# 28. Characterizing the Human Imprint on Landscapes for Ecological Assessment

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## 28.1. Introduction

Human activity has altered natural landscape patterns and ecosystem functioning to varying degrees over the course of recorded history (Turner 1990). Even the act of "preserving" a wilderness landscape results from a societal decision based on the value placed on that landscape. Such acts, as with many ecosystem uses, rarely happen by accident. Therefore, in order to assess ecosystem function and integrity, some understanding of the human dimension is necessary. It is useful to identify two critical aspects of the human dimension: factors that drive, and can be used to predict, human activities; and factors that characterize the impacts of those activities on ecosystems. By and large, the drivers of human activity are intangible (e.g., profit motive or concern for beauty) and the impacts result from tangible structures or activities on the landscape. At the same time, it is important to view human activity as a critical component of, and not separate from, ecosystem functioning. Ecosystem structure and function can influence society's valuation of resources, driving human activity. For example, the presence of a pristine or high quality landscape might drive development nearby, degrading the quality of that landscape.

The human imprint on landscapes is variable in time and space, and varies at a multitude of different time and space scales. Temporal variability implies that (a) data about human activities must be updated on a regular basis and (b) multi-temporal or time series data may be necessary to characterize changes in the human dimension, especially when those changes drive significant ecological changes. Spatial variability demands that these elements be represented spatially, usually using a geographic information system (GIS). A GIS facilitates the management of multi-thematic spatial data, and can be used to manage multiple scale representations of a given theme to deal with the variability in scale.

This chapter presents approaches for characterizing tangible and intangible elements of the landscape that are societal in nature (Table 1), discusses their ecological importance, and presents several practical and conceptual issues in dealing with these elements. The focus is on identifying the spatial distributions of each element. For each element, the discussion involves its ecological/environmental importance, potential data sources, and other issues related to spatial and temporal scale, spatial data structures, and related research needs. The spatial location and pattern of these elements are important determinants of their influence within an ecosystem, as are certain descriptive attributes.

Table 28.1: Elements of the human imprint on landscapes that might be included in an ecological assessment.

| Tangible Elements | Intangible Elements |
|---|---|
| Transportation corridors and junctions | Political and census boundaries |
| Utilities | Ownership boundaries |
| Land cover | Land use |
| Sites of cultural importance | |
| Key commercial/industrial concerns | |

## 28.2. Tangible Elements

Tangible elements often have a direct influence on ecosystem structure and function by actually changing the physical character of the landscape (e.g., pavement for roads and parking lots or the addition of structures). Sometimes they can have indirect influences on the way in which the ecosystem is perceived and used by people. For example, the addition of a cell phone tower will have a minimal direct impact on an ecosystem, but it will improve the accessibility of people in that ecosystem to information, thereby increasing the range of human activities that can be conducted in that ecosystem.

### *28.2.1. Transportation Corridors and Junctions*

Transportation systems are composed of corridors, which provide topological connection, and junctions or stations on the network. In terms of spatial data representation the corridors are commonly represented as linear objects and the junctions as point objects or nodes on the network. The linear objects can represent roads of various types, railroads, navigable rivers and canals, transit networks, runways, and hiking or biking trails. The point objects are destinations, junctions, or facilities and can include airports, highway/rail transfer terminals, and water ports.

The direct effects of the transportation systems can often be discerned with simple locational information. For example, a forest that is bisected by a road will tend to provide lower quality habitat for large mammals than the same forest without the road (i.e., few deer-car accidents occur in the forest). Further, roads can act as fire breaks and increase light penetration into a forest canopy. Attributes about the transportation network can improve our understanding of the direct and, especially, indirect effects of the transportation network. Attributes describing links and junctions in a transportation network include jurisdiction, capacity, actual volume (which is highly variable in time), pavement quality, and width. Indirect effects involve the relations between the quality of transportation links and the tendency for land around those links to be used for specific purposes (e.g., residential and commercial development). All other things being equal, a site with good transportation connections will tend to be more susceptible to development or “improvement” than a site without such connections.

Spatial and attribute data on transportation networks are usually available in some form as they provide an essential base layer for many management activities. In the United States, the U.S. Geological Survey (USGS) distributes digital line graphs (DLGs) which contain roads and other features. Table 2 lists some of the classes and attributes used in the DLGs to describe transportation features. However, the DLGs are not updated consistently. For up-to-date transportation-related information, transportation departments in various states are good places to start. The U.S. Department of Transportation (D.O.T.), through is Bureau of Transportation Statistics (BTS), produces a digital data product called the National Transportation Atlas Databases (USBTS 1996), with much of the tranportation-related data mapped at a base scale of 1:100,000. Many private companies provide relatively up-to-date transportation related information because of the growing demand for real-time vehicle navigation systems.

Research and development needs in this area include expanding the use of GIS network analysis capabilities in ecosystem assessments. For example, distances, which are often used to describe the influence that societal structures or features have on an ecosystem, are often more accurately depicted when based on the transportation network than using straight-line or Euclidean distance. For example, the potential of a place to be developed for residential use is a function of, among other things, nearness to urban employment centers and services. The distance perceived by a landowner, however, has more to do with travel time and distance on the transportation network than with straight-line distance (i.e., how far from the city as the crow flies). Distances, therefore, should be calculated along the road network, rather in a straight line.

Table 28.2: Classification of selected surface transportation features used by the U.S. Geological Survey for Digital Line Graphs (U.S.G.S. 1990).

| Feature Type | Classes | Sub-Classes | Other Attributes |
|---|---|---|---|
| Point | Bridge abutment<br>Tunnel portal<br>Gate<br>Cul-de-sac<br>Dead end<br>Drawbridge | | |
| Line | Class 1 road (Primary) | undivided, divided by centerline, divided with lanes separated, one way | Number of lanes<br>Interstate route number<br>U.S. route number<br>State route number |
| | Class 2 road (Secondary) | undivided, divided by centerline, divided with lanes separated, one way | Reservation, park, or military route number<br>County route number<br>Road width |
| | Class 3 road | undivided, divided by centerline, divided with lanes separated, one way | |
| | Class 4 road | undivided, one way | |
| | Class 5 trail | Four-wheel drive, other than four-wheel drive vehicle | |
| | Footbridge<br>Road ferry crossing | | |
| | Railroad<br>Railroad in street<br>Carline<br>Cog railroad | In tunnel, on bridge, elevated, rapid transit, private, U.S. Gov't. | Number of tracks<br>Angle of clockwise rotation |

## *28.2.2. Utilities*

Utility networks have a topological structure that is similar to transportation networks, with a primary exception being that flow on the networks is usually one-way. Utility networks that may be of interest in an ecological assessment can be placed into two categories: pipelines (including gas, oil, water, and sewer) and cables (including telephone, cable television, and electricity). The direct effects of the former are more obvious than the latter. Installation of pipelines tends to be more disruptive to an ecosystem and any break in the network can result in the release of a substantial quantity of polluting substances. In the case of both types of networks, there is usually some land clearing and maintainance involved along the route of the network resulting in some habitat fragmentation. The indirect effects of both types of utility networks are similar to those of transportation networks. Although development can occur in their absence, it tends to be more rapid in their presence. As communication links are improved and information flows more efficiently (e.g., with the introduction of fiber optic cable), rural areas are increasingly seen as alternative places for development of residential property and remote service industries.

Attributes of utility networks describe capacity and actual transmission rates, and might be useful in understanding the potential for indirect influences on ecosystems. These attributes are more commonly used in automated mapping and facilities management (AM/FM) systems. Such systems, maintained by utility companies, are the best source for network data. For this reason there is relatively little in the way of standardized data over large areas, except for the largest, national-scale pipeline networks (e.g., the Alaska Pipeline).

### *28.2.3. Land Cover*

Although land cover is a general term for that which covers the soil surface (including vegetation, litter, water, structures), some specific types of land cover (e.g., crops, built-up areas) are more obviously anthropogenic than others. Vegetation is often managed for human use in some manner and its pattern might also be viewed as anthropogenic to some extent. Among the more radical changes to land cover by humans is the paving of the soil surface, which interrupts hydrologic and nutrient cycles and affects micro-climate (e.g., the urban heat island effect). Buildings and other structures have a similar effect. Urbanized ecosystems, therefore, tend to function very differently from non-urbanized ecosystems; they tend to have warmer and more contaminated atmospheres with more rapid surface runoff. Replacement of natural vegetation with agricultural crops, orchards, and feed for animals (i.e., pasture) has a range of implications for these cycles as well. Conversion of wetlands for agricultural or urban uses can also have drastic effects on ecosystem function, eliminating the ecosystem services provided by wetlands while altering nutrient cycles for crop production.

Land cover is distinct from land use, which refers to the way in which the land is managed for human goals. The critical land cover issues address what is covering the surface at any given point in time and how that cover affects hydrological, biogeochemical, and biological functions. Different land uses may lead to different spatial and temporal patterns of land cover, but land use does not predict land cover perfectly. Regardless, land use and cover are often mapped together. Anderson et al. (1976) present a system of land use/cover classification for use with remotely sensed data that has become a standard in the field for land use/cover classification. Because the Anderson classification is not strictly a land cover or land use classification, developed to accommodate the method of remote sensing rather than analytical needs, it has limited usefulness for both modeling the human system and assessing its impact on the ecosytem. The NOAA Coastal Change and Analysis Program (C-CAP) developed a good land cover classification system (Dobson et al. 1995) for use with remotely sensed satellite data. Because that program focused on coastal areas, there was more detail in the wetland and water classes than is common for terrestrial investigations. Table 3 lists the classes identified as part of the C-CAP classification, with simplified wetland and water categories.

In addition to the type of land cover, spatial patterns of land cover can have very dramatic effects on ecosystem function. A growing literature in landscape ecology is focused on describing landscape pattern and its implications for landscape function (Forman 1997). Especially important are the effects of relative landscape fragmentation and the diversity of landscape types, which have been shown to affect habitat quality and biodiversity (Iida and Nadashizuka 1995). Descriptions of landscape pattern tend to be scale sensitive, producing very different descriptions depending on the scale of observation (Turner et al. 1989). Any ecological assessment should include a description (perhaps a multi-scale analysis) of a landscape’s spatial pattern, the dynamics in spatial pattern (O'Neill et al. 1988), and the socioeconomic drivers of changes in that pattern (Medley et al. 1995). Land cover patterns in much of North America, and other portions of the developed world, are the legacy of human use of the land.

Data on the amount of urbanized area or land cover in general can often be obtained through a national mapping agency (like the USGS) or a census-taking agency (like the U.S. Census Bureau). However, these data sources are rarely updated frequently enough to satisfy the demands of an ecological assessment, especially in areas that are undergoing rapid urbanization or other land cover changes. Also, these data attempt to measure land use more than land cover.

The most common approach to obtaining temporally sensitive information about land cover is through the use of remote sensing (Jensen 1996). Remote sensing can take the form of aerial or satellite imaging and can involve the use of photography, multispectral imaging, radar and laser sensing, and thermal sensing. Technical issues on the use of remote sensing are presented in Lachowski, Chapter 10. Because all remote sensing systems record information about the electromagnetic or structural properties of the land surface, they can only provide adequate information about land cover (as opposed to land use) when used without supplemental information. The most commonly used approach to characterizing land cover is through a multivariate classification process based on

Table 28.3: Classification of upland land cover types developed for NOAA C-CAP (Dobson et al. 1995).

| | | |
|---|---|---|
| **Upland** | | |
| | Developed | |
| | | High Intensity |
| | | Low Intensity |
| | Cultivated | |
| | | Orchards/Groves/Nurseries |
| | | Vines/Bushes |
| | | Cropland |
| | Grassland | |
| | | Unmanaged |
| | | Managed |
| | Woody | |
| | | Deciduous Forest |
| | | Deciduous Scrub/Shrub |
| | | Evergreen Forest |
| | | Evergreen Scrub/Shrub |
| | | Mixed Decidous/Evergreen |
| | Bare | |
| | Tundra | |
| | Snow/Ice | |
| | | Perennial Snow/Ice |
| | | Glaciers |
| **Wetland** | | |
| | Rocky Shore | |
| | Unconsolidated Shore | |
| | Emergent Wetland | |
| | Woody Wetland | |
| **Water and Submerged Land** | | |
| | Water | |
| | Reef | |
| | Aquatic Bed | |

information recorded in several spectral channels and some sort of ground truthing information. The result is a map in which each location (or pixel - picture element) is assigned to one of a number of pre-defined categories. New approaches, like spectral unmixing (Adams et al. 1995) attempt to obtain a more realistic portrayal of the landscape by determining the proportional area of each pixel in each land cover class. This process accounts for the mixed nature of many satellite-based image pixels, which have spatial resolutions of 20 to 1000 m.

At Michigan State University, we are currently examining changes in forest fragmentation in the Upper Midwest to understand the link between landscape pattern and socioeconomic variability. We are using georeferenced triplicates of Landsat Multispectral Scanner (MSS) data, called North American Landscape Characterization (NALC) data and representing conditions in the early 1970s, mid-1980s, and early 1990s (Lunetta et al. 1998). Metrics of spatial pattern discussed in the landscape ecology literature (McGarigal and Marks 1993) are being applied to characterize forest landscape patterns. These patterns will be linked to information on land use, land ownership, demographics, economics, and institutional factors through empirical and modeling approaches.

### *28.2.4. Cultural, Aesthetic, Spiritual, and Scientific Resources*

Although several features within an ecosystem may have the same apparent ecological significance, the value placed on those features may vary due to factors entirely unrelated to ecosystem function. Sites can have a relatively higher value because of their scientific value, their historical or pre-historical significance, their aesthetic value, or some spiritual value. These resources affect the way in which ecosystems have been managed, are being managed, and will be managed in the future. These sites are often given “special use designations” which legally limit the range of permitted activities. Although the value placed on the resource is intangible, in many cases the object of value is, in fact, quite tangible and it may have been managed or treated quite differently. For example, the Black Hills of South Dakota, and particular segments, have had a high spiritual importance to the Lakota (Sioux) people of North America (Geores 1996), and this fact has led to conflicts with European descendents regarding the management of this ecosystem. The spiritual importance of features or ecosystems can only be understood through qualitative assessment, such as through surveys or interviews.

Alternatively, segments of an ecosystem may have higher value simply because they are rare or unique. For example, rare oak openings in Southern Michigan are home to the endangered Karner Blue Butterfly (Lycaeides melissa samuelis). Ecosystem features may have high scientific value because of the uninvestigated properties of the species present. Their relative value in terms of ecosystem function may be unknown and they may need to be preserved for scientific scrutiny. Also of scientific value is any archaeological evidence that may be in place. An effort should be made, and in some cases is legislated, to preserve or catalog such cultural resources.

Information about resources with high cultural value is, by its nature, difficult to obtain and quantify. Known sites of archaeological interest are often recorded and mapped. In the U.S., state historical offices can be contacted to acquire some of this information. GIS-based models have been used by archaeologists in an attempt to predict the locations of culturally important sites, based on a variety of site and situation factors (Dolanski 1997). Sites of particular spiritual or aesthetic value may or may not be designated as parks or reserves. Boundaries of most Federal, State and Local parks, reserves, and other areas designated for special use are available with the USGS DLGs (USGS 1990) and the designations used are listed in Table 4.

Table 28.4: Forest, park, and reserve types as classified and mapped in Digital Line Graphs (USGS 1990).

| |
|---|
| National park, monument, lakeshore, seashore, parkway, battlefield, or recreation area |
| National forest or grassland |
| National wildlife refuge, game preserve, or fish hatchery |
| National scenic waterway, riverway, wild and scenic river, or wilderness area |
| State park, recreation area, arboretum, or lake |
| State wildlife refuge, game preserve, or fish hatchery |
| State forest or grassland |
| County game preserve |
| Large park (city, county, or private) |
| Small park (city, county, or private) |

The values placed on sites designated for special use are, of course, intangible elements of ecosystems. A variety of methods are available for characterizing these values. In order to understand the potential recreational value of an area, the U.S. Forest Service and Bureau of Land Management have employed a tool called the Recreational Opportunity Spectrum, or ROS. The ROS uses the following five criteria to determine the recreational potential of an area: remoteness, size, evidence of human use, social setting, and managerial setting. It can be applied to a particular site or the criteria can be mapped to portray a spatial representation of recreational value. A project by the U.S. Bureau of Land Management and U.S. Forest Service (n.d.) illustrates such application in Coos Bay, Oregon.

Where maintenance of scenic quality is an important management objective, characterization of scenic quality is imperative. The usefulness of viewshed analysis, a common GIS application, to quantify the views from key vantage points or corridors has been demonstrated elsewhere (e.g., Krist and Brown 1994; Lake et al. 1998).

### *28.2.5. Key Commercial/Industrial Concerns*

To understand the functioning of an ecosystem and changes over time, it is important to understand the commercial or industrial activities underway in that ecosystem. For example, extractive industries like logging, oil and gas extraction, mineral mining, and peat mining all occur because of the economic value placed on the resources. An ecosystem can be dramatically altered when some of its elements are altered removed, interrupting normal hydrological and biogeochemical functioning. Industries often metabolize raw natural resources and generate waste products in producing goods and services. Raw resource requirements might be met from biological, geological, hydrological, or atmospheric sources. Wastes can take the form of gaseous, liquid, and/or solid waste, which enter the atmosphere, hydrological system, or landfills. Although residences metabolize raw resources to create waste, the types of industries in an area will tend to have a greater influence on what resources are extracted and what wastes are produced.

Data on industrial activities are often collected through the use of agricultural and industrial censuses. Data may be in the form of materials ingested or wastes produced, but more often this information must be inferred from information on the dollar value, or quantity produced or people employed (U.S. Bureau of the Census 1992b). Although this information can be misleading if not used with care, it can provide a representation of the industrial activities in a region and the potential impact on the ecosystem. This information is typically, but not always, only available at an aggregate level (e.g., by county), and not for individual producers.

## 28.3. Intangible Elements

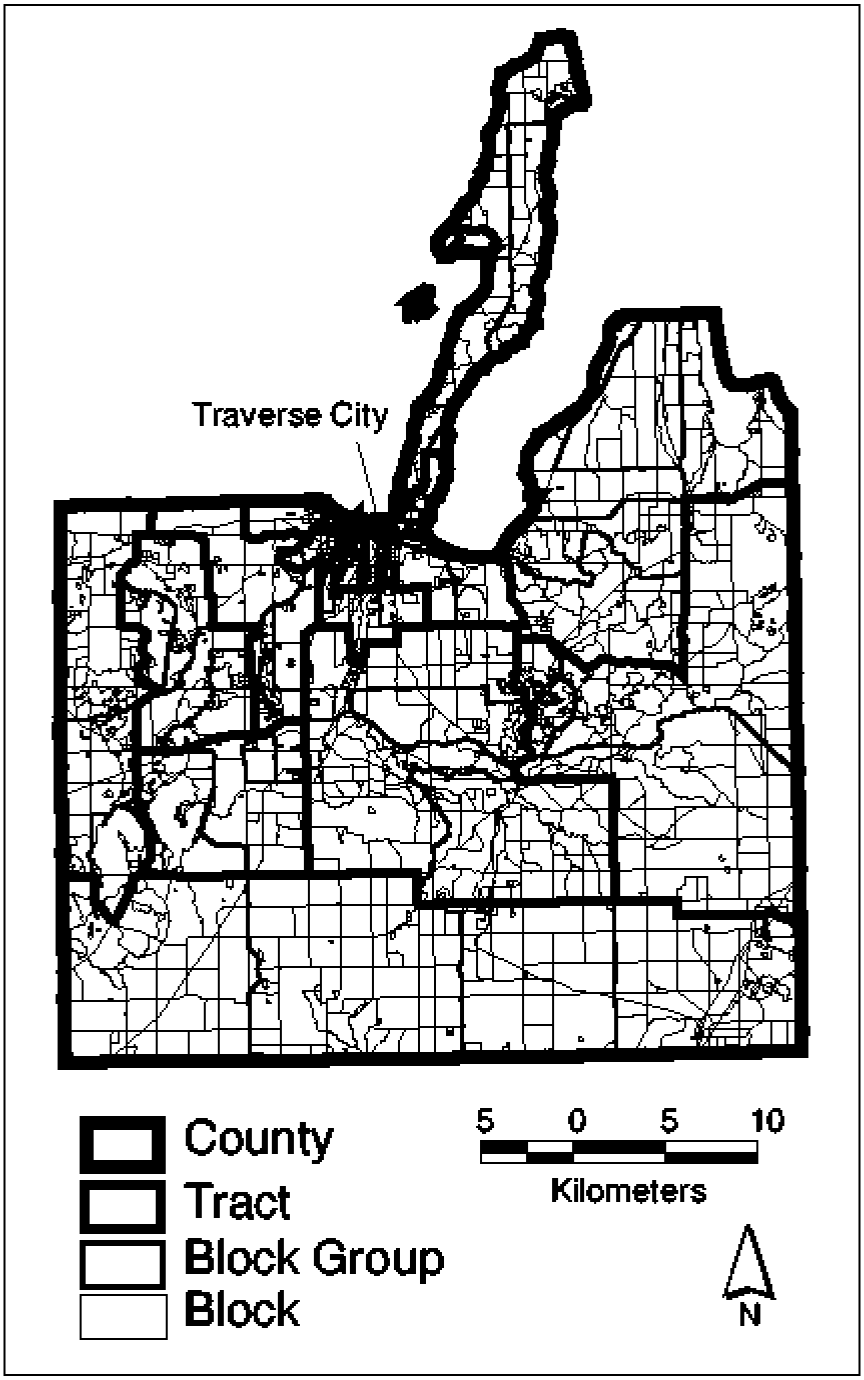
A number of intangible elements, although they do not necessarily directly affect ecosystem functioning, can have very obvious indirect influences. Intangible elements provide the framework for ecosystem functioning under human management. The geographies of land tenure, administration, use, and regulation can all have noticeable impacts on the structure and functioning of an ecosystem. The social, cultural, economic, historical, and institutional setting of an ecosystem tends to drive the human activities in that ecosystem (see Campbell, Chapter 29.). To be complete, an ecological assessment should include a characterization of these jurisdictional patterns.

The political, administrative, ownership, and other boundaries can be viewed as analogous to the ecological boundaries dividing various subdivisions within an ecosystem. Like ecological boundaries, the intangible social boundaries are porous to the movement of some materials and information and act as effective barriers to others. Just as a watershed boundary defines an area that is distinct hydrologically but not necessarily meteorologically or biogeochemically distinct, administrative boundaries define areas with homogenous legal characteristics that may have little to do with spatial variation in demographic or economic characteristics. Just as an animal may travel further to access a higher quality food source, people often travel greater distances to access employment opportunities where choices, pay, or benefits are better. When we view humans as a critical part of an ecosystem, information on these intangible elements is critical to understanding the societal components of ecosystems.

### *28.3.1. Political and Census Boundaries*

It is helpful to have the boundaries for all administrative units that have some regulatory control over the ecosystem. Political boundaries affecting ecosystem management, and therefore ecosystem function, may be present at a number of scales (e.g., national, sub-national, etc.). In the United States it may be useful to know the boundaries of states, counties, townships or minor civil divisions, legislative districts, school districts, census districts, and other agency-specific management districts. Figure 1 displays three levels in the administrative hierarchy within the State of Michigan. Minor civil divisions (MCDs) in Michigan correspond to townships and incorporated cities, towns, and

Figure 28.1: Three levels of administration boundaries in Michigan: state, county, and minor civil division (MCD).

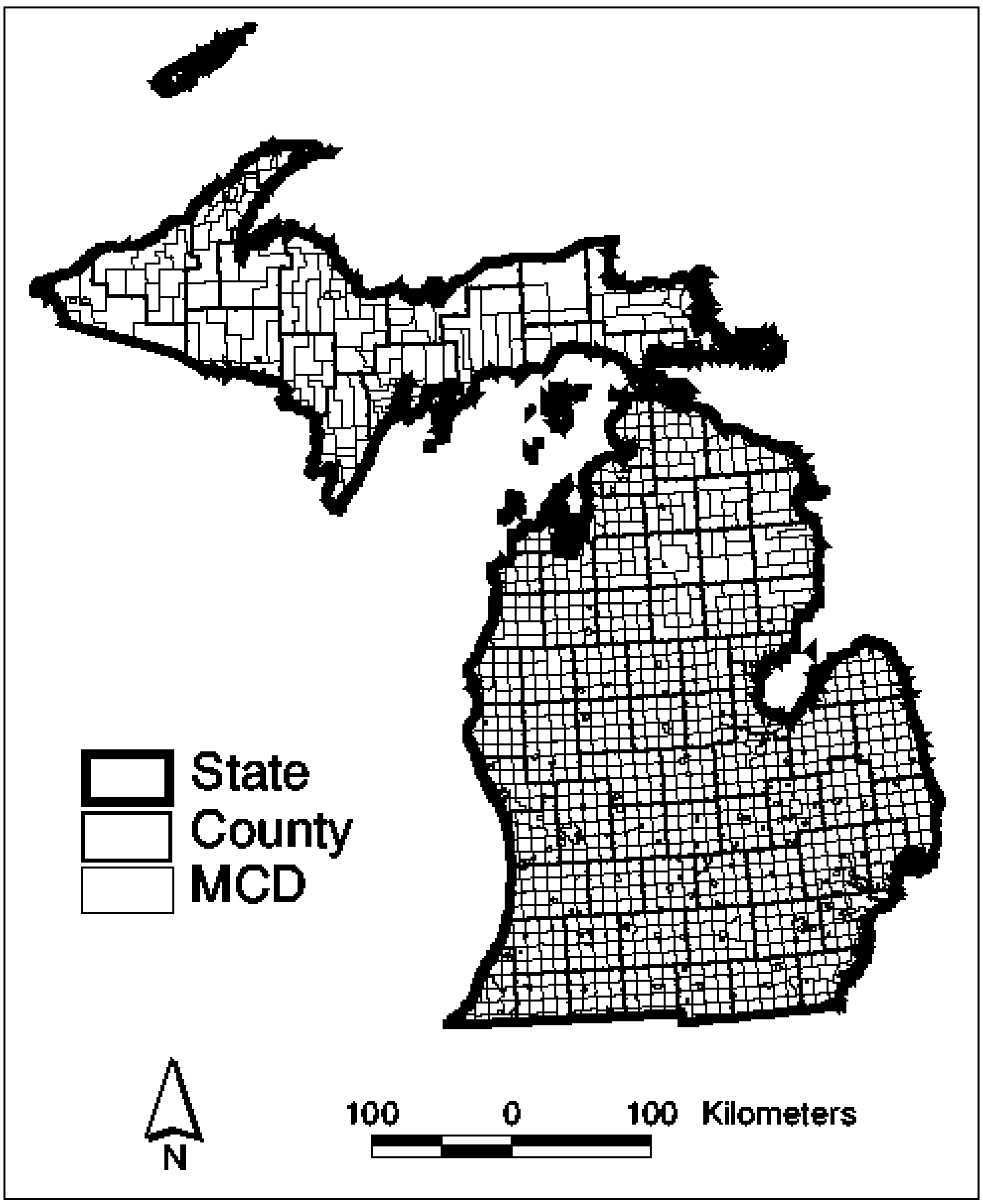


villages. The necessity of obtaining such boundary information arises from both the policy and management relevance of these boundaries on the ground and the availability of socioeconomic and environmental data summarized and available by these spatial units. For example, the data on the U.S. censuses of population, manufactures, business, and agriculture are all available by these units.

Many examples exist of very real landscape expressions of imaginary lines separating intangible entities (e.g., national or other jurisdictional boundaries). The landscape differences result from different policies, culture, history, institutions or economic situations on either side of the boundaries. For example, usage of a forest or grassland may be very intense on one side of a national boundary because of economic pressure or fewer regulations, whereas the other side may be less intense. Specific factors affecting differential management include differential taxation, land use regulations, enforcement of environmental regulations, and incentives.

In order to characterize the human dimension of ecosystem function, data on human activities are required. To allow for sampling of human activities and to protect the privacy of individuals, most socioeconomic data are collected in such a way that they are aggregated to some spatial unit. For example, the U.S. Census uses the census block as the smallest unit for which many data are available. Figure 2 displays four levels in the census geographical hierarchy for Grand Traverse County, Michigan. All units at one level are nested within the next larger units in the hierarchy. Census tracts, or block numbering areas (BNA) in non-urban areas, are delineated to be relatively

Figure 28.2: Four levels of census geography in Grand Traverse County, Michigan: county, tract or block numbering area, block group, and block.



homogenous with respect to population and economic characteristics, yet to remain relatively unmodified from census to census. In 1990, block groups contained about 400 housing units and tracts about 1700.

Administrative boundaries are typically easy to obtain from the agency that has authority over the policies within each unit. The U.S. Census Bureau produces a dataset containing all of the nested census units and many of the important administrative units (Figure 1). These Topological Integrated Geographic Encoding and Referencing (TIGER) line files are produced for each census year and updated on some intervening years (Bureau of the Census 1990).

The spatial aggregation of socioeconomic data has implications for ecological assessment. Any degree of aggregation masks detail in the data. For this reason it seems reasonable to acquire data at the finest scale possible; but for many socioeconomic attributes counties or MCDs are the finest scale available. Some (e.g., population counts) are available down to the block level. When aggregate data are used, it is preferable that the aggregation attempt to minimize heterogeneity within units. So, census tracts and BNAs, are more useful aggregation units than MCDs because they attempt to minimize heterogeneity. Other considerations in selecting the scale of data should include the scale of the process of interest and the scale of ecological data being used. Just as watersheds can be defined at a number of different scales (e.g., to correspond to $1^{st}$ versus $5^{th}$ order streams) and the scale should be selected at the scale of the process of interest, be it local or regional in scope, socioeconomic data can be represented at a number of different scales.

Overlay and regional characterization techniques common to many GIS systems can be used to facilitate integration of the socioeconomic aggregate data with other data. Conversion between areal aggregation units or the creation of new areal units which represent the intersection of two sets of units provide mechanisms for comparing disparate data. For example, it may be necessary to summarize population data by watershed. Data collected and aggregated to some spatial aggregation unit (e.g., counties) can be converted from those units to other spatial units (e.g., watersheds) by making assumptions or adding information about the spatial distributions of a quantity (e.g., population density) within a set of enumeration units (e.g., counties or tracts). This process, called areal interpolation, can be carried out using techniques outlined by Tobler (1979), Flowerdew and Green (1989), Langford *et al*. (1991), Martin and Bracken (1991), and Goodchild *et al*. (1993). A common assumption for many of these methods is that the value of the variable (say, population density) is constant throughout each of the units (Langford *et al*. 1991). Tobler's (1979) method relaxes this assumption by assuming smooth variation of a population density surface. Goodchild's *et al*. (1993) method relaxes this assumption by employing "control units" which are more likely to satisfy the homogeneity assumption. None of these methods is without error and it is important to acquire data measured directly for geographic areas of interest in an assessment (e.g., watersheds) if at all possible.

### *28.3.2. Ownership Boundaries*

The goals and rules of land management vary depending on who owns the land. Land might be held in private hands (e.g., corporate or personal) or by public agencies (e.g., federal, state, or local). Each class of owner has a different set of constraints on use and management defined by the economy, law, culture, tax systems, and regulations.

The system of publically held lands in the U.S. is a legacy of initial settlement policy, various preservation-oriented initiatives, and tax deliquencies which caused private land to revert back to public ownership. Governmental agencies that own lands can provide information about the locations and management of those lands. This information is often not up-to-date nor in a form readily accessible for analysis, but data quality is improving. The U.S. Geological Survey maintains boundary files for land owned by a number of federal, state, county, and local agencies, stored as DLGs (Table 4). These files, however, are rarely complete or recent. To address the needs by the Gap Analysis Program (GAP) for information on the locations of public lands, as well as attribute information on the level of management for wildlife and habitat preservation, McGhie et al. (1996) compiled the managed areas database (MAD), at a scale of 1:2,000,000, for the conterminous U.S. The database includes attributes on area name, designation, protection status, level of management, and data source. A variety of sources were used for that database, most of which ultimately came from the U.S. Geological Survey and Bureau of Land Management.

Private lands are much more difficult to characterize because many more different individuals and entities manage them, and because they change hands frequently than public lands. In some areas of the U.S., plat map books are produced on a regular basis, which show the boundaries of ownership parcels and list the names of owners (Rockford Map Publishers 1998). One trend that should improve the availability of information about private lands in the U.S. is the increasing tendency for county and local tax offices to maintain digital versions of their maps of parcels. The needs of this information for ecological assessment are such that there should be no need to invade the privacy of individuals. A useful attribute of private land ownership is simply whether the owner is a corporation or an individual. Other important attributes include the size of parcels and diversity of owners in a given area, which can affect the land use/cover and the ability to manage or intervene in a ecosystem's function.

Many rural areas in the United States are experiencing declines in ownership parcel sizes on private lands that have a variety of implications. In a recent study of parcel sizes in rural areas of the forested Upper Midwest, initially reported by Brown and Vasievich (1996), average parcel sizes were shown to have declined an estimated 1.2 percent per year between 1960 and 1990. Higher rates of decline were observed in the 1970s, when rural population growth rates were highest. Trends such as this have implications for how land is or can be used, the spatial patterning of land use and land cover, and appropriate landscape management approaches.

### *28.3.3. Land Use*

Land use is the intangible relative of land cover and refers to the way in which the land is managed for human goals. The management of land is a very important, but difficult, factor to characterize. The way the land is managed will have indirect, and sometimes direct, effects on what cover results and on the aspects of that cover (e.g., intensity) that affect ecosystem function. At the same time, land use is reflective of the socioeconomic forces driving landscape changes. Changes in demographic, economic, political, and institutional characteristics often lead to changes in land use (e.g., Vesterby and Heimlich 1991). Land management practices are included as a factor (P) in the universal soil loss equation (USLE) for characterizing average annual soil losses from agricultural fields (Wischmeier and Smith 1978). How to quantify management is not always clear. The incentives for and information about various management approaches are ever changing.

Market forces drive land use to a large extent. Over time, economic individuals use the land to maximizes the value that they can extract from the land. A variety of federal, state and local government initiatives have been implemented to affect land management toward a particular goal (e.g., conservation). Although government agencies have some record of the numbers of people taking advantage of various incentive programs, they rarely keep spatially referenced (i.e., GIS) databases on such programs. Egbert *et al*. (1997) demonstrated the use of remote sensing to identify the locations and amount of land that was enrolled in the conservation reserve program (CRP).

Whereas land cover information may be obtained via satellite remote sensing, information about land use usually requires much more direct observation. Aerial photography is an invaluable tool for characterizing land use, but it can rarely be effective in the absence of other information. Figure 3 illustrates an aerial photograph of a single square mile survey section (259 ha) in Grand Traverse County, Michigan. The aerial photograph can give clues to the land use. By overlaying the property boundaries on the photo, however, land use interpretation is dramatically improved. In fact, the size of the parcel may be the characteristic that distinguishes a forested lot used for silviculture versus one used primarily for residential purposes. Table 5 lists the land use classification scheme designed for an on-going study of the socioeconomic drivers of land use change in the Upper Midwest. The classification scheme will aid in interpreting the land use of ownership parcels from aerial photographs.

Another method of land use mapping involves "windshield" survey, in which properties are observed from a road and land use is recorded on a base map of ownership parcels. Also, the U.S. Bureau of the Census (1992a) reports proportions of various land use types in each county as part of its Census of Agriculture. Some aspects of land use, for example the intention of the owner or the actual day-to-day use of the land, can only be ascertained through surveys or interviews with individuals involved in use of the land.

The section displayed in Figure 3 is instructive for a number of reasons. The differences between land use and land cover are evident in the northern one-half of this one square mile survey section. The land cover would be classified as some sort of grassland, whereas the land use, at least in the majority of this area, is for pasture and hay production. The former has direct effects on ecosystem functioning (e.g., hydrologic and biogeochemical cycling functions differently on grasslands than forests), and the latter is driven by a myriad of economic, cultural,

Figure 28.3: Black and white infrared aerial photograph (November 1981) overlain with parcel boundaries (1980) in white. The area covered is a one survey section from Grand Traverse County, Michigan.

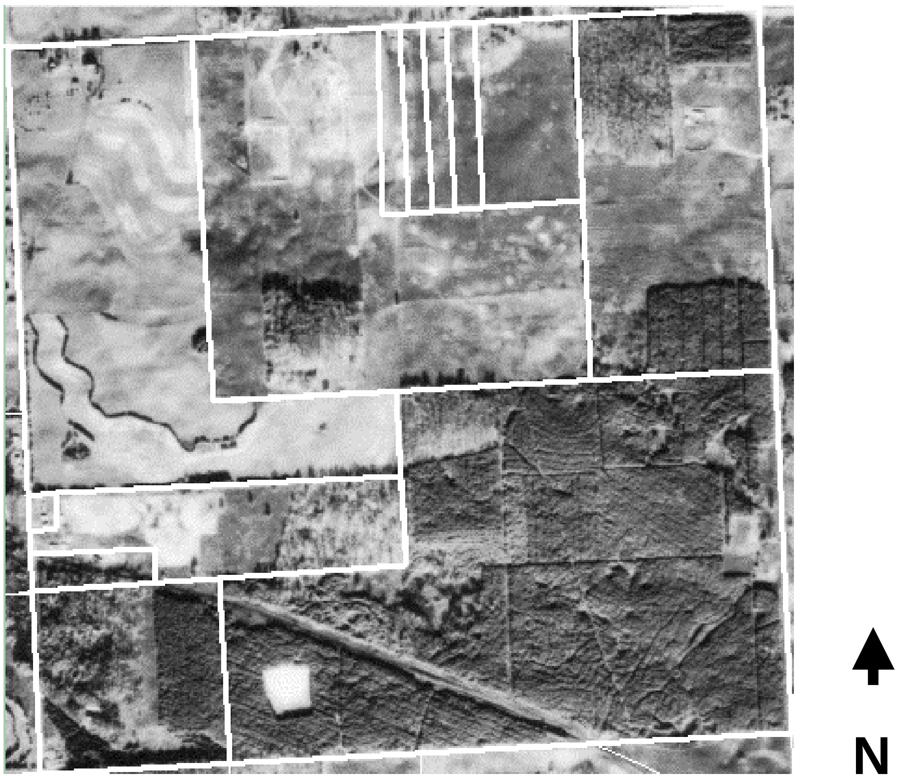


Table 28.5: Classification of land uses for a study of land use and cover change in the Upper Midwest. Mapped parcels were classified through overlay with and interpretation of aerial photographs.

| | | |
|---|---|---|
| **Developed** | | |
| | Residential | |
| | | High density residential |
| | | Low density residential |
| | Retail/office | |
| | Industrial/warehouse | |
| | Infrastructure/transportation | |
| | | Airport |
| | | Transport corridor or terminal |
| | | Utility corridor or station |
| | | Institutional |
| | Site-based outdoor recreation | |
| | | Campground |
| | | Golf course |
| | | Ski area |
| | | Marina |
| | | Park and outdoor assembly |
| | Mining/extractive | |
| | Other developed | |
| **Agriculture** | | |
| | Row crop | |
| | Non-row crop | |
| | Pasture/grazing | |
| | Other agriculture | |
| **Undeveloped** | | |
| | Open/grass | |
| | Old field/young forest | |
| | Mature forest | |
| | Tree plantation | |
| | Open water | |
| | Wetland | |
| | Forested wetland | |
| | Other undeveloped | |

demographic, and political factors. The rows of planted trees in the southeastern portion of the section suggest something of the history of the site. This area, like many areas in the Upper Midwest, was logged initially during the late 19th or early 20th century then farming was attempted. Now, because of the difficulty of farming the glacial soils with a short growing season, many sites have been planted to forest or are reverting to forest naturally.

The impacts of the intangible boundaries on the landscape are also evident in Figure 3. The ownership boundaries retain their rectilinear shape imposed during the initial survey and disposal of the land. The parcel in the extreme southwestern corner of the section is a 16 ha (40 acre) parcel, or one quarter-quarter section. In an attempt to reduce the amount of land subdivision in Michigan, the state legislature passed the Subdivision Control Act (or SCA) in 1967. To avoid paying high fees for subdividing their land, land owners could not divide and sell more than four parcels of 4 ha (10 acres) or less in a span of 10 years. This has led to proliferation of parcels that are just over 4 ha throughout rural Michigan (Norgaard 1994), like the four narrow parcels found along the northern edge of this section. The importance of boundary shapes for ecosystem structure is illustrated by the rectilinear boundaries that follow property boundaries of the plantation in the southeast corner of the section. Also, the tonal variation between the two grassland parcels in the northwest corner of the section suggest that, although the land cover class is the same, the degree and type of management has been different. Finally, a utility corridor right-of-way, which is not explicitly owned by the utility company, is evident as a swath through the plantation forest on the southern edge of the section.

## 28.4. Conclusions

This chapter has outlined a number of tangible and intangible human elements that are present in most ecosystems and that should be considered in a complete ecological assessment. Not all of these elements will be of importance in every situation, but taken as a whole they can dramatically affect ecosystem history, function, and potential. Although it is tempting to treat human activity as external to the functioning of natural ecosystems, the interrelationships between the value humans place on ecosystems, the goods and services they derive from them, and natural processes dictate that the human dimension be understood as evolving with the ecological system.

A variety of anthropogenic issues have been presented that should be considered in an ecological assessment. Two important common issues to the characterization of many of these elements are spatial scale and the temporal nature of these elements. The issue of spatial scale, while often determined by the availability of data, affects our ability to characterize various processes. Although of more importance to some of the elements than others, the dynamic nature of the human dimension requires vigilance in the obtaining and maintaining of data.

Integrating the human dimension within an ecological assessment poses challenges in both our ability to characterize the essential elements and to understand their significance. Given the importance of human activities in driving, constraining, and redirecting ecological function, it is imperative that these challenges be met.

## 28.5. References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