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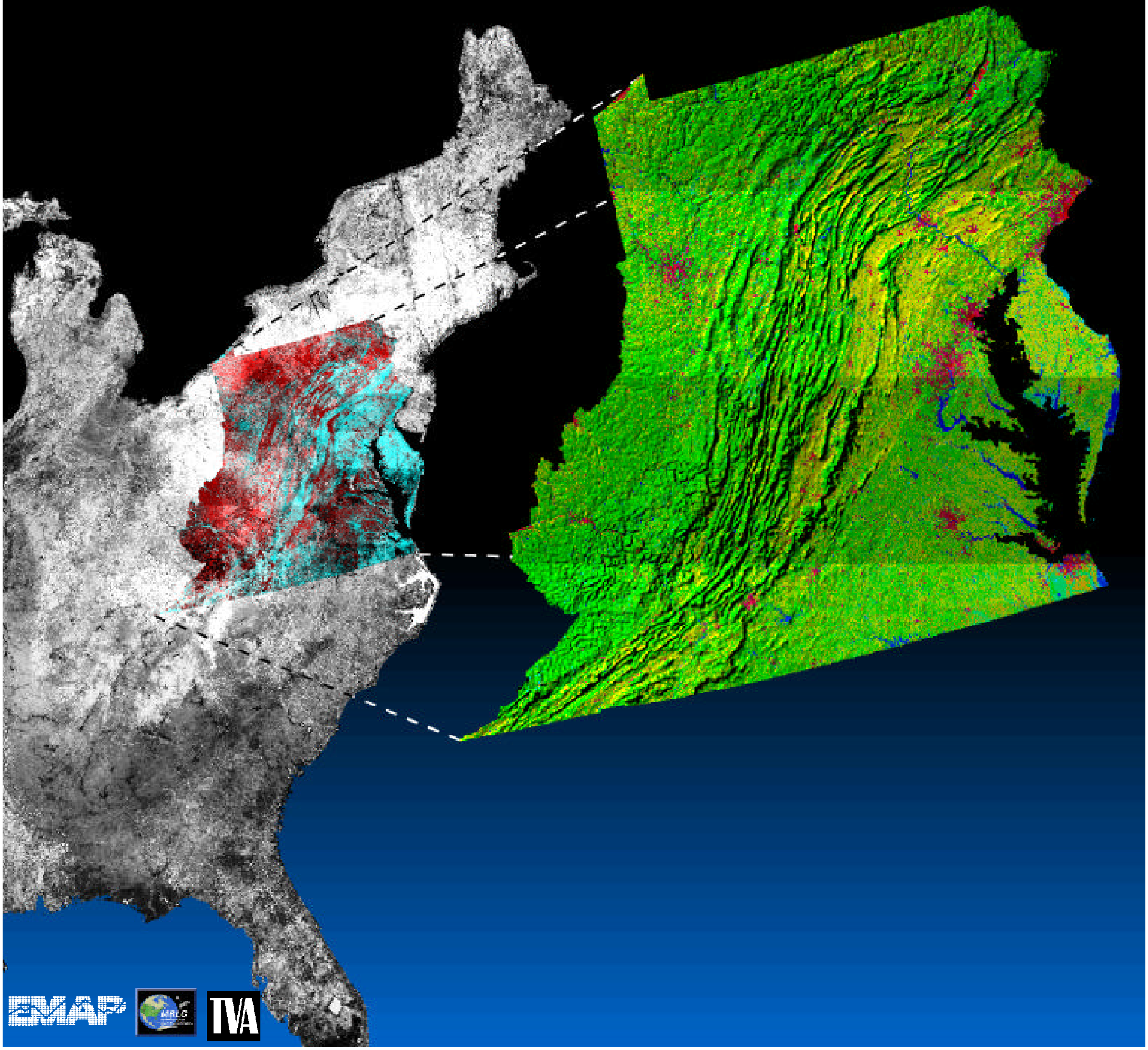
An Ecological Assessment of the United States Mid-Atlantic Region

A Landscape Atlas



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An Ecological Assessment of the United States Mid-Atlantic Region:

A Landscape Atlas

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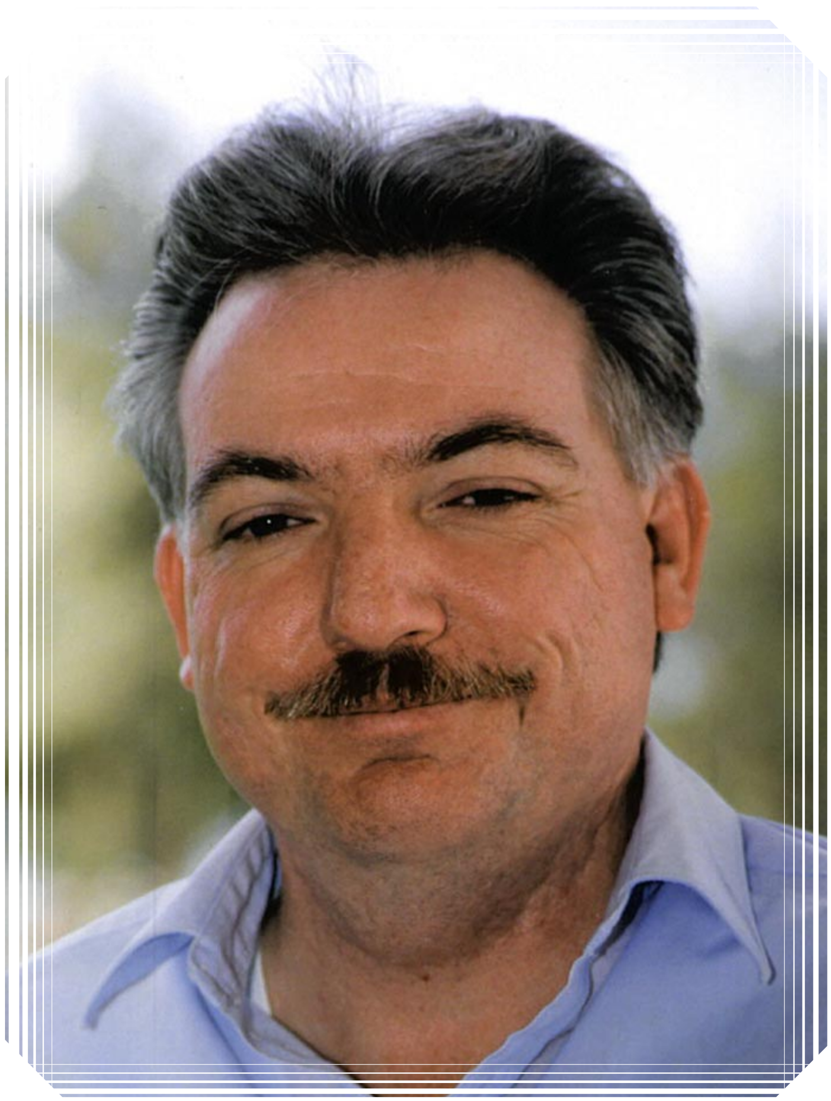
Dedication

This Atlas is dedicated to our friend and colleague Mason J. Hewitt, whose leadership and inspiration made many of the landscape analyses and displays used in this atlas possible. Mason pioneered and laid much of the foundation for Geographic Information System applications in the EPA. He made it possible for many government agencies to use and apply indicators highlighted in this atlas. Mason also contributed substantially to the education of many young people through the Boy Scouts of America, teaching young people how to respect and live in harmony with their natural environment. Mason's impact on the conservation of our environment will be felt for years to come, but his kindness, leadership, and vision will be sorely missed.



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Chapter 1: Taking a Broader View

Environmental quality affects our health, our quality of life, the sustainability of our economies, and the futures of our children. Yet pressures from an increasing population coupled with the need for economic development and an improved standard of living often have multiple effects on our natural resources. So just as a person with a less-than-healthy lifestyle is more prone to infection, a weakened ecosystem is more vulnerable to additional stress. Unfortunately, it is often difficult to see these changes in environmental quality because they occur slowly or at scales we do not normally consider.

There is growing public, legal, and scientific awareness that broader–scale views are important when assessing regional environmental quality. In the past, media attention has concentrated on dramatic events, focusing our environmental awareness on local or isolated phenomena such as cleaning up Superfund sites, stopping pollution from a drainage pipe, saving individual endangered species, or choosing a site for a county landfill. In an era of environmental regulations, measures of environmental quality were based on legal standards, like those for drinking water or air quality. As a result they reflected a limited view of the environment and the multiple factors that contribute to environmental problems. In response, scientists studied fine–scale model systems and often considered humans to be external factors. Today, our perceptions are changing. We realize that humans and our actions are an integral part of the global ecosystem, and that the environment is complicated and interconnected with human activities across local and regional scales. We have begun to take a broader view of the world and of our place in natural systems.

Technological advancements have made it easier to obtain new views of overall environmental quality. Computers and satellites allow us to study larger patterns and processes. Combined with a better understanding of how the pieces fit together, these technologies help us to assess where we are now with regard to environmental quality, to envision where we hope to be in the future, and to identify the steps we need to take. This atlas takes advantage of these advanced technologies in assessing environmental condition over the mid–Atlantic region of the United States.

Just as we now watch broad–scale weather patterns to get an idea of whether it will rain in the next few days, we can develop a better assessment of current environmental condition by combining regional and local–scale information. Broad–scale weather patterns are important because they affect and constrain what happens locally on any given day. By taking a broader view of the environment, or widening our perspective about how the environment is put together, it becomes easier to see where changes occur and to anticipate future problems before they materialize.

The Chesapeake Bay Program is one of the groups which helped to identify the environmental issues of concern in the mid–Atlantic region. The Chesapeake Bay watershed covers a large portion of the area considered in this atlas.

In the past, public and legal attention has been focused on site–specific environmental problems such as what is coming out of individual drainage pipes.

Purpose and Organization of this Atlas

This atlas is an environmental assessment of the mid–Atlantic region of the United States (Figure 1.1). The assessment was done using measurements derived from satellite imagery and spatial data bases. The information presented in this atlas is intended to help the reader visualize and understand the changing conditions across the region, and how the pattern of conditions can be used as a context for community–level situations. This atlas does not provide site–specific analyses of small areas such as individual woodlots. This atlas was developed as part of the Environmental Monitoring and Assessment Program (EMAP), and is part of a larger, multi-organizational effort to assess environmental condition in the mid-Atlantic Region.

The atlas is divided into four chapters with one appendix. This chapter introduces the reasons for doing a broad–scale regional analysis of environmental condition.

Chapter 2 places the mid–Atlantic region into the context of the lower 48 states. In Chapter 3, the landscape conditions in the mid–Atlantic region are analyzed and interpreted in terms of a set of ecological indicators, summarized by watersheds within the region. Chapter 4 summarizes the overall picture painted by these landscape indicators and compares relative conditions among watersheds in the region. The Appendix provides methodological information which is not in Chapter 3, and has a listing of all indicator scores for every watershed in the mid–Atlantic region.

__Figure 1.1.__

The mid–Atlantic region.

Landscape Ecology and the Analysis of Broad–Scale Environmental Condition

To most people, the term “landscape” suggests either a scenic vista or a backyard improvement project. To ecologists and other environmental scientists, a landscape is a conceptual unit for the study of spatial patterns in the physical environment and the influence of these patterns on important environmental resources. Landscape ecology is different from traditional ecology in several ways. First, it takes into account the spatial arrangements of the components or elements that make up the environment. Second, it recognizes that the relationships between ecological patterns and processes change with the scale of observation. Finally, landscape ecology includes both humans and their activities as an integral part of the environment.

There are many applications for landscape ecology and broad–scale information in regional assessments. For example, we can identify the areas that are most heavily impacted today by combining information on population density, roads, land cover, and air quality. In the mid–Atlantic region, we already have good information (from the U.S. Census Bureau) about which counties are most urbanized. But which counties have only a small proportion of adjacent forest cover along the stream length? Which counties are characterized by a high degree of forest fragmentation? What about information for watersheds instead of counties? Broad–scale measurements can be taken in order to make relative comparisons of these indicators over the entire region. Broad–scale data can also help in identifying the most vulnerable areas within the region. Vulnerable areas are not yet heavily impacted, but because of their circumstances they are in danger of becoming so. One example might be a watershed that has a relatively high percent of forest cover, but is also experiencing rapid population gains. Such an area might be more vulnerable to forest fragmentation than a similar area with less population or less forest area.

The ability to place localities into a regional context is another benefit of this approach. Some individual cities and neighborhoods in the mid–Atlantic Region may seem isolated, perhaps within a large forested area. However, all are connected by physical features and by ecological processes. Water flows from one place to another, roads provide a connecting infrastructure, and land cover patterns of forest and agriculture form a connected backdrop for all of our activities. While land management decisions are made and implemented at a local scale, a regional perspective can guide our decisions and make us better stewards of our environment. By placing our homes, neighborhoods, and government organizations into a regional landscape picture, we can begin to make informed decisions that consider not only our goals and actions, but our neighbors’ as well.

Figure 1.2 illustrates how a single community is linked to the landscape at several different scales and across different mapping units (watersheds and counties in this example). A small city is highlighted in the middle of the figure. At this scale we concentrate on individual land parcels and roads, and our decisions are based on a local perspective. Broader–scale perspectives emerge as we follow the lines up either side of the figure. We see that the community is part of both a watershed (left) and a county (right), which, in turn, are components of groups of watersheds and counties. These larger groups are components of the entire region.

How Can Landscape Indicators Help Us Understand Environmental Conditions?

An indicator is a value calculated by statistically combining and summarizing relevant data. Well–known economic indicators include the seasonally–adjusted unemployment percentage and number of housing starts, both of which indicate overall economic condition. In these indicators, seasonal adjustment is made with a model, and most economists look at several indicators together instead of just one at a time. Similarly, landscape indicators can be measurements of ecosystem components (such as the amount of forest) or processes (such as net primary productivity), and modeled adjustments can be used to help interpret the measurements in order to understand overall ecological conditions.

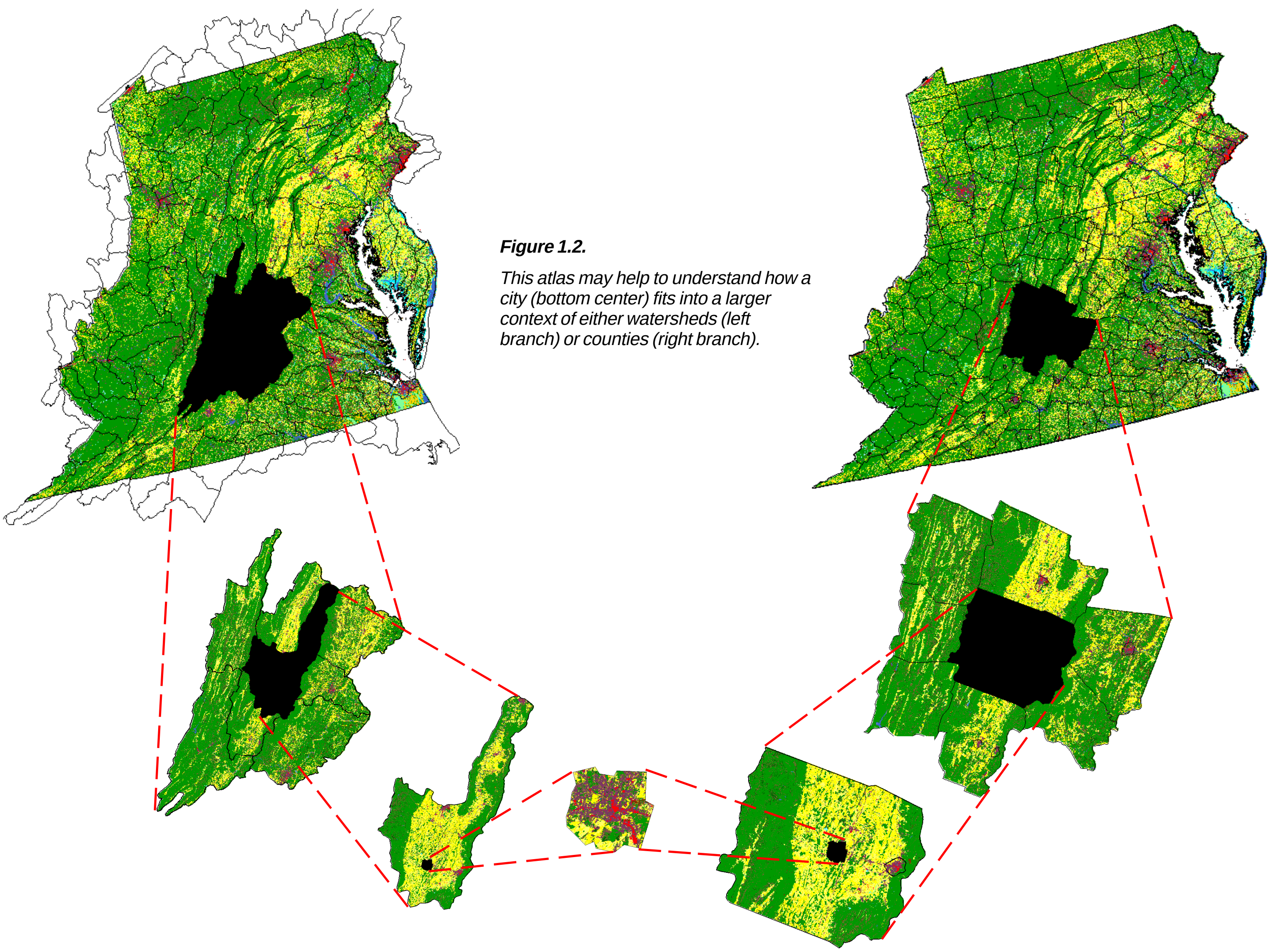


Figure 1.2.

This atlas may help to understand how a city (bottom center) fits into a larger context of either watersheds (left branch) or counties (right branch).

Figure 1.3 shows an example of measuring spatial patterns as an indicator of stream conditions. The distribution of streamside land cover has been mapped for the same county that was shown in Figure 1.2. Stream segments that are green have adjacent forest, and segments that are yellow and red have adjacent agriculture and urban land cover, respectively. The pattern of streams in relation to land cover is an indicator of conditions within the stream. Forests filter pollutants, preventing them from reaching the water, whereas agriculture and urban land often contribute pollutants to streams. A simple summary indicator might be the percentage of stream length in the county that is adjacent to forest land cover. To refine this indicator, a model might help to account for "natural" conditions, for example whether or not forest was the natural land cover for the county.

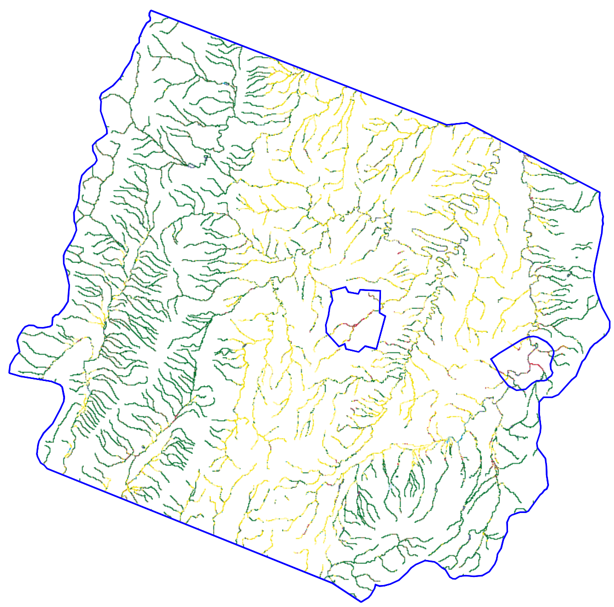


Figure 1.3.

Spatial patterns of land cover in relation to streams for a county in the mid–Atlantic region. Stream segments are colored green, yellow, or red, depending on whether the segments are adjacent to forest, agriculture, or urban land cover.

How Were the Landscape Indicators Selected?

As a starting point for selecting indicators, we considered what people in the region said they cared about. For example, concern for wildlife populations provides a reason to examine indicators of habitat fragmentation. Fragmentation of natural habitats can severely affect animal populations, as shown by the conceptual model illustrated in Figure 1.4. Concerns from the mid–Atlantic were then matched to our ability to take meaningful measurements, recognizing that some things just can't be measured very well given the available data or models. As a result of workshops and advice from people in the mid–Atlantic region, four general environmental themes were identified — people, water, forests, and landscape change. Figures 1.5 and 1.6 are pictorial representations of key landscape attributes that affect the sustainability of environmental condition across broad scales. Figure 1.5 shows some key landscape components that sustain a high quality environment, and Figure 1.6 shows some human modifications of the landscape that can reduce the sustainability of natural resources. These illustrations represent some of the important landscape indicators analyzed in this atlas.

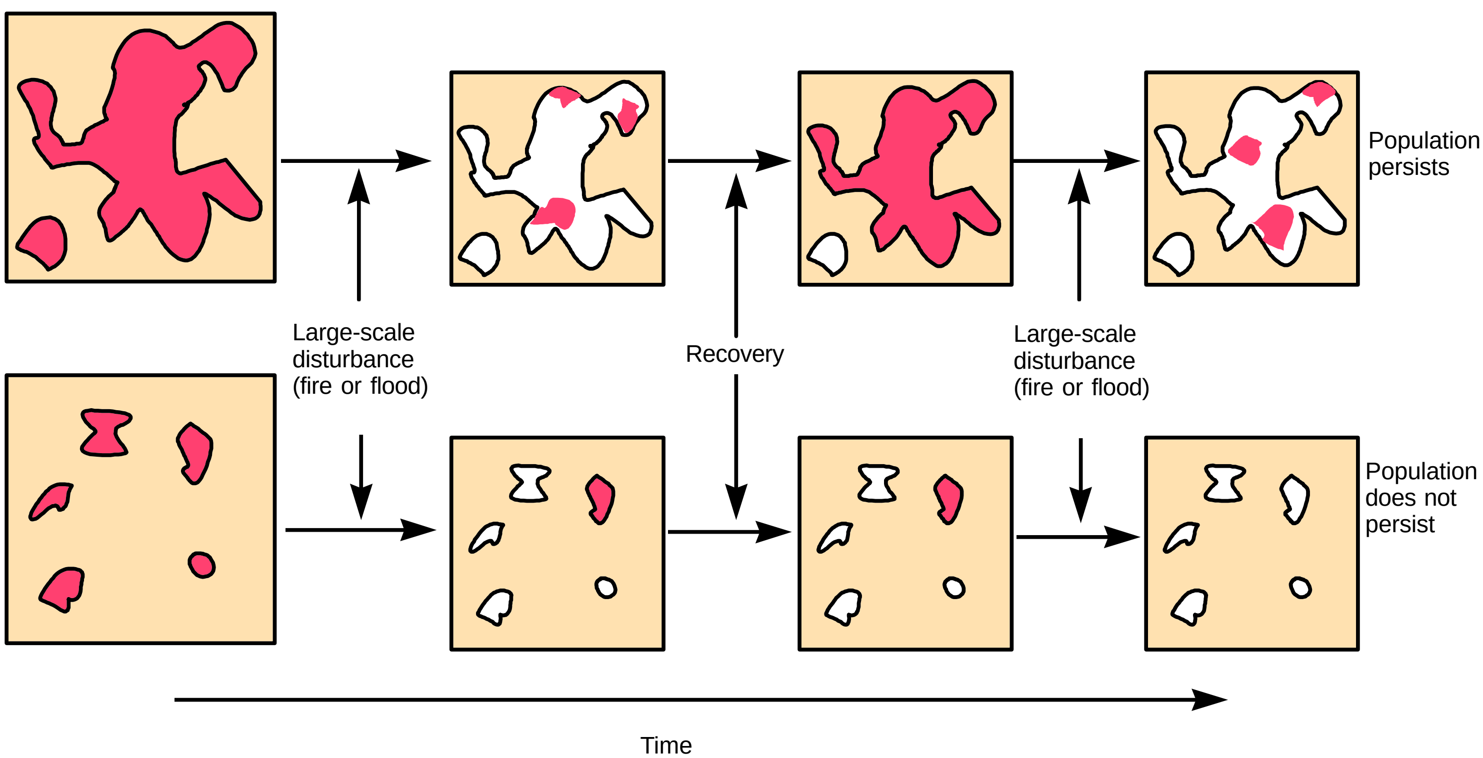


Figure 1.4.

Habitat fragmentation can result in the loss of a species due to natural disturbance. In this example larger, more connected habitat sustains the species over time, whereas smaller, more isolated habitat loses the species over time. (In this example, tan is non-habitat, red is occupied habitat, and white is unoccupied habitat.)

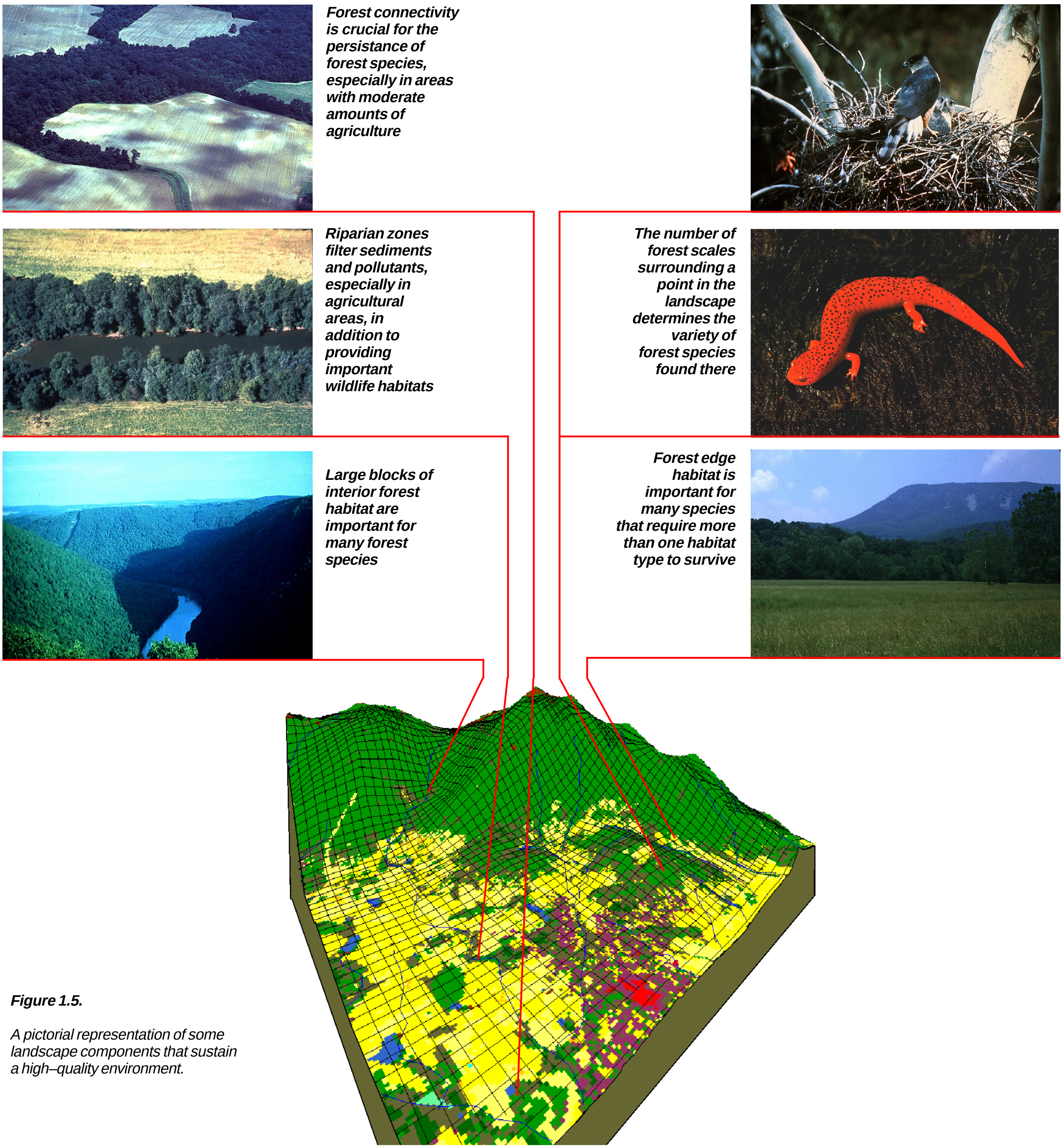
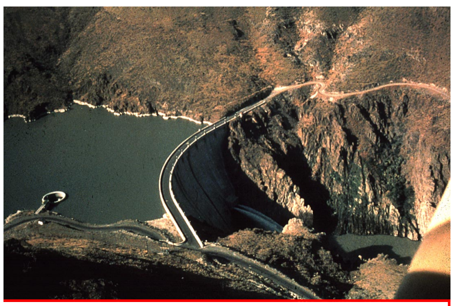


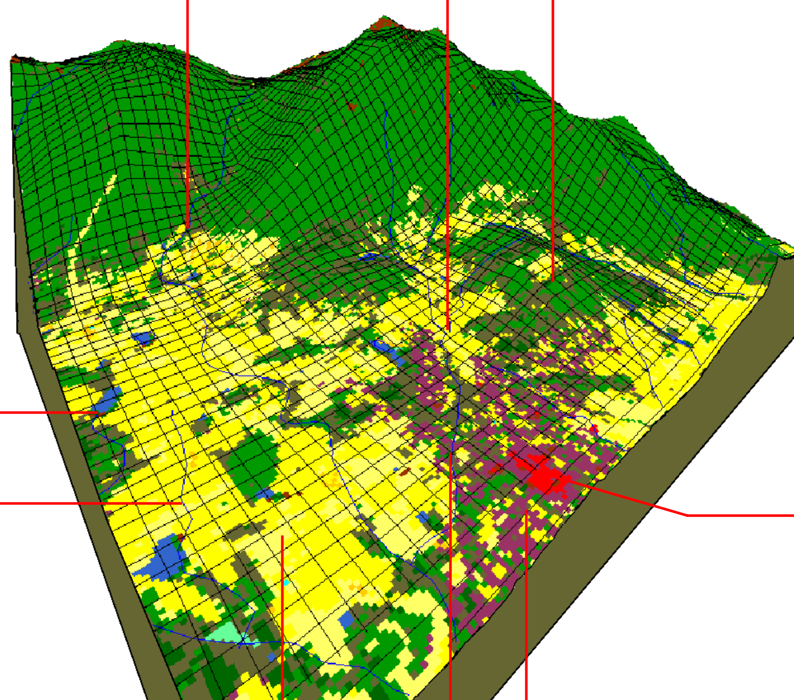
Figure 1.5.

A pictorial representation of some landscape components that sustain a high–quality environment.

Agriculture on steep slopes increases soil loss and sediment loading to streams



Dams alter the natural habitats and hydrology of streams



Agriculture areas near streams increase stream sediment loads and chemical inputs

The amount and location of agriculture in a watershed influences landscape pattern

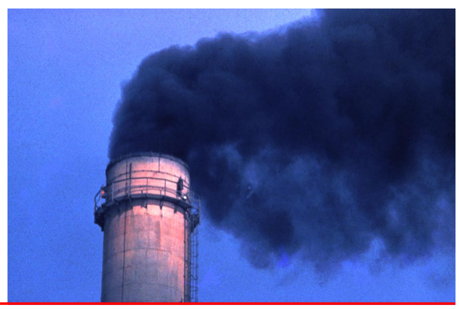
Figure 1.6

A pictorial representation of some human modifications of the landscape that reduce the sustainability of natural resources

Humans reduce riparian cover along streams, which decreases filtering capacity

Forest harvest practices influence forest connectivity and patch sizes

Air pollution spreads across the landscape, affecting regional air quality



Roads near streams increase sediment and pollution loads by increasing surface runoff

Population growth results in loss of forest and changes in overall watershed landscape pattern

The indicators reported in this atlas are not appropriate for addressing some kinds of questions. For example, they are not intended to assess conditions for very small areas. The goal was to develop a consistent and comprehensive look at the entire region, and there were trade–offs between the level of detail and the size of the area that could be considered. Future work would look at smaller areas using more detailed data sets. The regional perspective would be a valuable guide to determine where this additional expense might be warranted. The indicators reported here were not evaluated in absolute terms; only relative comparisons were made. In order to set absolute standards like the ones which exist for drinking water and air pollution, the system must either be very simple or intensively studied to provide very detailed scientific information. Regional ecosystems are simply too complicated to set absolute standards using our current technology and understanding.

Landscapes are very complicated, and the generality of the conceptual models is an accurate reflection of level of scientific understanding concerning landscape dynamics. Scientists who study landscape ecology are trying to improve our ability to interpret landscape indicators relative to environmental values. The improvements will help to interpret the information that is contained in this atlas and may suggest new landscape indicators that we have not considered. In the meantime, it is worth exploring how much is known about regional environmental conditions and what conclusions can be made using state of the art landscape indicators.

How Were the Landscape Indicators Measured?

Many kinds of data were used to prepare the indicators shown in this atlas. Federal agencies were the primary source for data, including maps of elevation, watershed boundaries, road and river locations, population, soils, land cover, and air pollution. Sources included the U.S. Geological Survey (USGS), the U.S. Environmental Protection Agency (USEPA), the U.S. Department of Agriculture (USDA), the U.S. Census Bureau, and the Multi–Resolution Land Characteristics Consortium (MRLC).

Data collected by satellites were used to map land cover and its change over time. The sensors carried on satellites measure the light reflected from the Earth's surface. Because different surfaces reflect different amounts of light at various wavelengths, it is possible to identify land cover from satellite measurements of reflected light. Figure 1.7 illustrates the differential reflectance properties of water, sediments suspended in water, and land surfaces for a typical satellite image. Examples of land cover maps derived from satellite images appear later in this atlas.

In a typical digital map, data are stored as a series of numbers for each map. These maps can be thought of as checkerboards, where each grid square (or pixel, which is an abbreviation of "picture element") represents a data value for a particular landscape attribute (for example soils, topography, or land cover type) at a specific location.

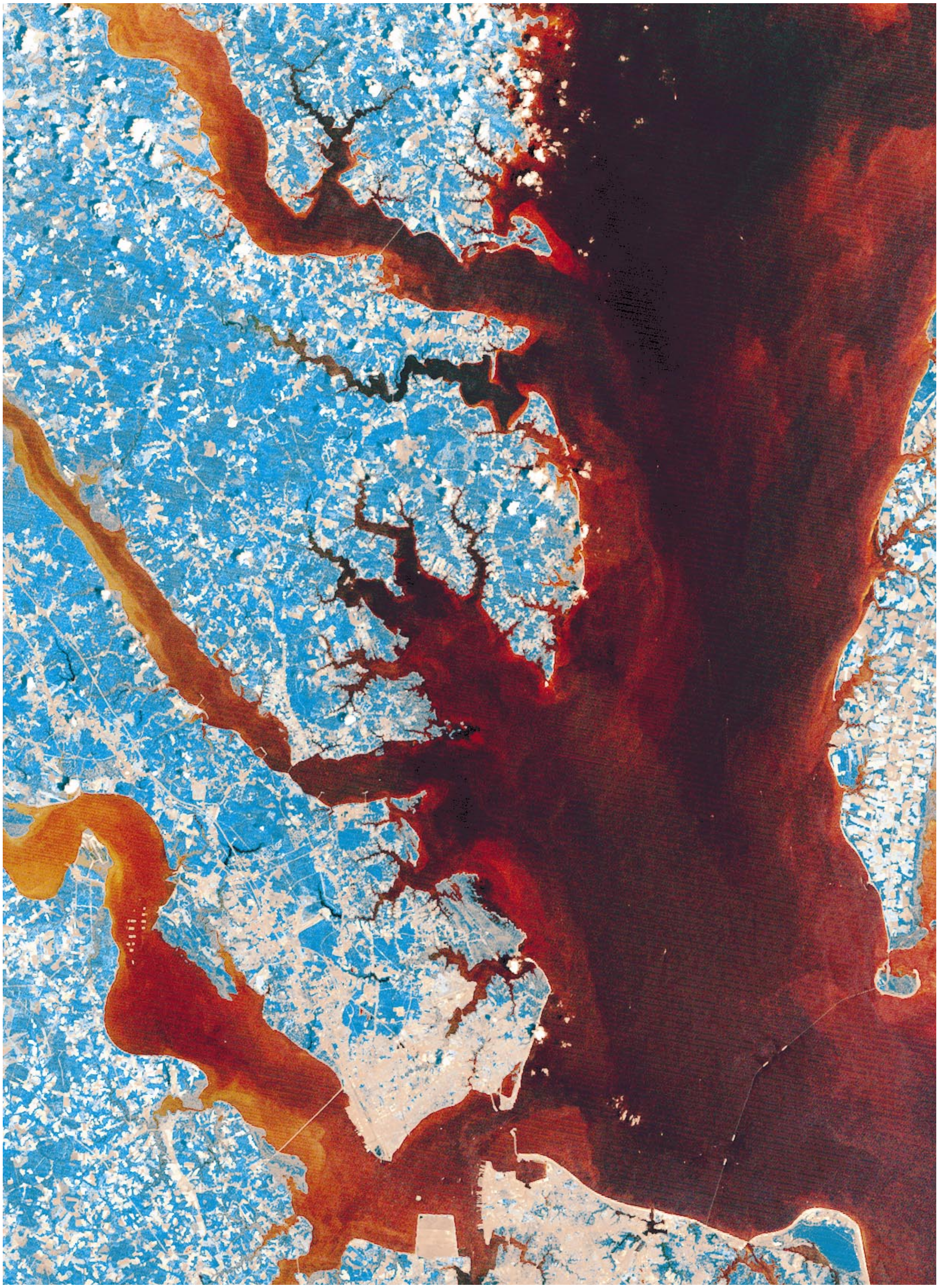


Figure 1.7.

Illustration of differential light reflectance properties for water, sediments suspended in water, and land surfaces over a portion of eastern Virginia and the Chesapeake Bay. These images can be manipulated in various ways to extract information about the Earth's surface.
Source: North American Landscape Characterization Program

Several techniques are used to take a measurement of a landscape indicator. One method ("overlaying") simply examines maps of different themes in order to extract information about spatial relationships among the themes (Figure 1.8). For example, by overlaying maps of land cover and topography, we can look at the occurrence of agriculture on steep slopes. These relationships are then stored as a new map which combines the information from the original set of maps. Another method ("spatial filtering") can be thought of as using a "sliding window" to calculate indicator values within small areas that are part of a larger map (Figure 1.9). Spatial filtering is used here to create surface maps of indicator values; these surface maps help us to visualize the spatial pattern of indicators in more detail than is provided by the watershed–level summaries described in the following section.

Land cover (with agriculture in red) is combined with topography to indicate agriculture on steep slopes. The combined map shows agriculture on slopes greater than 3%.

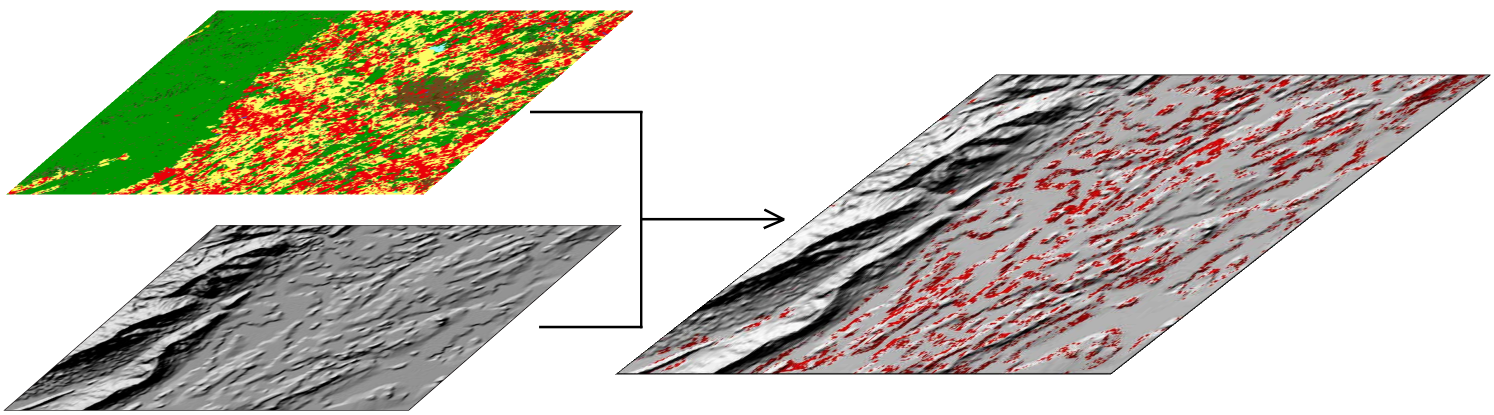
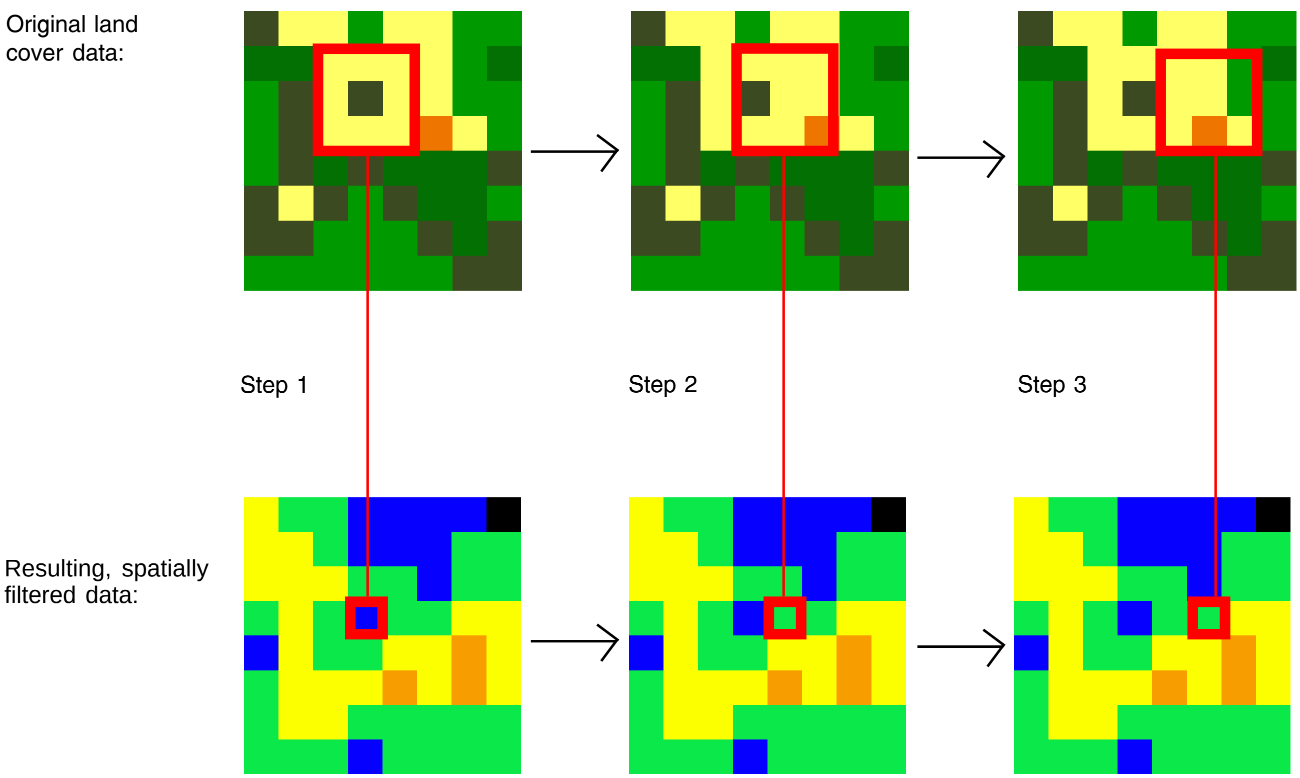


Figure 1.8.

Example of overlaying digital maps to produce a new map of an indicator.



In this example of the spatial filtering process, a 3 pixel by 3 pixel window (outlined in red - top row of figures) is used to map land cover diversity. In step 1, there are 2 cover types in the window which maps to a single blue pixel at the center of the window. In step 2, the window slides over one pixel. There are 3 cover types in the new window, mapping to a single green pixel in the center of the window. In step 3, the window again slides over one pixel. The third window includes 3 cover types and maps again to a single green pixel.

Legend for Filtered Coverage

- One Cover Type
- Two Cover Types
- Three Cover Types
- Four Cover Types
- More Than Four Cover Types

Figure 1.9.

Illustration of spatial filtering which creates a surface map.

How Were the Landscape Indicators Summarized?

This atlas uses watersheds, as defined by USGS hydrologic accounting units, to summarize landscape indicator values (Figure 1.10). Roughly speaking, hydrologic accounting units follow watershed boundaries. In many ecological studies, especially those which assess water–related concerns, watersheds are an appropriate unit for summarizing data. A watershed is defined as an area of land that is drained by a single stream, river, lake, or other body of water. The dividing lines between watersheds are formed by ridges. Water on one side flows into one stream, while water on the other side may flow into a different stream. Thus, watersheds are a natural unit defined by the landscape. Strictly speaking, the USGS hydrologic accounting units are not watersheds in the classical sense of a topographically–defined catchment area. They are used in this atlas because they are generally accepted and consistent across the entire nation.

To determine relative condition, the watersheds were ranked by the values for a given indicator, from highest to lowest, and then were divided into five groups. Each group had an equal number of watersheds; at the national scale (Chapter 2) there were approximately 425 watersheds in each group. At the mid–Atlantic regional scale (Chapters 3 and 4) there were 25 watersheds in each group. All watersheds within the same group were colored with one of five colors, using green to represent more-desirable conditions and red to represent less-desirable conditions. Maps based on rankings are useful for comparing relative conditions, but they do not convey the actual values of the indicators. That information is summarized in the companion bar charts which show the number of watersheds with different indicator values. By looking at the map and bar chart together, it is possible to estimate the ranges of indicator values associated with a given watershed group.

As a practical matter, the authors of this atlas made judgment calls when assigning ‘red’ and ‘green’ colors to the maps, and ‘more desirable’ and ‘less desirable’ interpretations to the indicator values. For example, forest edge was colored ‘green’ and interpreted as ‘more desirable’ when its values were high because the measurement was included as an indicator of a type of habitat. Similar judgment calls were made for other indicators. Higher values for the vegetation-increase indicator were considered to be a negative impact because much of this change did not represent restoration of the potential natural vegetation, but rather was more strongly associated with human activities. One of the advantages of presenting indicator scores for all watersheds (see Appendix) is that any reader can simply redefine the color scheme and make new judgments based on other criteria.

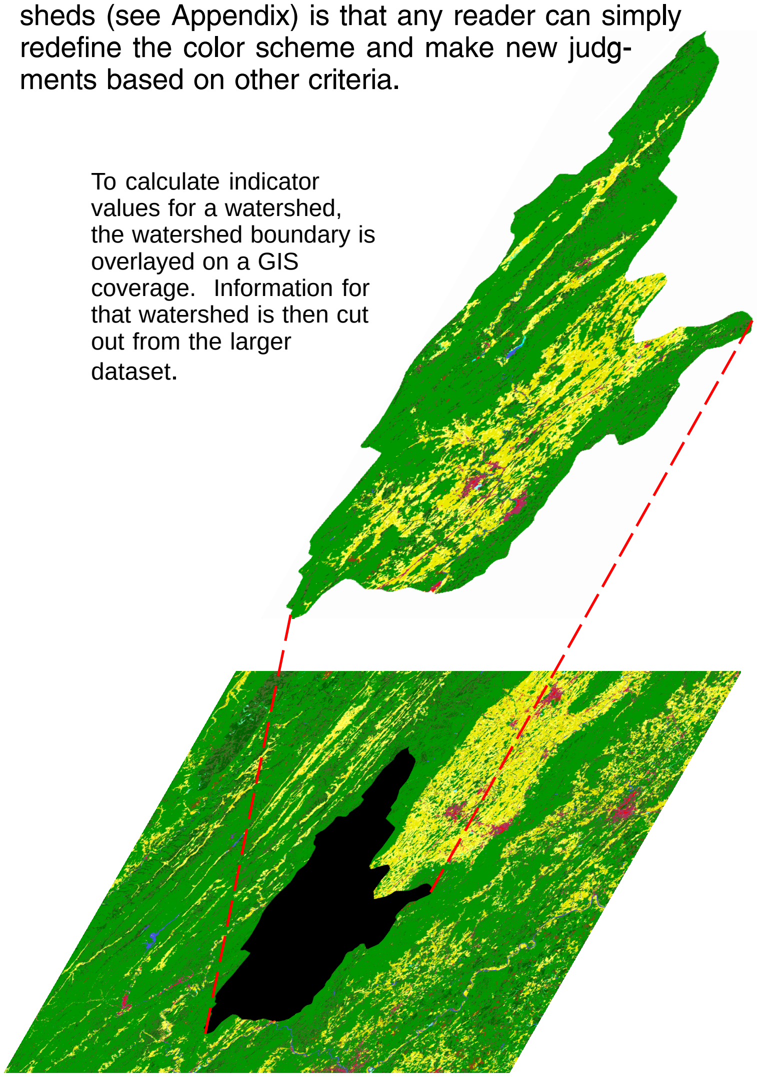


Figure 1.10.

Illustration of the cookie–cutter process that was used to summarize information by watershed.

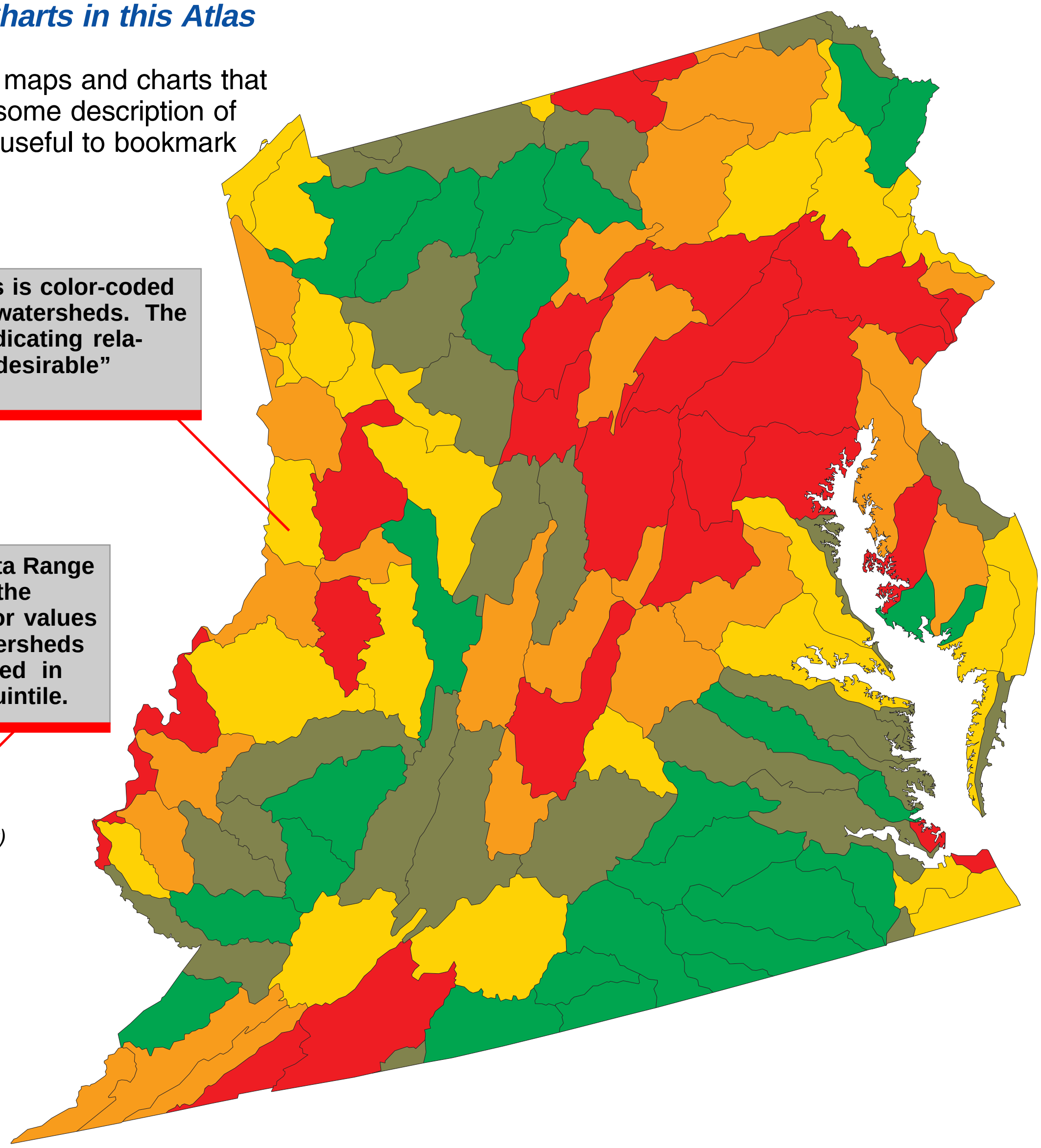
How to Read the Maps and Charts in this Atlas

Figure 1.11 illustrates the types of maps and charts that appear in Chapters 2 and 3, with some description of their various elements. It may be useful to bookmark this page for later reference.

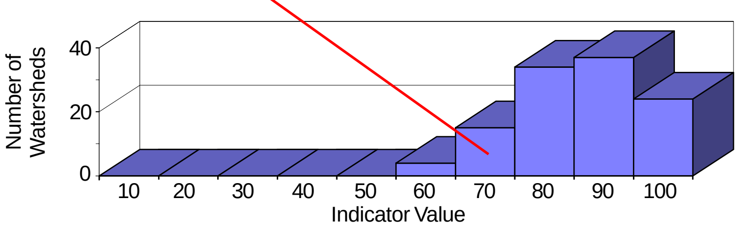
The map of mid-Atlantic watersheds is color-coded to show relative conditions among watersheds. The colors range from red to green, indicating relatively "less desirable" and "more desirable" conditions, respectively.

A quintile contains 1/5 of the watersheds. Quintiles are formed after ranking watersheds for the indicator.

The Data Range shows the indicator values for watersheds contained in each quintile.



The value shown on the X axis is the upper limit of a data range. For example, this bar shows the number of watersheds with data values between 60-70.



A brief explanation of the essential methods is given. Details are in the Appendix.

Woody landcover along streams was calculated as the percent of streamlength with forest landcover types. By intersecting a buffer zone around each stream with the landcover, a dataset is created which records all landcover types within a specified distance to stream center.
Sources: USGS 1:100,000 River Reach 3 stream data, and MRLC 30 meter Landsat land-cover data.

Figure 1.11.

How to read the maps and charts in this atlas.