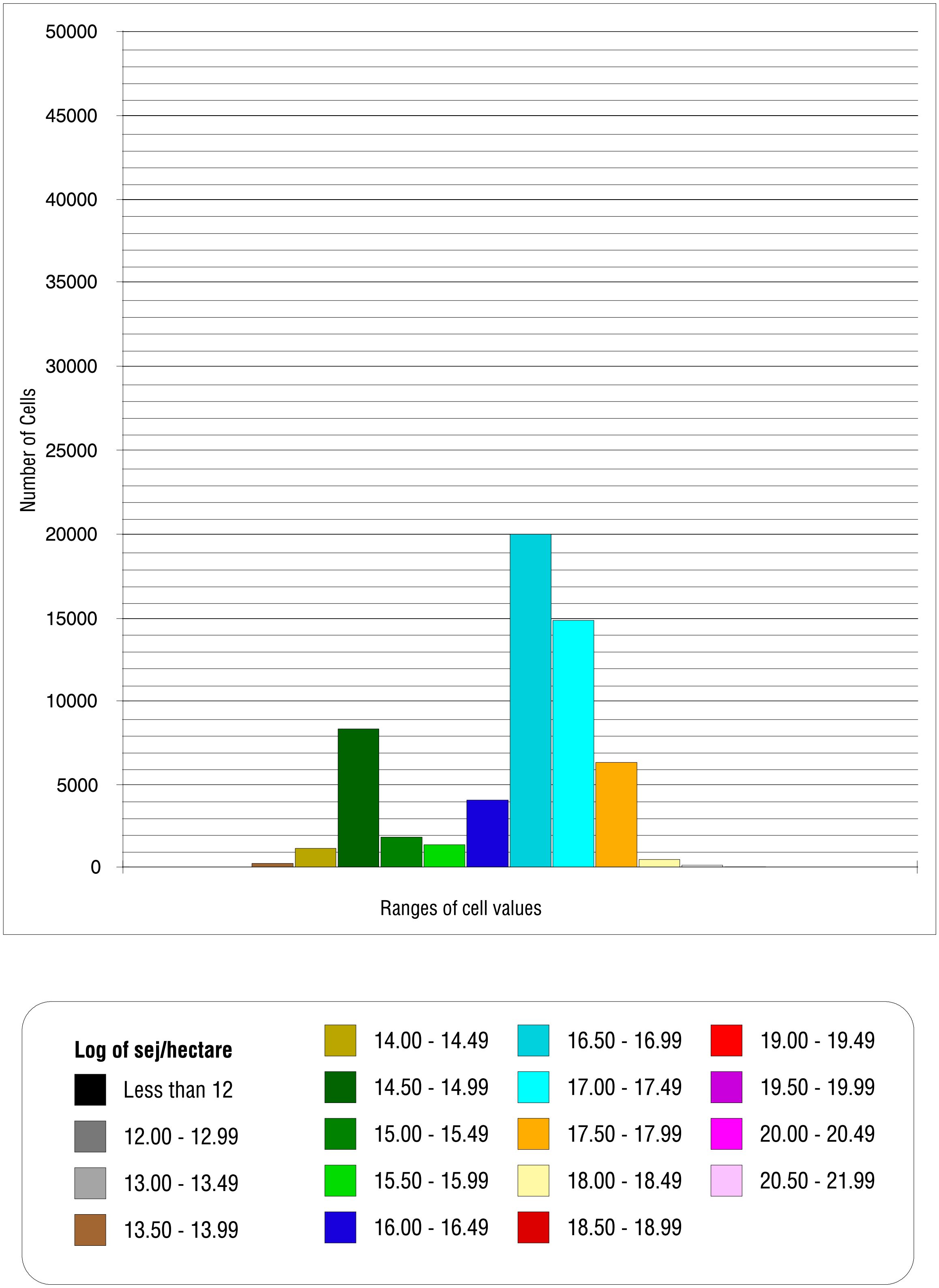


Figure 3-93: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called 'urbstr_log'.

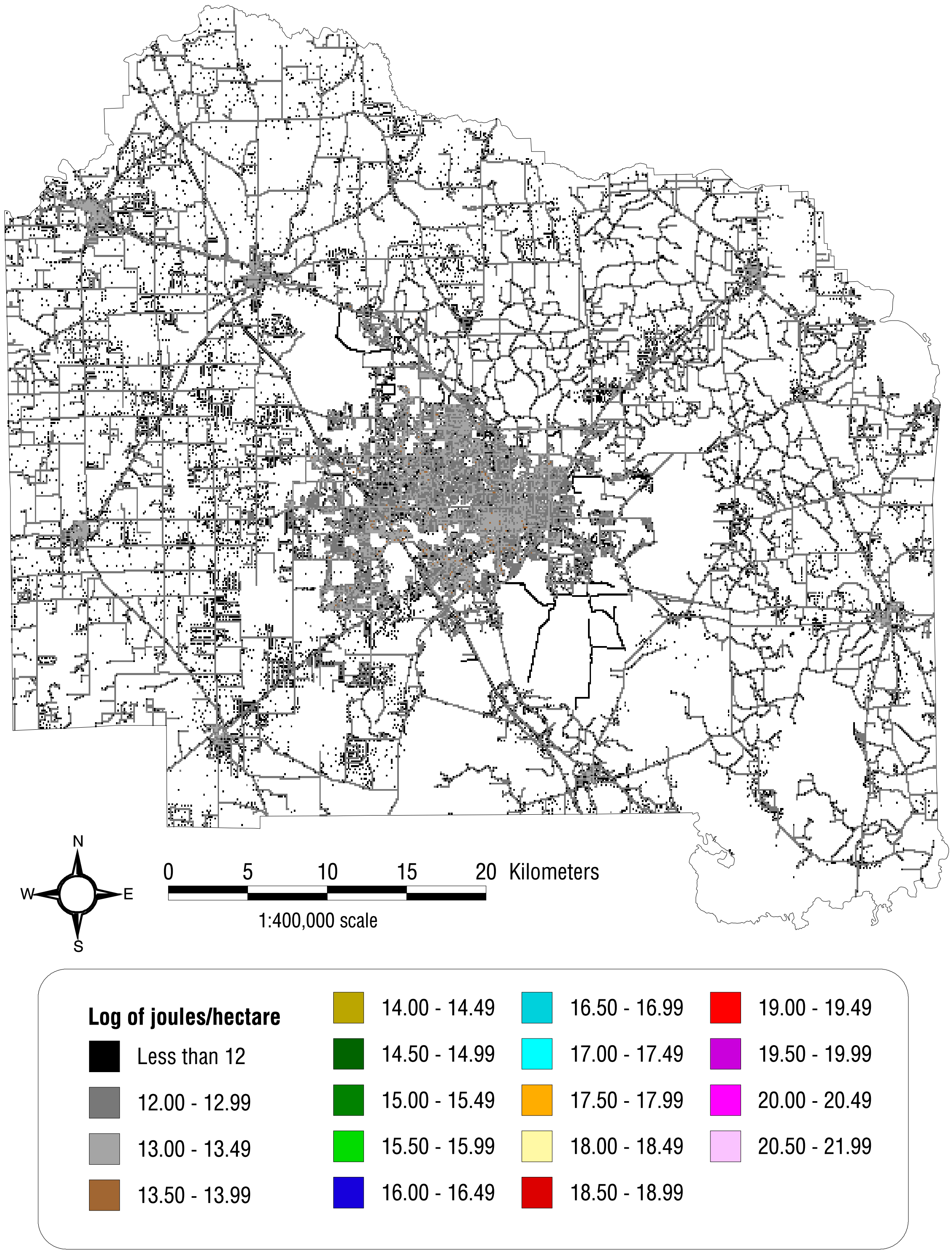


Figure 3-94: Map of the logarithm analytical energy component grid called 'urbstr_en_log'. This grid represents the log of the energy storage density (log j/ha) of urban system structure (including buildings, roads, and utilities infrastructure).

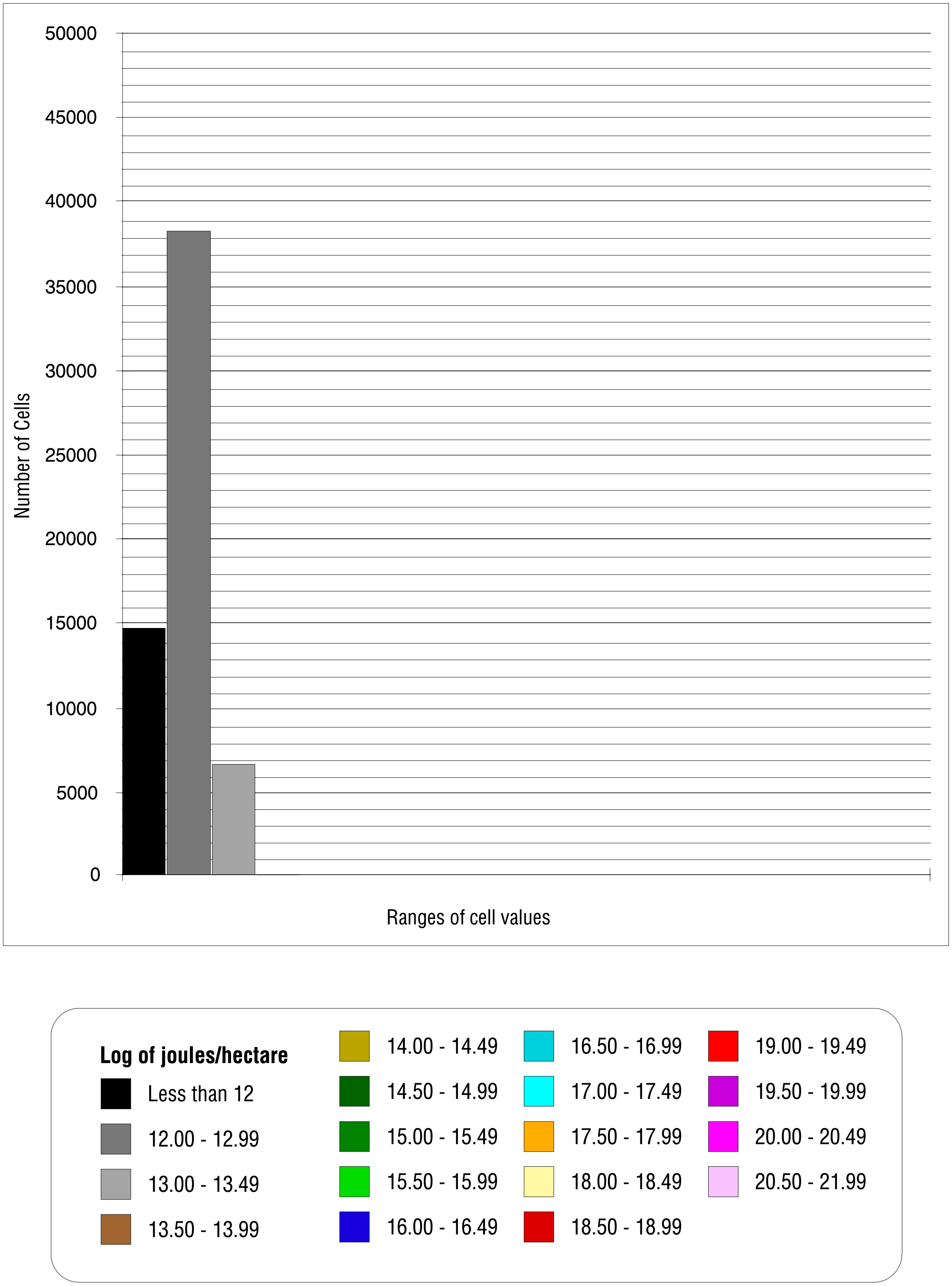


Figure 3-95: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'urbstr_en_log'.

Population storage component. This component models the average amount and location of energy and EMERGY stored in the people of each land unit (element #11 in Figure 1-3). Estimates of the number of employees/students in commercial, industrial, and institutional buildings (see Table 3-12) that were made to facilitate the services calculations were also used for storage calculations. Unlike the services component grid, in which agricultural services were distributed over land areas rather than being assigned to building point features, this component only models the location of people according to the location of buildings. This accounts for the major difference in the patterns observed in the service and storage component grids. A map of the logarithm analytical EMERGY component grid called ‘popstr_log’ is shown in Figure 3-96 and the associated histogram is shown in Figure 3-97. The cell distribution histogram reveals that the values in the EMERGY map are within the range of 16.5 to 17 log sej/ha. A map of the logarithm analytical energy component grid called ‘popstr_en_log’ is shown in Figure 3-98, and the associated histogram is shown in Figure 3-99. About 85% of the cells have values 18.5 and 22 sej/ha. The histogram reveals a pattern for these cells of an increasingly smaller number of cells associated with each increasingly higher EMERGY storage density value range. The highest storage density values, ranging above 20.5 log sej/ha/yr, are associated with the high density residential areas, the University of Florida, and the Shands Medical Center complex. A map of the logarithm analytical energy component grid called ‘popstr_en_log’ is shown in Figure 3-98 and its associated histogram is displayed in Figure 3-99.

Summary of cell value distribution patterns. Table 3-21 presents a summary of the distribution of grid cell values by log value range for all of the (sub)component grids.

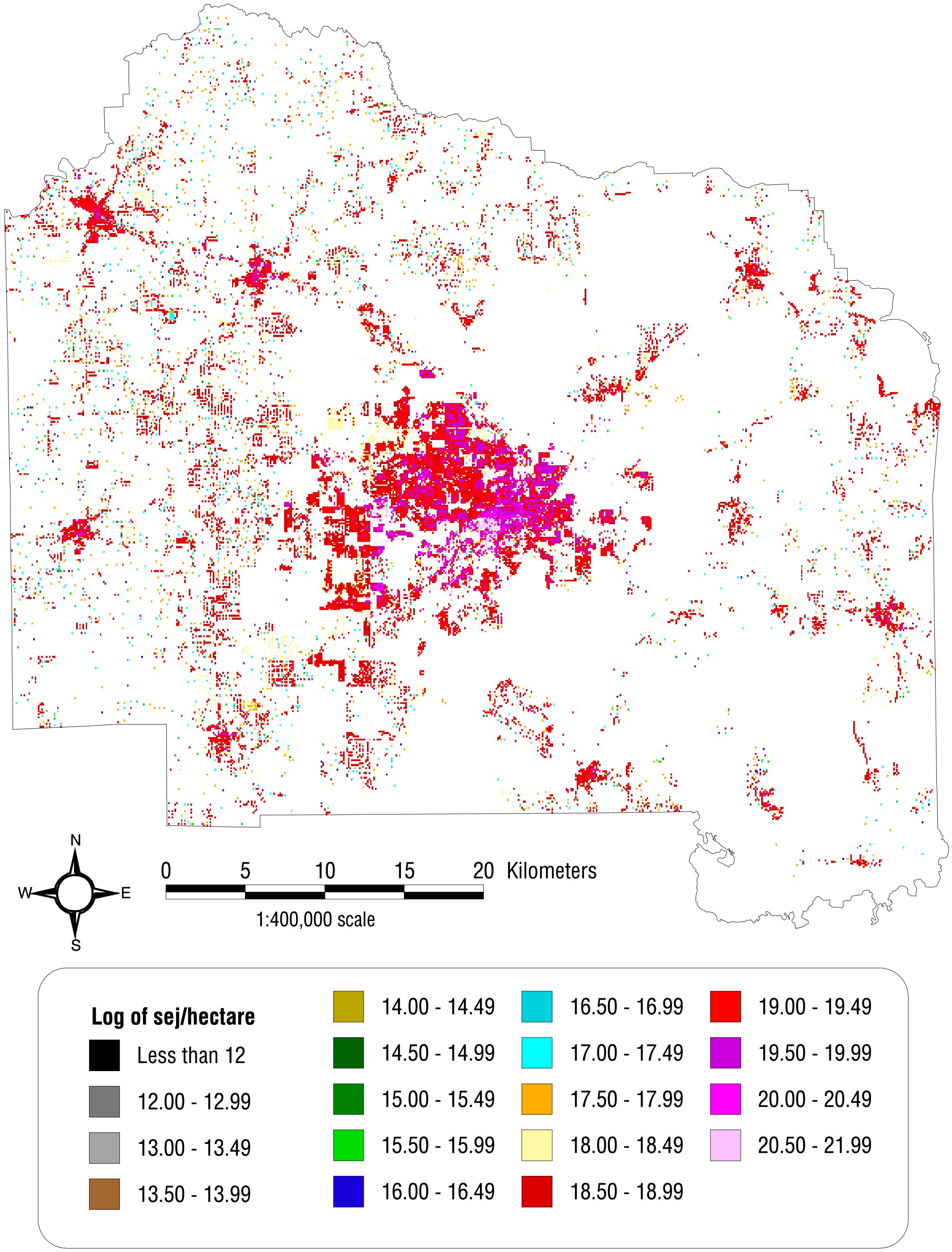


Figure 3-96: Map of the logarithm analytical EMERGY component grid called 'popstr_log'. This grid represents the log of the EMSTORAGE density (log sej/ha) of the human population.

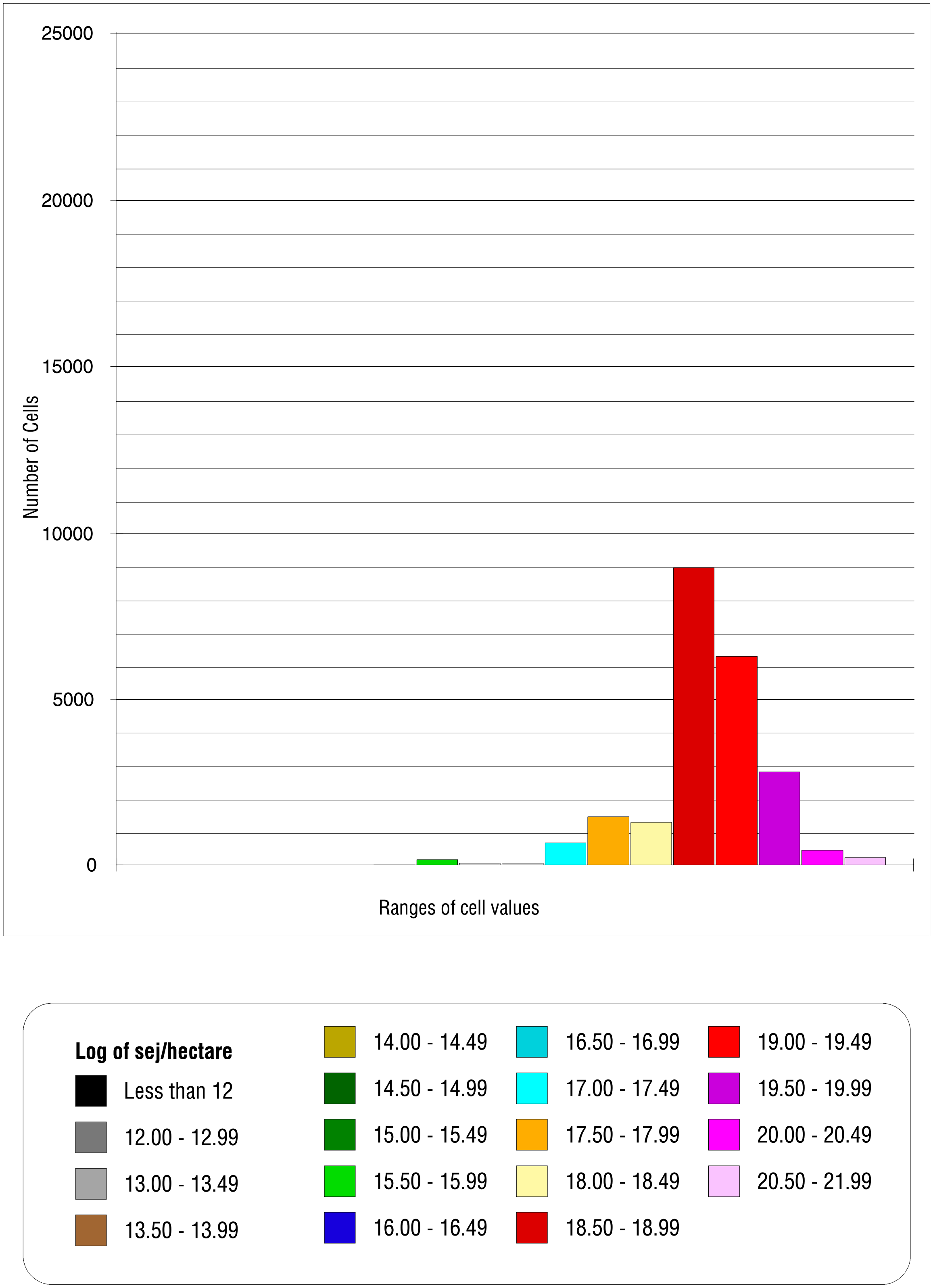


Figure 3-97: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY component grid called 'popstr_log'.

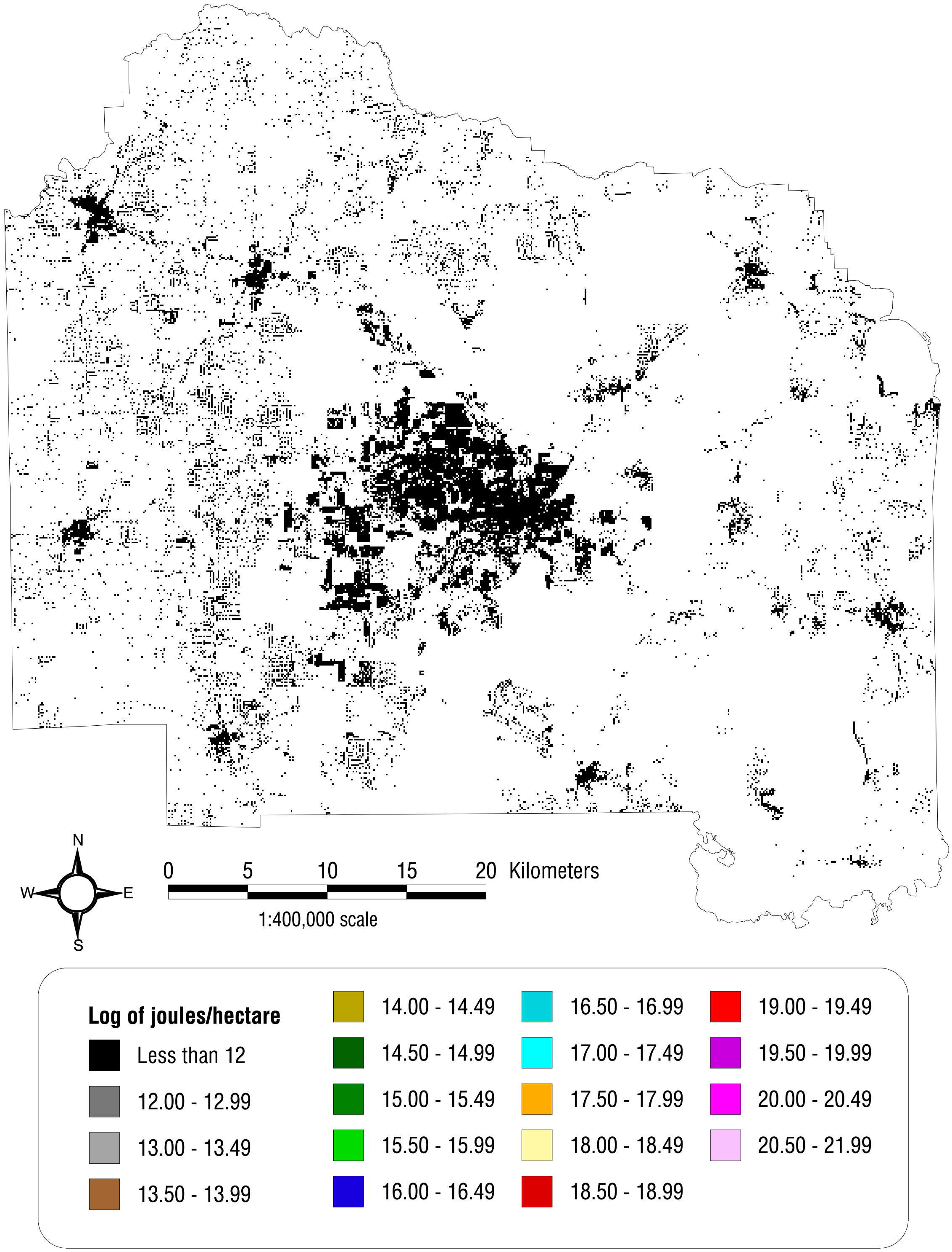


Figure 3-98: Map of the logarithm analytical energy component grid called 'popstr_en_log'. This grid represents the log of the energy storage density (log j/ha) of the human population.

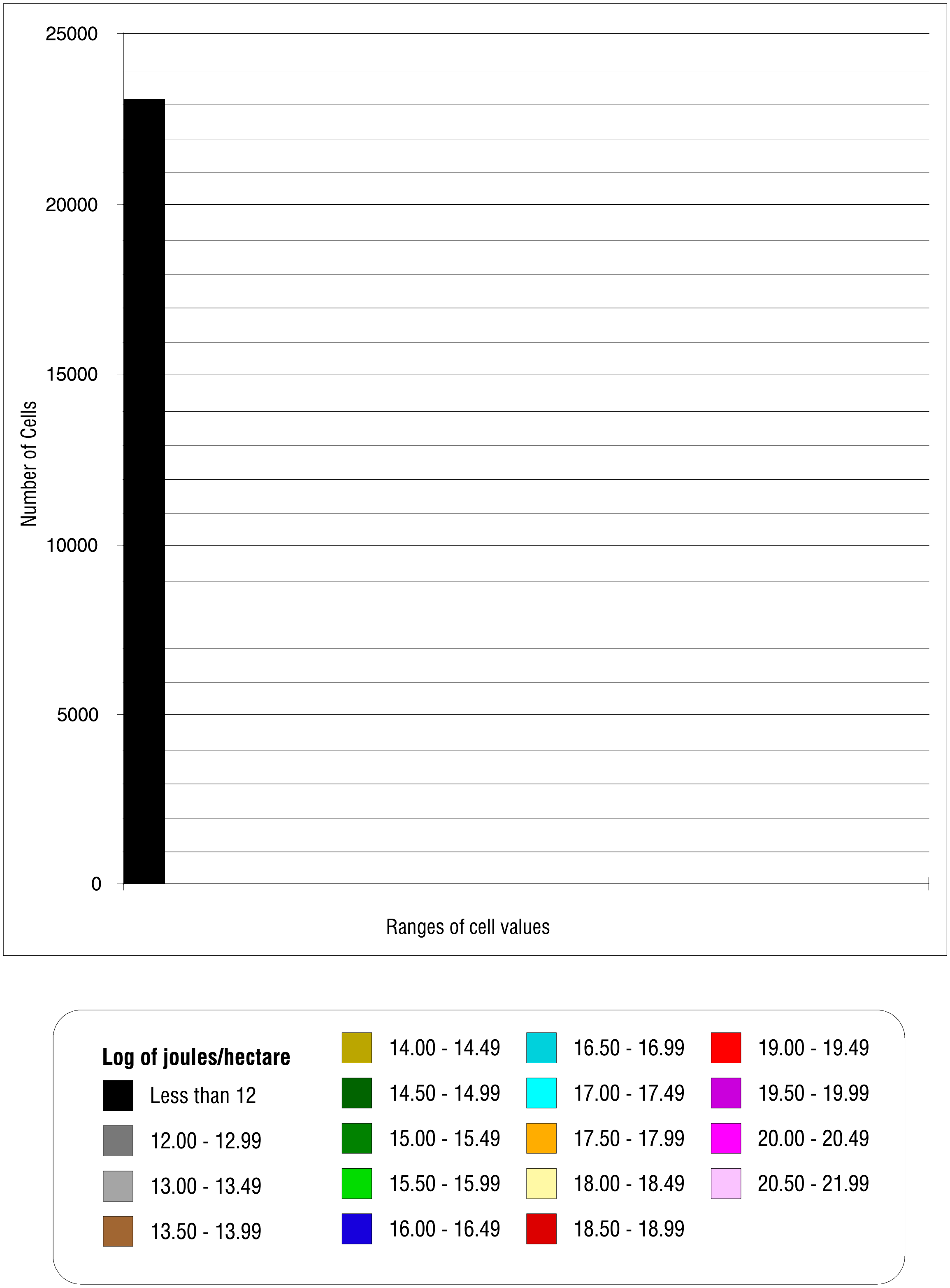


Figure 3-99: Histogram of the distribution of grid cell values found in the logarithm analytical energy component grid called 'popstr_en_log'.

Table 3-21: Summary of the distribution of grid cells by value ranges for the logarithm analytical (sub-)component grids.

		Number of grid cells within each range of logarithm values																	
Name Of Grid	Units For Range	Less Than 12	12 to 12.99	13 to 13.49	13.5 to 13.99	14 to 14.49	14.5 to 14.99	15 to 15.49	15.5 to 15.99	16 to 16.49	16.5 to 16.99	17 to 17.49	17.5 to 17.99	18 to 18.49	18.5 to 18.99	19 to 19.49	19.5 to 19.99	20 to 20.49	20.5 to 22
gpp_log	sej/ha/yr	2	152	460	59	256	23462	190299	34551	0	0	0	0	0	0	0	0	0	0
gpp_en_log	J/ha/yr	140457	110063	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
renew_log	sej/ha/yr	0	0	608	189	1264	30614	208293	9945	0	0	0	0	0	0	0	0	0	0
renew_en_log	J/ha/yr	198246	42391	9957	413	0	0	0	0	0	0	0	0	0	0	0	0	0	0
wtruse_log	sej/ha/yr	107	346	540	865	2018	10114	21355	5360	1866	345	128	9	0	0	0	0	0	0
wtruse_en_log	J/ha/yr	43089	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
trn_ful_log	sej/ha/yr	2	737	2022	8494	3026	5500	9357	5672	3980	3314	3219	727	1	0	0	0	0	0
trn_ful_en_log	J/ha/yr	40904	5160	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bag_ful_log	sej/ha/yr	26713	44550	3969	6004	16471	2720	2643	4822	9961	5377	1371	500	205	39	4	0	0	0
bag_ful_en_log	J/ha/yr	122582	1041	61	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0
fuel_log	sej/ha/yr	21625	39074	4660	11769	15291	5863	6876	7151	12719	7970	4424	1389	221	39	4	0	0	0
fuel_en_log	J/ha/yr	131448	6169	112	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0
goods_log	sej/ha/yr	1031	2905	4185	12912	11208	46797	9181	12272	11326	8365	3945	785	320	93	13	2	0	0
goods_en_log	J/ha/yr	124388	380	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
service_log	sej/ha/yr	3965	18167	22150	97625	16744	3510	2158	3965	1511	1203	8345	6472	3407	590	243	45	4	0
service_en_log	J/ha/yr	186588	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
waste_log	sej/ha/yr	0	0	0	0	13	199	520	4140	8569	6066	2169	890	316	93	13	0	0	0
waste_en_log	J/ha/yr	22787	245	12	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
recycle_log	sej/ha/yr	0	0	0	0	13	252	746	7107	6819	5384	1644	739	256	64	9	0	0	0
recycle_en_log	J/ha/yr	22848	186	10	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
biostr_log	sej/ha	0	2	4	4	129	718	27080	44756	63852	64177	49890	0	0	0	0	0	0	0
biostr_en_log	J/ha	79334	171659	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
wtrstr_log	sej/ha	0	0	0	0	0	0	0	0	244	250804	0	0	0	0	0	0	0	0
wtrstr_en_log	J/ha	694	250354	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
soilom_log	sej/ha	1	10	17	22	63	89	188	402	893	55778	148089	21779	8181	0	0	0	0	0
soilom_en_log	J/ha	4651	217553	14246	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
natstr_log	sej/ha	0	0	0	0	0	0	0	0	5	15586	160556	65533	9008	0	0	0	0	0
natstr_en_log	J/ha	10	213546	37527	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
bldg_log	sej/ha	0	0	0	0	40	155	771	1131	3346	7185	7065	3308	410	178	95	19	2	0
bldg_en_log	J/ha	15985	7553	126	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0
road_log	sej/ha	0	2	59	361	1291	8627	1388	865	3095	24520	5823	10	0	0	0	0	0	0
road_en_log	J/ha	8876	37197	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
util_log	sej/ha	0	0	0	5	46	143	440	1618	5233	24464	3535	13	0	0	0	0	0	0
util_en_log	J/ha	2253	29712	3535	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
urbstr_log	sej/ha	0	2	52	345	1274	8338	1938	1445	4129	19957	14898	6375	519	184	95	20	2	0
urbstr_en_log	J/ha	14674	38238	6597	123	1	0	0	0	0	0	0	0	0	0	0	0	0	0
popstr_log	sej/ha	0	0	0	0	0	8	65	245	127	94	745	1483	1356	8958	6303	2856	518	265
popstr_en_log	J/ha	23041	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Total EMERGY Consumption and Total EMERGY Storage

The following sections describe the results of creating ‘total annual EMERGY Consumption’ and ‘total EMERGY Storage’ analytical grids and their associated transformity analytical grids, and ‘county-wide total EMPOWER’ and ‘county-wide total EMSTORAGE’ component signature histograms.

Total EMPOWER Density Analytical Grids

The cell values of several of the component grids that represent flows of EMERGY were added together to create an analytical grid that represents the ‘Total annual EMERGY Consumption’ analytical grid, hereafter referred to as the ‘Total Annual EMPOWER Density’ analytical grid. The values in this analytical grid are the sum of the annual EMERGY flows in renewable resources used (as measured by transpiration—element #1 in Figure 1-3), water used in buildings and agriculture (element #3 in Figure 1-3), all fuels used (including transportation, building, and agricultural use—element #4 in Figure 1-3), all goods used (and EMERGY in services associated with the goods—element #5 in Figure 1-3), and in-situ human services used (element #6 in Figure 1-3). The corresponding component grids that represent annual flows of energy were added together resulting in the ‘Total Annual Energy Flow Density’ analytical grid. After adding the EMERGY or energy component grids together, the common logarithm (base 10) was computed for each number in each cell of the ‘Total’ grids to create the logarithm form of the ‘Total Annual EMPOWER Density’ and ‘Total Annual Energy Flow Density’ analytical grids.

Figure 3-100 displays a map of the logarithm analytical 'Total Annual EMPOWER Density' grid called 'empower_log'. To facilitate comparisons between this analytical grid and the component grids, the same standard legend value ranges have been used for this map that were used for all of the EMERGY and energy (sub)component grid maps. In fact, this was the grid used originally to select the color scheme for the standard legend. Similarly, Figure 3-101 displays a histogram (of the number of cells with values in each of the standard value ranges) that was created for this analytical grid in the same manner that histograms were created for the component grids. A detailed listing of the number of cells within each range is also included in Figure 3-101.

Total annual EMPOWER density values for rural and agricultural crop areas range from 14.5 to 16 log sej/ha/yr. Approximately 85% of the cells fall within this range of values. The majority of these cells actually fall within the narrow range of 15 to 15.5 log sej/ha/yr. Total annual EMPOWER density values for urban areas range from 17 to 20.5 log sej/ha/yr. The cell distribution histogram for this analytical grid displays a pattern for urban areas in which a relatively large percentage of the cells in the grid have relatively lower flow density values and an increasingly smaller number of cells are associated with each increasingly higher EMPOWER density value range. As expected, based on patterns observed previously in the component grid maps, the highest values in the County are associated with institutional and commercial land uses and range from 18.5 to 20.5 log sej/ha/yr. The highest values are associated with the Medical Center.

The map of the logarithm analytical 'Total Annual Energy Flow Density' grid called 'empower_en_log' is shown in Figure 3-102 and a histogram of cell value distribution is shown in Figure 3-103. As with most of the previous energy component maps, most of the values in the ‘Total Annual Energy Flow Density’ analytical grid are less than 12 log joules/ha/yr, and the standard legend does not display the actual variation that exists in the energy flow data values.

Figure 3-104 displays a map of the logarithm analytical total annual energy flow density grid with ranges of log values chosen to illustrate the true variation that exists in the energy grid values. A histogram of cell value distribution based on this new value range legend is presented in Figure 3-105. This histogram reveals a pattern of cell value distribution that is similar to the patterns observed for many of the EMERGY component grids (where there are many cells with lower values and fewer and fewer cells with increasing values).

Total EMSTORAGE Density Analytical Grids

The following EMERGY storage component grids were added together to create the ‘Total EMERGY Storage’ analytical grid: the ‘natstr’ component (natural system structure—sum of elements #9a, #9b, and #9c in Figure 1-3), the ‘urbstr’ component (urban system structure—sum of elements #10a, #10b, and #10c in Figure 1-3), and the ‘popstr’ component (population—element #11 in Figure 1-3). The values in this grid represent ‘Total EMSTORAGE density’ for each grid cell. The corresponding energy storage component grids were also added together to create the ‘Total Energy Storage Density’ analytical grid. Finally, the common logarithm (base 10) was computed for each of the ‘Total’ grids to create the logarithm form of the analytical grids.

The map of the logarithm analytical ‘Total EMSTORAGE Density’ grid called ‘emstore_log’ is shown in Figure 3-106. Figure 3-107 displays the corresponding histogram and includes a detailed listing of the number of cells within each range of logarithm values. Total EMSTORAGE density values for rural range from 16.5 to 18 log sej/ha. Approximately 88% of all of the cells in the grid fall within this range of values. Total EMSTORAGE density values for urban areas range from 17.5 to 22 log sej/ha/. The cell distribution histogram for this analytical grid displays a clear example of the pattern seen many times before--large numbers of the cells in the grid have relatively lower storage density values and an increasingly smaller number of cells are associated with each increasingly higher range of EMSTORAGE density values. Once again, the highest values in the grid are associated with institutional and commercial land uses and range from 20 to 22 log sej/ha. The highest values are associated with the University of Florida, Shands Medical Center, several of the major shopping center areas, and the downtown Gainesville government building complex.

The map of the logarithm analytical 'Total Energy Density' grid called 'emstore_en_log' is shown in Figure 3-108 and a histogram of cell value distribution is shown in Figure 3-109. The range of energy storage density values for this analytical grid are greater than those found in any of the component grids, with all values within the range of 12 to 13.5 log joules/ha. However, the standard legend still does not display the variety that exists in the energy storage values. Consequently, the map in Figure 3-110 was created to display the logarithm analytical total energy storage density grid with ranges of log values chosen to illustrate the variation in the total energy storage grid values. Note that this range of values is not the same one chosen to illustrate variation in the total annual energy flow density analytical grid values. The histogram in Figure 3-111 is based on this unique value range legend.

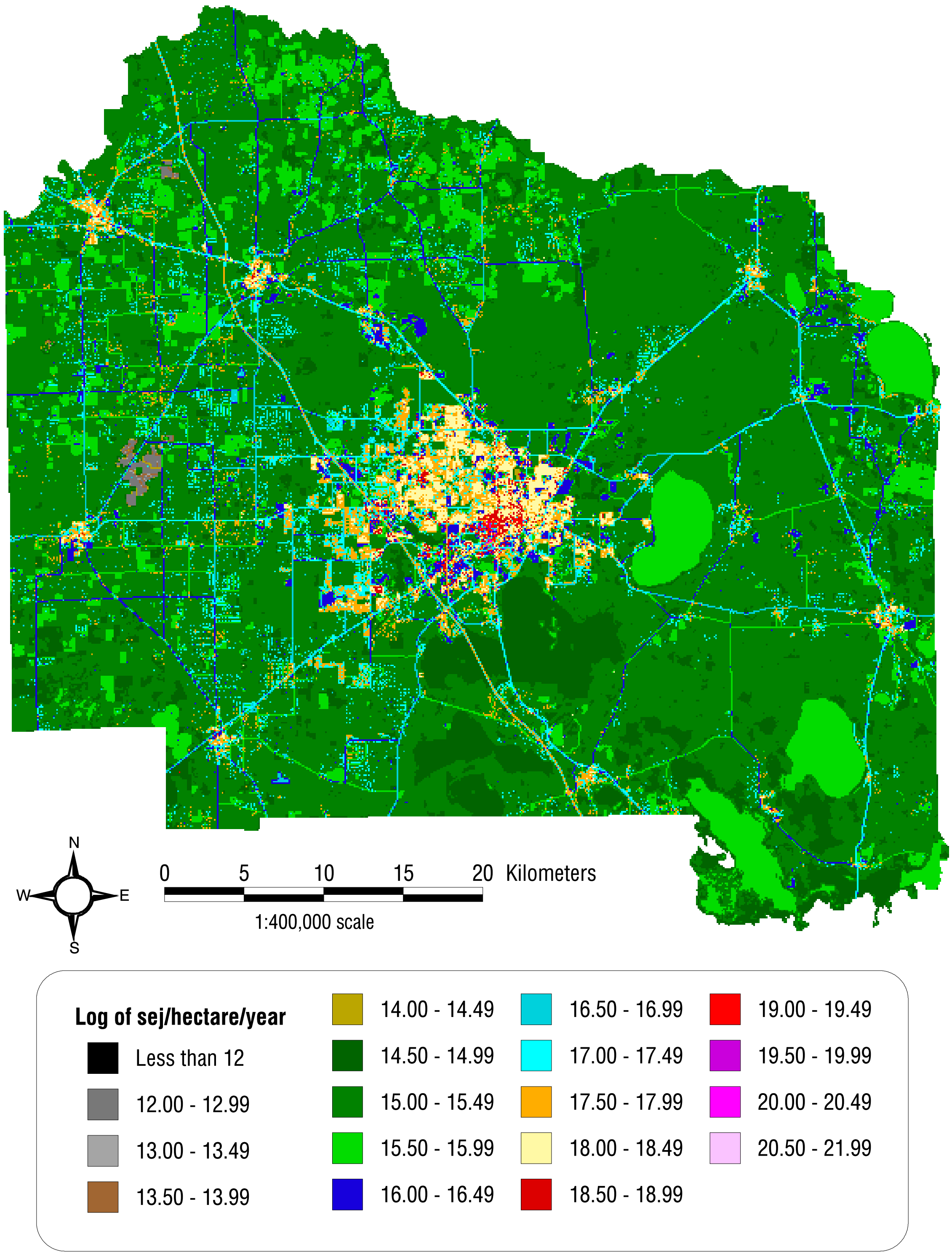
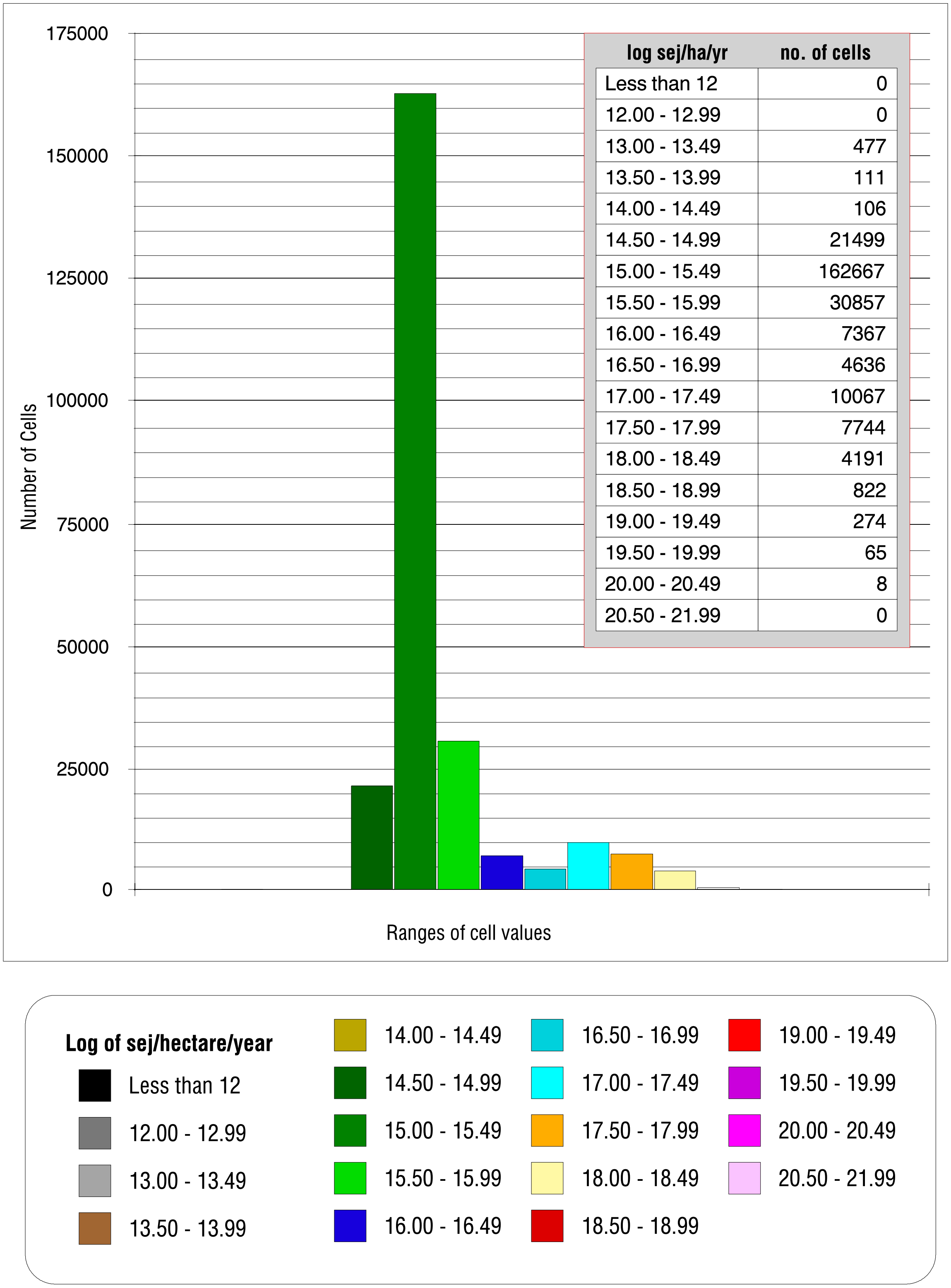


Figure 3-100: Map of the logarithm analytical EMERGY grid 'empower_log'. This grid represents the log of the total annual EMPOWER density (log sej/ha/yr). It was created by calculating the log of the sum of the grids representing the annual EMPOWER densities of the renewable resources used, the water used by man, the fuels used in transportation and buildings, the goods consumed, and the human services provided.



log sej/ha/yr	no. of cells
Less than 12	0
12.00 - 12.99	0
13.00 - 13.49	477
13.50 - 13.99	111
14.00 - 14.49	106
14.50 - 14.99	21499
15.00 - 15.49	162667
15.50 - 15.99	30857
16.00 - 16.49	7367
16.50 - 16.99	4636
17.00 - 17.49	10067
17.50 - 17.99	7744
18.00 - 18.49	4191
18.50 - 18.99	822
19.00 - 19.49	274
19.50 - 19.99	65
20.00 - 20.49	8
20.50 - 21.99	0

Figure 3-101: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY grid called 'empower_log'. The summary table lists the number of cells within each range of values for the log total EMPOWER density (log sej/ha/yr).

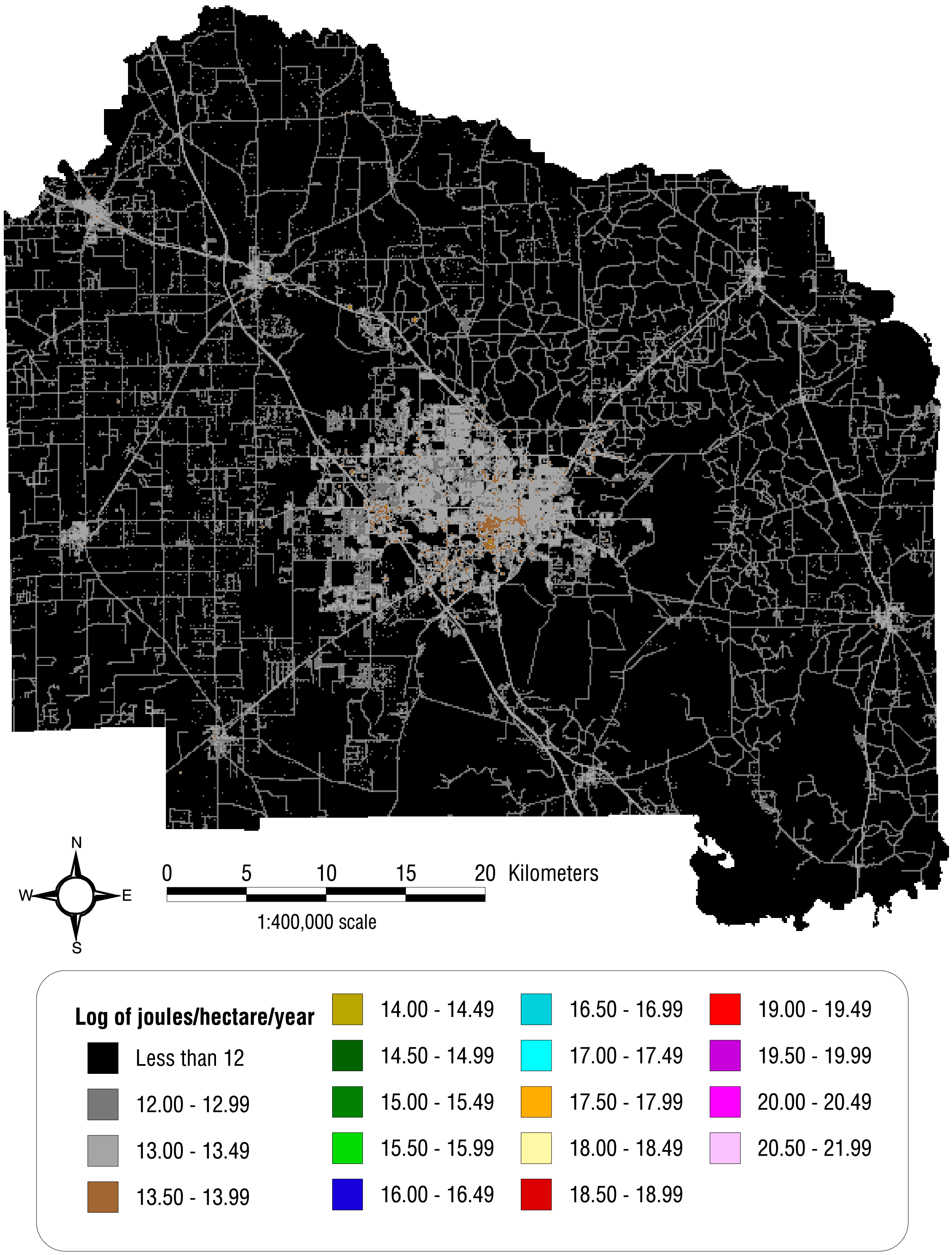
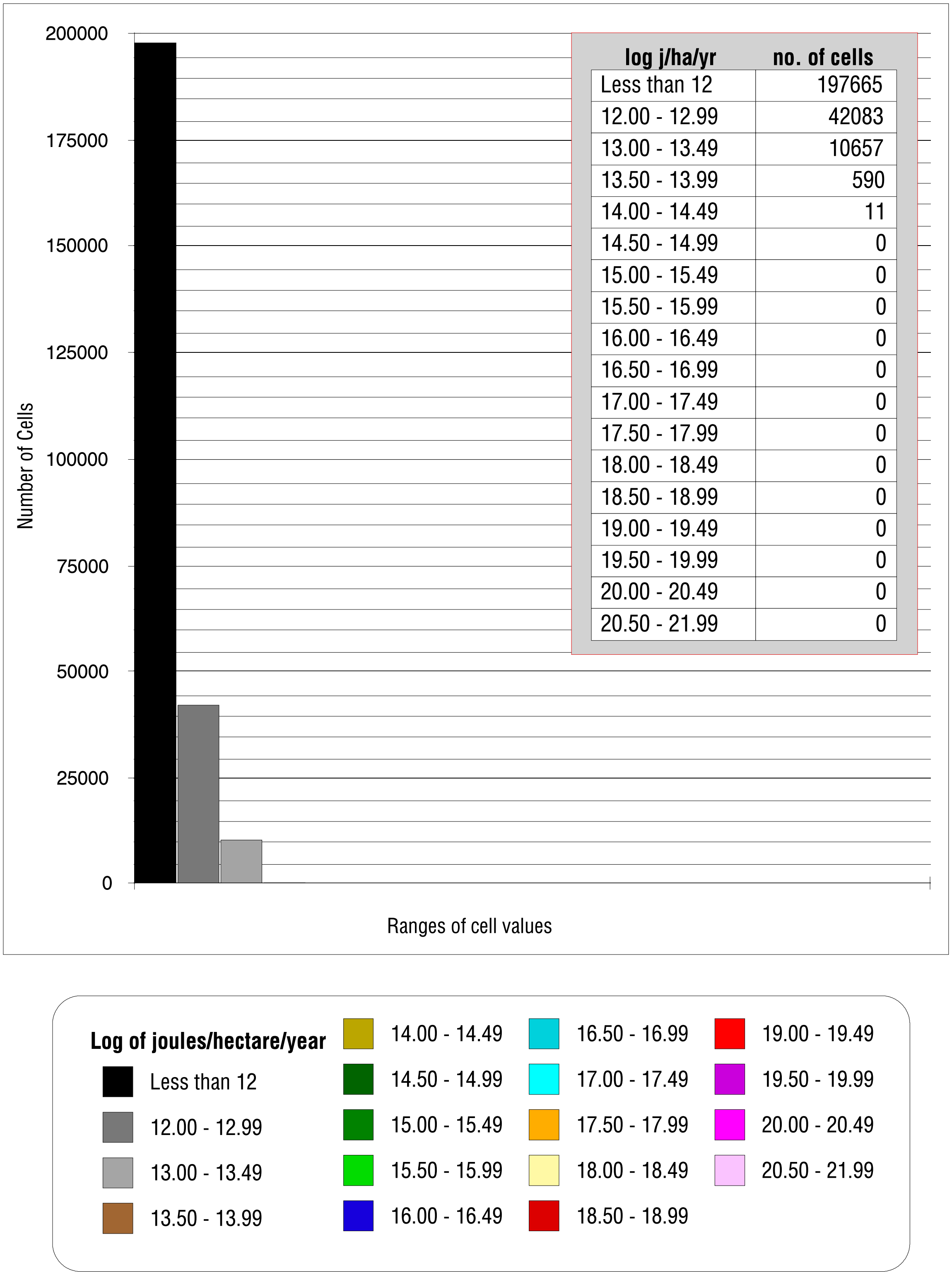


Figure 3-102: Map of the logarithm analytical energy grid (empower_en_log) representing the log of the total annual energy flow density (log j/ha/yr). It was created by calculating the log of the sum of the grids representing the annual energy flow densities of the renewable resources used, water used by man, fuels used in transportation and buildings, goods consumed, and human services.



log j/ha/yr	no. of cells
Less than 12	197665
12.00 - 12.99	42083
13.00 - 13.49	10657
13.50 - 13.99	590
14.00 - 14.49	11
14.50 - 14.99	0
15.00 - 15.49	0
15.50 - 15.99	0
16.00 - 16.49	0
16.50 - 16.99	0
17.00 - 17.49	0
17.50 - 17.99	0
18.00 - 18.49	0
18.50 - 18.99	0
19.00 - 19.49	0
19.50 - 19.99	0
20.00 - 20.49	0
20.50 - 21.99	0

Figure 3-103: Histogram of the distribution of grid cell values found in the logarithm analytical total annual energy flow density grid called 'empower_en_log'. The summary table lists the exact number of cells within each range of values for the log total energy flow density (log j/ha/yr).

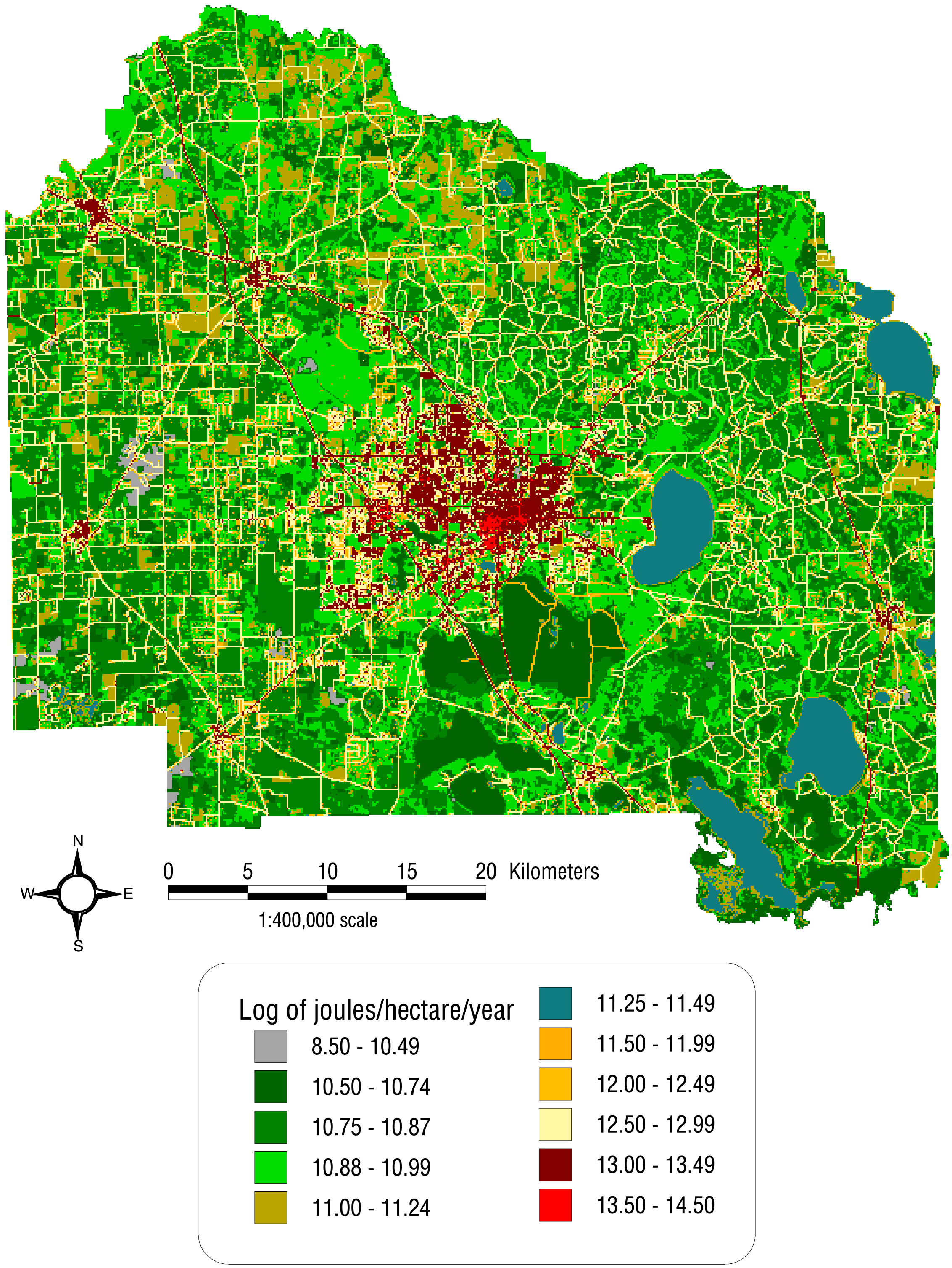


Figure 3-104: Map of the logarithm analytical total energy flow density grid called 'empower_en_log' with ranges of log values chosen to illustrate the variation in the energy grid values.

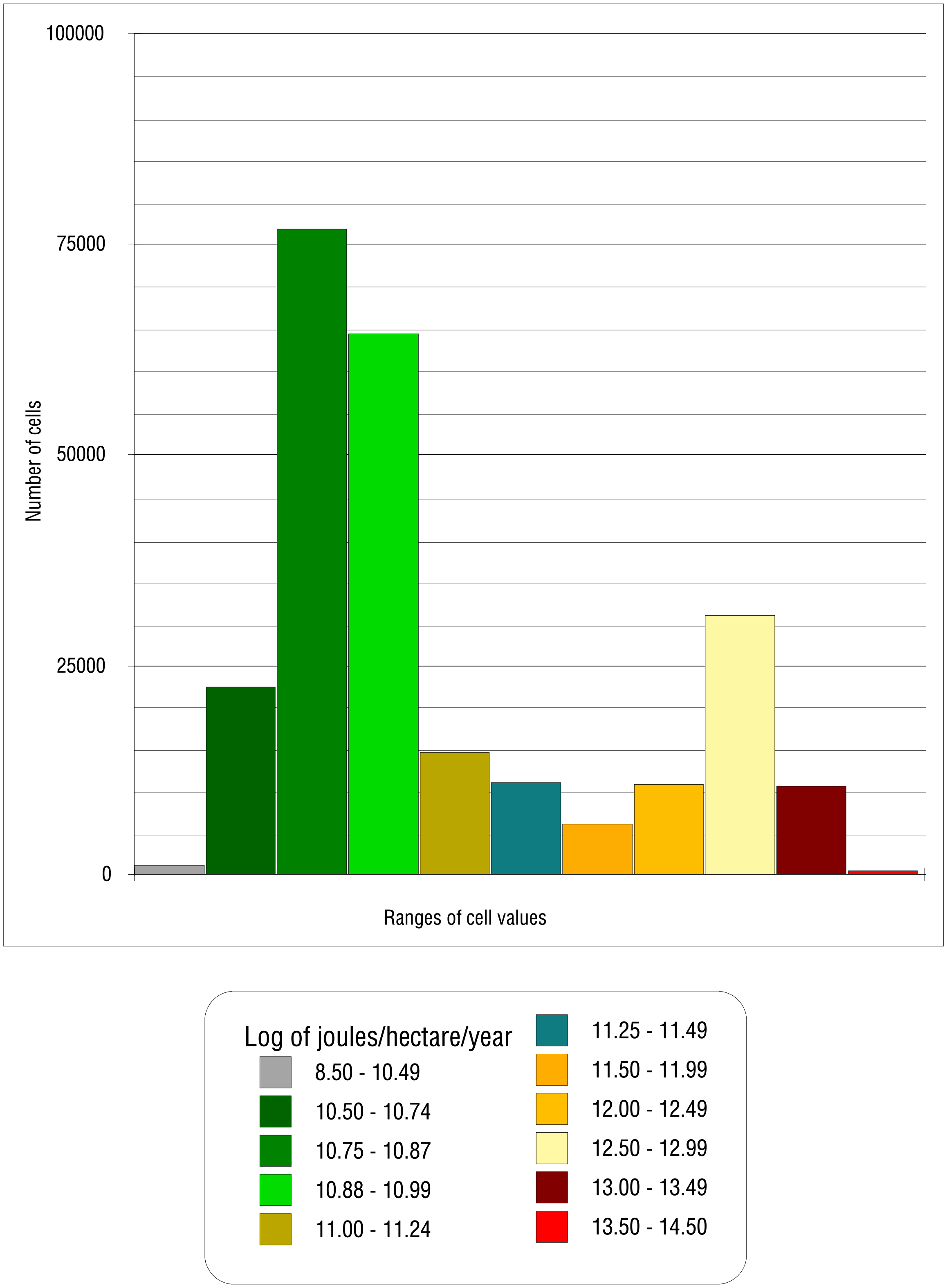


Figure 3-105: Histogram of the distribution of the grid cell values found in the logarithm analytical total energy flow density grid called 'empower_en_log' with ranges of log values chosen to illustrate the variation in the energy grid values.

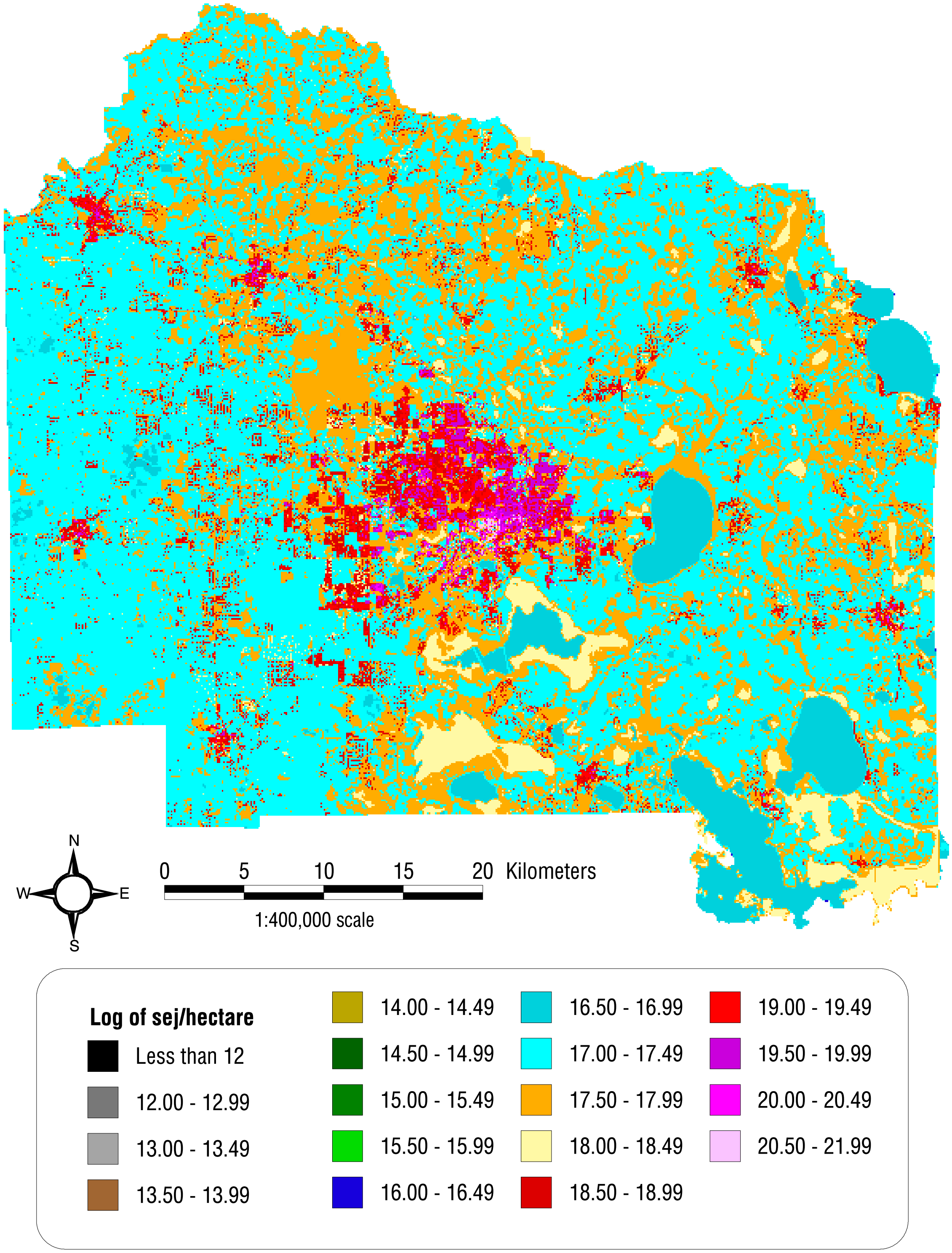


Figure 3-106: Map of the logarithm analytical EMERGY grid called 'emstore_log'. This grid represents the log of the total EMSTORAGE density (log sej/ha). It was created by calculating the log of the sum of the grids representing the EMSTORAGE densities for natural systems structure, urban system structure, and EMERGY stored in the human population.

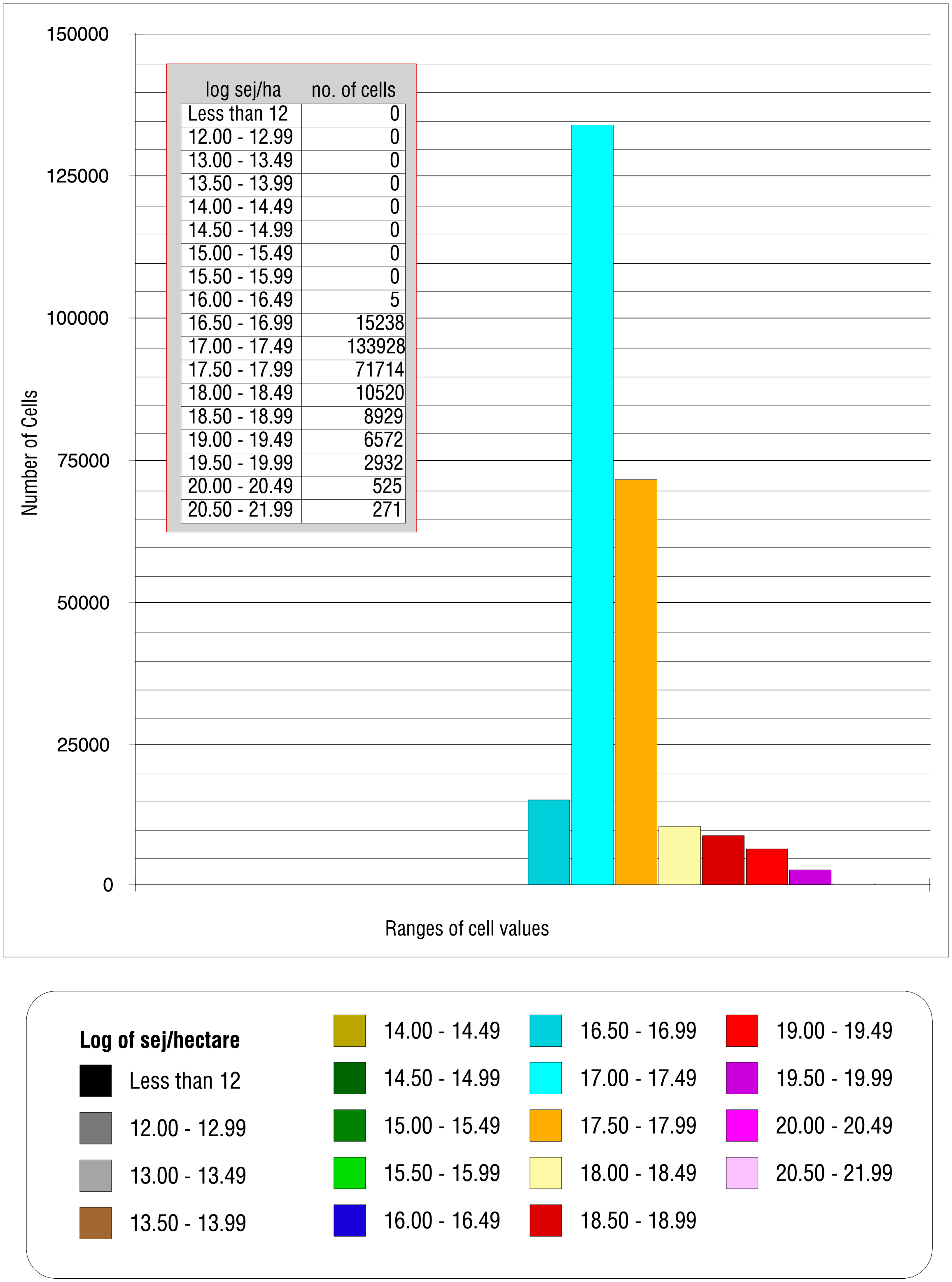


Figure 3-107: Histogram of the distribution of grid cell values found in the logarithm analytical EMERGY grid called 'emstore_log'. The summary table lists the exact number of cells within each range of values for the log total EMSTORAGE density (log sej/ha).

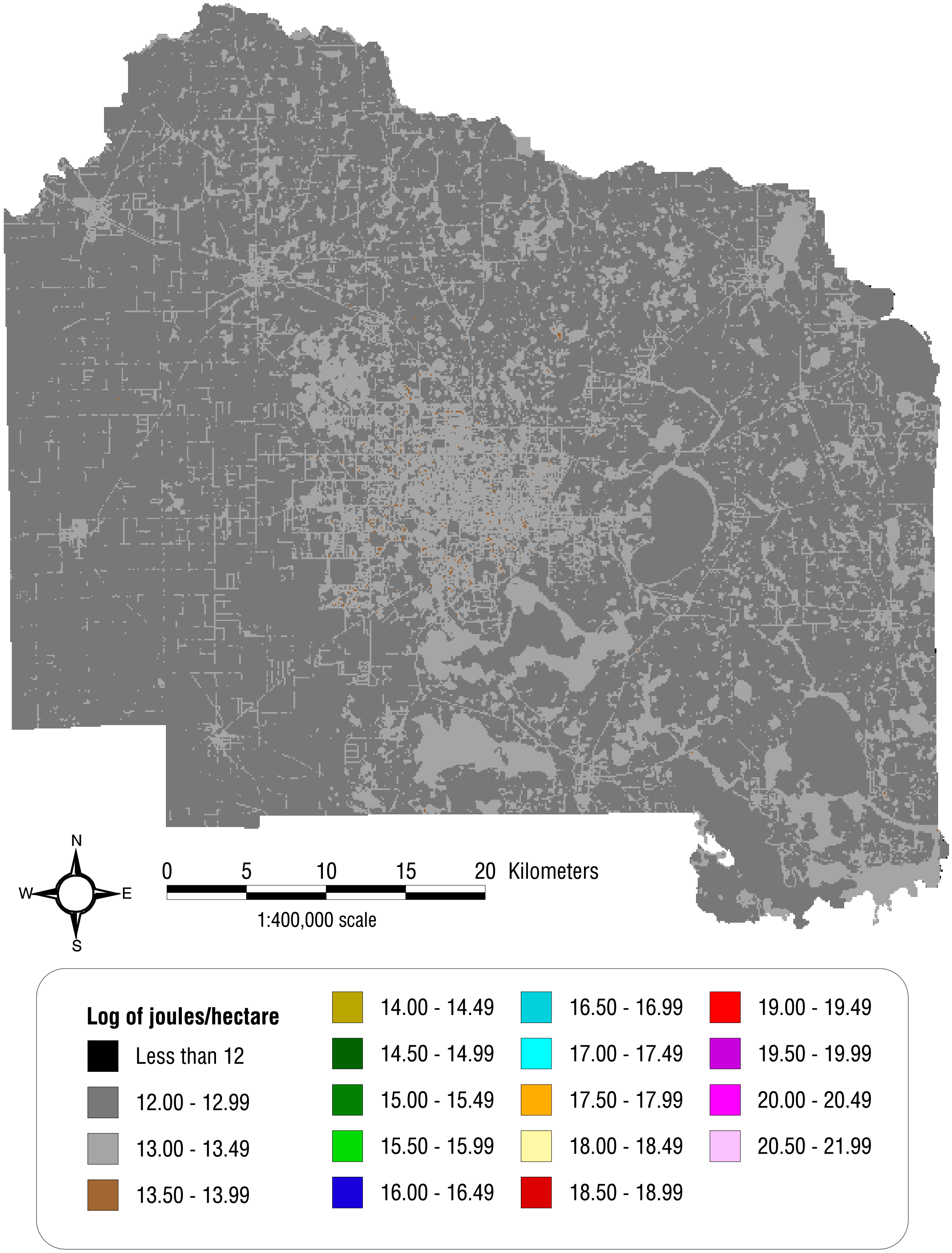


Figure 3-108: Map of the logarithm analytical energy grid (emstor_en_log) representing the log of the total energy storage density (log j/ha). This grid was created by calculating the log of the sum of the grids representing the total energy storage densities for natural systems, urban systems, and energy stored in the human population.

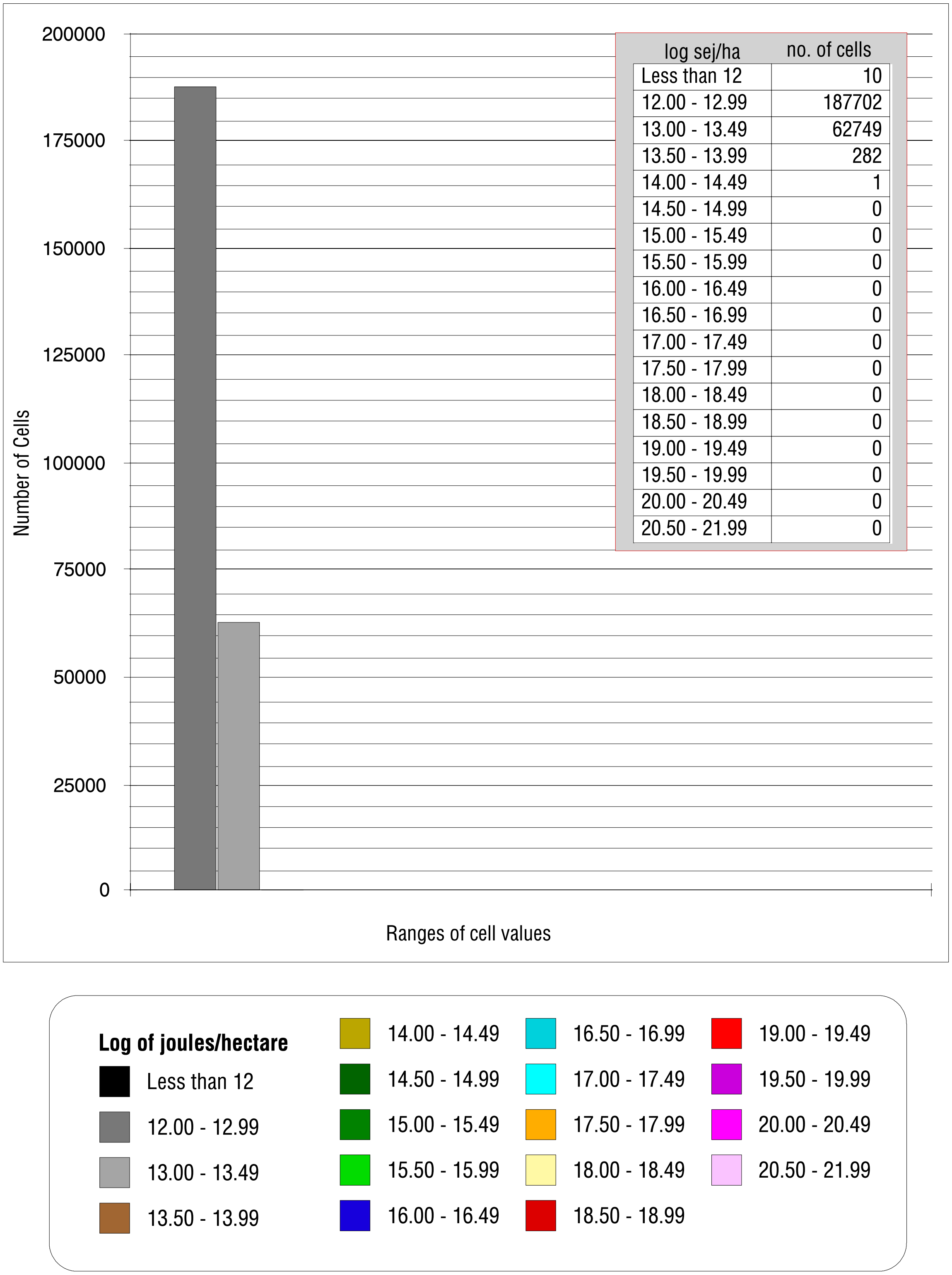


Figure 3-109: Histogram of the distribution of grid cell values found in the logarithm analytical energy grid called ’emstor_en_log’. The summary table lists the exact number of cells within each range of values for the log total energy storage density (log j/ha).

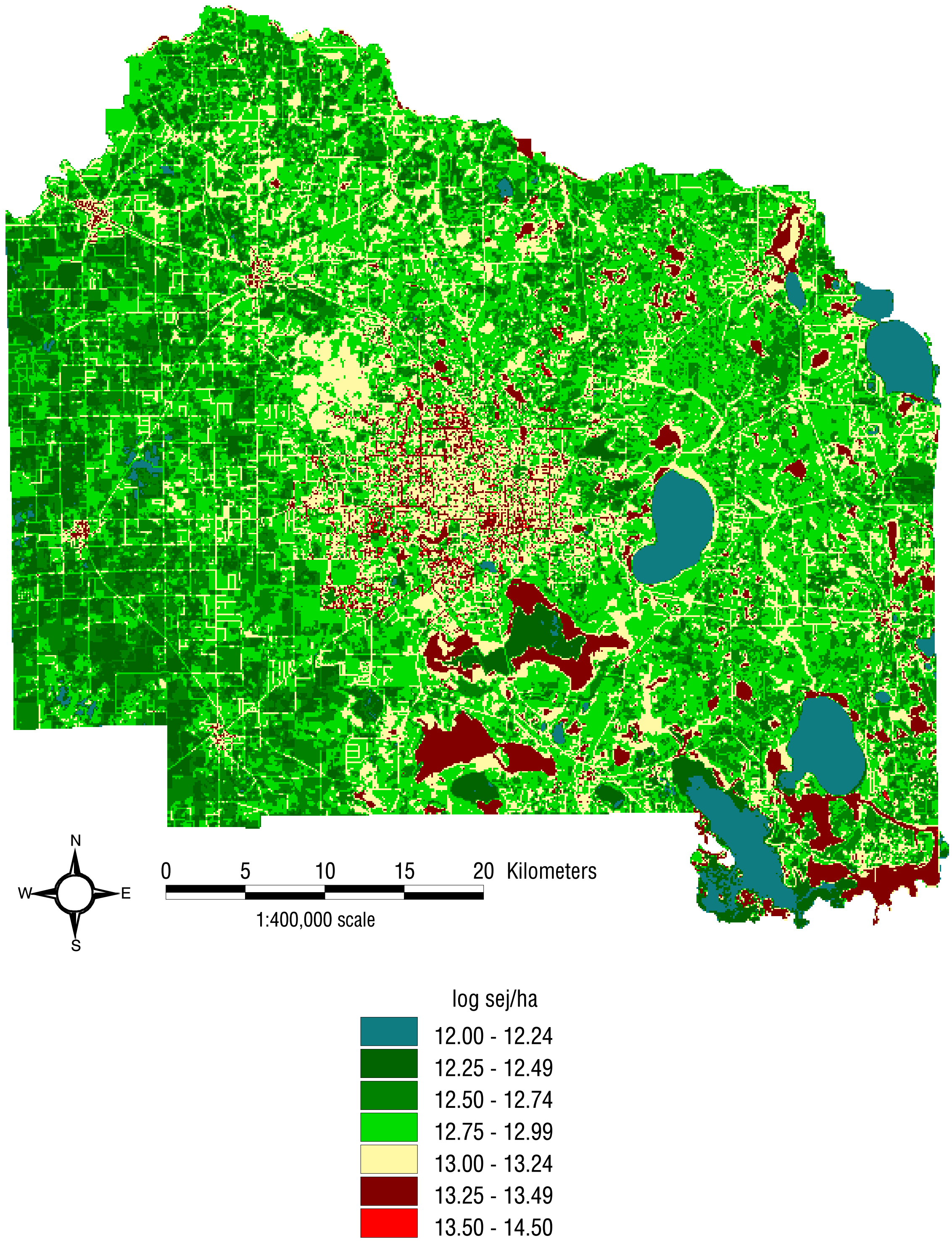


Figure 3-110: Map of the logarithm analytical total energy storage density grid called 'emstor_en_log' with ranges of log values chosen to illustrate the variation in the energy storage grid values.

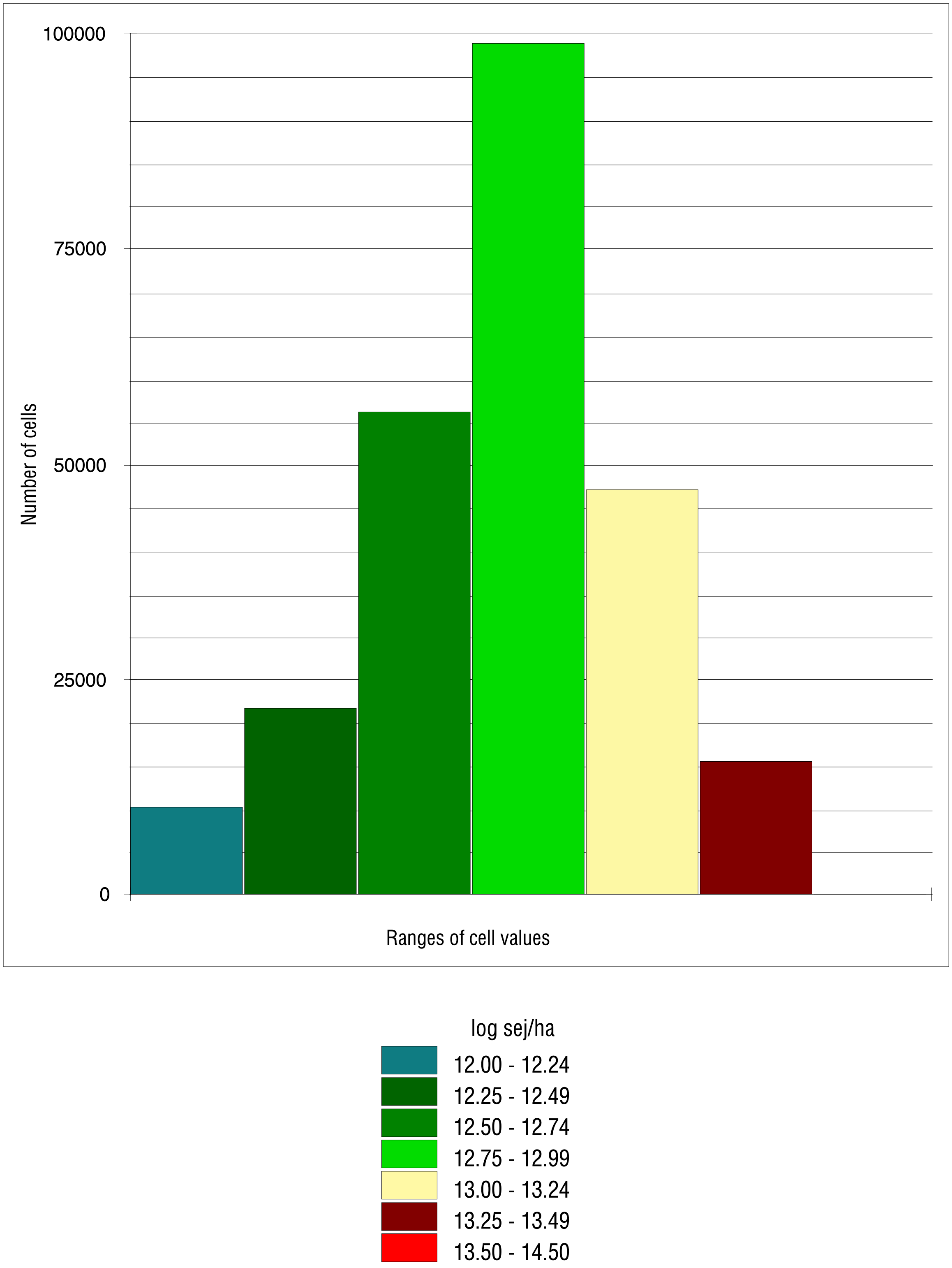


Figure 3-111: Histogram of the distribution of the grid cell values found in the logarithm analytical total energy storage density grid called 'emstor_en_log' with ranges of log values chosen to illustrate the variation in the energy grid values.

Transformity Analytical Grids

An analytical grid of the transformity (the ratio of solar emjoules/joule) of total annual EMPOWER density was created by dividing each cell value in the 'Total Annual EMPOWER Density' analytical grid by the values in the spatially coincident cells of the 'Total Annual Energy Flow Density' analytical grid. A map of the ranges of transformities for the total annual EMPOWER density is displayed in Figure 3-112. A histogram of cell value distribution based on the transformity value range legend is presented in Figure 3-113. The transformity values range from about 5 E3 sej/j to about 1.5 E6 sej/j. About 58% of the values fall within the range of 1 E4 to 2.5 E4 sej/j. Urban areas are characterized by a very wide range of transformities, ranging from 2.5 E4 to 1.5 E6 sej/j. The highest values are associated with institutional and commercial land uses. The transformity histogram reveals a pattern that is similar to the patterns observed for many of the EMERGY component grids. There are many cells with lower transformities and increasingly fewer cells with increasingly higher transformity values.

The transformity analytical grid for the total EMSTORAGE density was created by dividing the 'Total EMSTORAGE Density' grid by the 'Total Energy Storage Density' grid. The map of the transformity of the total EMSTORAGE density is displayed in Figure 3-114, and the associated cell value distribution histogram is presented in Figure 3-115. Transformities for rural areas range from 3 E4 to 7.5 E4 sej/j, and values for urban areas range from 1 E5 to 1.5 E8 sej/j with the highest values being associated with institutional and commercial land uses. The EMSTORAGE transformity histogram displays the familiar pattern of cell distribution.

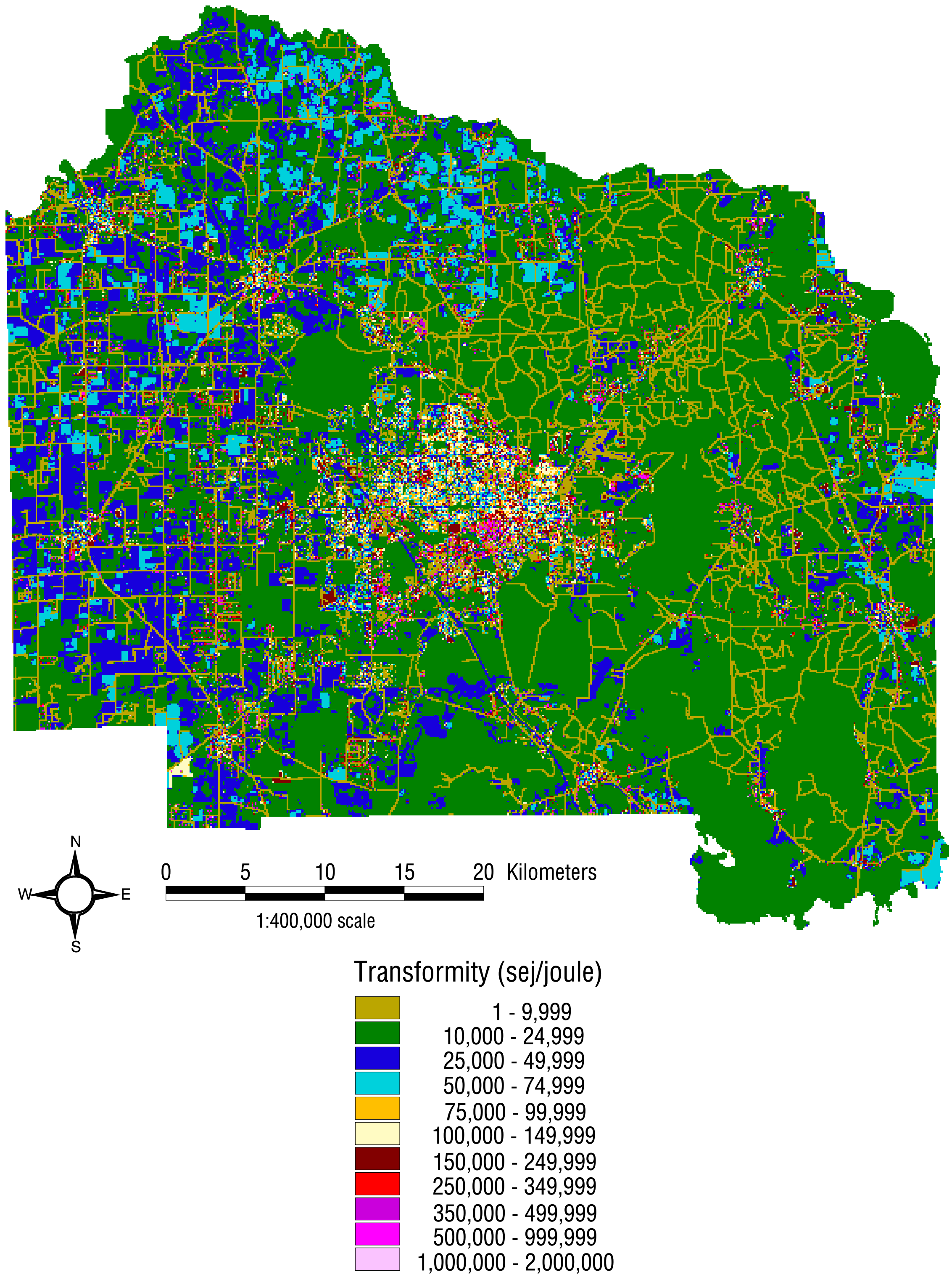
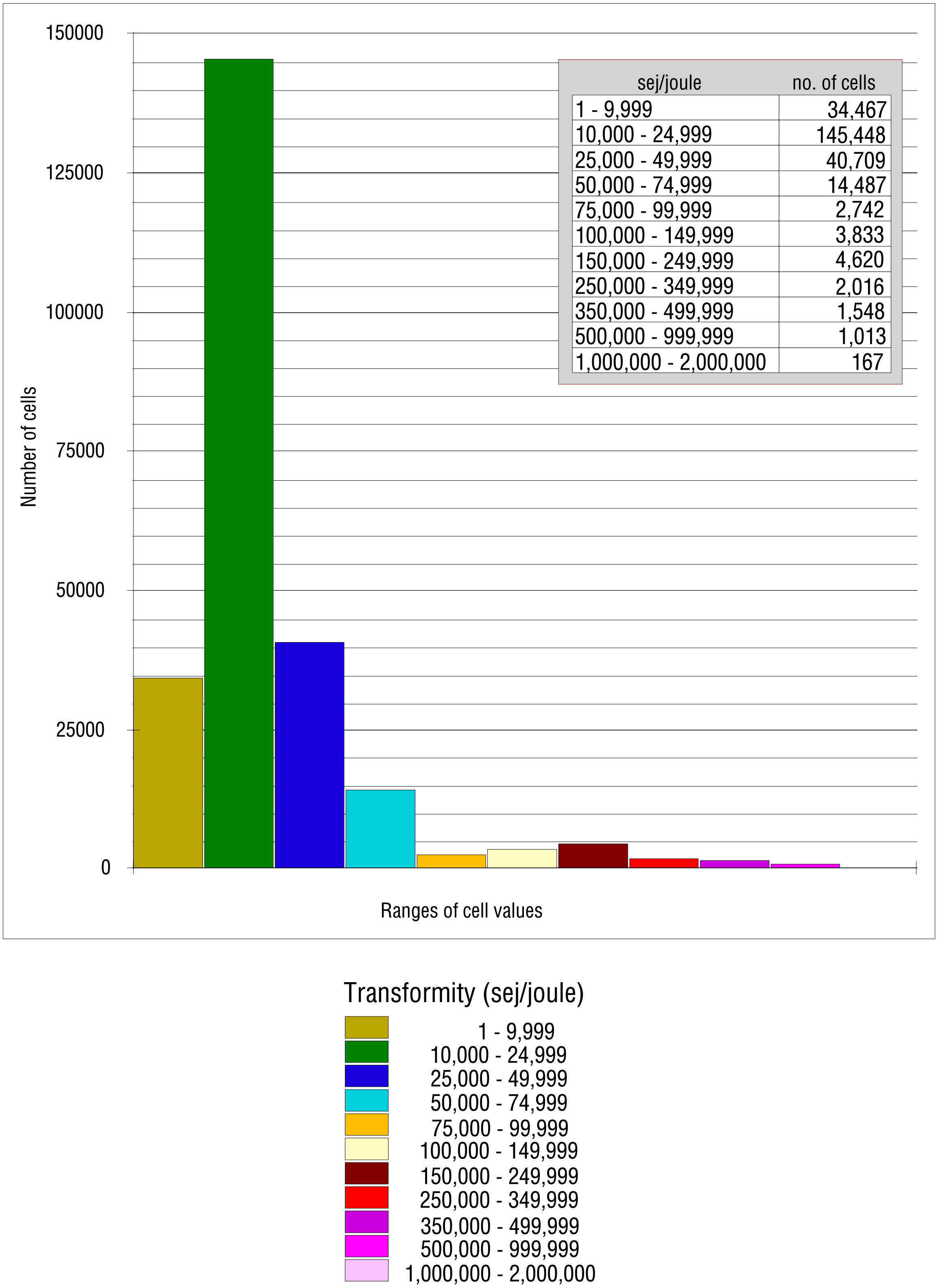


Figure 3-112: Map of the ranges of transformities (sej/joule) for the total annual EMPOWER density. This grid was created by dividing the values in each cell of the total empower density grid (with units of sej/ha/yr) by the spatially corresponding values in each cell of the total annual energy density grid (with units of joules/ha/yr).



sej/joule	no. of cells
1 - 9,999	34,467
10,000 - 24,999	145,448
25,000 - 49,999	40,709
50,000 - 74,999	14,487
75,000 - 99,999	2,742
100,000 - 149,999	3,833
150,000 - 249,999	4,620
250,000 - 349,999	2,016
350,000 - 499,999	1,548
500,000 - 999,999	1,013
1,000,000 - 2,000,000	167

Figure 3-113: Histogram of the ranges of transformities (sej/joule) for the total annual EMPOWER density grid. The summary table lists the number of cells with values in each range.

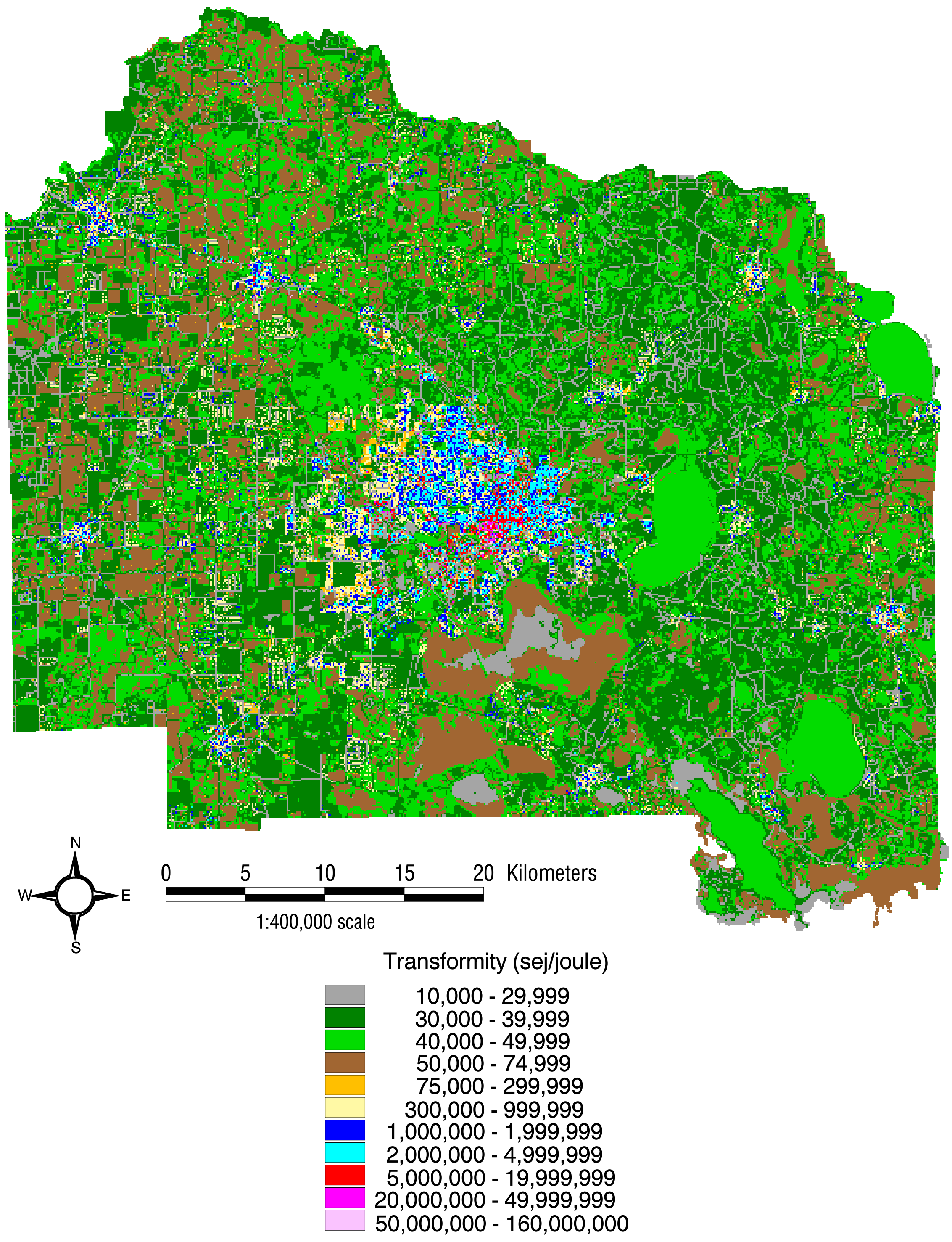
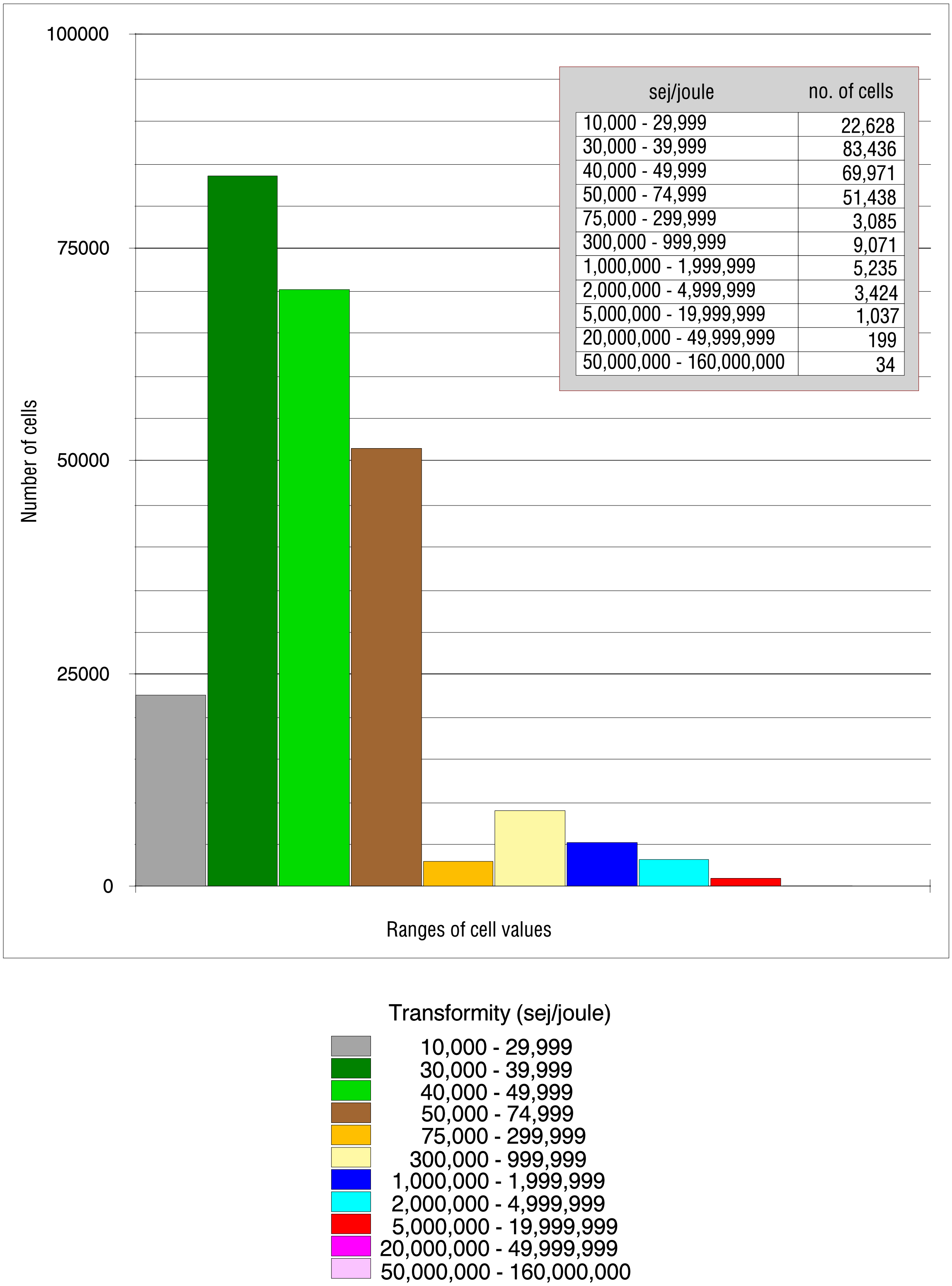


Figure 3-114: Map of the ranges of transformities (sej/joule) for the total EMSTORAGE density. This grid was created by dividing the values in each cell of the total EMSTORAGE density grid (with units of sej/ha) by the spatially corresponding values in each cell of the total energy storage density grid (with units of joules/ha).



sej/joule	no. of cells
10,000 - 29,999	22,628
30,000 - 39,999	83,436
40,000 - 49,999	69,971
50,000 - 74,999	51,438
75,000 - 299,999	3,085
300,000 - 999,999	9,071
1,000,000 - 1,999,999	5,235
2,000,000 - 4,999,999	3,424
5,000,000 - 19,999,999	1,037
20,000,000 - 49,999,999	199
50,000,000 - 160,000,000	34

Figure 3-115: Histogram of the ranges of transformities (sej/joule) for the total EMSTORAGE density grid. The summary table list the number of cells with values in each range of transformities.

County-wide (Sub)Component EMERGY Signatures

County-wide (Sub)Component EMERGY Signatures were created by calculating the log of the sum of the values for all of the cells in each of the (sub)component grids. These signature calculations are presented as histograms that display the log of total County-wide EMERGY flow or storage for each (sub)component of the model.

Four histograms were created corresponding to each of the sets of (sub)component annual EMPOWER density grids (Figure 3-116), annual energy flow density grids (Figure 3-117), EMSTORAGE density grids (Figure 3-119), and energy storage density grids (Figure 3-120). Summary tables are also provided for each signature with the sum values for each (sub)component grid listed in exponential form in addition to the log form of the values.

Calculations were also made to determine the percentages of the total county-wide annual EMPOWER (sej/county/yr) (Figure 3-118) and total county-wide EMSTORAGE (sej/county) (Figure 3-121) that were contributed by each of the (sub)component grids.

County-wide EMPOWER density signature. The 'Total Annual County-wide EMPOWER of Consumption' was calculated to be 276.39 E20 sej/county/year (22.44 log sej/county/year). This amount was calculated by adding the values shown in Figure 3-116 for the county-wide total EMPOWER for renewable sources used, water used, all fuels used, goods consumed, and in-situ human services (sum of the flows for elements 1, 3, 4, 5, and 6 in Figure 1-3 for all land area units, or cells, in the county for one year).

The service component flow contributes about 211.61 E20 sej/county/year (or 22.22 log sej/county/year) to the county-wide total EMPOWER density. In fact, 76.5% of the total flow is accounted for by the flow of in-situ human services. This is explained by the high transformities used to convert the energy flows of human services to EMERGY flows. The flow values for goods, 31.27 E20 sej/county/year, and fuels, 28.47 sej/county/year, are very similar. The chart in Figure 3-118 shows that about 98% of the total county-wide annual EMPOWER density is accounted for by adding together the service, goods, and fuel flows.

County-wide EMSTORAGE density signature. The total annual county-wide EMSTORAGE density was calculated to be 6895.80 E20 sej/county (or 23.84 log sej/county). This represents the total amount of EMERGY stored in all of the storages represented in the land area unit diagram for every land area unit (cell) in the county.

The population storage component contributes about 6003 E20 sej/county (or 23.78 log sej/county/year) to the county-wide total EMSTORAGE density. The chart in Figure 3-118 shows that about 87% of the total county-wide EMSTORAGE density is accounted for by the storage of EMERGY in humans. Once again, this is explained by the high transformities applied to the calculation for storage in the population.

Natural systems EMSTORAGE density is about 771 E20 sej/county. According to these calculations, soil organic matter contributes about 67% of the stored EMERGY in natural systems. The county-wide EMSTORAGE densities for biomass and surface water/groundwater storages are approximately equal with values around 129 E20 sej/county. The urban system EMSTORAGE density is about 121 E20 sej/county. Buildings account for about 65% of the stored EMERGY in the urban structure of the

County. Roads account for about 20% and utility infrastructure accounts for the remaining 15% of the EMERGY stored in urban system structure.

County-wide energy flow density signature. The total annual county-wide energy flow density was calculated as 4323.15 E14 joules/county/year (or 17.64 log j/county/year). The renewable sources component contributes about 4018 E14 joules/county/year to the County-wide total energy flow density. The chart in Figure 3-121 reveals that about 93% of the total county-wide energy flow density is accounted for by the flows of renewable sources (transpiration and sunlight). The energy in fuels used is the next largest flow at a rate of 268 E14 joules/county/year. Transportation fuel use accounts for about 69% of the total fuel energy flow. Goods consumption accounts for only 0.6% of the total density, and services only account for only 0.15% of the total annual energy flow density for the county.

County-wide Energy Storage Density Signature. The total annual county-wide energy storage density was calculated to be 20430 E20 joules/county (or 18.3 log sej/co.). Natural systems energy storage density is about 17655 E14 joules/county. Soil organic matter contributes about 46%, biomass contributes about 36%, and surface and groundwater contribute about 18% of the stored EMERGY in natural systems. The energy stored in natural system structure represents 86% of the total county-wide energy storage. The urban system energy storage density is about 2774 E14 joules/county. According to these calculations, the utility infrastructure accounts for about 63% of the stored energy in the urban structure of the county, roads account for about 27% and buildings account for the remaining 10% of the EMERGY stored in urban system structure.

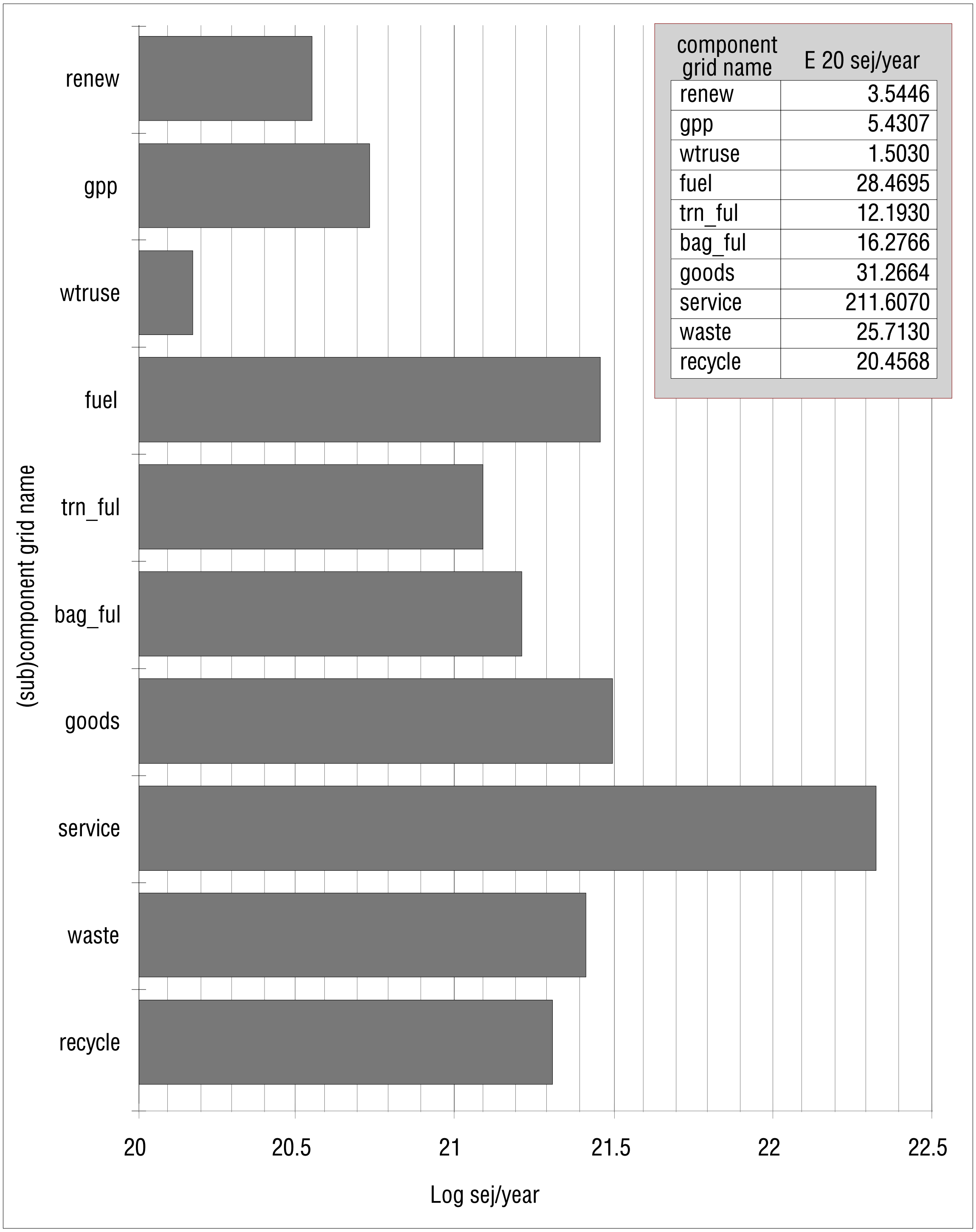


Figure 3-116: Chart showing the county-wide EMPOWER density (log sej/county/yr) for each of the spatial EMERGY model component and subcomponent grids. These values were calculated by taking the log of the sum of the values for all of the cells in each EMERGY (sub)component grid. The summary table lists the sum values for each (sub) component grid in units of 'E20 sej/year'. The total county-wide EMPOWER was found to be 276.39 E20 sej/year or 22.44 log sej/year (calculated by adding the renew, wtruse, fuel, goods, and service component sums).

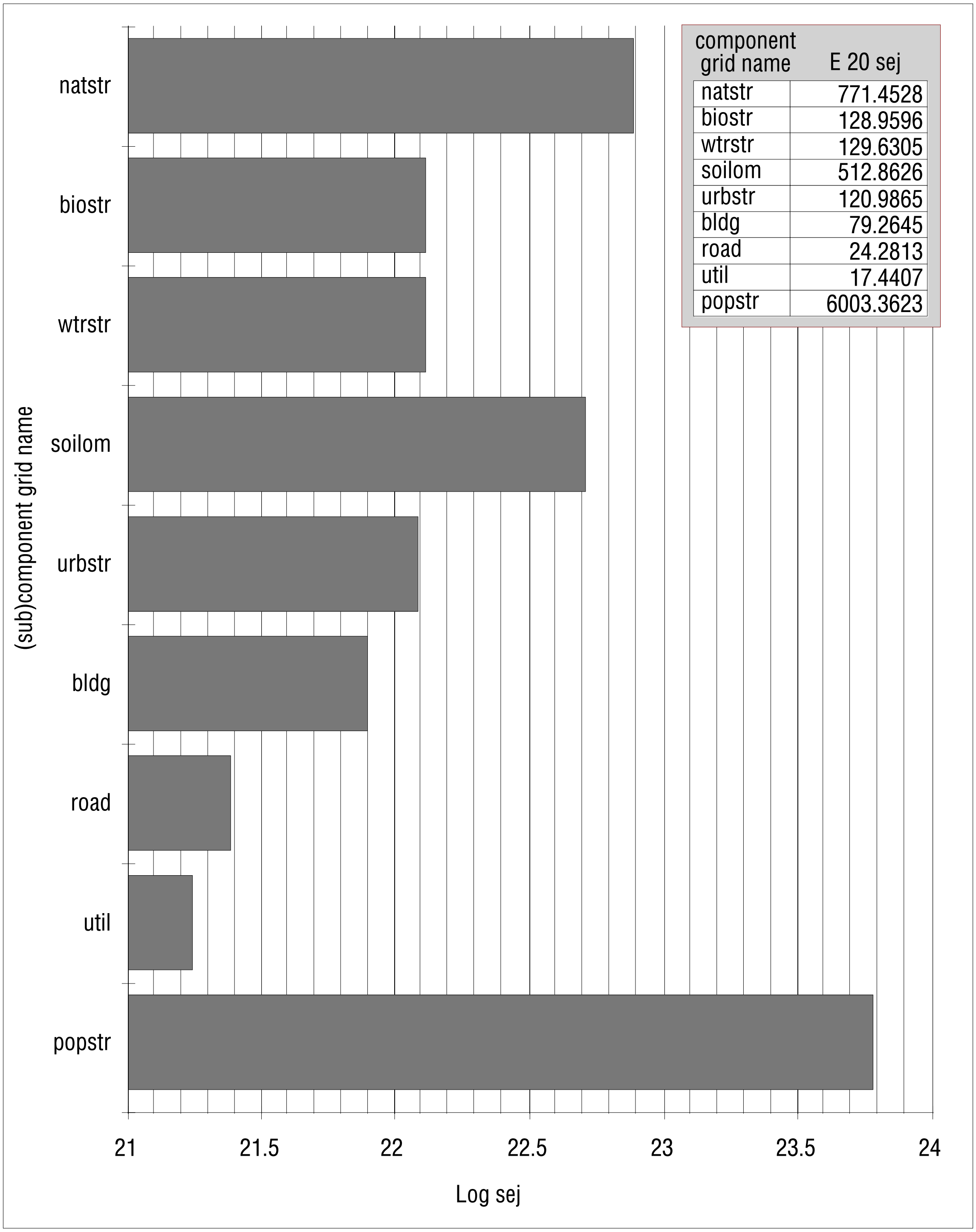


Figure 3-117: Chart showing the county-wide EMSTORAGE density (log sej/county) for each of the spatial EMERGY model component and subcomponent grids. These values were calculated by taking the log of the sum of the values for all of the cells in each EMERGY (sub)component grid. The summary table lists the sum values for each (sub) component grid in units of 'E20 sej/year'. The total county-wide EMSTORAGE was ound to be 6895.80 E20 sej or 23.84 log sej (calculated by adding the natstr, urbstr, and popstr component grid sums).

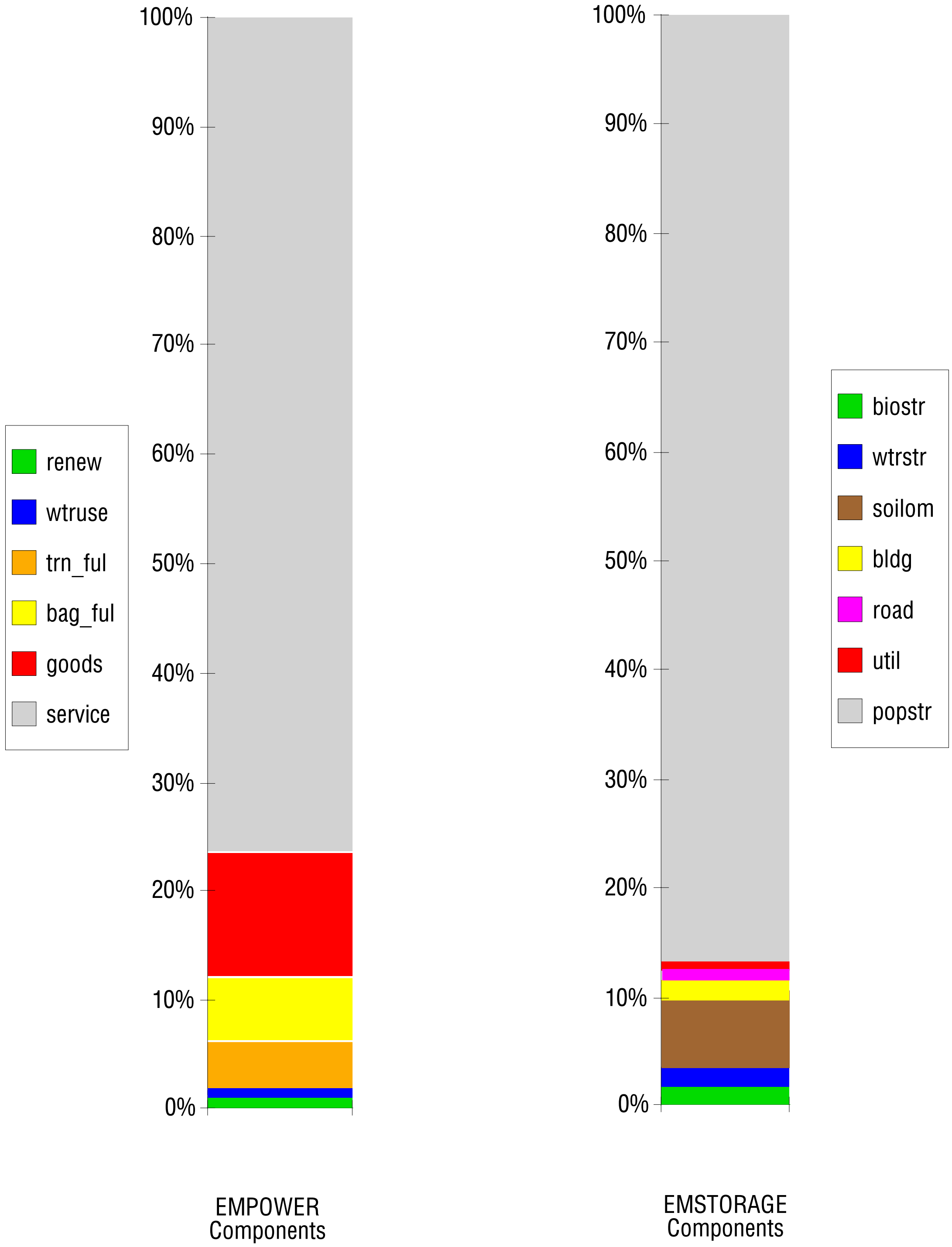
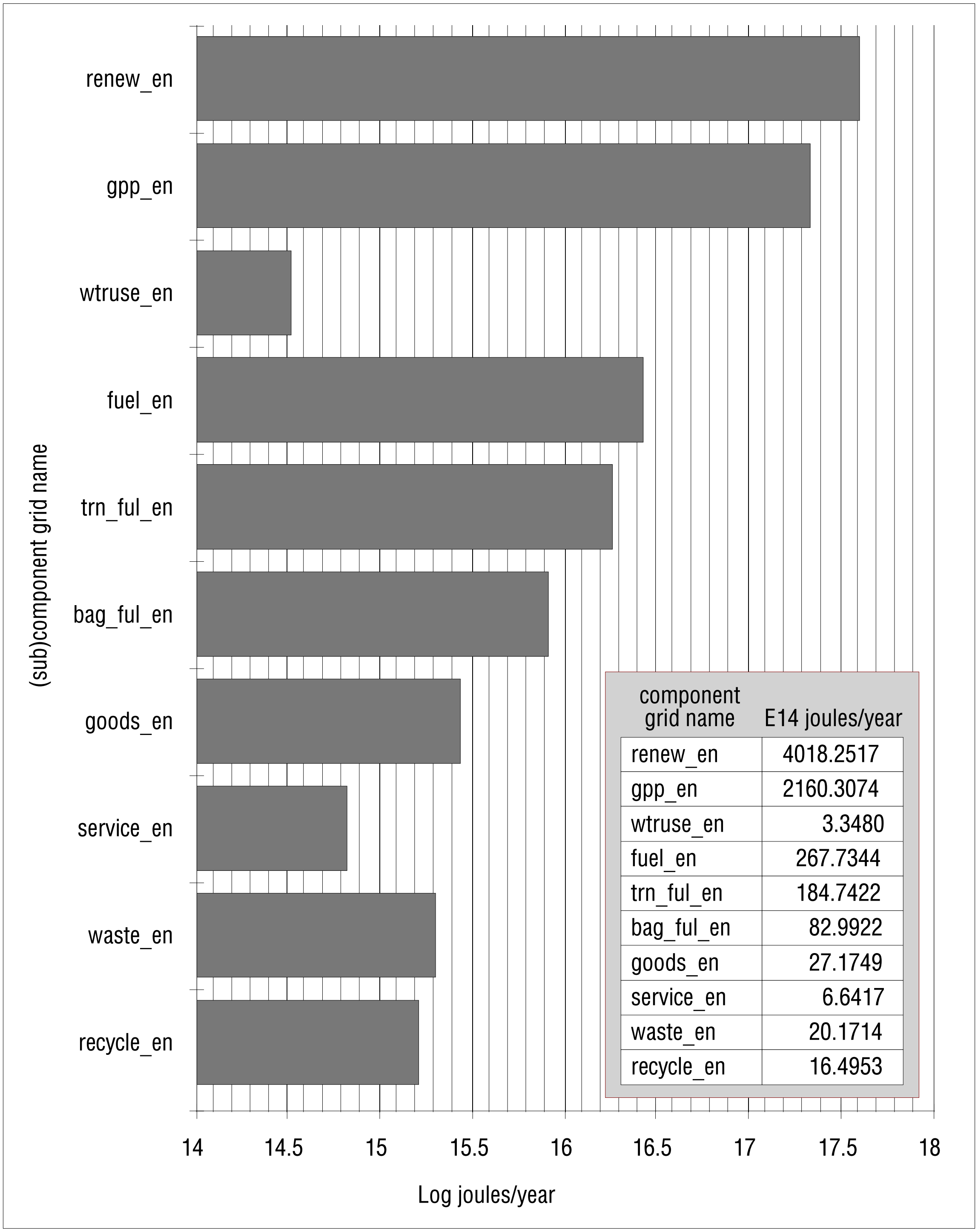


Figure 3-118: Chart showing the percentages of the total county-wide annual EMPOWER (sej/county/yr) and total county-wide EMSTORAGE (sej/county) contributed by each of the spatial EMERGY model component and sub-component grids that were included in the county-wide sum values.



component grid name	E14 joules/year
renew_en	4018.2517
gpp_en	2160.3074
wtruse_en	3.3480
fuel_en	267.7344
trn_ful_en	184.7422
bag_ful_en	82.9922
goods_en	27.1749
service_en	6.6417
waste_en	20.1714
recycle_en	16.4953

Figure 3-119: Chart showing the county-wide energy flow density (log joules/county/yr) for each of the spatial EMERGY model energy component and subcomponent grids. These values were calculated by taking the log of the sum of the values for all of the cells in each energy grid. The summary table lists the sum values for each (sub)component grid in units of 'E14 joules/year'. The total county-wide energy flow was found to be 4323.15 E14 joules/year or 17.64 log joules/year (calculated by adding the renew_en, wtruse_en, fuel_en, goods_en, and service_en component sums).

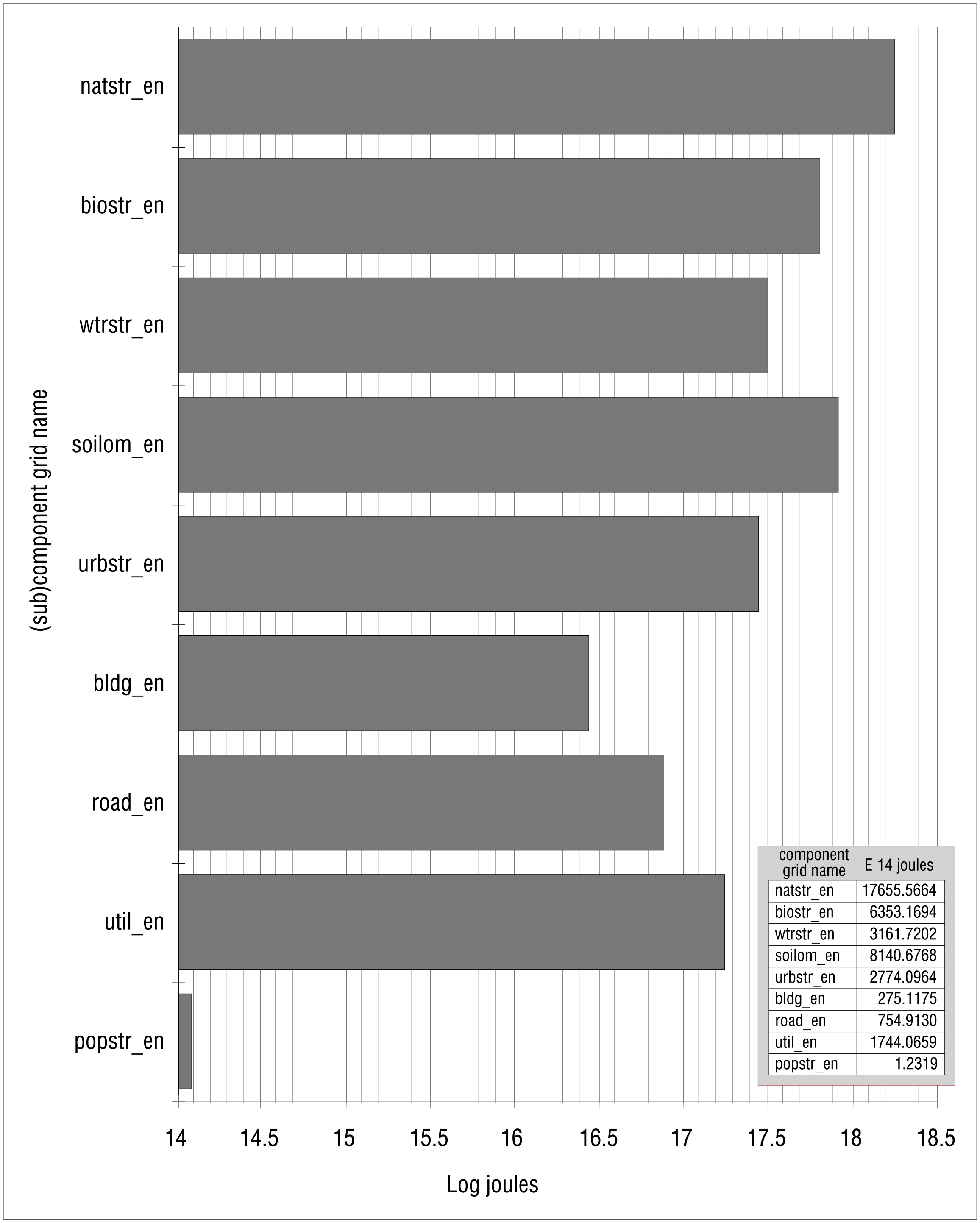


Figure 3-120: Chart showing the county-wide energy storage density (log joules/county) for each of the spatial EMERGY model energy component and subcomponent grids. These values were calculated by taking the log of the sum of the values for all of the cells in each energy grid. The summary table lists the sum values for each (sub)component grid in units of 'E14 joules/year'. The total county-wide energy storage was found to be 20430 E14 joules or 18.31 log joules (calculated by adding the natstr_en, urbstr_en, and popstr_en component sums).

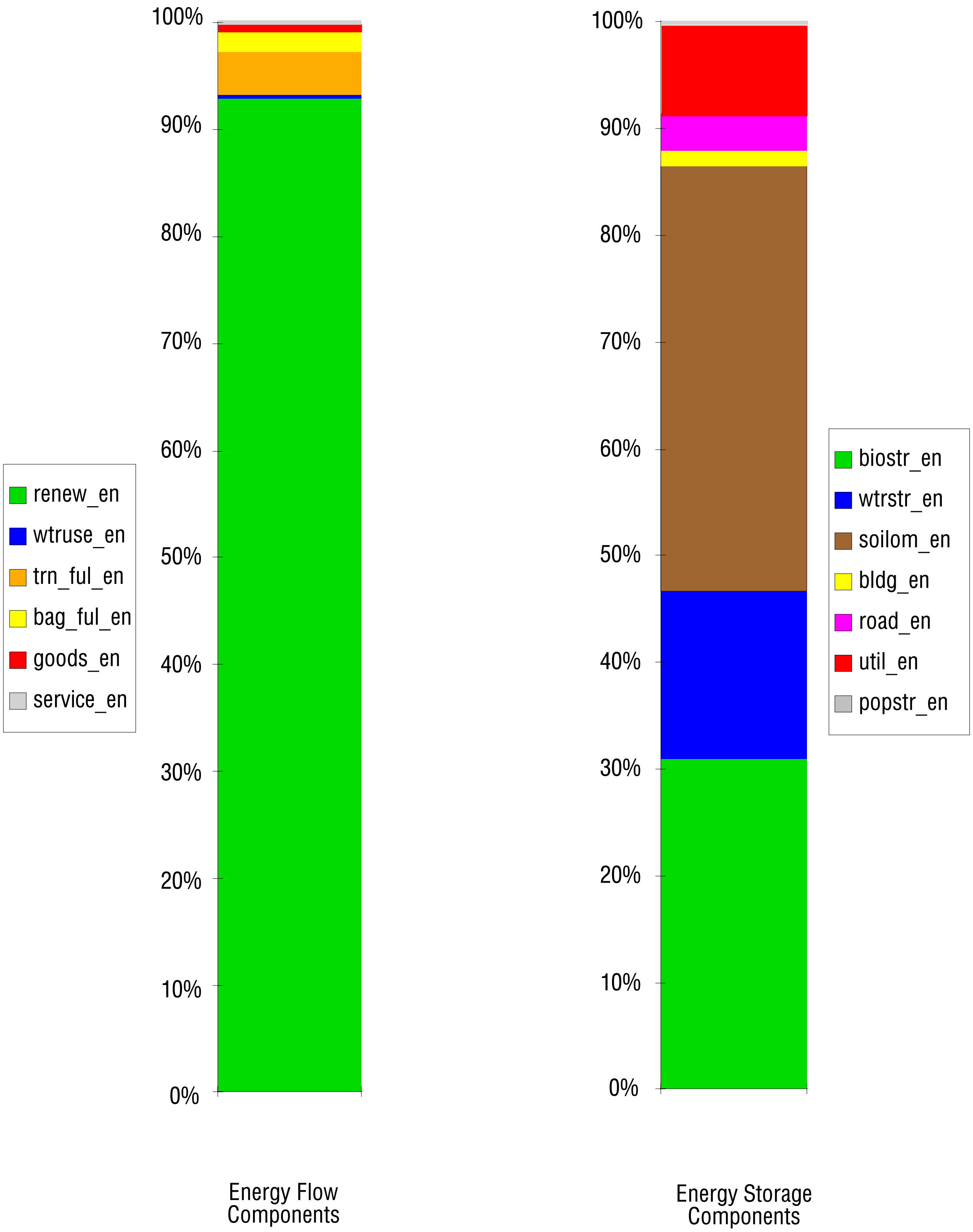


Figure 3-121: Chart showing the percentages of the total county-wide energy flow (joules/county/yr) and total county-wide energy storage (joules/county) contributed by each of the spatial EMERGY model component and sub-component energy grids that were included in the county-wide sum values.

County-Level Transformities

The total annual county-wide EMPOWER of consumption was calculated to be 276.39 E20 sej/county/year based on the data in the model, and the total county-wide annual energy consumption flow was calculated as 4323.15 joules/county/year. These values were calculated by adding the total County-wide energy or EMERGY flows from the ‘renew’, ‘wtruse’, ‘fuel’, ‘goods’, and ‘service’ component grids together. The individual county-wide EMPOWER sum values for each of these component grids are listed in Figure 3-116, and energy flow sums are listed in Figure 3-119.

The County-level EMPOWER transformity was calculated by dividing the value for the total annual EMPOWER by the value for the total annual energy flow. The transformity calculated for the total county-wide annual EMPOWER is 63,933 sej/joule.

The total annual county-wide EMSTORAGE amount was calculated to be 6895.80 E20 sej/county, and the total county-wide energy storage density was calculated as 20430 E14 joules/county. These values were calculated by adding the total county-wide energy or EMERGY storage values from the ‘natstr’, ‘urbstr’, and ‘popstr’ component grids together. The individual county-wide EMSTORAGE sum values for each of these component grids are listed in Figure 3-117, and energy flow sums are listed in Figure 3-121.

The county-level EMSTORAGE transformity was calculated by dividing the value for the total EMSTORAGE by the value for the total energy storage. The transformity calculated for the total county-wide EMSTORAGE is 337,533 sej/joule.

Comparative Studies

The following sections describe the results of three studies in which comparisons were made between different land areas of the county using EMERGY-related statistics as the basis of comparison. There are many ways to categorize land areas into units that can be described and analyzed. Three of the most common ways that planners categorize land areas were used for these studies: 1) land use/cover classification schemes, 2) boundaries of governance or management (called ‘planning units’ for this study), and, 3) land development units (such as neighborhoods).

In each of these studies, annual EMPOWER densities, EMSTORAGE densities, and transformities were calculated for each instance of a classification, planning unit, or neighborhood. A series of EMERGY component signature histograms was also created for each study.

Land Use and Cover Classification Study

The Florida Land Use and Cover Classification System (FLUCCS) (FDOT, 1985) was the system used in this study as the basis for comparing land areas according to land use/cover classification. The first step in this study was to use the 1995 land use and cover coverage to identify the land use/cover class of each cell in the model. Each component or analytical grid cell used in this study was assigned both a ‘level 3’ and a ‘level 2’ code based on the code values in the spatially corresponding polygon of the land use and cover polygon coverage. By having land use/cover codes for each cell, basic summary statistics could be created for those land areas (or cells) associated with each classification code (sometimes referred to later as a ‘land class’ or ‘class’).

In this study, the following summary statistics were calculated for the land areas associated with each land use/cover classification: the class sum of the ‘total EMERGY consumption’ flow and ‘total EMERGY storage’ (the sum of all cell values in a class), the class mean densities of these flows and storages, the class transformities, and the percentage of the county-wide total flow or storage represented by the class sum. These calculations were performed for the detailed FLUCCS ‘level 3’ classifications, the less detailed FLUCCS ‘level 2’ classifications, and an ‘aggregated’ classification scheme designed for this study that will be described in later sections.

EMPOWER analysis for level 3 land use and cover classifications. There are 163 FLUCCS ‘level 3’ land use and cover classifications found in the land use and cover coverage for Alachua County. Table 3-22 lists EMPOWER summary statistics for each land classification code. Mean ‘Total EMPOWER Density’ (sej/ha/yr) and total energy flow density (j/ha/yr) rates for each class were found by calculating the mean of the values for all of the cells with that classification code.

The mean values in Table 3-22 should be used cautiously by others since a review of the individual class values reveals some potential anomalies in the data. Although the relative magnitude of the values found for most of the classes are reasonable and intuitive, the mean values for some classes seem unusually high or low. Most of the anomalous values are associated with very specific land use classes (such as ‘rest areas’ or ‘kennels’) that are represented in very few cells (one cell, in the case of ‘rest areas’, or 11 cells, in the case of ‘kennels’). One explanation for these anomalies is that there are spatial and attribute inaccuracies in the land use and cover coverage, which was created by air photo interpretation methods, leading to cells being included in an inappropriate class. Another contributing factor is that each one-hectare cell had to be assigned only one classification code. In the 'overlay' method used to accomplish this assignment, there could be more than one polygon in the land use and cover coverage overlapping one cell. In these cases, the classification of the polygon covering the largest percentage of the cell was used to assign the classification to the cell.

The table is sorted in descending order according to the transformity calculated for each land class. These land class transformities were calculated by dividing the 'Total EMPOWER class density (E18 sej/class/year) by the energy flow class density (E12 joules/class/year). The EMPOWER or energy 'class densities' were calculated by adding the annual EMERGY or energy flows for all of the cells that have the same land use and cover classification. In this case 'class density' refers to varying sizes of areas and should not be confused with other density data. To reduce confusion, these values are simply referred to as the 'sum' values in Table 3-22.

As expected, the highest 'level 3' land class transformity (458,846 sej/j) was associated with the 'hospitals' classification. Apartment buildings, educational facilities, prisons, and shopping centers also have high transformities. Some of the calculated transformities are lower than might be expected, but are not really anomalies in the data. For instance, the transformity for the class 'electric power plants' is only 75,830 sej/joule. The reason for this lower than expected value is that the area covered by the land use coverage polygon(s) corresponding to this class includes large parking and storage areas and even some forested areas surrounding the actual power plant building. The flow density values for these areas are averaged in with the actual cell that contains the power plant, thus lowering the overall transformity for the class.

Table 3-22 also lists the percentage of the county-wide total EMPOWER or energy flow represented by the class sum. This simple statistic provides some insight into the relative amount of the county-wide total flows that is contributed by each land use classification. Notably large contributions to the total annual EMPOWER for the county come from medium-density residential (23.2%--sum of the values for codes 1210 and 1230), commercial and services (14.8%--sum of the values for codes 1400 and 1411), high-density residential (14.2%-- sum of the values for codes 1300,1330, and 1340), educational facilities (9.8%--based on code 1710), and hospitals (4.5%--based on code 1741). The importance of these simple statistics is more evident when one realizes that this small number of very specific codes account for about 66.5% of the total annual EMPOWER for the county. Significant contributions to the total annual energy flow for the county were made by the forest and agricultural land use/cover classes (30.8%--sum of the values for codes 2210, 4250, 4340, 4410, and 6300).

It is important to note that some specific land uses, such as prisons (code = 1765), have very high mean flow values and transformities, but, do not contribute a large amount to the overall county totals (‘prisons’ contribute only .34%). This should not be interpreted as implying that these relatively small, but intense, contributions are not important. In fact, the opposite is true. The EMERGY component and analytical maps presented earlier illustrated that there are many of these small-area, high-flow-intensity land uses that are scattered throughout the landscape. These high-intensity land uses can significantly affect surrounding land areas in both ‘negative’ (e.g., environmental) and ‘positive’ ways (e.g., providing access to services or flows of goods, etc.).

Table 3-22: Statistics summarized by 'Level 3' land use classifications for EMPOWER and energy flow class density. The table is sorted according to the calculated EMPOWER transformity of each land use class (transformity = sum,E18 sej/yr / sum,E12 j/yr).

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E15 sej/ha/yr	Sum, E18 sej/yr	% of Co.-wide total sej/yr	Mean, E10 j/ha/yr	Sum, E12 j/yr	% of Co.-wide total j/yr	EMPOWER Transformity (sej/j)
1741	Hospitals	56	0.0223	22253.00	1246.17	4.5088	4849.78	2715.88	0.6282	458,846
1340	multiple dwelling, highrise	264	0.1052	5942.29	1568.76	5.6760	2095.02	5530.85	1.2794	283,639
2530	Kennels	11	0.0044	1581.93	17.40	0.0630	603.17	66.35	0.0153	262,268
1710	educational facilities	826	0.3292	3266.76	2698.34	9.7629	1306.83	10794.44	2.4969	249,975
1765	municipal prisons	21	0.0084	4499.45	94.49	0.3419	1862.80	391.19	0.0905	241,542
1330	multiple dwelling, low rise	549	0.2188	3522.63	1933.92	6.9972	1694.90	9305.02	2.1524	207,837
1411	shopping centers	241	0.0960	4389.50	1057.87	3.8275	2136.12	5148.04	1.1908	205,490
2240	other tree crops	10	0.0040	20.10	0.20	0.0007	9.86	0.99	0.0002	203,833
8180	auto parking (rest areas)	1	0.0004	13119.83	13.12	0.0475	6470.05	64.70	0.0150	202,777
1555	container manufacturing	3	0.0012	4667.02	14.00	0.0507	2402.30	72.07	0.0167	194,274
1490	commercial construction	11	0.0044	3377.84	37.16	0.1344	1912.24	210.35	0.0487	176,643
1565	heavy industrial	16	0.0064	2753.89	44.06	0.1594	1617.46	258.79	0.0599	170,260
1300	Residential, high density	167	0.0666	2486.13	415.18	1.5022	1495.97	2498.27	0.5779	166,189
1700	Institutional	114	0.0454	1019.88	116.27	0.4207	627.67	715.55	0.1655	162,486
1552	electronics industry	22	0.0088	3390.29	74.59	0.2699	2131.89	469.02	0.1085	159,028
1400	Commercial and Services	1140	0.4543	2666.52	3039.83	10.9984	1695.63	19330.21	4.4713	157,258
1570	chemical processing	7	0.0028	1685.00	11.80	0.0427	1172.95	82.11	0.0190	143,654
1500	Industrial	10	0.0040	2172.80	21.73	0.0786	1518.12	151.81	0.0351	143,124
1551	boat building	27	0.0108	1633.00	44.09	0.1595	1269.32	342.72	0.0793	128,651
1720	religious facilities	80	0.0319	1398.22	111.86	0.4047	1099.21	879.37	0.2034	127,202
1350	mixed units, high density	39	0.0155	2373.32	92.56	0.3349	1875.38	731.40	0.1692	126,552
1550	light industrial	440	0.1753	1417.65	623.77	2.2569	1130.01	4972.06	1.1501	125,455
8350	solid waste disposal	166	0.0662	108.85	18.07	0.0654	86.93	144.30	0.0334	125,220
1756	govt. maintenance yards	41	0.0163	768.14	31.49	0.1139	623.78	255.75	0.0592	123,144
8113	private airport	31	0.0124	40.88	1.27	0.0046	36.80	11.41	0.0026	111,081
8880	other	3	0.0012	906.53	2.72	0.0098	825.78	24.77	0.0057	109,779
1310	single family, high density	172	0.0685	1599.09	275.04	0.9951	1467.87	2524.74	0.5840	108,940
6120	shrub swamps	3	0.0012	162.40	0.49	0.0018	152.46	4.57	0.0011	106,522
5100	Water (streams)	36	0.0143	61.82	2.23	0.0081	58.09	20.91	0.0048	106,435
1560	heavy industrial	15	0.0060	1531.80	22.98	0.0831	1450.33	217.55	0.0503	105,617
1470	mixed commercial/services	12	0.0048	1330.48	15.97	0.0578	1280.09	153.61	0.0355	103,936
1452	motels	45	0.0179	2284.47	102.80	0.3719	2313.07	1040.88	0.2408	98,763
1521	sawmills	33	0.0132	186.07	6.14	0.0222	190.30	62.80	0.0145	97,779
8340	sewage treatment plants	112	0.0446	397.29	44.50	0.1610	418.87	469.14	0.1085	94,846

Table 3-22 – continued.

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E15 sej/ha/yr	Sum, E18 sej/yr	% of Co.-wide total sej/yr	Mean, E10 j/ha/yr	Sum, E12 j/yr	% of Co.-wide total j/yr	EMPOWER Transformity (sej/j)
1527	woodyards	3	0.0012	606.18	1.82	0.0066	643.53	19.31	0.0045	94,194
5120	streams	15	0.0060	21.28	0.32	0.0012	23.54	3.53	0.0008	90,381
1230	mixed units, med. density	3529	1.4063	1142.18	4030.74	14.5837	1265.70	44666.38	10.3319	90,241
1910	undeveloped in urban area	107	0.0426	633.10	67.74	0.2451	721.81	772.34	0.1787	87,711
2590	other specialty farms	58	0.0231	190.19	11.03	0.0399	221.10	128.24	0.0297	86,022
1210	single family, med. density	2330	0.9285	1024.57	2387.25	8.6373	1263.99	29450.95	6.8124	81,058
8200	communications	3	0.0012	267.47	0.80	0.0029	334.66	10.04	0.0023	79,921
8311	electric power plant	113	0.0450	384.98	43.50	0.1574	507.68	573.68	0.1327	75,830
1424	farmers markets	2	0.0008	1099.06	2.20	0.0080	1460.58	29.21	0.0068	75,248
2200	tree crops	12	0.0048	112.41	1.35	0.0049	150.65	18.08	0.0042	74,614
2300	feeding operations	6	0.0024	345.57	2.07	0.0075	472.11	28.33	0.0066	73,196
1820	golf courses	370	0.1474	175.34	64.88	0.2347	240.61	890.26	0.2059	72,873
1130	mixed units, low density	1701	0.6779	457.91	778.90	2.8181	647.60	11015.70	2.5481	70,708
1423	junk yards	40	0.0159	317.04	12.68	0.0459	451.22	180.49	0.0417	70,262
1200	Residential, med. density	472	0.1881	579.35	273.45	0.9894	829.19	3913.80	0.9053	69,869
1860	community recreation	116	0.0462	375.82	43.59	0.1577	550.87	639.01	0.1478	68,222
2420	sod farms	4	0.0016	16.33	0.07	0.0002	23.94	0.96	0.0002	68,206
2210	citrus groves	58	0.0231	48.66	2.82	0.0102	71.95	41.73	0.0097	67,627
5330	reservoirs, 10-100 acres	52	0.0207	39.42	2.05	0.0074	60.84	31.64	0.0073	64,797
8312	electric power plant	15	0.0060	875.19	13.13	0.0475	1399.53	209.93	0.0486	62,535
1800	Recreational	16	0.0064	217.08	3.47	0.0126	361.20	57.79	0.0134	60,098
1110	single family, low density	1428	0.5691	376.42	537.53	1.9448	653.81	9336.46	2.1596	57,573
1220	mobile homes, med. density	213	0.0849	465.74	99.20	0.3589	888.89	1893.33	0.4380	52,396
1600	Extractive	16	0.0064	143.12	2.29	0.0083	276.56	44.25	0.0102	51,750
1100	Residential, low density	1939	0.7727	182.63	354.12	1.2812	365.44	7085.85	1.6390	49,976
5240	lakes, < 10 acres	121	0.0482	31.72	3.84	0.0139	67.17	81.27	0.0188	47,226
5340	reservoirs, <10 acres	178	0.0709	119.43	21.26	0.0769	257.08	457.61	0.1059	46,454
3100	Rangeland (herbaceous)	15	0.0060	4.14	0.06	0.0002	8.94	1.34	0.0003	46,291
2430	ornamental nurseries	84	0.0335	61.31	5.15	0.0186	134.36	112.86	0.0261	45,633
6210	cypress	2068	0.8241	10.25	21.20	0.0767	22.53	465.98	0.1078	45,499
1160	ranchettes - mixed units	8741	3.4833	112.39	982.44	3.5546	250.49	21895.30	5.0647	44,870
1120	mobile homes, low density	21	0.0084	205.82	4.32	0.0156	467.16	98.10	0.0227	44,058
4310	beech-magnolia	199	0.0793	13.28	2.64	0.0096	30.20	60.09	0.0139	43,992
1460	oil and gas storage	4	0.0016	339.37	1.36	0.0049	809.64	32.39	0.0075	41,917
1320	mobile homes, high density	96	0.0383	475.43	45.64	0.1651	1135.39	1089.97	0.2521	41,874

Table 3-22 – continued.

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E15 sej/ha/yr	Sum, E18 sej/yr	% of Co.-wide total sej/yr	Mean, E10 j/ha/yr	Sum, E12 j/yr	% of Co.-wide total j/yr	EMPOWER Transformity (sej/j)
1850	parks	15	0.0060	108.53	1.63	0.0059	261.14	39.17	0.0091	41,561
1140	ranchettes - single family	3443	1.3721	101.04	347.87	1.2586	257.03	8849.65	2.0470	39,309
1900	Open Land	58	0.0231	120.51	6.99	0.0253	314.56	182.44	0.0422	38,311
1150	ranchettes - mobile homes	1086	0.4328	75.37	81.85	0.2961	202.75	2201.92	0.5093	37,171
8310	Utililities (electric plant	3	0.0012	143.97	0.43	0.0016	430.13	12.90	0.0030	33,471
2220	fruit orchards	12	0.0048	21.90	0.26	0.0010	65.97	7.92	0.0018	33,196
1890	other recreation	101	0.0402	165.35	16.70	0.0604	500.56	505.56	0.1169	33,033
2410	tree nurseries	120	0.0478	39.92	4.79	0.0173	122.47	146.96	0.0340	32,594
5230	lakes, 10-100 acres	347	0.1383	7.56	2.62	0.0095	23.67	82.12	0.0190	31,954
4230	oak - pine - hickory	827	0.3296	15.62	12.92	0.0467	49.16	406.57	0.0940	31,777
4250	temperate hardwoods	16752	6.6758	32.50	544.41	1.9697	104.35	17481.13	4.0436	31,143
2230	other groves	10	0.0040	23.36	0.23	0.0008	75.15	7.52	0.0017	31,084
6110	bay swamps	316	0.1259	3.43	1.08	0.0039	11.37	35.92	0.0083	30,134
4340	hardwood - conifer mixed	20661	8.2335	35.31	729.63	2.6399	117.22	24218.46	5.6020	30,127
8142	divided highways ,state/fed	468	0.1865	537.18	251.40	0.9096	1818.19	8509.12	1.9683	29,545
2510	horse farms	89	0.0355	53.43	4.76	0.0172	191.65	170.57	0.0395	27,880
2150	field crops	488	0.1945	27.26	13.30	0.0481	101.79	496.73	0.1149	26,780
1770	other institutional	64	0.0255	234.10	14.98	0.0542	879.06	562.60	0.1301	26,631
1924	inactive (forested > 10%)	332	0.1323	57.38	19.05	0.0689	216.74	719.56	0.1664	26,474
3200	shrub and brushland	120	0.0478	16.87	2.02	0.0073	64.04	76.85	0.0178	26,342
2231	pecans	599	0.2387	40.48	24.25	0.0877	160.46	961.13	0.2223	25,231
1620	sand and gravel pits	49	0.0195	52.62	2.58	0.0093	211.29	103.53	0.0239	24,906
2130	woodland pasture	5001	1.9929	24.25	121.29	0.4388	98.95	4948.48	1.1446	24,510
8141	interstate highways	260	0.1036	392.77	102.12	0.3695	1656.10	4305.86	0.9960	23,716
8320	electric transmission lines	268	0.1068	50.46	13.52	0.0489	237.61	636.79	0.1473	21,237
5210	lakes, > 500 acres	4130	1.6458	4.55	18.78	0.0679	21.51	888.56	0.2055	21,133
5200	lakes	5995	2.3890	4.28	25.68	0.0929	20.79	1246.50	0.2883	20,605
2610	fallow crop land	13	0.0052	6.55	0.09	0.0003	32.12	4.18	0.0010	20,401
7410	other disturbed land	42	0.0167	35.46	1.49	0.0054	175.43	73.68	0.0170	20,211
6440	emergent aquatic vegetation	2326	0.9269	2.43	5.65	0.0204	12.13	282.04	0.0652	20,020
1851	city parks	4	0.0016	101.27	0.41	0.0015	515.31	20.61	0.0048	19,653
1480	cemetaries	116	0.0462	80.00	9.28	0.0336	412.79	478.83	0.1108	19,382
4460	forest regeneration	1	0.0004	1.15	0.00	0.0000	6.21	0.06	0.0000	19,324
8140	roads and highways	382	0.1522	304.97	116.50	0.4215	1579.30	6032.92	1.3955	19,310
2540	aquaculture	39	0.0155	15.98	0.62	0.0023	83.88	32.71	0.0076	19,057

Table 3-22 – continued.

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E15 sej/ha/yr	Sum, E18 sej/yr	% of Co.-wide total sej/yr	Mean, E10 j/ha/yr	Sum, E12 j/yr	% of Co.-wide total j/yr	EMPOWER Transformity (sej/j)
6140	shrub swamps	292	0.1164	4.60	1.34	0.0049	24.35	71.11	0.0164	18,900
6460	aquatic vegetation	1836	0.7317	4.60	8.45	0.0306	25.16	461.98	0.1069	18,288
6420	freshwater marshes	4	0.0016	1.10	0.00	0.0000	6.03	0.24	0.0001	18,227
2140	row crops	11758	4.6856	13.37	157.25	0.5689	73.95	8695.45	2.0114	18,084
6310	hydric hammock	197	0.0785	1.63	0.32	0.0012	9.04	17.82	0.0041	18,056
4190	plantation woodlands	285	0.1136	1.32	0.38	0.0014	7.33	20.90	0.0048	18,039
1923	inactive (non-forested)	168	0.0669	28.20	4.74	0.0171	156.34	262.66	0.0608	18,037
5220	lakes, 100-500 acres	379	0.1510	3.50	1.33	0.0048	19.41	73.58	0.0170	18,021
6450	submergent aquatic veg.	73	0.0291	1.14	0.08	0.0003	6.31	4.60	0.0011	18,010
6300	wetland forested mixed	13589	5.4153	7.53	102.31	0.3702	41.86	5687.91	1.3157	17,987
4140	pine-mesic oak	110	0.0438	16.08	1.77	0.0064	90.65	99.71	0.0231	17,743
5300	reservoirs	5	0.0020	76.06	0.38	0.0014	430.19	21.51	0.0050	17,681
4200	upland hardwood forest	301	0.1200	25.49	7.67	0.0278	146.04	439.57	0.1017	17,454
6170	mixed wetland hardwoods	289	0.1152	5.71	1.65	0.0060	34.06	98.42	0.0228	16,771
8315	electric sub stations	18	0.0072	83.96	1.51	0.0055	512.07	92.17	0.0213	16,396
2120	unimproved pasture	526	0.2096	18.14	9.54	0.0345	112.10	589.64	0.1364	16,183
2160	field crops	36	0.0143	7.77	0.28	0.0010	48.20	17.35	0.0040	16,125
2110	Agriculture (imp. pasture)	41450	16.5181	13.33	552.35	1.9985	83.31	34532.75	7.9879	15,995
2310	cattle feeding	23	0.0092	60.43	1.39	0.0050	393.32	90.46	0.0209	15,365
2620	old fields	1291	0.5145	13.35	17.23	0.0623	88.52	1142.84	0.2644	15,078
8147	other highways	384	0.1530	132.53	50.89	0.1841	885.84	3401.63	0.7868	14,961
2450	floriculture	2	0.0008	29.09	0.06	0.0002	196.91	3.94	0.0009	14,778
2600	other open lands, rural	44	0.0175	28.61	1.26	0.0046	204.01	89.76	0.0208	14,023
8143	two-lane highways	131	0.0522	110.14	14.43	0.0522	787.85	1032.08	0.2387	13,979
6150	bottomland hardwood forest	1273	0.5073	4.79	6.09	0.0220	34.29	436.50	0.1010	13,962
6410	freshwater marshes	8241	3.2841	1.93	15.93	0.0576	14.60	1203.43	0.2784	13,234
3290	other shrub and brush	3881	1.5466	9.59	37.22	0.1347	72.50	2813.82	0.6509	13,228
6220	pond pine	897	0.3575	5.23	4.69	0.0170	44.03	394.94	0.0914	11,874
2224	blueberries	352	0.1403	14.73	5.19	0.0188	128.04	450.71	0.1043	11,505
8330	water supply plants	17	0.0068	63.79	1.08	0.0039	555.32	94.40	0.0218	11,488
1920	inactive w/streets only	106	0.0422	46.46	4.92	0.0178	406.44	430.83	0.0997	11,431
3300	mixed rangeland	189	0.0753	18.69	3.53	0.0128	171.31	323.78	0.0749	10,911
4110	Upland Forest (flatwoods)	1529	0.6093	12.03	18.40	0.0666	118.76	1815.87	0.4200	10,134
6430	wet prairies	1295	0.5161	1.62	2.09	0.0076	16.38	212.09	0.0491	9,875
7420	borrow areas	34	0.0135	6.43	0.22	0.0008	74.02	25.17	0.0058	8,682

Table 3-22 – continued.

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E15 sej/ha/yr	Sum, E18 sej/yr	% of Co.-wide total sej/yr	Mean, E10 j/ha/yr	Sum, E12 j/yr	% of Co.-wide total j/yr	EMPOWER Transformity (sej/j)
1454	campgrounds	40	0.0159	24.76	0.99	0.0036	298.70	119.48	0.0276	8,291
4410	pine plantations	43241	17.2318	8.66	374.31	1.3543	118.78	51361.42	11.8806	7,288
8111	Transportation (airport)	347	0.1383	49.03	17.01	0.0616	753.03	2613.02	0.6044	6,511
1831	auto race tracks	93	0.0371	20.27	1.88	0.0068	341.12	317.24	0.0734	5,941
1631	rock quarries, limerock	112	0.0446	8.43	0.94	0.0034	147.29	164.96	0.0382	5,723
6530	ephemeral ponds	657	0.2618	3.22	2.11	0.0077	57.02	374.63	0.0867	5,645
4120	longleaf sandhill	266	0.1060	4.88	1.30	0.0047	86.81	230.92	0.0534	5,625
2320	poultry feeding	35	0.0139	11.29	0.40	0.0014	215.49	75.42	0.0174	5,239
8170	transmission lines	44	0.0175	28.97	1.27	0.0046	591.29	260.17	0.0602	4,900
6600	cutover wetlands	116	0.0462	1.03	0.12	0.0004	21.57	25.02	0.0058	4,796
4210	oak sandhill	657	0.2618	3.52	2.31	0.0084	75.36	495.13	0.1145	4,672
6200	wetland coniferous forest	43	0.0171	1.68	0.07	0.0003	36.50	15.70	0.0036	4,606
2520	dairies	51	0.0203	6.99	0.36	0.0013	179.31	91.45	0.0212	3,900
6100	Wetlands	17	0.0068	3.71	0.06	0.0002	98.53	16.75	0.0039	3,767
4430	forest regeneration	10700	4.2640	3.82	40.90	0.1480	102.13	10927.75	2.5277	3,743
7400	Barren land (disturbed)	20	0.0080	4.90	0.10	0.0004	133.78	26.76	0.0062	3,666
4400	tree plantations	9367	3.7328	3.41	31.94	0.1155	97.85	9165.20	2.1200	3,484
1453	travel trailer parks	9	0.0036	17.75	0.16	0.0006	822.58	74.03	0.0171	2,159
1516	grain processing	1	0.0004	8.97	0.01	0.0000	442.75	4.43	0.0010	2,033
1614	strip mines, phosphate	502	0.2001	2.64	1.33	0.0048	138.09	693.21	0.1603	1,912
1611	strip mines, clays	3	0.0012	2.49	0.01	0.0000	210.70	6.32	0.0015	1,187
1660	holding ponds	114	0.0454	0.45	0.05	0.0002	54.13	61.70	0.0143	831
8120	railroads	15	0.0060	2.98	0.04	0.0002	384.90	57.74	0.0134	776
1670	inactive strip mines	76	0.0303	1.33	0.10	0.0004	271.15	206.07	0.0477	489

EMPOWER analysis for level 2 land use and cover classifications. In contrast to the more detailed ‘level 3’ classification scheme, there are 36 FLUCCS ‘level 2’ land use and cover classifications found in the land use and cover coverage for Alachua County. Table 3-23 lists the EMPOWER summary statistics for each ‘level 2’ land classification code. Using the same methods applied in the ‘level 3’ analysis, mean total EMPOWER of consumption density (sej/ha/yr) and energy flow density (j/ha/yr) rates were calculated for each land class.

As discussed previously in the discussion for the ‘level 3’ analysis, the mean values in Table 3-23 should be used cautiously for other studies because of potential anomalies in the individual class values. The same possible explanations given for the ‘level 3’ anomalies apply to this data set. There are, however, relatively fewer obvious anomalies in these statistics than were observed in the ‘level 3’ statistics. This may be explained by the more generalized classification scheme—there are fewer very specifically-coded polygons that might not ‘line up’ perfectly with a one-hectare cell.

The table is sorted in descending order according to the transformity calculated for each land class. The land class transformities were calculated using the method described previously for the ‘level 3’ analysis.

The highest ‘level 2’ land class transformity (264,142 sej/j) was associated with the ‘Institutional’ classification. This general classification includes the more specific ‘hospitals’ class that was noted as having the highest transformity in the ‘level 3’ analysis (458,846 sej/j). The ‘level 2-Institutional’ class also includes the values from the cells assigned to the ‘level 3-educational facilities’ class (which has a transformity of 249,975). Since there are many more ‘educational’ class cells that are averaged in with the relatively fewer, higher-transformity ‘hospital’ class cells, the transformity for the more general ‘level 2-institutional’ class tends to reflect the lower value of the ‘education’ class cells.

The same ‘dilution effect’ can be observed in the statistics for the mean densities. Using the ‘institutional’ class as an example, the mean ‘level 2’ EMPOWER density value (3,586 E15 sej/ha/yr) reflects the dilution by the ‘level 3-educational’ class density value (3,267 E15 sej/ha/yr). It is clear that in the ‘level 2’ analysis, small areas with significantly high mean EMPOWER density values are lost in the generalization process (such as the ‘level 3-hospital’ class with a mean EMPOWER density of 22,253 E15 sej/ha/yr).

This is a more important observation than is immediately apparent. It means that, although these mean values accurately reflect the actual total flows, the use of these ‘level 2’ mean values for mapping purposes will result in a map that does not reflect the location of some of very important high-EMPOWER flows in the system. It also means that for rural- and agricultural-classified areas (that are characterized by large areas with lower EMPOWER densities and a few interspersed higher density areas--buildings, roads, etc.), that the class mean flow density values will tend to be higher than the typical flow density values found in these areas.

This ‘dilution effect’ is apparent in the map shown in Figure 3-122. The map was created by plotting the log of the total annual EMPOWER density based on the calculations of the mean density values for each ‘level 2’ land use class that was presented in Table 3-23. The effect is more apparent when this version of the total annual EMPOWER density is compared to the original total annual EMPOWER density map in Figure 3-100 that was created by adding the EMPOWER component grids together. Figure 3-123 shows a map of the ranges of total annual EMPOWER density transformities that is based on the transformity values that were calculated for each ‘level 2’ land use class in Table 3-23. The ‘dilution effect’ is also apparent in this map of transformities when it is compared with the map shown in Figure 3-112 that was based on cell-by-cell calculations using the component grid sums.

Table 3-23 lists the percentage of the county-wide total EMPOWER or energy flow that is represented by each of the class sum flow values. In these ‘level 2’ calculations, the largest contribution to the total annual EMPOWER for the County, 24.5%, comes from ‘medium-density residential’ (code 1200). The ‘Commercial and services’ (1400), ‘high-density residential’ (1300), and ‘institutional’ classes each contribute about 15.6% to the overall County total. The ‘Low-density residential’ class (1100) contributes about 11.2% to the total. The land areas associated with these five classes account for about 82.5% of the total annual EMPOWER for the county.

The highest contribution to the total annual energy flow for the county, 18.5%, was made by the ‘medium-density residential’ classification. The ‘low-density residential’ class contributed 14%, and the ‘high-density residential class contributed 5% of the total energy flow. Other notable urban class contributions include ‘institutional’, with 3.8% of the total, and ‘commercial and services’ with 6.2% of the total.

The combined contributions from the forest-type classifications account for about 29% of the total annual energy flow (16.6% of this from ‘pine plantations’, class 4400). Agricultural-related classes made minor contributions except for the ‘pasture and row crops’ class (2100), which accounted for about 11.5% of the total energy flow.

Table 3-23: Statistics summarized by ‘level 2’ land use classifications for EMPOWER and energy flow density. The table is sorted according to the calculated EMPOWER transformity of each land use class (transformity = sum,E18 sej/yr / sum,E12 j/yr).

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E15 sej/ha/yr	Sum, E18 sej/yr	% of Co.-wide total sej/yr	Mean, E10 joules/ha/yr	Sum, E12 joules/yr	% of Co.-wide total joules/yr	EMPOWER Transformity (sej/joule)
1700	Institutional	1203	0.4794	3585.93	4313.87	15.6081	1357.57	16331.61	3.7777	264,142
1300	Residential-High Density	1287	0.5129	3362.33	4327.32	15.6567	1684.45	21678.93	5.0146	199,610
1400	Commercial and Services	1672	0.6663	2570.06	4297.14	15.5475	1614.83	27000.00	6.2454	159,153
1500	Industrial	576	0.2295	1499.54	863.74	3.1251	1153.87	6646.31	1.5374	129,957
8800	Other Utilities	3	0.0012	906.53	2.72	0.0098	825.78	24.77	0.0057	109,779
5100	Streams	49	0.0195	51.85	2.54	0.0092	49.40	24.21	0.0056	104,953
1200	Residential-Med Density	6544	2.6078	1038.21	6794.04	24.5816	1222.10	79974.26	18.4991	84,953
8200	Communications	3	0.0012	267.47	0.80	0.0029	334.66	10.04	0.0023	79,921
2500	Horse Farms	248	0.0988	137.77	34.17	0.1236	197.30	489.32	0.1132	69,828
8300	Utilities Plants	706	0.2813	192.49	135.90	0.4917	312.97	2209.58	0.5111	61,504
1800	Recreational	713	0.2841	183.36	130.73	0.4730	343.54	2449.47	0.5666	53,372
1100	Residential-Low Density	18348	7.3117	168.28	3087.61	11.1713	330.49	60638.18	14.0264	50,919
5300	Reservoirs	232	0.0925	102.06	23.68	0.0857	219.97	510.34	0.1180	46,395
3100	Rangeland (herbaceous)	15	0.0060	4.14	0.06	0.0002	8.94	1.34	0.0003	46,291
1900	Open Land	772	0.3076	134.83	104.09	0.3766	307.75	2375.84	0.5496	43,811
2400	Nurseries	210	0.0837	47.92	10.06	0.0364	126.06	264.72	0.0612	38,017
4200	Hardwood Forest	18483	7.3655	30.64	566.35	2.0491	101.27	18717.98	4.3297	30,257
4300	Mixed Forest	20801	8.2892	35.15	731.26	2.6458	116.26	24183.48	5.5939	30,238
6200	Cypress Domes	3007	1.1983	8.63	25.96	0.0939	29.09	874.78	0.2023	29,680
2200	Tree Crops	1050	0.4184	32.61	34.24	0.1239	139.95	1469.45	0.3399	23,299
5200	Lakes	10944	4.3612	4.77	52.18	0.1888	21.64	2368.68	0.5479	22,029
8100	Transportation	2028	0.8082	271.67	550.95	1.9934	1267.32	25701.28	5.9450	21,437
2300	Livestock Feeding	64	0.0255	60.29	3.86	0.0140	303.46	194.21	0.0449	19,867
6300	Forested Wetlands (mixed)	13739	5.4750	7.45	102.40	0.3705	41.18	5658.22	1.3088	18,098
2100	Pasture and Row Crops	59404	23.6725	14.42	856.79	3.1000	83.51	49610.53	11.4756	17,270
6100	Bottomland Hardwoods	2182	0.8695	4.90	10.70	0.0387	29.89	652.25	0.1509	16,400
2600	Old Fields	1346	0.5364	13.80	18.57	0.0672	91.88	1236.68	0.2861	15,018
6400	Marshes and Wet Prairies	13847	5.5180	2.41	33.37	0.1207	16.12	2231.65	0.5162	14,952
7400	Barren Land	96	0.0383	18.81	1.81	0.0065	130.84	125.61	0.0291	14,377
3200	Rangeland (shrubby)	3995	1.5920	9.82	39.22	0.1419	71.89	2872.08	0.6643	13,655
3300	Rangeland (mixed)	189	0.0753	18.69	3.53	0.0128	171.31	323.78	0.0749	10,911
4100	Mesic Flatwoods	2184	0.8703	10.00	21.84	0.0790	98.95	2161.03	0.4999	10,104
4400	Pine Plantations	63360	25.2490	7.07	447.72	1.6199	112.96	71571.88	16.5555	6,256
1600	Extractive	874	0.3483	8.35	7.30	0.0264	146.47	1280.12	0.2961	5,702
6500	Ephemeral Ponds	652	0.2598	3.23	2.10	0.0076	57.37	374.05	0.0865	5,625
6600	Cutover Wetlands	115	0.0458	1.03	0.12	0.0004	21.70	24.96	0.0058	4,760

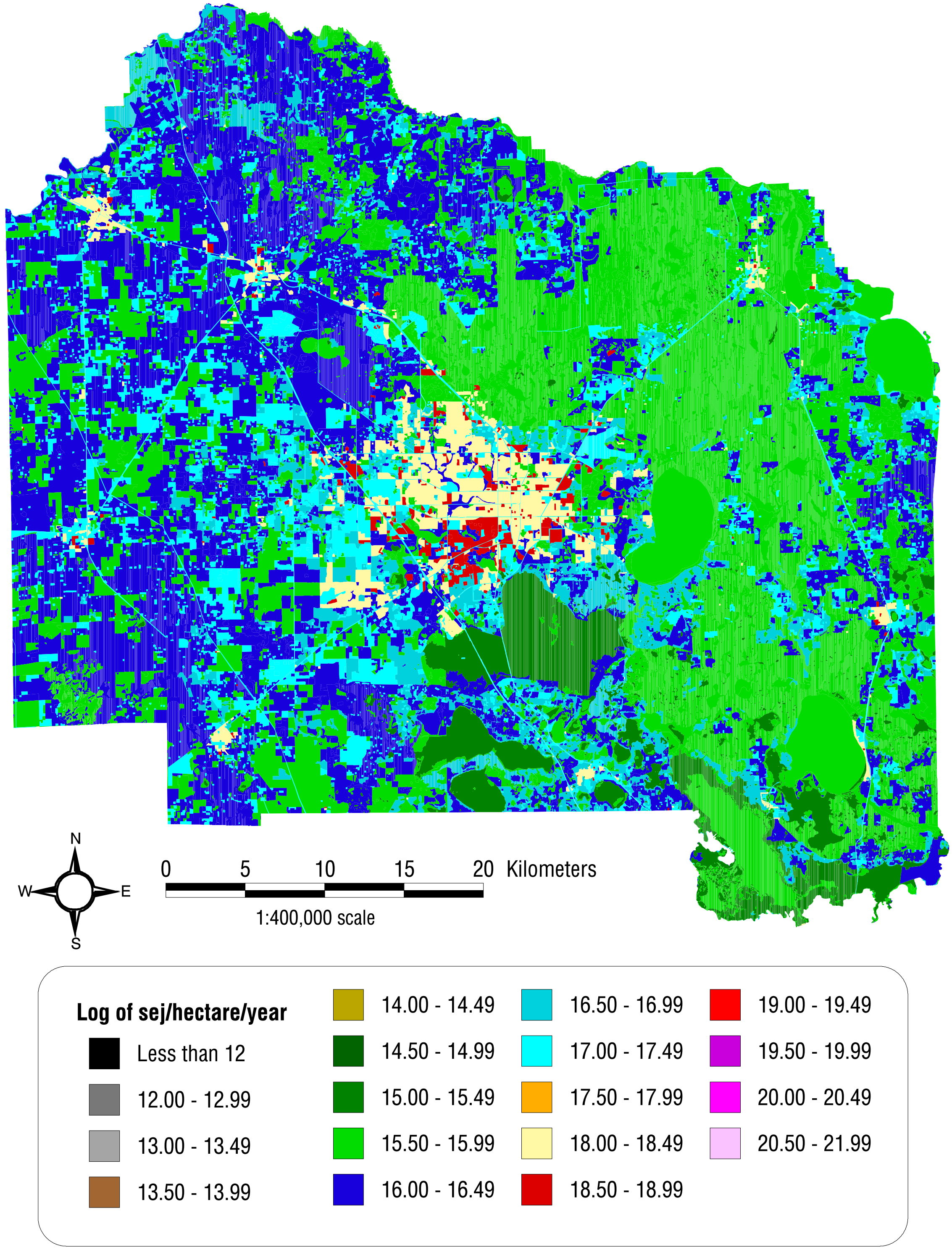


Figure 3-122: Map of the the log of the annual total EMPOWER density based on mean values calculated for each level 2 landuse class in Table 3-23. When this derived version is compared to the EMPOWER density grid (see Fig. 3-100), it becomes apparent that the landuse polygon mean-based values tend to be higher in rural and residential areas and lower in commercial and institutional areas than the individual cell-based measured values in the EMPOWER density grid.

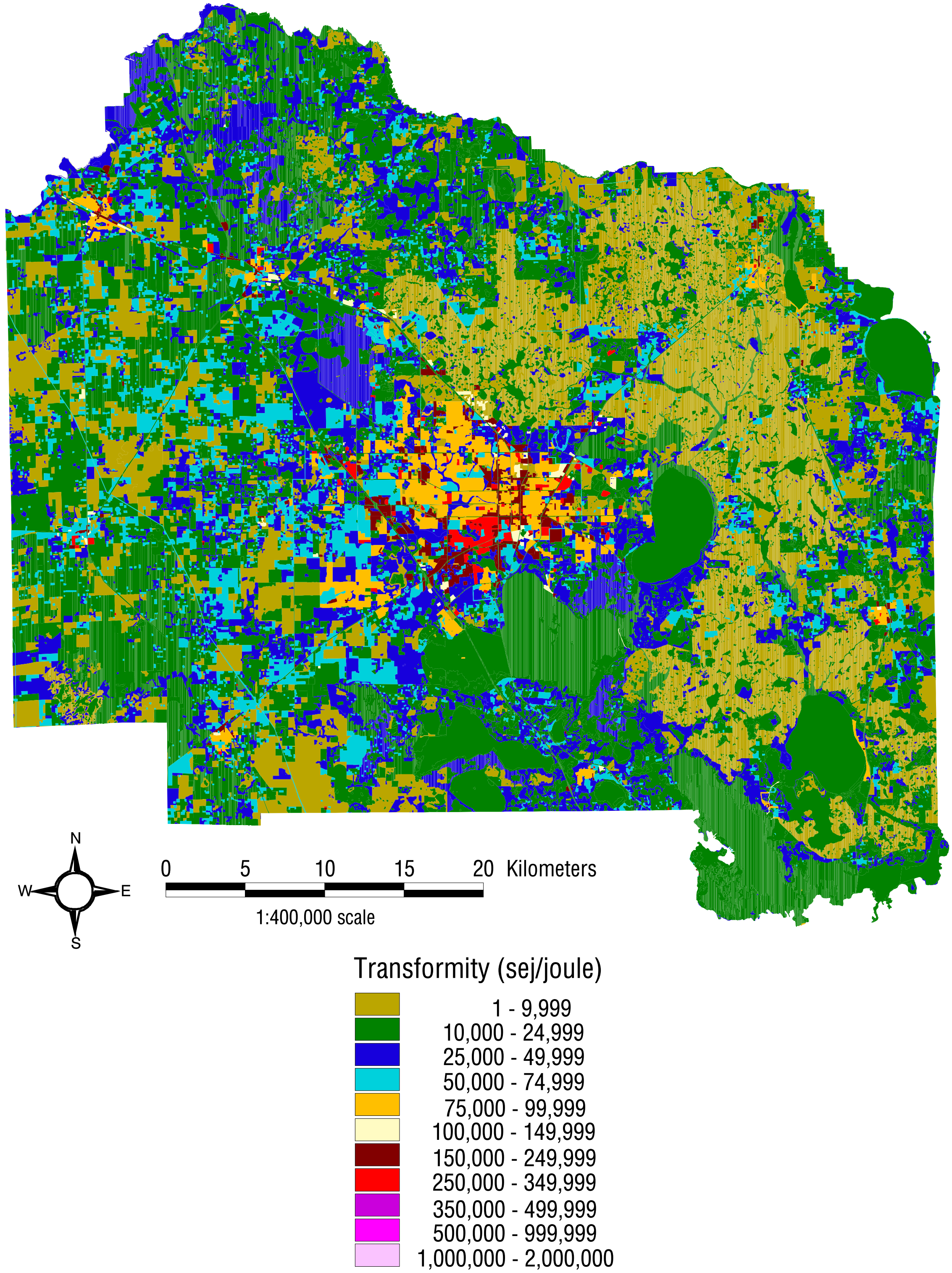


Figure 3-123: Map of the ranges of total EMPOWER density transformities that were calculated for each level 2 landuse class in Table 3-23. These transformities were calculated by dividing the sum of the values in all of the cells of the total EMPOWER density grid which were in a particular landuse class by the sum of the values in all of the corresponding cells of the total annual energy density grid.

EMSTORAGE analysis for level 3 land use and cover classifications. The EMSTORAGE summary statistics for each land class are listed in Table 3-24. Mean total EMSTORAGE (sej/ha) and mean total energy storage densities (j/ha) for each class were calculated as the mean of the values for all of the cells with that classification code.

The same cautionary statements apply to the mean values in Table 3-24 that were made for the mean values in the 'level 3' EMPOWER summary statistics. There may be potential anomalies in the mean values for some classes because of spatial and attribute inaccuracies in the land use and cover coverage leading to cells being included in an inappropriate class and because of the methods used to create the summary statistics. Examples in Table 3-24 may include the 'rest areas' and 'kennels' classes.

Table 3-24 is sorted in descending order according to the EMSTORAGE transformity calculated for each land class. Land class transformity values were calculated by dividing the EMSTORAGE class density (E18 sej/class) by the energy storage class density (E12 joules/class). The EMSTORAGE or energy 'class densities' were calculated by adding the EMERGY or energy storage values for all of the cells that have the same land use and cover classification.

Once again, the highest 'level 3' class EMSTORAGE transformity (27,095,219 sej/j) was associated with the 'hospitals' classification. The 'Prisons' classification also has a notably high EMSTORAGE transformity value (13,676,297 sej/j). The 'multiple dwelling', 'educational facilities', and 'shopping center' classes that had high EMPOWER transformities also have relatively high EMSTORAGE transformities. Based on this method of calculating transformities, most natural system classes have EMSTORAGE transformities in the range of about 40,000 sej/j to about 100,000 sej/j.

Table 3-24 lists the percentages of the county-wide total EMSTORAGE or energy storage represented by the values for the class sums. The largest contribution, 22%, to the county-wide total EMSTORAGE came from the ‘medium-density residential’ classes (codes 1210 and 1230). Interestingly, the ‘medium-density residential’ class also contributed 23.2% of the total EMPOWER (also the largest percentage contribution).

Other notable class summary statistics include: the ‘high-density residential’ classes (codes 1300,1330, and 1340) contributed 14.5% of the total EMSTORAGE (compared to 14.2% of the total EMPOWER); the ‘commercial and services’ classes (codes 1400 and 1411) contributed 13% of the total EMSTORAGE (compared to 14.8% of the total EMPOWER); the ‘educational facilities’ class (code 1710) contributed 9.5% of the total EMSTORAGE (compared to 9.8% of the total EMPOWER); and the ‘hospitals’ class (code 1741) contributed 4.2% of the total EMSTORAGE (compared to 4.5% of the total EMPOWER). These specific codes account for about 63.2% of the total EMSTORAGE and 66.5% of the total annual EMPOWER for the county.

These are very interesting statistics. Although the actual sum of EMPOWER values may be an order of magnitude lower than the sum of EMSTORAGE values, the percentages of the total county-wide flow are remarkably similar to the percentages of the total county-wide storage.

The percentage (52%) of the total energy storage for the county was contributed by several of the forest and agricultural land use/cover classes (codes 2210, 4250, 4340, and 4410, 6300) compared to 30.8% of the total annual energy flow.

Table 3-24: Statistics summarized by 'level 3' land use classification for EMSTORAGE and energy storage density. The table is sorted according to the calculated EMSTORAGE transformity of each land use class (transformity = sum,E20 sej / sum,E12 joules).

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E17 sej/ha	Sum, E20 Sej	% of Co.-wide total sej	Mean, E10 joules/ha	Sum, E12 joules	% of Co.-wide total joules	EMSTORAGE Transformity (sej/joule)
1741	Hospitals	56	0.0223	5185.58	290.39	4.2113	1913.84	1071.75	0.0525	27,095,219
8180	auto parking (rest areas)	1	0.0004	3116.37	3.12	0.0452	1355.61	13.56	0.0007	22,988,913
1765	Municipal prisons	21	0.0084	1099.70	23.09	0.3349	804.09	168.86	0.0083	13,676,297
1490	Commercial construction	11	0.0044	792.25	8.71	0.1264	833.01	91.63	0.0045	9,510,677
1340	multiple dwelling, highrise	264	0.1052	1552.62	409.89	5.9443	2006.22	5296.42	0.2592	7,739,025
1411	Shopping centers	241	0.0960	945.75	227.93	3.3054	1242.32	2993.98	0.1465	7,612,836
1710	Educational facilities	826	0.3292	798.09	659.22	9.5601	1147.76	9480.47	0.4640	6,953,473
2530	Kennels	11	0.0044	388.03	4.27	0.0619	642.10	70.63	0.0035	6,043,131
1565	heavy industrial	16	0.0064	518.25	8.29	0.1203	915.94	146.55	0.0072	5,658,163
1555	Container manufacturing	3	0.0012	506.08	1.52	0.0220	1005.72	30.17	0.0015	5,031,884
1330	multiple dwelling, low rise	549	0.2188	879.54	482.87	7.0026	1866.40	10246.55	0.5015	4,712,503
1400	Commercial and Services	1140	0.4543	590.24	672.88	9.7581	1312.66	14964.38	0.7325	4,496,517
1552	Electronics industry	22	0.0088	364.30	8.01	0.1162	931.19	204.86	0.0100	3,912,179
8880	Other	3	0.0012	232.13	0.70	0.0101	691.29	20.74	0.0010	3,357,957
1300	Residential, high density	167	0.0666	623.41	104.11	1.5098	1863.99	3112.86	0.1524	3,344,507
1350	mixed units, high density	39	0.0155	591.99	23.09	0.3348	1857.17	724.30	0.0355	3,187,616
1720	religious facilities	80	0.0319	337.68	27.01	0.3918	1127.64	902.11	0.0442	2,994,550
1700	Institutional	114	0.0454	246.19	28.07	0.4070	825.79	941.40	0.0461	2,981,267
1570	Chemical processing	7	0.0028	303.52	2.12	0.0308	1088.84	76.22	0.0037	2,787,621
1310	single family, high density	172	0.0685	384.95	66.21	0.9602	1504.49	2587.72	0.1267	2,558,713
1551	boat building	27	0.0108	213.08	5.75	0.0834	843.06	227.63	0.0111	2,527,534
1470	mixed commercial/services	12	0.0048	295.46	3.55	0.0514	1248.36	149.80	0.0073	2,366,834
1756	govt. maintenance yards	41	0.0163	176.82	7.25	0.1051	761.09	312.05	0.0153	2,323,254
1500	Industrial	10	0.0040	240.31	2.40	0.0348	1049.40	104.94	0.0051	2,289,971
1550	light industrial	440	0.1753	236.52	104.07	1.5092	1036.66	4561.29	0.2233	2,281,585
1452	Motels	45	0.0179	319.19	14.36	0.2083	1417.33	637.80	0.0312	2,252,075
1560	heavy industrial	15	0.0060	172.29	2.58	0.0375	949.23	142.39	0.0070	1,815,009
1230	mixed units, med. density	3529	1.4063	271.42	957.84	13.8907	1578.95	55721.20	2.7274	1,718,982
2300	feeding operations	6	0.0024	78.65	0.47	0.0068	459.38	27.56	0.0013	1,712,090
8200	Communications	3	0.0012	65.57	0.20	0.0029	385.93	11.58	0.0006	1,698,941
1210	single family, med. density	2330	0.9285	241.38	562.41	8.1561	1608.47	37477.31	1.8344	1,500,657
1910	Undeveloped in urban area	107	0.0426	148.95	15.94	0.2311	1203.34	1287.57	0.0630	1,237,796
8340	sewage treatment plants	112	0.0446	76.67	8.59	0.1245	635.21	711.44	0.0348	1,207,035
1200	Residential, med. density	472	0.1881	139.41	65.80	0.9543	1344.61	6346.58	0.3107	1,036,826

Table 3-24 – continued.

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E17 sej/ha	Sum, E20 Sej	% of Co.-wide total sej	Mean, E10 joules/ha	Sum, E12 joules	% of Co.-wide total joules	EMSTORAGE Transformity (sej/joule)
8311	electric power plant	113	0.0450	57.94	6.55	0.0949	588.48	664.98	0.0325	984,522
1130	mixed units, low density	1701	0.6779	111.67	189.95	2.7547	1232.98	20973.02	1.0266	905,694
8350	solid waste disposal	166	0.0662	27.85	4.62	0.0671	324.14	538.07	0.0263	859,292
1770	other institutional	64	0.0255	60.27	3.86	0.0559	705.03	451.22	0.0221	854,798
1320	mobile homes, high density	96	0.0383	107.57	10.33	0.1498	1411.74	1355.27	0.0663	761,958
1527	woodyards	3	0.0012	59.75	0.18	0.0026	829.86	24.90	0.0012	720,205
8312	electric power plant	15	0.0060	148.02	2.22	0.0322	2072.91	310.94	0.0152	714,037
1423	junk yards	40	0.0159	48.45	1.94	0.0281	681.20	272.48	0.0133	711,278
1860	community recreation	116	0.0462	65.09	7.55	0.1095	922.77	1070.41	0.0524	705,374
1460	oil and gas storage	4	0.0016	51.25	0.21	0.0030	741.51	29.66	0.0015	691,155
1110	single family, low density	1428	0.5691	87.56	125.03	1.8132	1316.89	18805.20	0.9205	664,876
1220	mobile homes, med. density	213	0.0849	112.23	23.90	0.3467	1697.65	3615.99	0.1770	661,081
2590	other specialty farms	58	0.0231	42.99	2.49	0.0362	710.92	412.34	0.0202	604,750
1800	Recreational	16	0.0064	50.24	0.80	0.0117	876.89	140.30	0.0069	572,908
1820	golf courses	370	0.1474	35.60	13.17	0.1910	712.47	2636.15	0.1290	499,663
1120	mobile homes, low density	21	0.0084	49.51	1.04	0.0151	991.73	208.26	0.0102	499,223
8142	divided highways ,state/fed	468	0.1865	68.75	32.18	0.4666	1453.73	6803.45	0.3330	472,936
1424	farmers markets	2	0.0008	80.51	0.16	0.0023	1713.73	34.27	0.0017	469,737
5340	reservoirs, <10 acres	178	0.0709	26.65	4.74	0.0688	582.09	1036.12	0.0507	457,853
1600	Extractive	16	0.0064	36.75	0.59	0.0085	815.60	130.50	0.0064	450,587
1100	Residential, low density	1939	0.7727	45.32	87.87	1.2743	1056.23	20480.26	1.0025	429,043
1521	sawmills	33	0.0132	23.41	0.77	0.0112	579.75	191.32	0.0094	403,728
1890	other recreation	101	0.0402	31.39	3.17	0.0460	843.45	851.88	0.0417	372,141
5100	Water (streams)	36	0.0143	17.63	0.63	0.0092	503.08	181.11	0.0089	350,511
1900	Open Land	58	0.0231	24.87	1.44	0.0209	721.67	418.57	0.0205	344,577
6120	shrub swamps	3	0.0012	39.18	0.12	0.0017	1187.11	35.61	0.0017	329,933
8310	Utililities (electric plant	3	0.0012	31.19	0.09	0.0014	946.79	28.40	0.0014	329,533
1850	parks	15	0.0060	19.20	0.29	0.0042	593.42	89.01	0.0044	323,659
1160	ranchettes - mixed units	8741	3.4833	28.33	247.67	3.5918	951.56	83176.01	4.0713	297,769
8111	Transportation (airport)	347	0.1383	11.92	4.14	0.0600	429.53	1490.46	0.0730	277,505
1140	ranchettes - single family	3443	1.3721	24.96	85.93	1.2461	973.85	33529.52	1.6412	256,268
1620	sand and gravel pits	49	0.0195	12.49	0.61	0.0089	526.31	257.89	0.0126	237,232
2200	tree crops	12	0.0048	28.97	0.35	0.0050	1223.87	146.86	0.0072	236,749
5330	reservoirs, 10-100 acres	52	0.0207	11.05	0.57	0.0083	479.65	249.42	0.0122	230,336
1851	city parks	4	0.0016	21.47	0.09	0.0012	960.21	38.41	0.0019	223,649

Table 3-24 – continued.

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E17 sej/ha	Sum, E20 Sej	% of Co.-wide total sej	Mean, E10 joules/ha	Sum, E12 joules	% of Co.-wide total joules	EMSTORAGE Transformity (sej/joule)
2510	horse farms	89	0.0355	12.08	1.08	0.0156	541.08	481.56	0.0236	223,232
1150	ranchettes - mobile homes	1086	0.4328	20.08	21.81	0.3162	902.67	9803.02	0.4798	222,432
1480	Cemetaries	116	0.0462	15.71	1.82	0.0264	723.13	838.83	0.0411	217,197
8113	private airport	31	0.0124	9.36	0.29	0.0042	434.20	134.60	0.0066	215,523
8143	two-lane highways	131	0.0522	20.82	2.73	0.0396	1042.05	1365.08	0.0668	199,797
2210	citrus groves	58	0.0231	9.12	0.53	0.0077	503.84	292.23	0.0143	181,024
2430	ornamental nurseries	84	0.0335	9.05	0.76	0.0110	518.30	435.37	0.0213	174,655
5240	lakes, < 10 acres	121	0.0482	7.14	0.86	0.0125	422.82	511.61	0.0250	168,801
5300	Reservoirs	5	0.0020	15.45	0.08	0.0011	954.97	47.75	0.0023	161,891
8320	electric transmission lines	268	0.1068	10.68	2.86	0.0415	689.37	1847.52	0.0904	154,942
5120	Streams	15	0.0060	6.20	0.09	0.0013	412.31	61.85	0.0030	150,211
1924	inactive (forested > 10%)	332	0.1323	15.21	5.05	0.0733	1060.71	3521.56	0.1724	143,439
8140	roads and highways	382	0.1522	14.71	5.62	0.0815	1073.83	4102.02	0.2008	136,972
8147	other highways	384	0.1530	14.60	5.61	0.0813	1081.15	4151.62	0.2032	135,085
2130	woodland pasture	5001	1.9929	7.18	35.93	0.5211	555.30	27770.72	1.3593	129,378
1920	inactive w/streets only	106	0.0422	13.86	1.47	0.0213	1117.32	1184.36	0.0580	124,076
7410	other disturbed land	42	0.0167	7.22	0.30	0.0044	586.31	246.25	0.0121	123,209
1923	inactive (non-forested)	168	0.0669	7.68	1.29	0.0187	630.65	1059.50	0.0519	121,831
2150	field crops	488	0.1945	7.09	3.46	0.0502	598.18	2919.10	0.1429	118,516
8330	water supply plants	17	0.0068	8.96	0.15	0.0022	795.28	135.20	0.0066	112,650
4340	hardwood - conifer mixed	20661	8.2335	10.40	214.94	3.1171	956.50	197622.98	9.6732	108,764
4200	upland hardwood forest	301	0.1200	7.22	2.17	0.0315	704.15	2119.50	0.1037	102,496
2310	cattle feeding	23	0.0092	5.97	0.14	0.0020	595.13	136.88	0.0067	100,307
4250	temperate hardwoods	16752	6.6758	10.43	174.78	2.5347	1041.50	174472.58	8.5400	100,176
2231	Pecans	599	0.2387	7.08	4.24	0.0615	709.81	4251.79	0.2081	99,779
1631	rock quarries, limerock	112	0.0446	3.20	0.36	0.0052	325.00	363.99	0.0178	98,408
2540	Aquaculture	39	0.0155	5.58	0.22	0.0032	568.68	221.79	0.0109	98,068
3300	mixed rangeland	189	0.0753	6.42	1.21	0.0176	658.20	1244.00	0.0609	97,540
1831	auto race tracks	93	0.0371	4.59	0.43	0.0062	485.00	451.05	0.0221	94,646
2120	Unimproved pasture	526	0.2096	5.90	3.10	0.0450	634.68	3338.40	0.1634	92,997
2620	old fields	1291	0.5145	4.59	5.92	0.0859	519.51	6706.82	0.3283	88,294
2110	Agriculture (imp. pasture)	41450	16.5181	4.16	172.37	2.4997	472.08	195678.13	9.5780	88,087
4140	pine-mesic oak	110	0.0438	6.70	0.74	0.0107	893.69	983.06	0.0481	74,960
5230	lakes, 10-100 acres	347	0.1383	2.74	0.95	0.0138	367.21	1274.23	0.0624	74,492
3290	other shrub and brush	3881	1.5466	4.31	16.74	0.2428	590.99	22936.24	1.1227	72,988

Table 3-24 – continued.

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E17 sej/ha	Sum, E20 Sej	% of Co.-wide total sej	Mean, E10 joules/ha	Sum, E12 joules	% of Co.-wide total joules	EMSTORAGE Transformity (sej/joule)
8315	electric sub stations	18	0.0072	8.12	0.15	0.0021	1124.41	202.39	0.0099	72,235
4230	oak - pine - hickory	827	0.3296	7.13	5.90	0.0856	1002.73	8292.56	0.4059	71,152
2140	row crops	11758	4.6856	3.63	42.71	0.6193	514.55	60500.73	2.9614	70,589
2224	blueberries	352	0.1403	3.37	1.19	0.0172	480.45	1691.18	0.0828	70,140
8141	interstate highways	260	0.1036	5.65	1.47	0.0213	808.63	2102.43	0.1029	69,909
2410	tree nurseries	120	0.0478	3.95	0.47	0.0069	567.91	681.50	0.0334	69,509
4310	beech-magnolia	199	0.0793	7.19	1.43	0.0207	1079.45	2148.11	0.1051	66,589
3200	shrub and brushland	120	0.0478	4.64	0.56	0.0081	700.87	841.05	0.0412	66,215
7420	borrow areas	34	0.0135	3.01	0.10	0.0015	486.23	165.32	0.0081	62,002
2420	sod farms	4	0.0016	2.53	0.01	0.0001	415.52	16.62	0.0008	60,768
2220	fruit orchards	12	0.0048	3.29	0.04	0.0006	551.66	66.20	0.0032	59,669
2240	other tree crops	10	0.0040	2.90	0.03	0.0004	491.32	49.13	0.0024	59,025
6460	aquatic vegetation	1836	0.7317	7.29	13.38	0.1941	1250.29	22955.32	1.1236	58,292
6440	emergent aquatic vegetation	2326	0.9269	7.91	18.39	0.2667	1360.34	31641.61	1.5488	58,117
6210	cypress	2068	0.8241	9.33	19.30	0.2799	1613.37	33364.54	1.6331	57,845
4110	Upland Forest (flatwoods)	1529	0.6093	4.55	6.96	0.1010	791.71	12105.30	0.5925	57,508
6410	freshwater marshes	8241	3.2841	6.90	56.83	0.8242	1221.64	100675.22	4.9278	56,454
6420	freshwater marshes	4	0.0016	9.37	0.04	0.0005	1695.59	67.82	0.0033	55,290
2230	other groves	10	0.0040	3.17	0.03	0.0005	574.03	57.40	0.0028	55,224
1614	strip mines, phosphate	502	0.2001	1.60	0.80	0.0116	296.77	1489.80	0.0729	53,813
2160	field crops	36	0.0143	2.84	0.10	0.0015	528.47	190.25	0.0093	53,771
6430	wet prairies	1295	0.5161	12.51	16.20	0.2349	2333.46	30218.36	1.4791	53,611
6140	shrub swamps	292	0.1164	8.09	2.36	0.0342	1518.27	4433.34	0.2170	53,269
4410	pine plantations	43241	17.2318	3.74	161.70	2.3450	708.45	306338.88	14.9946	52,786
5210	lakes, > 500 acres	4130	1.6458	0.87	3.60	0.0522	165.80	6847.72	0.3352	52,542
6300	wetland forested mixed	13589	5.4153	7.20	97.84	1.4188	1370.51	186238.77	9.1159	52,533
3100	Rangeland (herbaceous)	15	0.0060	3.13	0.05	0.0007	600.95	90.14	0.0044	52,028
6220	pond pine	897	0.3575	6.32	5.66	0.0822	1217.51	10921.02	0.5346	51,870
6530	ephemeral ponds	657	0.2618	3.40	2.23	0.0324	660.47	4339.31	0.2124	51,455
2610	fallow crop land	13	0.0052	2.82	0.04	0.0005	549.01	71.37	0.0035	51,281
5200	lakes	5995	2.3890	0.91	5.48	0.0795	178.73	10715.01	0.5245	51,175
6600	cutover wetlands	116	0.0462	3.81	0.44	0.0064	765.61	888.11	0.0435	49,769
2320	poultry feeding	35	0.0139	2.59	0.09	0.0013	529.38	185.28	0.0091	49,006
6150	bottomland hardwood forest	1273	0.5073	7.40	9.42	0.1366	1510.85	19233.06	0.9414	48,987
1454	campgrounds	40	0.0159	4.05	0.16	0.0024	831.86	332.74	0.0163	48,716

Table 3-24 – continued.

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E17 sej/ha	Sum, E20 Sej	% of Co.-wide total sej	Mean, E10 joules/ha	Sum, E12 joules	% of Co.-wide total joules	EMSTORAGE Transformity (sej/joule)
6110	bay swamps	316	0.1259	7.88	2.49	0.0361	1644.31	5196.02	0.2543	47,902
2520	dairies	51	0.0203	2.24	0.11	0.0017	470.87	240.14	0.0118	47,638
4120	longleaf sandhill	266	0.1060	2.86	0.76	0.0111	610.86	1624.88	0.0795	46,896
6170	mixed wetland hardwoods	289	0.1152	5.32	1.54	0.0223	1159.08	3349.73	0.1640	45,857
6200	wetland coniferous forest	43	0.0171	6.66	0.29	0.0042	1461.70	628.53	0.0308	45,551
4430	forest regeneration	10700	4.2640	2.64	28.23	0.4094	579.25	61979.83	3.0338	45,545
5220	lakes, 100-500 acres	379	0.1510	1.02	0.39	0.0056	227.12	860.79	0.0421	44,808
1660	holding ponds	114	0.0454	1.03	0.12	0.0017	234.80	267.67	0.0131	43,860
6100	Wetlands	17	0.0068	4.99	0.08	0.0012	1153.30	196.06	0.0096	43,252
6310	hydric hammock	197	0.0785	4.91	0.97	0.0140	1138.42	2242.70	0.1098	43,122
8170	transmission lines	44	0.0175	3.89	0.17	0.0025	913.27	401.84	0.0197	42,654
4210	oak sandhill	657	0.2618	2.30	1.51	0.0220	556.02	3653.07	0.1788	41,447
2600	other open lands, rural	44	0.0175	2.94	0.13	0.0019	717.41	315.66	0.0155	40,930
2450	floriculture	2	0.0008	1.81	0.00	0.0001	440.64	8.81	0.0004	40,850
4400	tree plantations	9367	3.7328	2.63	24.68	0.3579	689.29	64565.88	3.1603	38,223
7400	Barren land (disturbed)	20	0.0080	2.40	0.05	0.0007	656.87	131.37	0.0064	36,461
6450	submergent aquatic veg.	73	0.0291	0.98	0.07	0.0010	279.84	204.28	0.0100	34,903
1670	inactive strip mines	76	0.0303	0.96	0.07	0.0011	281.96	214.29	0.0105	34,020
1611	strip mines, clays	3	0.0012	1.52	0.00	0.0001	469.56	14.09	0.0007	32,655
1453	travel trailer parks	9	0.0036	4.01	0.04	0.0005	1237.69	111.39	0.0055	32,408
4190	plantation woodlands	285	0.1136	1.91	0.54	0.0079	607.45	1731.24	0.0847	31,371
8120	railroads	15	0.0060	2.22	0.03	0.0005	710.87	106.63	0.0052	31,230
1516	grain processing	1	0.0004	2.81	0.00	0.0000	949.26	9.49	0.0005	29,497
4460	forest regeneration	1	0.0004	0.62	0.00	0.0000	243.10	2.43	0.0001	24,681

EMSTORAGE analysis for level 2 land use and cover classifications. The EMSTORAGE summary statistics for 'level 2' land classification codes are listed in Table 3-25. Using the same methods applied in the 'level 3' analysis, mean total EMSTORAGE densities (sej/ha) and mean total energy storage densities (j/ha) were calculated for each land class. As discussed previously, these mean values should be used with caution because of potential anomalies in the individual class values.

As with the previous summary tables, Table 3-25 is sorted in descending order according to the EMSTORAGE transformity calculated for each land class. As in the previous tables, the highest 'level 2' land class transformity (7,786,939 sej/j) was associated with the 'Institutional' classification which includes the 'level 3-hospital' and 'level 3-educational facilities' classes.

The same 'dilution effect' that was observed in the 'level 2' EMPOWER statistics can be observed in these statistics for mean EMSTORAGE densities. The 'dilution effect' is shown in map form (Figure 3-124) by plotting the log of the total EMSTORAGE density based on the calculations of the mean density values for each 'level 2' land use class that was presented in Table 3-25. To appreciate the 'effect', this version of a total EMSTORAGE density map should be compared to the original total EMSTORAGE density map shown in Figure 3-106 that was created by adding the EMSTORAGE component grids together.

Figure 3-125 shows a map of the ranges of transformities for the total EMSTORAGE density. These transformity values were calculated for each 'level 2' land use class in Table 3-25 using the EMERGY and energy sums for each class. To see the ‘dilution effect’ this map of transformities should be compared with the map shown in Figure 3-114 that was based on cell-by-cell calculations using the component grids.

Table 3-25 lists the percentage of the county-wide total EMSTORAGE or energy storage that is represented by each of the ‘level 2’ class sum flow values. The ‘medium-density residential’ class (code 1200) contributed the largest amount, 23.6%, to the total EMSTORAGE. This class also contributed the largest percentage, 23.2%, of the total EMPOWER .

A few other comparisons include: the ‘high-density residential’ class (code 1300) contributed 15.8% of the total EMSTORAGE (compared to 15.6% of the total EMPOWER); the ‘commercial and services’ class (code 1400) contributed 13.5% of the total EMSTORAGE (compared to 15.5% of the total EMPOWER); the ‘institutional’ class (code 1700) contributed 15% of the total EMSTORAGE (compared to 15.6% of the total EMPOWER); the ‘low-density residential’ class (code 1100) contributed 11% of the total EMSTORAGE (compared to 11.2% of the total EMPOWER). The contributions by the land areas associated with these codes account for about 79% of the total EMSTORAGE and 82.5% of the total annual EMPOWER.

These comparative statistics for percentages of county-wide total EMSTORAGE and EMPOWER seem to point to a pattern of the percentages of the total county-wide EMERGY flow being very similar to the percentages of the total EMERGY storage.

49.4% of the total energy storage for the county was contributed by several of the forest land use/cover classes (codes 4200, 4300, 4400, and 6300) compared to 29% of the total annual energy flow. The ‘pasture and row crops’ class contributed 14.3% of the total energy storage compared to 11.5% of the total energy flow.

Table 3-25: Statistics summarized by 'level 2' land use classification for EMSTORAGE and energy storage density. The table is sorted according to the calculated EMSTORAGE transformity of each land use class (transformity = sum,E20 sej / sum,E12 joules).

Level 3 Code	Description	No. of cells (# of ha.)	% of Co.-wide area	Mean, E17 sej/ha	Sum, E20 Sej	% of Co.-wide total sej	Mean, E10 joules/ha	Sum, E12 joules	% of Co.-wide total joules	EMSTORAGE Transformity (sej/joule)
1700	Institutional	1203	0.4794	863.59	1038.90	15.0663	1109.02	13341.57	0.6530	7,786,939
1300	Residential-High Density	1287	0.5129	851.23	1095.54	15.8876	1813.25	23336.50	1.1423	4,694,518
1400	Commercial and Services	1672	0.6663	559.14	934.88	13.5577	1234.32	20637.75	1.0102	4,529,940
8800	Other Utilities	3	0.0012	232.13	0.70	0.0101	691.29	20.74	0.0010	3,357,957
1500	Industrial	576	0.2295	235.09	135.41	1.9637	991.82	5712.87	0.2796	2,370,258
8200	Communications	3	0.0012	65.57	0.20	0.0029	385.93	11.58	0.0006	1,698,941
1200	Residential-Med Density	6544	2.6078	246.14	1610.72	23.3589	1576.98	103197.88	5.0513	1,560,810
2500	Horse Farms	248	0.0988	32.94	8.17	0.1185	575.18	1426.46	0.0698	572,671
8300	Utilities Plants	706	0.2813	35.77	25.25	0.3662	626.66	4424.21	0.2166	570,807
1800	Recreational	713	0.2841	35.20	25.10	0.3640	737.13	5255.75	0.2573	477,508
5300	Reservoirs	232	0.0925	23.18	5.38	0.0780	561.87	1303.55	0.0638	412,598
1100	Residential-Low Density	18348	7.3117	41.38	759.21	11.0102	1019.31	187023.86	9.1544	405,942
1900	Open Land	772	0.3076	32.83	25.35	0.3676	969.56	7485.03	0.3664	338,645
5100	Streams	49	0.0195	14.75	0.72	0.0105	473.74	232.13	0.0114	311,328
8100	Transportation	2028	0.8082	26.21	53.15	0.7708	993.52	20148.59	0.9862	263,788
2300	Livestock Feeding	64	0.0255	10.94	0.70	0.0102	546.45	349.73	0.0171	200,156
2400	Nurseries	210	0.0837	5.94	1.25	0.0181	543.95	1142.30	0.0559	109,244
4300	Mixed Forest	20801	8.2892	10.39	216.06	3.1333	957.83	199238.66	9.7523	108,441
2200	Tree Crops	1050	0.4184	6.09	6.39	0.0927	620.73	6517.67	0.3190	98,067
4200	Hardwood Forest	18483	7.3655	9.96	184.10	2.6698	1017.50	188064.08	9.2053	97,891
3300	Rangeland (mixed)	189	0.0753	6.42	1.21	0.0176	658.20	1244.00	0.0609	97,540
1600	Extractive	874	0.3483	2.93	2.56	0.0371	313.83	2742.85	0.1343	93,221
2100	Pasture and Row Crops	59404	23.6725	4.34	257.96	3.7409	490.65	291468.28	14.2667	88,503
2600	Old Fields	1346	0.5364	4.52	6.08	0.0882	526.55	7087.42	0.3469	85,851
7400	Barren Land	96	0.0383	4.73	0.45	0.0066	565.56	542.94	0.0266	83,582
3200	Rangeland (shrubby)	3995	1.5920	4.32	17.27	0.2504	593.37	23705.05	1.1603	72,842
6400	Marshes and Wet Prairies	13847	5.5180	7.61	105.33	1.5275	1347.10	186533.45	9.1304	56,467
6200	Cypress Domes	3007	1.1983	8.39	25.24	0.3660	1492.91	44891.86	2.1973	56,217
5200	Lakes	10944	4.3612	1.03	11.23	0.1629	183.74	20108.91	0.9843	55,863
4100	Mesic Flatwoods	2184	0.8703	4.11	8.98	0.1302	750.31	16386.78	0.8021	54,794
6300	Forested Wetlands (mixed)	13739	5.4750	7.17	98.53	1.4290	1367.66	187902.36	9.1974	52,439
3100	Rangeland (herbaceous)	15	0.0060	3.13	0.05	0.0007	600.95	90.14	0.0044	52,028
6500	Ephemeral Ponds	652	0.2598	3.40	2.22	0.0322	661.66	4314.03	0.2112	51,455
6600	Cutover Wetlands	115	0.0458	3.80	0.44	0.0063	764.22	878.86	0.0430	49,769
4400	Pine Plantations	63360	25.2490	3.39	214.85	3.1157	683.97	433366.22	21.2122	49,576
6100	Bottomland Hardwoods	2182	0.8695	7.32	15.97	0.2316	1482.74	32353.44	1.5836	49,369

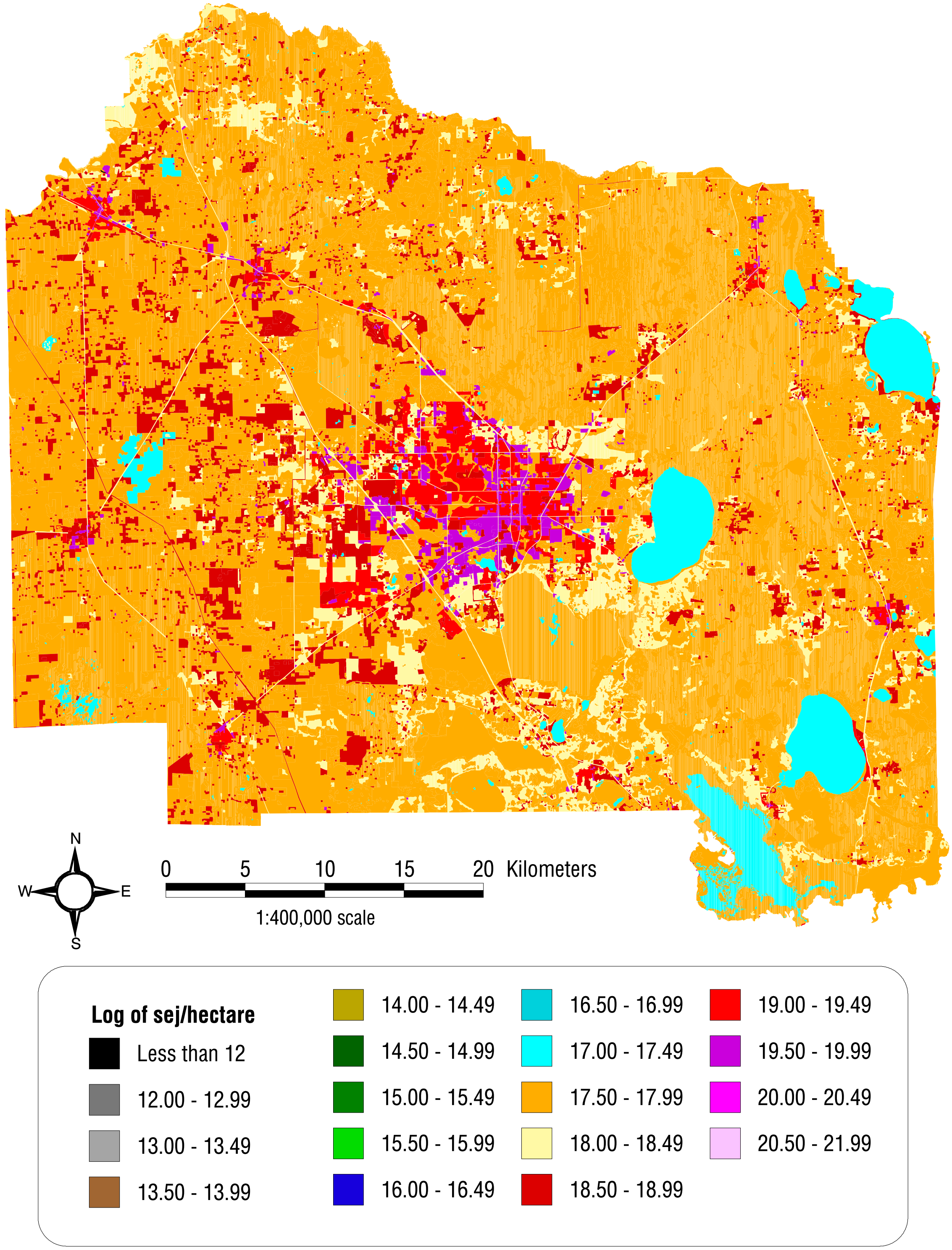


Figure 3-124: Map of the the log of total EMSTORAGE density based on mean values calculated for each level 2 landuse class in Table 3-25. When this derived version is compared to the EMSTORAGE density grid (see Fig. 3-106), it becomes apparent that the landuse polygon mean-based values tend to be higher in rural and residential areas and lower in commercial and institutional areas than the individual cell-based measured values in the EMSTORAGE density grid.

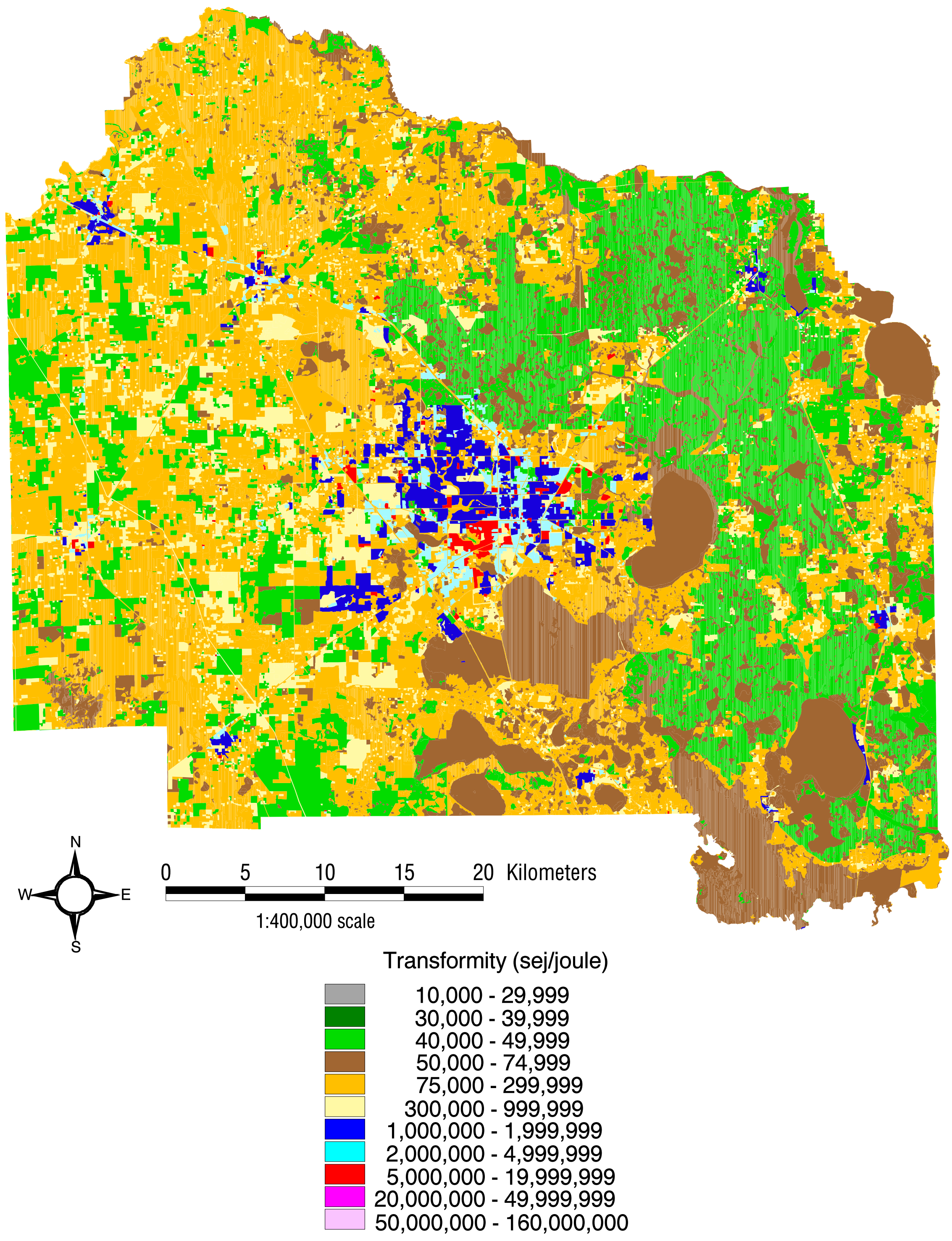


Figure 3-125: Map of the ranges of total EMSTORAGE density transformities that were calculated for each level 2 landuse class in Table 3-25. These transformities were calculated by dividing the sum of the values in all of the cells of the total EMSTORAGE density grid which were in a particular landuse class by the sum of the values in all of the corresponding cells of the total annual energy storage density grid.

Aggregated land use and cover classifications. The Alachua County land use and cover GIS database has 163 'level 3' land use classes and the 36 'level 2' classes. This large number of classes results in long tables of statistics that are difficult to digest. To facilitate land class-based EMERGY component signature analysis, and to improve comprehension of the results, an aggregated land use classification scheme was created that only has 10 classes. The new scheme is similar to the FLUCCS 'level 1' classification scheme except for the inclusion in this scheme of more specific residential classes (including 'low-density', 'medium-density', and 'high-density'). Table 3-26 provides a cross-reference between the FLUCCS 'level 2' classes and the 'aggregated' land classification system. A map showing the areas classified according to the new classes in the aggregated land use classification system is presented in Figure 3-126.

EMPOWER analysis using the aggregated land use and cover classifications. Table 3-27 lists the EMPOWER summary statistics for each 'aggregated' land classification. Using the same methods described previously, total EMPOWER class density (sej/class/yr) and total energy flow class density (j/class/yr) rates were calculated for each aggregated land class (Table 3-27 lists these as the 'sum, E18 sej/yr). The class transformities and percentages were also calculated using methods described previously.

The transformity, and percentage values for many of the classes in Table 3-27 are the same as (or very similar to) those in the corresponding 'level 2' table. In fact, several of the aggregated urban classes are not really aggregated at all (for example, 'commercial and services'). By referring to the cross-reference list in Table 3-26, it becomes apparent that the majority of the 'level 2' land use classes that were aggregated for this scheme are in the 'agriculture', 'upland forest', 'wetlands', and 'transportation' aggregated classes.

Table 3-26: Table of cross-references between the standard Level 2 land use classifications (used previously for various statistics) and the aggregated land use classification categories created to simplify the EMERGY component signature analysis. There are 36 categories in the standard classification scheme and 10 categories in the aggregated classification scheme.

Level 2 Code	No. of cells	Level 2 Land Use Description	Aggregated Classification Description
1100	18348	Residential-Low Density	Residential-Low Density
1200	6544	Residential-Med Density	Residential-Med Density
1300	1287	Residential-High Density	Residential-High Density
1400	1672	Commercial and Services	Commercial/Services
1500	576	Industrial	Industrial/Extractive
1600	874	Extractive	Industrial/Extractive
1700	1203	Institutional	Institutional
1800	713	Recreational	Upland Forest
1900	772	Open Land	Residential-Low Density
2100	59404	Pasture and Row Crops	Agriculture
2200	1050	Tree Crops	Agriculture
2300	64	Livestock Feeding	Agriculture
2400	210	Nurseries	Agriculture
2500	248	Horse Farms	Agriculture
2600	1346	Old Fields	Agriculture
3100	15	Rangeland (herbaceous)	Agriculture
3200	3995	Rangeland (shrubby)	Agriculture
3300	189	Rangeland (mixed)	Agriculture
4100	2184	Mesic Flatwoods	Upland Forest
4200	18483	Hardwood Forest	Upland Forest
4300	20801	Mixed Forest	Upland Forest
4400	63360	Pine Plantations	Upland Forest
5100	49	Streams	Wetlands/Water
5200	10944	Lakes	Wetlands/Water
5300	232	Reservoirs	Wetlands/Water
6100	2182	Bottomland Hardwoods	Wetlands/Water
6200	3007	Cypress Domes	Wetlands/Water
6300	13739	Forested Wetlands (mixed)	Wetlands/Water
6400	13847	Marshes and Wet Prairies	Wetlands/Water
6500	652	Ephemeral Ponds	Wetlands/Water
6600	115	Cutover Wetlands	Wetlands/Water
7400	96	Barren Land	Agriculture
8100	2028	Transportation	Transportation/Utilities
8200	3	Communications	Transportation/Utilities
8300	706	Utilities Plants	Transportation/Utilities
8800	3	Other Utilities	Transportation/Utilities

Table 3-27 is sorted in descending order according to the transformity calculated for each aggregated land class. Based on intuition, there are no obvious anomalies in the rank order of the land class transformities. Previously observed anomalies were most often associated with 'minor' land classes that represented relatively small areas of land, and were more susceptible to spatial and attribute inaccuracies in the land use and cover polygon coverage.

EMSTORAGE analysis using the aggregated land use and cover classifications. Table 3-28 lists the EMSTORAGE summary statistics for each 'aggregated' land class. Using the same methods described previously, the total EMSTORAGE class density (sej/class) and total energy storage class density (j/class) was calculated for each aggregated land class (Table 3-28 lists these values as the 'sum, E20 sej). The land class EMSTORAGE transformities and percentages of the total county-wide EMSTORAGE were also calculated for the new land classes. As explained previously, some of the mean, transformity, and percentage values for many of the classes in Table 3-28 are the same as (or very similar to) those in the corresponding 'level 2' table (refer to the cross-reference list in Table 3-26).

Table 3-28 is sorted in descending order according to the EMSTORAGE transformity calculated for each aggregated land class. The transformities range from the 7,786,939 sej/joule (associated with the 'Institutional' classification) to 55,393 sej/joule (associated with the 'Wetlands and Water' classification. Based on the same intuition used to evaluate the EMPOWER aggregated land class transformities , there are no anomalies in the rank order of the EMSTORAGE aggregated class transformities.

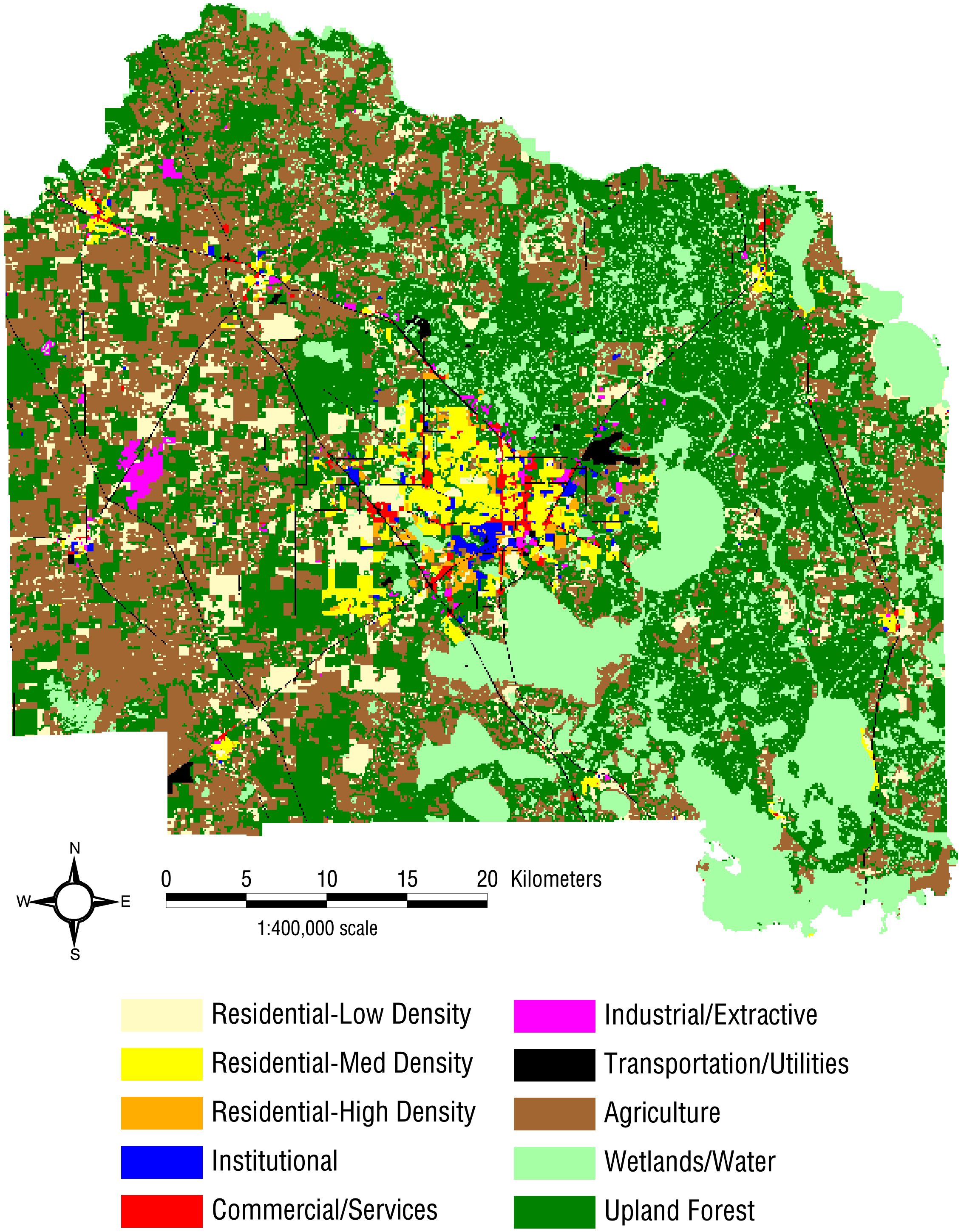


Figure 3-126: Map of the aggregated land use classification categories that were created to simplify the EMERGY signature analysis. Table 3-23 provides a cross-reference with the Level 2 landuse classification codes which have been used in previous calculations.

Table 3-27: Statistics summarized by the ‘aggregated’ land use classification categories for the county-wide total annual EMPOWER and energy flow density. The table is sorted in descending order according to the calculated total EMPOWER transformity of each aggregated land use classification. Each transformity was calculated by dividing the sum of the annual EMPOWER for the total area of each land use category by the sum of the energy flow for the area of the same classification.

Description	No. of cells (# ha)	% of Co-wide area	Sum, E18 sej/yr	Sum, E12 j/yr	EMPOWER Transformity (sej/j)	% of Co-wide total sej/yr	% of Co-wide total j/yr
Institutional	1203	0.48	4313.9	16332	264,142	15.61	3.78
Residential - High Density	1287	0.51	4327.3	21679	199,610	15.66	5.01
Commercial/ Services	1672	0.67	4297.1	27000	159,153	15.55	6.25
Industrial/ Extractive	1450	0.58	871.0	7926	109,890	3.15	1.83
Residential – Medium Density	6544	2.61	6794.0	79974	84,953	24.58	18.50
Residential – Low Density	19120	7.62	3191.7	63014	50,651	11.55	14.58
Transportation/ Utilities	2740	1.09	690.4	27946	24,704	2.50	6.46
Wetlands/ Water	44767	17.84	253.1	12719	19,895	0.92	2.94
Agriculture	66617	26.55	1002.3	56588	17,713	3.63	13.09
Upland Forest	105541	42.06	1897.9	119084	15,937	6.87	27.55

Table 3-28: Statistics summarized by the ‘aggregated’ land use classification categories for the county-wide total annual EMSTORAGE and energy storage density. The table is sorted in descending order according to the calculated EMSTORAGE transformity of each aggregated land use classification. Each transformity was calculated by dividing the sum of the EMSTORAGE for the total area of each land use category by the sum of the energy storage for the area of the same classification.

Description	No. of cells (# ha)	% of Co-wide area	Sum, E20 sej	Sum, E12 joules	EMSTORAGE Transformity (sej/j)	% of Co-wide total sej	% of Co-wide total joules
Institutional	1203	0.48	1039	13342	7,786,939	15.07	0.65
Residential – High Density	1287	0.51	1096	23337	4,694,518	15.89	1.14
Commercial/ Services	1672	0.67	935	20638	4,529,940	13.56	1.01
Industrial/ Extractive	1450	0.58	138	8456	1,631,637	2.00	0.41
Residential – Medium Density	6544	2.61	1611	103198	1,560,810	23.36	5.05
Residential – Low Density	19120	7.62	785	194509	403,353	11.38	9.52
Transportation/ Utilities	2740	1.09	79	24605	322,276	1.15	1.20
Agriculture	66617	26.55	299	333574	89,795	4.34	16.33
Upland Forest	105541	42.06	649	842312	77,059	9.41	41.24
Wetlands/ Water	44767	17.84	265	478519	55,393	3.84	23.43

EMERGY component signatures for aggregated land use classes. The statistics presented previously listed the 'total' annual EMPOWER of consumption and EMSTORAGE densities for each land use class. Table 3-29 provides additional insight into the spatial patterns of EMERGY flows and storages by listing the sum of the EMERGY flow or storage for each of the (sub)components within the area of each aggregated land use classification. Because the area of each class is different, the term 'component class density' is used to refer to the sum of the component flow (E18 sej/class/yr) or storage (E18 sej/class) occurring within the area of a land use class. A group of component class density values associated with a particular land class is referred to as the EMERGY component signature for that land class.

If the component class density values for the 'renew', 'wtruse', 'fuel', 'goods', and 'service' components are added together for a land use class, the value should be the same as the EMPOWER density value in Table 3-27 for that particular land use class. The same relation exists for the EMSTORAGE values in the table—if the component class density values for the 'natstr', 'urbstr', and 'popstr' components are added together for a class, the sum should equal the total EMSTORAGE value for the land class found in Table 3-28. In fact, some of the sum values may not be exactly the same as those in the corresponding tables due to the 'rounding off' of the numbers used in the calculations.

The data in Table 3-29 also provide the potential for insights into the spatial distribution (by land class) of the total EMERGY flow or storage of a particular (sub)component of the model. For instance, from the data in the table, one can calculate that 39.8% of the county-wide total flow of renewable EMERGY occurs through the 'upland forest' land class ((141.11 E18 sej/class/yr / 354.46 E18 sej/class/yr) *100).

Table 3-29: Summary table of the EMPOWER and EMSTORAGE densities for each of the spatial EMERGY model component and sub-component grids within the area of each aggregated land use classification. Because the area of each class is different, the term 'class density' is used to refer to the sum of a particular flow or storage occurring within the area of a land use classification.

EMERGY Component Grid Name	Aggregated Land Use Classification										County-wide Component Sum
	Residential - Low Density	Residential – Medium Density	Residential – High Density	Commercial and Services	Industrial and Extractive	Institutional	Transportation and Utilities	Agriculture	Upland Forest	Wetlands and Water Bodies	
	EMPOWER Component Class Density (E18 sej/class/yr)										
renew	26.95	7.44	0.73	0.79	0.29	1.25	3.26	87.34	141.11	85.28	354.46
gpp	38.99	28.07	5.80	4.59	0.90	11.34	6.66	198.34	161.02	87.32	543.07
wtruse	13.91	33.76	21.13	17.67	4.47	14.34	2.45	33.07	8.45	1.05	150.30
fuel	251.77	433.00	189.78	496.68	185.67	276.34	461.29	169.30	342.95	40.07	2846.95
trn_ful	111.69	117.35	37.43	96.08	10.33	38.57	407.22	121.89	248.06	30.58	1219.30
bag_ful	140.08	315.65	152.35	400.60	175.35	237.77	54.07	47.41	94.89	9.49	1627.66
goods	307.41	627.80	346.46	542.20	211.92	613.08	90.34	181.80	184.54	21.09	3126.64
service	2587.78	5590.10	3781.59	3150.01	457.82	3399.13	362.22	503.73	1194.74	133.58	21160.70
waste	210.45	348.86	213.14	644.08	192.97	574.32	79.02	135.61	155.66	17.18	2571.30
recycle	163.45	261.63	159.26	522.46	157.12	470.85	63.89	109.52	123.80	13.71	2045.68
	EMSTORAGE Component Class Density (E18 sej/class)										
natstr	5412.43	1659.89	281.07	316.29	210.10	321.51	677.19	14934.29	29468.41	23852.64	77145.28
biostr	1748.73	579.03	66.14	59.68	16.18	119.97	84.37	942.65	7203.30	2074.28	12895.96
wtrstr	1003.88	329.88	65.17	84.08	73.75	60.98	168.51	3365.98	5311.67	2498.06	12963.05
soilom	2659.81	750.99	149.76	172.52	120.18	140.56	424.31	10625.66	16953.43	19280.30	51286.26
urbstr	1557.27	2484.15	1132.59	965.61	194.41	2986.47	580.74	772.06	1309.96	115.36	12098.65
bldg	789.49	1628.41	928.44	768.87	142.82	2882.90	201.05	177.49	370.12	36.86	7926.45
road	438.82	453.89	87.77	109.86	26.51	50.85	272.74	372.32	566.82	48.49	2428.13
util	328.96	401.85	116.37	86.87	25.08	52.72	106.94	222.25	373.02	30.00	1744.07
popstr	71535.27	154814.02	108625.70	90698.12	13209.12	100420.57	10337.30	13798.45	33175.02	3722.67	600336.23

Table 3-30 presents a summary of the percentages of county-wide component EMPOWER and EMSTORAGE that were calculated for the area of each aggregated land use class. The percentages in the table add up to 100 for each (sub)component (plus or minus 100 due to rounding). The following equation was used to create the table:

((sej/component-class(/yr) / sej/component-county(/yr)) * 100)

A group of EMERGY (sub)component percentages associated with a particular land class could also be thought of as another type of EMERGY component signature for that land class. The purpose of calculating these percentages of component total flows or storages is to help reveal interesting relations that may not be obvious from the data for the actual flow or storage values (E18 sej/class/yr or E18 sej/class) for each component that was presented in Table 3-29.

For instance, the actual value for water use in the 'agriculture' land class (33 E18 sej/class/yr) is relatively low when compared to the flow value for services (503 E18 sej/class/yr). However, this water use component value represents 22% of the total county-wide water use component EMERGY flow. And the value for the services component only represents 2.4% of the total county-wide EMERGY flow of services.

There are a few counter-intuitive values in Tables 3-29 and 3-30. For instance, there are small, but significant flows noted for fuel use in buildings and transportation in the 'wetlands and water bodies' land class. Normally, one would not think of these flows as being part of this type of ecosystem. However, the area covered by this generalized land use class (and the 'agriculture' and 'upland forest' classes) includes a few elements of urban systems such as roads and buildings that contribute to these component flows.

Table 3-30: Summary table of the percent of county-wide Component EMPOWER and EMSTORAGE densities found within the area of each aggregated land use classification. The following equation was used to calculate the percentages in the table: ((sej/component-class(/yr) / sej/component-county(/yr)) * 100).

EMERGY Component Grid Name	Aggregated Land Use Classification									
	Residential - Low Density	Residential – Medium Density	Residential – High Density	Commercial and Services	Industrial and Extractive	Institutional	Transportation and Utilities	Agriculture	Upland Forest	Wetlands and Water Bodies
	Percent of county-wide Component EMPOWER Density									
renew	7.6	2.1	0.2	0.2	0.1	0.4	0.9	24.6	39.8	24.1
gpp	7.2	5.2	1.1	0.9	0.2	2.1	1.2	36.5	29.7	16.1
wtruse	9.3	22.5	14.1	11.8	3.0	9.5	1.6	22.0	5.6	0.7
fuel	8.8	15.2	6.7	17.5	6.5	9.7	16.2	6.0	12.1	1.4
trn_ful	9.2	9.6	3.1	7.9	0.9	3.2	33.4	10.0	20.3	2.5
bag_ful	8.6	19.4	9.4	24.6	10.8	14.6	3.3	2.9	5.8	0.6
goods	9.8	20.1	11.1	17.3	6.8	19.6	2.9	5.8	5.9	0.7
service	12.2	26.4	17.9	14.9	2.2	16.1	1.7	2.4	5.7	0.6
waste	8.2	13.6	8.3	25.1	7.5	22.3	3.1	5.3	6.1	0.7
recycle	8.0	12.8	7.8	25.5	7.7	23.0	3.1	5.4	6.1	0.7
	Percent of county-wide Component EMSTORAGE Density									
natstr	7.0	2.2	0.4	0.4	0.3	0.4	0.9	19.4	38.2	30.9
biostr	13.6	4.5	0.5	0.5	0.1	0.9	0.7	7.3	55.9	16.1
wtrstr	7.7	2.5	0.5	0.7	0.6	0.5	1.3	26.0	41.0	19.3
soilom	5.2	1.5	0.3	0.3	0.2	0.3	0.8	20.7	33.1	37.6
urbstr	12.9	20.5	9.4	8.0	1.6	24.7	4.8	6.4	10.8	1.0
bldg	10.0	20.5	11.7	9.7	1.8	36.4	2.5	2.2	4.7	0.5
road	18.1	18.7	3.6	4.5	1.1	2.1	11.2	15.3	23.3	2.0
util	18.9	23.0	6.7	5.0	1.4	3.0	6.1	12.7	21.4	1.7
popstr	11.9	25.8	18.1	15.1	2.2	16.7	1.7	2.3	5.5	0.6

Table 3-31 presents the results of calculating the log values of the EMPOWER and EMSTORAGE for each of the (sub)component grids found within the area of each aggregated land use classification. A group of log values for each (sub)component associated with a land class can be thought of as another form (the log form) of EMERGY component signature for that land class. The log component class EMPOWER and EMSTORAGE densities (log sej/class/yr or log sej/class) were primarily calculated to facilitate the creation of EMERGY component signature histograms for each of the aggregated land classes. The log values in Table 3-31 were used to create ten separate histogram charts (Figures 3-127 to 3-136, corresponding to each of the aggregated land use classes) that present log-form EMERGY component signatures. Each particular land class chart includes the flow and storage log values for both the EMPOWER components and the EMSTORAGE components for that land class.

The signature charts help to reinforce some of the patterns that can be seen in the other forms of signatures presented (actual values in Table 3-29 and percentages in Table 3-30). For instance, the charts show clearly that the 'service' EMERGY component flows and the 'population' EMERGY component storages are dominant in all of the land classes except for the 'agriculture' and 'wetlands' classes. The histograms also make patterns such as decreasing renewable flows with increasing residential density more obvious. Two summary charts of the land class log-form EMERGY component signatures were also created. Figure 3-137 enables comparisons between component EMPOWER class density flows (sej/component-class/yr) for the aggregated land classes, and the chart in Figure 3-138 enables comparisons between the component EMSTORAGE class densities (sej/component-class).

Table 3-31: Summary table of the log values of the EMPOWER and EMSTORAGE for each of the (sub)component grids found within the area of each aggregated land use classification (log component class density).

EMERGY Component Grid Name	Aggregated Land Use Classification Categories									
	Residential - Low Density	Residential – Medium Density	Residential – High Density	Commercial and Services	Industrial and Extractive	Institutional	Transportation and Utilities	Agriculture	Upland Forest	Wetlands and Water Bodies
	Log EMPOWER Component Class Density (log sej/class/yr)									
renew	19.43	18.87	17.86	17.90	17.46	18.10	18.51	19.94	20.15	19.93
gpp	19.59	19.45	18.76	18.66	17.95	19.05	18.82	20.30	20.21	19.94
wtruse	19.14	19.53	19.32	19.25	18.65	19.16	18.39	19.52	18.93	18.02
fuel	20.40	20.64	20.28	20.70	20.27	20.44	20.66	20.23	20.54	19.60
trn_ful	20.05	20.07	19.57	19.98	19.01	19.59	20.61	20.09	20.39	19.49
bag_ful	20.15	20.50	20.18	20.60	20.24	20.38	19.73	19.68	19.98	18.98
goods	20.49	20.80	20.54	20.73	20.33	20.79	19.96	20.26	20.27	19.32
service	21.41	21.75	21.58	21.50	20.66	21.53	20.56	20.70	21.08	20.13
waste	20.32	20.54	20.33	20.81	20.29	20.76	19.90	20.13	20.19	19.23
recycle	20.21	20.42	20.20	20.72	20.20	20.67	19.81	20.04	20.09	19.14
	Log EMSTORAGE Component Class Density (log sej/class)									
natstr	21.73	21.22	20.45	20.50	20.32	20.51	20.83	22.17	22.47	22.38
biostr	21.24	20.76	19.82	19.78	19.21	20.08	19.93	20.97	21.86	21.32
wtrstr	21.00	20.52	19.81	19.92	19.87	19.79	20.23	21.53	21.73	21.40
soilom	21.42	20.88	20.18	20.24	20.08	20.15	20.63	22.03	22.23	22.29
urbstr	21.19	21.40	21.05	20.98	20.29	21.48	20.76	20.89	21.12	20.06
bldg	20.90	21.21	20.97	20.89	20.15	21.46	20.30	20.25	20.57	19.57
road	20.64	20.66	19.94	20.04	19.42	19.71	20.44	20.57	20.75	19.69
util	20.52	20.60	20.07	19.94	19.40	19.72	20.03	20.35	20.57	19.48
popstr	22.85	23.19	23.04	22.96	22.12	23.00	22.01	22.14	22.52	21.57

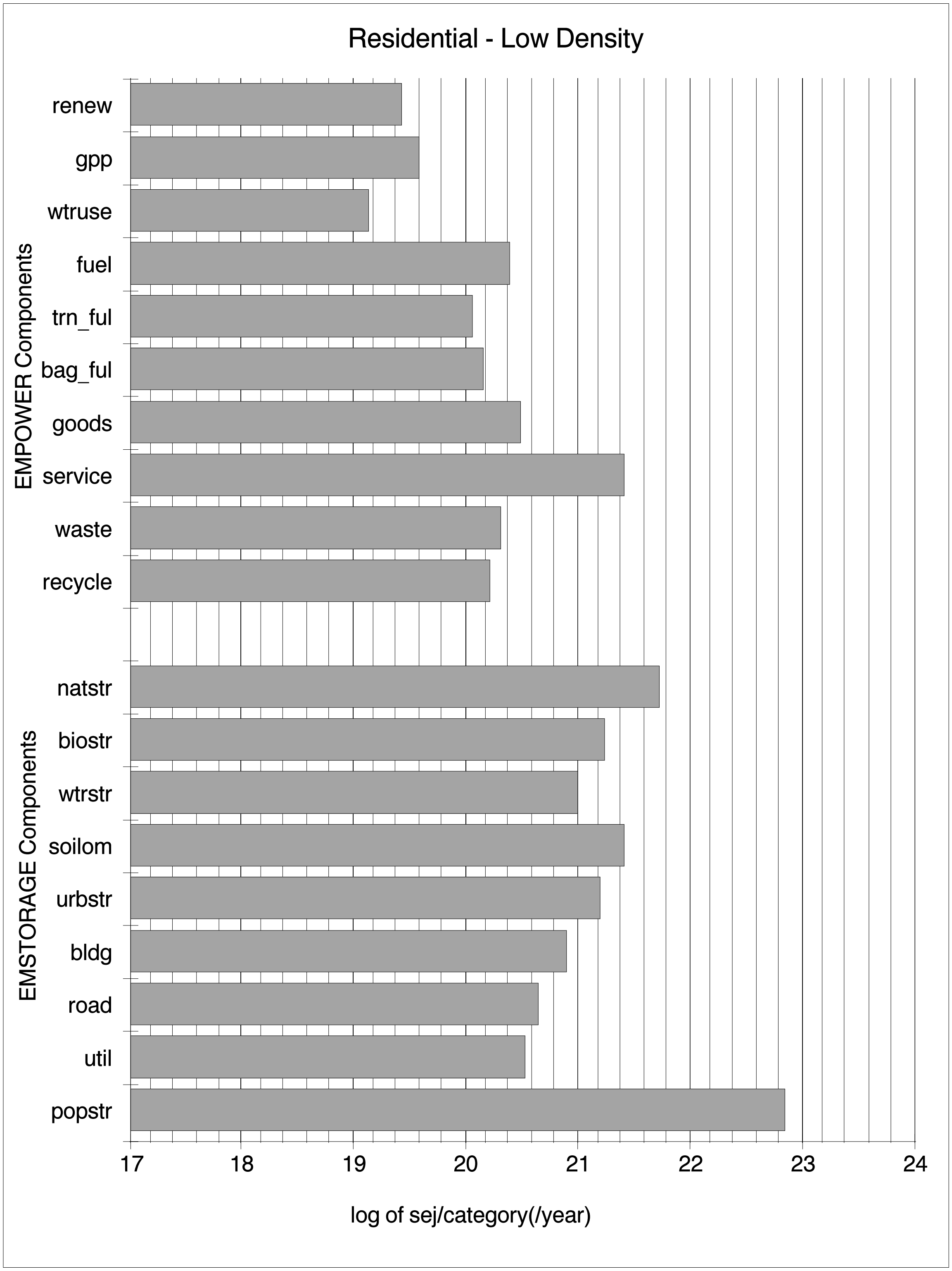


Figure 3-127: Chart of the EMERGY Component Signature for the aggregated landuse classification category 'Residential - Low Density'. The values in the chart represent the log categorical component EMPOWER and EMSTORAGE densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each aggregated landuse classification category for each of the spatial EMERGY model (sub-)component grids).

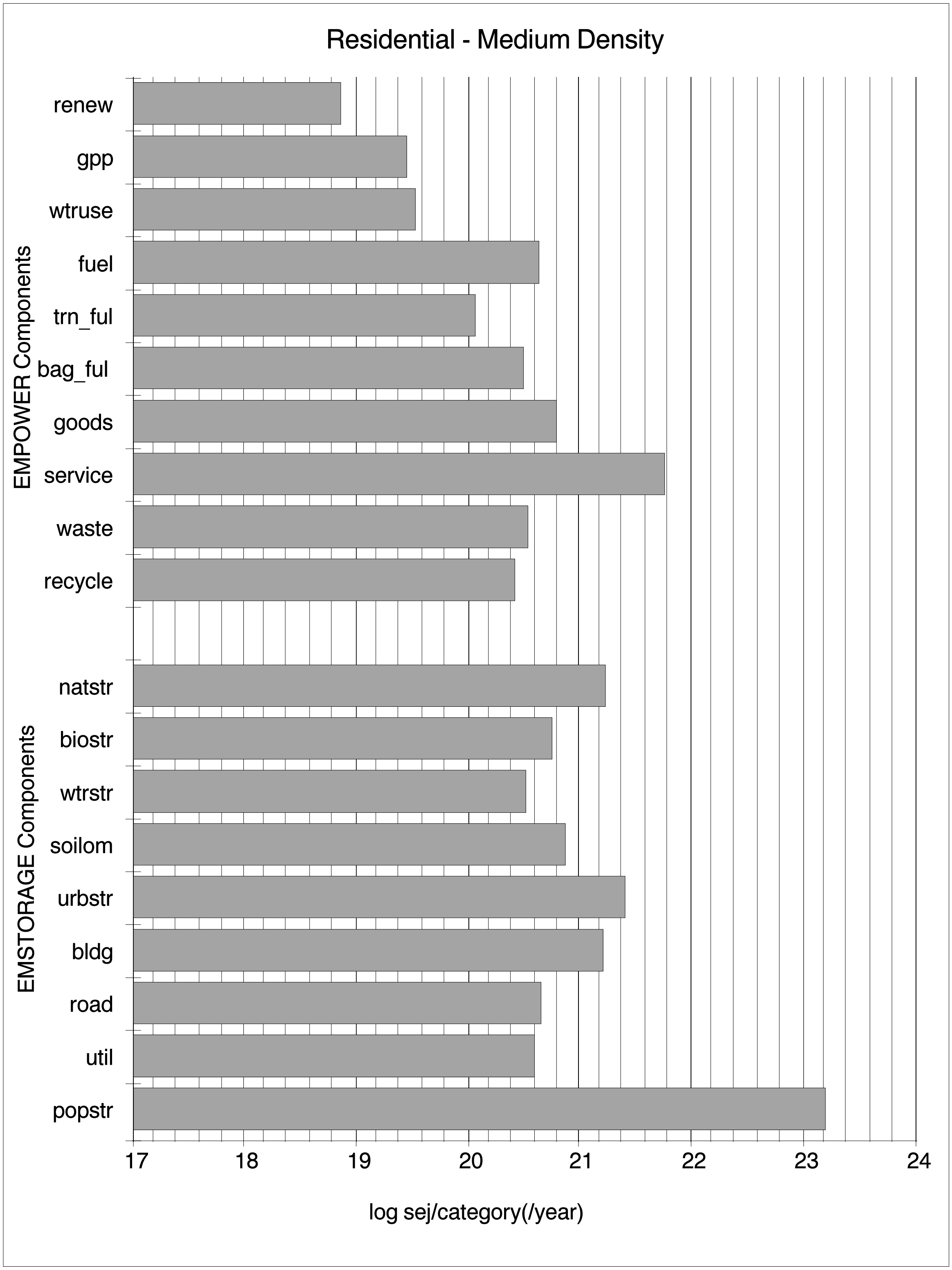


Figure 3-128: Chart of the EMERGY Component Signature for the aggregated landuse classification category 'Residential - Medium Density'. The values in the chart represent the log categorical component EMPOWER and EMSTORAGE densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each aggregated landuse classification category for each of the spatial EMERGY model (sub-)component grids).

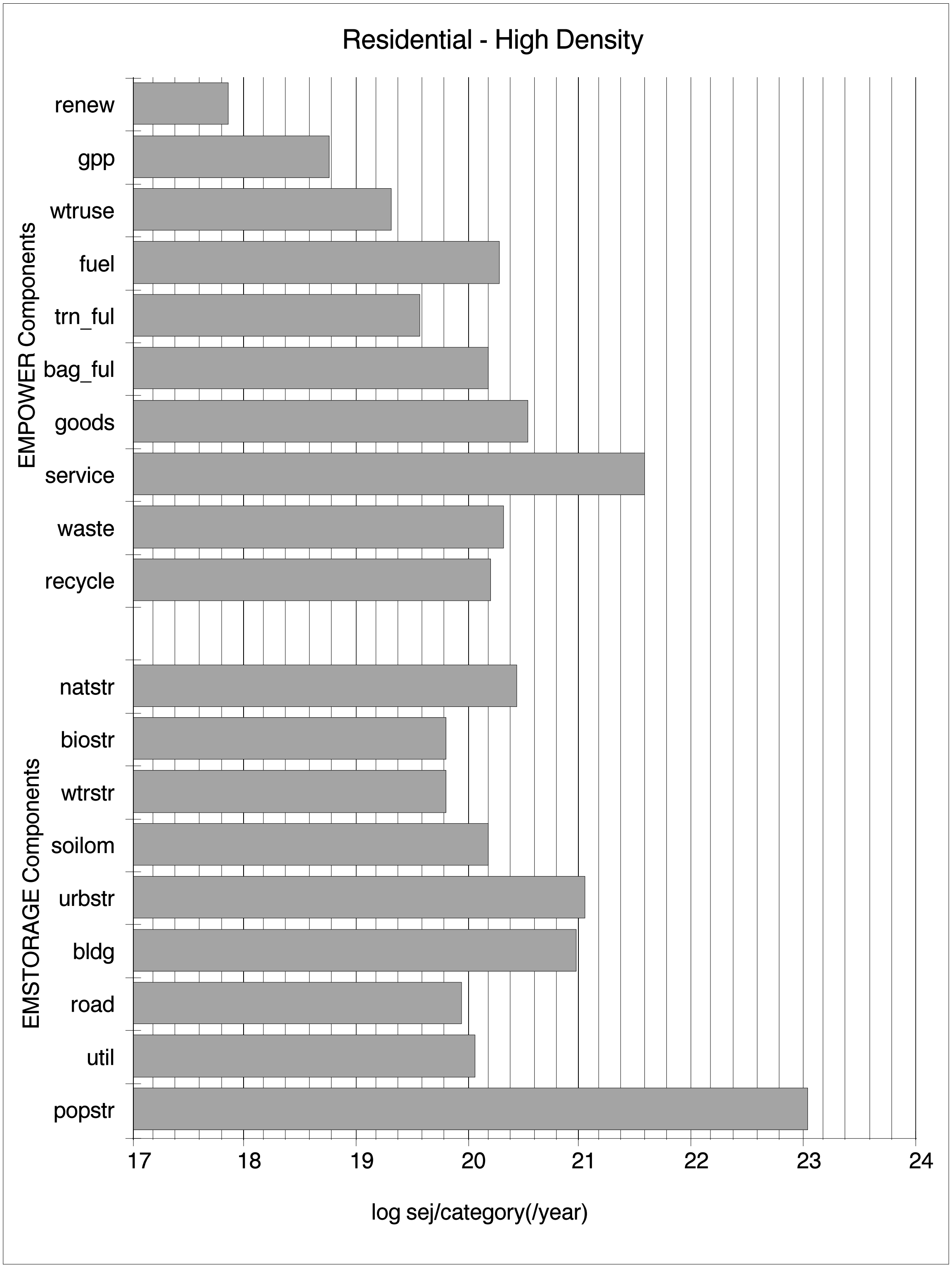


Figure 3-129: Chart of the EMERGY Component Signature for the aggregated landuse classification category 'Residential - High Density'. The values in the chart represent the log categorical component EMPOWER and EMSTORAGE densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each aggregated landuse classification category for each of the spatial EMERGY model (sub-)component grids).

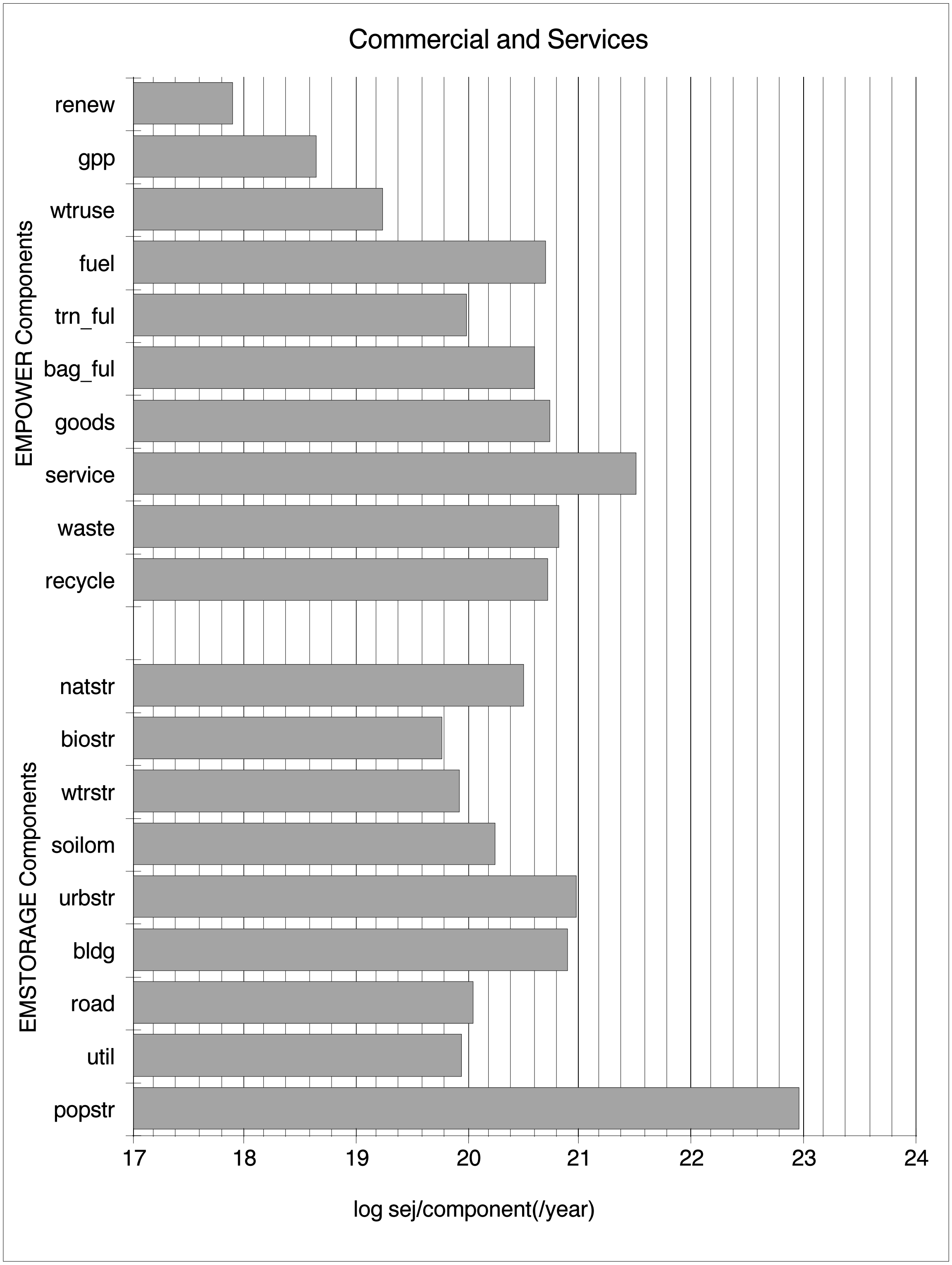


Figure 3-130: Chart of the EMERGY Component Signature for the aggregated landuse classification category 'Commercial and Services'. The values in the chart represent the log categorical component EMPOWER and EMSTORAGE densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each aggregated landuse classification category for each of the spatial EMERGY model (sub-)component grids).

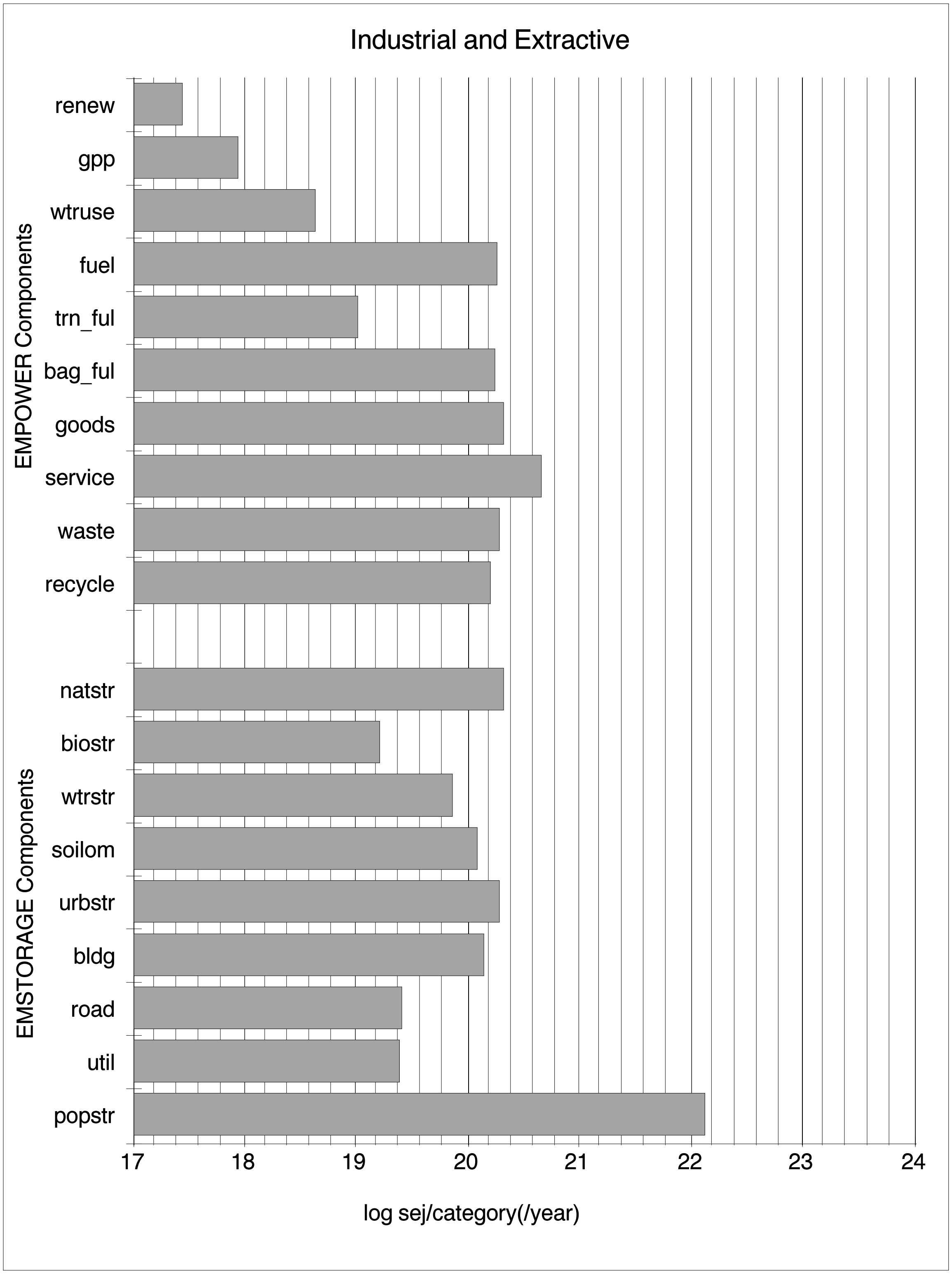


Figure 3-131: Chart of the EMERGY Component Signature for the aggregated landuse classification category 'Industrial and Extractive'. The values in the chart represent the log categorical component EMPOWER and EMSTORAGE densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each aggregated landuse classification category for each of the spatial EMERGY model (sub-)component grids).

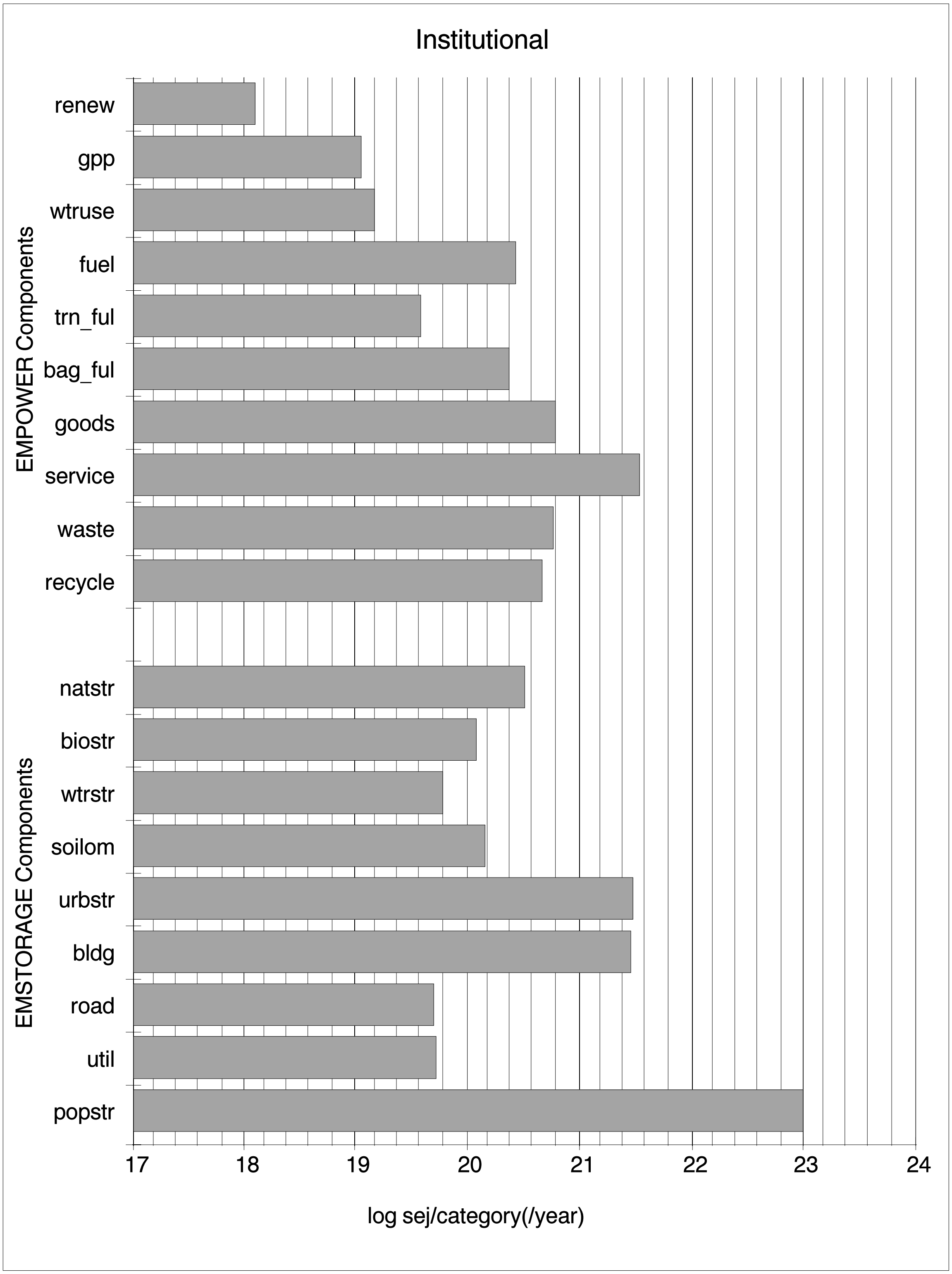


Figure 3-132: Chart of the EMERGY Component Signature for the aggregated landuse classification category 'Institutional'. The values in the chart represent the log categorical component EMPOWER and EMSTORAGE densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each aggregated landuse classification category for each of the spatial EMERGY model (sub-)component grids).

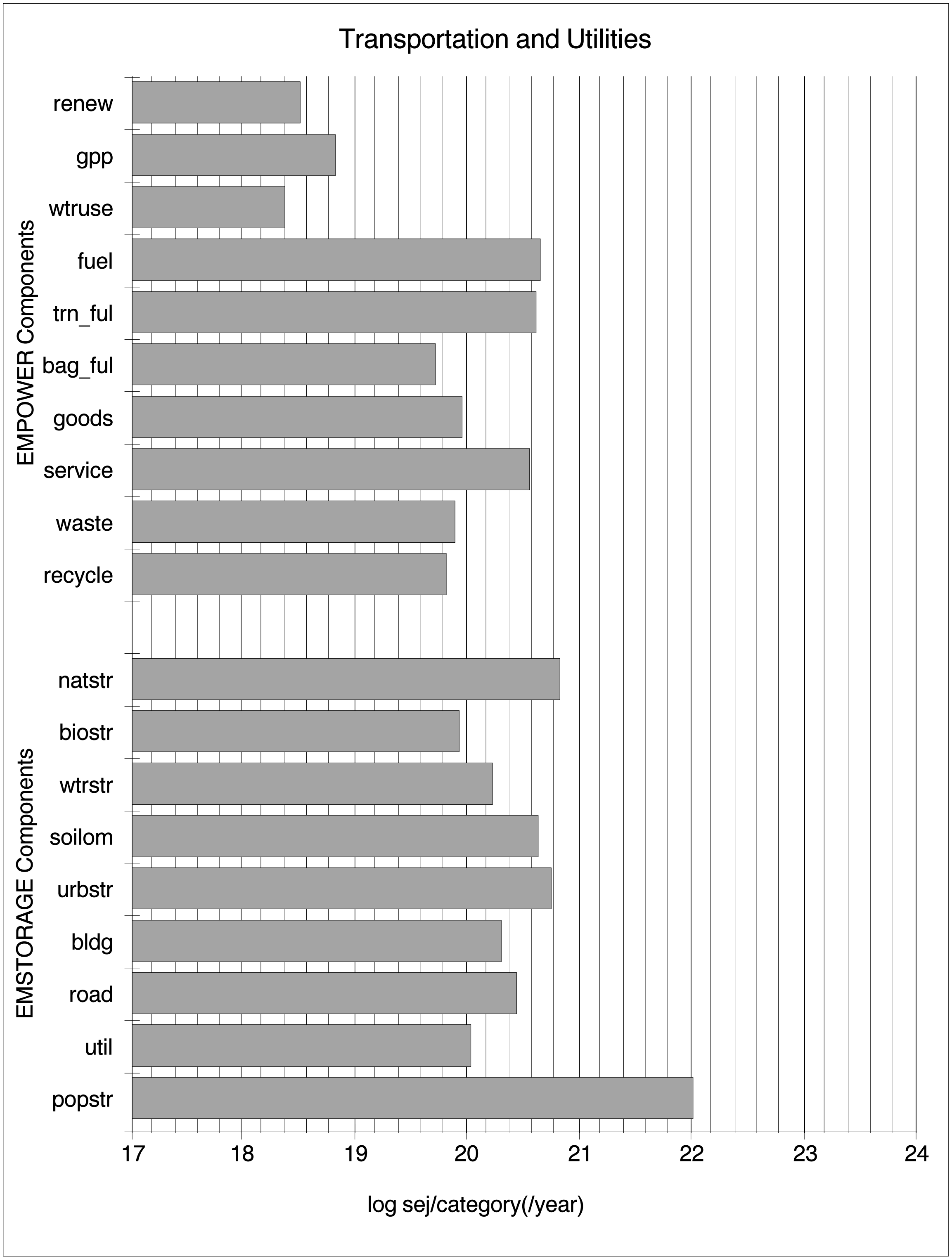


Figure 3-133: Chart of the EMERGY Component Signature for the aggregated landuse classification category 'Transportation and Utilities'. The values in the chart represent the log categorical component EMPOWER and EMSTORAGE densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each aggregated landuse classification category for each of the spatial EMERGY model (sub-)component grids).

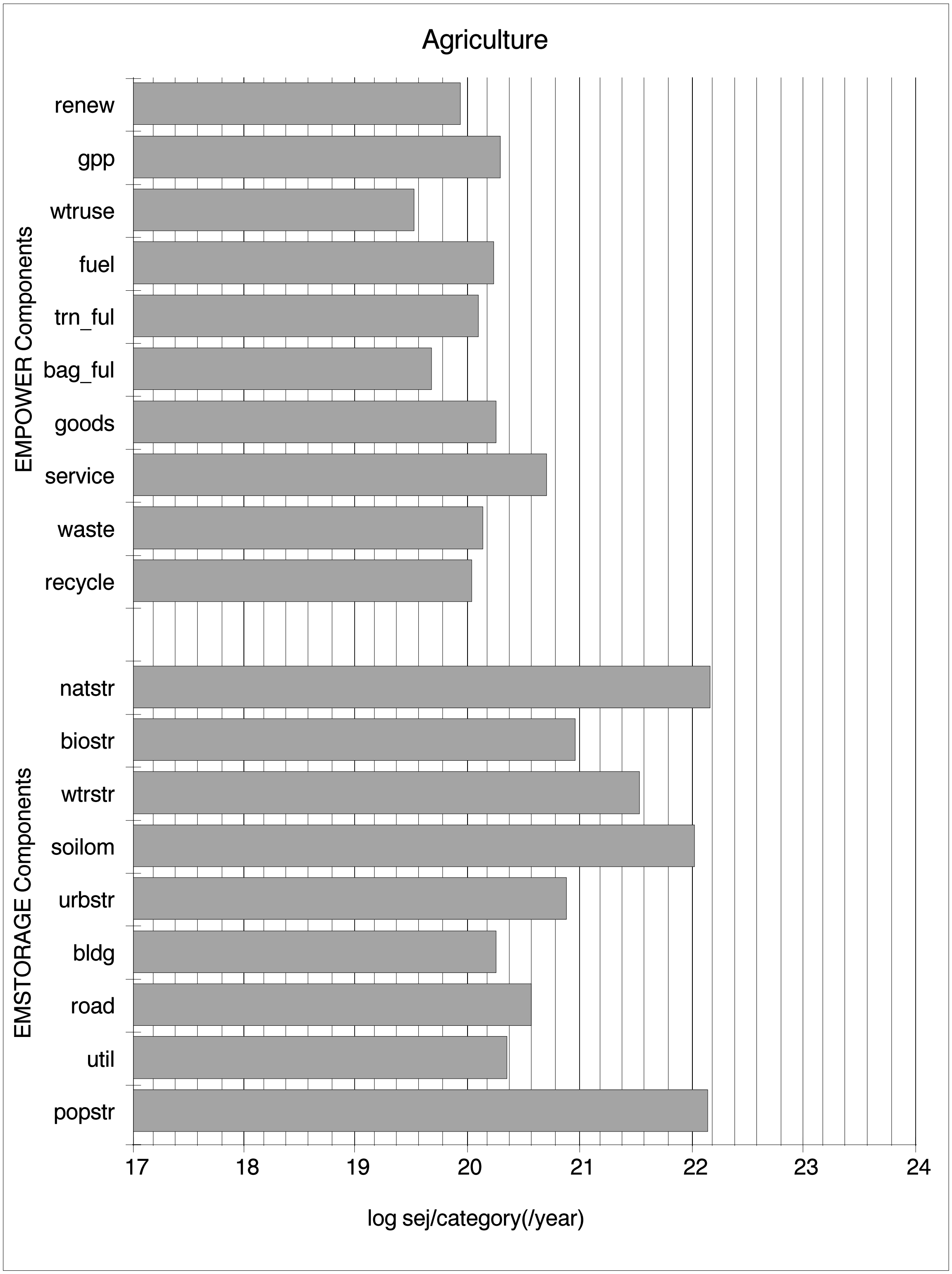


Figure 3-134: Chart of the EMERGY Component Signature for the aggregated landuse classification category ’Agriculture’. The values in the chart represent the log categorical component EMPOWER and EMSTORAGE densities (defined as the total amount of sej’s in storage or sej/yr flow within the area of each aggregated landuse classification category for each of the spatial EMERGY model (sub-)component grids).

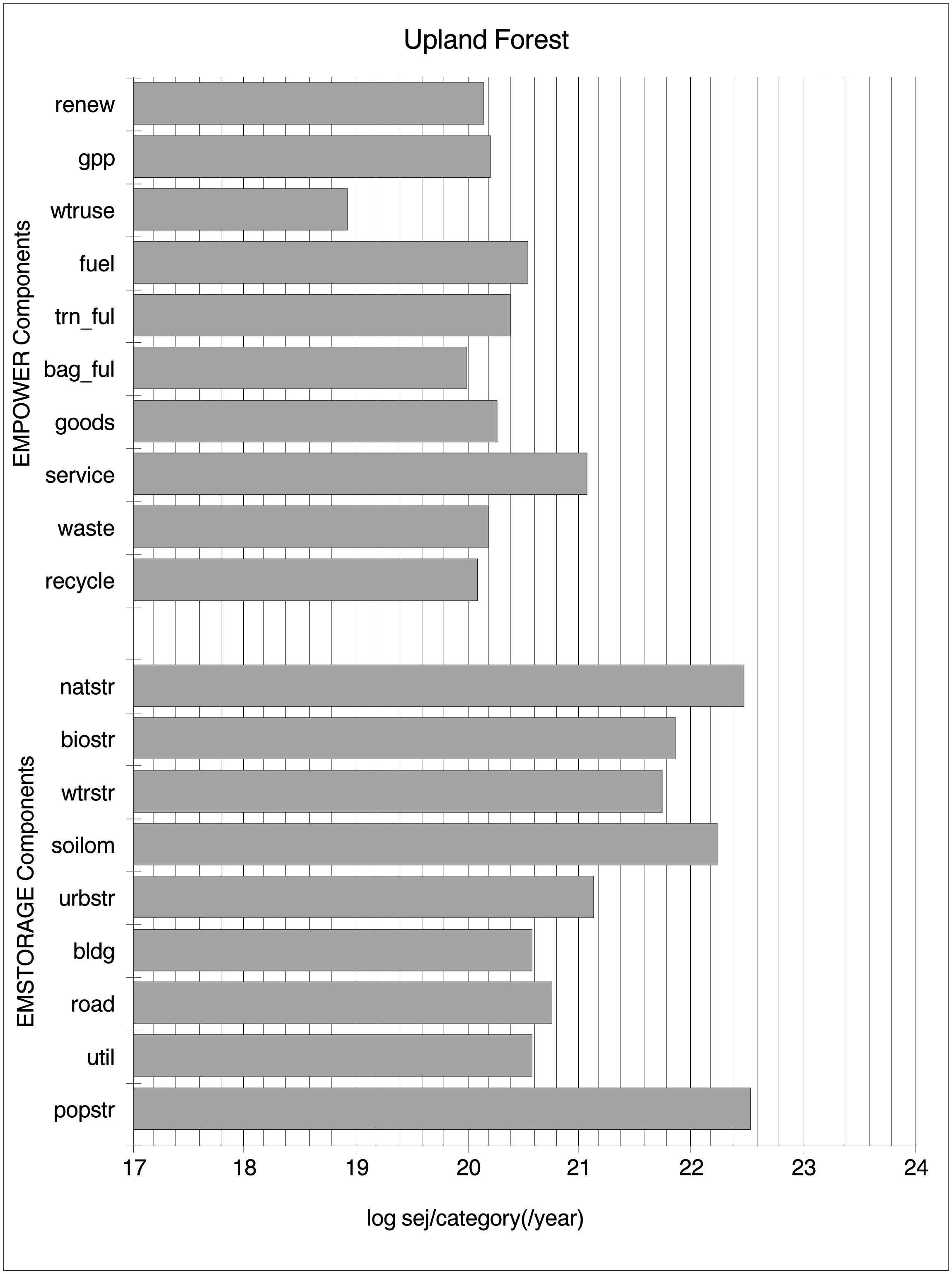


Figure 3-135: Chart of the EMERGY Component Signature for the aggregated landuse classification category 'Upland Forest'. The values in the chart represent the log categorical component EMPOWER and EMSTORAGE densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each aggregated landuse classification category for each of the spatial EMERGY model (sub-)component grids).

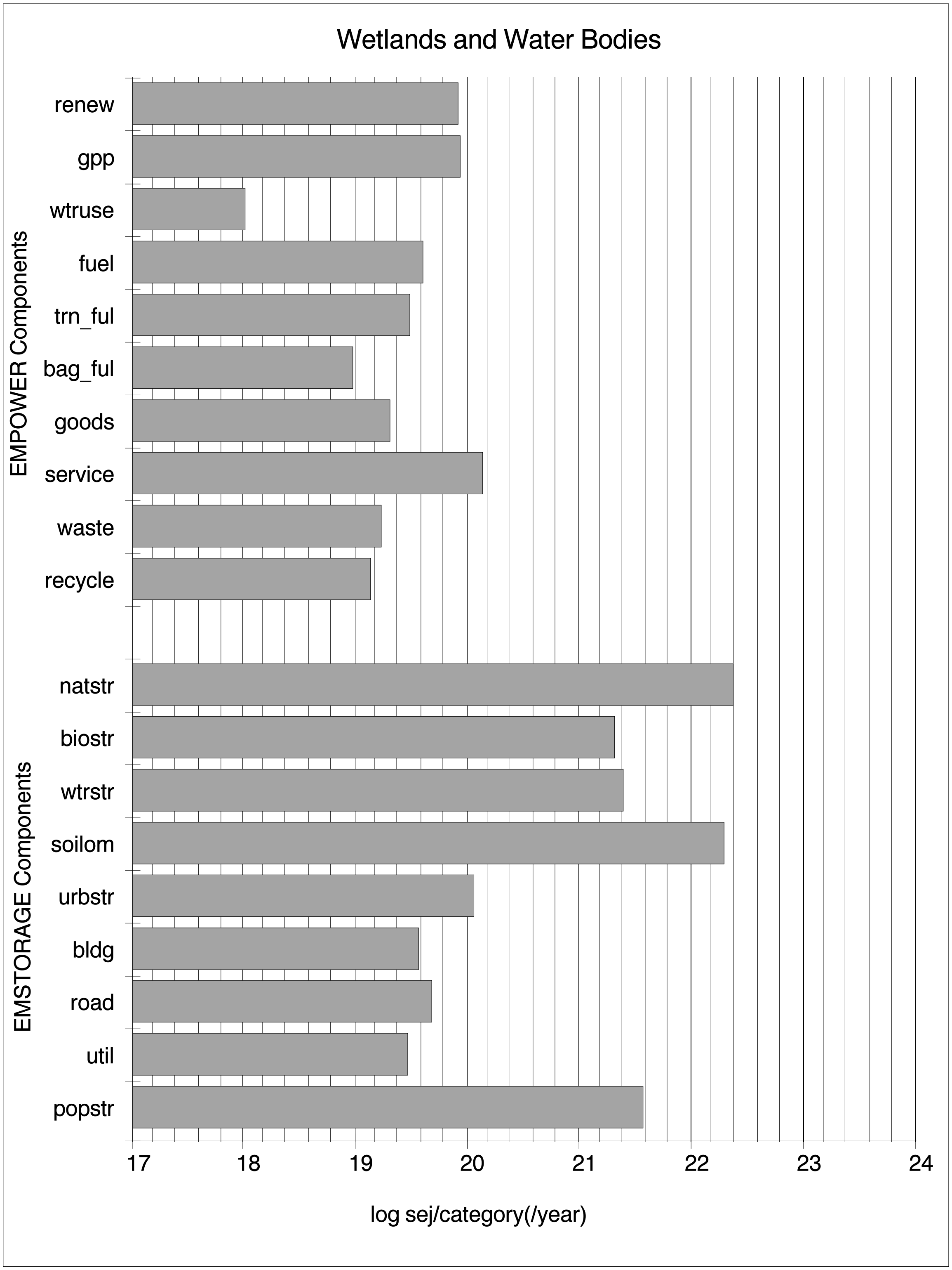


Figure 3-136: Chart of the EMERGY Component Signature for the aggregated landuse classification category 'Wetlands and Water Bodies'. The values in the chart represent the log categorical component EMPOWER and EMSTORAGE densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each aggregated landuse classification category for each of the spatial EMERGY model (sub-)component grids).

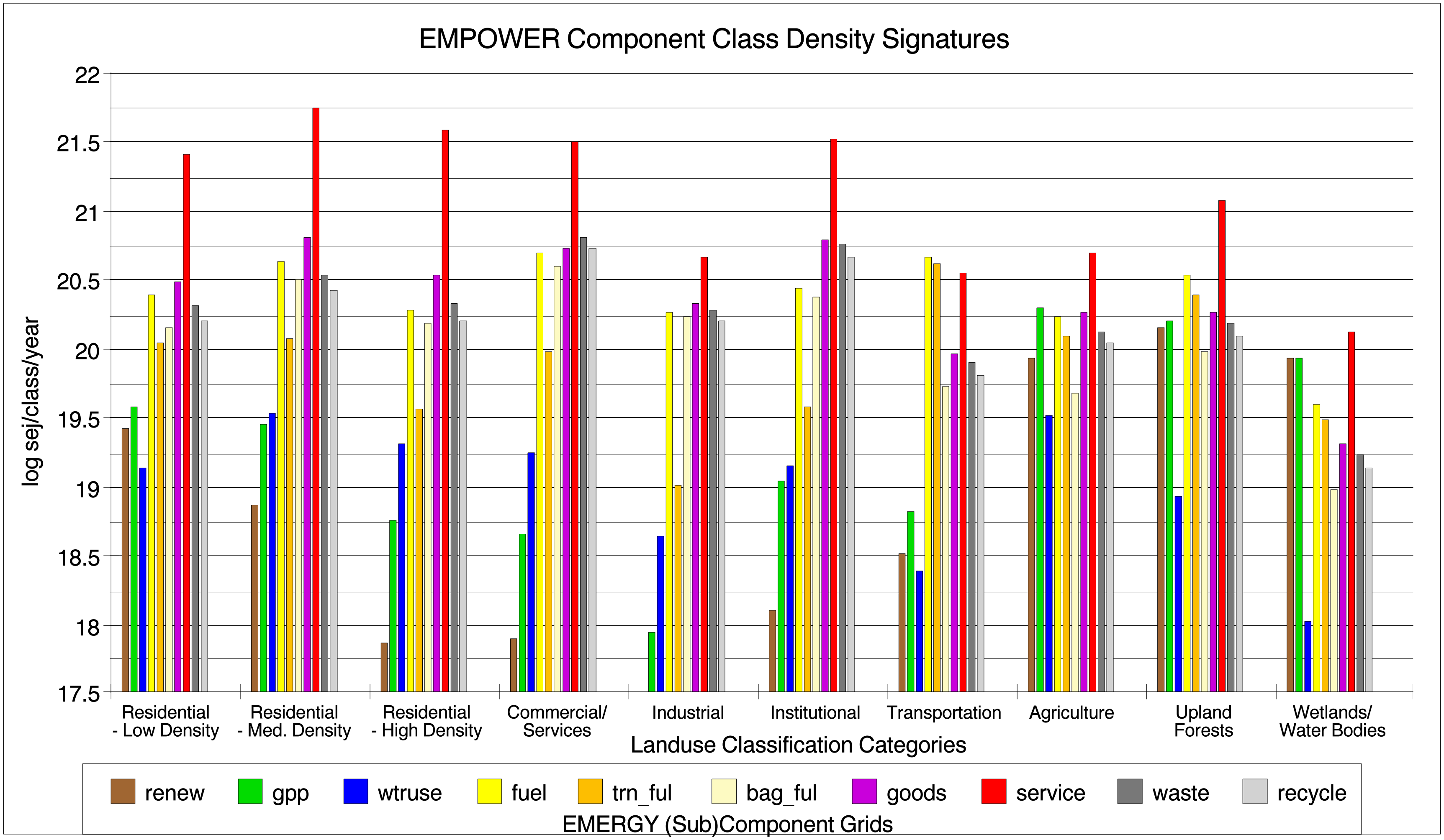


Figure 3-137: Chart of the 'EMPOWER Component Class Density Signatures' for the aggregated landuse classification categories. The values in the chart represent the log of the total EMERGY flow (sej/year) within the area of each aggregated landuse classification category for each of the spatial EMERGY model flow component or subcomponent grids.

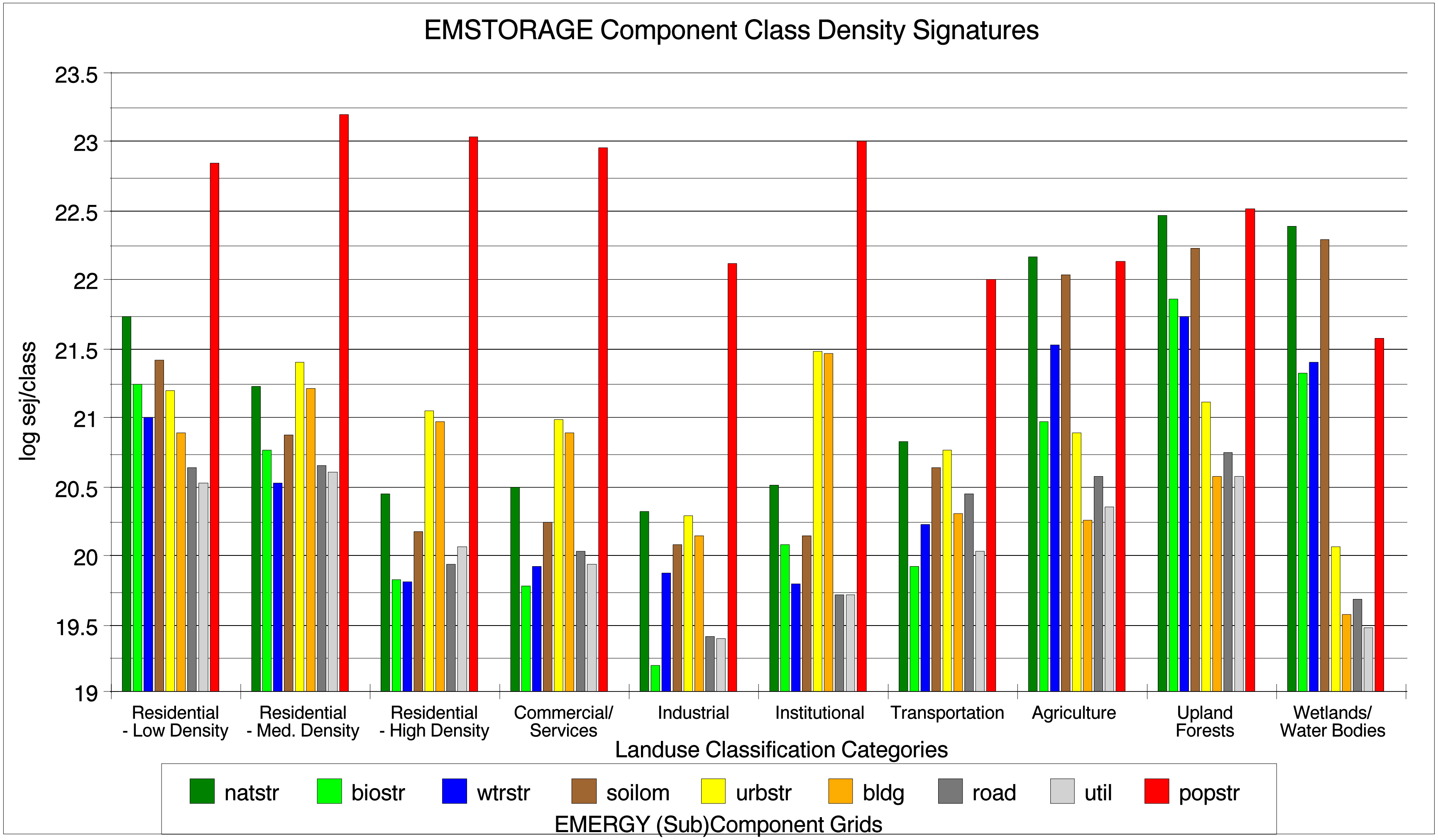


Figure 3-138: Chart of the 'EMSTORAGE Component Class Density Signatures' for the aggregated landuse classification categories. The values in the chart represent the log of the total EMERGY storage (log sej) within the area of each aggregated landuse classification category for each of the spatial EMERGY model storage component or subcomponent grids.

<u>Planning Unit Study</u>

The planning unit study is the second of three studies in which comparisons were made between different land areas of the county using EMERGY-related statistics as the basis of comparison. As noted previously, there are many ways to categorize land areas into units that can be described and analyzed. This study uses ‘planning units’ whose boundaries are defined by governance or management. It is hoped that comparison of the EMERGY flow and storage characteristics of planning units will provide useful insights for urban planners. Using the same methods described for the land use classification study, annual EMPOWER densities, EMSTORAGE densities, and transformities were calculated for each planning unit, and EMERGY component signature histograms were plotted for each planning unit.

Four planning units in the county (Figure 3-139) were chosen for this comparative analysis. The ‘City of Gainesville’ planning unit is defined by the city limits. The ‘urban services area’ planning unit was defined for this study as those areas contiguous to the City of Gainesville that receive Gainesville Regional Utilities services. In contrast to the other planning units that were defined by long-term legal boundaries of governance, the boundary of this planning unit is defined by urban service management agreements between the city and the county that change as the area of urban development grows. The ‘other incorporated areas’ planning unit includes the combined areas within the city limits of the following small towns: Alachua, High Springs, Newberry, Archer, Micanopy, Hawthorne, Waldo, and LaCrosse. All of the remaining areas define the limits of the ‘Alachua County’ planning unit.

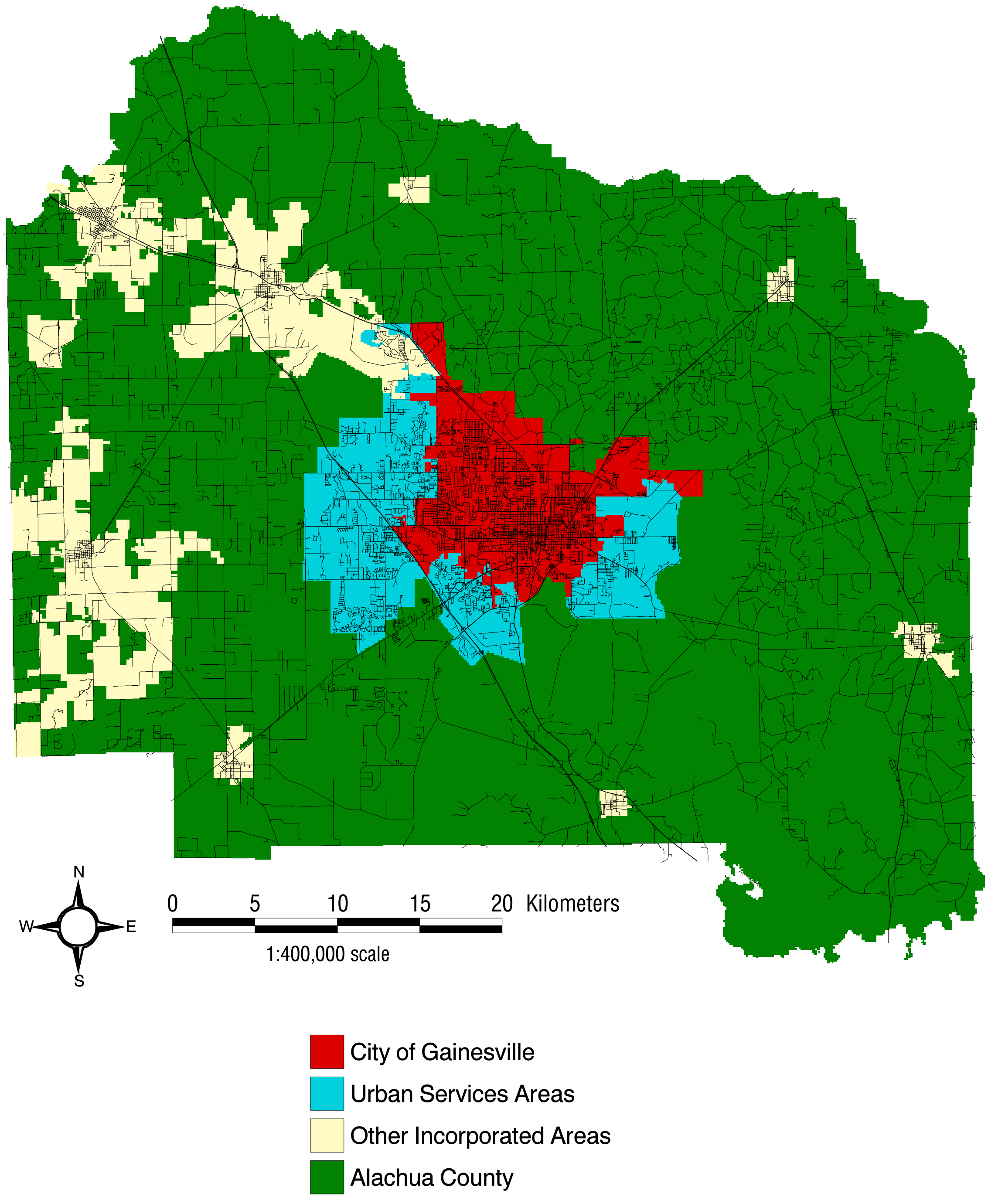


Figure 3-139: Map of the planning units used for this study. The 'City of Gainesville' planning unit is defined by the City's limits. The 'Urban Services Area' unit is defined as those areas contiguous to Gainesville which receive City utility services. The 'Other Incorporated Areas" unit includes those areas within the limits of the following small towns: Alachua, High Springs, Newberry, Archer, Micanopy, Hawthorne, Waldo, and La Crosse. All other areas belong to the 'Alachua County' planning unit.

<u>EMPOWER analysis of the planning units.</u> Table 3-32 lists the EMPOWER summary statistics for each planning unit. Using the methods described previously, total annual EMPOWER of consumption unit densities (sej/unit/yr) and total energy flow unit densities (j/unit/yr) were calculated for each planning unit. The total EMPOWER of consumption transformities were calculated for each unit using the sum EMERGY and energy values for each unit. The percentage of total county-wide total energy flow and EMPOWER represented by the sum flows through the area of each planning unit was also calculated using methods described previously in the land use classification study.

The EMPOWER part of Table 3-32 is sorted in descending order according to the EMPOWER transformities calculated for each planning unit. The rank order and relative magnitude of the calculated transformities is both intuitive and consistent with the trends observed in previous calculations.

The transformities of each planning unit reflect the relative EMPOWER intensities of each unit. For example, the City of Gainesville, with the highest EMPOWER transformity, occupies only 5% of the area of the county, but accounts for 56% of the total county-wide EMERGY flow. On the other hand, the Alachua County unit, with the lowest EMPOWER transformity, occupies about 79% of the area, but only contributes 14.6% of the EMERGY flow. But, the county unit contributes about 76% of the county-wide total energy flow. The urban services area, which could be characterized by calling the area ‘suburban’, occupies 6% of the area and contributes about 21% of the total EMERGY flow.

Using these statistics, the average EMPOWER density for the urban services areas was found to be about 32% as large as the average EMPOWER density of the City of Gainesville (using figures adjusted for the same area). The average EMPOWER density in the county unit was only 2% as large as the average EMPOWER density for the city. These comparisons of percentages indicate the relative EMPOWER intensity levels between the planning units.

EMSTORAGE analysis of the planning units. Table 3-32 also lists the EMSTORAGE summary statistics for each planning unit. Total EMSTORAGE unit densities (sej/unit), total energy storage unit densities (j/unit), total EMSTORAGE transformities, and the percentages of total county-wide total energy storage and EMSTORAGE were calculated using methods described previously. The EMSTORAGE part of Table 3-32 is also sorted in descending order according to the EMSTORAGE transformities calculated for each planning unit. The rank order of transformities is the same as the rank order found for the EMPOWER transformities.

The table reveals patterns for the distribution of EMSTORAGE that are similar to those observed for EMPOWER. Using the same comparison, the City of Gainesville (highest transformity, 5% of the area of the County), accounts for 53% of the total county-wide EMSTORAGE, and the Alachua County unit (lowest transformity, 79% of the area) contributes 20% of the EMSTORAGE. The county unit contributes about 76% of the county-wide total energy storage. The average EMSTORAGE density for the urban services areas was found to be about 31% of the average EMSTORAGE density for the City of Gainesville (compared to 32% of EMPOWER density), and the average EMSTORAGE density in the county unit was only about 2% as large as the average EMPOWER density for the city (compared to 2% of EMPOWER density).

Table 3-32: Statistics summarized by “Planning Unit” categories for the county-wide total annual EMPOWER, total energy flow, total EMSTORAGE, and total energy storage. The top portion of the table is sorted in descending order according to the calculated EMPOWER transformity of each planning unit. The bottom portion of the table is sorted in descending order according to the calculated EMSTORAGE transformity of each planning unit. Each transformity was calculated by dividing the sum of the annual EMPOWER or EMSTORAGE for the total area of each planning unit by the sum of the energy flow or storage for the area of the planning unit.

			EMPOWER				
Planning Unit	**No. of cells (# ha)**	**% of Co-wide area**	**Sum, E18 Sej/yr**	**% of Co.-wide total sej/yr**	**Sum, E12 J/yr**	**% of Co.-wide total j/yr**	**EMPOWER Transformity (sej/j)**
City of Gainesville	12,641	5.04	15,503.5	56.09	119,868	27.73	129,339
Urban Services Area	15,109	6.02	5,905.2	21.37	68,761	15.91	85,881
Other Incorporated Areas (small towns)	24,018	9.57	2,196.5	7.95	46,610	10.78	47,124
Alachua County	199248	79.38	4,033.7	14.59	197,071	45.58	20,469

	EMSTORAGE				
Planning Unit	**Sum, E20 sej**	**% of Co.-wide total sej**	**Sum, E12 joules**	**% of Co.-wide total joules**	**EMSTORAGE Transformity (sej/j)**
City of Gainesville	3,659.4	53.07	160,272	7.84	2,283,220
Urban Services Area	1,363.8	19.78	171,552	8.40	794,976
Other Incorporated Areas (small towns)	496.1	7.19	163,453	8.00	303,497
Alachua County	1,376.5	19.96	1547582	75.75	88,943

EMERGY component signatures for planning units. Table 3-33 lists the sum of the EMERGY flow or storage for each of the (sub)components within the area of each planning unit. The term 'component unit density' is used to refer to the sum of the EMPOWER component flow (E18 sej/unit/yr) or EMSTORAGE component (E18 sej/unit) occurring within the area of a planning unit. A group of component unit density values associated with a particular planning unit is referred to as an EMPOWER or EMSTORAGE component signature for that planning unit.

If the component unit density values for the 'renew', 'wtruse', 'fuel', 'goods', and 'service' components are added together, the sum is the 'total' EMPOWER unit density for that particular planning unit. If the component unit density values for the 'natstr', 'urbstr', and 'popstr' components are added together for a unit, the sum is the 'total' EMSTORAGE unit density for the planning unit.

Table 3-33 also shows how the total EMERGY flow or storage of any particular (sub)component is distributed according to planning units both in terms of the actual values (E18 sej/unit/yr or E18 sej/unit). The table also lists the distribution of component flows or storages in terms of percentages of the total county-wide component flow or storage (% of E18 sej/component/yr or % of E18 sej/component).

As was observed in the land classification study, these percentage calculations can lead to insights that are not so obvious by looking at the actual values for component flows. For example, from the calculations in Table 3-33, one can make the observation that the county planning unit is responsible for about 80% of the EMERGY in stored water and uses about 27% of the EMERGY flow from water use. On the other hand, the City of Gainesville only has 5% of the storage and uses 46% of the flow. This is, of course, already a familiar relationship for planners, but it does point out how these previously known relationships can also be seen in these data which have been created using EMERGY units and concepts.

Using the values in Table 3-33, the log component EMPOWER and EMSTORAGE unit densities (log sej/unit/yr or log sej/unit) were calculated to facilitate the creation of the EMERGY component signature histograms for each of the planning units (Figures 3-140 to 3-143) in the same manner as those created for the land use study.

Each planning unit chart includes the flow and storage log values for both the EMPOWER components and the EMSTORAGE components for that planning unit. The histogram charts help show how the ‘service’ EMERGY component flows dominate the EMPOWER signatures of all of the planning units. The ‘population’ EMERGY component is the largest storage component for all of the planning units, however, the County’s EMSTORAGE signature shows that the value for the ‘natural structure’ component is close to the value for the ‘population’ component.

Two summary charts of the planning unit log form EMERGY component signatures were also created. The chart in Figure 3-144 enables comparisons between component EMPOWER unit density flows (sej/component-unit/yr) for the planning units, and the chart in Figure 3-145 enables comparisons between the component EMSTORAGE unit densities (sej/component-unit). For example, the EMPOWER signature chart helps one see how similar the patterns are for the nonrenewable EMERGY flow component values for the City, urban services area, and small towns planning units, and the EMSTORAGE signature chart helps one make the observation that the value for natural structure is higher in all of the planning units except the City.

Table 3-33: Summary table of the EMPOWER and EMSTORAGE component unit densities for each of the ‘planning units’. The term ‘component unit density’ is used here to refer to the sum of a component flow or storage occurring within the area of planning unit. For each planning unit, the percent of the County-wide sum for each EMERGY component flows/storages was also calculated.

EMERGY Component Grid Name	Planning Units								County-wide
	City of Gainesville		Urban Services Area		Other Incorporated Areas (small towns)		Alachua County		
	EMPOWER								
	E18 sej/unit/yr	% of Co-wide Comp. Sum	E18 sej/unit/yr	% of Co-wide Comp. Sum	E18 sej/unit/yr	% of Co-wide Comp. Sum	E18 sej/unit/yr	% of Co-wide Comp. Sum	E18 sej/component/yr (Co-wide comp. sum)
renew	14.02	3.96	19.64	5.54	32.23	9.09	288.55	81.40	354.46
gpp	44.24	8.15	38.45	7.08	59.86	11.02	400.49	73.75	543.07
wtruse	68.81	45.78	26.57	17.68	14.84	9.87	40.07	26.66	150.30
fuel	1261.06	44.30	624.51	21.94	303.66	10.67	657.62	23.10	2846.95
trn_ful	364.39	29.89	266.83	21.88	125.65	10.30	462.33	37.92	1219.30
bag_ful	896.67	55.09	357.68	21.98	178.02	10.94	195.28	12.00	1627.66
goods	1768.07	56.55	652.46	20.87	270.46	8.65	435.65	13.93	3126.64
service	12391.53	58.56	4582.05	21.65	1575.26	7.44	2611.86	12.34	21160.70
waste	1515.04	58.92	465.66	18.11	235.66	9.17	354.94	13.80	2571.30
recycle	1208.49	59.08	367.74	17.98	187.18	9.15	282.27	13.80	2045.68
	EMSTORAGE								
	E18 sej/unit	% of Co-wide Comp. Sum	E18 sej/unit	% of Co-wide Comp. Sum	E18 sej/unit/yr	% of Co-wide Comp. Sum	E18 sej/unit/yr	% of Co-wide Comp. Sum	E18 sej/component/yr (Co-wide comp. sum)
natstr	3632.25	4.71	4604.08	5.97	5632.86	7.30	63265.24	82.01	77145.28
biostr	928.01	7.20	1266.74	9.82	1278.72	9.92	9421.01	73.05	12895.96
wtrstr	649.56	5.01	776.35	5.99	1231.88	9.50	10304.29	79.49	12963.05
soilom	2054.68	4.01	2560.99	4.99	3122.27	6.09	43539.94	84.90	51286.26
urbstr	6453.04	53.34	2380.75	19.68	932.48	7.71	2332.33	19.28	12098.65
bldg	5348.04	67.47	1556.99	19.64	391.45	4.94	629.99	7.95	7926.45
road	594.66	24.49	389.22	16.03	319.88	13.17	1124.33	46.30	2428.13
util	510.35	29.26	434.54	24.92	221.16	12.68	578.02	33.14	1744.07
popstr	355850.47	59.28	129394.5	21.55	43042.07	7.17	72049.22	12.00	600336.23

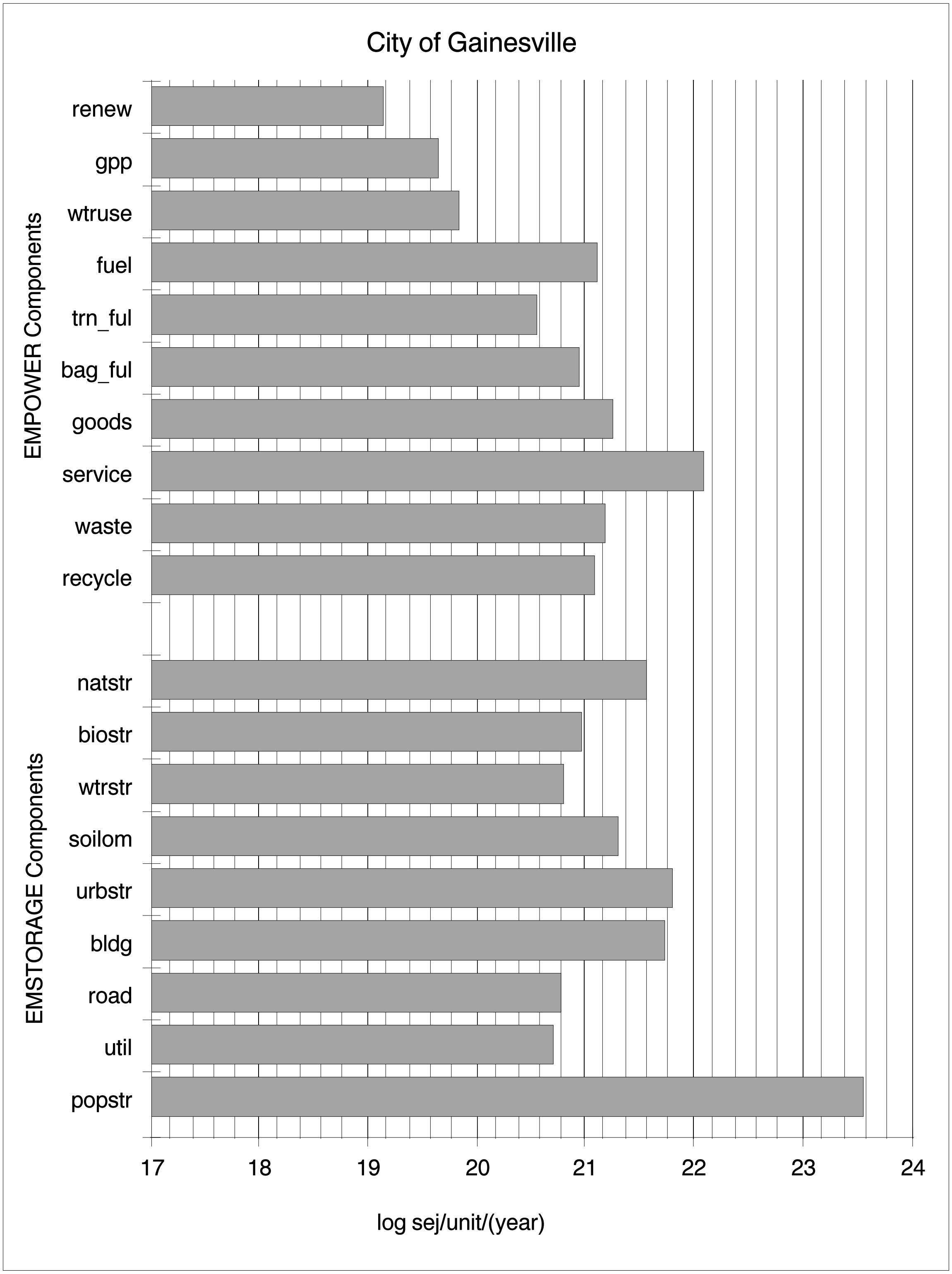


Figure 3-140: Chart of the EMERGY Component Signature for the 'City of Gainesville' planning unit. The values in the chart represent the log EMPOWER and EMSTORAGE component unit densities. The component unit density is defined here as the total amount of sej's in storage or sej/yr flow within the area of each planning unit for each of the spatial EMERGY model (sub)component grids.

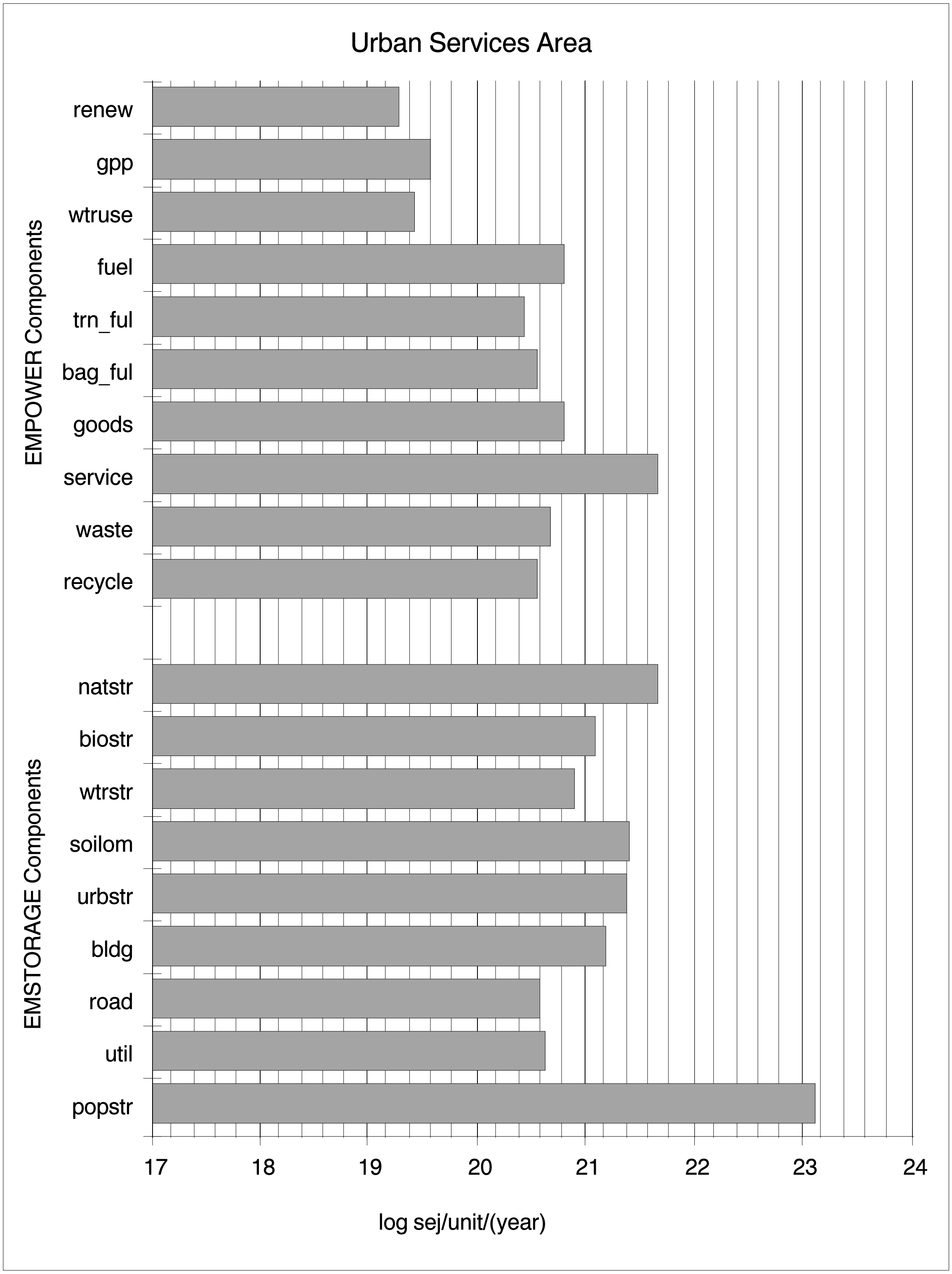


Figure 3-141: Chart of the EMERGY Component Signature for the 'Urban Services Area' planning unit. The values in the chart represent the log EMPOWER and EMSTORAGE component unit densities. The component unit density is defined here as the total amount of sej's in storage or sej/yr flow within the area of each planning unit for each of the spatial EMERGY model (sub)component grids.

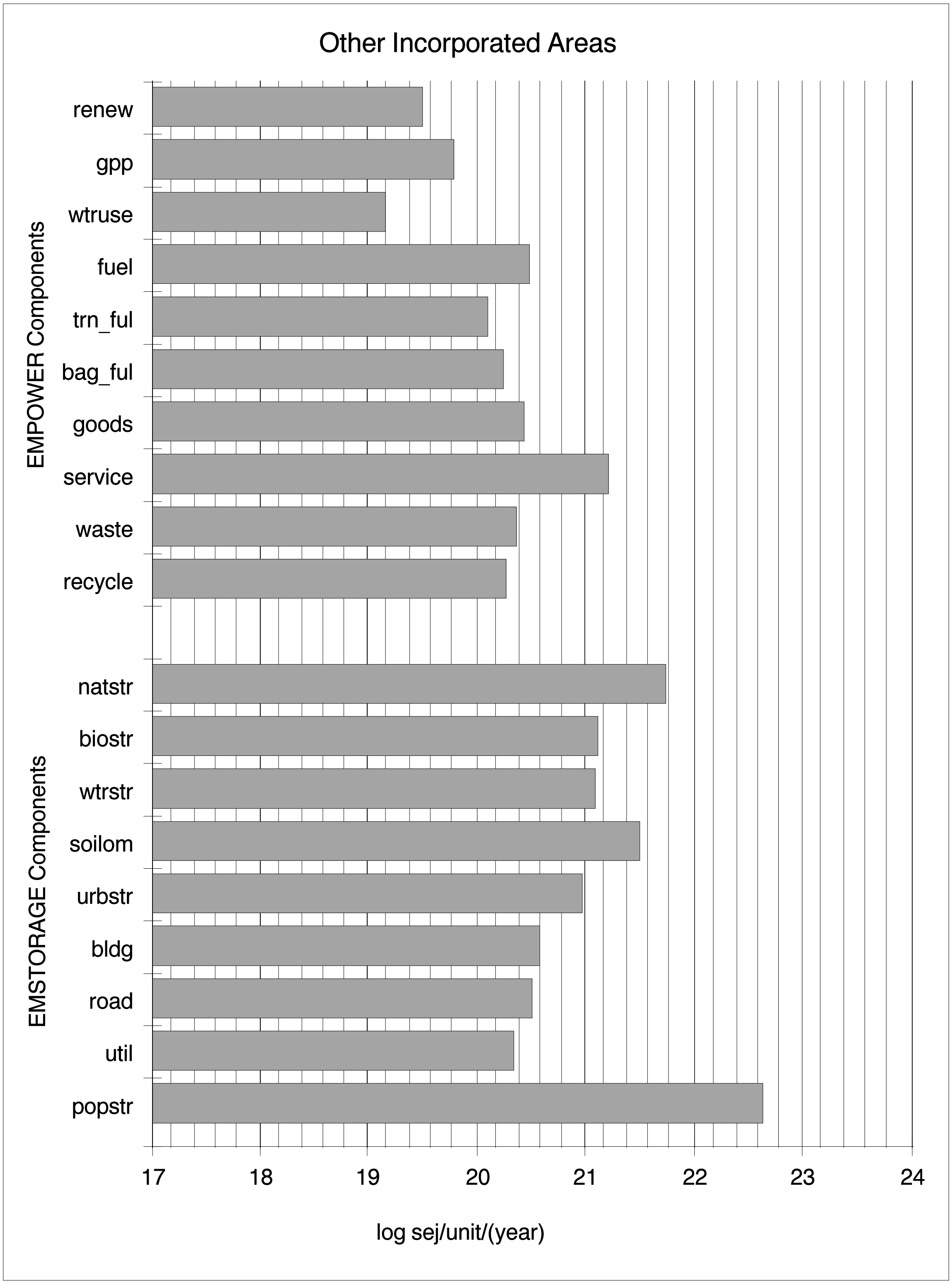


Figure 3-142: Chart of the EMERGY Component Signature for the 'Other Incorporated Areas' planning unit. The values in the chart represent the log EMPOWER and EMSTORAGE component unit densities. The component unit density is defined here as the total amount of sej's in storage or sej/yr flow within the area of each planning unit for each of the spatial EMERGY model (sub)component grids.

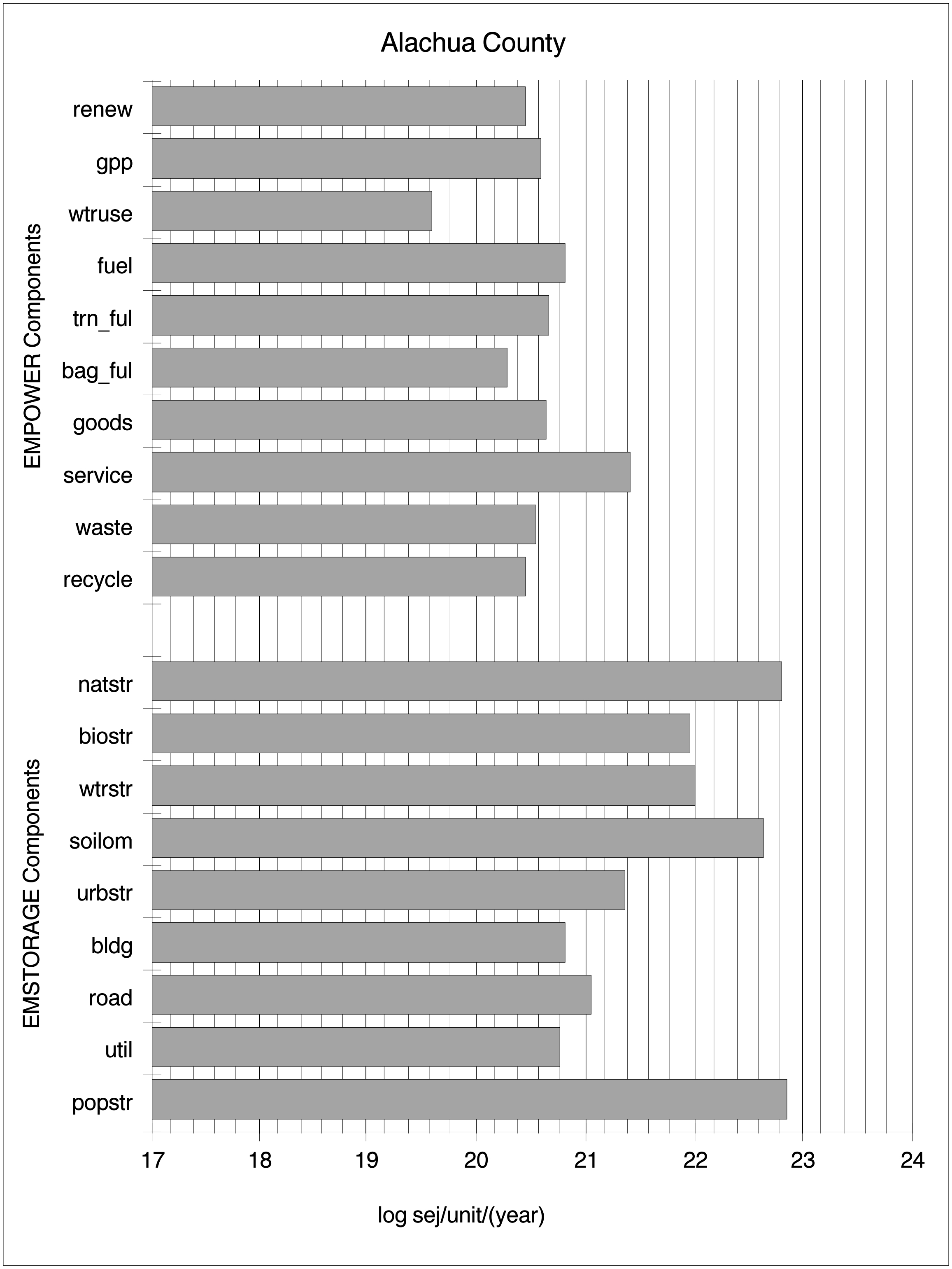


Figure 3-143: Chart of the EMERGY Component Signature for the 'Alachua County' planning unit. The values in the chart represent the log EMPOWER and EMSTORAGE component unit densities. The component unit density is defined here as the total amount of sej's in storage or sej/yr flow within the area of each planning unit for each of the spatial EMERGY model (sub)component grids.

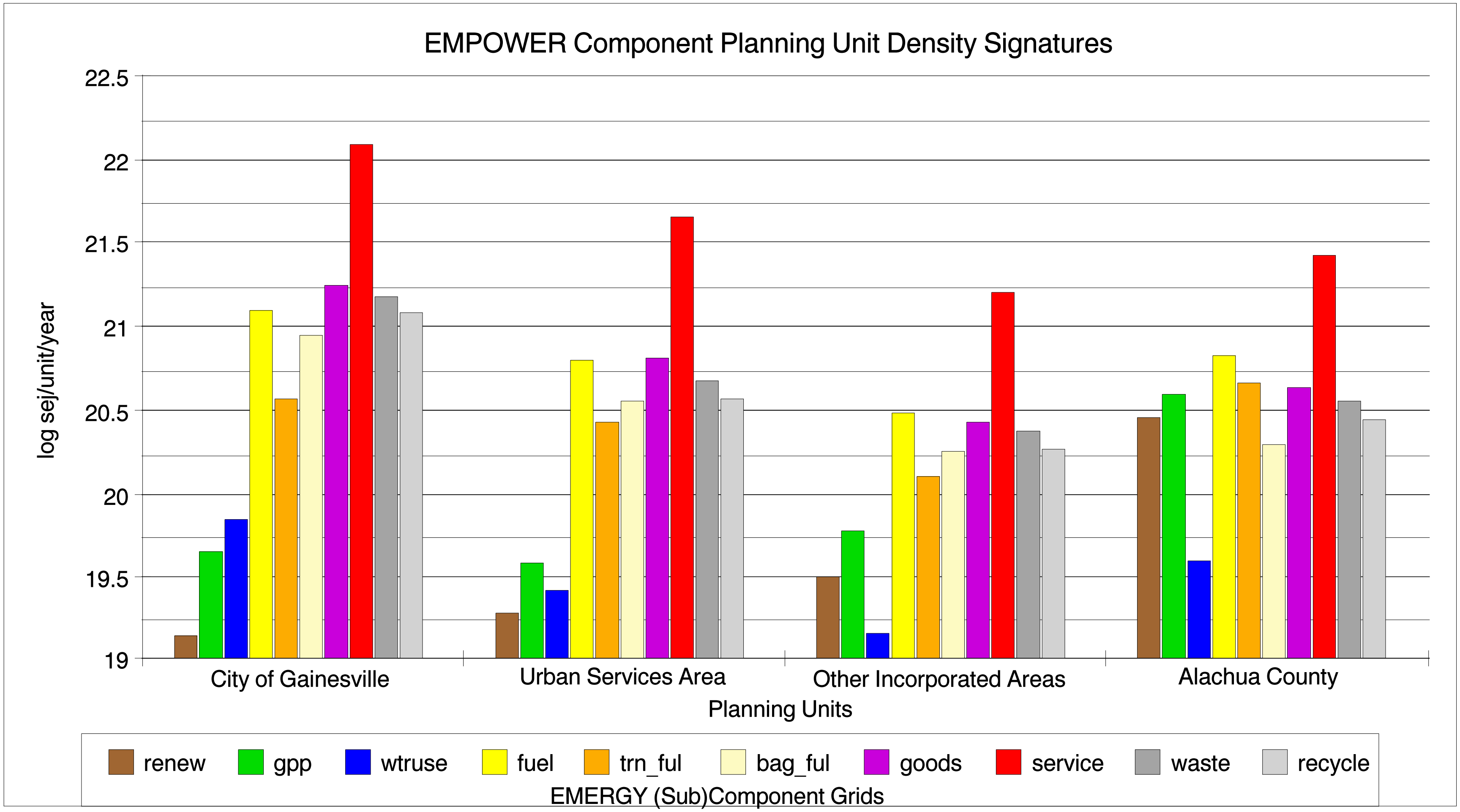


Figure 3-144: Chart of the EMPOWER Component Density Signatures for each of the planning units. The values in the chart represent the log of the total EMERGY flow (sej/year) within the area of each planning unit for each of the spatial EMERGY model flow component or subcomponent grids.

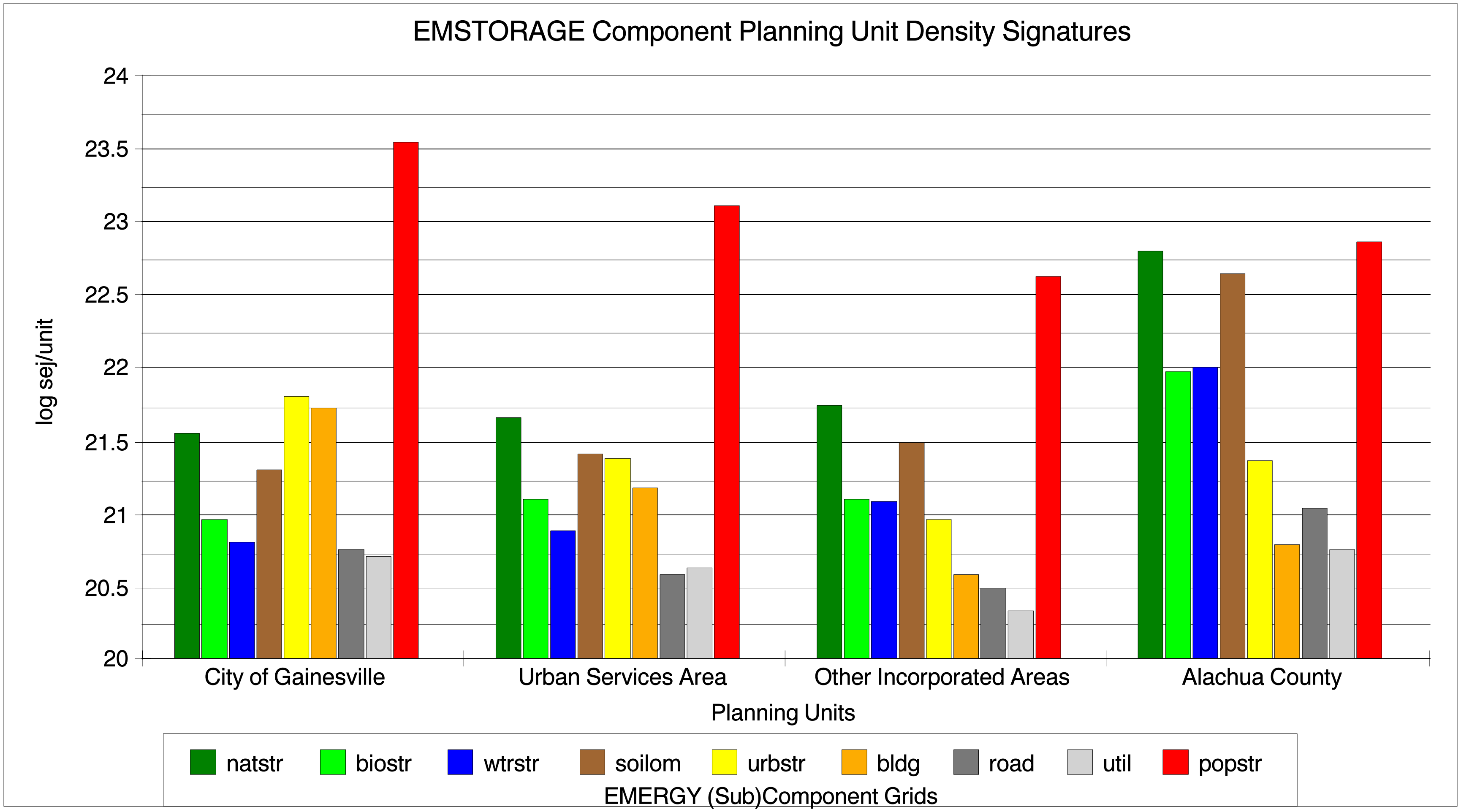


Figure 3-145: Chart of the EMSTORAGE Component Density Signatures for each of the planning units. The values in the chart represent the log of the total EMERGY storage (log sej) within the area of each planning unit for each of the spatial EMERGY model storage component or subcomponent grids.

Neighborhood Study

The neighborhood study is the third study in which comparisons are made between different land areas of the county using EMERGY-related statistics as the basis of comparison. Neighborhoods are one of the many ways that planners categorize land areas into units that can be studied and described. Using the same methods applied in the previous two studies, annual EMPOWER densities, EMSTORAGE densities, and transformities were calculated for each neighborhood, and EMERGY component signature histograms were created for each neighborhood.

The locations of the four representative neighborhoods used for comparisons in this study are shown in the map in Figure 3-146. Each neighborhood was chosen to represent an alternative type of residential development. A 70-hectare area within each neighborhood was chosen as a sample area for the study.

Table 3-34 lists descriptive characteristics of the four neighborhoods. The ‘Millhopper Ranchettes’ neighborhood has a mean lot size of about 5 acres. The neighborhood is characterized by moderate-value ($), single-family residences. There are several other ranchette-style developments, similar to this one, in the County. Like this neighborhood, most of these ranchette developments are located along the suburban-rural fringe surrounding the more developed areas of the county.

‘The Hammock’ neighborhood was chosen to represent those neighborhoods characterized by larger, ‘up-scale’ single-family residences on ‘estate-size’ lots. The mean lot size in ‘The Hammock’ neighborhood is about 1.8 acres. The homes are about 27% larger than those in the ranchette neighborhood, and about 50% more expensive.

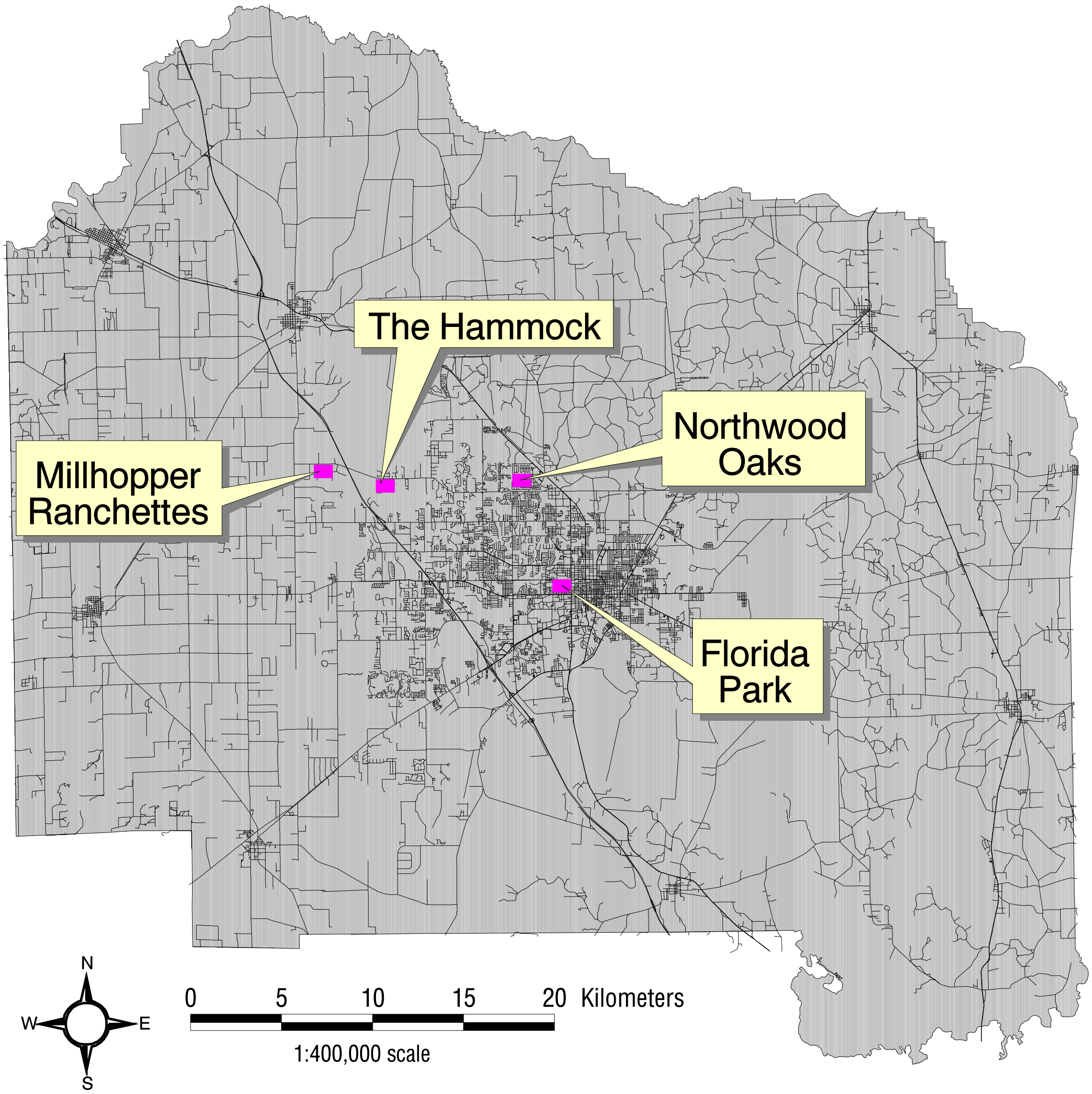


Figure 3-146: Map of the representative neighborhoods used for this study. Within the area of each of the four neighborhoods, an area of 70 hectares was used to create the comparative statistics and EMERGY component signatures.

Table 3-34: Characteristics of the four representative neighborhoods chosen for comparison in this study.

Neighborhood	No. of residents	No. of buildings	Mean lot size (acres)	Mean Building Size (sq.ft.)	No. of bedrooms/ baths	Mean tax-appraised home value ($)
Millhopper Ranchettes	76	24	5.31	2169	3/2.5	70769
The Hammock	268	86	1.84	2745	4/2.7	109947
Northwood Oaks	1366	440	0.31	1380	3/1.9	40600
Florida Park	2033	374	0.27	3062	3/1.7	48994

The ‘Northwood Oaks’ neighborhood is a typical example of many of the residential developments in the county. The homes are half the size of those in ‘The Hammock,’ and the mean lot size is about 1/3 acre. The appraised value of the residences is about 40% of those in ‘The Hammock.’

The ‘Florida Park’ neighborhood was chosen to represent the more diverse, older, neighborhoods found near downtown Gainesville and the University of Florida campus. This neighborhood is characterized by a mix of single-family and multi-family residences which results in a much higher-density of residents. In fact, the ‘Florida Park’ sample area (70 ha) has about 27 times more residents than the sample area for the ‘Millhopper Ranchettes’ neighborhood.

EMPOWER analysis of the neighborhoods. Table 3-35 lists the EMPOWER summary statistics for each neighborhood. Using the same methods described previously for the land class and planning unit studies, the EMPOWER neighborhood densities (sej/neighborhood/yr) and energy flow neighborhood densities (j/ neighborhood/yr) were calculated. The EMPOWER transformities were calculated for each neighborhood using the sum EMERGY and energy values for each neighborhood. The percentage of total county-wide total energy flow and EMPOWER represented by the sum flows through the area of each neighborhood was also calculated.

Table 3-35 is sorted in descending order according to the EMPOWER transformities calculated for each neighborhood. Intuitively, the rank order of the neighborhood transformities reflects the relative population densities of each neighborhood. For instance, the EMPOWER neighborhood density of the ‘Florida Park’ neighborhood is about 30 times that of the ‘Millhopper Ranchettes’ neighborhood. This

EMPOWER density relationship corresponds closely with the population density relationship mentioned previously ('Florida Park' has 27 times more residents than the 'Ranchettes' neighborhood). The percentage of county-wide total EMPOWER represented by the 'Millhopper Ranchettes' neighborhood flows is .03%, compared to .79% for the 'Florida Park' neighborhood. It is interesting that the total flows percentage for the 'Ranchettes' is equal to the percent of the county area (.03%).

EMSTORAGE analysis of neighborhoods. Table 3-35 also lists the EMSTORAGE summary statistics for each neighborhood. EMSTORAGE neighborhood densities (sej/ neighborhood), energy storage neighborhood densities (j/neighborhood), EMSTORAGE transformities, and the percentages of total county-wide total energy storage and EMSTORAGE were calculated using methods described previously. The EMSTORAGE part of Table 3-35 is sorted in descending order according to the EMSTORAGE transformities calculated for each neighborhood. The rank order of transformities is the same as the rank order found for the EMPOWER transformities.

The table reveals patterns for the distribution of EMSTORAGE that are similar to those observed for EMPOWER. In particular, the values for the percentages of total county-wide EMSTORAGE are almost the same as the percentages of total county-wide EMPOWER. This is a pattern that has been observed previously in the land classification study. The EMSTORAGE transformities calculated for the neighborhoods probably reflects the number of buildings found in the neighborhoods. For example, there are 15.6 times more buildings in the 'Florida Park' neighborhood than in the 'Millhopper Ranchettes' neighborhood, and the neighborhood transformity for 'Florida Park' is about 14 times that of the 'Ranchettes' neighborhood.

Table 3-35: Statistics summarized by "Neighborhoods" for the county-wide total annual EMPOWER, energy flow, EMSTORAGE, and energy storage. The table is sorted in descending order according to the calculated EMPOWER or EMSTORAGE transformity of each neighborhood. Each transformity was calculated by dividing the sum of the annual EMPOWER or EMSTORAGE for the total area of each neighborhood by the sum of the energy flow or storage for the area of the neighborhood.

			EMPOWER				
Neighborhood	**No. of cells (# ha)**	**% of Co-wide area**	**Sum, E18 Sej/yr**	**% of Co.-wide total sej/yr**	**Sum, E12 J/yr**	**% of Co.-wide total j/yr**	**EMPOWER Transformity (sej/j)**
Florida Park	70	.03	217.08	0.79	1589.97	0.37	136,534
Northwood Oaks	70	.03	110.45	0.40	975.87	0.23	113,179
The Hammock	70	.03	23.52	0.09	401.80	0.09	58,528
Millhopper Ranchettes	70	.03	7.24	0.03	132.16	0.03	54,746

	EMSTORAGE				
Neighborhood	**Sum, E18 Sej**	**% of Co.-wide Total Sej**	**Sum, E12 joules**	**% of Co.-wide total joules**	**EMSTORAGE Transformity (sej/j)**
Florida Park	5559.70	0.81	1343.84	0.07	4,137,166
Northwood Oaks	2673.90	0.39	1221.62	0.06	2,188,817
The Hammock	572.81	0.08	933.64	0.05	613,522
Millhopper Ranchettes	195.44	0.03	660.74	0.03	295,786

EMERGY component signatures for neighborhoods. Table 3-36 lists the sum of the EMERGY flow or storage for each of the (sub)components within the 70 hectare sample area of each neighborhood. The term ‘component neighborhood density’ is used to refer to the sum of the EMPOWER component flow (E18 sej/unit/yr) or EMSTORAGE component (E18 sej/unit) occurring within the sample area of a neighborhood. A group of component neighborhood density values associated with a particular neighborhood is referred to as an EMPOWER or EMSTORAGE component signature for that neighborhood.

If the component neighborhood density values for the ‘renew’, ‘wtruse’, ‘fuel’, ‘goods’, and ‘service’ components are added together, the sum is the ‘total’ EMPOWER neighborhood density for that particular neighborhood. If the component neighborhood density values for the ‘natstr’, ‘urbstr’, and ‘popstr’ components are added together for a neighborhood, the sum is the ‘total’ EMSTORAGE neighborhood density.

The table lists the distribution of component flows or storages in terms of percentages of the total county-wide component flow or storage (% of E16 sej/component/yr or % of E16 sej/component). Based on the values in Table 3-36, the log component EMPOWER and EMSTORAGE neighborhood densities (log sej/ neighborhood /yr or log sej/ neighborhood) were calculated. These values were used to create the EMERGY component signature histograms for each of the neighborhoods that are shown in Figures 3-147 to 3-150. Two summary charts of the neighborhood log form EMERGY component signatures were also created. The chart in Figure 3-151 enables comparisons between component EMPOWER density flows, and the chart in Figure 3-152 enables comparisons between the component EMSTORAGE densities.

Table 3-36: Summary of the EMPOWER and EMSTORAGE component densities for each 'neighborhood'. The term 'component neighborhood density' is used here to refer to the sum of a component flow or storage occurring within the area of a neighborhood. For each neighborhood, the percent of the county-wide sum for each EMERGY component flows/storage was also calculated.

EMERGY Component Grid Name	Neighborhoods								County-wide
	Millhopper Ranchettes		The Hammock		Northwood Oaks		Florida Park		
	EMPOWER								
	E16 sej/unit/yr	% of Co-wide Comp. Sum	E16 sej/unit/yr	% of Co-wide Comp. Sum	E16 sej/unit/yr	% of Co-wide Comp. Sum	E16 sej/unit/yr	% of Co-wide Comp. Sum	E16 sej/component/yr (Co-wide comp. sum)
renew	10.03	0.03	10.09	0.03	7.67	0.02	5.40	0.02	35446
gpp	12.39	0.02	18.84	0.03	41.47	0.08	35.21	0.06	54307
wtruse	2.23	0.01	2.64	0.02	60.01	0.40	98.90	0.66	15030
fuel	31.21	0.01	124.55	0.04	461.59	0.16	1004.84	0.35	284695
trn_ful	0.91	0.00	8.99	0.01	28.52	0.02	239.89	0.20	121930
bag_ful	30.30	0.02	115.56	0.07	433.07	0.27	764.96	0.47	162766
goods	74.72	0.02	244.57	0.08	968.43	0.31	1913.68	0.61	312664
service	605.32	0.03	1969.81	0.09	9547.11	0.45	18685.59	0.88	2116070
waste	35.88	0.01	32.32	0.01	498.95	0.19	1041.29	0.40	257130
recycle	27.31	0.01	26.00	0.01	361.95	0.18	778.85	0.38	204568
	EMSTORAGE								
	E16 sej/unit	% of Co-wide Comp. Sum	E16 sej/unit	% of Co-wide Comp. Sum	E16 sej/unit/yr	% of Co-wide Comp. Sum	E16 sej/unit/yr	% of Co-wide Comp. Sum	E16 sej/component/yr (Co-wide comp. sum)
natstr	2050.55	0.03	2546.55	0.03	2168.90	0.03	1442.06	0.02	7714528
biostr	697.13	0.05	643.05	0.05	649.65	0.05	468.22	0.04	1289596
wtrstr	358.75	0.03	360.99	0.03	358.75	0.03	358.75	0.03	1296305
soilom	994.67	0.02	1542.51	0.03	1160.49	0.02	615.09	0.01	5128626
urbstr	383.50	0.03	1712.20	0.14	3326.84	0.27	4384.75	0.36	1209865
bldg	252.08	0.03	1295.39	0.16	2322.20	0.29	2870.49	0.36	792645
road	84.49	0.03	207.82	0.09	504.63	0.21	909.50	0.37	242813
util	46.93	0.03	208.99	0.12	500.00	0.29	604.76	0.35	174407
popstr	17109.74	0.03	53022.46	0.09	261894.34	0.44	550143.70	0.92	60033623

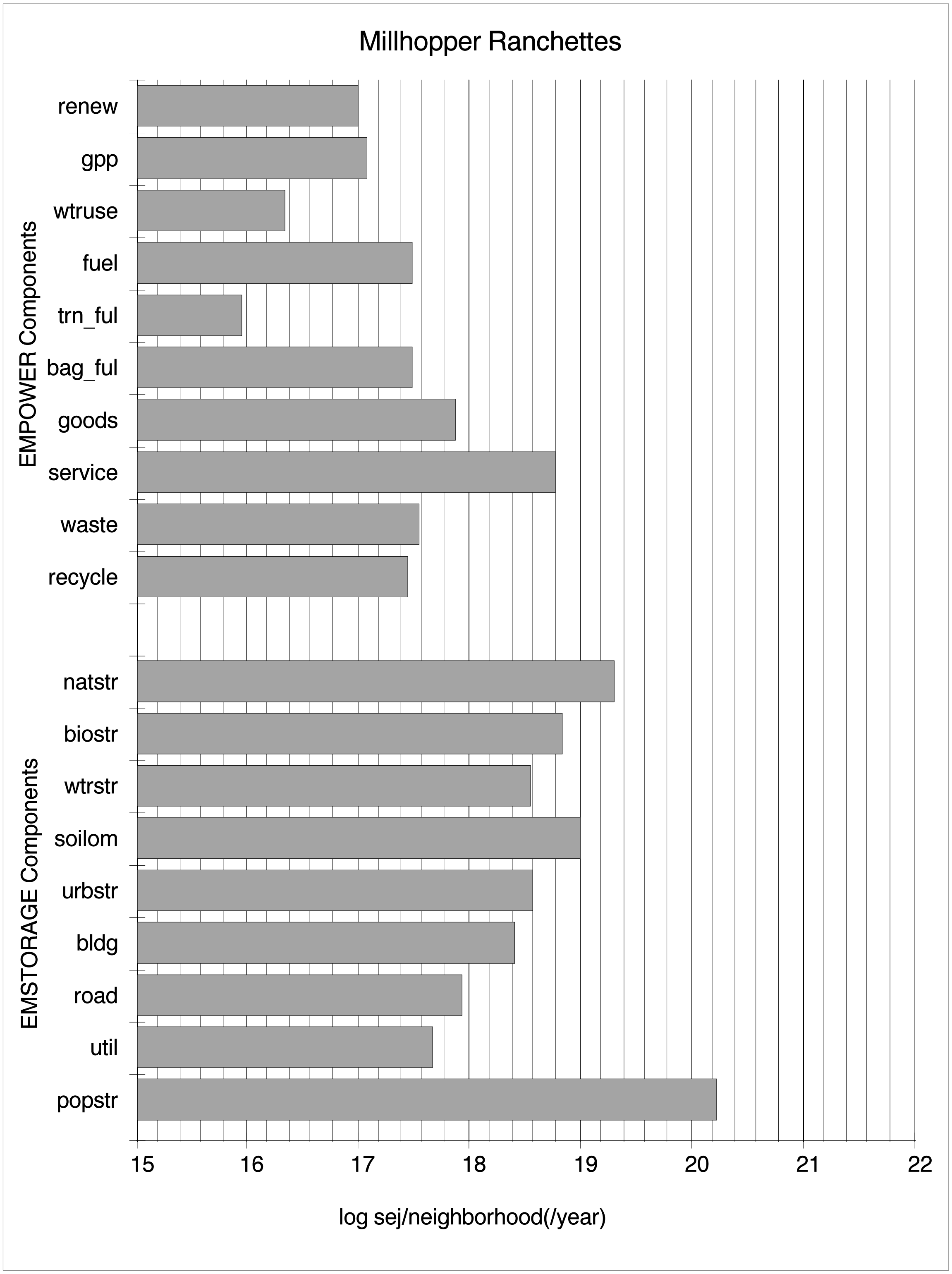


Figure 3-147: Chart of the EMERGY Component Signature for the 'Millhopper Ranchettes' neighborhood. The values in the chart represent the log EMPOWER and EMSTORAGE component neighborhood densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each neighborhood (70 hectares) for each of the spatial EMERGY model (sub)component grids).

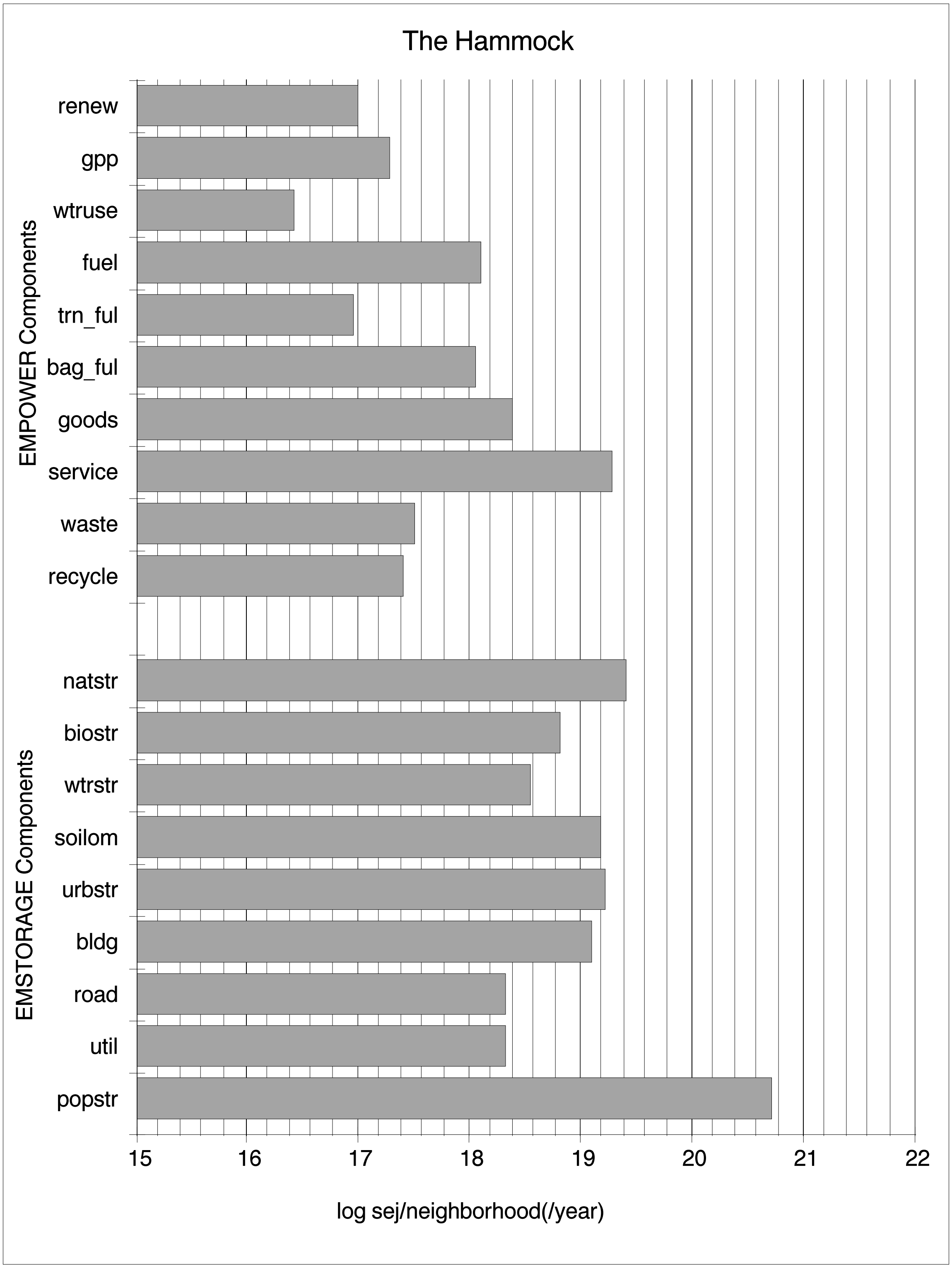


Figure 3-148: Chart of the EMERGY Component Signature for 'The Hammock' neighborhood. The values in the chart represent the log EMPOWER and EMSTORAGE component neighborhood densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each neighborhood (70 hectares) for each of the spatial EMERGY model (sub)component grids).

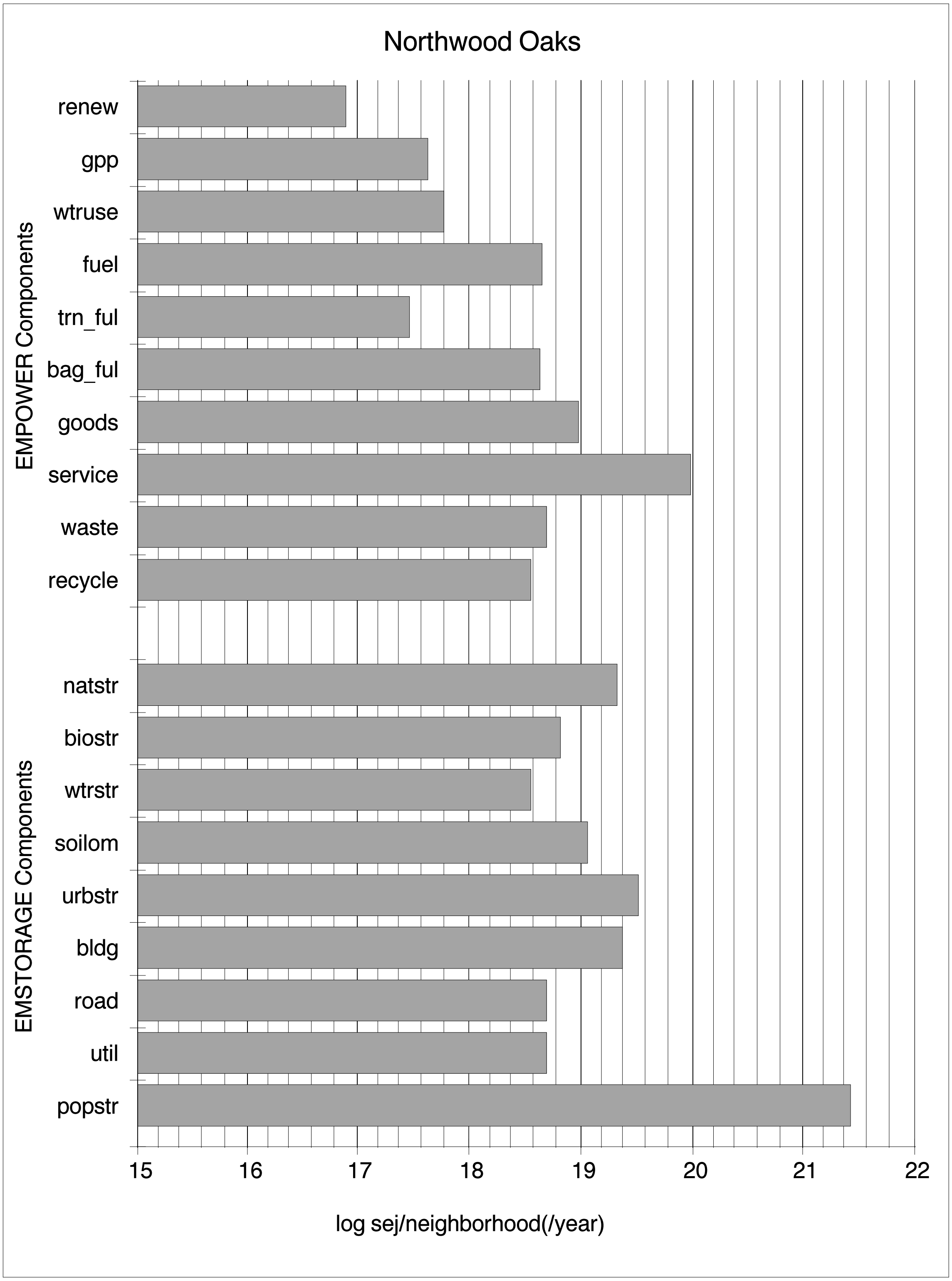


Figure 3-149: Chart of the EMERGY Component Signature for the 'Northwood Oaks' neighborhood. The values in the chart represent the log EMPOWER and EMSTORAGE component neighborhood densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each neighborhood (70 hectares) for each of the spatial EMERGY model (sub)component grids).

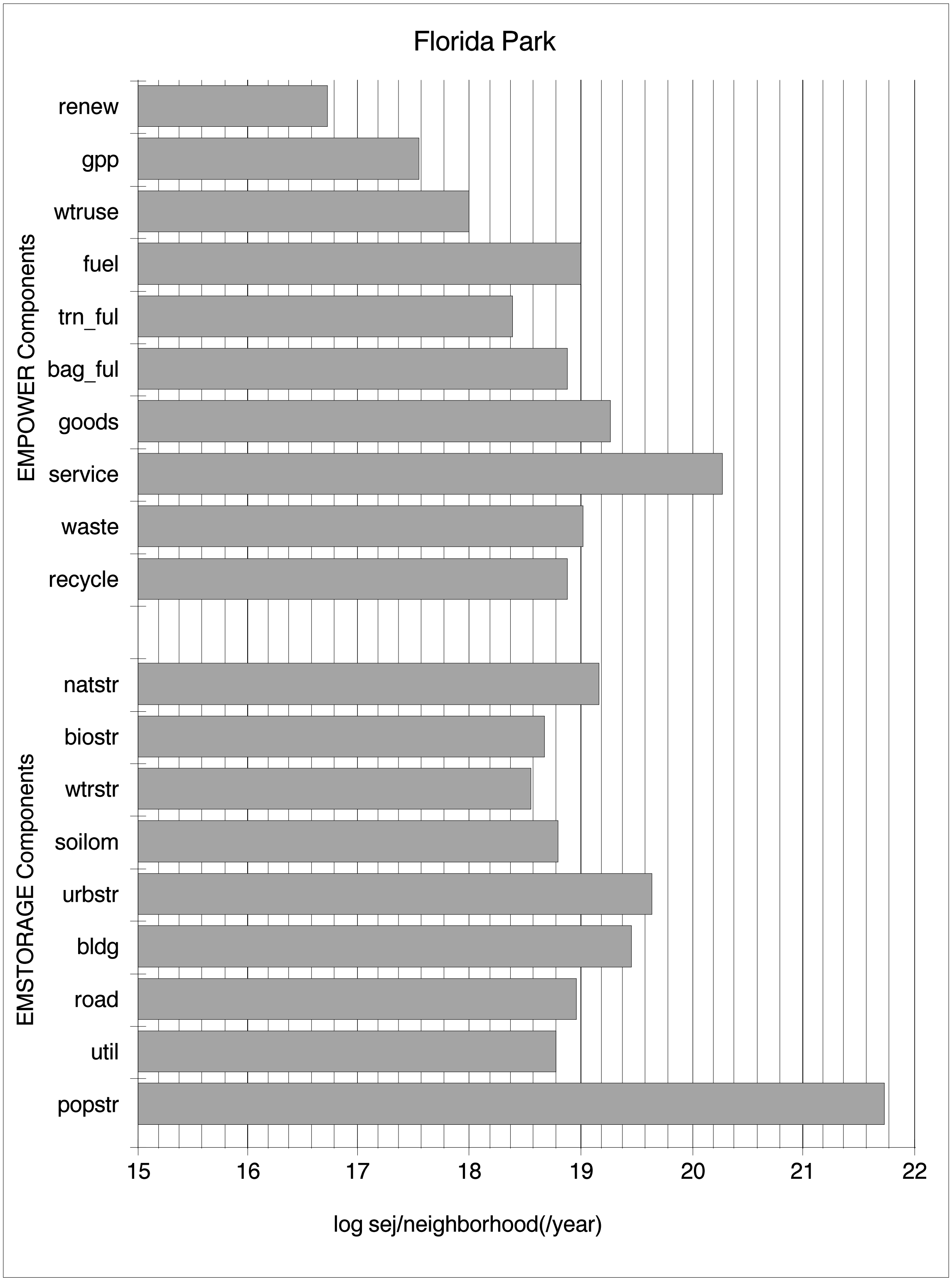


Figure 3-150: Chart of the EMERGY Component Signature for the 'Florida Park' neighborhood. The values in the chart represent the log EMPOWER and EMSTORAGE component neighborhood densities (defined as the total amount of sej's in storage or sej/yr flow within the area of each neighborhood (70 hectares) for each of the spatial EMERGY model (sub)component grids).

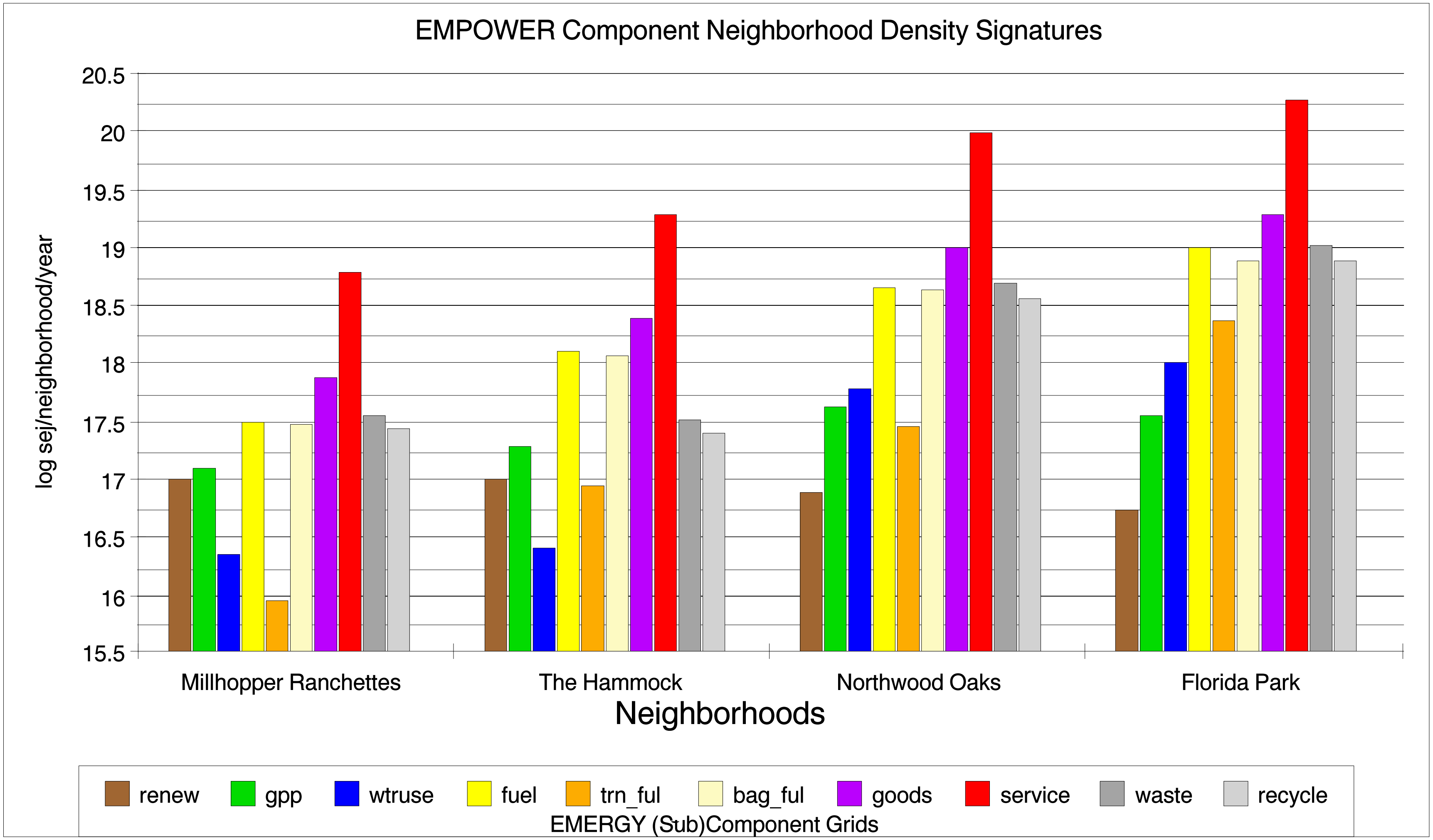


Figure 3-151: Chart of the EMPOWER Component Neighborhood Density Signatures for the representative neighborhoods. The values in the chart represent the log of the total EMERGY flow (sej/year) within the area of each neighborhood for each of the spatial EMERGY model flow component or subcomponent grids.

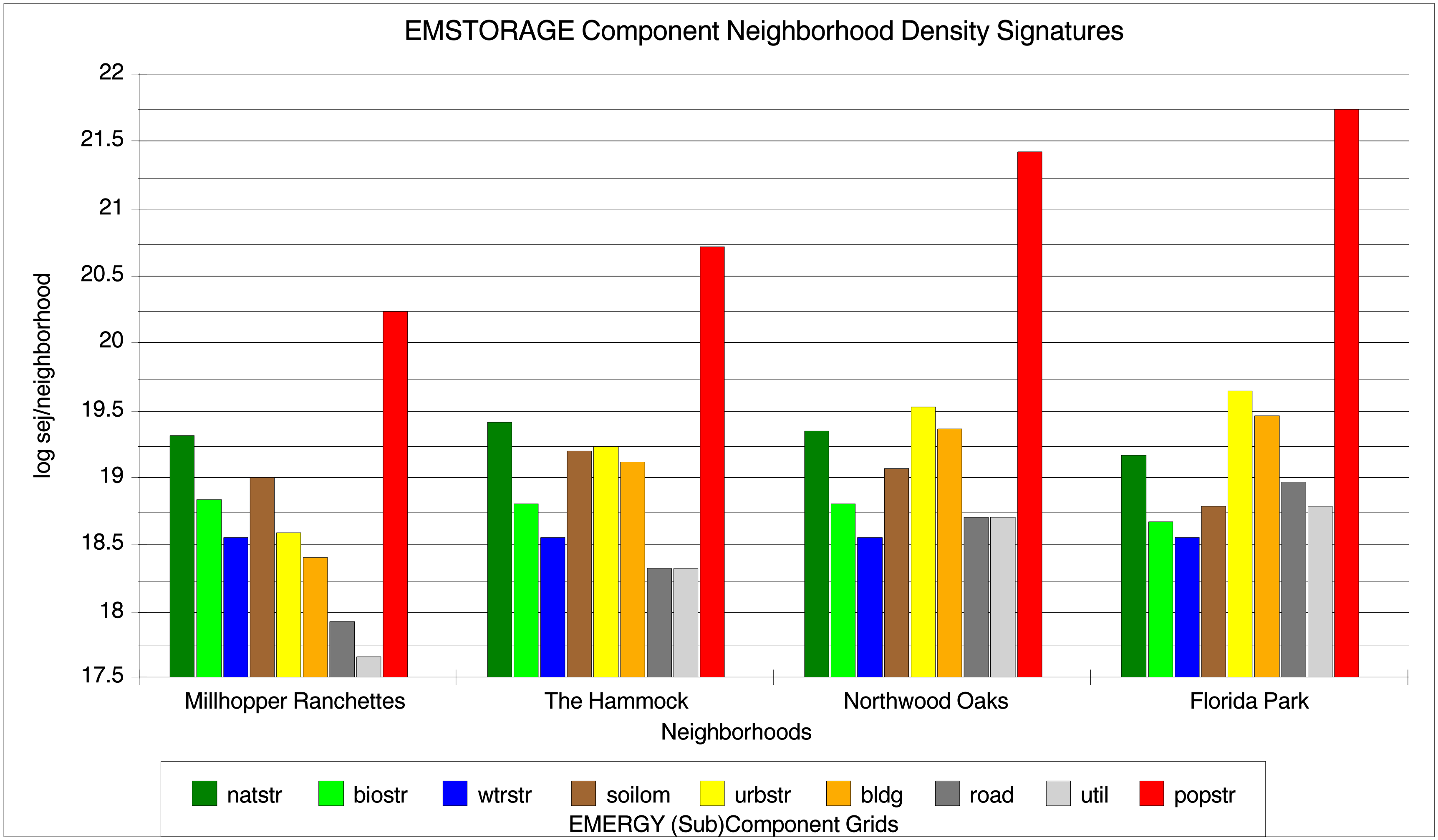


Figure 3-152: Chart of the EMSTORAGE Component Neighborhood Density Signatures for the representative neighborhoods. The values in the chart represent the log of the total EMERGY storage within the area of each neighborhood (log sej/neighborhood) for each of the spatial EMERGY model storage component or subcomponent grids.

EMERGY Ratio Analysis

In the previous sections, it was shown that EMERGY component signatures are a useful method for characterizing and comparing land classes, planning units, and neighborhoods. In this section, additional insight into the EMERGY flow and storage characteristics of these land areas is provided through the presentation of the results of several county-wide EMERGY ratio analyses. Additionally, using methods similar to those described for the comparative studies, ratios were calculated for the land areas associated with each aggregated land use classification, planning unit, and neighborhood.

The method for conducting EMERGY ratio analysis begins with creating a ratio analytical grid. The EMERGY ratio analytical grids are calculated by dividing the values in each cell of one component, or analytical, grid by the values in each spatially coincident cell of another component, or analytical, grid. In this study, the values in the ratio grids are unit-less ratio numbers because EMPOWER grids are divided only by other EMPOWER grids, and EMSTORAGE grids are divided only by other EMSTORAGE grids.

Resource Use Analytical Grids

Three new analytical grids were created for use in the ratio analyses. The primary reason for creating these additional analytical grids is because it has been demonstrated that the contributions from the EMERGY flow of in-situ human services are so large that they tend to dominate total EMPOWER density component signatures. By excluding the values for human services from ‘resource use’ analytical grids, it is easier to observe the patterns of nonrenewable and renewable resource use.

‘Total Resource Use’ Analytical Grid. A ‘total resource use’ analytical grid, called ‘resuse’, was created by adding the component grids representing renewable resources used (the ‘renew’ component), water used by man (the ‘wtruse’ component grid), fuels used in buildings and transportation (the ‘fuels’ component grid), and goods consumed (the ‘goods’ component grid). The ‘total resource use’ analytical grid differs from the total EMPOWER density analytical grid only by the exclusion of the EMERGY flow of in-situ human services from it’s sum. A map of the log-form of the ‘total resource use’ analytical grid (the ‘resuse_log’ logarithm analytical grid) is shown in Figure 3-153. As expected, the log values in the ‘total resource use’ map clearly reflect the exclusion of the in-situ human services. The log values in areas that have significant flows of human services are typically about one log unit lower in the ‘total resource use’ analytical grid than the log values in the corresponding areas of the total EMPOWER density analytical grid (see Figure 3-100). Areas dominated by medium-density residential development typically have EMPOWER density values that range from 16.5 to 17.5 log sej/ha/yr in the ‘total resource use’ analytical grid compared to values ranging from 17.5 to 18.5 log sej/ha/yr in the total EMPOWER density analytical grid. Areas characterized by commercial and services land uses typically have EMPOWER density values that range from 17.5 to 18.5 log sej/ha/yr in the ‘total resource use’ analytical grid compared to values ranging from 18.5 to 19.5 log sej/ha/yr in the total EMPOWER density analytical grid. The highest values in the ‘total resource use’ analytical grid, 19.5 to 20.5 log sej/ha/yr, are associated with the areas dominated by institutional land uses.

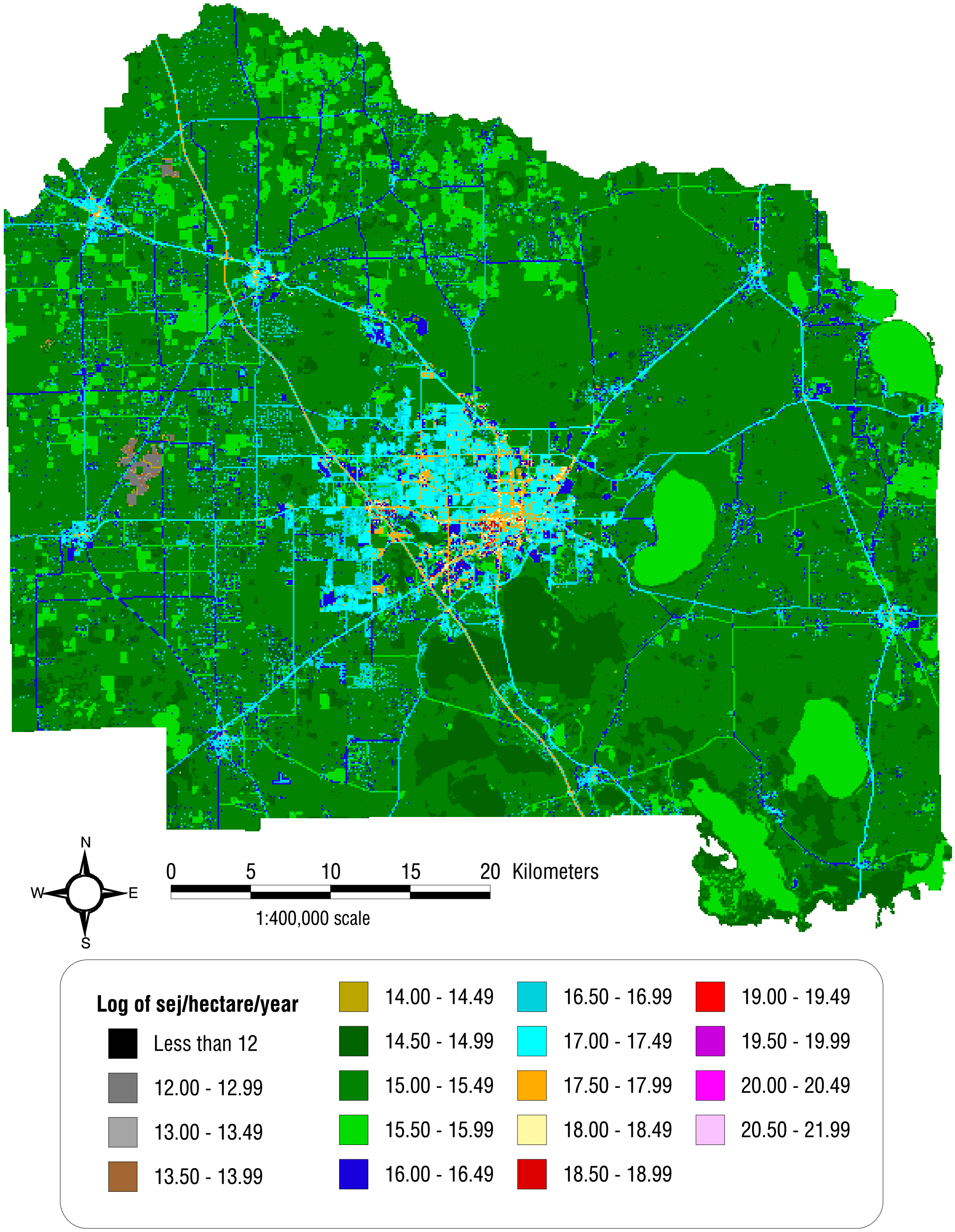


Figure 3-153: Map showing the log of the annual EMPOWER density (log sej/ha/yr)of both non-renewable and renewable resource use flows. The logarithm analytical EMERGY grid called 'resuse_log' was created by calculating the log of the sum of the component grids for renewable resources used, water used by man, fuels used in both transportation and buildings, and goods consumed. This analytical grid differs from the total EMPOWER density grid ('empower_log') only by the exclusion of the EMERGY flow of in-situ human services from it's sum.

'Nonrenewable Resource Use' Analytical Grid. The 'nonrenewable resource use' analytical grid, called 'nonrenew', was created by adding the component grids representing water used by man (the 'wtruse' component grid), fuels used in buildings and transportation (the 'fuels' component grid), and goods consumed (the 'goods' component grid). The 'nonrenewable resource use' analytical grid differs from the total EMPOWER density analytical grid by the exclusion of both the EMERGY flow of in-situ human services and renewable sources from it's sum. A map of the 'nonrenewable resource use' logarithm analytical grid ('resuse_log') is shown in Figure 3-154. The log values in the 'nonrenewable resource use' map clearly reflect the exclusion of both the renewable sources and in-situ human service flows. The values for areas dominated by nonrenewable flows are typically equivalent to values in the 'total resource use' grid.

'Nonrenewable Resource Use Excluding Transporation Fuels Used' Analytical Grid. This analytical grid, called 'nonrenotr', was created by adding the two component grids representing water used by man ('wtruse' component) and goods consumed ('goods' component) with the subcomponent grid representing fuels used in buildings and agriculture (the 'bag_ful' subcomponent grid). The primary reason for creating this analytical grid was to demonstrate that there are many possible ways to combine component and subcomponent grids into analytical grids designed for specific inquiries. A map of the 'nonrenewable-less-transportation fuels' resource use logarithm analytical grid is shown in Figure 3-155. The log values in the map clearly reflect the exclusion of the EMPOWER from flows of fuel used for transportation. The areas of some major highways display low EMPOWER density values associated with the fuels used for road shoulder mowing and maintenance.

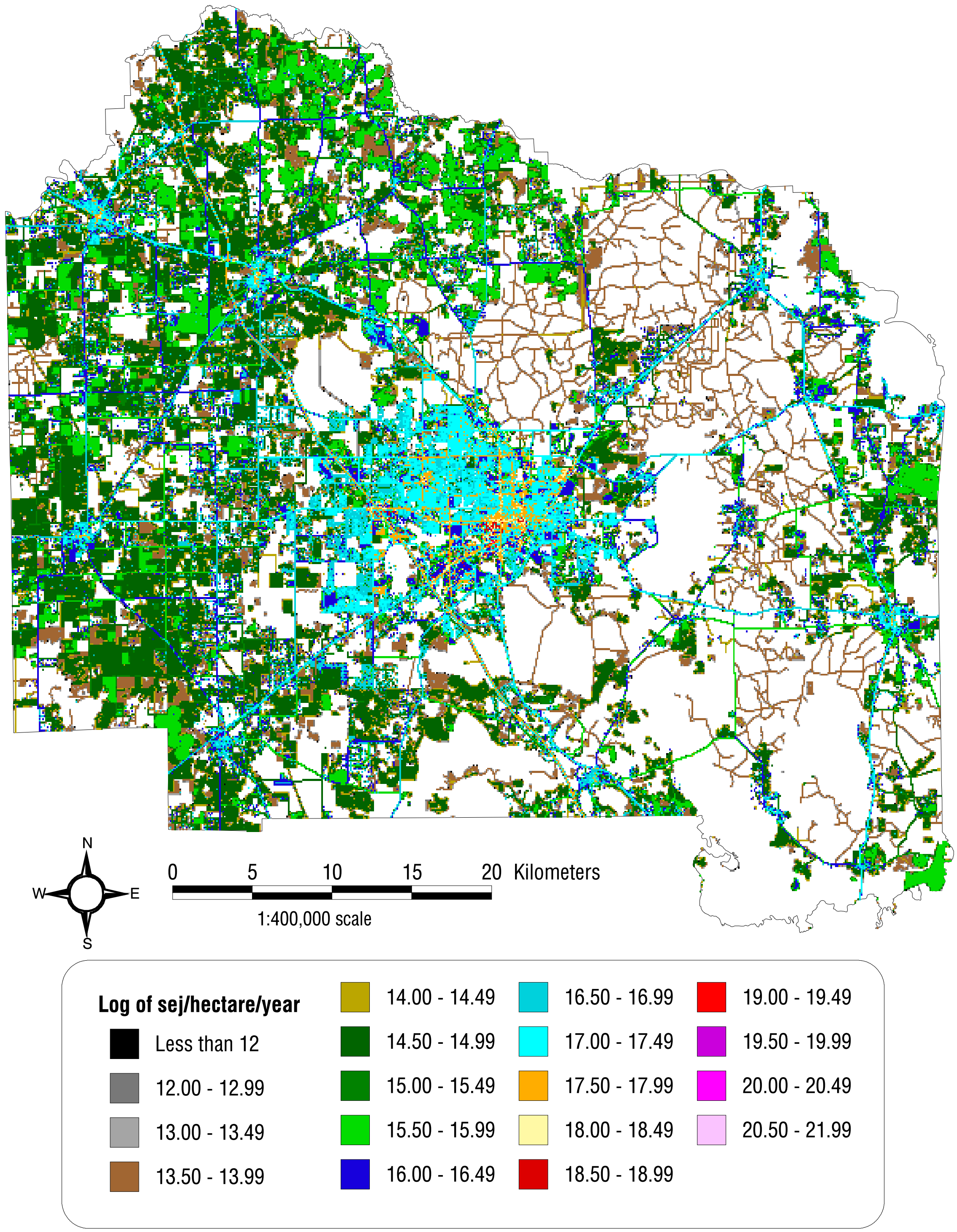


Figure 3-154: Map showing the log of the annual EMPOWER density (log sej/ha/yr) of the non-renewable resource use flows. The logarithm analytical EMERGY grid called 'nonrenew_log' was created by calculating the log of the sum of the EMERGY component grids representing water used by man, fuels used in both transportation and buildings, and goods consumed. This analytical grid differs from the total EMPOWER density grid ('empower_log') by the exclusion of both renewable EMERGY flows and the EMERGY flow of in-situ human services from it's sum.

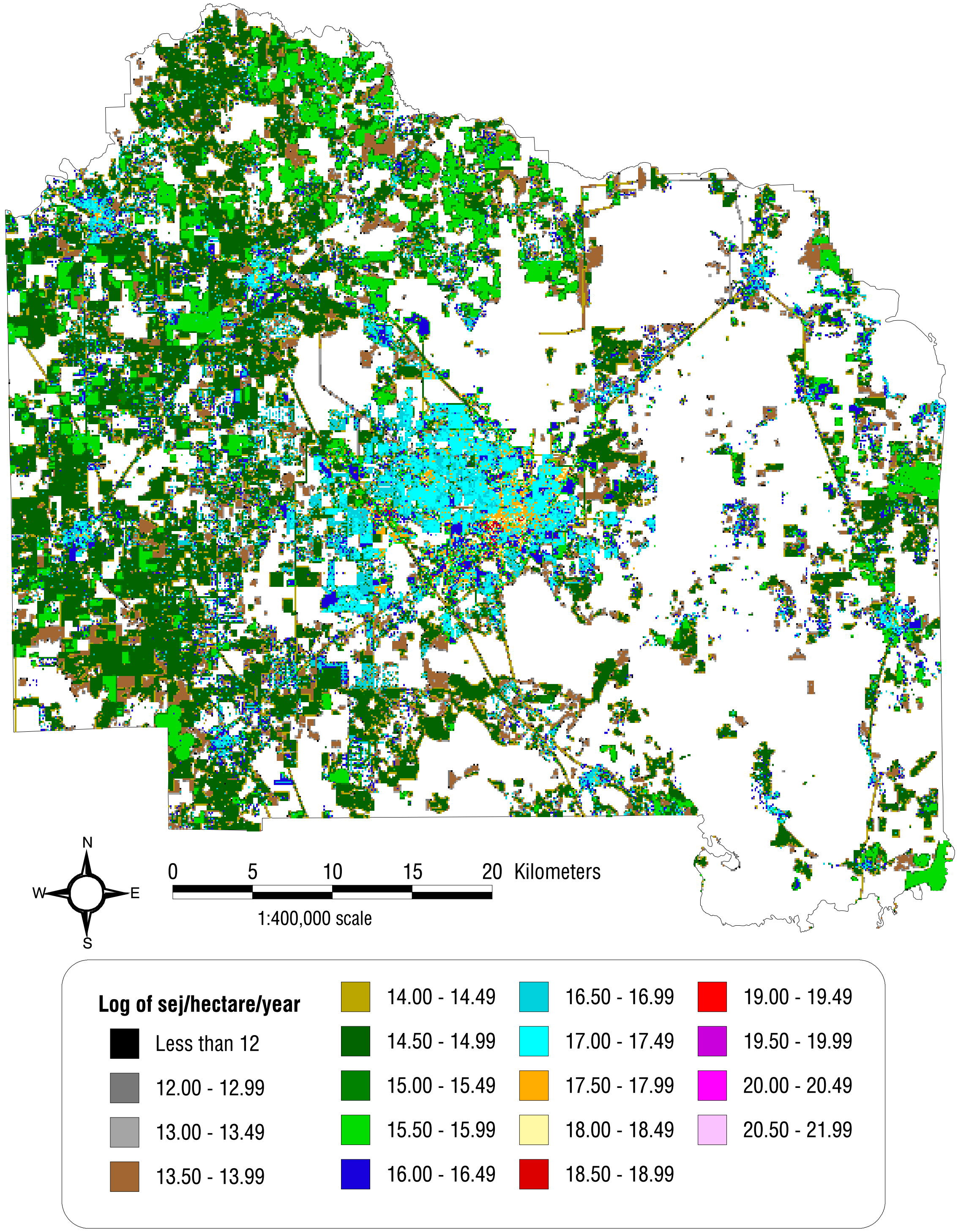


Figure 3-155: Map showing the log of the annual EMPOWER density (log sej/ha/yr)of the non-renewable resource use flows excluding fuels used in transportation. The logarithm analytical EMERGY grid called 'nonrenotr_log' was created by calculating the log of the sum of the EMERGY component grids representing water used by man and goods consumed, and the sub-component grid representing fuels used in buildings and agriculture. This analytical grid differs from the total EMPOWER density grid ('empower_log') by the exclusion of renewable EMERGY flows, the EMERGY flow of in-situ human services, and transportation fuel use from it's sum.

EMPOWER Ratios

County-wide EMPOWER ratio grids. Using various EMPOWER-related component and analytical grids, EMPOWER ratio analytical grids were calculated for the following ratios: 1) the 'nonrenewable use' analytical grid (NR) divided by the 'renewable use' component grid (R), called the 'NR/R' ratio; 2) the 'nonrenewable-less-transportation fuels use' analytical grid (NR-T) divided by 'renewable use' component grid (R), called the 'NR-T/R' ratio; 3) the 'in-situ human services' component grid (S) divided by 'nonrenewable use' analytical grid (NR), called the 'S/NR' ratio; and 4) the 'in-situ human services' component grid (S) divided by 'resource use' analytical grid (RU), called the 'S/RU' ratio . County-wide EMPOWER ratio maps were produced for each of the ratio analytical grids.

The NR/R Ratio Analytical Grid. A map of the values for the ratio of the 'nonrenewable' to 'renewable EMPOWER density, the NR/R ratio, is shown in Figure 3-156. In the map, there are some areas with zero values since, according to the model, there are no nonrenewable flows through these areas.

The agricultural areas display ratio values ranging from less than one to around 4 to 1, with the higher values associated with row crops and other irrigated fields. Areas dominated by medium-density residential development have ratio values in the range of 50-500 to 1, and areas characterized by commercial and services land uses display ratio ranges of 500-5,000 to 1. The highest ratio values, which are greater than 5,000 to 1, are associated with areas dominated by institutional land uses.

The NR-T/R Ratio Analytical Grid. The values for the ratio of nonrenewable-less-transportation to renewable EMPOWER density, the NR-T/R ratio, are shown in the map in Figure 3-157. As expected, the values in this map reflect the exclusion of the fuels used in transportation. The ratio values for all other areas are essentially the same as those in the 'NR/R' ratio map.

The S/NR Ratio Analytical Grid. Figure 3-158 shows the map of ratio values for the service to nonrenewable EMPOWER ratio. Areas with zero values correspond to nonexistent nonrenewable or service flows through these areas. The agricultural areas have ratio values ranging less than .5 to 1, with some values being close to .001 to 1. Areas dominated by medium-density residential development have ratio values in the range of 3-10 to 1. Most commercial and services land uses are in the range 5-10 to 1. The highest ratio values, associated with areas dominated by institutional land uses, are in the 25-100 to 1 range with the highest value being associated with the medical center.

The S/RU Ratio Analytical Grid. A map showing the values for the ratio of service to resource use EMPOWER density, the S/RU ratio, is shown in Figure 3-159. The zero values in the map correspond to areas with no service flows. The major difference between this ratio map and the S/NR map is the addition of the 'renewable use' component flow values into the ratio. Because of this there are fewer 'zero value areas' in this map. However, the ratio values in these rural and natural areas only fall within the range of .001-.5 to 1. The ratio values for the urban areas are virtually the same as those in the S/NR ratio grid. Although this map is not very different from the S/NR map, it does demonstrate and reinforce the concept of combining specific component grids into analytical grids designed to support specific inquiries.

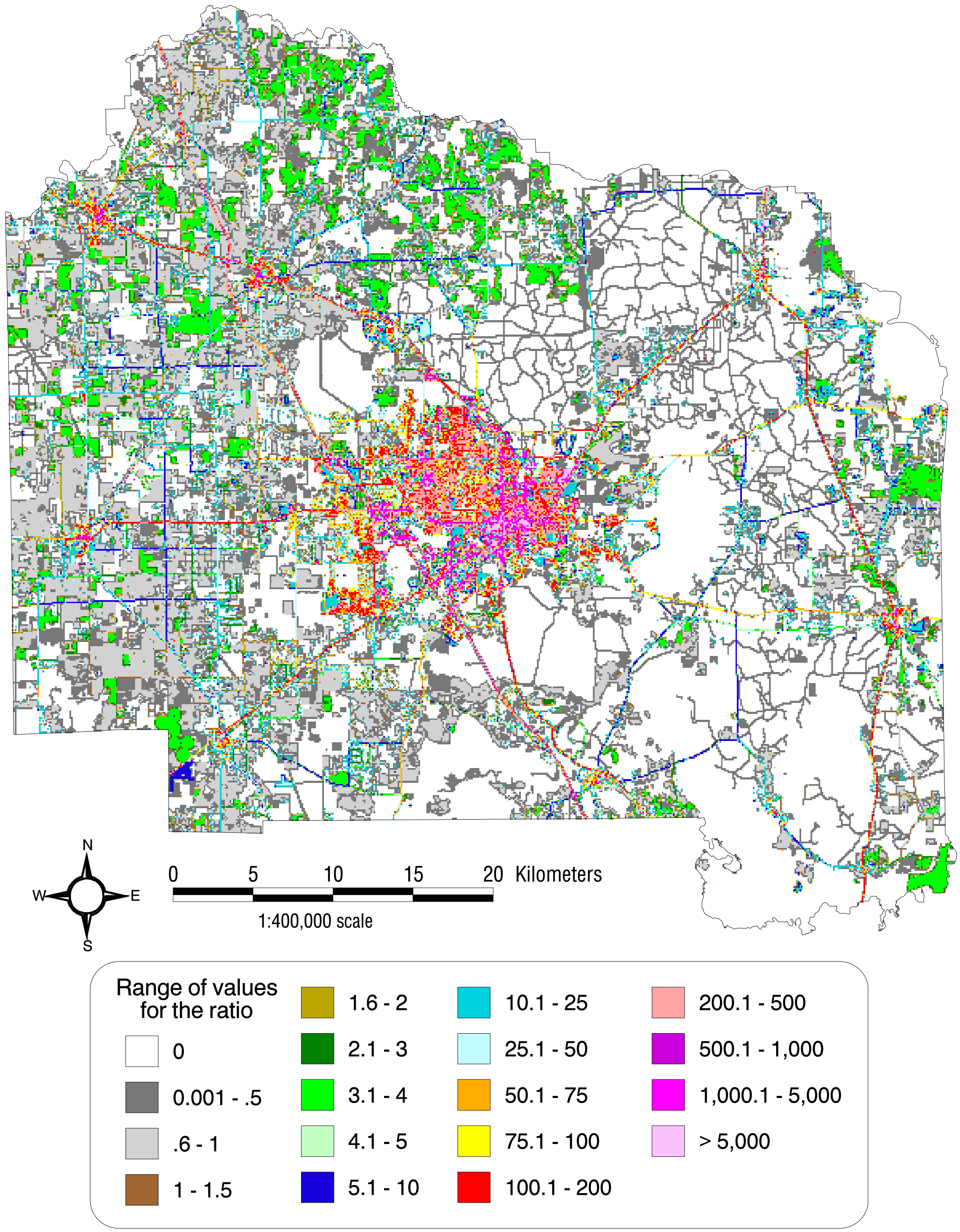


Figure 3-156: Map showing the values for the ratio of non-renewable to renewable EMPOWER density (sej/ha/yr). The values in the analytical grid called ’nonrenew’ were divided by the values in the component EMERGY grid called ’renew’ to obtain this analytical ratio grid.

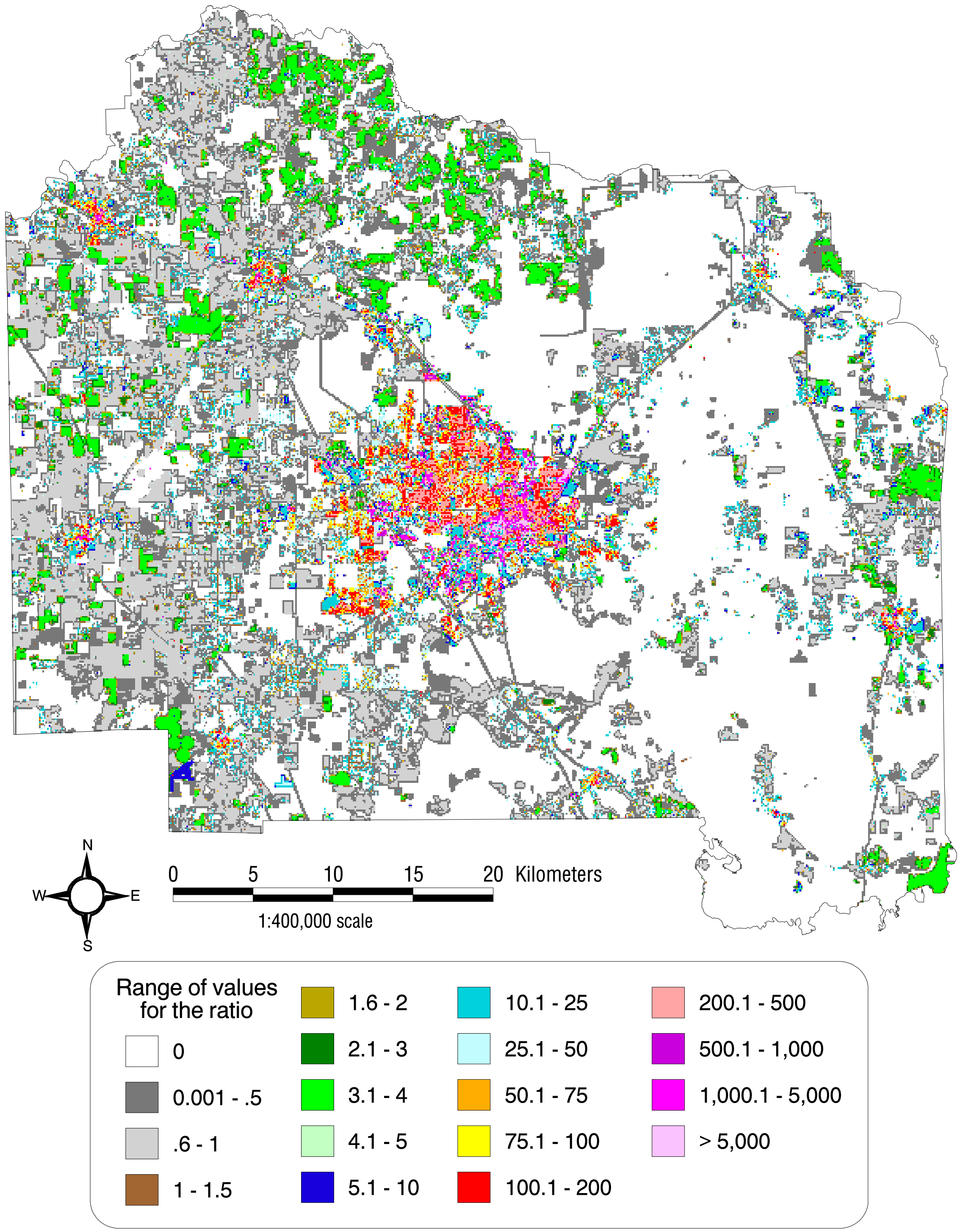


Figure 3-157: Map showing the values for the ratio of non-renewable-less-transportation to renewable EMPOWER density (sej/ha/yr). The values in the analytical grid called 'nonrenotr' were divided by the values in the component EMERGY grid called 'renew' to obtain this analytical ratio grid. The analytical grid 'nonrenotr' represents the sum of the EMERGY in water used by man, fuels used in buildings and agriculture, and goods consumed--it does not include the EMERGY included in fuels used for transportation.

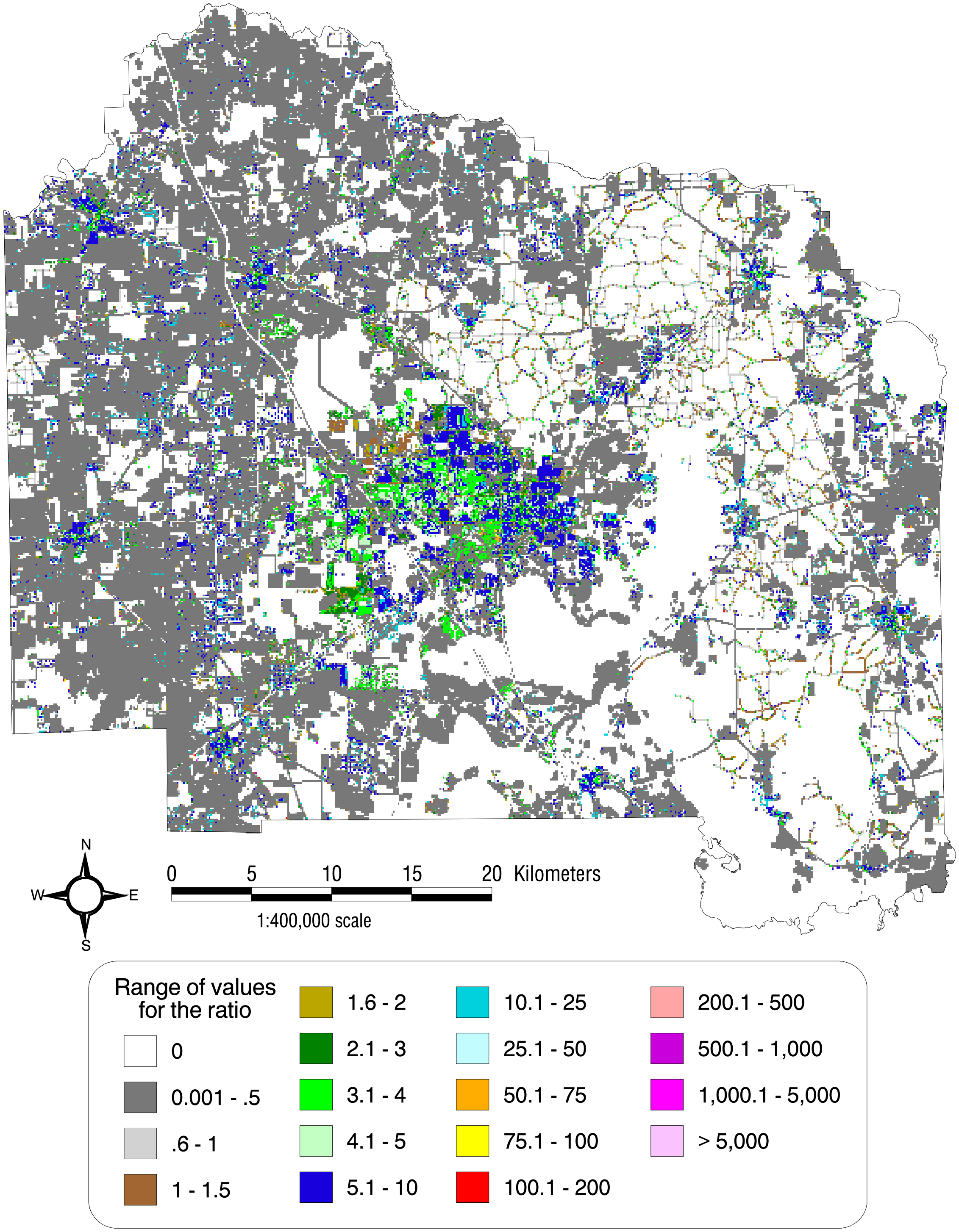


Figure 3-158: Map showing the values for the ratio of service to non-renewable EMPOWER density (sej/ha/yr). The values in the EMERGY component grid called 'service' were divided by the values in the analytical grid called 'nonrenew' to obtain this analytical ratio grid.

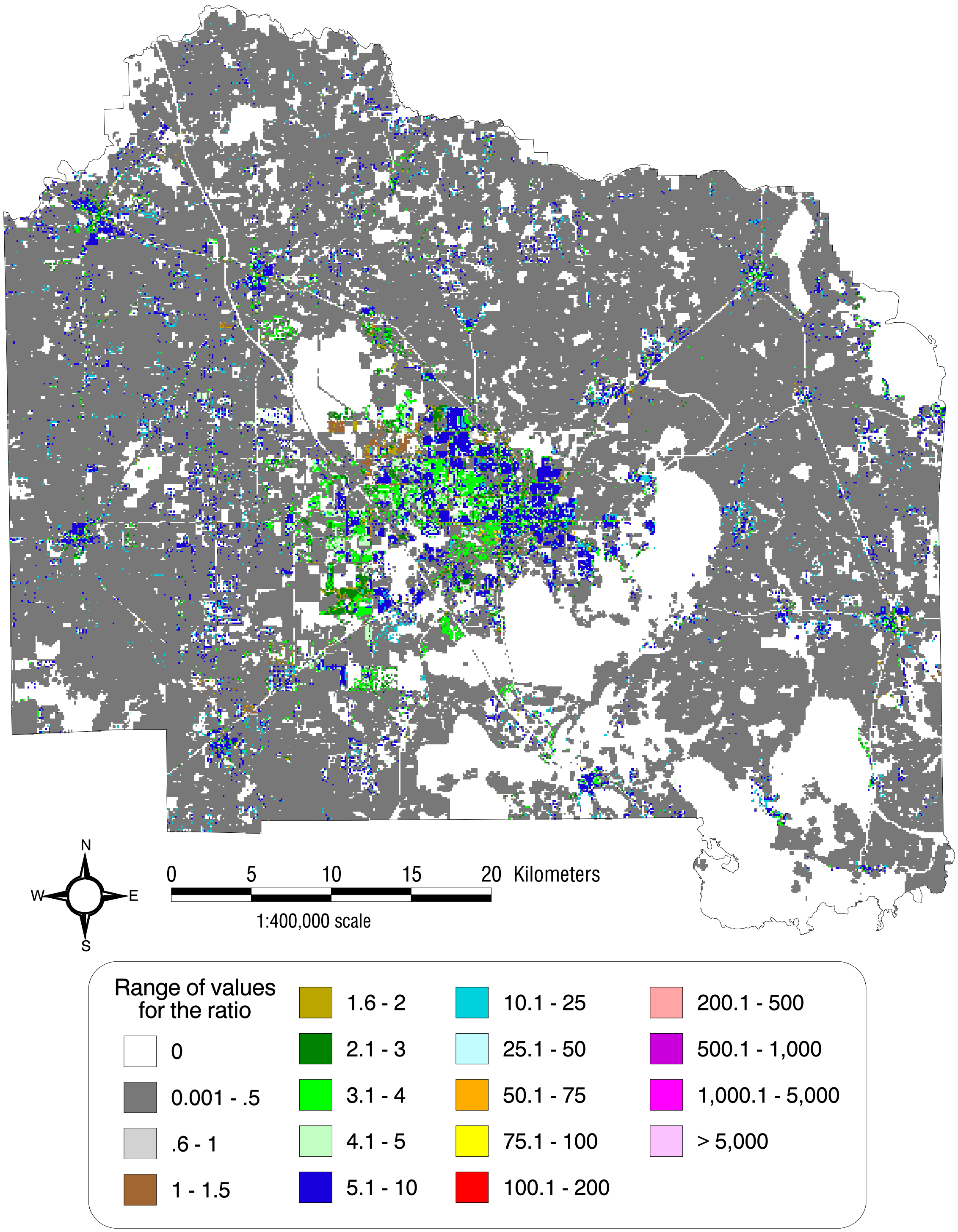


Figure 3-159: Map showing the values for the ratio of service to resource use EMPOWER density (sej/ha/yr). The values in the EMERGY component grid called 'service' were divided by the values in the analytical grid called 'resuse' to obtain this analytical ratio grid. The 'resuse' analytical grid represents the sum of the EMERGY in renewable resources used, water used by man, and fuels used in buildings, agriculture, and transportation.

EMPOWER ratios for land use classifications. Table 3-37 lists land class density data that were derived from relevant component EMPOWER class density values (E18 sej/class/yr) in Table 3-29. Using these derived class density values, EMPOWER class density ratios were calculated for each land class, and for the entire county. For consistency, the EMPOWER class density ratios calculated for the land classes correspond to the county-wide EMPOWER ratios described previously (NR/R, NR-T/R, S/NR, S/RU).

The ratio values presented in Table 3-37 are more precise than the ranges of ratio values that were presented in the ratio maps. Whereas, the ratio maps are particularly valuable for evaluating overall spatial trends, land unit density ratios, such as those presented in Table 3-37, make quantitative comparisons between land units much easier and more obvious.

For example, the obvious and intuitive trend observed for the NR/R class density ratio values in Table 3-37 is not as obvious when one analyzes the NR/R ratio map in Figure 3-156. The class density ratio values in the table clearly show a trend toward higher and higher values as the density and intensity of land use increase. For instance, the NR/R class density ratio value for the 'high-density residential' land class is about 36 times greater (and the 'medium-density residential' land class is about 7 times greater) than the NR/R class density ratio value for the 'low-density residential' land class.

There are several other interesting class density ratios in Table 3-37 as well. For example, the NR/R ratio value for the 'agriculture' land class is 4.4 compared to the NR-T/R ratio (NR less transportation fuel use) value of 3.0. The EMPOWER contributions to the ‘agriculture’ land class from transportation fuel use come from fuels used by cars on highways that just happen to intersect the area of the land class. Therefore, the NR-T/R class density ratio is more relevant for general discussion of the EMPOWER characteristics of agricultural production, where the particular NR/R ratio may be more indicative of the actual EMPOWER characteristics of the land areas classified as ‘agriculture’. This example highlights the value of creating special analytical grids (such as the NR-T grid) for specific inquiries.

Another interesting trend can be observed in the values for the S/NR class density ratio. Increasing residential density is associated with increasing S/NR ratio values, which implies that increasing population density also increases efficiency of nonrenewable resource use.

<u>EMPOWER ratios for planning units.</u> Table 3-38 lists planning unit density data that were derived from relevant component EMPOWER unit density values (E18 sej/unit/yr) in Table 3-33. Using these derived unit density values, EMPOWER unit density ratios were calculated for each planning unit (NR/R, NR-T/R, S/NR, S/RU).

A trend can be seen for the NR/R class density ratio values in Table 3-38 in which the ratio values increase with increasing land use intensity. For instance, the NR/R unit density ratio value for the city is about 3.3 times greater than the ratio for the ‘urban services area’ (and 56 times greater than the ounty NR/R unit density ratio value).

There are several other interesting unit density ratio relations that can be found in Table 3-38. For example, the percentage difference between the NR/R ratio value and the NR-T/R ratio value (NR less transportation fuel use) can be calculated (using the equation: (((NR/R)-(NR-T/R))/(NR/R)) * 100)) for each planning unit. The proportional percentage of EMPOWER contributed by 'transportation fuel use' increases with decreasing planning unit intensity (12% for the city, 20% for the urban services area and the small towns, and 40% for the county unit). This is another example the potential value of creating special analytical grids.

A trend can be observed for the S/NR unit density ratio values in which the more intensely-developed planning units have higher S/NR ratio. This trend, which is similar to trends observed for land classes, implies that increasing population density increases efficiency of nonrenewable resource use.

<u>EMPOWER ratios for neighborhoods.</u> Table 3-39 lists neighborhood density data that were derived from relevant component EMPOWER unit density values (E16 sej/ neighborhood /yr) in Table 3-36. Using these derived neighborhood density values, EMPOWER neighborhood density ratios were calculated for each neighborhood (NR/R, NR-T/R, S/NR, S/RU).

Relations between the ratio values for the neighborhoods reveal trends that are similar to those found for the land class and planning unit ratio values. For example, the NR/R ratio values (and the NR-T/R ratio value) increase with increasing residential development density.

The trend for the S/NR neighborhood density ratio values is not as clear. The ratio values would imply that the most efficient neighborhood, in terms of the amount of 'service' flow supported by the nonrenewable flows, is the 'Northwood Oaks' neighborhood. In fact, the ratio values for all of the neighborhoods are very similar—which may turn out to be significant. The mean S/NR ratio for the four neighborhoods is 5.88, and none of the S/NR ratios vary by more than 10% from this mean value.

Table 3-37: EMPOWER class density ratios for aggregated landuse classifications based on class densities calculated for component and analytical grids.

EMERGY Component / Analytical Grid	Aggregated Land Use Classifications										County-wide Component / Analytical Sum / Ratio
	Residential - Low Density	Residential – Medium Density	Residential – High Density	Commercial and Services	Industrial and Extractive	Institutional	Transportation and Utilities	Agriculture	Upland Forest	Wetlands and Water Bodies	
	EMPOWER Component and Analytical Grid Class Density (E18 sej/class/yr)										
R[1]	26.95	7.44	0.73	0.79	0.29	1.25	3.26	87.34	141.11	85.28	354.46
RU[2]	600.05	1102.00	558.10	1057.34	402.35	905.00	557.34	471.51	677.05	147.49	6478.35
NR[3]	573.10	1094.56	557.37	1056.55	402.06	903.76	554.08	384.17	535.94	62.21	6123.89
NR-T[4]	461.41	977.21	519.94	960.47	391.73	865.18	146.86	262.28	287.88	31.63	4904.60
S[5]	2587.78	5590.10	3781.59	3150.01	457.82	3399.13	362.22	503.73	1194.74	133.58	21160.70
	EMPOWER Class Density Ratios										
NR/R[6]	21.26	147.15	766.31	1343.24	1383.67	725.13	169.93	4.40	3.80	0.73	17.28
NR-T/R[7]	17.12	131.38	714.84	1221.09	1348.13	694.18	45.04	3.00	2.04	0.37	13.84
S/NR[8]	4.52	5.11	6.78	2.98	1.14	3.76	0.65	1.31	2.23	2.15	3.46
S/RU[9]	4.31	5.07	6.78	2.98	1.14	3.76	0.65	1.07	1.76	0.91	3.27

Notes

1) **R = "*Renew*" component grid.** The renewable EMERGY flow class density values were taken from Table 3-29.
2) **RU = "Resource Use" analytical grid.** Sum of *renew*, *wtruse*, *fuel*, and *goods* component class densities taken from Table 3-29.
3) **NR = "Non-renewable Use" analytical grid.** Sum of *wtruse*, *fuel*, and *goods* component class densities taken from Table 3-29.
4) **NR-T = "Non-renewable Use less Transportation Fuels" analytical grid.** *NR* grid values minus *trn_ful* values from Table 3-29.
5) **S = "*Service*" component grid.** The EMERGY flow from in-situ human services. Class densities taken from Table 3-29.
6) **NR/R = "Non-renewable/Renewable" analytical ratio grid.** Ratio of *NR* analytical grid divided by the *R* analytical grid.
7) **NR-T/R = "Non-renewable less Transportation/Renewable" analytical ratio grid.** Ratio of *NR-T* grid divided by the *R* grid.
8) **S/R = "Service/Renewable" analytical ratio grid.** Ratio of *Service(S)* component grid divided by the *R* analytical grid.
9) **S/RU = "Service/Resource Use" analytical ratio grid.** Ratio of *Service(S)* component grid divided by the *RU* analytical grid.

Table 3-38: EMPOWER unit density ratios for each of the 'planning units' based on unit densities calculated for EMERGY component and analytical grids.

EMERGY Component / Analytical Grid	Planning Units				County-wide
	City of Gainesville	Urban Services Area	Other Incorporated Areas (small towns)	Alachua County	
	EMPOWER Component and Analytical Grid Unit Density (E18 sej/unit/yr)				
R[1]	14.02	19.64	32.23	288.55	354.46
RU[2]	3111.96	1323.18	621.20	1421.89	6478.35
NR[3]	3097.94	1303.54	588.97	1133.34	6123.89
NR-T[4]	2733.55	1036.70	463.32	671.01	4904.60
S[5]	12391.53	4582.05	1575.26	2611.86	21160.70
	EMPOWER Unit Density Ratios				
NR/R[6]	220.96	66.37	18.27	3.93	17.28
NR-T/R[7]	194.97	52.79	14.38	2.33	13.84
S/NR[8]	4.00	3.52	2.67	2.30	3.46
S/RU[9]	3.98	3.46	2.54	1.84	3.27

Notes

1) **R = "*Renew*" component grid.** The renewable EMERGY flow unit density values were taken from Table 3-33.
2) **RU = "Resource Use" analytical grid.** Sum of *renew*, *wtruse*, *fuel*, and *goods* component unit densities taken from Table 3-33.
3) **NR = "Non-renewable Use" analytical grid.** Sum of *wtruse*, *fuel*, and *goods* component unit densities taken from Table 3-33.
4) **NR-T = "Non-renewable Use less Transportation Fuels" analytical grid.** *NR* grid values minus *trn_ful* values from Table 3-33.
5) **S = "*Service*" component grid.** The EMERGY flow from in-situ human services. Unit densities were taken from Table 3-33.
6) **NR/R = "Non-renewable/Renewable" analytical ratio grid.** Ratio of *NR* analytical grid divided by the *R* analytical grid.
7) **NR-T/R = "Non-renewable less Transportation/Renewable" analytical ratio grid.** Ratio of *NR-T* grid divided by the *R* grid.
8) **S/R = "Service/Renewable" analytical ratio grid.** Ratio of *Service(S)* component grid divided by the *R* analytical grid.
9) **S/RU = "Service/Resource Use" analytical ratio grid.** Ratio of *Service(S)* component grid divided by the *RU* analytical grid.

Table 3-39: EMPOWER neighborhood density ratios for each of the representative neighborhoods based on neighborhood densities calculated for EMERGY component and analytical grids.

EMERGY Component / Analytical Grid	Neighborhoods				County-wide
	Millhopper Ranchettes	The Hammock	Northwood Oaks	Florida Park	
	EMPOWER Component and Analytical Grid Neighborhood Density (E16 sej/neighborhood/yr)				
R[1]	10.03	10.09	7.67	5.40	35446
RU[2]	118.18	381.85	1497.69	3022.82	647835.00
NR[3]	108.15	371.76	1490.02	3017.42	612389.00
NR-T[4]	107.24	362.77	1461.50	2777.54	490460.00
S[5]	605.32	1969.81	9547.11	18685.59	2116070
	EMPOWER Neighborhood Density Ratios				
NR/R[6]	10.79	36.85	194.35	558.80	17.28
NR-T/R[7]	10.69	35.96	190.63	514.38	13.84
S/NR[8]	5.60	5.30	6.41	6.19	3.46
S/RU[9]	5.12	5.16	6.37	6.18	3.27

<u>Notes</u>

1) **R = "*Renew*" component grid.** The renewable EMERGY flow neighborhood density values were taken from Table 3-36.
2) **RU = "Resource Use" analytical grid.** Sum of *renew*, *wtruse*, *fuel*, and *goods* component densities taken from Table 3-36.
3) **NR = "Non-renewable Use" analytical grid.** Sum of *wtruse*, *fuel*, and *goods* component densities taken from Table 3-36.
4) **NR-T = "Non-renewable Use less Transportation Fuels" analytical grid.** *NR* grid values minus *trn_ful* values from Table 3-36.
5) **S = "*Service*" component grid.** The EMERGY flow from in-situ human services. Neighborhood densities taken from Table 3-36.
6) **NR/R = "Non-renewable/Renewable" analytical ratio grid.** Ratio of *NR* analytical grid divided by the *R* analytical grid.
7) **NR-T/R = "Non-renewable less Transportation/Renewable" analytical ratio grid.** Ratio of *NR-T* grid divided by the *R* grid.
8) **S/R = "Service/Renewable" analytical ratio grid.** Ratio of *Service(S)* component grid divided by the *R* analytical grid.
9) **S/RU = "Service/Resource Use" analytical ratio grid.** Ratio of *Service(S)* component grid divided by the *RU* analytical grid

EMSTORAGE Ratios

County-wide EMSTORAGE ratio grids. Using various EMSTORAGE-related component and analytical grids, EMSTORAGE ratio analytical grids were calculated for the following ratios:

1) the ‘urban system structure’ component grid (U) divided by the ‘natural system structure’ component grid (N), called the ‘U/N’ ratio;

2) the ‘urban system structure’ component grid (U) divided by the ‘biomass’ subcomponent grid (B), called the ‘U/B ratio’;

3) the ‘population’ component grid (P) divided by the ‘urban system structure’ component grid (U), called the ‘P/U’ ratio; and

4) the ‘population’ component grid (P) divided by the ‘biomass’ subcomponent grid (B), called the ‘P/B’ ratio.

The U/N ratio analytical grid. A map of the values for the ratio of ‘urban structure’ to ‘natural structure’ EMSTORAGE density reveals large areas with zero values because, according to the model, there is no urban structure in these areas (Figure 3-160). In rural areas of the county, the pattern of the ratio values reflects the pattern of roads, low-density residential development, and agricultural buildings and miscellaneous improvements.

Most of the ratio values in the rural areas range from .001-1.0 to 1, with occasional slightly higher values associated with roads and residential developments. Typical ratio values for areas dominated by medium-density residential development are in the range of 1-4 to 1. ‘Commercial and services’ land uses display ratio ranges of 5-25 to 1. Most areas of institutional land uses display a ratio value range of 50-500 to 1, however, a few of the grid cells associated with the Shands Medical Center and the University have values of over 1000 to 1.

<u>The U/B ratio analytical grid.</u> Figure 3-161 shows a map of the values for the ratio of the ‘urban structure’ component values to ‘biomass storage’ subcomponent EMSTORAGE density values. Once again, the pattern in the map reflects the pattern of urban structure development with large areas having zero values where there is no urban structure. In general, the values in this ratio analytical grid are higher than in the U/N grid because the calculations for the U/N ratio grid were based on using the ‘natural systems structure’ component grid that also includes the natural storages of water and soil organic matter.

Most of the ratio values in rural areas range from .001-50 to 1. The highest values in rural areas tend to be associated with roads and medium-density residential developments. Typical ratio values for medium-density residential development in the urban areas are in the range of 1-10 to 1. High-density residential development areas have values in the range of 10-25 to 1, with some values being higher. Typical ratio values for ‘commercial and services’ land uses are in the range of 25-200 to 1. Institutional land uses have a wide ratio range of 100->5,000 to 1, and, once again, the highest values are associated with the areas around the University and the Medical Center which have already been characterized as having the highest values for urban structure.

<u>The P/U ratio analytical grid.</u> The map of the values for the ratio of the ‘population’ storage component to ‘urban structure’ component EMSTORAGE density values is shown in Figure 3-162. Large areas with zero values exist where there is no

urban structure or population. The ratio values in this analytical grid tend to follow an opposite trend compared to the values in the previously discussed ratio grids. The highest values are found in the rural, less developed areas of the county, and relatively lower values characterize the urban areas.

In fact, the ratio values in the rural areas range very widely, from 2-5,000 to 1, with some individual cells exhibiting very high values because of relatively high numbers of residents living in relatively lower value structures such as mobile homes. Typical ratio values for medium-density residential development are in the range of 10-200 to 1. In the higher-density residential areas, particularly in the eastern half of Gainesville, the range of ratio values tends to be higher, with values of 75-500 to 1. Institutional land uses, characterized by very high EMSTORAGE values for urban structure, have a relatively low range of P/U ratios with values of 10-50 to 1.

The P/B ratio analytical grid. The ratio of the 'population' storage component to 'biomass' subcomponent EMSTORAGE density values are shown in the map in Figure 3-163. Unlike the P/U ratio grid, the ratio values in the P/B analytical grid tend to follow the more familiar trend of the relatively lower values in the rural, less developed areas of the county, and relatively higher values in the urban areas.

Typical ratio values in rural areas range from 10-100 to 1, with some much higher values. Typical ratio values for medium-density residential development are in the range of 100-500 to 1. A pattern of higher ratio values, 500-5000 to 1, similar to the one observed in the P/U ratio, exists for the higher-density residential areas in the eastern half of Gainesville. Both commercial and institutional land uses have very high P/B ratios values of 1,000-5,000 to 1

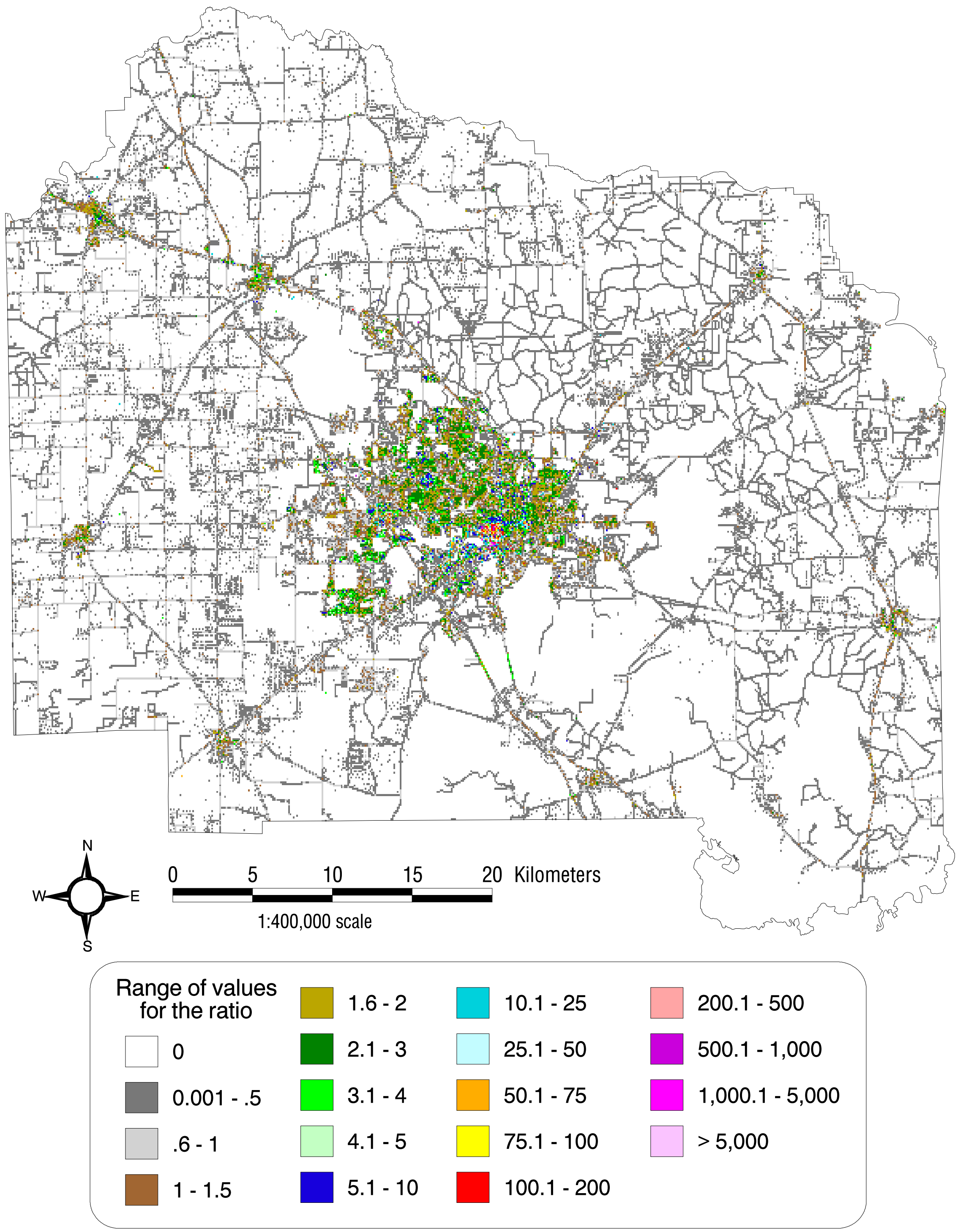


Figure 3-160: Map showing the values for the ratio of urban to natural EMSTORAGE density (sej/ha). The values in the EMERGY component grid called 'urbstr' were divided by the values in the EMERGY component grid called 'natstr' to obtain this analytical ratio grid.

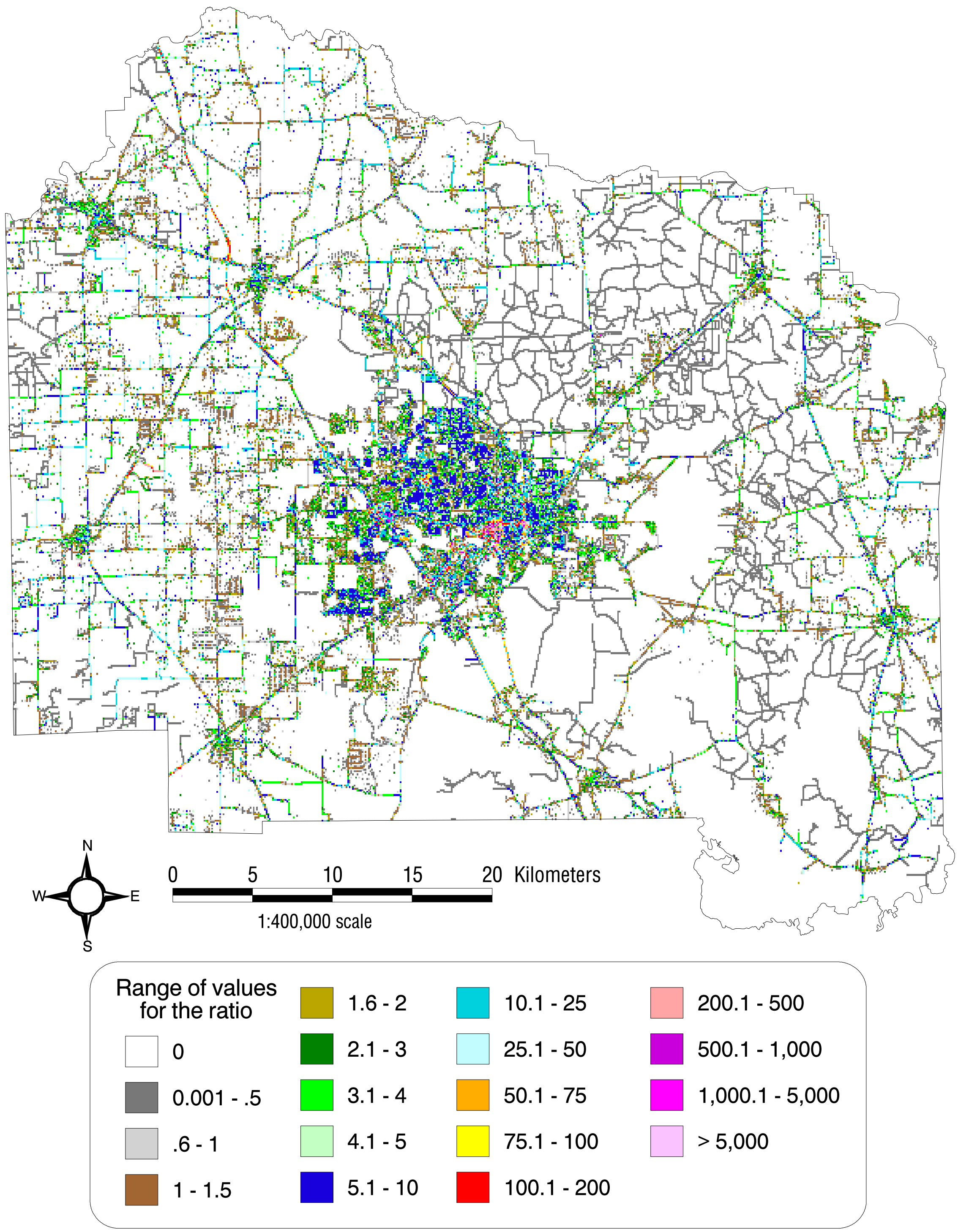


Figure 3-161: Map showing the values for the ratio of urban structure to biomass EMSTORAGE density (sej/ha). The values in the EMERGY component grid called 'urbstr' were divided by the values in the EMERGY component grid called 'biostr' to obtain this analytical ratio grid.

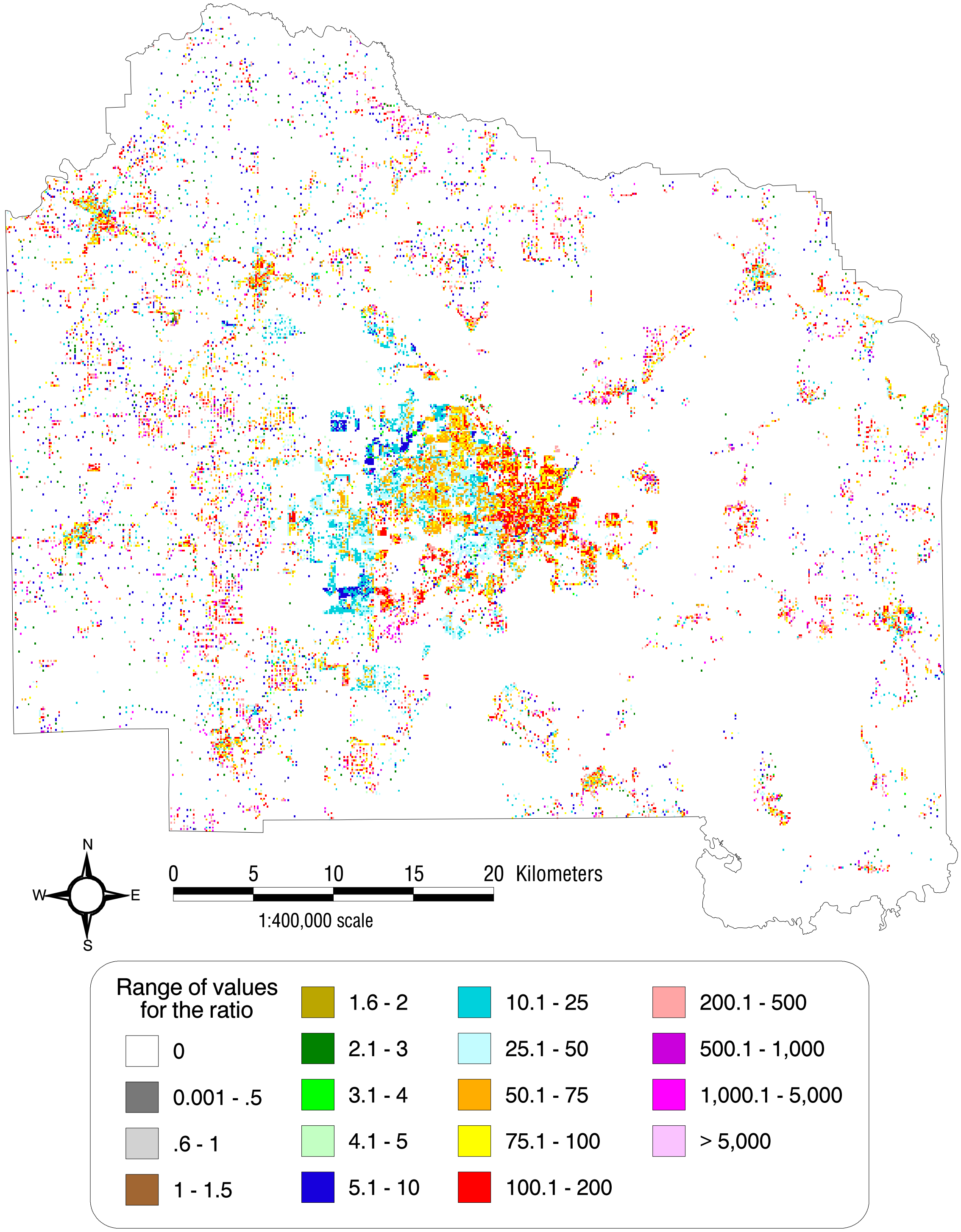


Figure 3-162: Map showing the values for the ratio of population to urban structure EMSTORAGE density (sej/ha). The values in the EMERGY component grid called 'popstr' were divided by the values in the EMERGY component grid called 'urbstr' to obtain this analytical ratio grid.

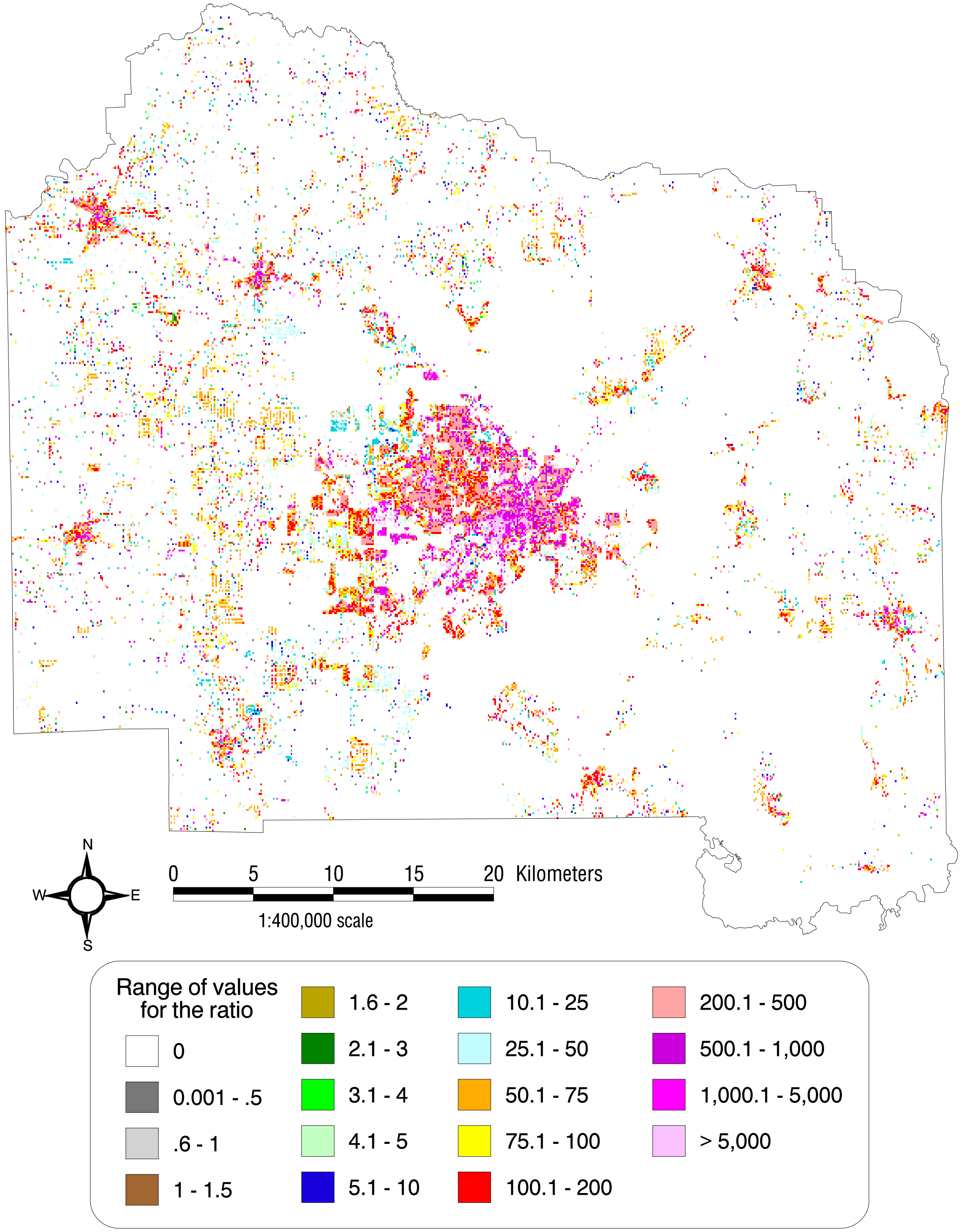


Figure 3-163: Map showing the values for the ratio of population to biomass EMSTORAGE density (sej/ha). The values in the EMERGY component grid called 'popstr' were divided by the values in the EMERGY component grid called 'biostr' to obtain this analytical ratio grid.

EMSTORAGE ratios for land use classifications. Table 3-40 lists the class density data that was derived from relevant component EMSTORAGE class density values (E18 sej/class) in Table 3-29. The EMSTORAGE class density ratios calculated for the land classes correspond to the county-wide EMSTORAGE ratios described previously (U/N, U/B, P/U, and P/B).

Several interesting relationships can be seen in Table 3-40, but the most obvious is the clear trend that can be seen in the ratio value data for the three residential land classes. In general, the data shows that for all four of the ratios the values get higher with increasing development density. More specifically, the 'urban' to 'natural' structure ratio value, U/N, for the high-density residential land class is 2.7 times greater than the medium-density class, and about 14 times greater than the low-density residential class. A similar relationship exists for the U/B density ratio values.

The 'population' to 'urban structure' ratios do not vary as widely. The P/U ratio for the high-density residential is only 1.5 times greater than medium-density, and 2 times greater than low-density residential. The values for the P/U ratio still point to a trend of increasing 'efficiency' with increasing density—relatively more people supported by relatively less urban structure.

The P/B ratio could be referred to as an index of 'people to trees'. The class density ratio data implies that residents in low-density developments enjoy the presence of about 40 times more biomass per person than do residents of high-density residential areas (note: 'person' is used loosely here since the ratio is based on EMERGY storage in the human population).

EMSTORAGE ratios for planning units. Table 3-41 lists planning unit density data that was derived from relevant component EMSTORAGE unit density values (E18 sej/unit) in Table 3-33. Using these derived unit density values, EMSTORAGE unit density ratios were calculated for each planning unit (U/N, U/B, P/U, and P/B).

The same relationships can be seen in Table 3-41 that were observed for the land class density ratio comparisons. The values for all four of the unit ratios get higher with increasing development density. In the case of the ‘urban’ to ‘natural’ structure unit density ratio, U/N, the value for the City of Gainesville is 44.5 times greater than the U/N ratio value for the county unit. The value for the U/B unit density ratio for the city unit is about 28 times higher than the county unit. The ‘population’ to ‘urban structure’ ratios do not vary as widely, but still display the trend. The P/B ratio (index of ‘people to trees’) for the city unit is about 50 times the ratio value for the county unit.

EMSTORAGE ratios for neighborhoods. Table 3-42 lists neighborhood density data that was derived from relevant component EMSTORAGE unit density values (E16 sej/ neighborhood) in Table 3-36.

In general, the same relationship of higher ratio values with increasing development density can be seen in Table 3-42 that were observed in the previous two comparison studies. For example, the U/N neighborhood density ratio value for the highest density neighborhood, ‘Florida Park’, is about 16 times higher than the lowest density neighborhood. The P/B ratio (index of ‘people to trees’) for ‘Florida Park’ is about 48 times the value for the ‘Millhopper Ranchettes’ neighborhood (similar to the city unit to county unit relationship for the P/B ratio).

Table 3-40: EMSTORAGE class density ratios for aggregated landuse classifications based on class densities calculated for component and analytical grids.

EMERGY Component / Analytical Grid	Aggregated Land Use Classifications										County-wide Component / Analytical Sum / Ratio
	Residential - Low Density	Residential – Medium Density	Residential – High Density	Commercial and Services	Industrial and Extractive	Institutional	Transportation and Utilities	Agriculture	Upland Forest	Wetlands and Water Bodies	
	EMSTORAGE Component and Analytical Grid Class Density (E18 sej/class)										
B[1]	1748.73	579.03	66.14	59.68	16.18	119.97	84.37	942.65	7203.30	2074.28	12895.96
N[2]	5412.43	1659.89	281.07	316.29	210.10	321.51	677.19	14934.29	29468.41	23852.64	77145.28
U[3]	1557.27	2484.15	1132.59	965.61	194.41	2986.47	580.74	772.06	1309.96	115.36	12098.65
P[4]	71535.27	154814.02	108625.70	90698.12	13209.12	100420.57	10337.30	13798.45	33175.02	3722.67	600336.23
	EMSTORAGE Class Density Ratios										
U / N[5]	0.29	1.50	4.03	3.05	0.93	9.29	0.86	0.05	0.04	0.01	0.16
U / B[6]	0.89	4.29	17.12	16.18	12.02	24.89	6.88	0.82	0.18	0.06	0.94
P / U[7]	45.94	62.32	95.91	93.93	67.95	33.63	17.80	17.87	25.33	32.27	49.62
P / B[8]	40.91	267.37	1642.44	1519.66	816.63	837.05	122.52	14.64	4.61	1.79	46.55

Notes

1) **B = "biostr" component grid.** The biomass EMERGY storage class density values were taken from Table 3-29.
2) **N = "natstr" component grid.** The natural systems EMERGY storage grid is the sum of the *biostr, wtrstr, and soilom* sub-component grids. The class density values were taken from Table 3-29.
3) **U = "urbstr" component grid.** The urban systems EMERGY storage grid is the sum of the *bldg, road, and util* sub-component grids. The class density values were taken from Table 3-29.
4) **P = "popstr" component grid.** The population EMERGY storage component grid. Class density values are from Table 3-29.
5) **U/N = "urbstr / natstr" analytical ratio grid.** Ratio of *urbstr* component grid divided by the *natstr* component grid.
6) **U/B = "urbstr / biostr" analytical ratio grid.** Ratio of *urbstr* component grid divided by the *biostr* component grid.
7) **P/U = "popstr / urbstr" analytical ratio grid.** Ratio of *popstr* component grid divided by the *urbstr* component grid.
8) **P/B = "popstr / biostr" analytical ratio grid.** Ratio of *popstr* component grid divided by the *biostr* component grid.

Table 3-41: EMSTORAGE unit density ratios for each of the 'planning units' based on unit densities calculated for EMERGY component and analytical grids.

EMERGY Component / Analytical Grid	Planning Units				County-wide
	City of Gainesville	Urban Services Area	Other Incorporated Areas (small towns)	Alachua County	
	EMSTORAGE Component and Analytical Grid Unit Density (E18 sej/unit)				
B[1]	928.01	1266.74	1278.72	9421.01	12895.96
N[2]	3632.25	4604.08	5632.86	63265.24	77145.28
U[3]	6453.04	2380.75	932.48	2332.33	12098.65
P[4]	355850.47	129394.47	43042.07	72049.22	600336.23
	EMSTORAGE Unit Density Ratios				
U / N[5]	1.78	0.52	0.17	0.04	0.16
U / B[6]	6.95	1.88	0.73	0.25	0.94
P / U[7]	55.14	54.35	46.16	30.89	49.62
P / B[8]	383.46	102.15	33.66	7.65	46.55

Notes

1) **B = "biostr" component grid.** The biomass EMERGY storage unit density values were taken from Table 3-33.
2) **N = "natstr" component grid.** The natural systems EMERGY storage grid is the sum of the *biostr*, *wtrstr*, *and soilom* sub-component grids. The unit density values were taken from Table 3-33.
3) **U = "urbstr" component grid.** The urban systems EMERGY storage grid is the sum of the *bldg*, *road*, *and util* sub-component grids. The unit density values were taken from Table 3-33.
4) **P = "popstr" component grid.** The population EMERGY storage component grid. Unit density values are from Table 3-33.
5) **U/N = "urbstr / natstr" analytical ratio grid.** Ratio of *urbstr* component grid divided by the *natstr* component grid.
6) **U/B = "urbstr / biostr" analytical ratio grid.** Ratio of *urbstr* component grid divided by the *biostr* component grid.
7) **P/U = "popstr / urbstr" analytical ratio grid.** Ratio of *popstr* component grid divided by the *urbstr* component grid.
8) **P/B = "popstr / biostr" analytical ratio grid.** Ratio of *popstr* component grid divided by the *biostr* component grid.

Table 3-42: EMSTORAGE neighborhood density ratios for each of the representative neighborhoods based on neighborhood densities calculated for EMERGY component and analytical grids.

EMERGY Component / Analytical Grid	Neighborhoods				County-wide
	Millhopper Ranchettes	The Hammock	Northwood Oaks	Florida Park	
	EMSTORAGE Component and Analytical Grid Neighborhood Density (E16 sej/neighborhood)				
B[1]	697.13	643.05	649.65	468.22	1289596
N[2]	2050.55	2546.55	2168.90	1442.06	7714528
U[3]	383.50	1712.20	3326.84	4384.75	1209865
P[4]	17109.74	53022.46	261894.34	550143.70	60033623
	EMSTORAGE Neighborhood Density Ratios				
U / N[5]	0.19	0.67	1.53	3.04	0.16
U / B[6]	0.55	2.66	5.12	9.36	0.94
P / U[7]	44.62	30.97	78.72	125.47	49.62
P / B[8]	24.54	82.45	403.13	1174.98	46.55

<u>Notes</u>

1) **B = "biostr" component grid.** The biomass EMERGY storage neighborhood density values were taken from Table 3-36.
2) **N = "natstr" component grid.** The natural systems EMERGY storage grid is the sum of the *biostr*, *wtrstr*, *and soilom* sub-component grids. The neighborhood density values were taken from Table 3-36.
3) **U = "urbstr" component grid.** The urban systems EMERGY storage grid is the sum of the *bldg*, *road*, *and util* sub-component grids. The neighborhood density values were taken from Table 3-36.
4) **P = "popstr" component grid.** The population EMERGY storage component grid. Density values are from Table 3-36.
5) **U/N = "urbstr / natstr" analytical ratio grid.** Ratio of *urbstr* component grid divided by the *natstr* component grid.
6) **U/B = "urbstr / biostr" analytical ratio grid.** Ratio of *urbstr* component grid divided by the *biostr* component grid.
7) **P/U = "popstr / urbstr" analytical ratio grid.** Ratio of *popstr* component grid divided by the *urbstr* component grid.
8) **P/B = "popstr / biostr" analytical ratio grid.** Ratio of *popstr* component grid divided by the *biostr* component grid.

Spatial Context Analysis

In the previous sections, the results of EMERGY component signature and EMERGY ratio analyses were presented. Observations and examples were given to demonstrate that these analyses are useful methods for characterizing and comparing land classes, planning units, and neighborhoods. Whereas the previous analyses were directed toward characterizations and comparisons of land areas, this section will present the results of analysis that is aimed at characterizing the spatial context of individual grid cells.

Spatial context analyses quantify the cell value relationships between an individual cell and the group of cells that surround it—it's neighbor cells. Surrounding cells that are included in quantitative comparisons with a central cell are defined here as being in the 'neighborhood' of the central cell.

The method used for these spatial context analyses is similar to what is commonly referred to as 'moving window analysis' in the remote sensing and image processing discipline (Lillesand and Kiefer, 1987). The window referred to is the group of cells surrounding the central cell. This study will refer to the general method as 'spatial context analysis' and use the word 'neighborhood' because it is so useful for describing the basic concept behind this type of spatial analysis.

Various sizes and shapes of 'neighborhoods of cells' can be defined around an individual cell. The size of the neighborhood can be defined in map units or in terms of numbers of cells. The shape of the neighborhood can be defined as a circle, having a radius measured out from the center cell, or as any other meaningful shape (such as a square or rectangle).

Three neighborhood-types were used for this study: the one-cell-, three-cell-, and five-cell-radius neighborhoods. Only those adjacent cells whose cell-center is within 100 meters (the dimensions of one cell) of the cell-center of the central cell belong to the one-cell-radius neighborhood of a particular cell. Three- and five-cell-radius neighborhoods are defined and calculated in the same manner as the one-cell-radius neighborhoods. The value of the central cell is included in calculations of means, maximum values, and percentages.

Three different contextual indices were calculated for each of the three neighborhood types: log of the mean of the density values of the cells in the neighborhood, log of the maximum density value of all of the cells within the neighborhood, and the percentage of the maximum neighborhood density value that the density value of the central cell represents.

Each of the three contextual indices was calculated for each of the three neighborhood types for both the total annual EMPOWER density analytical grid and the total EMSTORAGE density analytical grid. The value in each cell of the resulting context analytical grids is the value of the contextual index that was calculated for its neighborhood.

The primary purpose of performing any particular contextual analysis is to gain additional insight into the spatial distribution patterns of EMERGY flows and storages. In most cases, in order to observe and analyze trends, one has to view the three different cell-radius neighborhood maps as a group.

EMPOWER Density Context Analysis

Neighborhood nean total annual EMPOWER density. The results of the calculation of neighborhood mean value for the total annual EMPOWER density are shown in Figure 3-164 (the ‘one-cell-radius neighborhood’ mean), Figure 3-165 (the ‘three-cell-radius neighborhood’ mean), and Figure 3-166 (the ‘five-cell-radius neighborhood’ mean).

These three figures have to be considered as a group to observe the effect of increasing the neighborhood size. In rural areas, the effect of increasing neighborhood size is that there are increasing numbers of cells with higher values, and the most obvious trend in urban areas is that there are fewer isolated cells with very high values as the cell radius increases. This trend is completely logical based on the mathematics used in the method. A similar phenomenon was observed when mean values were calculated for level 2 land use classifications—in that case it was referred to as the ‘dilution effect’ on aggregated class density values. In the case of the total annual EMPOWER density analytical grid, there are many small areas in the county (usually corresponding to building and road locations) that have relatively higher EMPOWER densities than the surrounding areas. By examining the patterns in the three context mean maps, one can see that these small areas of relatively higher EMPOWER density are more spatially dispersed in rural areas than in urban areas. Because of this dispersal pattern, these higher values tend to raise the mean values of their neighboring cells more in rural areas than in urban areas. In other words, high EMPOWER densities associated with buildings and roads are more ‘out of context’ in rural areas than in urban areas.

Neighborhood maximum total annual EMPOWER density. The results of the calculation of neighborhood maximum value for the total annual EMPOWER density are shown in Figure 3-167 (the ‘one-cell-radius’ maximum), Figure 3-168 (the ‘three-cell-radius’ maximum), and Figure 3-169 (the ‘five-cell-radius’ maximum). In this analysis, the value of each cell in the output analytical grid is set to the maximum value that is found for the cells within the neighborhood. This analysis is aimed at emphasizing the spatial distribution of the relatively higher EMPOWER density values. The patterns in the three context maximum maps reinforce the observation that small areas of very high EMPOWER density are more widely dispersed in rural areas than in urban areas.

Percent of neighborhood maximum total annual EMPOWER density. The results of the calculation of the percentage of the neighborhood maximum value for the total annual EMPOWER density are shown in Figure 3-170 (% the ‘one-cell-radius’ maximum), Figure 3-171 (% the ‘three-cell-radius’ maximum), and Figure 3-172 (% the ‘five-cell-radius’ maximum). Figure 3-173 presents a histogram showing the number of cells within each range of percentages of the neighborhood maximum for the three different (1,3, or 5) cell-radius neighborhoods. This analysis was aimed at highlighting the magnitude of the difference between each cell value and its maximum neighborhood value. The maps are designed to emphasize the areas with the greatest percentage difference in values. Because of the pattern of dispersed, small, high EMPOWER density areas, there a large portions of the rural areas of the county that have density values that are less than 1% of their neighborhood maximum. The map series helps identify the ‘edges’ in the spatial pattern of EMPOWER density—‘edges’ being defined as cells that have significantly lower/higher density values than surrounding cells.

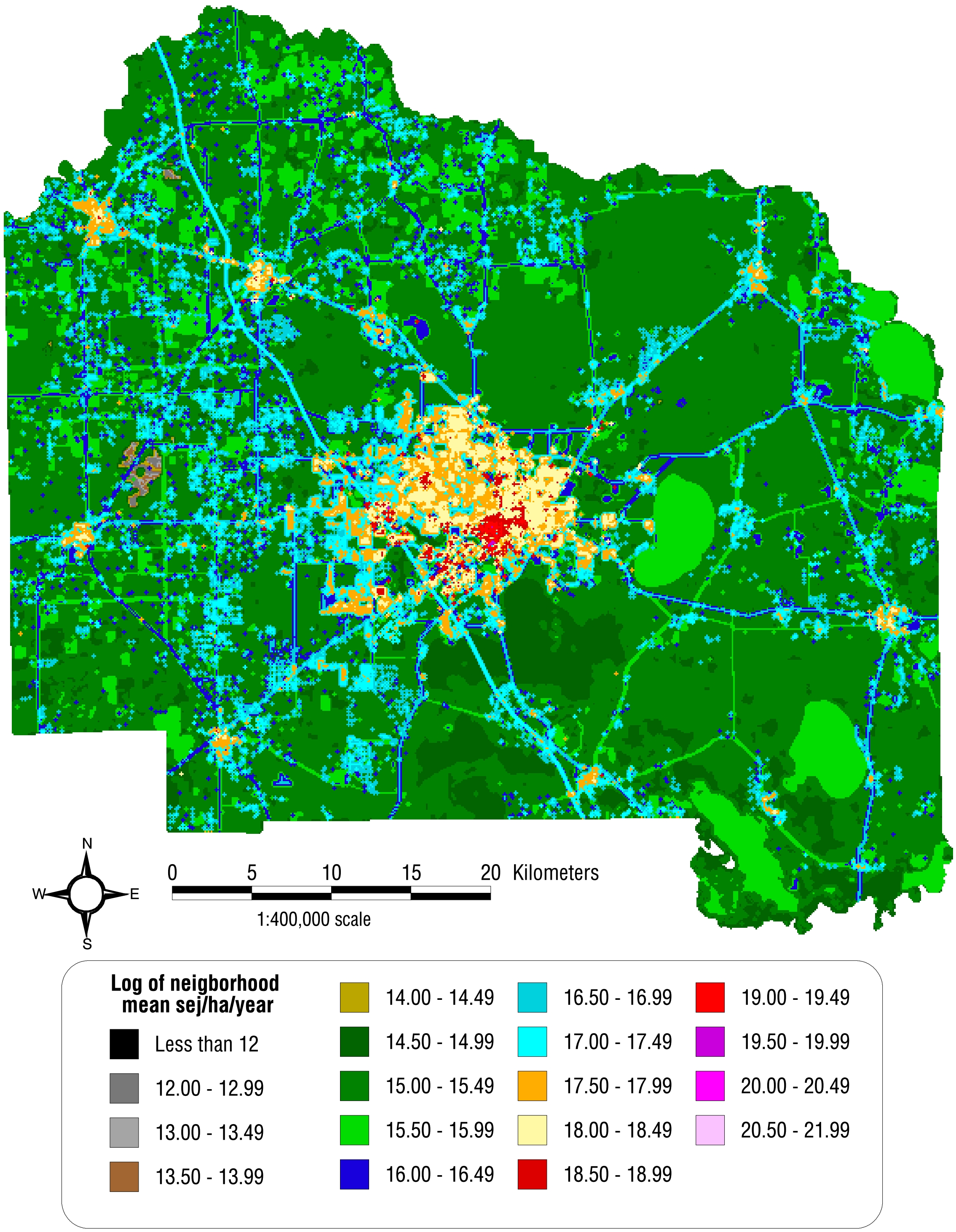


Figure 3 -164: Map showing the log of the 'one-cell-radius neighborhood' mean total annual EMPOWER density (log of neighborhood mean sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmean1c' (shown here) represent the log of the mean of the total EMPOWER density values (sej/ha/yr) of those cells that are within a 'neigborhood' defined by a one cell radius around each cell.

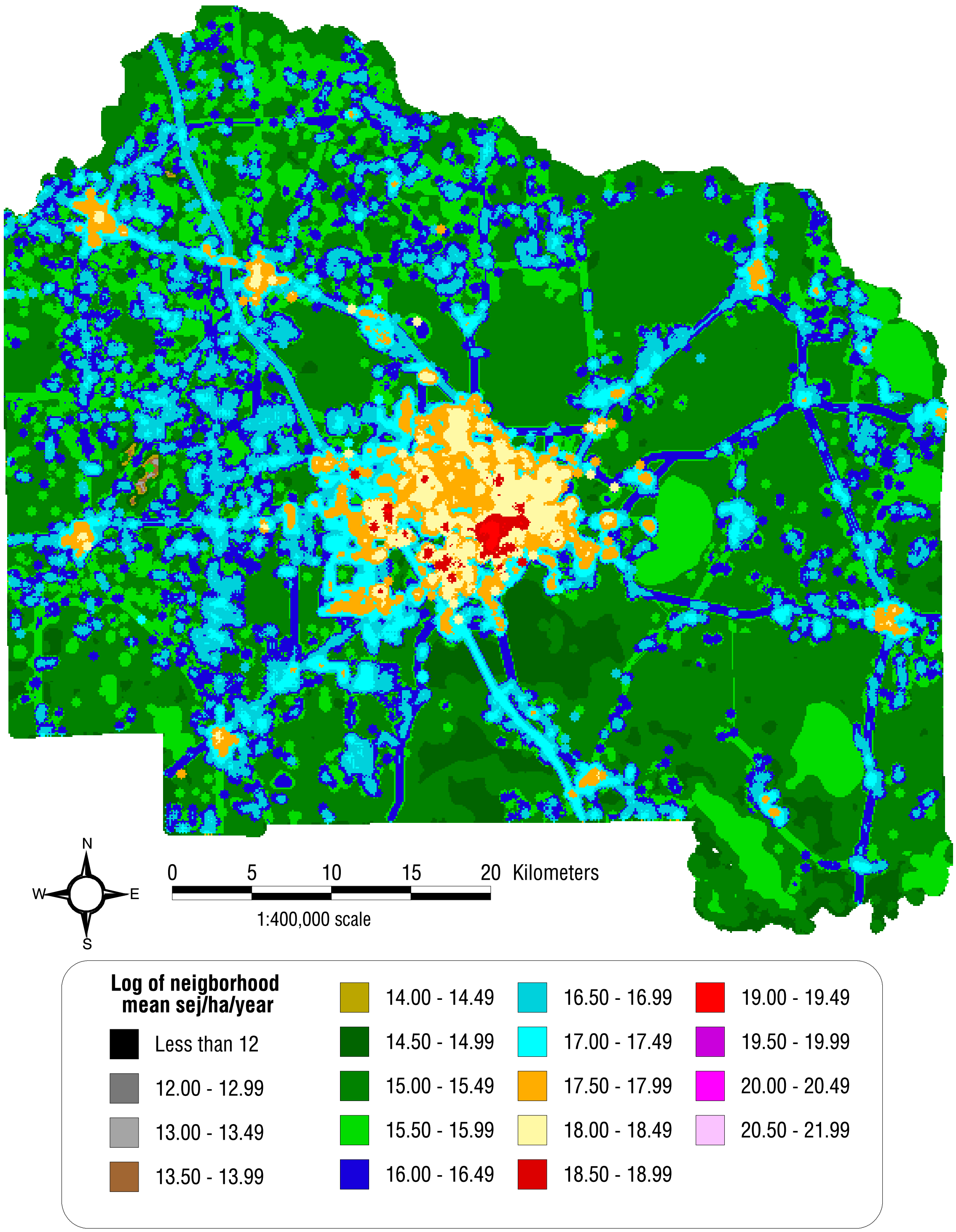


Figure 3 -165: Map showing the log of the 'three-cell-radius neighborhood' mean total annual EMPOWER density (log of neighborhood mean sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmean3c' (shown here) represent the log of the mean of the total EMPOWER density values (sej/ha/yr) of those cells that are within a 'neigborhood' defined by a three cell radius around each cell.

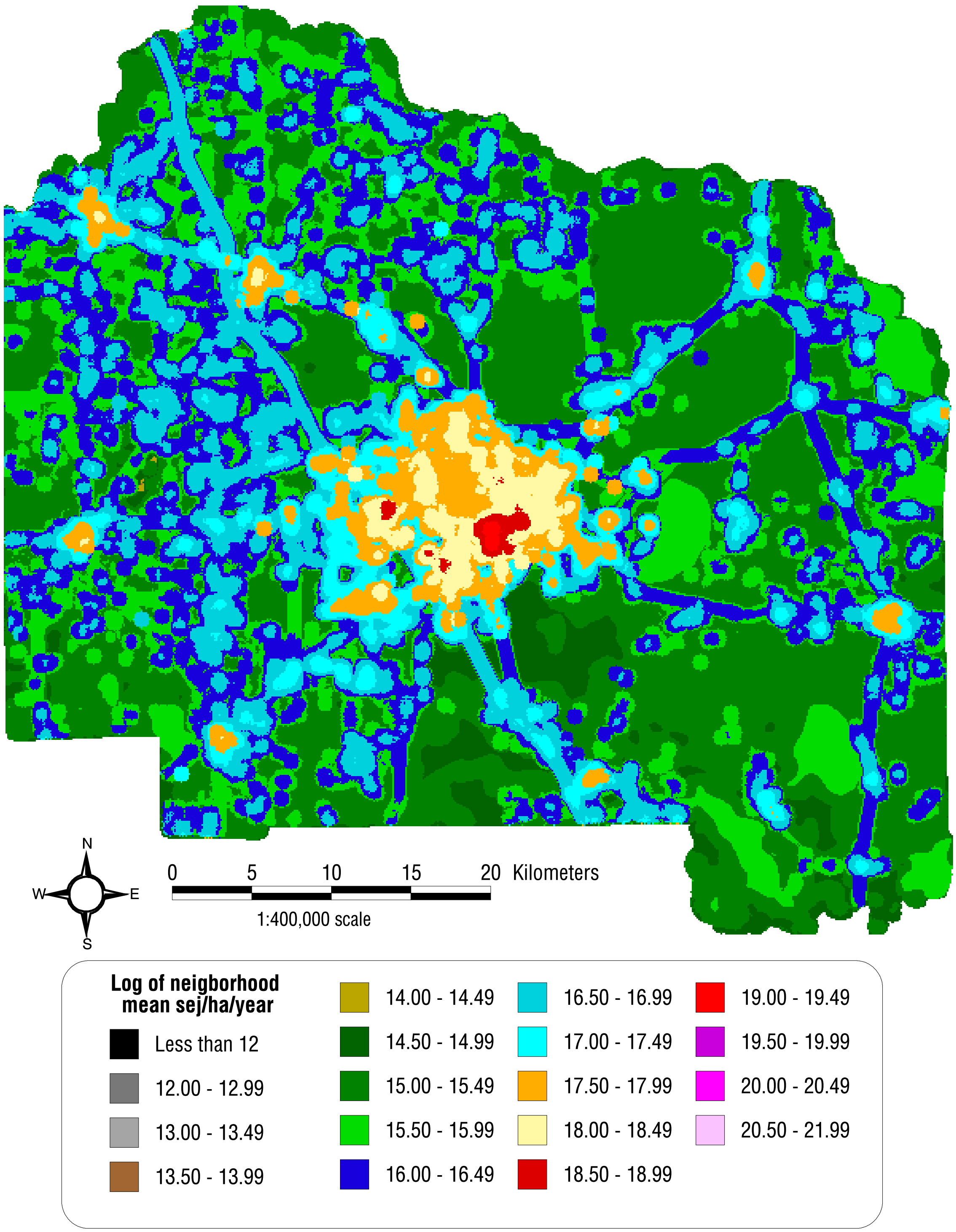


Figure 3 -166: Map showing the log of the 'five-cell-radius neighborhood' mean total annual EMPOWER density (log of neighborhood mean sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmean5c' (shown here) represent the log of the mean of the total EMPOWER density values (sej/ha/yr) of those cells that are within a 'neigborhood' defined by a five cell radius around each cell.

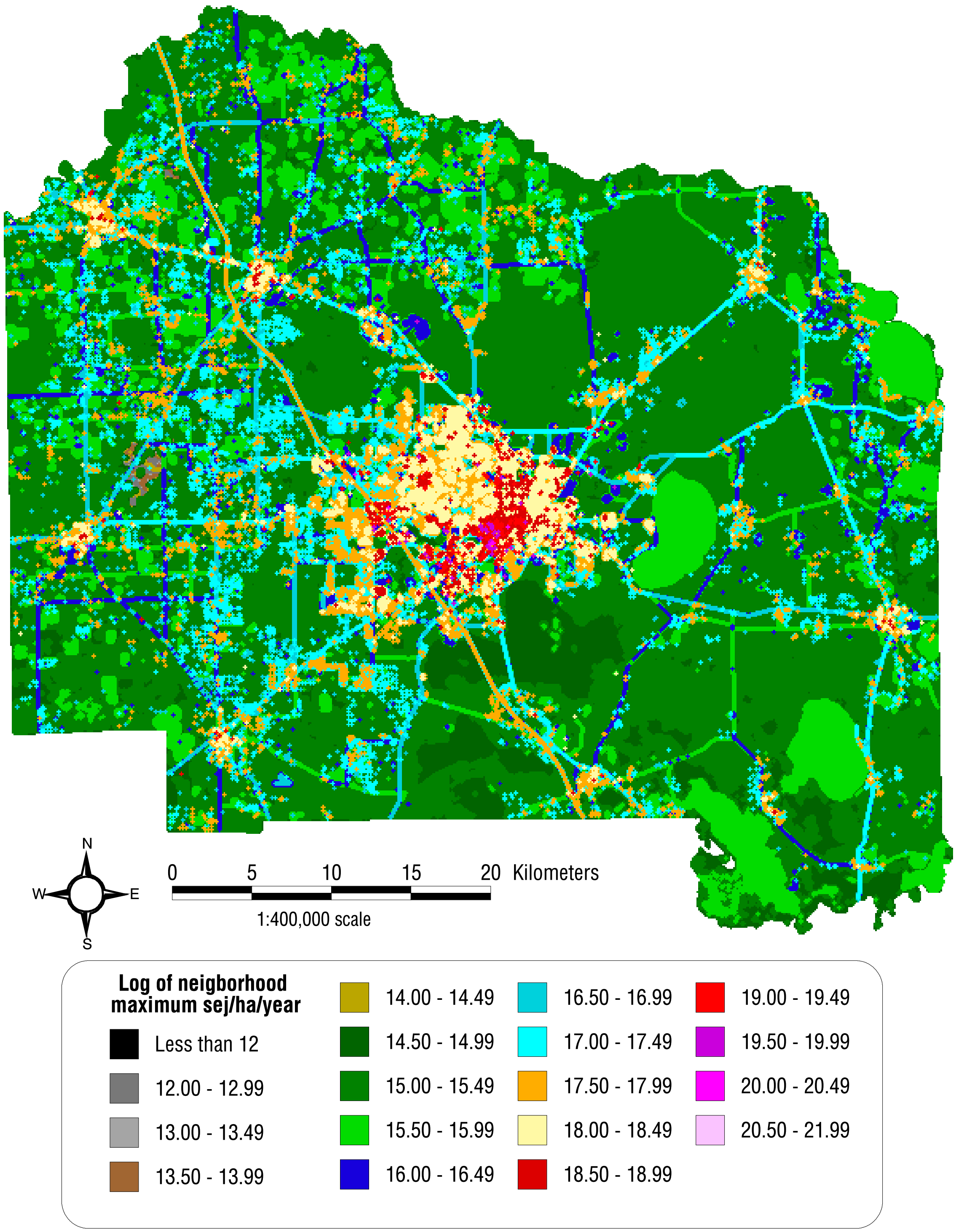


Figure 3 -167: Map showing the log of the 'one-cell-radius neighborhood' maximum value for the total annual EMPOWER density (log of neighborhood maximum sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmax1c' (shown here) represent the log of the maximum value for total EMPOWER density taken from the values (sej/ha/yr) of those cells that are within a 'neigborhood' defined by a one cell radius around each cell.

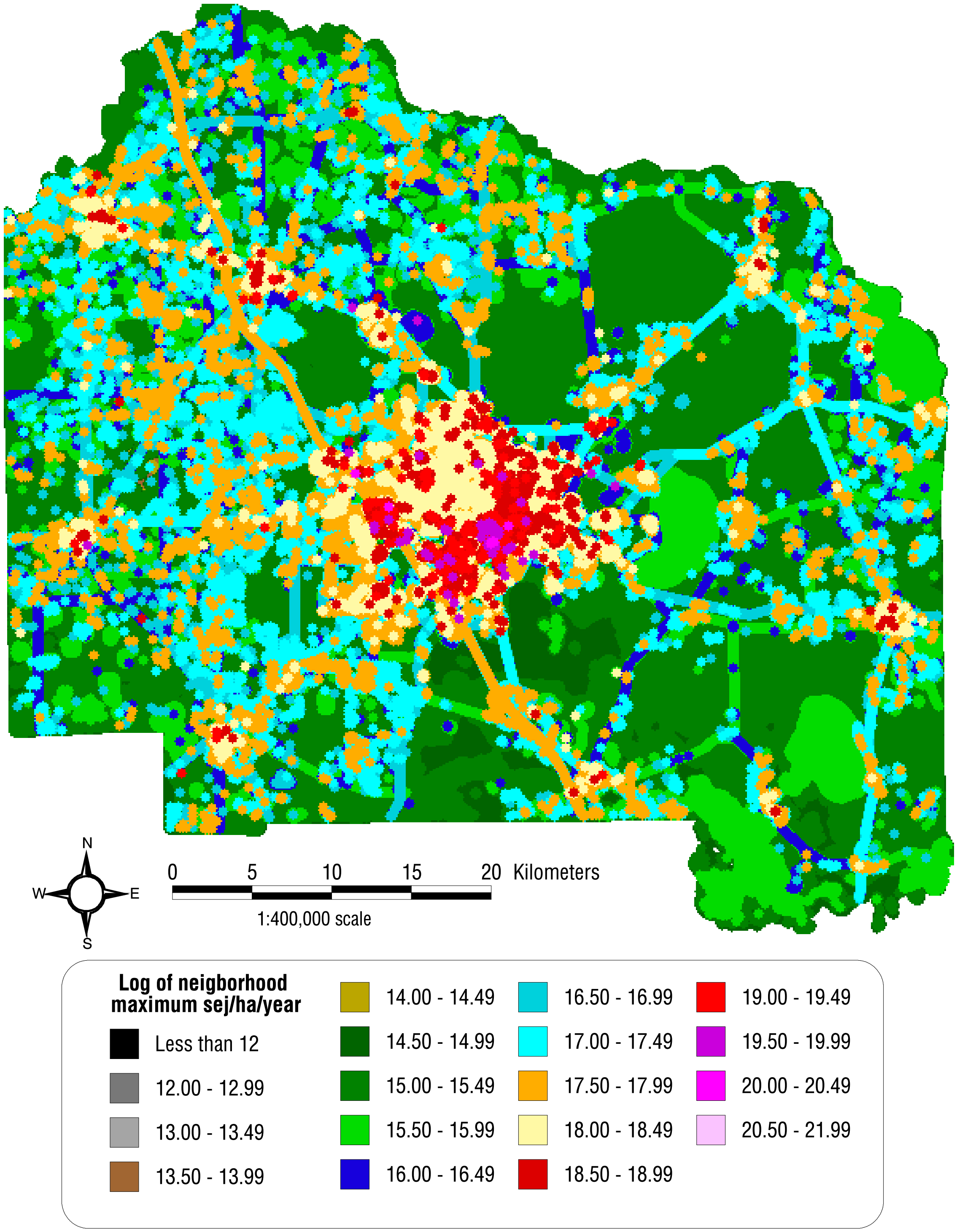


Figure 3 -168: Map showing the log of the 'three-cell-radius neighborhood' maximum value for the total annual EMPOWER density (log of neighborhood maximum sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmax3c' (shown here) represent the log of the maximum value for total EMPOWER density taken from the values (sej/ha/yr) of those cells that are within a 'neigborhood' defined by a three cell radius around each cell.

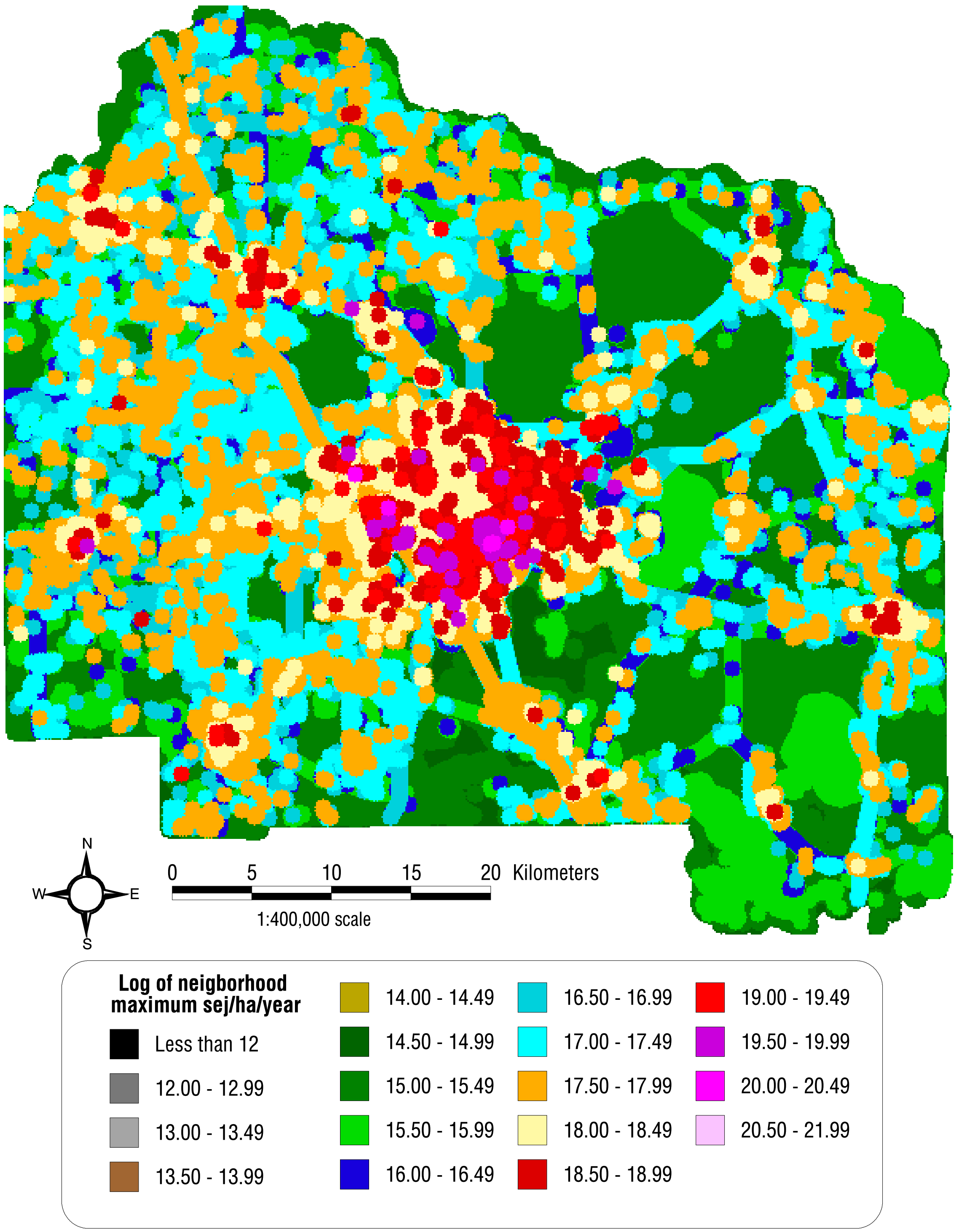


Figure 3 -169: Map showing the log of the 'five-cell-radius neighborhood' maximum value for the total annual EMPOWER density (log of neighborhood maximum sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmax5c' (shown here) represent the log of the maximum value for total EMPOWER density taken from the values (sej/ha/yr) of those cells that are within a 'neigborhood' defined by a five cell radius around each cell.

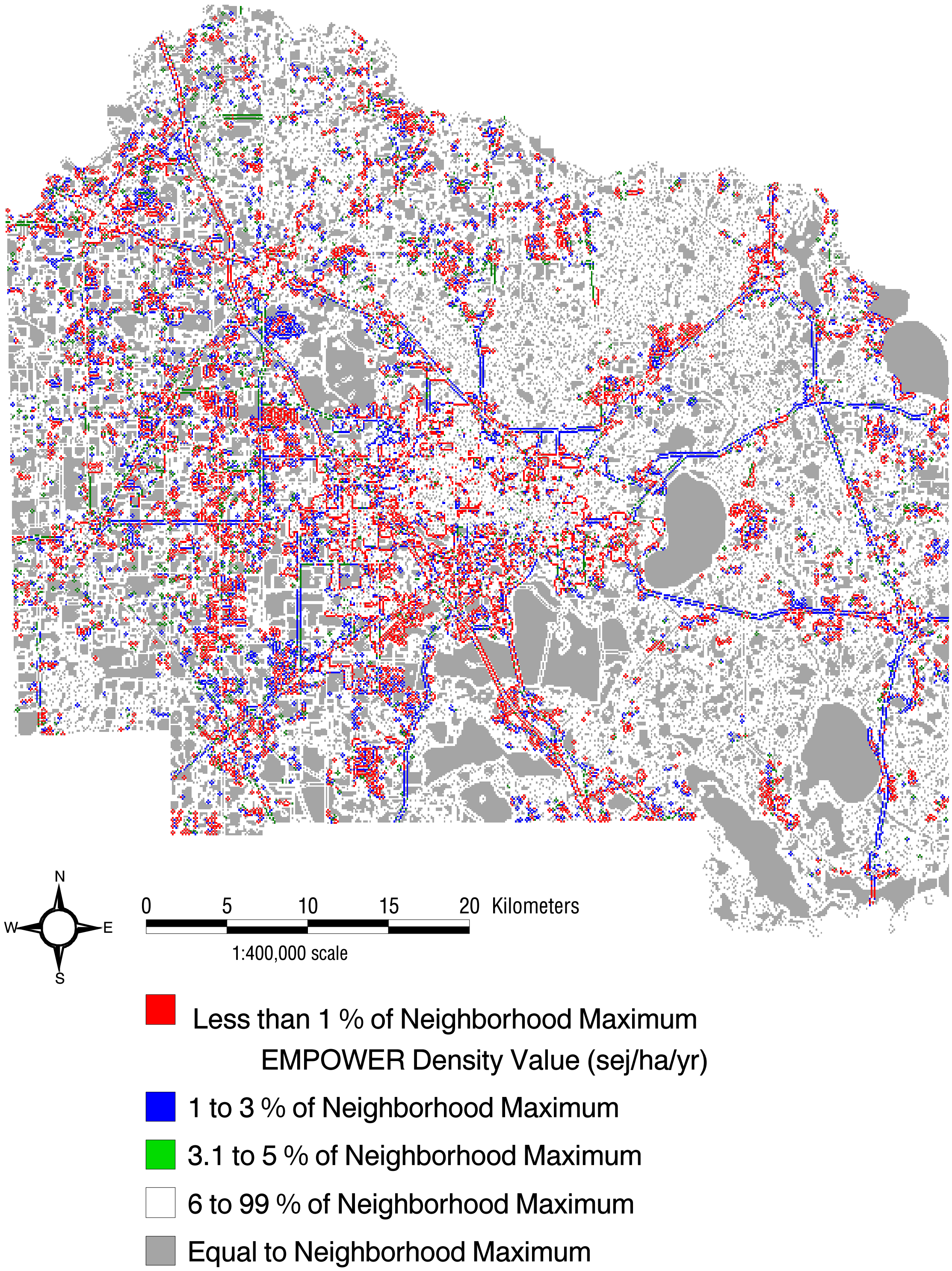


Figure 3 -170: Map of the percentage of the 'one-cell-radius neighborhood' maximum value for total annual EMPOWER density. The values in each cell of the analytical grid called 'pctmaxpwr1c' (shown here) were calculated by: first, finding the maximum EMPOWER density value (sej/ha/yr) in those cells that are within a 'neigborhood' defined by a one cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 to get the percentage values.

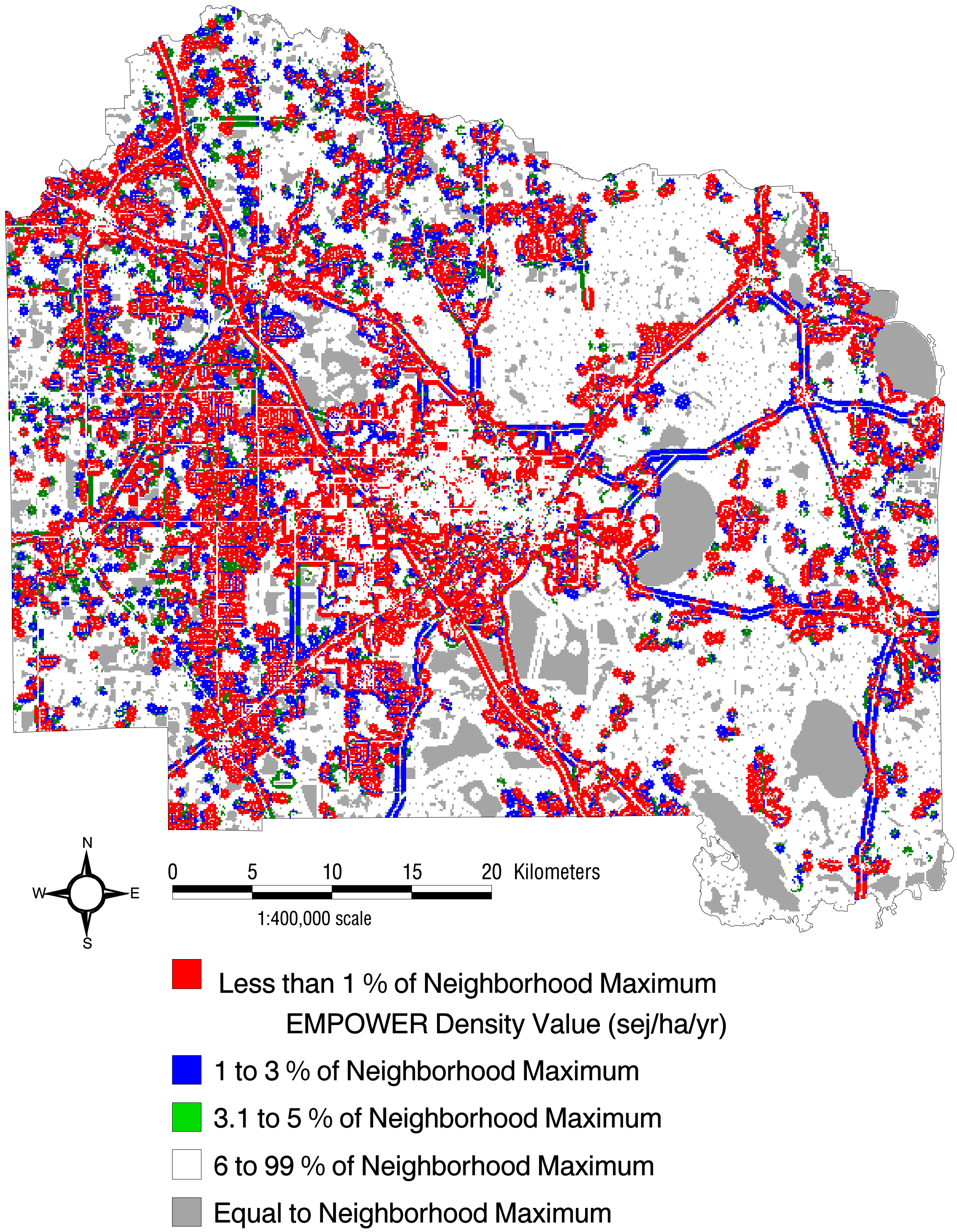


Figure 3 -171: Map of the percentage of the 'three-cell-radius neighborhood' maximum value for total annual EMPOWER density. The values in each cell of the analytical grid called 'pctmaxpwr3c' (shown here) were calculated by: first, finding the maximum EMPOWER density value (sej/ha/yr) in those cells that are within a 'neigborhood' defined by a three cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 to get the percentage values.

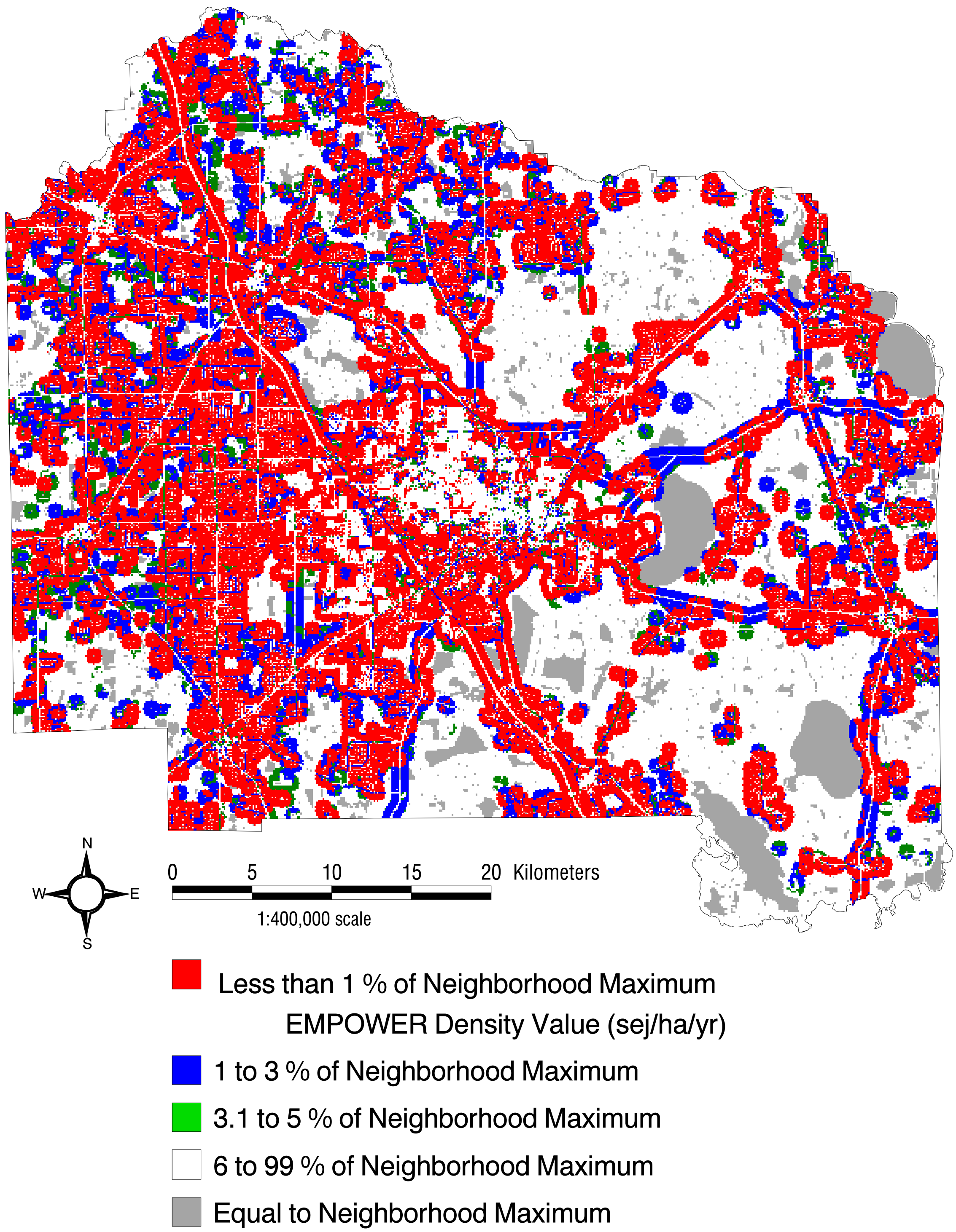


Figure 3 -172: Map of the percentage of the 'five-cell-radius neighborhood' maximum value for total annual EMPOWER density. The values in each cell of the analytical grid called 'pctmaxpwr5c' (shown here) were calculated by: first, finding the maximum EMPOWER density value (sej/ha/yr) in those cells that are within a 'neigborhood' defined by a five cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 to get the percentage values.

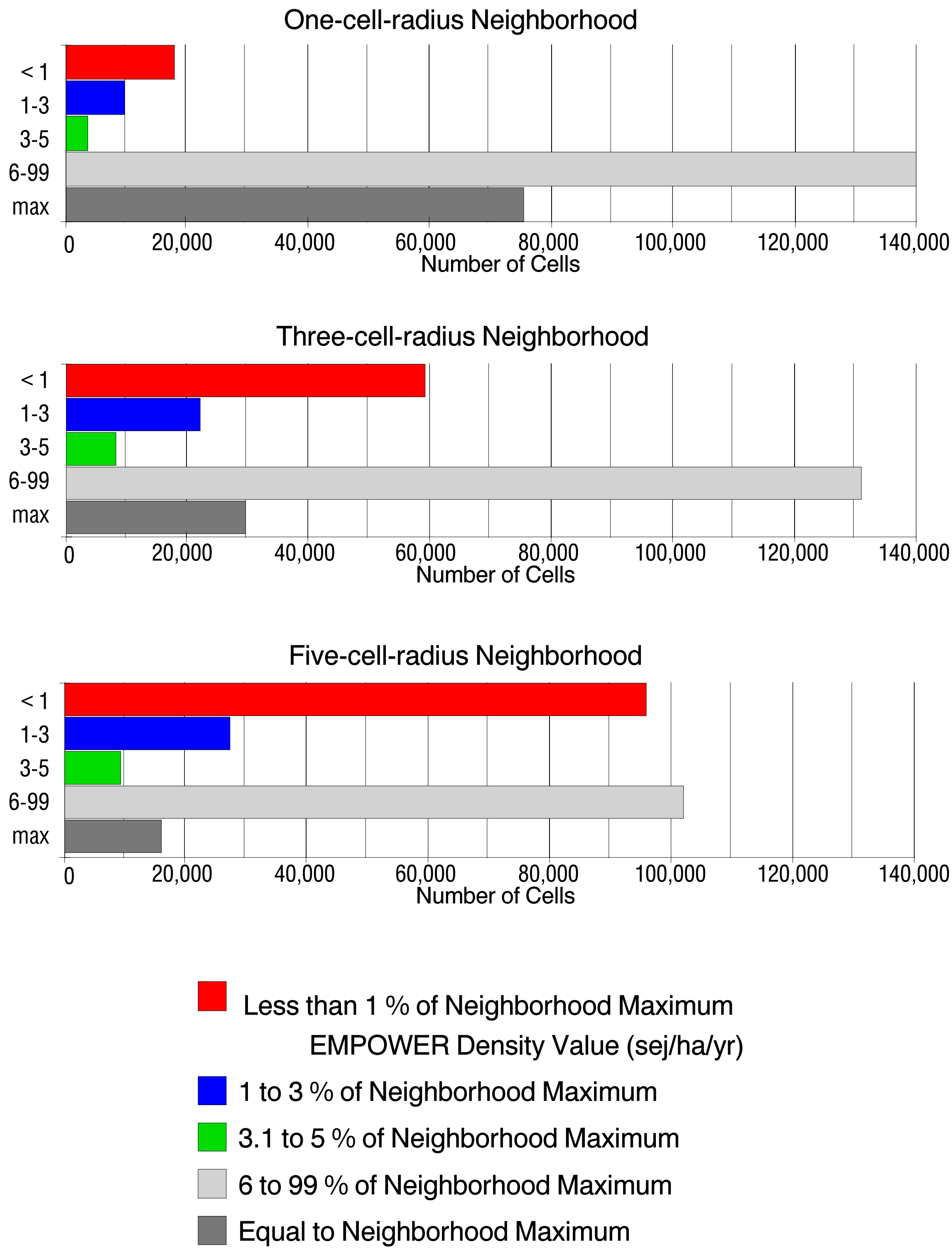


Figure 3-173: Histograms showing the number of cells within each range of percentages of the neighborhood maximum EMPOWER density for the three different (1,3, or 5) cell-radius neighborhood analyses.

EMSTORAGE Density Context Analysis

Neighborhood mean total annual EMSTORAGE density. The results of the calculation of neighborhood mean value for the total annual EMSTORAGE density are shown in Figure 3-174 (the 'one-cell-radius neighborhood' mean), Figure 3-175 (the 'three-cell-radius neighborhood' mean), and Figure 3-176 (the 'five-cell-radius neighborhood' mean). As noted previously, the three different cell-radius maps have to be considered as a group to observe the effect of increasing the neighborhood size. Because the range of EMSTORAGE density values is not as wide as the range for the EMPOWER density values, the effect of increasing neighborhood size is slightly less pronounced. However, there are still increasing numbers of cells with higher values, and fewer isolated cells with very high values as the cell radius increases as a result of the mathematical method.

Neighborhood maximum total annual EMSTORAGE density. The results of the calculation of neighborhood maximum value for the total annual EMSTORAGE density are shown in Figure 3-177 (the 'one-cell-radius' maximum), Figure 3-178 (the 'three-cell-radius' maximum), and Figure 3-179 (the 'five-cell-radius' maximum). As was done for the EMPOWER analysis, the value of each cell in the output analytical grid is set to the maximum value that is found for the cells within the neighborhood. The map series presenting the results of this analysis emphasizes the spatial distribution of the highest EMSTORAGE density values. These high value areas are primarily associated with buildings—road structure is not prominent in the spatial patterns of the maps because the storage density values are actually lower than other components contributing to the total

EMSTORAGE density. The patterns in the three neighborhood maximum maps reinforce the previous observation that small areas of relatively high EMSTORAGE density are widely dispersed throughout the rural areas of the county. The three-cell-radius and five-cell-radius maps help to emphasize the location of urban areas with very high EMSTORAGE density values (greater than 20.5 sej/ha). These areas are associated with commercial and institutional land uses.

Percent of neighborhood maximum total annual EMSTORAGE density. The results of the calculation of the percentage of the neighborhood maximum value for the total annual EMSTORAGE density are shown in Figure 3-180 (% the 'one-cell-radius' maximum), Figure 3-181 (% the 'three-cell-radius' maximum), and Figure 3-182 (% the 'five-cell-radius' maximum). Figure 3-183 presents a histogram showing the number of cells within each range of percentages of the neighborhood maximum for the three different (1,3, or 5) cell-radius neighborhoods. The histogram shows that, compared to the number of cells with EMPOWER density values that were less than 1% of the neighborhood maximum value, that there are much fewer cells that have EMSTORAGE density values that are less than 1% of the neighborhood maximum. This observation is reinforced by the patterns seen in the three cell-radius maps. The magnitude of the difference between each cell value and its maximum neighborhood value is generally lower in the EMSTORAGE density analytical grid. The areas with the greatest percentage difference in values are generally found at the interface between urban and rural areas. The 'edges' in rural areas are less pronounced than those observed in the EMPOWER density analysis because the difference between the EMPOWER density values for 'urban structure' and 'natural structure' is not as great in rural areas.

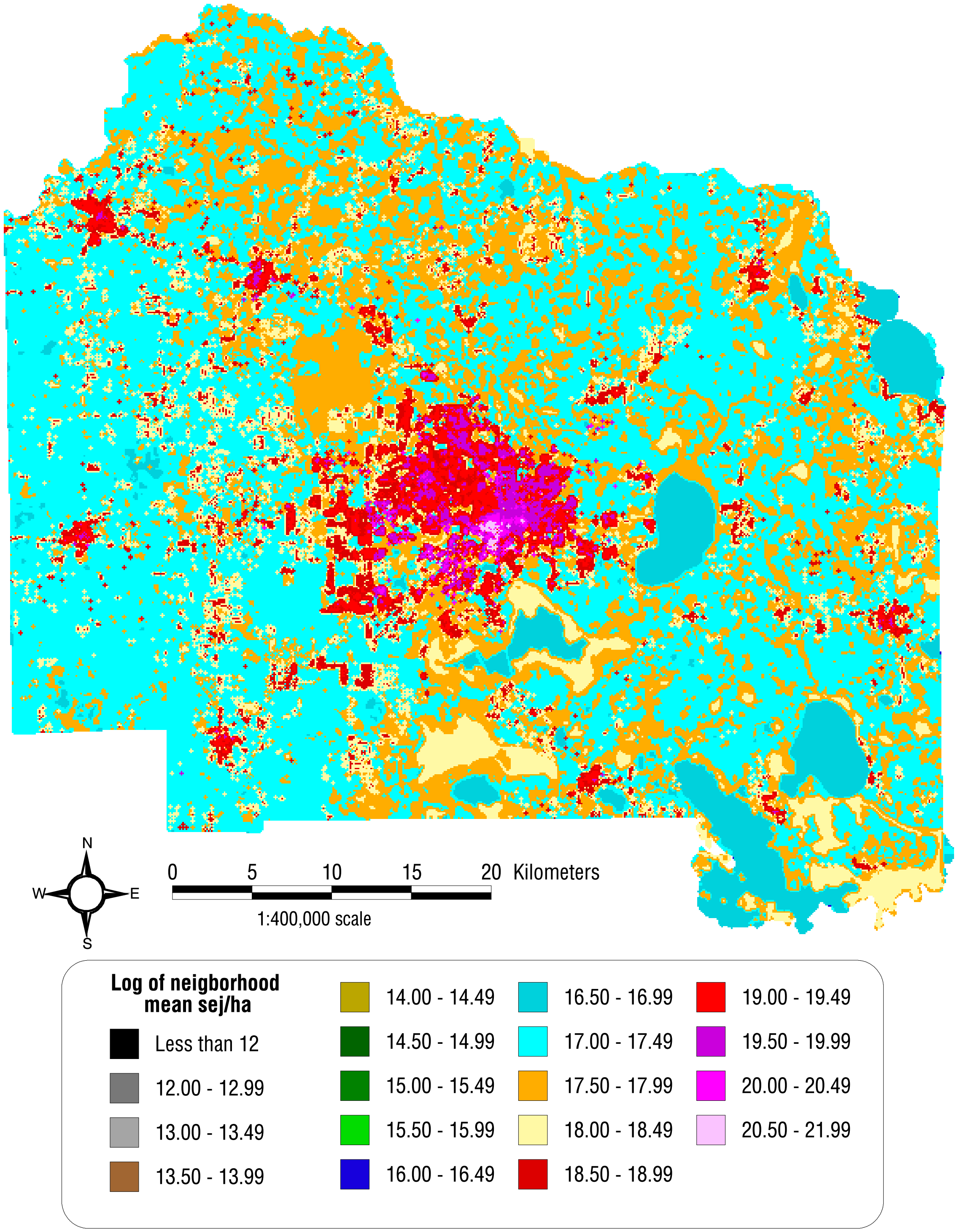


Figure 3-174: Map showing the log of the 'one-cell-radius neighborhood' mean total EMSTORAGE density (log of neighborhood mean sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmean1c' (shown here) represent the log of the mean of the total EMSTORAGE density values (sej/ha) of those cells that are within a 'neigborhood' defined by a one cell radius around each cell.

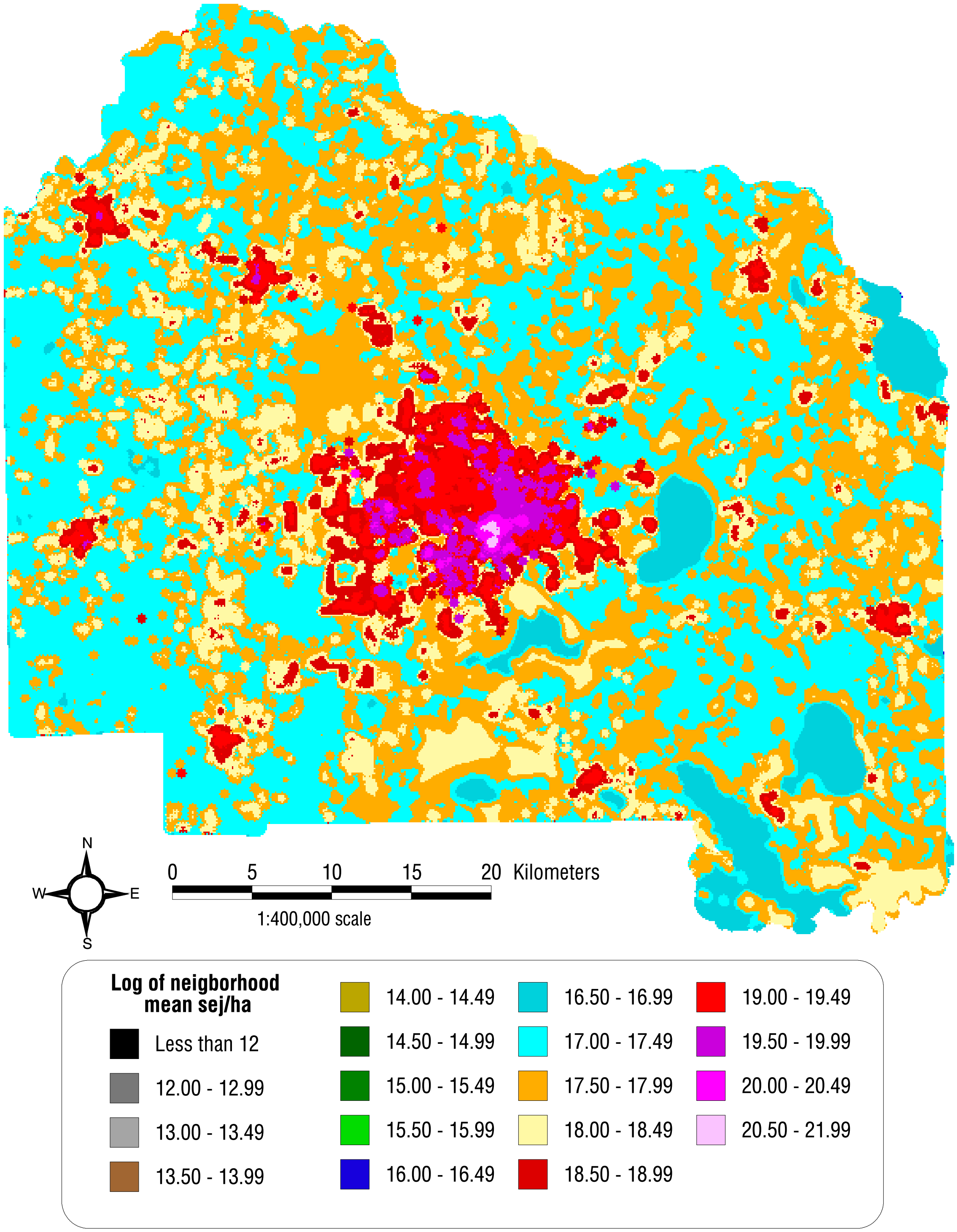


Figure 3-175: Map showing the log of the 'three-cell-radius neighborhood' mean total EMSTORAGE density (log of neighborhood mean sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmean3c' (shown here) represent the log of the mean of the total EMSTORAGE density values (sej/ha) of those cells that are within a 'neigborhood' defined by a three cell radius around each cell.

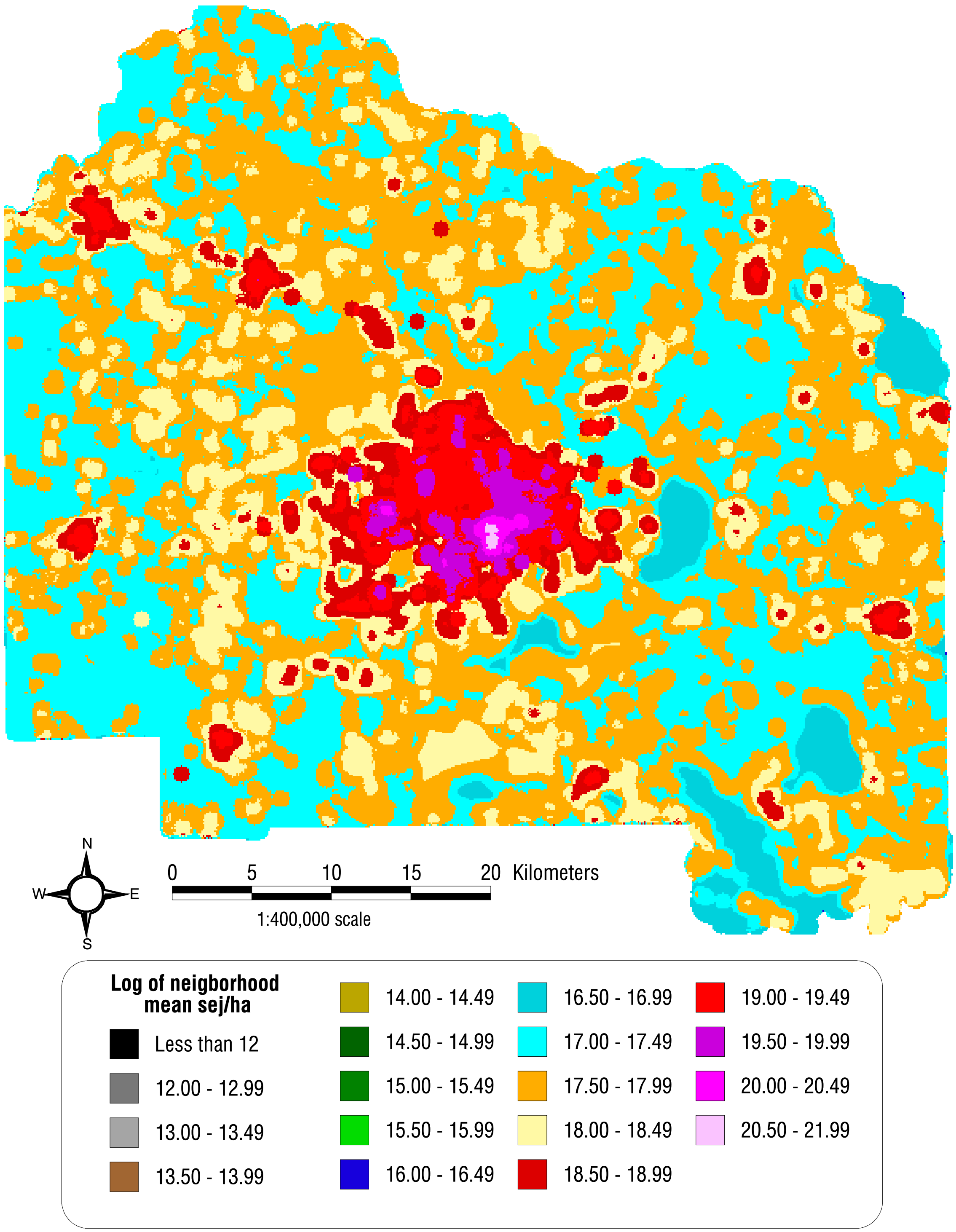


Figure 3-176: Map showing the log of the 'five-cell-radius neighborhood' mean total EMSTORAGE density (log of neighborhood mean sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmean5c' (shown here) represent the log of the mean of the total EMSTORAGE density values (sej/ha) of those cells that are within a 'neigborhood' defined by a five cell radius around each cell.

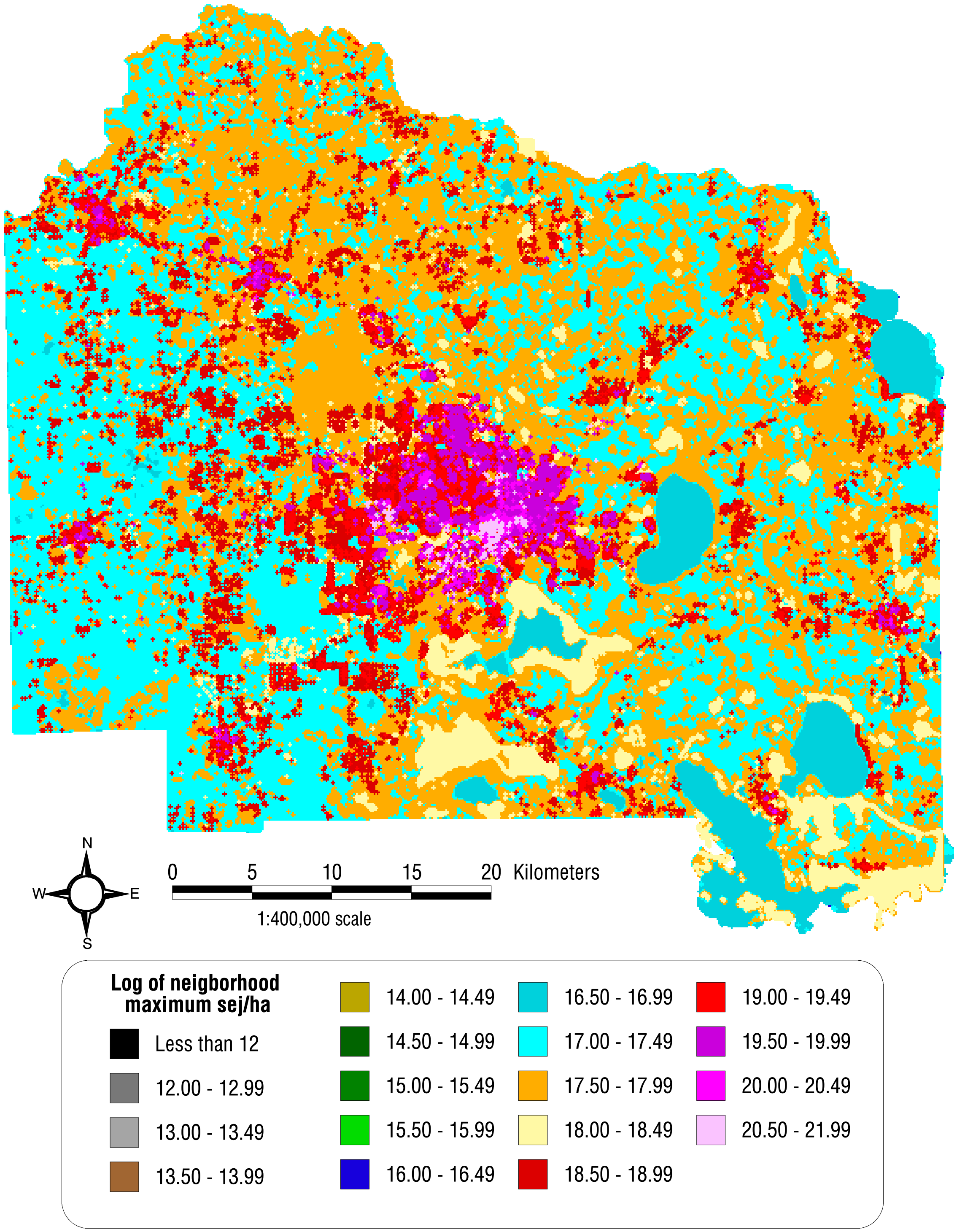


Figure 3 -177: Map showing the log of the 'one-cell-radius neighborhood' maximum value for the total EMSTORAGE density (log of neighborhood maximum sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmax1c' (shown here) represent the log of the maximum value for total EMSTORAGE density taken from the values (sej/ha) of those cells that are within a 'neigborhood' defined by a one cell radius around each cell.

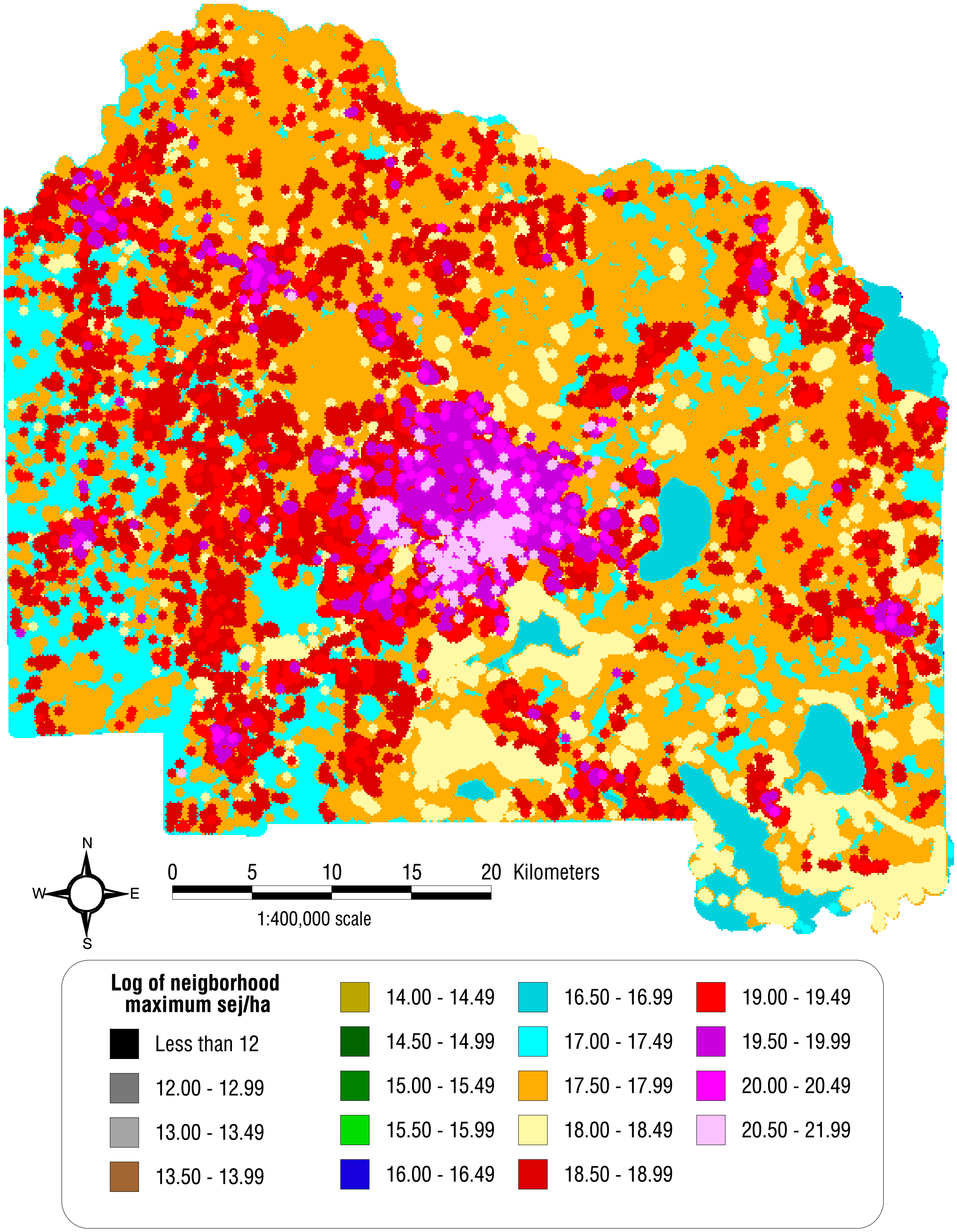


Figure 3-178: Map showing the log of the 'three-cell-radius neighborhood' maximum value for the total EMSTORAGE density (log of neighborhood maximum sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmax3c' (shown here) represent the log of the maximum value for total EMSTORAGE density taken from the values (sej/ha) of those cells that are within a 'neigborhood' defined by a three cell radius around each cell.

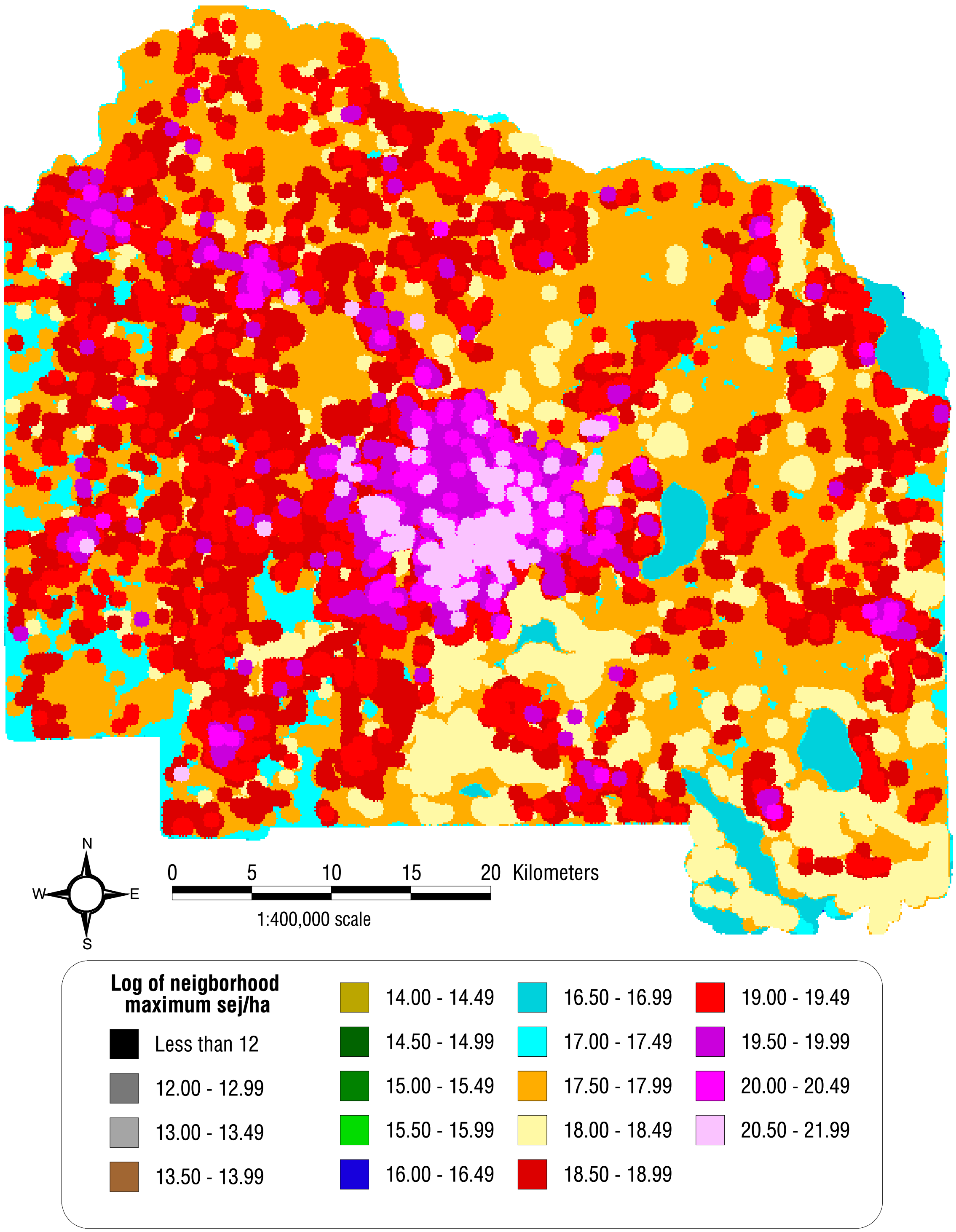


Figure 3-179: Map showing the log of the 'five-cell-radius neighborhood' maximum value for the total EMSTORAGE density (log of neighborhood maximum sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmax5c' (shown here) represent the log of the maximum value for total EMSTORAGE density taken from the values (sej/ha) of those cells that are within a 'neigborhood' defined by a five cell radius around each cell.

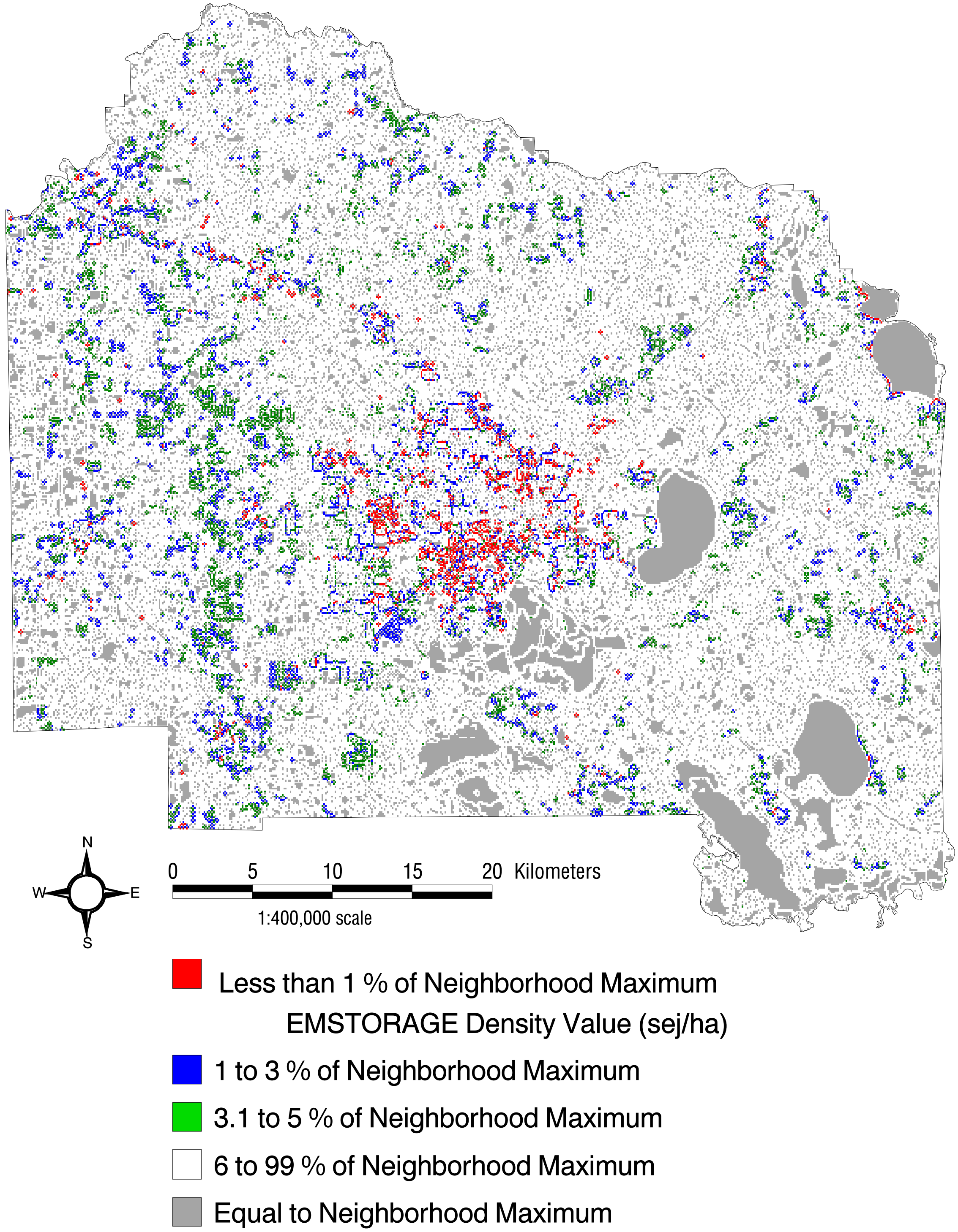


Figure 3-180: Map of the percentage of the 'one-cell-radius neighborhood' maximum value for total EMSTORAGE density. The values in each cell of the analytical grid called 'pctmaxstr1c' (shown here) were calculated by: first, finding the maximum EMSTORAGE density value (sej/ha) in those cells that are within a 'neigborhood' defined by a one cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 to get the percentage values.

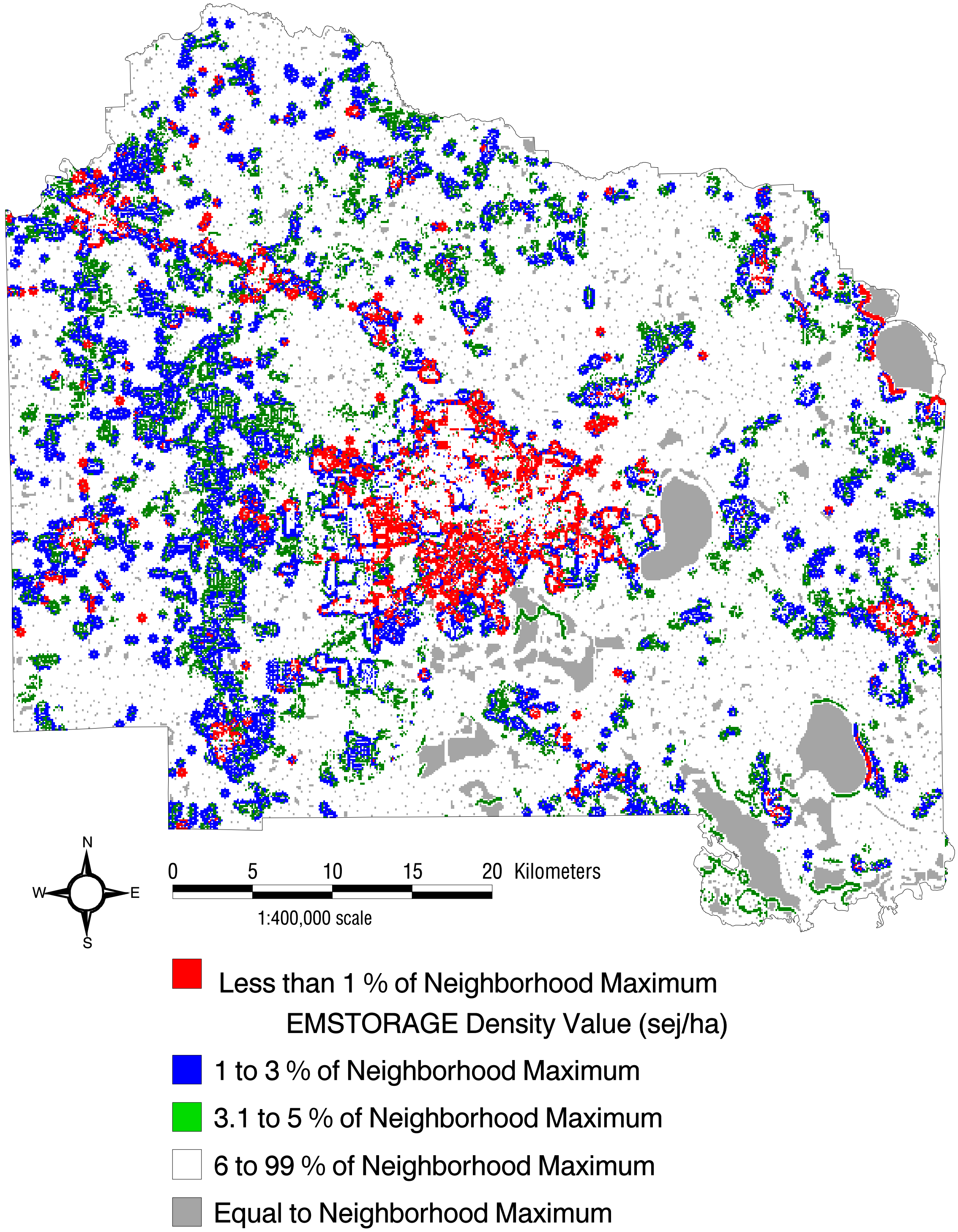


Figure 3-181: Map of the percentage of the 'three-cell-radius neighborhood' maximum value for total EMSTORAGE density. The values in each cell of the analytical grid called 'pctmaxstr3c' (shown here) were calculated by: first, finding the maximum EMSTORAGE density value (sej/ha) in those cells that are within a 'neigborhood' defined by a three cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 to get the percentage values.

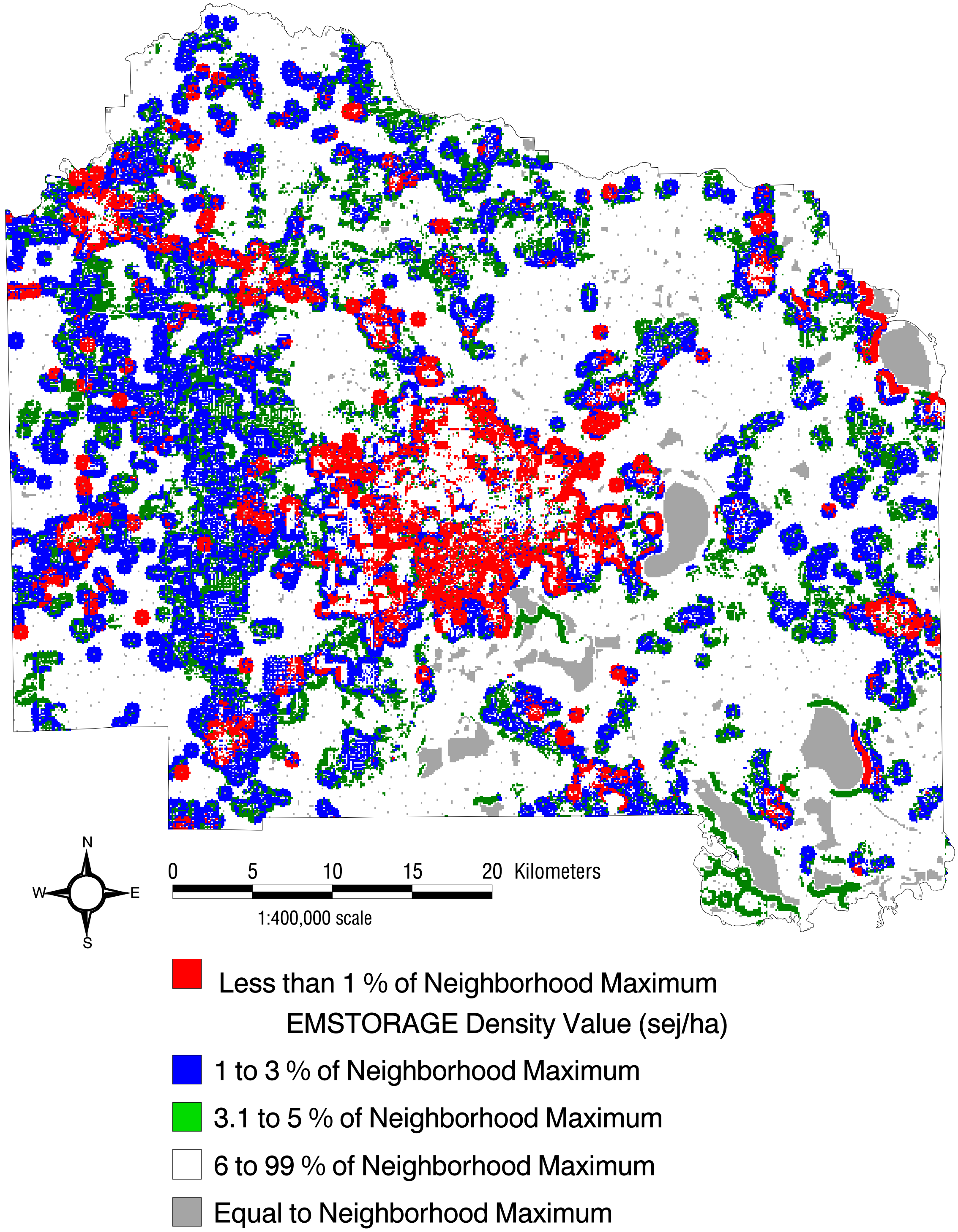


Figure 3-182: Map of the percentage of the 'five-cell-radius neighborhood' maximum value for total EMSTORAGE density. The values in each cell of the analytical grid called 'pctmaxstr5c' (shown here) were calculated by: first, finding the maximum EMSTORAGE density value (sej/ha) in those cells that are within a 'neigborhood' defined by a five cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 to get the percentage values.

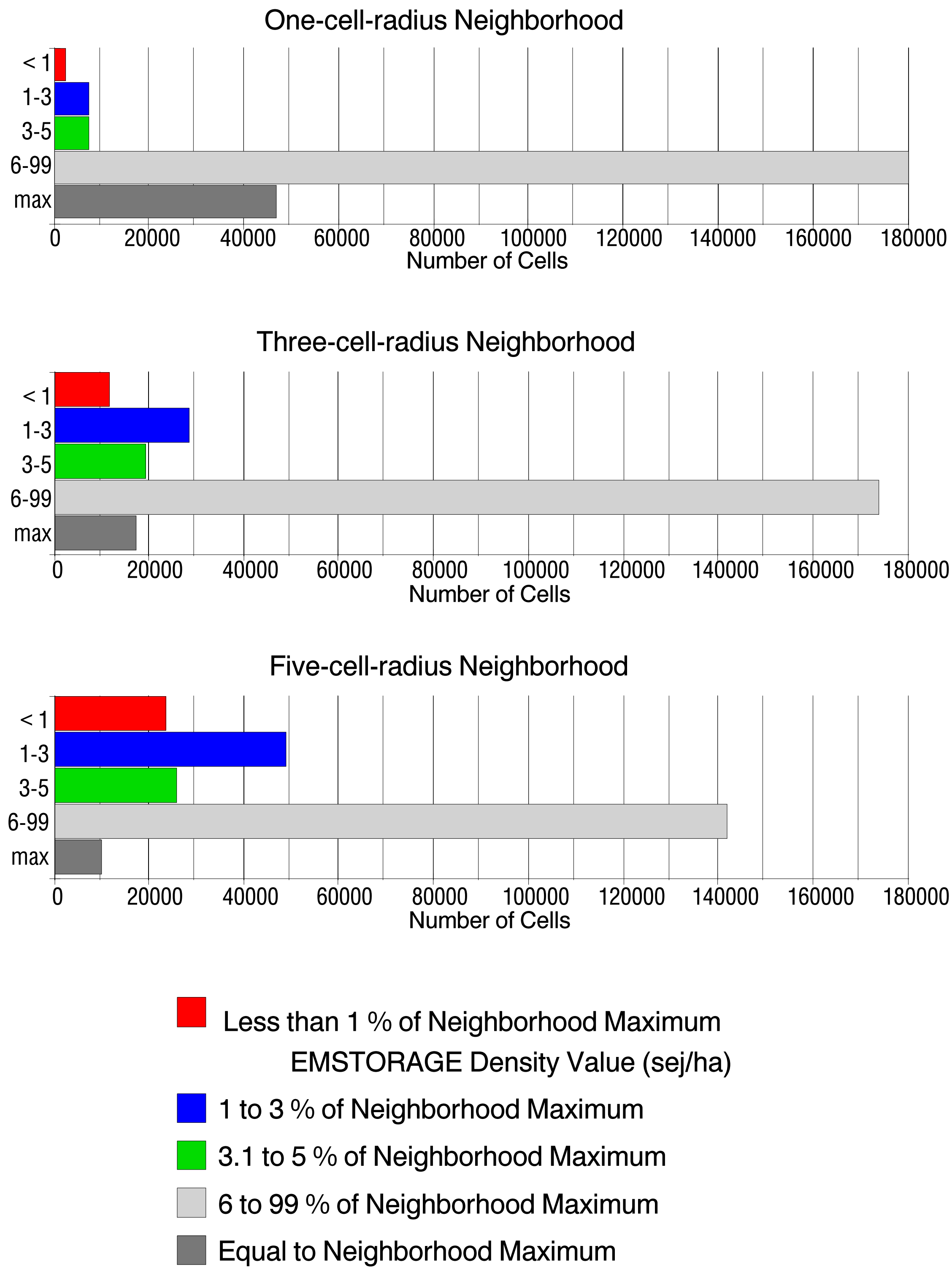


Figure 3-183: Histograms showing the number of cells within each range of percentages of the neighborhood maximum EMSTORAGE density for the three different (1,3, or 5) cell-radius neighborhood analyses.

One-Kilometer-Resolution Model

All of the component and analytical grids presented previously have had one-hectare size cells. This resolution has been shown to be appropriate for creating EMERGY component and analytical grids and maps that show enough spatial detail to be useful for examining EMERGY distribution patterns in urban landscapes. However, if one wanted to make a spatial EMERGY model for a much larger region, such as a state or country, a coarser resolution model might be more appropriate. In anticipation of creating models of larger regions, several of the analytical grids created for this study were generalized to create analytical grids with one-kilometer cells.

A map showing the log of the total annual EMPOWER density for one kilometer square cells is presented in Figure 3-184. The values in each one kilometer cell represent the log of the sum of the total annual EMPOWER density values in the 100 spatially coincident cells of the one-hectare cell size analytical grid. When this map is compared to the original EMPOWER density map (in Figure 3-100), the effect of summing the values from the one-hectare cell model is obvious by the larger magnitude of the values in the one-kilometer model.

In the one-kilometer model it is much harder to recognize features such as roads, agricultural fields, and neighborhoods. The generalized patterns are not nearly as intuitive as the more precise patterns that are observable in the one-hectare model. It is clear that neighborhood and land use class comparisons would not be practical at the one-kilometer scale—planning unit comparisons could still be useful. Context analysis would probably not be as meaningful at this scale.

Because of the smaller range of EMSTORAGE density values, the patterns in the map of the one-kilometer model of total EMSTORAGE density, shown in Figure 3-185, are very generalized. In fact, the whole City of Gainesville is shown as having the same density value range. This generalization makes observations about the structure of urban areas impossible. Compared to the one-hectare model of EMSTORAGE density, shown in Figure 3-106, the one-kilometer model is only moderately useful for understanding the patterns of distribution, and could not be used effectively for many of the analyses presented in this study.

Figure 3-186 shows a map of the annual 'resource use' EMPOWER density for one kilometer square cells, and Figure 3-187 shows the map of the annual nonrenewable resource use EMPOWER density for one kilometer square cells. Interestingly, these maps display more recognizable patterns than the previous two maps did. However, these maps would still not be useful for the comparison and context analyses.

Although it has been shown that the one-kilometer model results will not be nearly as useful for studying the EMERGY distribution patterns of cities, this resolution could still be useful for state and country scale studies. At this scale, planning unit comparison studies, especially EMERGY ratio analysis, would be appropriate and could be meaningful. In any case, the one-kilometer model maps help to reinforce the suitability of the one-hectare cell size for spatial EMERGY models of cities and smaller regions such as counties.

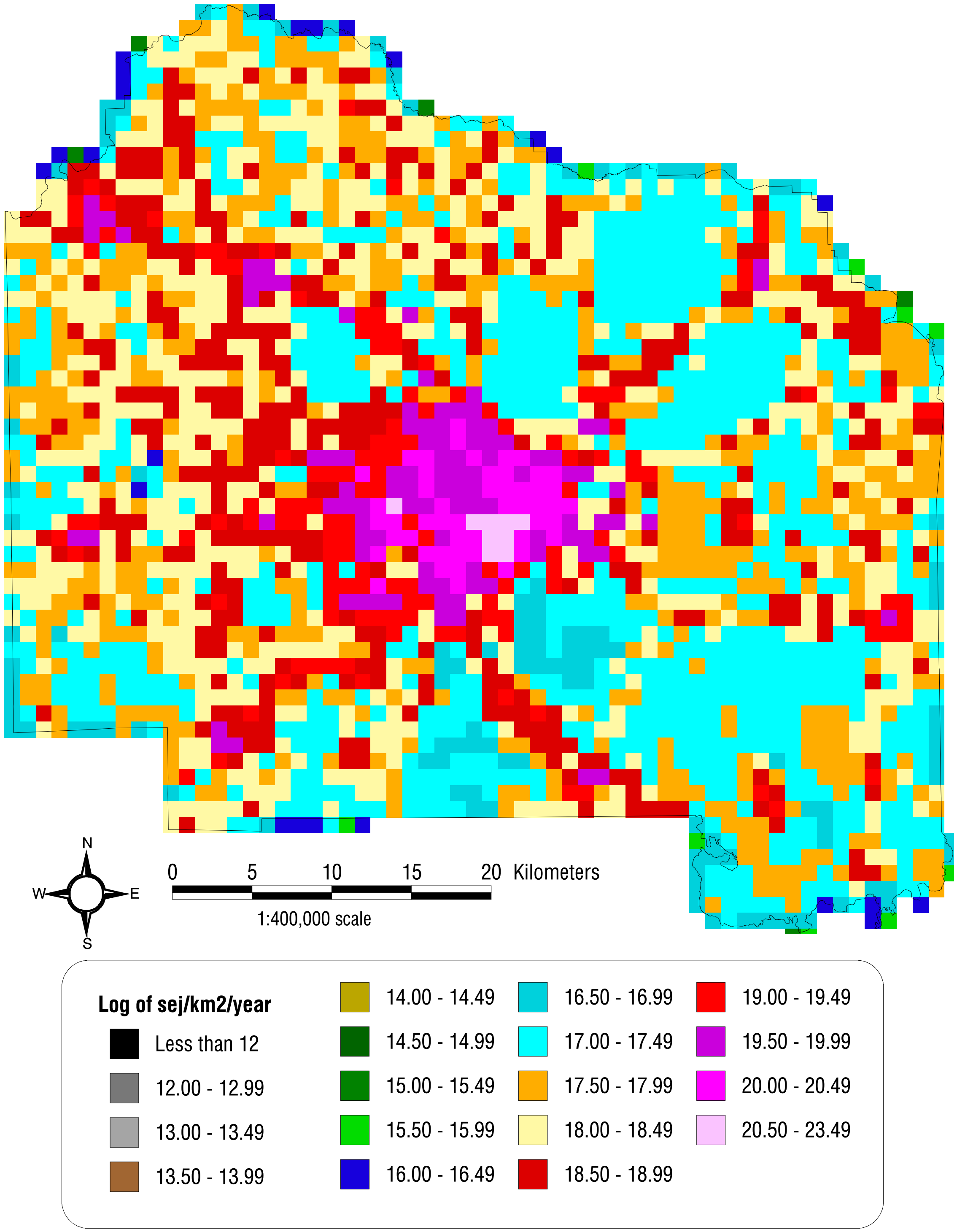


Figure 3-184: Map showing the log of the total annual EMPOWER density for one kilometer square cells (log sej/km2/yr). The values in each one kilometer square cell of the logarithm analytical EMERGY grid called 'empwr_1k_log' (shown here) represent the log of the sum of the total EMPOWER density values (sej/ha/yr) in the spatially corresponding cells of the analytical grid called 'empower' (i.e., the sum of the100 one hectare cell density values in each square kilometer).

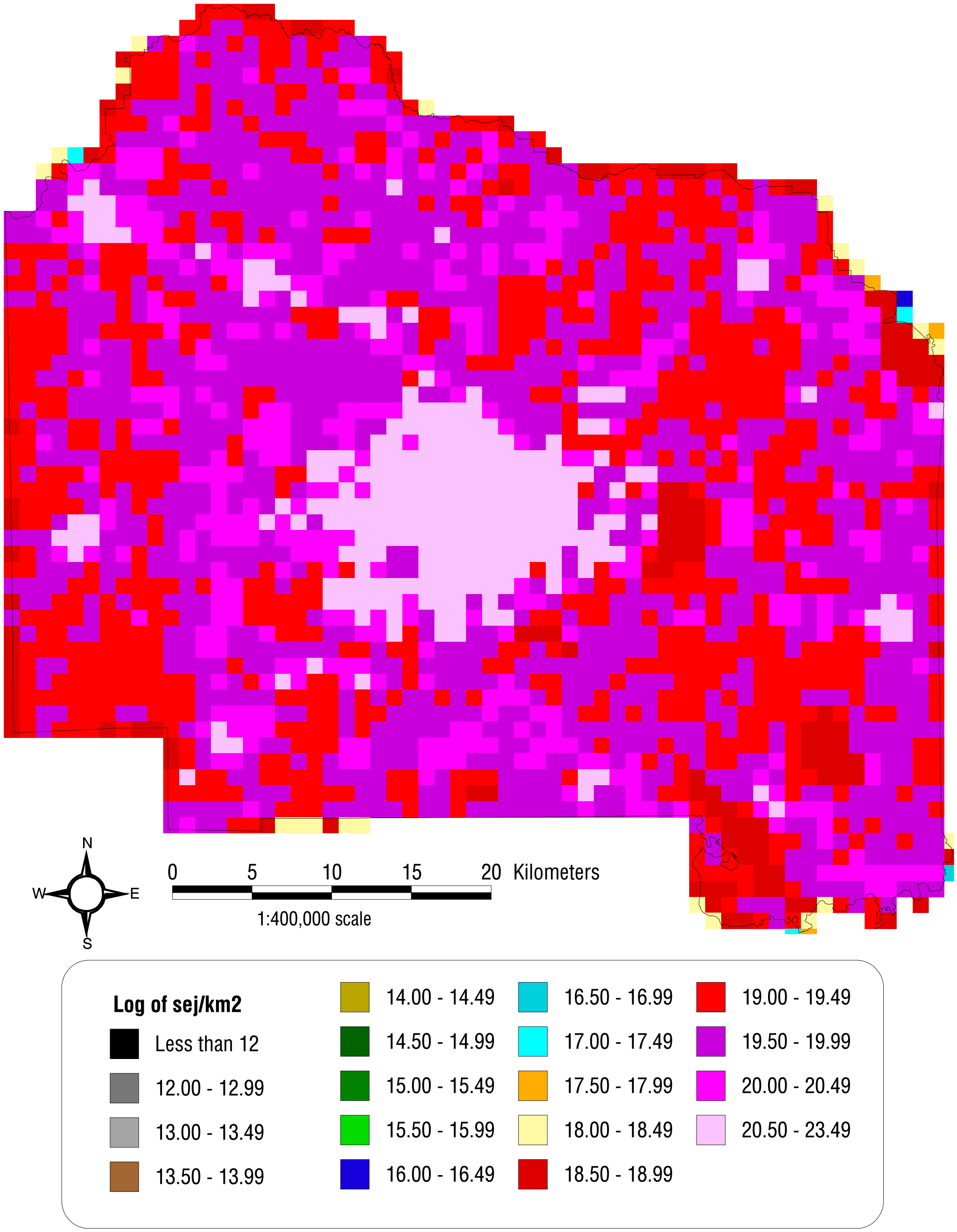


Figure 3-185: Map showing the log of the total EMSTORAGE density for one kilometer square cells (log sej/km2). The values in each one kilometer square cell of the logarithm analytical EMERGY grid called 'emstr_1k_log' (shown here) represent the log of the sum of the total EMSTORAGE density values (sej/ha) in the spatially corresponding cells of the analytical grid called 'emstore' (i.e., the sum of the100 one hectare cell density values in each square kilometer).

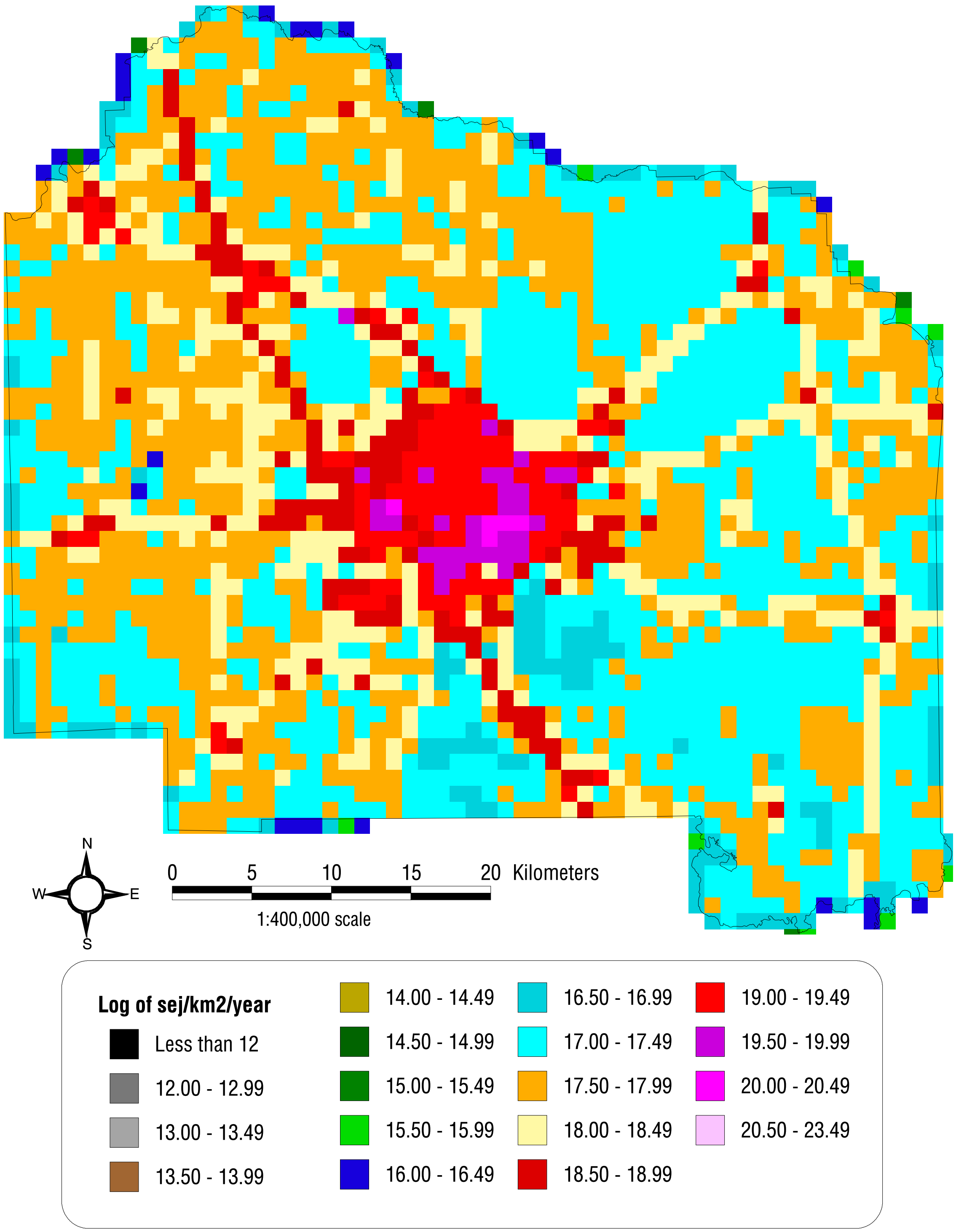


Figure 3-186: Map showing the log of the annual resource use EMPOWER density for one kilometer square cells (log sej/km2/yr). The values in each one kilometer square cell of the logarithm analytical EMERGY grid called 'resuse_1k_log' (shown here) represent the log of the sum of the EMPOWER density values (sej/ha/yr) in the corresponding cells of the analytical grid called 'resuse' (i.e., the sum of the100 one hectare cell density values in each square kilometer). The 'resuse' grid is the sum of the component grids representing renewable resources used, water used, all fuels used, and goods consumed.

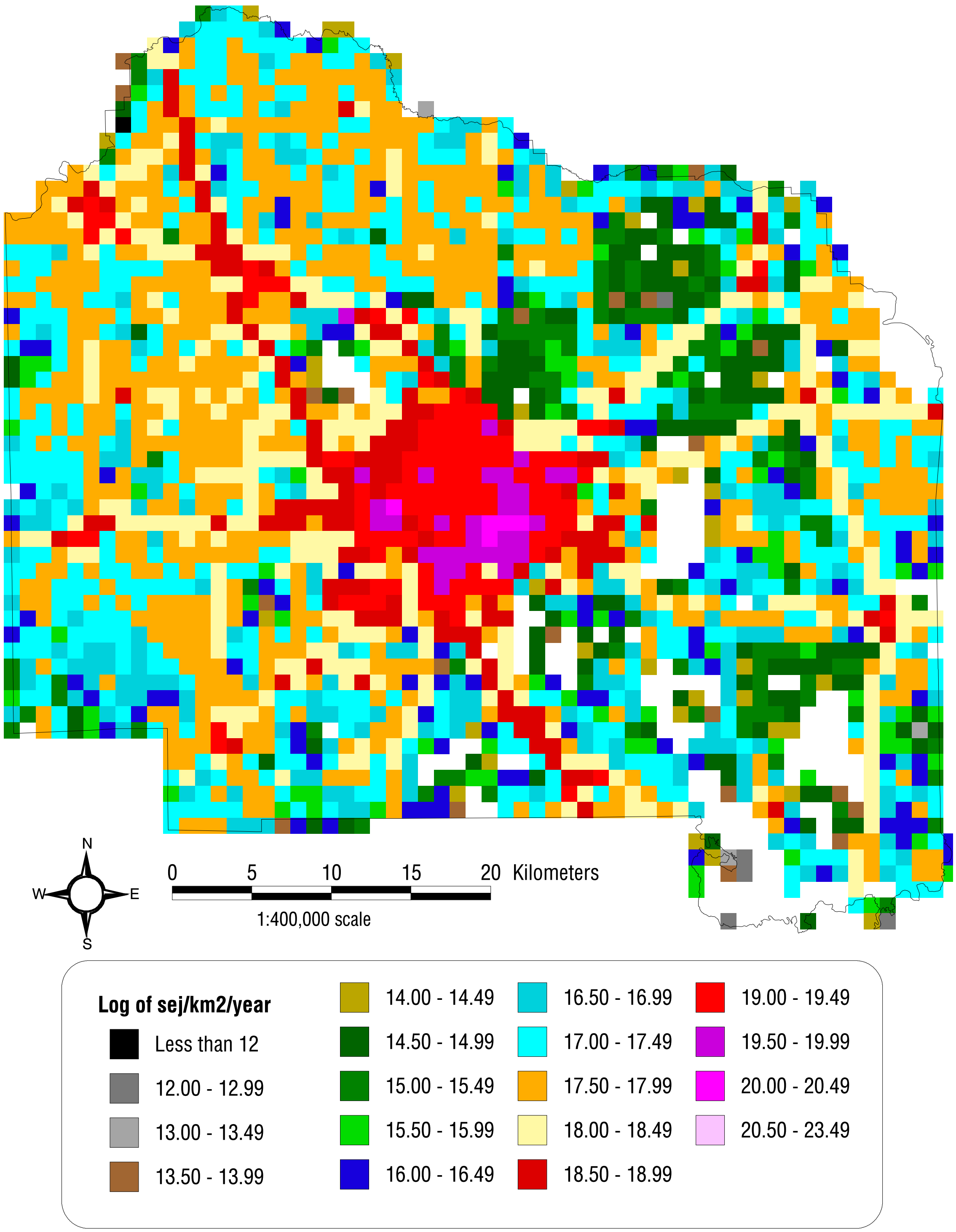


Figure 3-187: Map showing the log of the annual non-renewable resource use EMPOWER density for one kilometer square cells (log sej/km2/yr). The values in each one kilometer cell of the logarithm analytical EMERGY grid called 'nonren_1k_log' (shown here) represent the log of the sum of the EMPOWER density values (sej/ha/yr) in the corresponding cells of the analytical grid called 'nonrenew' (i.e., the sum of the100 one hectare cell density values in each square kilometer). The 'nonrenew' grid is the sum of the component grids representing water used, all fuels used, and goods consumed.

DISCUSSION

The primary goal for the study has been accomplished. The results of this study have demonstrated that the spatial model can provide insight into the spatial patterns of EMERGY and energy in relation to human settlement. A major conclusion taken from the many maps, charts, and tables presented in this study is that these results reinforce the observations and hypotheses of other researchers regarding the spatial patterns of energy transformation hierarchy.

Based on the results presented here, the land area unit modeling method is an appropriate and promising approach for modeling the spatial patterns of energy and EMERGY flows and storages in urban and regional landscapes. The method has the major advantage of being general enough that it can be used to study any urban system landscape with the results being directly comparable with results from studies of other urban systems.

The secondary goal of the study has also been accomplished. The types of analyses presented demonstrate that new advances in computer and GIS technology have greatly increased the potential for studying new aspects of these complex spatial patterns.

It is hoped that the specific analyses conducted using the model will be of interest to the primary target audience—urban planners. The results demonstrate that the land area unit modeling approach, using one-hectare cells as the area of the land unit, is capable of generating maps that are detailed enough to serve the needs of urban planners.

The following sections include more detailed discussion corresponding to the specific objectives stated in the introduction and some suggestions for future research.

General Theoretical Method

The first primary objective of this study was to develop a general method for the spatial modeling of energy flows and storages in an urban and regional landscape using energy transformation hierarchy theory and the land area unit energy system diagram model as a theoretical basis.

It has been pointed out that several previous related studies suggest that urban and regional systems may develop similar spatial patterns in terms of energy transformation hierarchies. Unfortunately, the non-standard methods used in these studies can make direct quantitative comparisons of some of the results difficult. For instance, all of the previous studies have employed slightly different land use classification systems to make estimates of energy densities. Some of the studies of used different planning units as the basis for making estimates of energy densities because the data was summarized according to these units. Although the general concepts have been demonstrated and the general range of density values for general categories are generally comparable, the actual density values from these studies are not directly comparable.

There are two other potential problems with using land use classification maps as a basis for this type of model. The first is the loss of the variability that occurs within the class (for example, larger and more expensive homes compared to smaller, less expensive homes). The second is that different methods used to create land use maps may result in similar areas being classified differently depending on the method used to create the data set. Based on the author's professional experience working with land use data sets, misclassification is a major potential weakness of the land use class method.

Strengths and Weaknesses of the Land Area Unit Spatial Modeling Approach

The concept of the land area unit spatial model is a more general approach to modeling the spatial distribution of energy flows and storages. If the same flows and storages are modeled for the same unit area, then much of the uncertainty of comparing values between different urban and regional landscapes will be eliminated.

Hence, the real value of this work will be realized when others implement this modeling method for other urban systems. Since the method presented here is entirely general and repeatable, these future researchers should be able to compare the patterns observed in their systems with the ones presented in this study. Conceptually, other models created using these methods should generate values that are quantitatively comparable with the values in these results.

The method used in this study is similar to the method proposed by McHarg (1966) of overlaying shaded maps (drawn on transparent mylar sheets) representing different components of the natural and economic systems to find suitable land for development. His method is essentially an additive process that is similar to adding together EMERGY component grids. Of course, the method proposed here is more general, quantitative, and repeatable.

There are, of course, some weaknesses in the approach presented in this study. For instance, to realize the full potential of comparable results, subsequent studies should be preceded by consensus on the values for transformities that should be used to convert various forms of energy values into EMERGY values. A complicating factor for those using this modeling approach is that currently there is little standardization in the methods used to attribute urban feature GIS databases. Hence, different algorithms may have to be applied to estimate the energy in these features. However, based on the professional experience of the author, there is still a much higher level of consistency and accuracy found in the typical urban feature database than is found in most land use classification databases. At least the potential for comparable results exists.

The spatial model presented in this study was designed with the objective in mind of being able to study spatial patterns of energy in relation to spatially recognizable elements of urban systems. This objective required a level of detail work that is not typical of EMERGY analysis methods that have been used previously to study urban systems.

For instance, using methods described by Odum (1996) for EMERGY analysis, total flows and storages (or rates) would be estimated from literature sources and calculations (that may be similar to those used in this study), and the values would be entered into a spreadsheet or simulation program. In a typical analysis, these estimates are based on readily available statistical data for definable urban units such as cities or counties. These summary statistics (such as total annual sales of fuel, total population, total square footage of buildings, etc.) are simply converted to energy and EMERGY units using algorithms and transformities and plugged into the model.

On the other hand, if one wants to create a spatial model, these values must also be spatially distributed to the proper locations. This extra requirement presents a real challenge. Previous studies that have modeled the spatial distributions of energy have used the land use classification maps to distribute all of the total energy flow and storage data according to estimated average density rates. In contrast, this study used the approach of calculating most of the flow and storage estimates based on the attributes of individual features (buildings, roads, etc.) in the urban landscape.

This method results in more spatially precise patterns that reflect the true variation and texture of the urban pattern. Of course, this approach was not possible, or practical, previously because GIS databases such as those used in this study were not readily available, and it was not practical to manipulate the data with the computer hardware that was available.

It is important to point out that there were still some cases in this study where it was most appropriate to spatially distribute the flows and storages in a manner similar to using average density rates for land classes. This was the case for any of the flows or storages that were more evenly distributed throughout the landscape. The flows that were distributed according to average densities include gross primary production and renewable resources used (transpiration). The storages that were distributed in this manner were biomass, water, and organic matter in soils.

The most important advantage that the feature-based distribution method provides is that the results based on this method reveal more recognizable relationships between different urban system elements than would be observable using the land classes method alone. For instance, within the area of some land classes, clustered patterns of high flow and storage density surrounded by, or interspersed with pockets of, lower density areas can be observed. Observation of this type of pattern would not possible in maps generated using the average density distribution method. It is, however, this type of observation that may become important for characterizing urban system patterns as more studies are done and comparisons are made between different urban systems.

Evidence of Spatial Patterns of Energy Transformation Hierarchy

The second primary objective of this study was to examine the spatial patterns of the energy transformation hierarchy in Alachua County. In general, this study appears to support the hypotheses proposed by others (Odum, 1971; Odum and Brown, 1976; Constanza, 1975, Brown, 1980, Odum, 1983, 1996; Whitfield, 1994; Huang, 1998) about the spatial distribution of energy flows and storages according to the level of transformity for the flow or storage.

For instance, this study found that the lower transformity component flows are more widely dispersed compared to the higher transformity component flows. The results also show that there is a ‘city center’ that has a higher total consumption transformity than the suburbs surrounding the city center, and that rural areas outside the city have the lowest total consumption transformity. In the case of storages, the study area has many smaller, lower transformity storages that are widely dispersed, and fewer of the larger, higher transformity storages.

Hierarchical Patterns Associated With Individual Components

A significant finding of this study was that spatial patterns of energy transformation hierarchy are apparent in the maps of many of the individual flow and storage components of the model. Many of the cell value distribution histograms that were created for each of the (sub)component grids also display the familiar hierarchical patterns of distribution. In fact, the hierarchical patterns that exist for some of the (sub)component grids are only apparent by looking at these histograms.

Issues associated with the standardized legend. The logarithm analytical component grids for each of the energy and EMERGY flow component grids of the spatial EMERGY model were used to graphically display the final model results. A standard set of log value ranges has been used to present the results for each component to facilitate comparisons between the component grids. This approach has the advantage of making it easier to visually compare the patterns and values of components.

However, in some cases, the standard set of log value ranges was not finely divided enough for the reader to fully appreciate the variation in values that actually exists in the data. Because of the continuous nature of the data, much more detailed patterns could be mapped and studied for individual component grids. Because of the relative complexity of the model results, it was decided that this limitation was not as important as using a standardized legend for the presentation of the results.

It is important to note that the standard legend chosen for this study may not be the best one to use for this type of data. Future researchers using this method may want to experiment with different legend ranges. For instance, a potential problem with the standard legend used in this study is that even intervals were chosen for the log ranges. Hence, the log intervals do not actually represent equal intervals of the data values.

It is not clear how much this may effect the reader’s perception of the results. For instance, if a cell value distribution histogram created for an individual (sub)component grid displays a relatively smaller number of cells in a lower value range (for example log 14.50 – 14.99) than a higher value range (for example log 15.00 – 15.49) this may imply that there is not a hierarchy, or that the hierarchical theory is not general, when in fact the pattern seen in the histogram may just be an artifact of the choice of the value ranges used to display the data. There are several known cases in this study where a significant proportion of the component grid cell values were very close to the edge of a particular value range interval.

It is possible that specific value ranges (still with equal intervals) could be chosen for each component grid to more clearly display the presence or absence of the hierarchical pattern of cell distribution according to EMERGY values. This phenomenon illustrates the fact that the individual data sets created for this study could be examined in more detail, and that this additional study could further reinforce the hypotheses that energy transformation hierarchy exists in the individual component flows and storages.

<u>Log value relationship with energy transformation steps.</u> Odum (1996) has demonstrated that, if some assumptions are made about the efficiency of energy transformations, that equations relating the rates of an energy flow and the transformity of that energy flow can be derived which predict or estimate the number of transformations that a particular type of energy has gone through to get to its present form.

This suggests that the log value in a particular cell of one of the logarithm analytical component grids may be used to infer the relative number of transformation steps required for the EMERGY flow density in that cell. For example, a cell with an EMPOWER density of value of 18 log sej/ha/year could be thought of as requiring three more ecological or economic transformation processes to support this EMERGY flow rate than a cell with an EMPOWER density of only 15 log sej/ha/year.

Examples of energy transformation hierarchy in flow components. It is important to keep in mind that the spatial patterns observed in the maps of energy and EMERGY flows and storages reflect the methods used to create the each of the (sub)component grids. For instance, the location of many of the flows were based on the location of buildings rather than areal features and the maps reflect this method.

The water use EMERGY component grid map (Figure 3-32) is a good example of why the cell value distribution histograms are useful for examining patterns of hierarchy in individual components. Hierarchical patterns are not readily apparent from looking at the map, however, the histogram (Figure 3-33) implies that a hierarchical pattern exists in the data. The cell distribution histogram illustrates an intuitive spatial pattern for this component. There are many cells in the EMERGY component grid with relatively lower values (primarily associated with agricultural crops), and an increasingly smaller number of cells associated with each increasingly higher EMERGY value range. As would be expected, the highest values are associated with high-density residential, commercial, and institutional land uses.

The water use EMPOWER density cell distribution histogram is also a good example of how the land area unit modeling can result in intuitive, but not necessarily expected, cell value distribution patterns. For instance, the water use EMERGY histogram displays a cell value distribution pattern that resembles a ‘normal distribution curve’.

This pattern can be explained by the fact that there are grid cells in rural areas with low-density residential developments that have relatively low water use flows. Variations of this ‘normal distribution pattern’ can be seen is several of the other component grid histograms. These histogram distribution patterns could be studied in more detail to determine if this is a more general spatial phenomenon.

The hierarchical patterns observed in the EMERGY map of transportation fuel use reflect the hierarchical nature of the transportation infrastructure in the county. The cell value distribution histogram for this component displays a wide range of values reflecting the wide range of traffic counts for the roads that was used to estimate fuel use. It is easy to identify both major and minor roads from the pattern shown in the EMERGY subcomponent map.

Whereas the histograms are the best way to see that a pattern of cell value distribution hierarchy exists for some of the components, the maps are clearly the only way to observe spatial patterns of energy transformation hierarchies in the component grid maps. Good examples of this can be seen in the EMPOWER density maps of fuels used in buildings and agriculture (Figure 3-40), total fuels used (Figure 3-44), goods consumed (Figure 3-48), and in-situ human services (Figure 3-52).

In all of these cases, the cell value distribution histograms are display less obvious patterns of hierarchy than can be readily observed in the maps of component EMPOWER density. For instance, the histogram for the total fuel use EMPOWER density map (Figure 3-44) displays a wide range of values from less than 12 to 18 log sej/ha/yr. But the map displays an obvious spatial hierarchical pattern of fuel use. One has to look very closely, but there are also a few important cells with values in the range of 18 to 19 log sej/ha/yr (and a high value of 19.25 log sej/ha/yr corresponding to the Shands Medical complex). These small areas of very high fuel EMERGY use correspond to areas where there are both large transportation use flows and building use flows.

Examples of energy transformation hierarchy in storage components. Spatial patterns of hierarchy are not as pronounced in the natural structure component grids. However, the cell value histogram for the total natural EMSTORAGE density map displays a hierarchical distribution pattern (Figure 3-77). The population EMSTORAGE component is an example of how both the histogram and the map (Figures 3-96 and 3-97) display clear hierarchical patterns. The urban structure component grid maps, on the other hand, are further examples of how sometimes the cell value distribution histograms are not as useful as the maps for understanding the hierarchical patterns that exist in the component grid data. For example, although the histogram for the EMSTORAGE density map of buildings (Figure 3-81) displays hierarchical patterns, a spatial pattern that clearly corresponds to the level of land use intensity is obvious only by looking at the corresponding EMSTORAGE density map (Figure 3-80).

Total EMERGY Consumption and Total EMERGY Storage

The 'Total EMPOWER Density' (or 'Total EMERGY Consumption') analytical grid map (Figure 3-100) displays a pattern that is very similar to the classic market distribution pattern diagram proposed by Christaller (1966). This pattern may not be as obvious in other regional landscapes as it is for Alachua County, however, this remains to be seen when other landscapes are modeled using the approach proposed in this study.

Both the spatial pattern in the 'Total EMPOWER Density' map and the cell value distribution patterns in the associated histogram display clear patterns of energy transformation hierarchy. Figure 3-104 displays a map of the logarithm analytical total annual energy flow density grid with ranges of log values chosen to illustrate the true variation that exists in the energy grid values. By using these value ranges for the energy density map and histogram, hierarchical patterns of energy density values can be seen.

The ‘Total EMSTORAGE density’ map (Figure 3-106) and its associated histogram also display the pattern seen many times before--large numbers of the cells in the grid have relatively lower EMSTORAGE density values and an increasingly smaller number of cells are associated with each increasingly higher range of EMSTORAGE density values. The higher values are associated with institutional and commercial land uses and range from 20 to 22 log sej/ha, with the highest values being associated with the University of Florida, Shands Medical Center, several of the major shopping center areas, and the downtown Gainesville government building complex. New ranges of log values were used for the map of the logarithm analytical ‘total energy storage density’ grid (Figure 3-110) to illustrate the true variation in the energy values. This energy storage density map and histogram also display patterns of spatial and cell distribution hierarchy.

Transformities for Total EMERGY Consumption and Total EMERGY Storage

Total EMPOWER density transformity values range from about 5 E3 sej/j to about 1.5 E6 sej/j. The largest percentage (58%) of the cells in this grid have transformity values that fall within the range of 1 E4 to 2.5 E4 sej/j. Most of these cells are in rural and agricultural areas. The urban areas are characterized by a very wide range of transformities, ranging from 2.5 E4 to 1.5 E6 sej/j. The highest transformity values are associated with institutional and commercial land uses. The transformity histogram reveals a pattern that is similar to the patterns observed for many of the EMERGY component grids. There are many cells with lower transformities and increasingly fewer cells with increasingly higher transformity values. These observations are consistent with predicted spatial patterns based on energy transformation hierarchies. Total EMSTORAGE density transformities for rural areas range from 3 E4 to 7.5 E4 sej/j, and values for urban areas range from 1 E5 to 1.5 E8 sej/j with the highest values also being associated with institutional and commercial land uses. The EMSTORAGE transformity map and histogram also display patterns that are predicted by energy transformation hierarchy theory.

Transformities, Mean Densities, and Percentages for Land Use Classifications

The mean ‘Total EMPOWER density’ and ‘Total EMSTORAGE density’ values and the associated transformities that were calculated for each Level 3 land use classification (Table 3-22 and Table 3-24) should be used cautiously by others since there are some potential anomalies in the data. However, the relative magnitude of mean density values and the rank order according to calculated transformity for most of the classes are reasonable and intuitively demonstrate energy transformation hierarchies associated with increasing land use intensity.

The mean ‘Total EMPOWER density’ and ‘Total EMSTORAGE density’ values and the associated transformities for Level 2 land use classifications (Table 3-23 and Table 3-25) have fewer anomalies and the density and transformity values display very intuitive rank order results. Although the mean density values for level 2 classes accurately reflect the actual total flows and the rank order of calculated transformities is reasonable, it is not suggested that these values should be used for mapping purposes since they will result in a map that does not reflect the location of some of very important high-EMPOWER and high-EMSTORAGE land areas.

Instead, the land use classification comparison study suggests that if average density rates are to be used to create maps of EMPOWER and EMSTORAGE density that level-3 classification schemes should be used to ensure that representations of important high transformity features are preserved. The comparison study demonstrates that if level 2 classification schemes are used that the resulting distribution patterns will also not reflect the variation that exists. More importantly, because of the 'dilution effect' of averaging, the results may not represent those very few, very high density values that are associated with features that may responsible for the other patterns that are more observable in the generalized level 2 land use pattern. An example of this that was observed in this study was the Shands Medical Center. If an average density value for a level 2 'institutional' land class had been used, the importance of this very small area, which has the highest EMPOWER density and EMSTORAGE density values in the county, would not be represented in the model.

Percent of county-wide total EMPOWER and percent of county-wide total EMSTORAGE. It has been pointed out previously that these simple statistics provide some useful insight into the relative amount of the county-wide total flows and storages contributed by each land use classification. For instance, in Table 3-22 a small number of very specific level 3 codes account for about 66.5% of the total annual EMPOWER for the county. The significance of these simple statistics is also demonstrated by values for the level 3 land use for prisons (code = 1765). Prisons have very high mean total EMPOWER density values and transformities, but contribute only .34% to the overall county total. It has been pointed out however, that there are many of these small-area, high-flow-intensity land uses that are scattered throughout the landscape that can significantly affect surrounding land areas in both ‘negative’ (e.g., environmental) and ‘positive’ ways (e.g., providing access to services or flows of goods, etc.).

The most interesting relationship discovered by calculating these percentages was between the percentages of the county-wide total EMPOWER represented by level 3 and level 2 class sum total EMPOWER flows and the percentages of the county-wide total EMSTORAGE represented by level 3 and level 2 class sum total EMSTORAGE values (see Tables 3-22, 3-23, 3-24, and 3.25).

It was found that for many land classes that there was a very close correspondence between the percentage of the county-wide total EMPOWER represented by the class sum total EMPOWER flow and the percentage of the county-wide total EMSTORAGE represented by the class sum total EMSTORAGE. The relationship appears to exist in both the level 2 and level 3 land use classification calculations.

For example, level 3 percentage calculations (from Table 3-22 and 3-24) reveal that the largest contribution, 22%, to the county-wide total EMSTORAGE came from the ‘medium-density residential’ classes, and that this class also contributed 23.2% of the total EMPOWER (also the largest percentage contribution). Other notable level 3 examples include: the ‘high-density residential’ classes contributed 14.5% of the total EMSTORAGE (compared to 14.2% of the total EMPOWER); the ‘commercial and services’ classes contributed 13% of the total EMSTORAGE (compared to 14.8% of the total EMPOWER); the ‘educational facilities’ class contributed 9.5% of the total EMSTORAGE (compared to 9.8% of the total EMPOWER); and the ‘hospitals’ class contributed 4.2% of the total EMSTORAGE (compared to 4.5% of the total EMPOWER). These specific codes account for about 63.2% of the total EMSTORAGE and 66.5% of the total annual EMPOWER for the county. As noted before, these are indeed very interesting statistics. Although the actual sum EMPOWER and EMSTORAGE values for each class are an order of magnitude different (with the EMSTORAGE values being the larger values), the percentages of the total county-wide flow are remarkably similar to the percentages of the total county-wide storage.

Similar relationships exist for the level 2 classes. For example: the ‘medium-density residential’ class contributed the largest percentage, 23.6%, to the total EMSTORAGE and the largest percentage, 23.2%, of the total EMPOWER; the ‘high-density residential’ class contributed 15.8% of the total EMSTORAGE (compared to 15.6% of the total EMPOWER); the ‘commercial and services’ class contributed 13.5% of the total EMSTORAGE (compared to 15.5% of the total EMPOWER); the ‘institutional’ class contributed 15% of the total EMSTORAGE (compared to 15.6% of the total EMPOWER); the ‘low-density residential’ class contributed 11% of the total EMSTORAGE (compared to 11.2% of the total EMPOWER). In the level 2 land class scheme, the contributions by the land areas associated with these codes account for about 79% of the total EMSTORAGE and 82.5% of the total annual EMPOWER.

These comparative statistics for percentages of county-wide total EMSTORAGE and EMPOWER seem to point to a pattern of the percentages of the total county-wide EMERGY flow being very similar to the percentages of the total EMERGY storage. More research and models of other regions are needed to determine if this is a general relationship that is associated with urban landscapes.

Value Added by Using GIS Technology

The third primary objective of this study was to demonstrate how GIS technologies and methods could increase the potential for studying spatial relationships of energy transformation hierarchy.

Earlier studies did not have the technological advantage, or the data (in a usable form) to conduct a study at this level of detail. Clearly, this study would not have been possible without the use of GIS technology. The availability of very detailed GIS databases of urban structural features and urban flows such as traffic counts and electricity usage made these very detailed spatial analyses possible.

By using GIS analysis methods in this study, patterns of energy distribution were demonstrated that could not have been shown previously. The EMERGY ratio analyses and spatial context analyses were presented specifically to demonstrate the additional capabilities made possible by the GIS technology. However, it is clear that the sheer magnitude of the data used in this study could not have been manipulated without the use of some type of computer technology.

Suggestions for Future Research

The specific types of analysis that were conducted in this study were chosen for their potential relevance to urban planners. There are certainly more analyses that could be performed using the spatial EMERGY model component grids as input.

For instance, there is great potential in creating more detailed subcomponent grids to support specific analyses. In fact, the intermediate component grids that were created for this study could be used for more detailed study of some spatial patterns. For example, the buildings component grid is actually made up of two intermediate component grids representing the residential and commercial buildings. Using these more detailed intermediate components, specific studies on the patterns of energy flow and storage for the commercial sector could be conducted. Also, the land area unit model diagram can be modified to include more detailed flows and storages if this detail is necessary to study a specific phenomenon or a specific subsystem

Although this is not a dynamic model, temporal analyses are possible using this method. For example, the buildings database has an attribute that indicates the year that each building was constructed. Using these data, a time series analysis could be conducted to show how the patterns of urban structure have evolved over time. The only problem is that the other databases that would be required to do a complete study do not contain this type of information. In the future, as more municipal GIS databases become available, the land area unit model could be linked to actual electricity use records because of the feature-based nature of the model. This capability could lead to the potential to study daily and seasonal patterns of energy use. Perhaps spatial pulsing patterns could be observed in a more dynamic form of this type of model.

The energy signature of the land area unit, that includes both energy flow and storage magnitudes (measured in units of the same kind—in this case, EMERGY), could be used as a multivariate land classification scheme that links the classes with processes. Huang (1998) used multivariate analysis to cluster administrative districts into energy zones according to shared energy signature characteristics. The development of a general scheme for an energetic land use classification system should be based on the results of studies that use the general land area unit modeling approach.

Closing Remarks

Probably the most important finding of this study is that the land area unit model has an advantage over other methods used previously to study spatial patterns of energy hierarchy because it is more general. The land area unit model provides an approach that allows direct comparison between the energetic characteristics of one unit of land with another. Hence, the real value of this study will only be realized when others use the same approach to study other urban systems and are able to compare the results.

This study has demonstrated that spatial patterns of energy distribution can be modeled at a high level of detail. However, one may want to ask the question in the end as to whether or not the detail adds enough new insight to be worth the enormous effort required to manipulate such large amounts of data. The answer to that question may have to wait until more studies are done at this level of spatial detail. However, one perspective of the one-hectare resolution of this model is that this is a land area unit that may correspond to the 'sense of place' experienced by humans that live in, and move through, the landscape.

From this perspective, the concept of 'EMSENSE of place' is proposed (as the author's EM-prefix contribution). EMSENSE is defined here as a state of mind that a person attains when they begin to see the landscape around them in terms of the EMERGY that is in the flows that support the processes that build the storages that are real wealth. It is possible that once a person's EMSENSE is fully developed, they will forever see their immediate surroundings in terms of the EMERGY in the environmental and economic processes and in the natural and built structure.

APPENDIX

This appendix contains larger-scale versions of a selected set of the maps that were presented in the results. The county-wide maps shown in the results were drawn at a scale of 1:400,000 or 1:500,000. These maps, focusing on the area of the City of Gainesville, are drawn at a scale of 1:100,000. The road network features are also included in these maps to help the reader interpret the results in more detail.

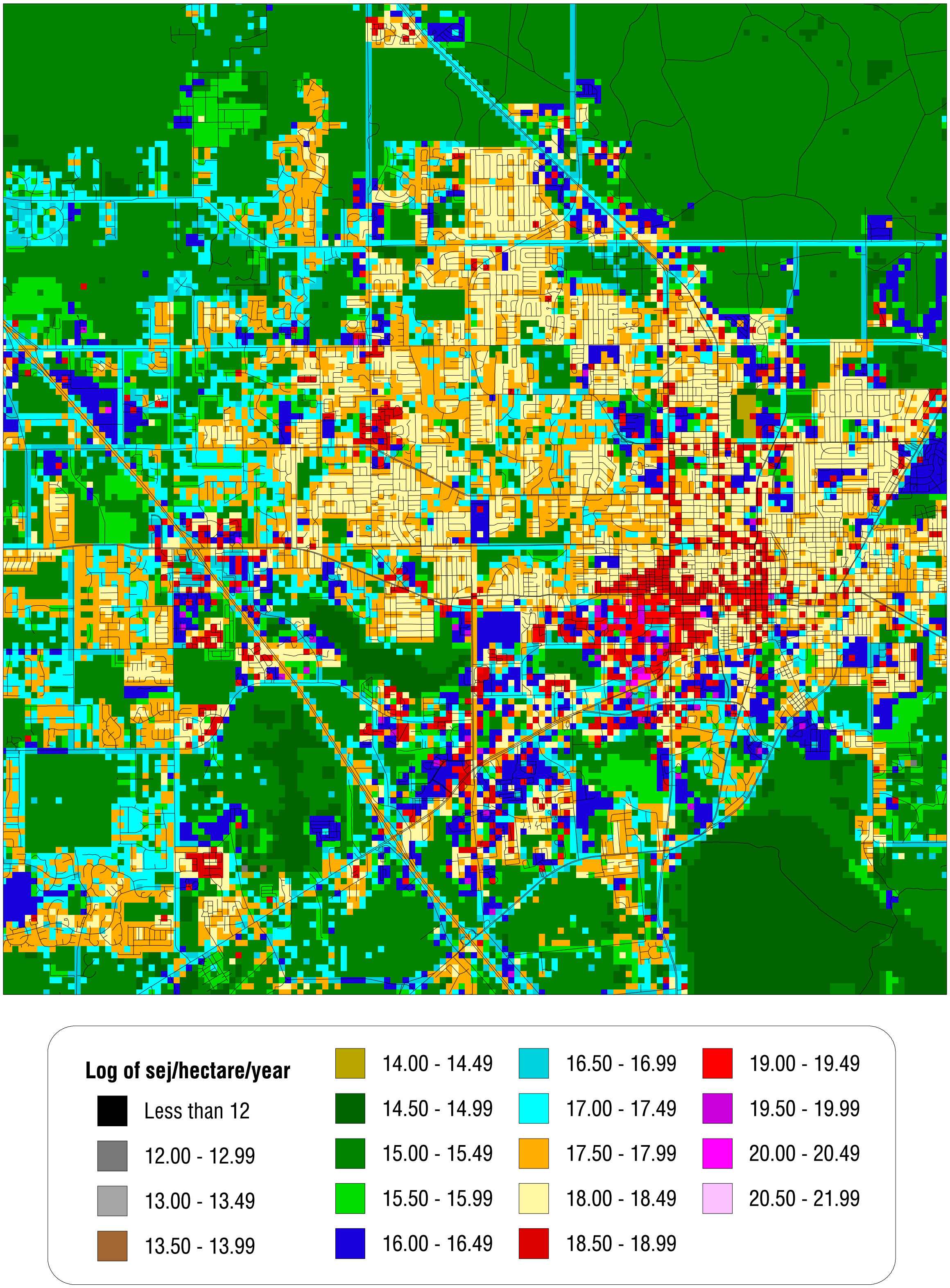


Figure A-1: 'Gainesville Closeup' map of the logarithm analytical EMERGY grid called 'empower_log. This grid represents the log of the total annual EMPOWER density (log sej/ha/yr). The values represent the sum of the flows of renewable resources used, water used by man, all fuels used, goods consumed, and in-situ human services.

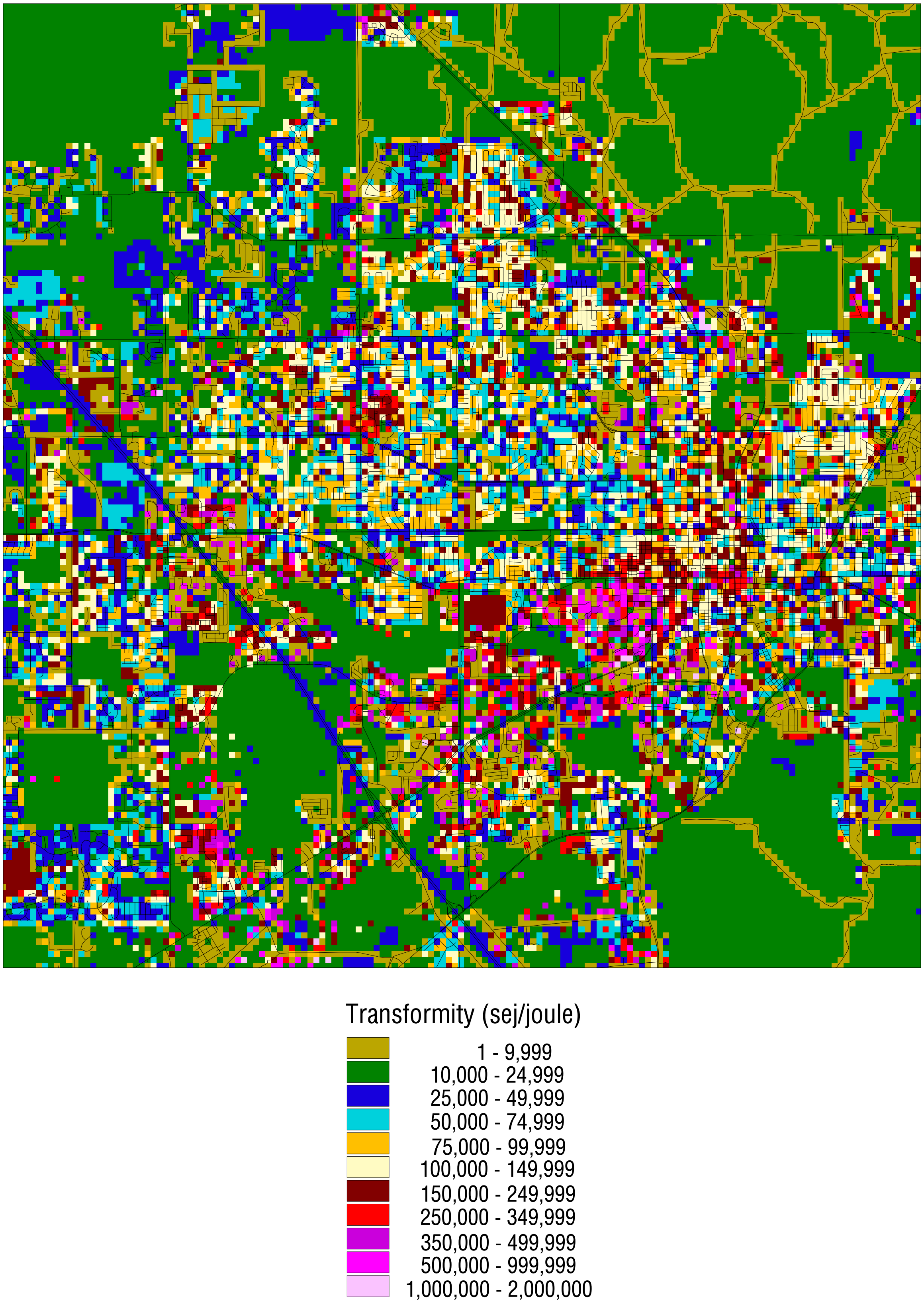


Figure A-2: 'Gainesville Closeup' map of the ranges of transformities (sej/joule) for the total annual EMPOWER density.

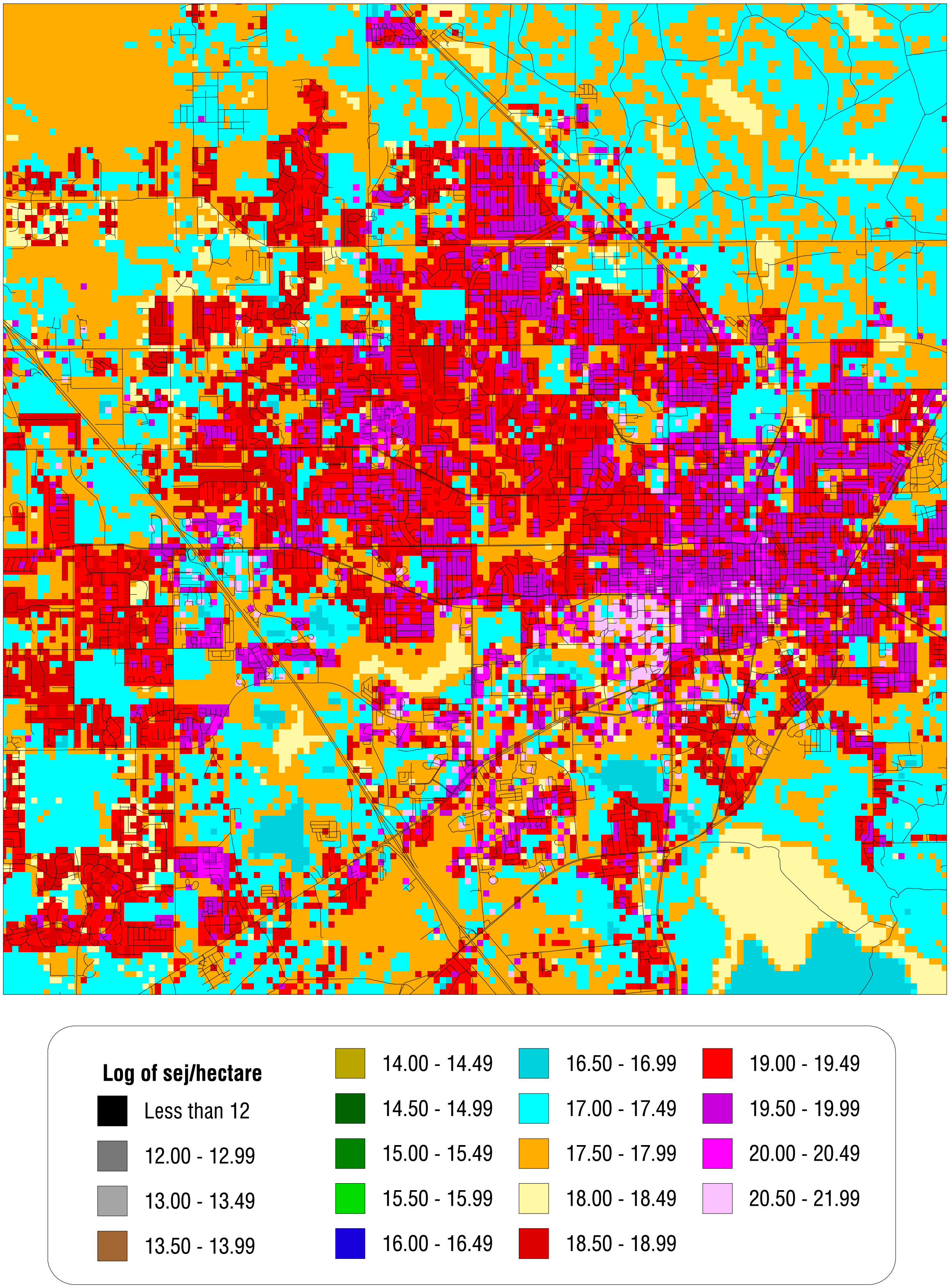


Figure A-3: 'Gainesville Closeup' map of the logarithm analytical EMERGY component grid called 'emstore_log. This grid represents the log of the total EMSTORAGE density (log sej/ha/yr). The values represent the sum of the values for natural system structure, urban system structure, and EMERGY stored in the human population.

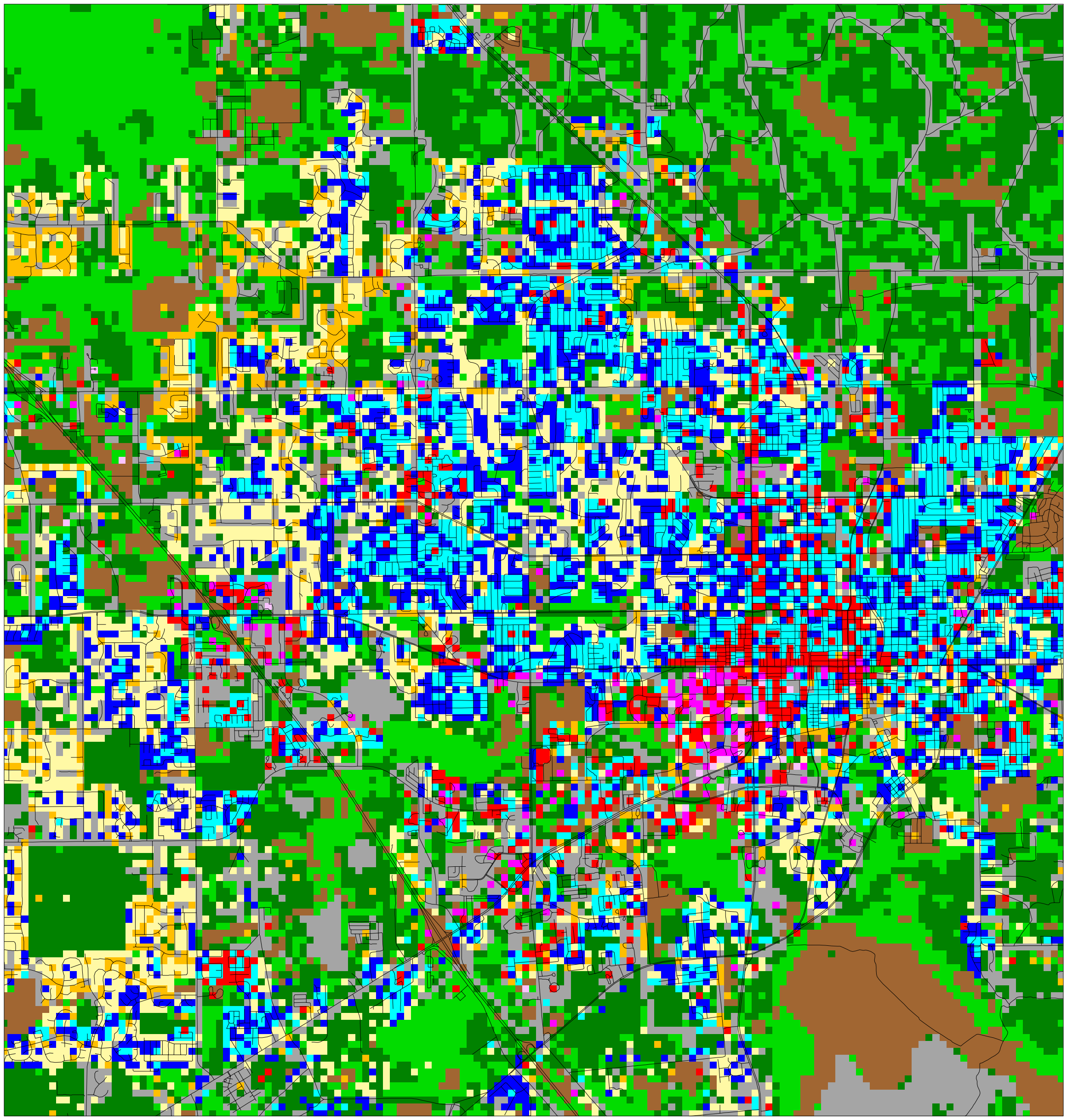


Figure A-4: 'Gainesville Closeup' map of the ranges of transformities (sej/joule) for the total EMSTORAGE density.

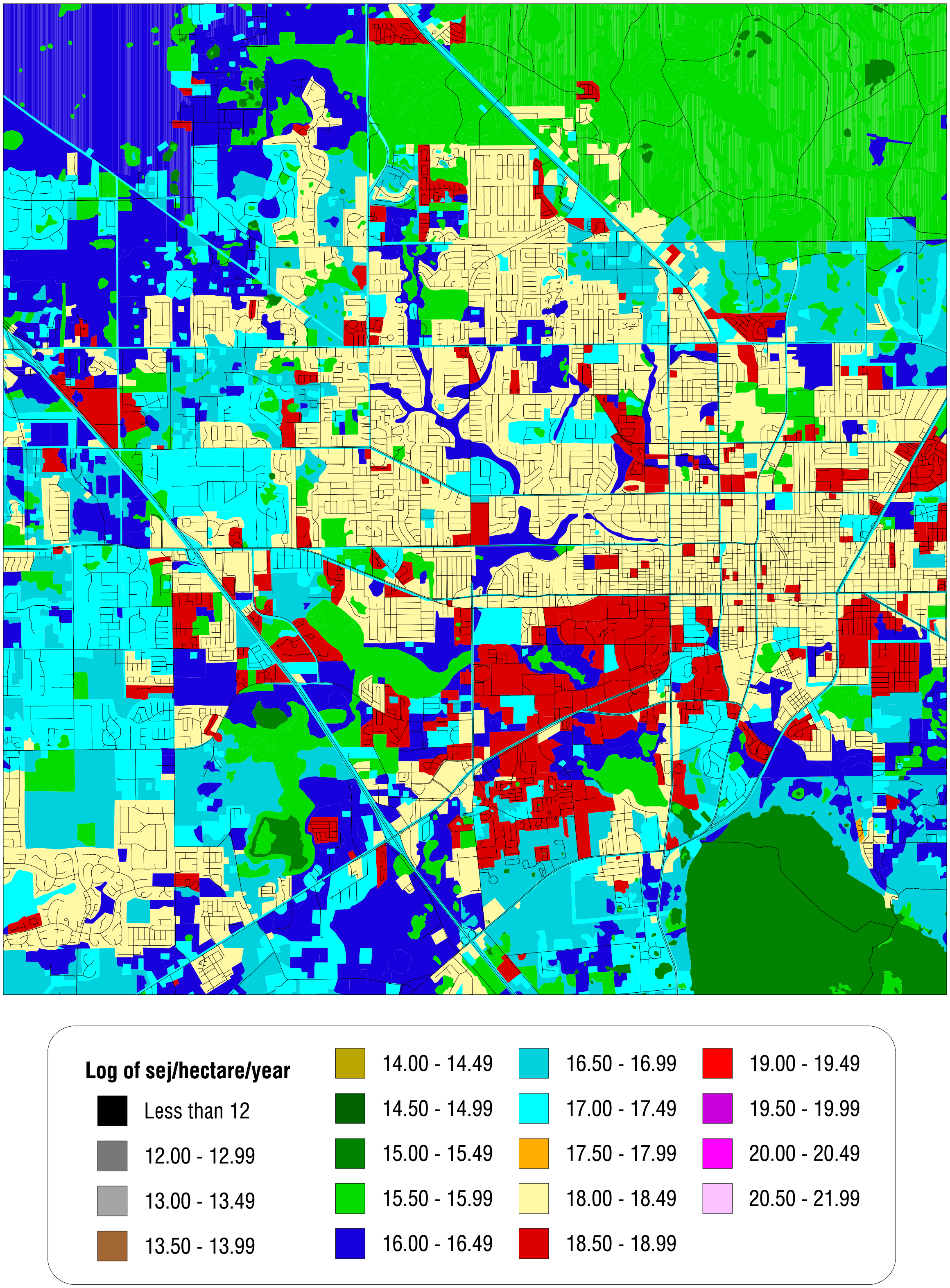


Figure A-5: 'Gainesville Closeup' map of the log of the annual total EMPOWER density based on the mean values calculated for each level 2 landuse class in Table 3-23.

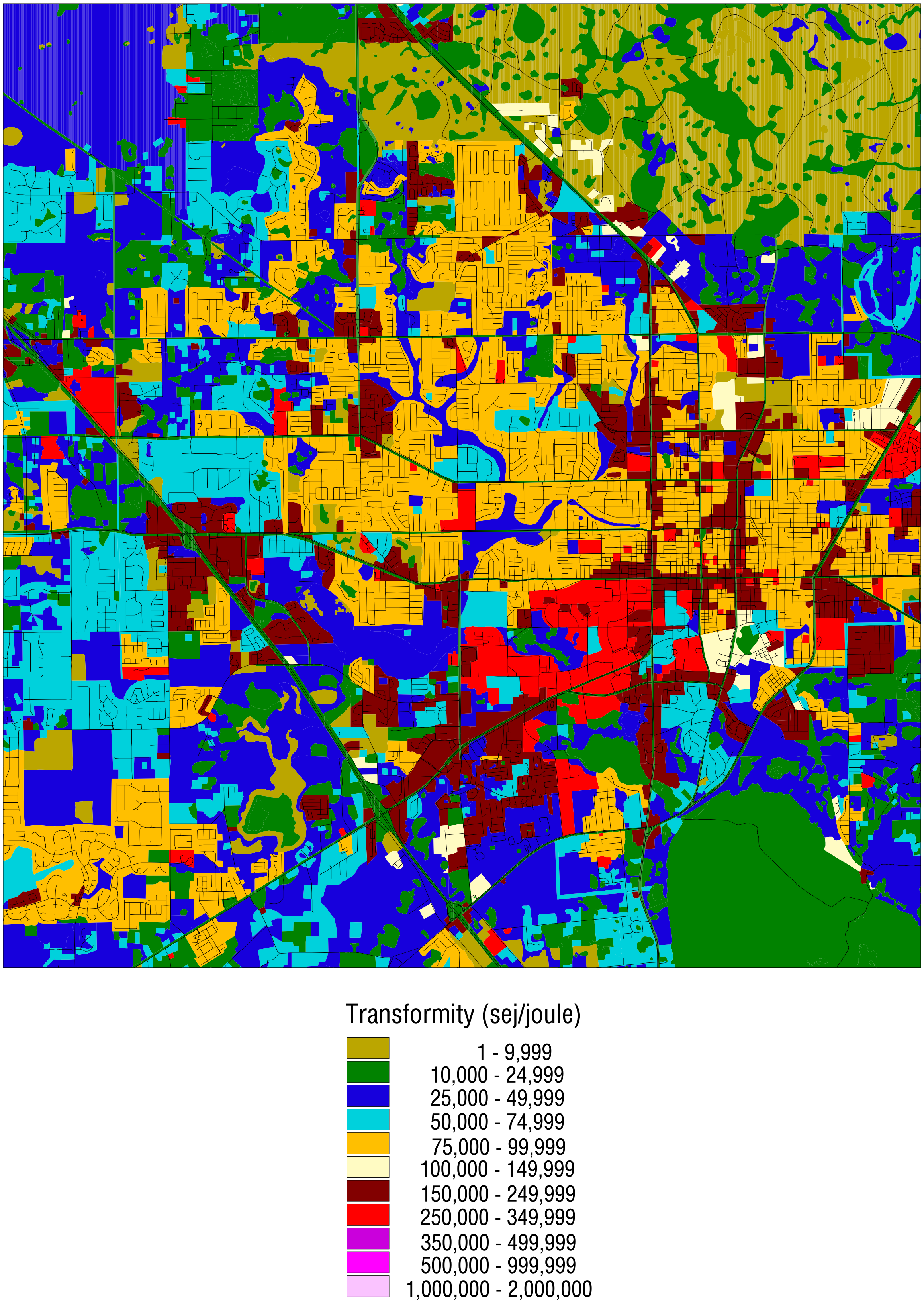


Figure A-6: 'Gainesville Closeup' map of the ranges of total EMPOWER density transformities that were calculated for each level 2 landuse class in Table 3-23.

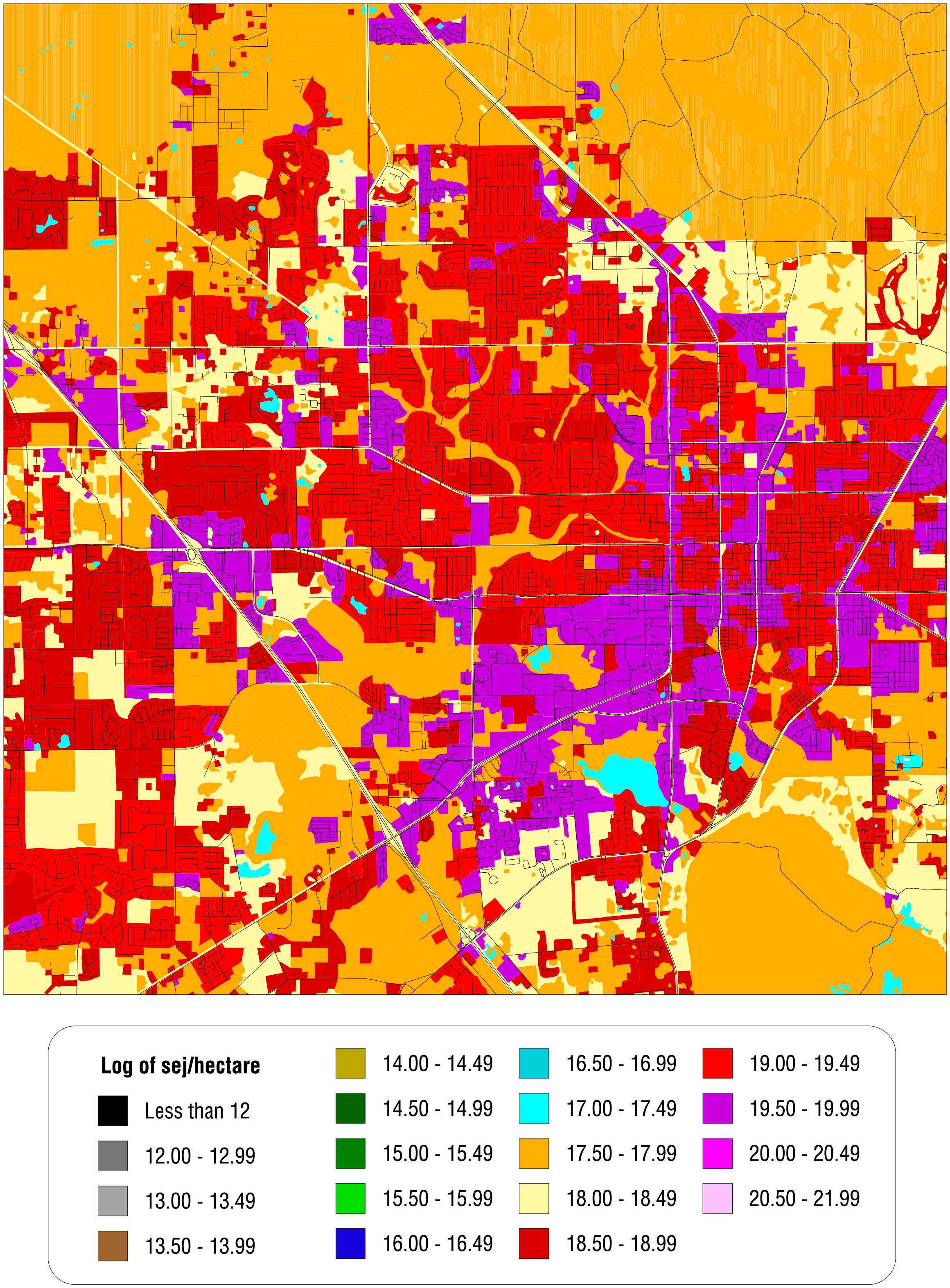


Figure A-7: 'Gainesville Closeup' map of the log of the total EMSTORAGE density based on the mean values calculated for each level 2 landuse class in Table 3-25.

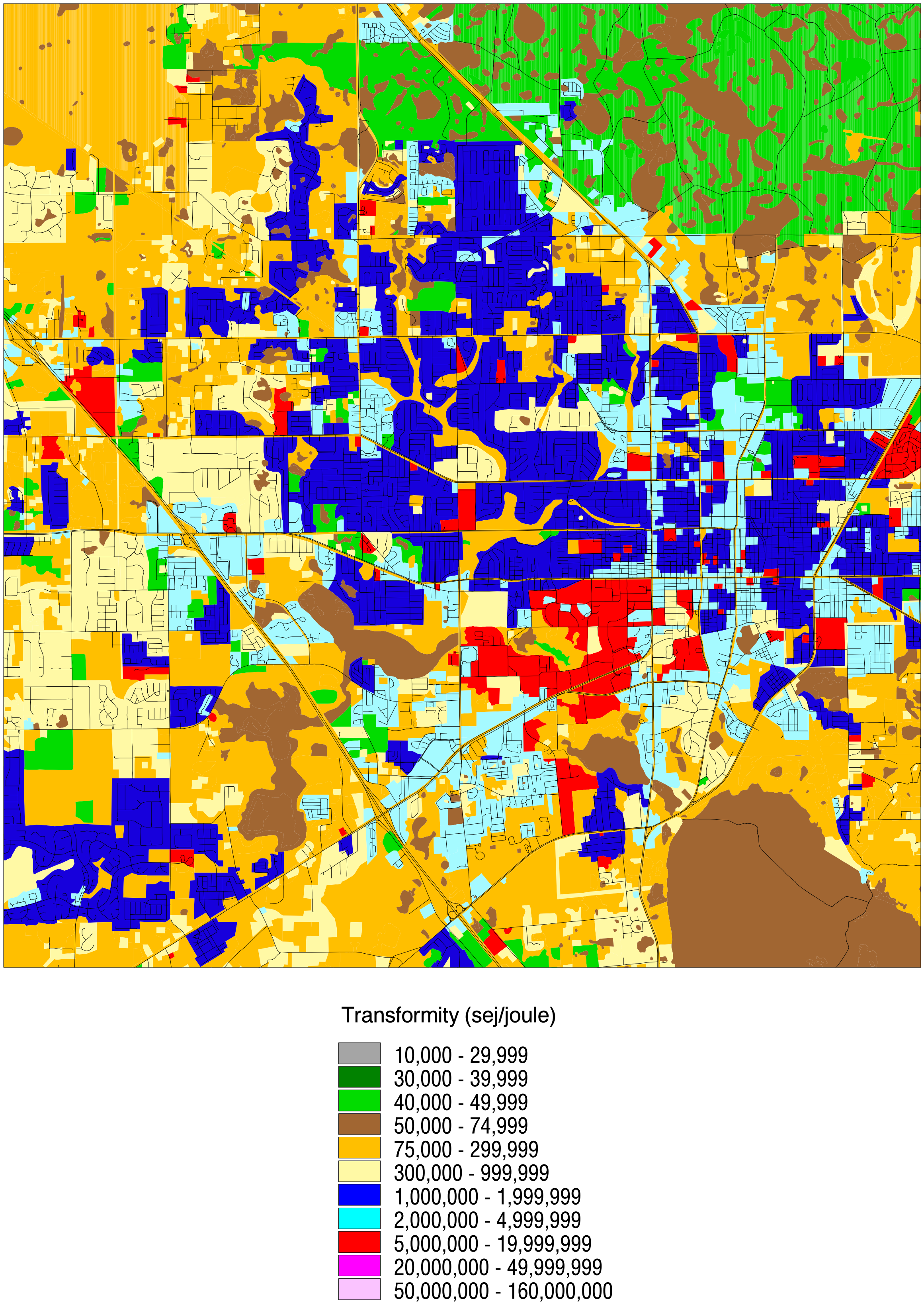


Figure A-8: 'Gainesville Closeup' map of the ranges of total EMSTORAGE density transformities that were calculated for each level 2 landuse class in Table 3-25.

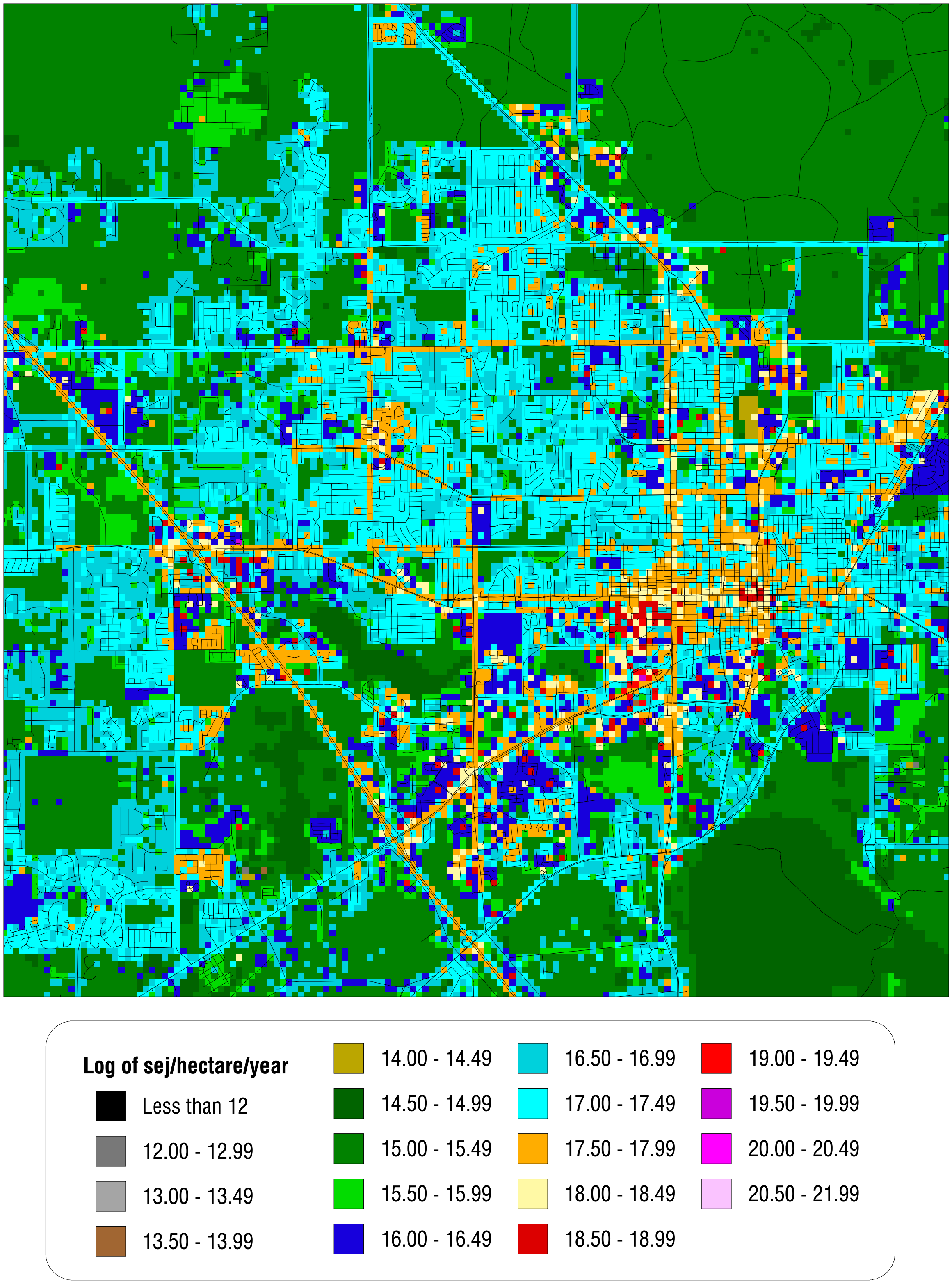


Figure A-9: 'Gainesville Closeup' map of the logarithm analytical EMERGY grid called 'resuse_log'. This grid represents the log of the annual EMPOWER density of all resource use. The values represent the sum of the renewable resources used, water used by man, all fuels used, and goods consumed. It does not include the in-situ human services that are included in the total annual EMPOWER density grid.

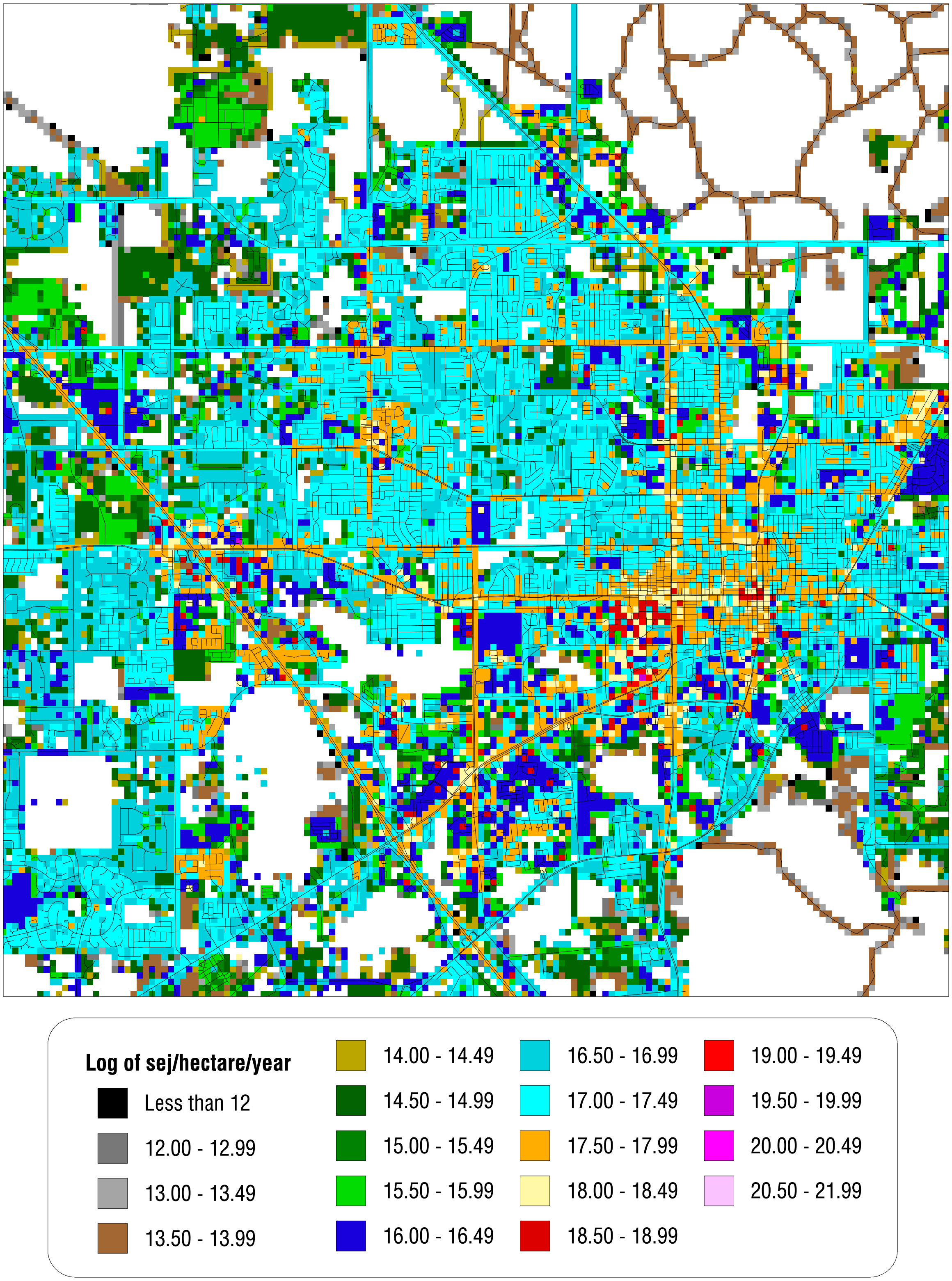


Figure A-10: 'Gainesville Closeup' map of the logarithm analytical EMERGY grid called 'nonrenew_log'. This grid represents the log of the annual EMPOWER density of all non-renewable resource use. The values represent the sum of the water used by man, all fuels used, and goods consumed. It does not include the renewable resource use and in-situ human services that are included in the total annual EMPOWER density grid.

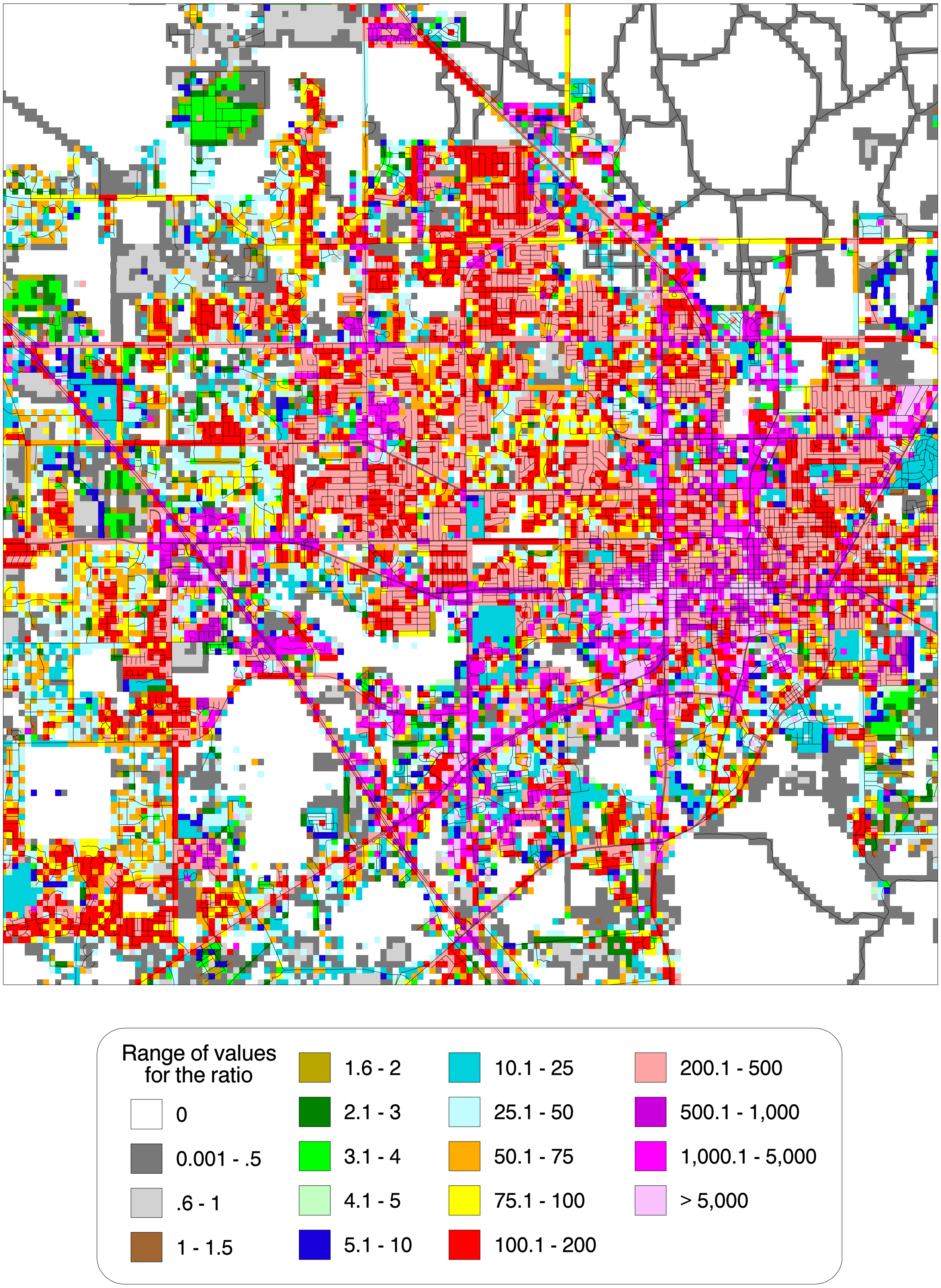


Figure A-11: 'Gainesville Closeup' map showing the values for the ratio of non-renewable to renewable EMPOWER density (sej/ha/yr). The values in the analytical grid called 'nonrenew' were divided by the values in the component EMERGY grid called 'renew' to obtain this analytical ratio grid.

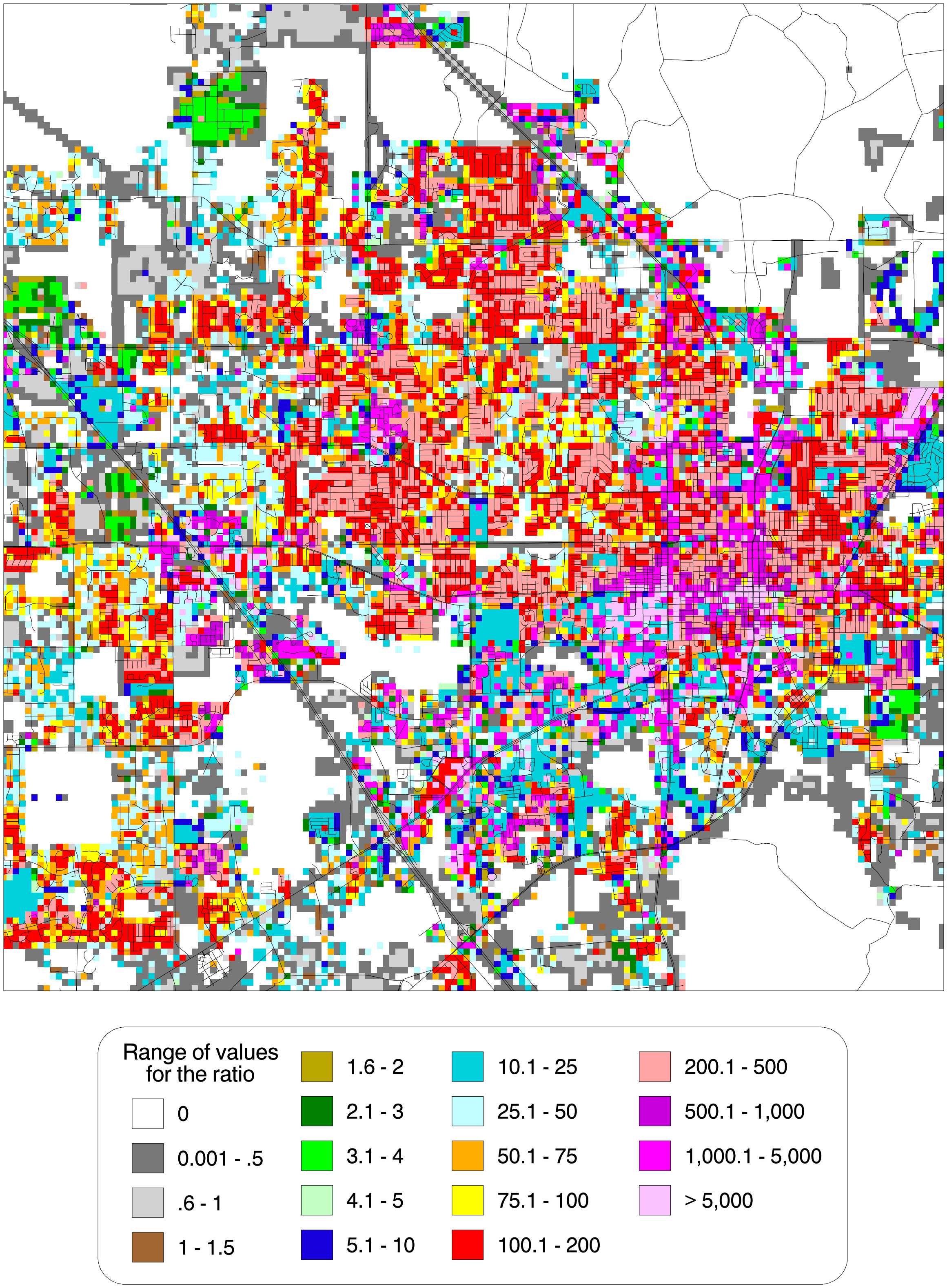


Figure A-12: 'Gainesville Closeup' map showing the values for the ratio of non-renewable-less-transportation to renewable EMPOWER density (sej/ha/yr). The values in the analytical grid called 'nonrenotr' were divided by the values in the component EMERGY grid called 'renew' to obtain this analytical ratio grid.

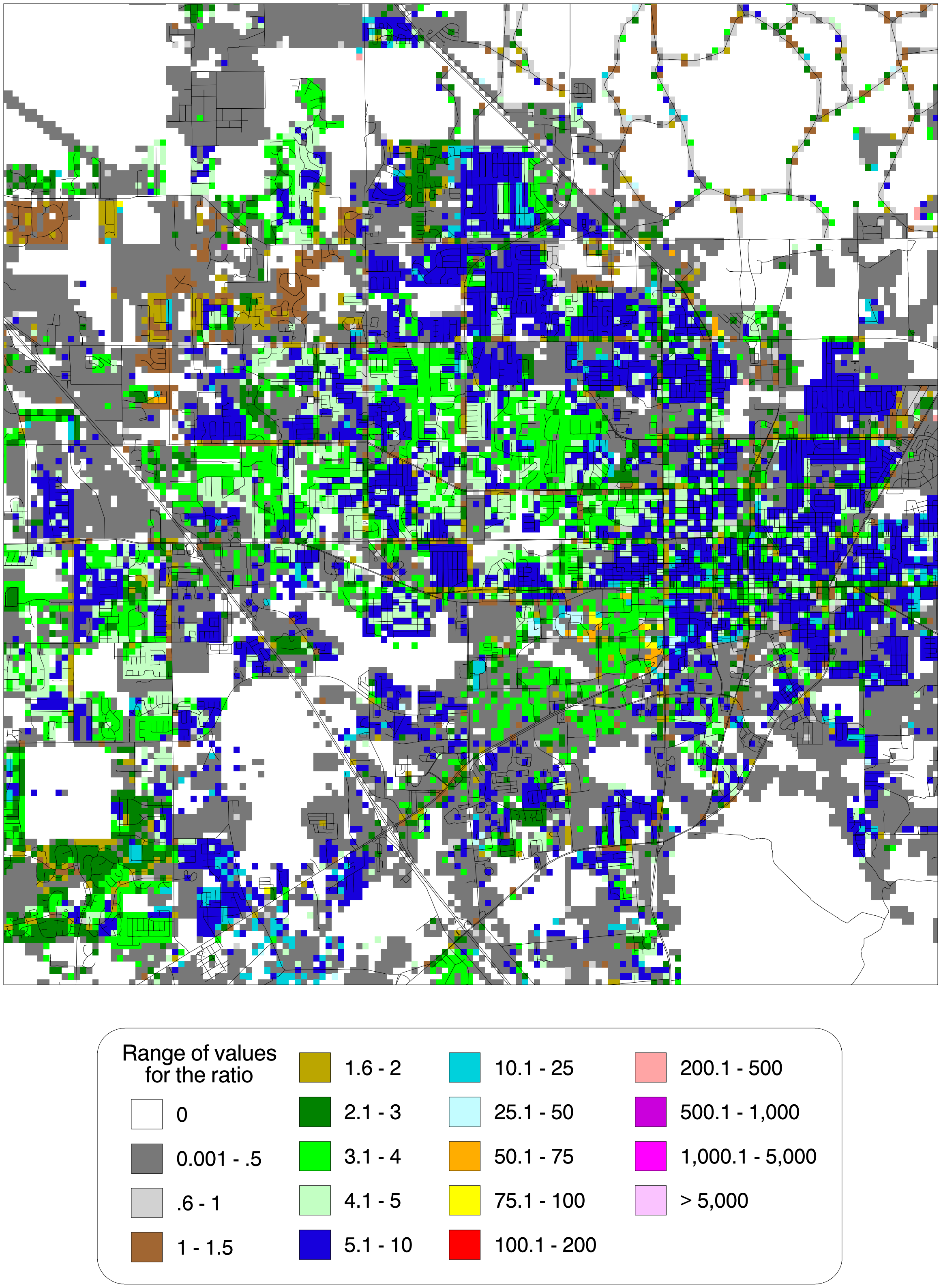


Figure A-13: 'Gainesville Closeup' map showing the values for the ratio of service to non-renewable EMPOWER density (sej/ha/yr). The values in the EMERGY component grid called 'service' were divided by the values in the analytical grid called 'nonrenew' to obtain this analytical ratio grid.

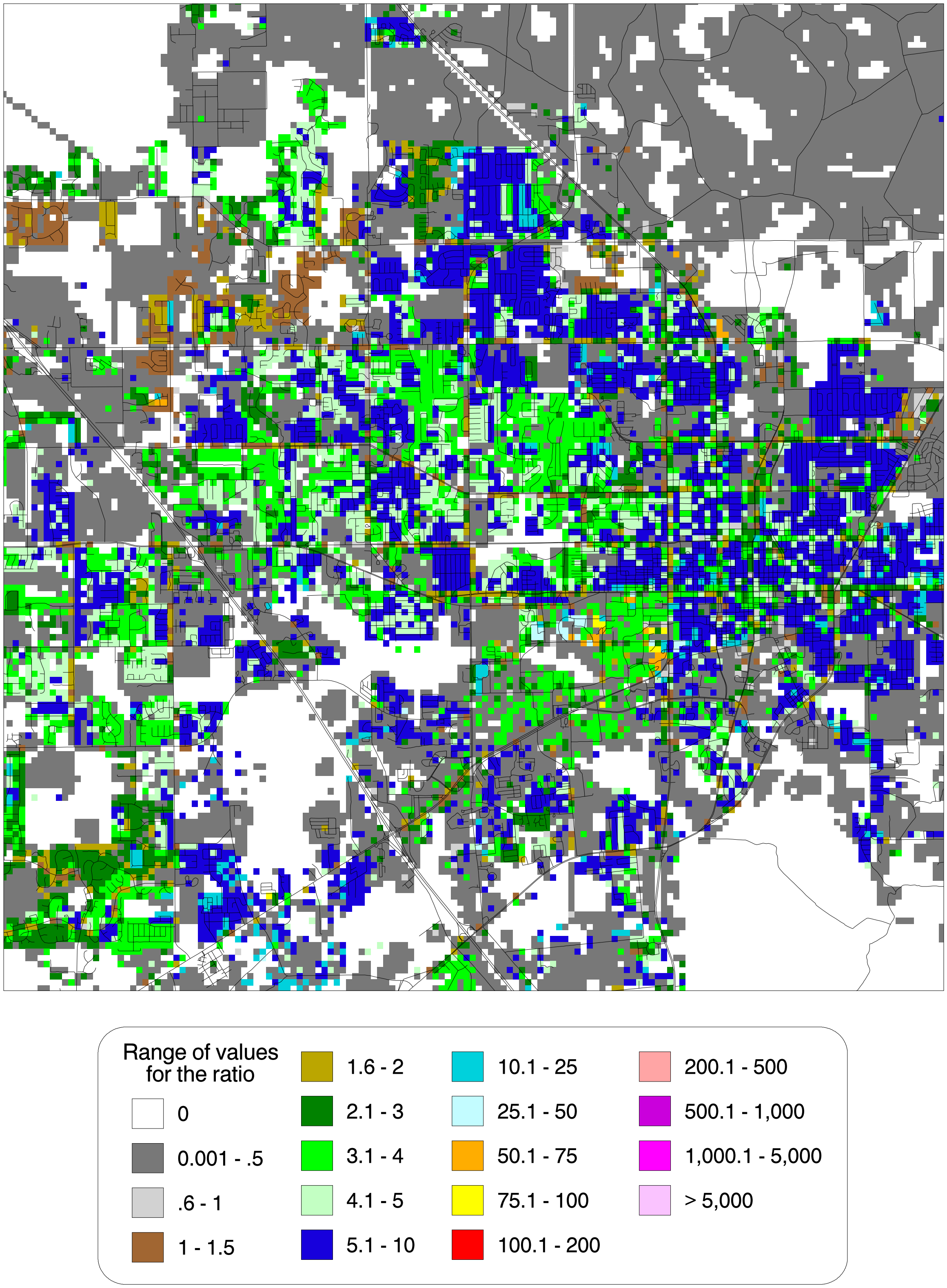


Figure A-14: 'Gainesville Closeup' map showing the values for the ratio of service to resource use EMPOWER density (sej/ha/yr). The values in the EMERGY component grid called 'service' were divided by the values in the analytical grid called 'resuse' to obtain this analytical ratio grid.

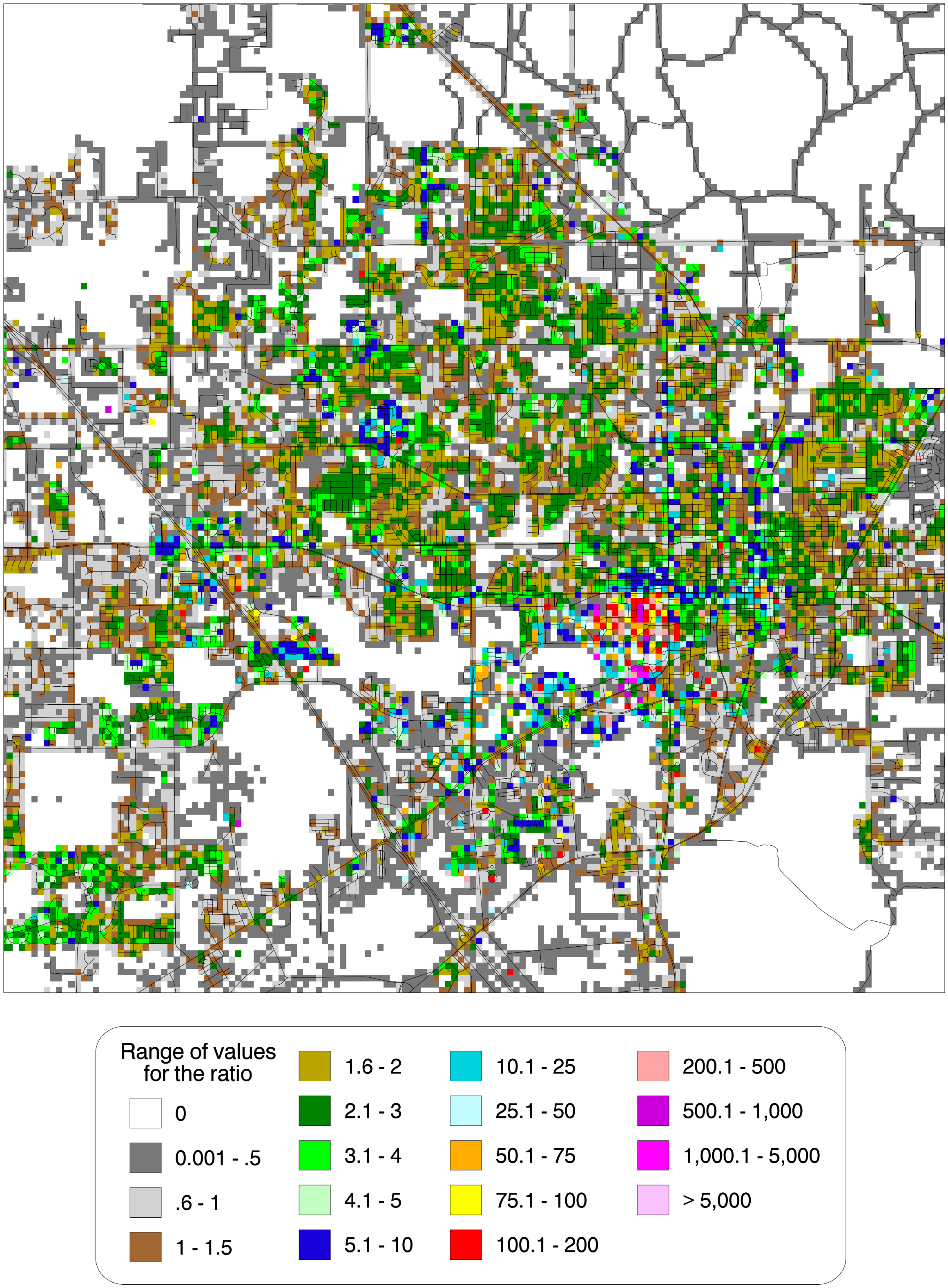


Figure A-15: 'Gainesville Closeup' map showing the values for the ratio of urban to natural EMSTORAGE density (sej/ha). The values in the EMERGY component grid called 'urbstr' were divided by the values in the EMERGY component grid called 'natstr' to obtain this analytical ratio grid.

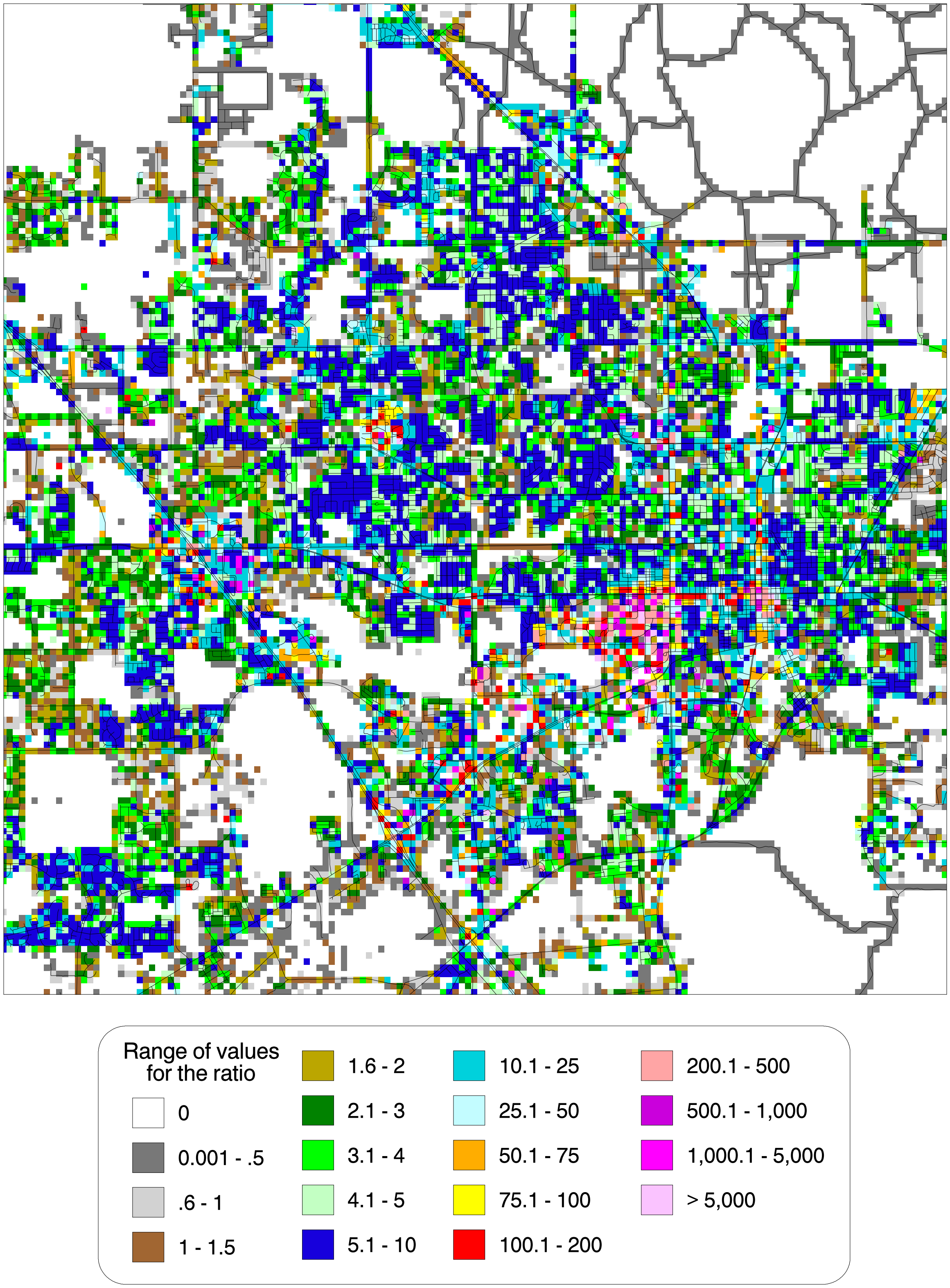


Figure A-16: 'Gainesville Closeup' map showing the values for the ratio of urban structure to biomass EMSTORAGE density (sej/ha). The values in the EMERGY component grid called 'urbstr' were divided by the values in the EMERGY component grid called 'biostr' to obtain this analytical ratio grid.

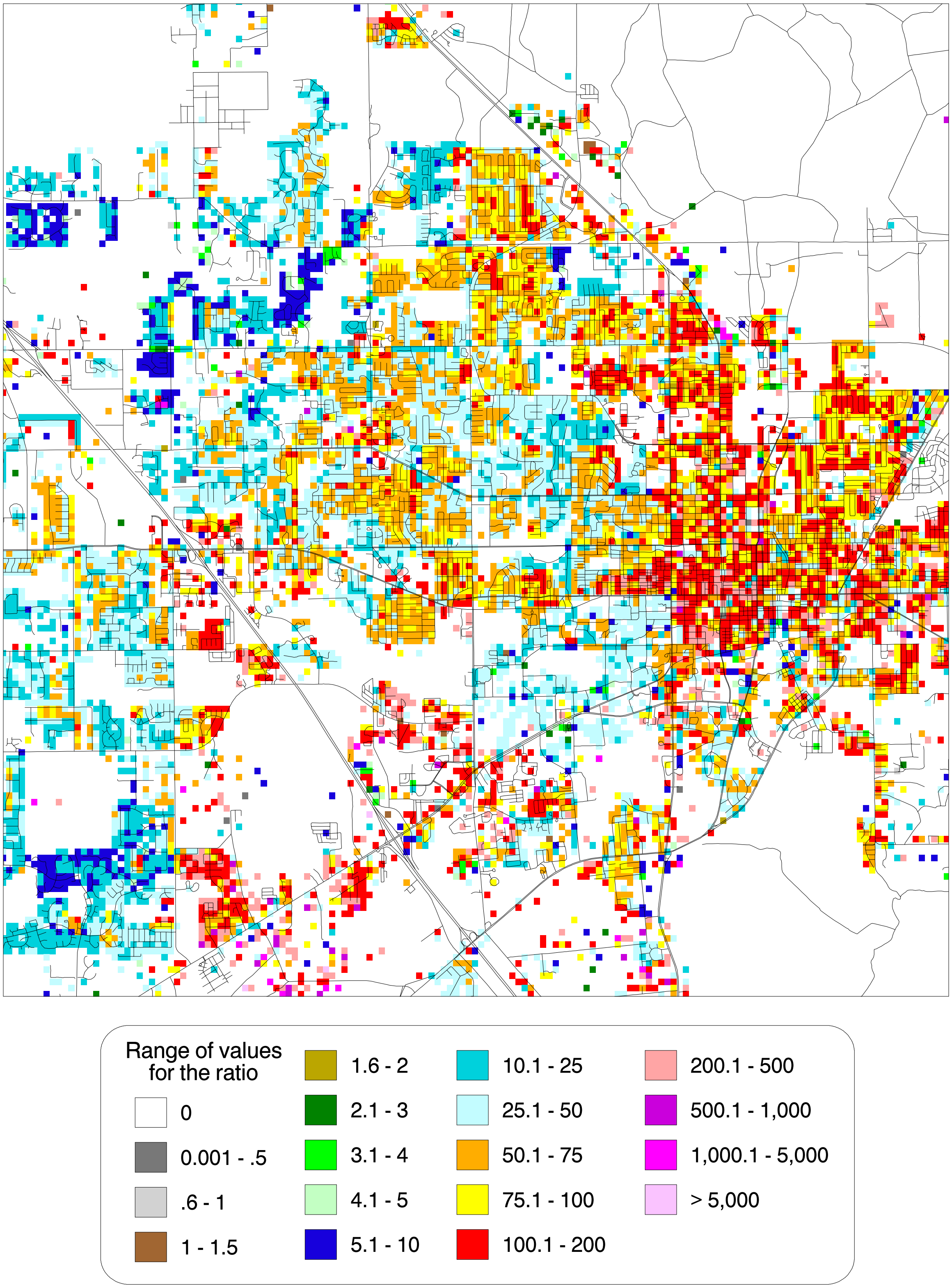


Figure A-17: 'Gainesville Closeup' map showing the values for the ratio of population to urban structure EMSTORAGE density (sej/ha). The values in the EMERGY component grid called 'popstr' were divided by the values in the EMERGY component grid called 'urbstr' to obtain this analytical ratio grid.

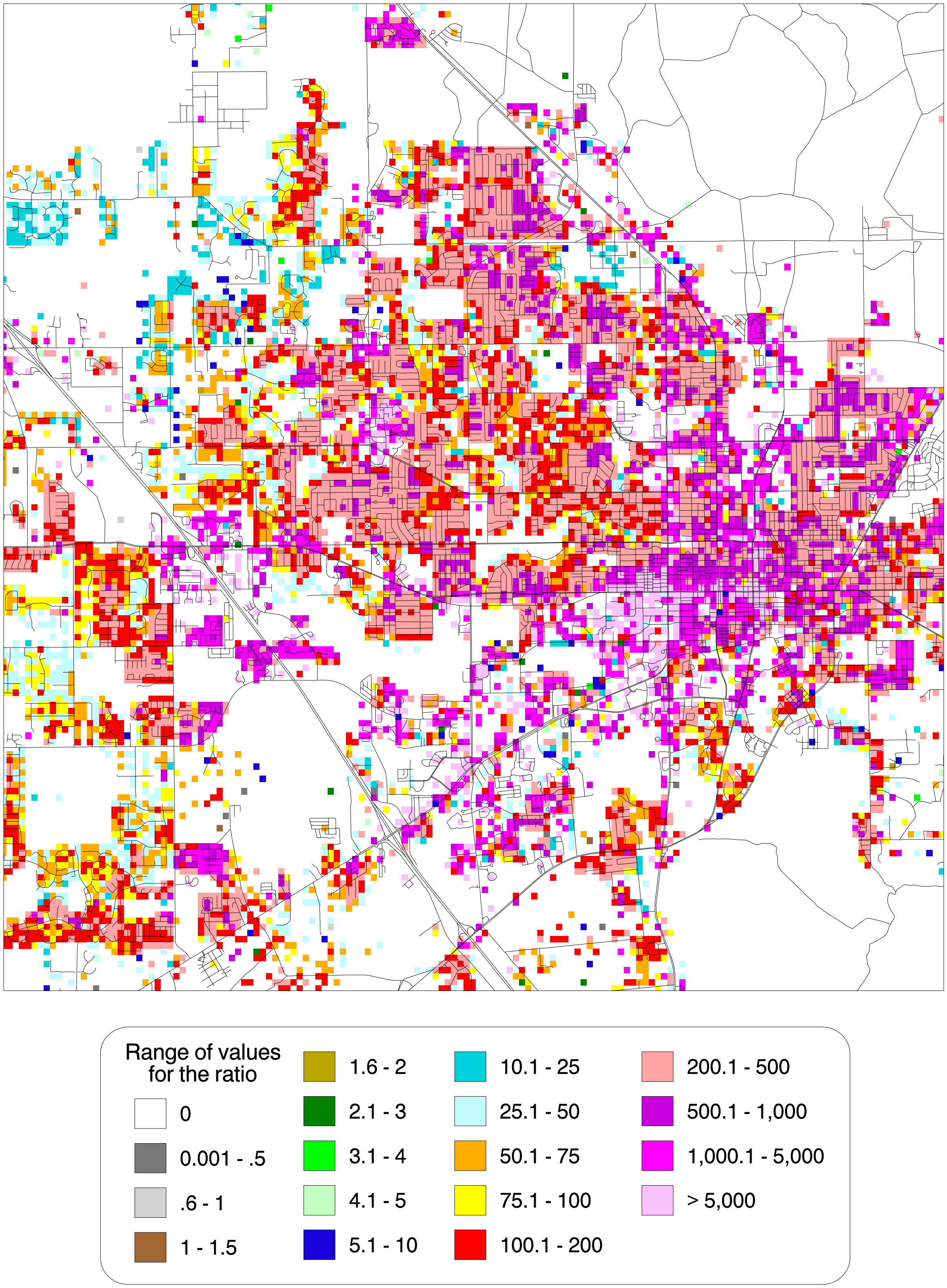


Figure A-18: 'Gainesville Closeup' map showing the values for the ratio of population to biomass EMSTORAGE density (sej/ha). The values in the EMERGY component grid called 'popstr' were divided by the values in the EMERGY component grid called 'biostr' to obtain this analytical ratio grid.

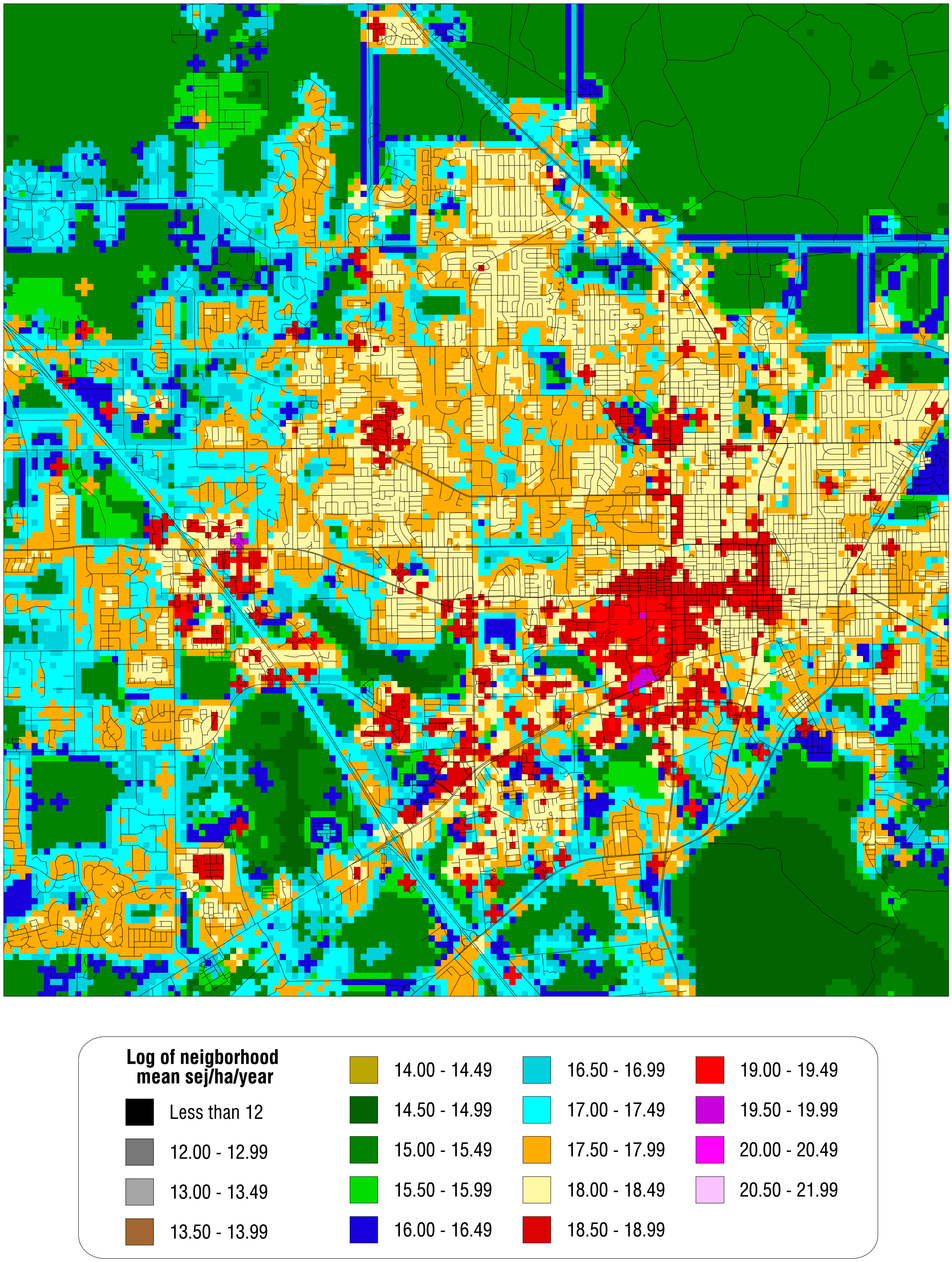


Figure A-19: 'Gainesville Closeup' map showing the log of the 'one-cell-radius neighborhood' mean total annual EMPOWER density (log neighborhood mean sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmean1c' (shown) represent the log of the mean of the total EMPOWER density values (sej/ha/yr) of those cells within a 'neigborhood' defined by a one cell radius around each cell.

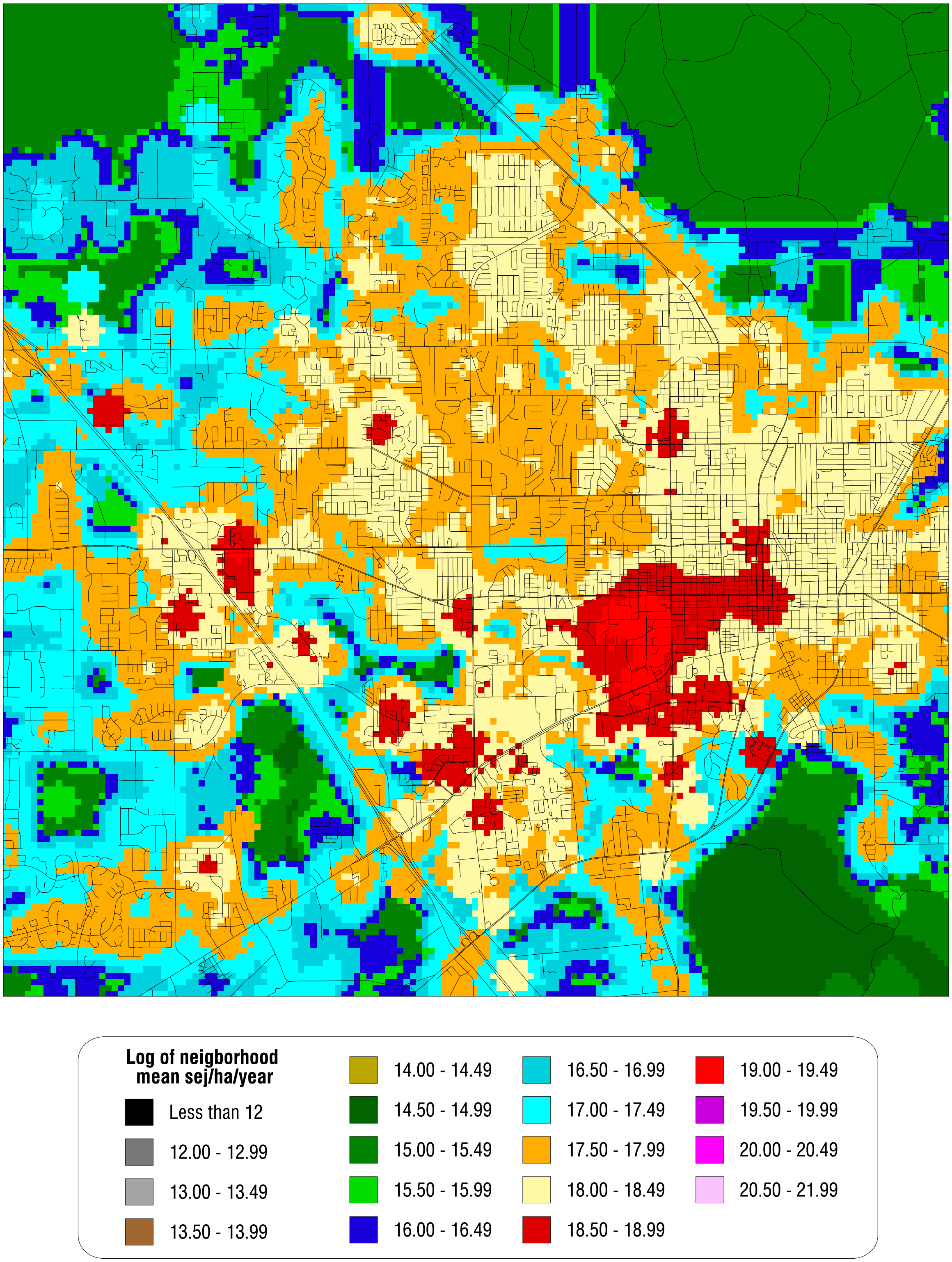


Figure A-20: ’Gainesville Closeup’ map showing the log of the ’three-cell-radius neighborhood’ mean total annual EMPOWER density (log neighborhood mean sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called ’empwrmean3c’ (shown) represent the log of the mean of the total EMPOWER density values (sej/ha/yr) of those cells within a ’neigborhood’ defined by a three cell radius around each cell.

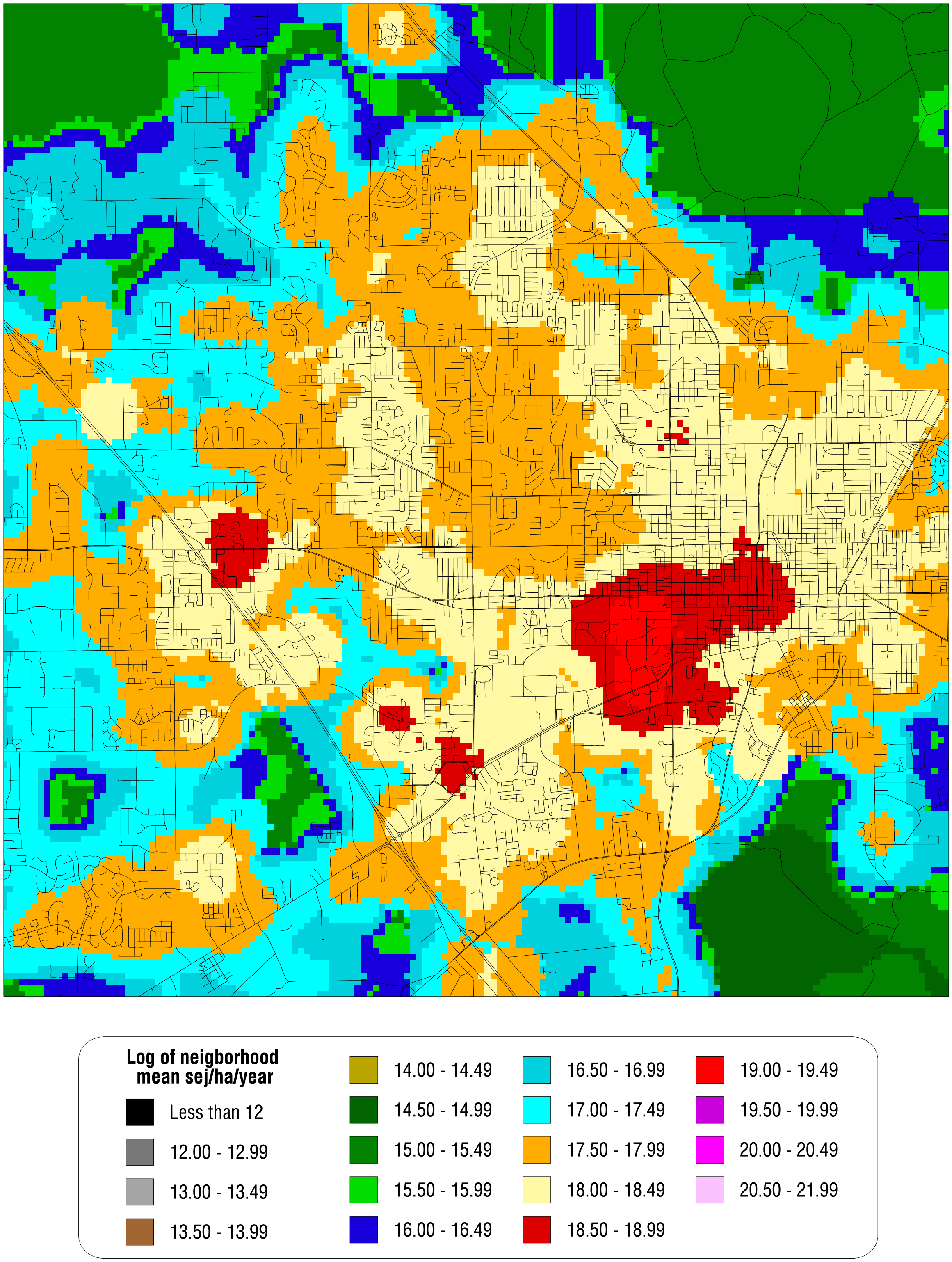


Figure A-21: 'Gainesville Closeup' map showing the log of the 'five-cell-radius neighborhood' mean total annual EMPOWER density (log neighborhood mean sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmean5c' (shown) represent the log of the mean of the total EMPOWER density values (sej/ha/yr) of those cells within a 'neigborhood' defined by a five cell radius around each cell.

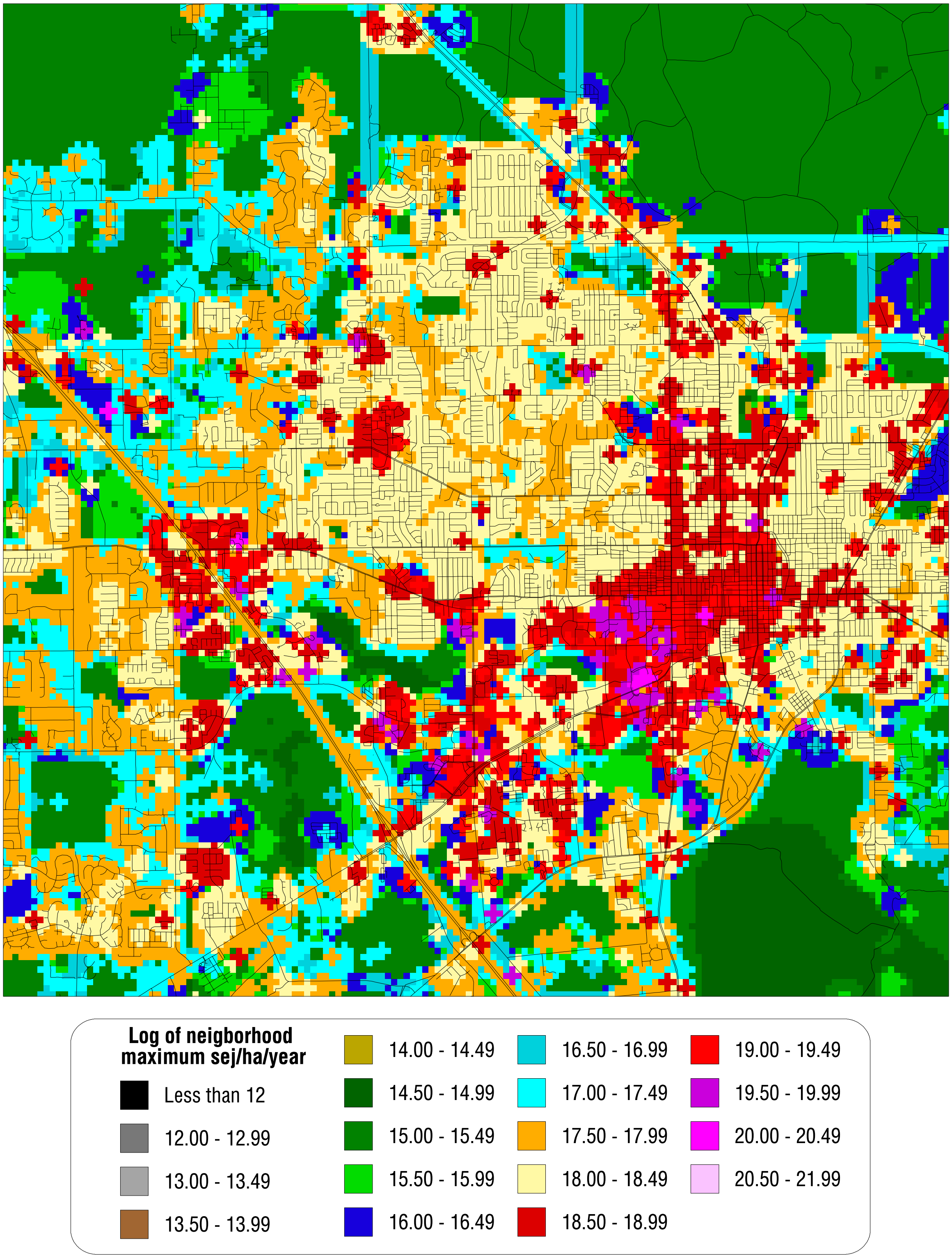


Figure A-22: 'Gainesville Closeup' map showing the log of the 'one-cell-radius neighborhood' maximum value for the total annual EMPOWER density (log neighborhood maximum sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmax1c' (shown) are the log of the maximum value for total EMPOWER density taken from the values (sej/ha/yr) of those cells that are within a 'neigborhood' defined by a one cell radius around each cell.

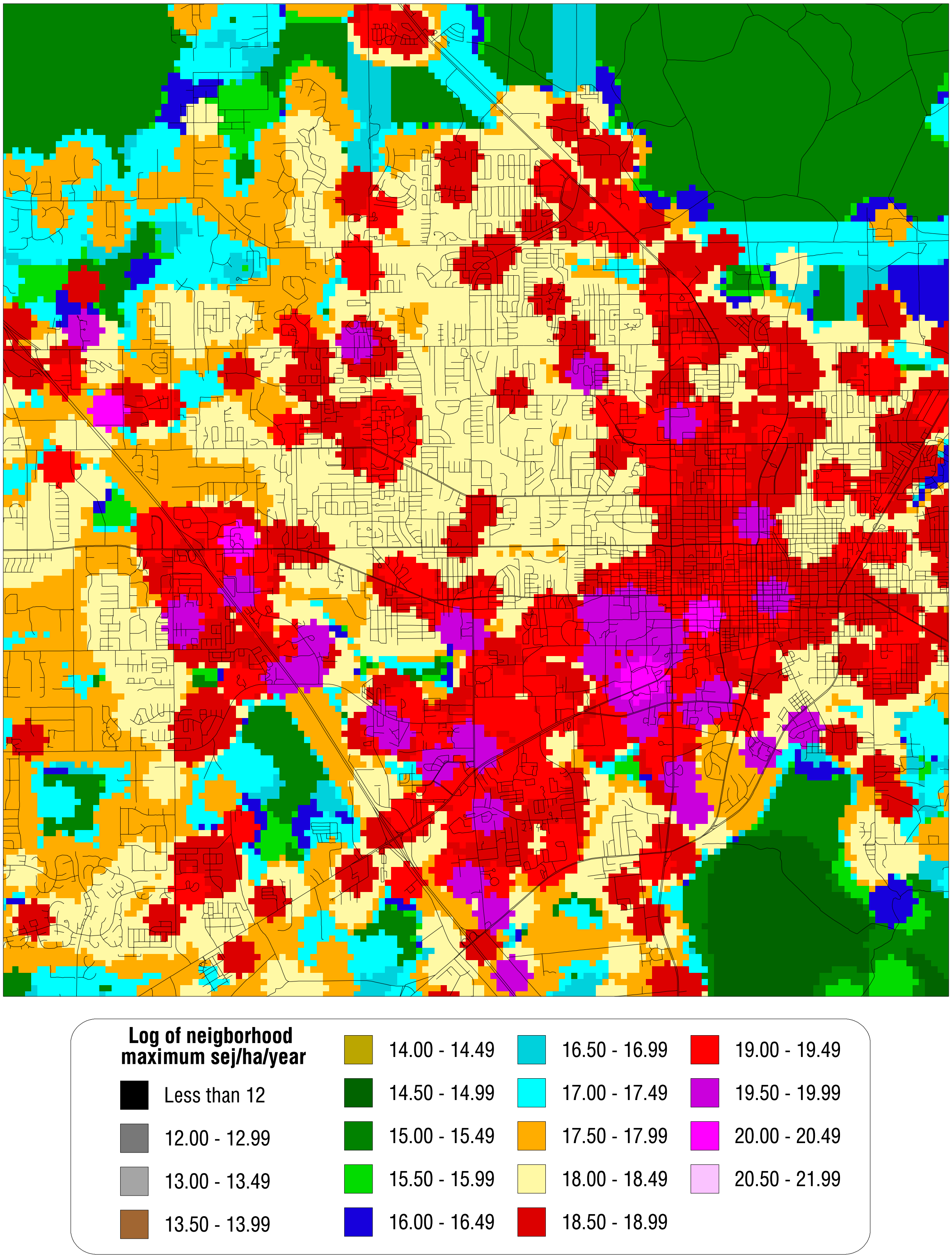


Figure A-23: 'Gainesville Closeup' map showing the log of the 'three-cell-radius neighborhood' maximum value for the total annual EMPOWER density (log neighborhood maximum sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmax3c' (shown) are the log of the maximum value for total EMPOWER density taken from the values (sej/ha/yr) of those cells that are within a 'neigborhood' defined by a three cell radius around each cell.

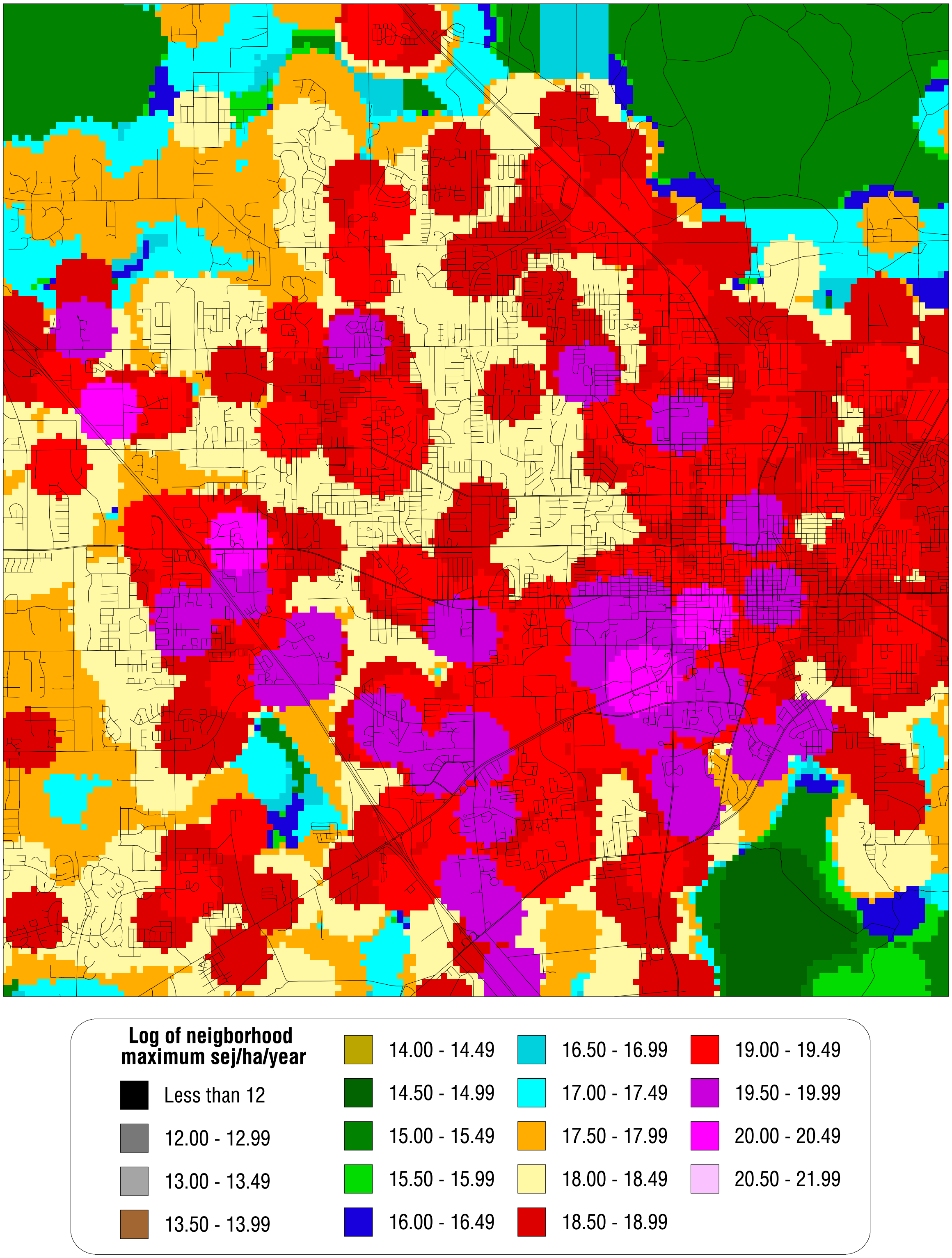
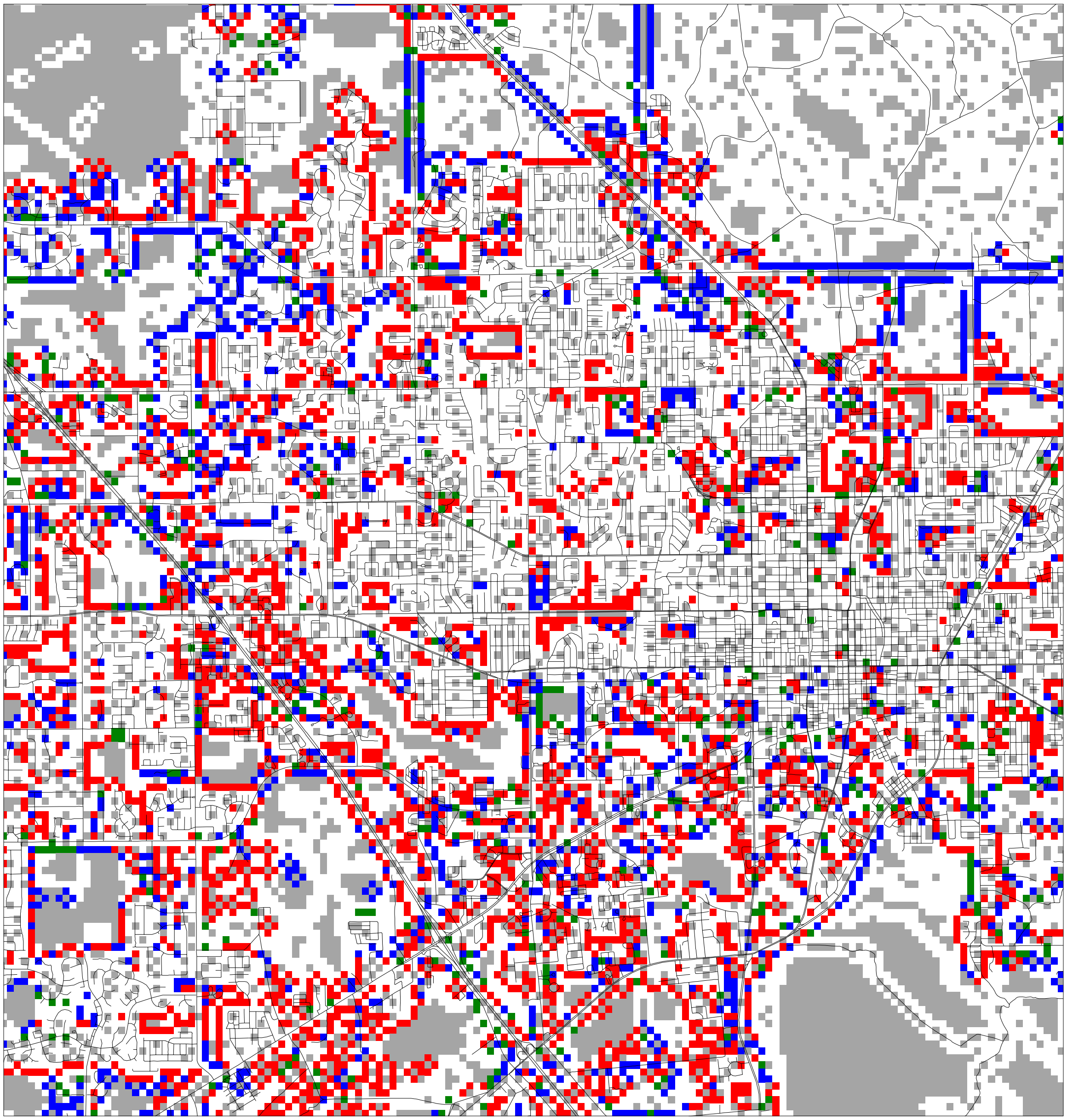


Figure A-24: 'Gainesville Closeup' map showing the log of the 'five-cell-radius neighborhood' maximum value for the total annual EMPOWER density (log neighborhood maximum sej/ha/yr). The values in each cell of the logarithm analytical EMERGY grid called 'empwrmax5c' (shown) are the log of the maximum value for total EMPOWER density taken from the values (sej/ha/yr) of those cells that are within a 'neigborhood' defined by a five cell radius around each cell.



Less than 1 % of Neighborhood Maximum EMPOWER Density Value (sej/ha/yr)

1 to 3 % of Neighborhood Maximum

3.1 to 5 % of Neighborhood Maximum

6 to 99 % of Neighborhood Maximum

Equal to Neighborhood Maximum

Figure A-25: 'Gainesville Closeup' map of the percentage of the 'one-cell-radius neighborhood' maximum value for total annual EMPOWER density. The values in each cell of the analytical grid called 'pctmaxpwr1c' (shown) were calculated by: first, finding the maximum EMPOWER density value (sej/ha/yr) in those cells that are within a 'neigborhood' defined by a one cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 for the percentage.

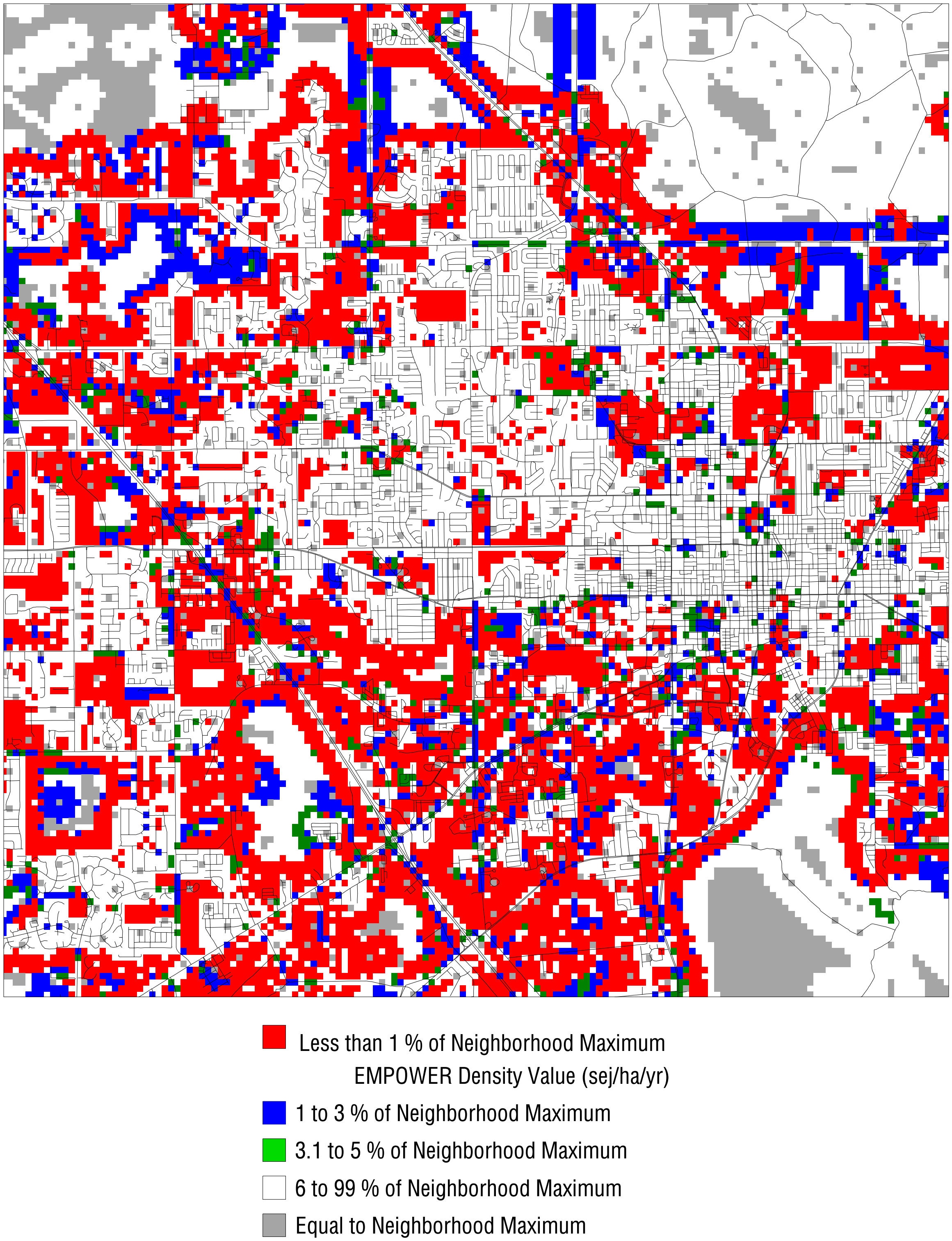


Figure A-26: 'Gainesville Closeup' map of the percentage of the 'three-cell-radius neighborhood' maximum value for total annual EMPOWER density. The values in each cell of the analytical grid called 'pctmaxpwr3c' (shown) were calculated by: first, finding the maximum EMPOWER density value (sej/ha/yr) in those cells that are within a 'neigborhood' defined by a three cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 for the percentage.

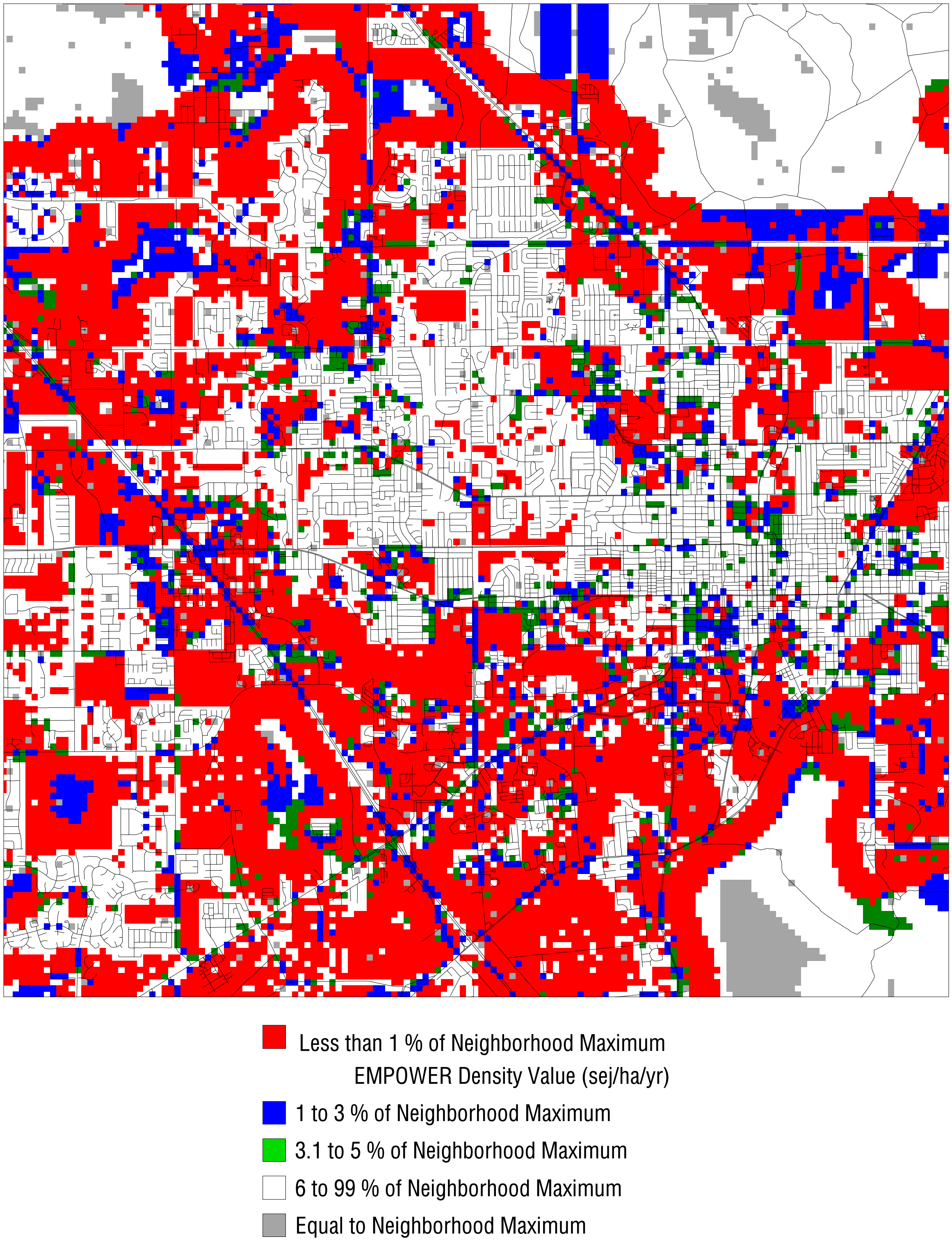


Figure A-27: 'Gainesville Closeup' map of the percentage of the 'five-cell-radius neighborhood' maximum value for total annual EMPOWER density. The values in each cell of the analytical grid called 'pctmaxpwr5c' (shown) were calculated by: first, finding the maximum EMPOWER density value (sej/ha/yr) in those cells that are within a 'neigborhood' defined by a five cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 for the percentage.

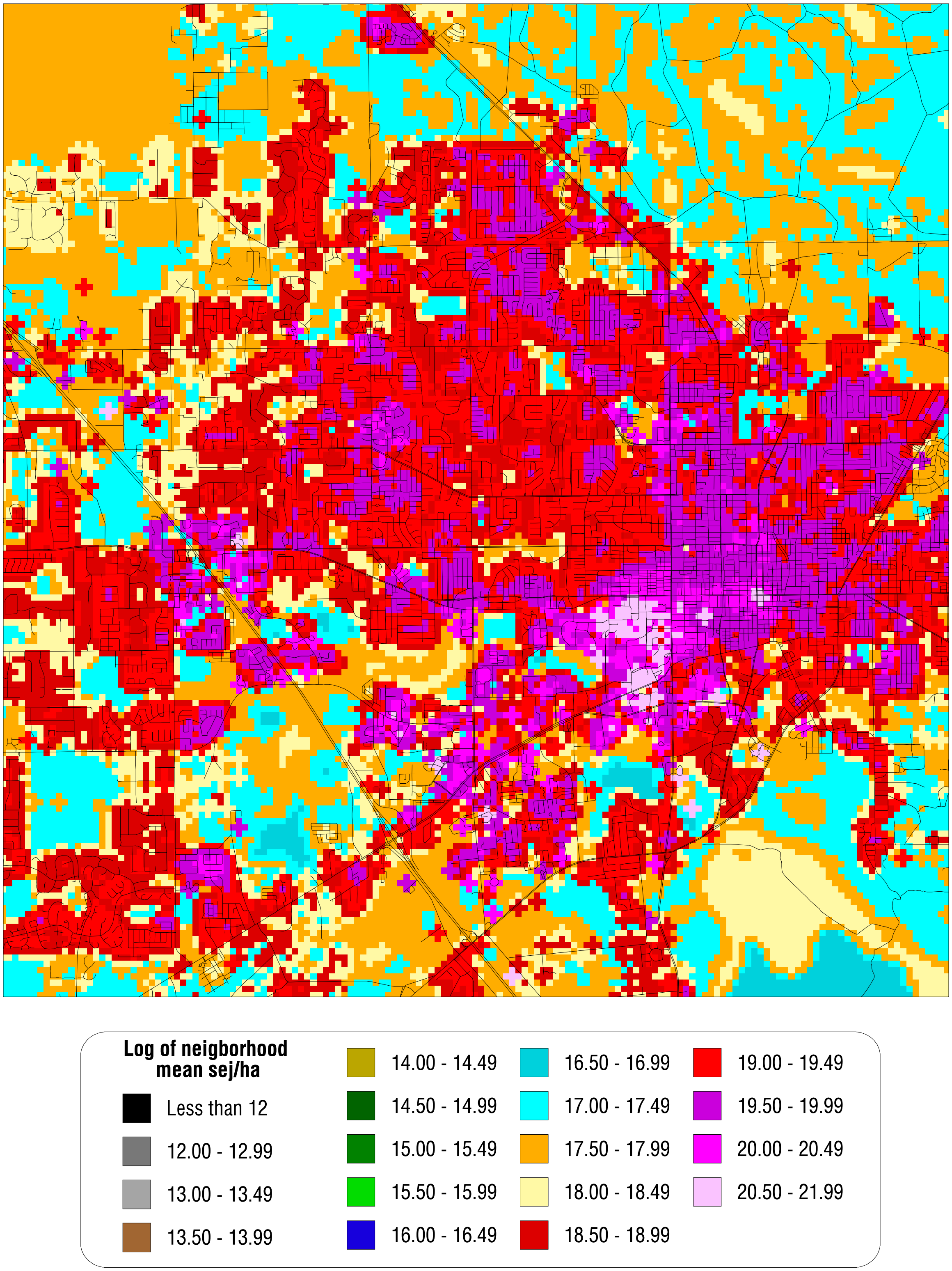


Figure A-28: 'Gainesville Closeup' map showing the log of the 'one-cell-radius neighborhood' mean total EMSTORAGE density (log of neighborhood mean sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmean1c' (shown) represent the log of the mean of the total EMSTORAGE density values (sej/ha) of those cells that are within a 'neigborhood' defined by a one cell radius around each cell.

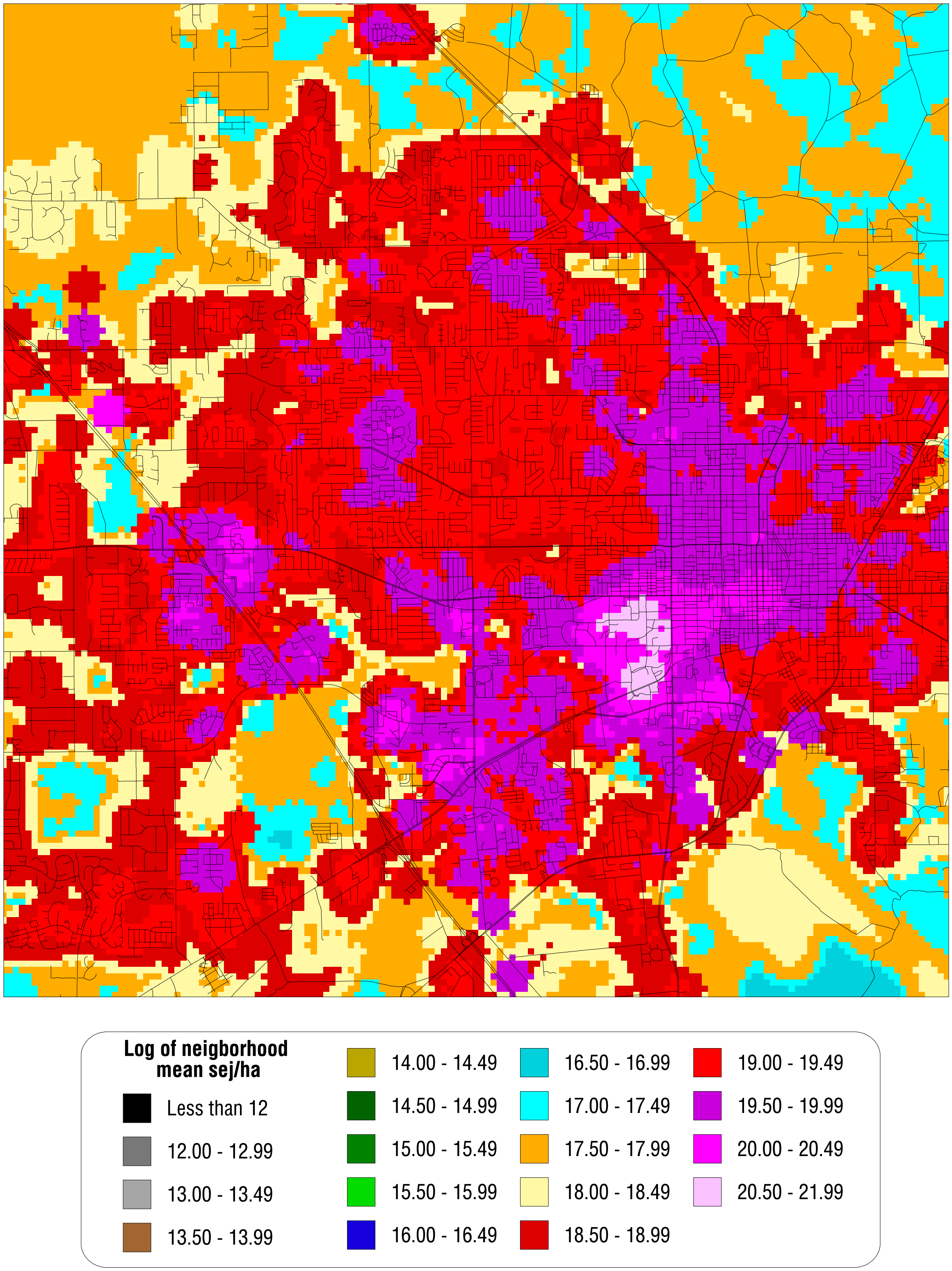


Figure A-29: 'Gainesville Closeup' map showing the log of the 'three-cell-radius neighborhood' mean total EMSTORAGE density (log neighborhood mean sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmean3c' (shown) represent the log of the mean of the total EMSTORAGE density values (sej/ha) of those cells within a 'neigborhood' defined by a three cell radius around each cell.

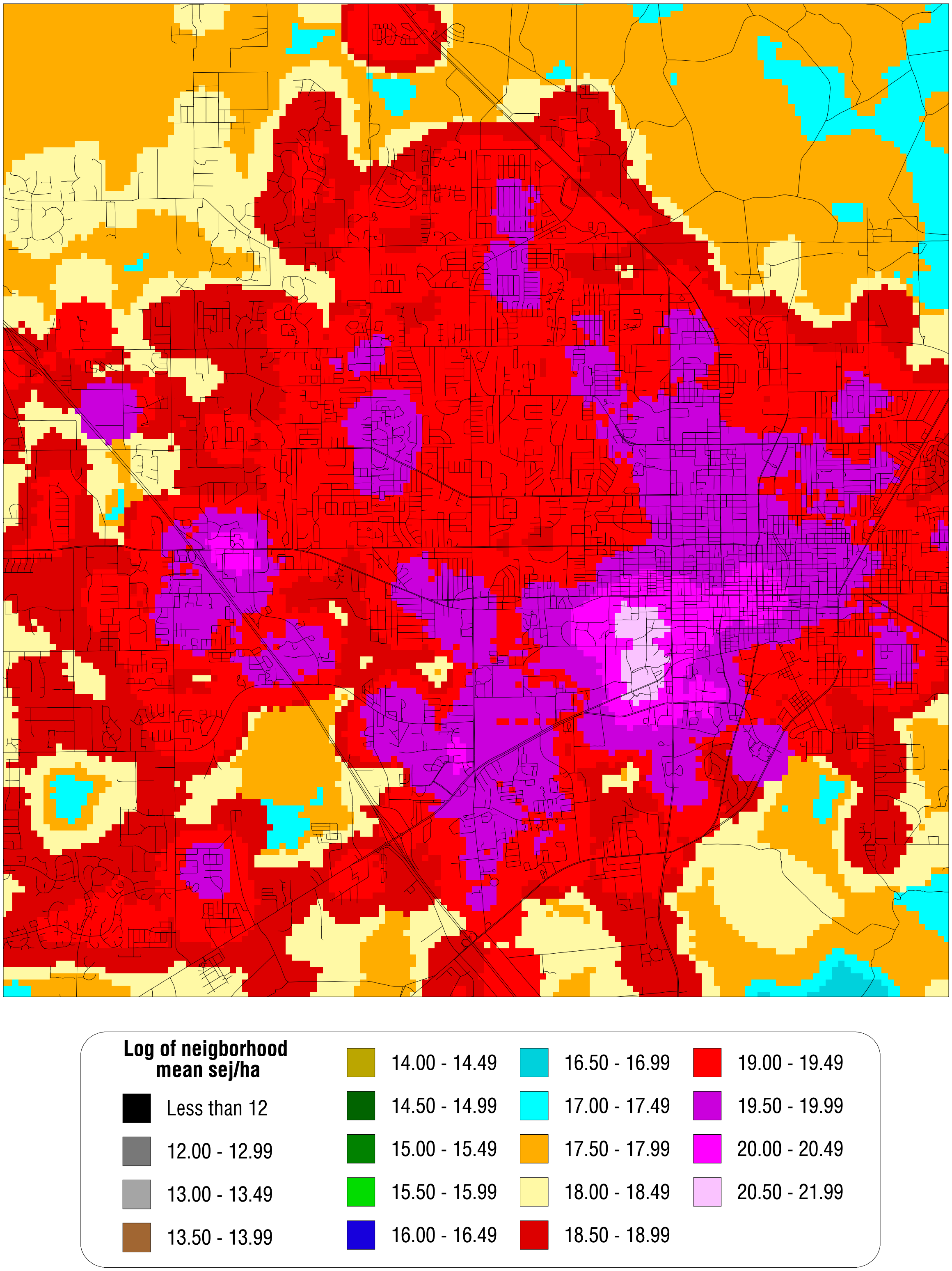


Figure A-30: 'Gainesville Closeup' map showing the log of the 'five-cell-radius neighborhood' mean total EMSTORAGE density (log neighborhood mean sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmean5c' (shown) represent the log of the mean of the total EMSTORAGE density values (sej/ha) of those cells that are within a 'neigborhood' defined by a five cell radius around each cell.

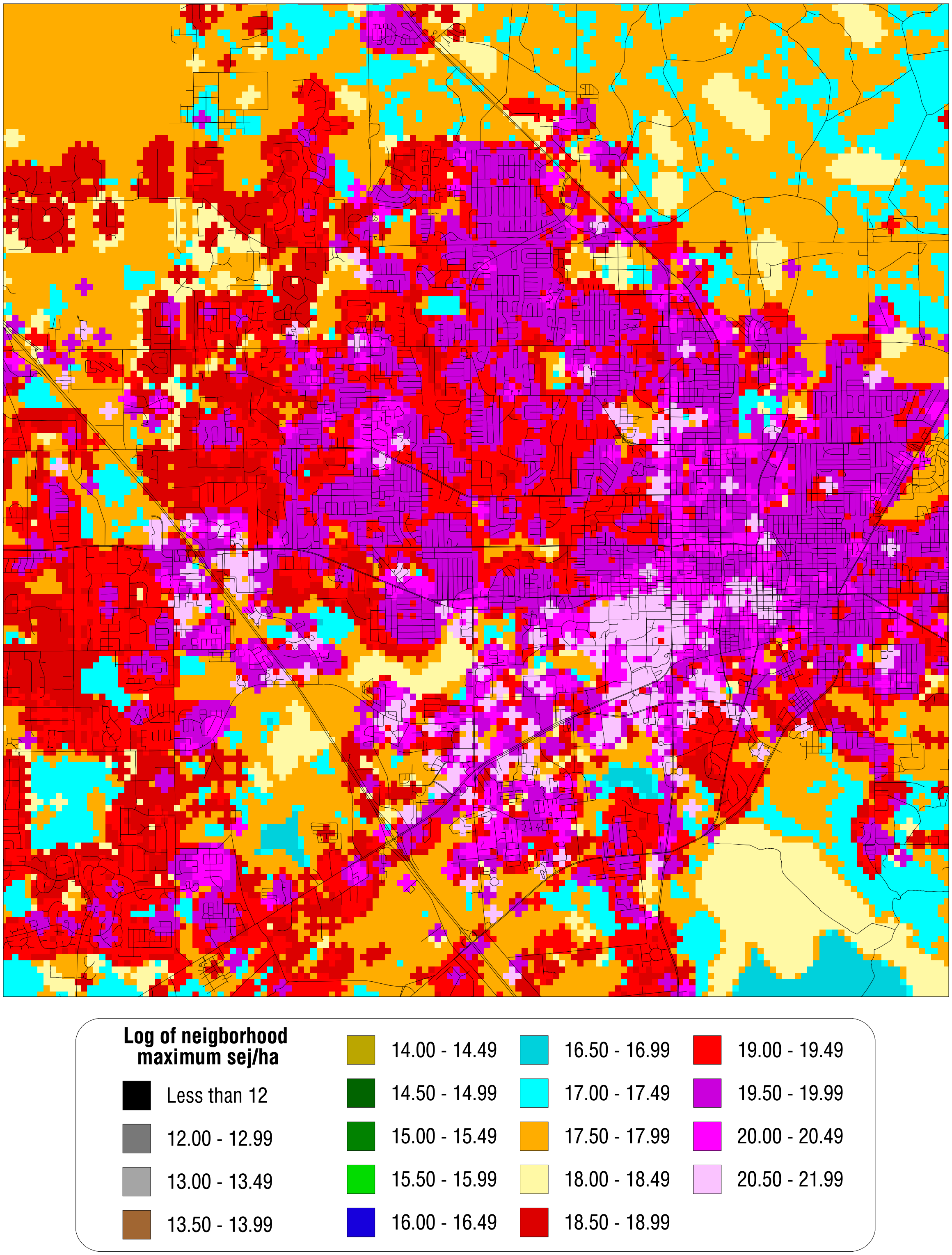


Figure A-31: 'Gainesville Closeup` map showing the log of the 'one-cell-radius neighborhood' maximum value for the total EMSTORAGE density (log of neighborhood maximum sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmax1c' (shown here) represent the log of the maximum value for total EMSTORAGE density taken from the values (sej/ha) of those cells that are within a 'neigborhood' defined by a one cell radius around each cell.

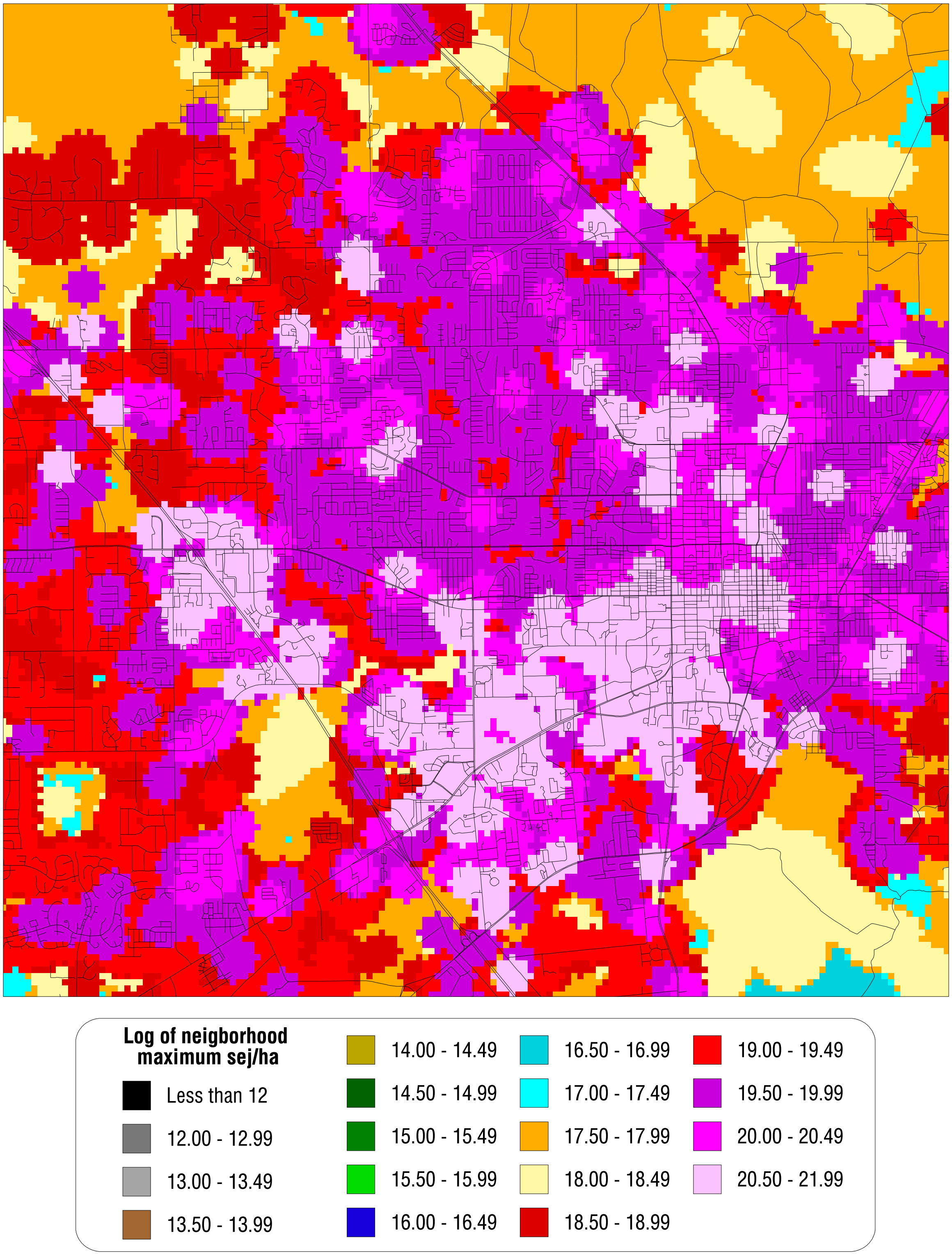


Figure A-32: 'Gainesville Closeup` map showing the log of the 'three-cell-radius neighborhood' maximum value for the total EMSTORAGE density (log of neighborhood maximum sej/ha). The values in each cell of the logarithm analytical EMERGY grid called 'emstrmax3c' (shown here) represent the log of the maximum value for total EMSTORAGE density taken from the values (sej/ha) of those cells that are within a 'neigborhood' defined by a three cell radius around each cell.

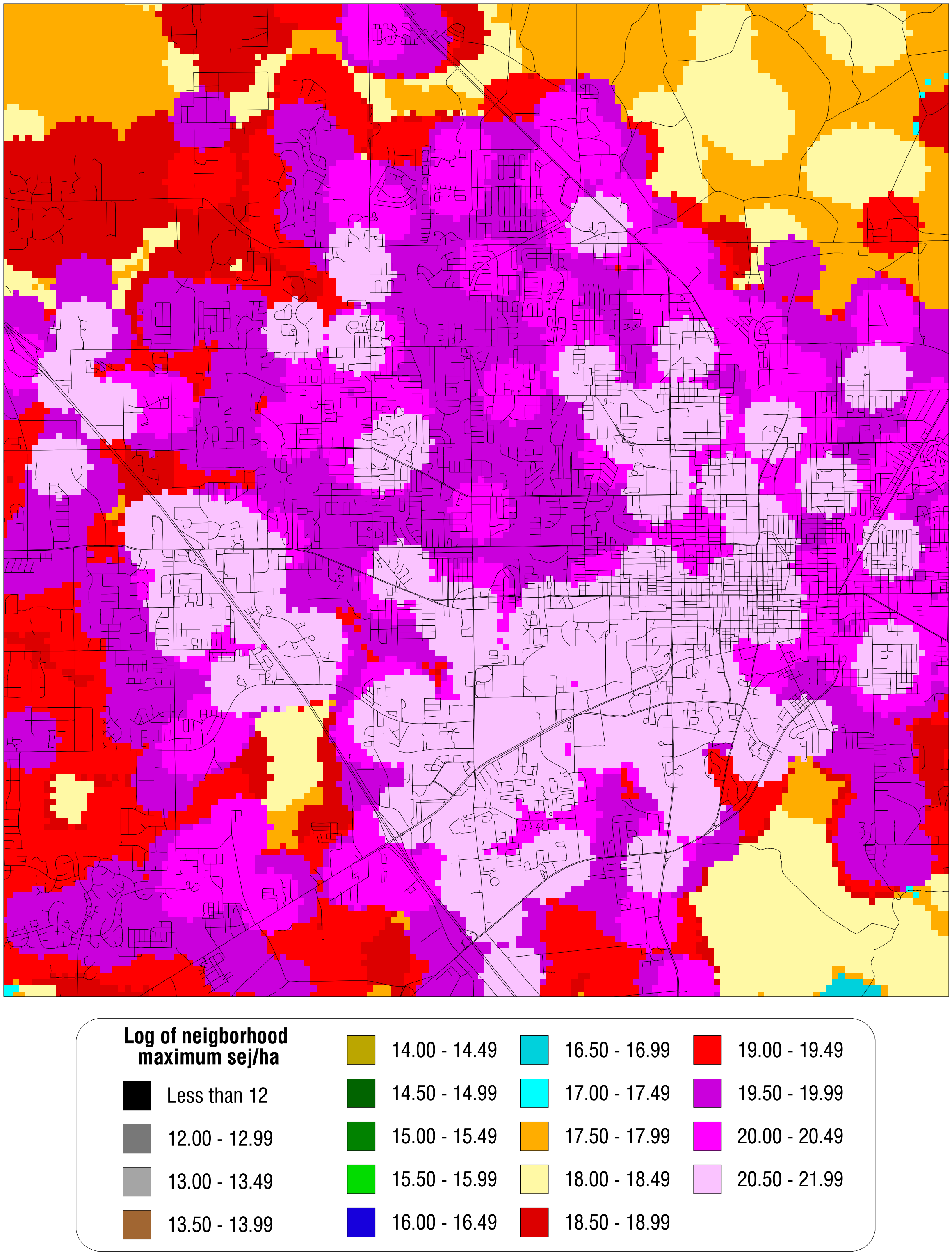
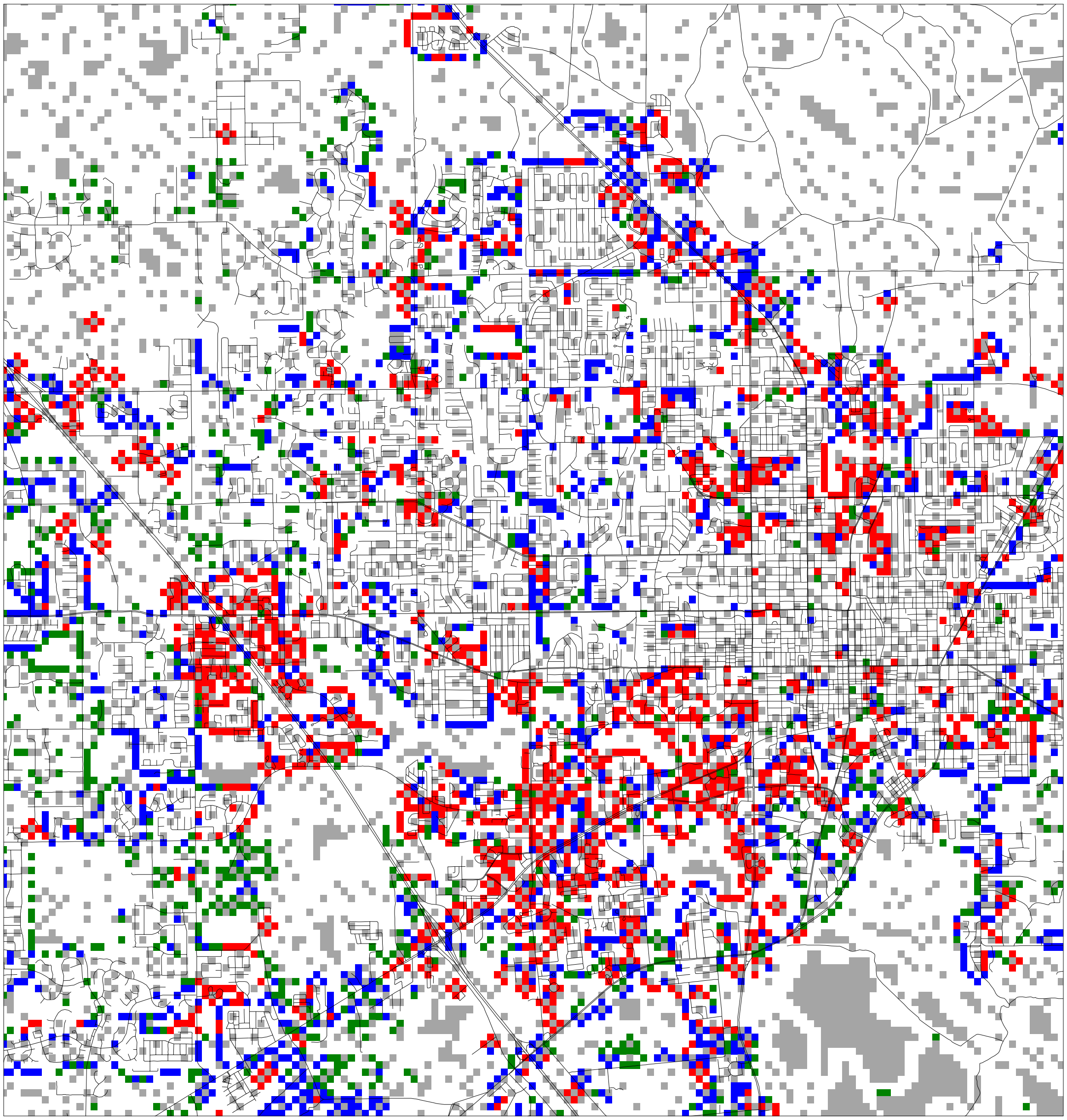


Figure A-33: ’Gainesville Closeup` map showing the log of the ’five-cell-radius neighborhood’ maximum value for the total EMSTORAGE density (log of neighborhood maximum sej/ha). The values in each cell of the logarithm analytical EMERGY grid called ’emstrmax5c’ (shown here) represent the log of the maximum value for total EMSTORAGE density taken from the values (sej/ha) of those cells that are within a ’neigborhood’ defined by a five cell radius around each cell.



Less than 1 % of Neighborhood Maximum EMSTORAGE Density Value (sej/ha)

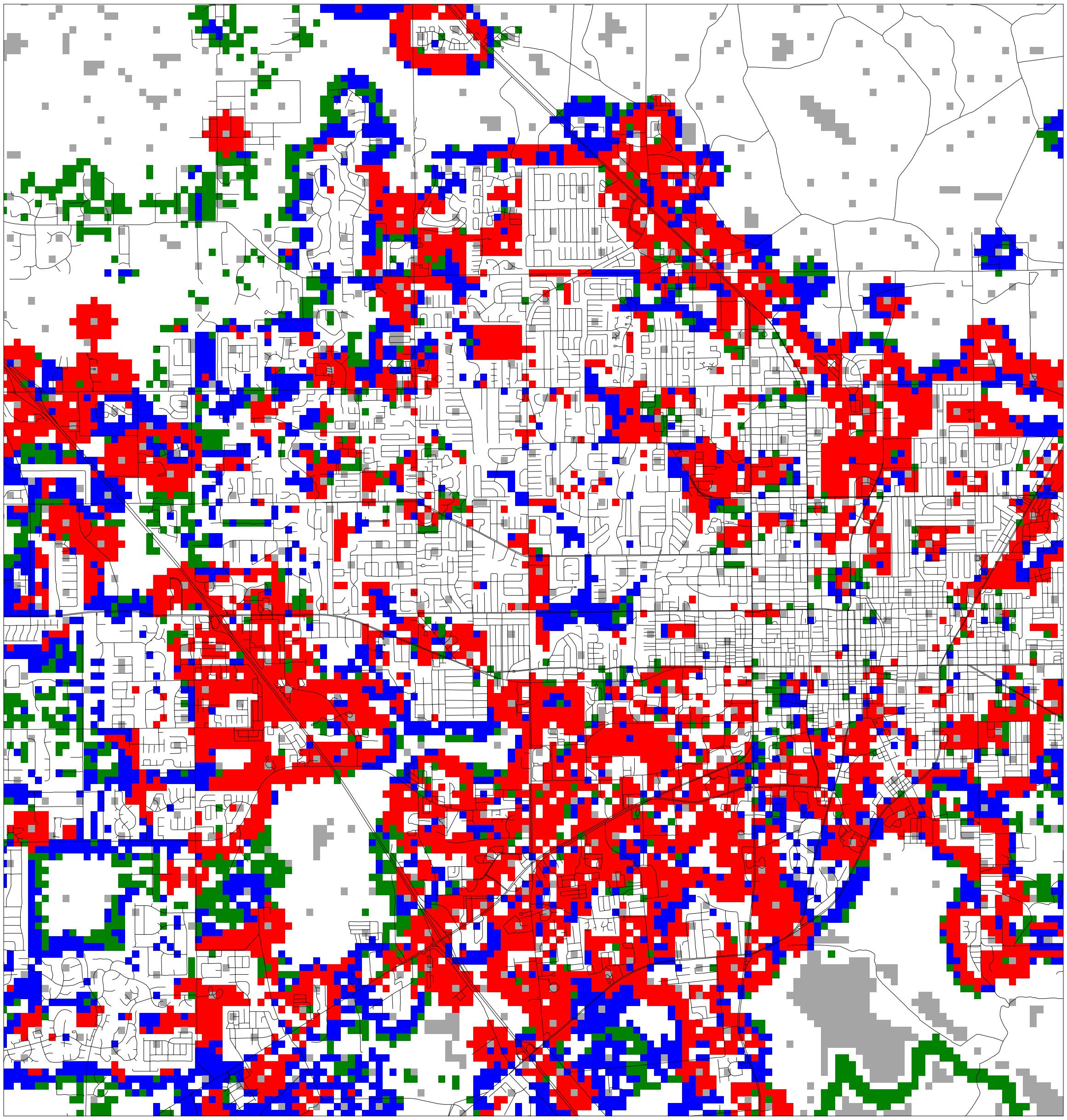
1 to 3 % of Neighborhood Maximum

3.1 to 5 % of Neighborhood Maximum

6 to 99 % of Neighborhood Maximum

Equal to Neighborhood Maximum

Figure A-34: 'Gainesville Closeup' map of the percentage of the 'one-cell-radius neighborhood' maximum value for total EMSTORAGE density. The values in each cell of the analytical grid called 'pctmaxstr1c' (shown) were calculated by: first, finding the maximum EMSTORAGE density value (sej/ha) in those cells within a 'neigborhood' defined by a one cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 to get the percentage values.



Less than 1 % of Neighborhood Maximum EMSTORAGE Density Value (sej/ha)

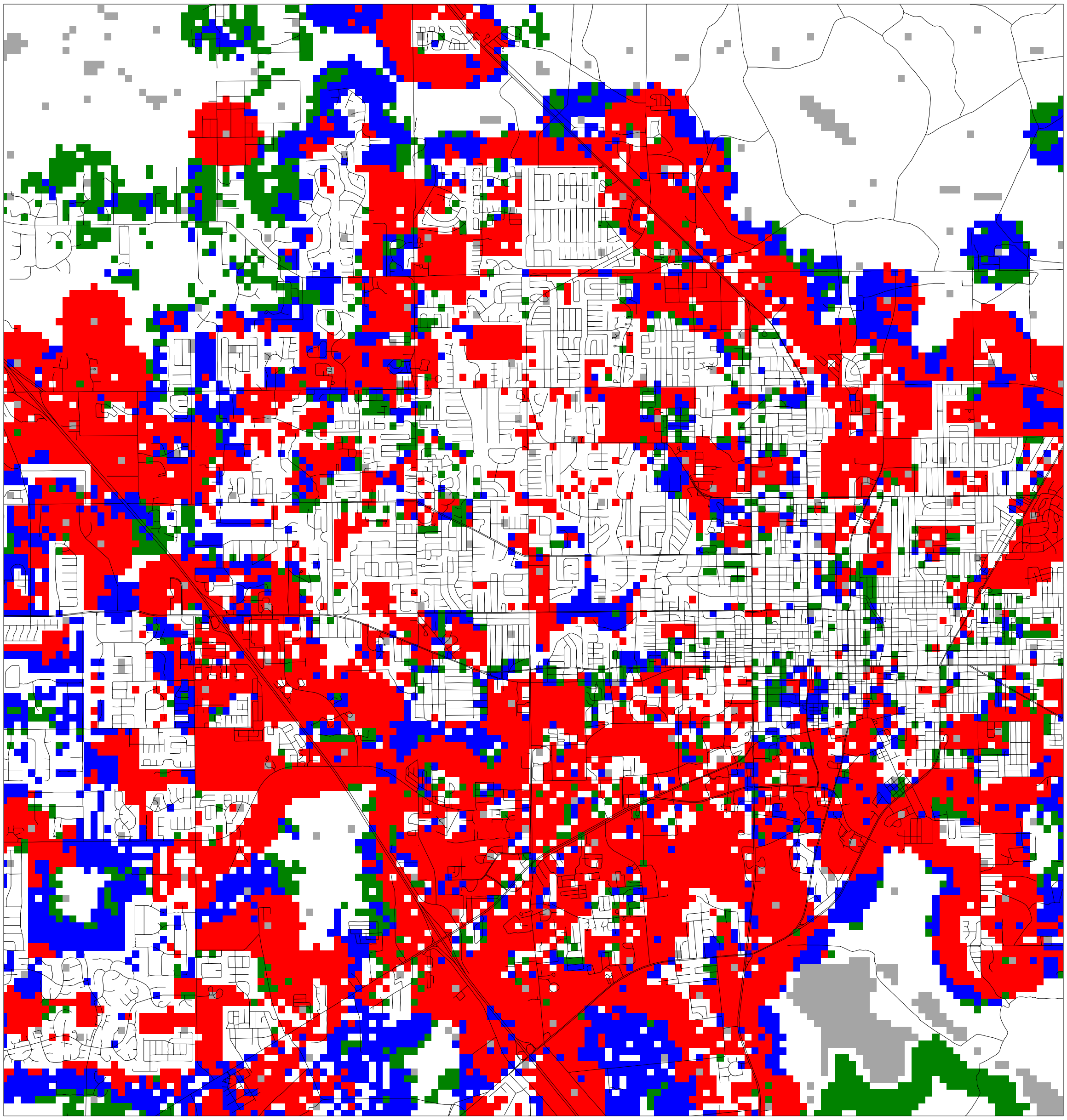
1 to 3 % of Neighborhood Maximum

3.1 to 5 % of Neighborhood Maximum

6 to 99 % of Neighborhood Maximum

Equal to Neighborhood Maximum

Figure A-35: 'Gainesville Closeup' map of the percentage of the 'three-cell-radius neighborhood' maximum value for total EMSTORAGE density. The values in each cell of the analytical grid called 'pctmaxstr3c' (shown) were calculated by: first, finding the maximum EMSTORAGE density value (sej/ha) in those cells within a 'neigborhood' defined by a three cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 to get the percentage values.



Less than 1 % of Neighborhood Maximum EMSTORAGE Density Value (sej/ha)

1 to 3 % of Neighborhood Maximum

3.1 to 5 % of Neighborhood Maximum

6 to 99 % of Neighborhood Maximum

Equal to Neighborhood Maximum

Figure A-36: 'Gainesville Closeup' map of the percentage of the 'five-cell-radius neighborhood' maximum value for total EMSTORAGE density. The values in each cell of the analytical grid called 'pctmaxstr5c' (shown) were calculated by: first, finding the maximum EMSTORAGE density value (sej/ha) in those cells within a 'neigborhood' defined by a five cell radius around each cell; and second, by dividing each cell value by the neighborhood maximum value and multiplying by 100 to get the percentage values.

LIST OF REFERENCES

Abrahamson, W.G., and D.C. Hartnett. 1990. Pine Flatwoods and Dry Prairies. In: by R.L. Meyers and J.J. Ewel, eds., Ecosystems of Florida. University of Central Florida Press, Orlando.

Ahmad, Y.J., S.E. Serafy, and E. Lutz, eds. 1989. Environmental Accounting for Sustainable Development. The World Bank, Washington, DC.

Alachua County, 1994. Alachua County Traffic Improvement Plan. Author, Gainesville, FL.

Alachua County, 1995. Alachua County Transportation Plan. Author, Gainesville, FL.

Alexander, J. F., 1981. Organization of Communities and Landscapes Into Effective Patterns of Human Settlements and Environments. In: M.T. Brown and H.T. Odum, eds., Research Needs for a Basic Science of the System of Humanity and Nature and Nature and Appropriate Technology for the Future–Results of a Workshop at Gainesville, Florida, May, 1981. Center for Wetlands, University of Florida, Gainesville.

Apps, M.J., and D.T. Price (eds.). 1996. Forest Ecosystems, Forest Management, and the Global Carbon Cycle-NATO ASI Series Volume 40. Springer-Verlag, Berlin.

Archibold, O.W. 1995. Ecology of World Vegetation. Chapman & Hall, London.

Art, H.W., and P.L. Marks. 1978. A Summary Table of Biomass and Net Annual Primary Production in Forest Ecosystems of the World. In: H. Leith, ed., Patterns of Primary Production in the Biosphere-Benchmark Papers in Ecology, Volume 8. Dowden, Hutchinson, & Ross, Inc., and Academic Press, New York.

Beard, J.B. 1985. An Assessment of Water Use by Turfgrass. In: Turfgrass Water Conservation. University of California Cooperative Extension, Riverside, CA.

Bernatzky, A. 1978. Tree Ecology and Preservation-Developments in Agricultural and Managed-Forest Ecology, 2. Elsevier Scientific Publishing Co., Amsterdam.

Brown, M. T. 1980. Energy Basis for Hierarchies in Urban and Regional Landscapes. Ph.D. Dissertation, Department of Environmental Engineering Sciences, University of Florida, Gainesville.

Brown, M.T. 1981. General Theoretical Principles for a Science of the Landscape. In: M.T. Brown and H.T. Odum, eds., Research Needs for a Basic Science of the System of Humanity and Nature and Appropriate Technology for the Future– Results of a Workshop at Gainesville, Florida, May, 1981.. Center for Wetlands, University of Florida, Gainesville.

Brown, M.T., and G.V. Genova. 1973. Energy Indices in the Urban pattern. Master's Terminal Project, Department of Architecture, University of Florida, Gainesville.

Brown, M.T., and H.T. Odum, eds. 1981. Research Needs for a Basic Science of the System of Humanity and Nature and Appropriate Technology for the Future– Results of a Workshop at Gainesville, Florida, May, 1981. Center for Wetlands, University of Florida, Gainesville.

Brown, S.L., S.W. Cowles, and H.T. Odum. 1984a. Metabolism and Transpiration of Cypress Domes in North-Central Florida. In: K.C. Ewel and H.T. Odum, eds., Cypress Swamps. University Presses of Florida, Gainesville.

Brown, S.L., E.W. Flohrschutz, and H.T. Odum. 1984b. Structure, Productivity, and Phosphorus Cycling of the Scrub Cypress Ecosystem. In: K.C. Ewel and H.T. Odum, eds., Cypress Swamps. University Presses of Florida, Gainesville.

Bureau of Economic and Business Research (BEBR). 1993. County Business Patterns - Alachua County, 1993. University of Florida, Gainesville.

Bureau of Economic and Business Research (BEBR). 1995. Florida Statistical Abstract, 1995. University of Florida, Gainesville.

Center for Urban Transportation Research. 1991, July. Functional Classification of Florida's Roadways. Report to the Florida Department of Transportation. University of South Florida, Tampa.

Center for Urban Transportation Research. 1994, May. Moving People in Florida: Transit, TDM, and Congestion. Report to the Florida Department of Transportation. University of South Florida, Tampa.

Christaller, W. 1966. Central Places in Southern Germany. Prentice Hall, Inc., Englewood Cliffs, NJ.

Costanza, R. 1975. The Spatial Distribution of Land Use Subsystems, Incoming Energy, and Energy Use in South Florida from 1900 to 1973. Master's Thesis, Department of Architecture, University of Florida, Gainesville.

Costanza, R. 1979. Embodied Energy Basis for Economic-Ecologic Systems. Ph.D. Dissertation, Department of Environmental Engineering Sciences, University of Florida, Gainesville.

Costanza, R., ed., 1991. Ecological Economics, The Science and Management of Sustainability. Columbia University Press, New York.

Day, F.P. 1984. Biomass and Litter Accumulation in the Great Dismal Swamp. In: K.C. Ewel and H.T. Odum, eds., Cypress Swamps. University Presses of Florida, Gainesville.

DeBellevue. E.B. 1976. Energy Basis for an Agricultural Region: Hendry County, Florida. Master's Thesis. Department of Environmental Engineering Sciences. University of Florida, Gainesville.

DeBellevue. E.B., R. Guttierrez, and S. Bayley. 1975. Action and Research Alternatives for Pasture Systems. In: Carrying Capacity for Man and Nature in South Florida. Center for Wetlands, University of Florida, Gainesville.

Duryea, M.L., and J.C. Edwards. 1987. Planting Southern Pines. Extension Circular 767. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Energy Information Administration (EIA). 1991. Manufacturing Consumption of Energy-1991 Energy Consumption in Manufacturing Survey. U.S. Department of Energy, Washington, DC.

Energy Information Administration (EIA). 1992. Commercial Buildings Energy Consumption and Expenditures-1992 Commercial Building Energy Survey. U.S. Department of Energy, Washington, DC.

Energy Information Administration (EIA). 1993. Household Energy Consumption and Expenditures-1993 Residential Energy Consumption Survey. U.S. Department of Energy, Washington, DC.

Energy Information Administration (EIA). 1994. State Energy Data Report, 1994. U.S. Department of Energy, Washington, DC.

Environmental Systems Research Institute (ESRI). 1996. Understanding GIS: The Arc/Info Method. Redlands, CA.

Ewel, K.C. 1990. Swamps. In: R.L. Meyers and J.J. Ewel , eds., Ecosystems of Florida.. University of Central Florida Press, Orlando.

Federal Highway Administration. 1989. Highway Functional Classification: Concepts, Criteria, and Procedures-Publication No. FHWA-ED-90-006. U.S. Department of Transportation, Washington, DC.

Fernald, E.A., and D.J. Patton, eds. 1984. Water Resources Atlas of Florida. Institute of Science and Public Affairs, Florida State University, Tallahassee, Florida.

Florida Department of Environmental Protection (FDEP). 1995. Solid Waste Management Annual Report to the Florida Legislature, 1994-1995. Author, Tallahassee.

Florida Department of Transportation (FDOT). 1985. Florida Land Use, Cover and Forms Classification System. Technical Procedure Document No. 550-010-001-A. State Topographic Bureau, Thematic Mapping Section. Author, Tallahassee.

Florida Department of Transportation. 1994. Transportation Costs Report-1994. Author, Tallahassee.

Florida Department of Transportation. 1993. Road Characteristics Inventory-Features and Characteristics Manual. Author, Tallahassee.

Fluck, R.C. 1992. Energy in Florida Agriculture-Extension Fact Sheet EES-79. Florida Energy Extension Service, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Fluck, R.C. 1992b. Energy for Florida Beef-Extension Fact Sheet EES-83. Florida Energy Extension Service, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Gainesville Regional Utilities, Inc. (GRU). 1996. Gainesville Regional Utilities 1996 Annual Report-Emerging Opportunities. Author, Gainesville.

Gholz, H.L., and R.F. Fisher. 1982. Organic Matter Production and Distribution in Slash Pine Ecosystems. Ecology, 63: 1827 - 1839.

Golkin, K.R. 1981. A Computer Simulation of the Carbon, Phosphorus, and Hydrologic Cycles of a Pine Flatwoods System. Master's Thesis. School of Forest Resources and Conservation, University of Florida, Gainesville.

Golkin, K.R., and K.C. Ewel. 1984. A Computer Simulation of the Carbon, Phosphorus, and Hydrologic Cycles of a Pine Flatwoods Ecosystem. Ecological Modeling, 24: 113-136.

Golley, F.B. 1965. Energy Dynamics of a Food Chain of an Old Field Community. Michigan State University, East Lansing.

Gottgens, J.F., and C.L. Montague. 1987. Orange, Lochloosa, and Newnans Lakes: A Survey and Preliminary Interpretation of Environmental Data. Report for SJRWMD Project 15-200-33. Department of Environmental Engineering Sciences, University of Florida, Gainesville.

Gutierrez, R.J. 1978. Energy Analysis and Computer Simulations of Pastures in Florida. Master's thesis, Department of Environmental Engineering Sciences, University of Florida, Gainesville.

Hall, C.A.S. 1995. Maximum Power–The Ideas and Applications of H.T. Odum. University Press of Colorado, Niwot, CO.

Hensley, D.L. 1994. Professional Landscape Management. Stipes Publishing L.L.C., Champaign, IL.

Huang, S.,-L. 1998. Spatial Hierarchy of Urban Energetic System. In: S. Ulgiati, ed., Advances in Energy Studies–Energy Flows in Ecology and Economy-Proceedings of the International Workshop held May, 1998. Museum of Science and Scientific Information, Rome.

Kangas, P. C. 1983. Energy Analysis of Landforms, Succession, and Reclamation. Ph.D. Dissertation, Department of Environmental Engineering Sciences, University of Florida, Gainesville.

Kaiser, E.J., D.R. Godschalk, and F.S. Chapin, Jr. 1995. Urban Land Use Planning. University of Illinois Press, Chicago.

Kushlan, J.A. 1990. Freshwater Marshes. In: R.L. Meyers and J.J. Ewel, eds., Ecosystems of Florida. University of Central Florida Press, Orlando.

Lambert, J.D., 1996. Alachua County Property Parcel GIS Conversion Project. Report submitted to the Alachua County Property Appraiser's Department and Gainesville Regional Utilities. GeoPlan Center, University of Florida, Gainesville.

Lambert, J.D., and P.D. Zwick, 1997. Florida Geographic Data Library: A Case Study in the Design of a State-wide GIS Data Depository. Proceedings of GIS AM/FM ASIA '97 & GeoInformatics '97-Mapping the Future of Asia Pacific. Taipei, Taiwan.

Leith, H. 1975. Primary Productivity of the Major Vegetation Units of the World. In: H. Leith and R.H. Whittaker, eds., Primary Productivity of the Biosphere. Springer-Verlag, New York.

Leith, H., ed. 1978. Patterns of Primary Production in the Biosphere-Benchmark Papers in Ecology, Volume 8. Dowden, Hutchinson, & Ross, Inc., and Academic Press, New York.

Lillesand, T.M. and R.W. Kiefer. 1987. Remote Sensing and Image Interpretation, 2nd Edition. John Wiley & Sons, New York.

Littlejohn, C. B. 1973. An Energetics Approach to Land Use Planning in a Coastal Community of Southwest Florida. Master's Thesis, Department of Environmental Engineering Sciences, University of Florida, Gainesville.

Long, S.P., M.B. Jones, and M.J. Roberts. 1992. Primary Productivity of Grass Ecosystems for the Tropics and Sub-tropics. Chapman & Hall, London.

Lotka, A.J. 1922. A Contribution to the Energetics of Evolution. Proceedings of the National Academy of Science, 8:147-55.

Lugo, A.E. 1978. Structure, Productivity, and Transpiration of a Subtropical Dry Forest in Puerto Rico. Biotropica, 10:278-91.

Maltby, D.K. 1977. Energy and Resource Models of an Urban Ecosystem-Jacksonville, Florida. Master's Thesis, Department of Urban and Regional Planning, University of Florida, Gainesville.

Marella, R. L. 1992. Water Withdrawals, Use, and Trends in Florida, 1990: U.S. Geological Survey Water Resources Investigations Report 92-4140. U.S. Geological Survey, Washington, DC.

Marella, R. L. 1993. Public Water Supply Water Use in Florida, 1990: U.S. Geological Survey Open-File Report 93-134. U.S. Geological Survey, Washington, DC.

Marella, R. L. 1994. Estimated Discharge of Treated Wastewater in Florida, 1990: U.S. Geological Survey Open-File Report 93-364. U.S. Geological Survey, Washington, DC.

May, B. 1993. St. John's River Water Management District Geographic Information System Data Documentation. Technical report by the GIS Division, Department of Groundwater Programs & Technical Support, St. John's River Water Management District, Palatka, FL.

McHarg, I.L. 1969. Design with Nature. Natural History Press, Garden City, NY.

Meyers, R.L., and J.J. Ewel, eds. 1990. Ecosystems of Florida. University of Central Florida Press, Orlando.

National Academy of Sciences. 1975. Proceedings of the Symposium on Productivity of World Ecosystems. U.S. National Committee for the International Biological Program, Seattle, Washington, Sept. 1972. National Academy of Sciences, Washington, DC.

Natural Resources Conservation Service. 1995. Soil Survey Geographic (SSURGO) Data Base - Data Use Information. Miscellaneous Publication 1527. National Soil Survey Center, Fort Worth, TX.

Nessel, J.K., and S.E. Bayley. 1984. Distribution and Dynamics of Organic Matter and Phosphorus in a Sewage-Enriched Cypress Swamp. In: K.C. Ewel and H.T. Odum, eds., Cypress Swamps. University Presses of Florida, Gainesville.

Odum, E.P. 1971. Fundamentals of Ecology, Third Edition. Saunders College Publishing. Philadelphia, PA.

Odum, H.T. 1971. Environment, Power, and Society. John Wiley & Sons, Inc., New York.

Odum, H.T. 1976. Energy Quality and Carrying Capacity of the Earth. Tropical Ecology, 16(1):1-8.

Odum, H.T. 1983. Systems Ecology. John Wiley & Sons, Inc., New York.

Odum, H.T. 1988. Self-Organization, Transformity, and Information. Science, 242: 1132-1139.

Odum, H.T. 1992a. Emergy and Public Policy, Part II. Center for Environmental Policy, Environmental Engineering Sciences, University of Florida, Gainesville.

Odum, H.T. 1992b. Manual for Evaluation of Wetlands in Florida. Paper included with the Plenary Presentation at the IV International Wetlands Conference, Columbus, Ohio, Sept. 18, 1992. Center for Environmental Policy, University of Florida, Gainesville.

Odum, H.T. 1993. Ecological and General Systems. University Press of Colorado, Niwot, CO.

Odum, H.T. 1996. Environmental Accounting: EMERGY and Environmental Decision Making. John Wiley & Sons, Inc., New York.

Odum, H.T., and J.E. Arding. 1991. EMERGY Analysis of Shrimp Mariculture in Ecuador, Working Paper. Department of Environmental Engineering Sciences and Center for Wetlands, University of Florida, Gainesville.

Odum, H.T. and M.T. Brown, eds. 1976. Carrying Capacity of Man and Nature in South Florida. Final contract report to the U.S. Department of the Interior, National Park Service, Washington, DC. Department of Environmental Engineering Sciences and Center for Wetlands, University of Florida, Gainesville.

Odum, H.T., M.T. Brown, and R. Costanza. 1976. Developing a Steady State for Man and Land: Energy Procedures for Regional Planning. Proceedings of the International Congress on the Human Environment, Kyoto. pp. 343-361.

Odum, H.T., and E.C. Odum. 1976. Energy Basis for Man and Nature. McGraw-Hill, New York.

Odum, H.T., E.C. Odum, and M.T. Brown. 1998. Environment and Society in Florida. Lewis Publishers, Boca Raton, FL.

Olson, J.S. 1975. Productivity of Forest Ecosystems. In: Productivity of World Ecosystems: Proceedings of a Symposium for the International Biological Program, September, 1972, Seattle, Washington. National Academy of Sciences, Washington, DC.

Packham, J.R., D.J.L. Harding, G.M. Hilton, and R.A. Stuttard. 1992. Functional Ecology of Woodlands and Forests. Chapman & Hall, London.

Regan, E.J. Jr. 1977. The Natural Energy Basis for Soils and Urban Growth in Florida. Master's Thesis, Department of Environmental Engineering Sciences, University of Florida, Gainesville.

Reichle, D.E., ed. 1981. Dynamic Properties of Forest Ecosystems - International Biological Programme 23. Cambridge University Press, Cambridge, UK.

Reid, G.K., and R.D. Wood. 1976. Ecology of Inland Waters and Estuaries. D. Van Nostrand Company. New York.

Richardson, J.F. 1988. Spatial Patterns and Maximum Power in Ecosystems. Ph.D. Dissertation, Department of Environmental Engineering Sciences, University of Florida, Gainesville.

Roudebush, W.H. 1992. Environmental Value Engineering (EVE): A System for Analyzing the Environmental Impact of Built Environment Alternatives. Ph.D. Dissertation, College of Architecture, University of Florida, Gainesville.

Rodin, L.E., N.I. Bazilevich, and N.N. Rozov. 1975. Productivity of the World's Main Ecosystems. In: Proceedings of the Symposium on Productivity of World Ecosystems. U.S. National Committee for the International Biological Program, Seattle, Washington, Sept. 1972. National Academy of Sciences, Washington, DC.

Ruelke, O.C., and G.B. Killinger. 1976. Forage and Pastures. In: Beef Cattle in Florida- Bulletin No. 28. Florida Department of Agriculture and Consumer Services. Tallahassee.

Satoo, T. 1982. Forest Biomass. Martinus/Nijhoff/Dr W. Junk Publishers, The Hague, Netherlands.

Scienceman, D.M. 1987. Energy and EMERGY. In: G. Pillet and T. Murota, eds., Environmental Economics. Roland Leimgruber, Geneva.

Sipe, N.G. 1978. An Overview Energy Analysis of Sarasota County. Urban and Regional Planning Series, No. 12. Department of Urban and Regional Planning, University of Florida, Gainesville.

Sipe, N.G., D.P. Swaney, and M. McGinty. 1979. Energy Basis for Hillsborough County—A Past, Present, and Future Analysis. Center for Wetlands, University of Florida, Gainesville.

Smith, S.A., and T.G. Taylor. 1991. Production Costs for Selected Vegetables in Florida, 1990-1991. Economic Information Report EI 91-2. Food and Resource Economics Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Smith, S.A., and T.G. Taylor. 1995. Production Costs for Selected Vegetables in Florida, 1994-1995. Economic Information Report EI 95-1. Food and Resource Economics Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Southern Resource Mapping Co., 1990. Alachua County Control Densification and Identification of Land Corners Project. Report to the Alachua County Board of County Commissioners. Author, Ormond Beach, FL.

Steller, D. L. 1976. Energy Evaluation of Residential Development Alternatives in Mangroves. Master's Thesis, Department of Environmental Engineering Sciences, University of Florida, Gainesville.

Suwannee River Water Management District. 1995. Category Definitions and Photo ID Data. In: SRWMD Mapping Manual. Author, Live Oak, FL.

Tivy, J. 1993. Biogeography: A Study of Plants in the Ecosphere. Longman Scientific & Technical, UK, and John Wiley & Sons, Inc., New York.

TIA Solid Waste Management Consultants, Inc. (TIA) 1991, November. Alachua County Waste Composition Study. Submitted to Alachua County Board of County Commissioners. Author, Gainesville.

Twilley, R.R. 1995. Properties of Mangrove Ecosystems Related to the Energy Signature of Coastal Environments. In: C.A.S. Hall, ed., Maximum Power–The Ideas and Applications of H.T. Odum. University Press of Colorado, Niwot, CO.

Uno, K., and P. Bartelmus, eds. 1998. Environmental Accounting in Theory and Practice. Kluwer Academic Publishers, Dordrecht, The Netherlands.

U.S. Environmental Protection Agency (USEPA). 1997, June. Characterization of Municipal Solid Waste in the United States: 1996 Update Report No. EPA530-R-97-015. U.S. Environmental Protection Agency, Municipal and Industrial Solid Waste Division, Office of Solid Waste, Washington, DC.

U.S. Department of Agriculture (USDA). 1985. Soil Survey of Alachua County, Florida. National Cooperative Soil Survey, Washington, DC.

U.S. Department of Commerce (USDOC). 1996a. 1992 Census of Retail Trade-Report No. RC92-S-2: Measures of Value Produced, Capital Expenditures, Depreciable Assets, and Operating Expenses. Economics and Statistics Administration, Washington, DC.

U.S. Department of Commerce (USDOC). 1996b. 1992 Census of Service Industries-Report No. SC92-S-2: Capital Expenditures, Depreciable Assets, and Operating Expenses. Economics and Statistics Administration, Washington, DC.

U.S. Department of Commerce (USDOC). 1996c. 1992 Census of Wholesale Trade-Report No. WC92-S-2: Measures of Value Produced, Capital Expenditures, Depreciable Assets, and Operating Expenses. Economics and Statistics Administration, Washington, DC.

U.S. Department of Labor (USDL). 1995. Consumer Expenditure Survey, 1993. Report by the Bureau of Labor Statistics, Office of Prices and Living Conditions, Washington, DC.

Walker, L.C. 1995. The Southern Pine Region. In: J.W. Barrett, ed., Regional Silviculture of the United States. John Wiley & Sons, Inc., New York.

Ware, G.W., and J.P. McCollum. 1975. Producing Vegetable Crops. The Interstate Printers and Publishers, Inc., Danville, IL.

Waring, R. H., and W.H. Schlesinger. 1985. Forest Ecosystems: Concepts and Management. Academic Press, Inc., New York.

Whitfield, D.F. 1994. EMERGY Basis for Urban Land Use Patterns in Jacksonville, Florida. Master’s Thesis, Department of Landscape Architecture, University of Florida, Gainesville.

Whittaker, R.H. 1970. Communities and Ecosystems. Macmillan Company, New York.

Whittaker, R.H., and G.E. Likens. 1975. The Biosphere and Man. In: H. Lieth and R.H. Whittaker, eds., Primary Productivity of the Biosphere-Ecological Studies 14. Springer-Verlag, New York.

Whittaker, R.H. and P.L. Marks. 1975. Methods of Assessing Terrestrial Productivity. In: H. Lieth and R.H. Whittaker, eds., Primary Productivity of the Biosphere-Ecological Studies 14. Springer-Verlag, New York.

Zucchetto, J.J. 1975. Energy Basis for Miami, Florida, and Other Urban Systems. Ph.D. Dissertation, Department of Environmental Engineering Sciences, University of Florida, Gainesville.

BIOGRAPHICAL SKETCH

James David Lambert was born March 13, 1958, in Huntington, West Virginia, to James and Janet Lambert. He grew up in both West Virginia and Virginia. He graduated from Midlothian High School in Richmond, Virginia, in 1975. He received a B.S. degree in horticulture from the Virginia Polytechnic Institute and State University in 1979 and a M.S. degree in horticulture from the same institution in 1982.

Between 1983 and 1990, he worked for the Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. During these years he served as a county extension agent in Charlotte County, Florida, as the county extension director in Dixie County, Florida, and as an extension agent in the School of Forest Resources and Conservation at the University of Florida.

He entered the Ph.D. program in the School of Forest Resources and Conservation at the University of Florida in 1989 while he was on the faculty of the School. In 1990 he transferred to the Ph.D. program in the College of Architecture to pursue his interest in environmental planning and graduated from that program in 1999.