USGS
science for a changing world

Analyzing Land Use Change In Urban Environments

Metropolitan areas in the United States are growing at unprecedented rates, creating extensive urban landscapes. Many of the farmlands, wetlands, forests, and deserts that formed the America of 1900 have been transformed during the past 100 years into human settlements. Almost everyone has seen these changes to their local environment but without a clear understanding of their impacts. It is not until we study these landscapes from a spatial perspective and the time scale of decades that we can begin to measure the changes that have occurred and predict the impact of changes to come.

The U.S. Geological Survey's (USGS) Urban Dynamics Research (UDR) program studies the landscape transformations that result from the growth of metropolitan regions over time. Using sources such as historic maps, aerial photographs, and Landsat satellite data, USGS scientists first assemble retrospective urban land use databases that reflect several decades of change. These databases are then used to analyze the effects of urbanization on the landscape, and to model urban growth and land use change under alternative growth scenarios.

Land Use Change

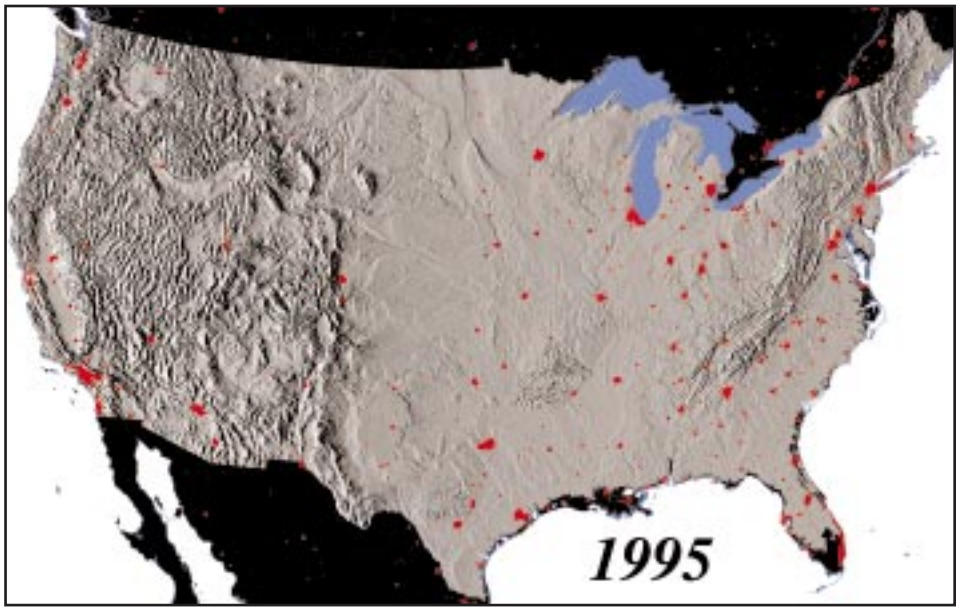
Most major metropolitan areas face the growing problems of urban sprawl, loss of natural vegetation and open space, and a general decline in the extent and connectivity of wetlands and wildlife habitat. The public identifies with these problems when they see residential and commercial development replacing undeveloped land around them. Urban growth rates show no signs of slowing, especially when viewed at the global scale, since these problems can be generally attributed to increasing population. Cities have changed from small, isolated population centers to large, interconnected economic, physical, and environmental features.

Urban growth and the concentration of people in urban areas are creating societal problems world-wide. One hundred years ago, approximately 15 percent of the world's population was living in urban areas. Today, the percentage is nearly 50 percent. In the last 200 years, world population has increased six times, stressing ecological and social systems. Over that same time period, the urban population has increased 100 times, concentrating more people on less land even as the total land devoted to urbanization expands. Yet the temporal and spatial dimensions of the land use changes that shape urbanization are little known, even in the United States.

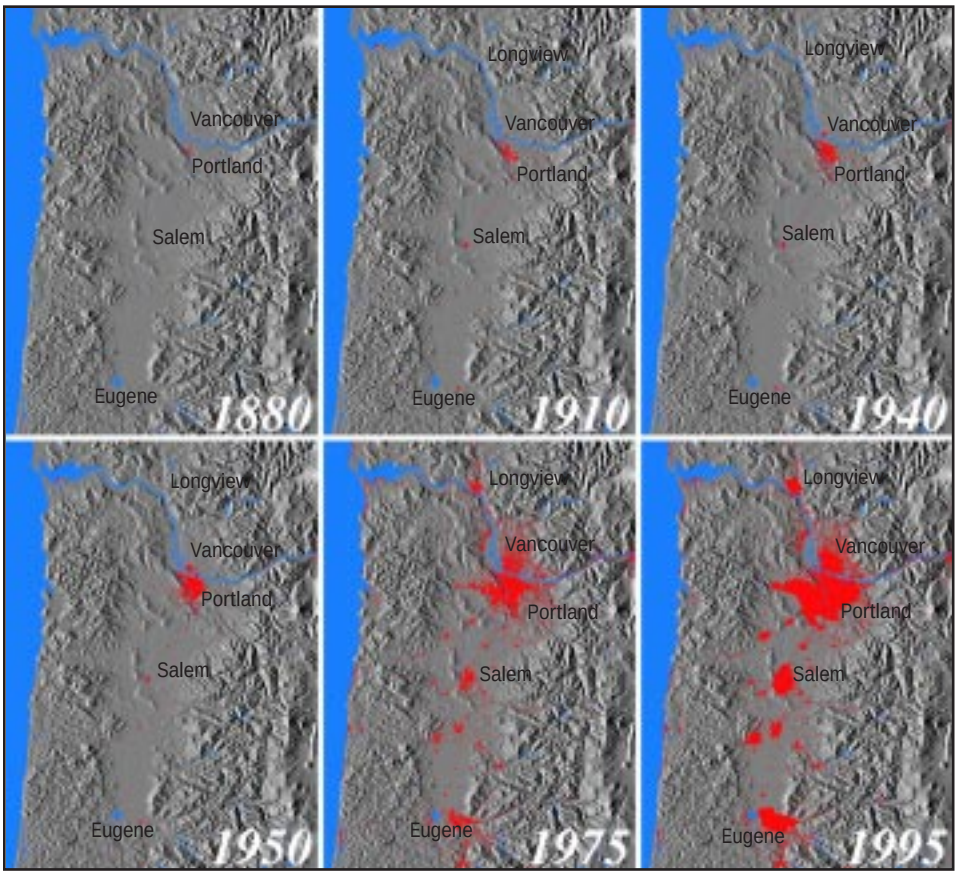
In the United States, policymakers and the public continue to raise concerns about the effects that unchecked urbanization has on the landscape. In 1998, more than 200 communities across the Nation voted on, and the vast majority adopted, measures to manage urban sprawl. The UDR program provides basic data, predictions, and perspectives to help in forming sound policies for guiding environmentally sustainable growth.

Mapping Land Use Change

Databases developed by the UDR program contain interpretations of urban extent, transportation routes, water features, and other important land uses. Selected regional studies are currently in progress across the Nation. Data source availability for each region, in conjunction with historical significance, determines the time periods that are mapped. Features are interpreted from diverse data sources including historical topographic maps, satellite images, census statistics, and aerial photographs. The resulting tem-



Nearly 80 percent of U.S. residents live in urban areas. This map, compiled from nighttime imagery acquired by the Defense Meteorological Satellite Program, shows city lights for urban areas in red for the conterminous United States in 1995.



This time series documents urban change in the Willamette Valley region over 115 years. The background in each map is a shaded-relief image. The red areas represent urban extent for each time period. The Pacific Ocean and the Columbia River are shown in blue. This study region extends from southern Washington south to Eugene, OR. Within Oregon, politically defined urban growth boundaries have been in place since the early 1970's in an attempt to control urban expansion.

poral database is a spatial record of the pace and extent of the urbanization process.

A temporal database can be visualized as a sequence of maps, such as those shown above and on the next pages, or as computer animations. Sequential maps show urbanization as a static pattern that changes with each time period that is mapped. Animations illustrate the temporal dynamics, revealing patterns and trends that are not possible to discern from tabular data or static maps.

Understanding Land Use Change

The geographic understanding of land use change in urban areas is a key aspect of the UDR program. By analyzing a temporal database for spatial patterns, rates of change, and trends, the UDR program can provide insight into how cities have developed under varying social, economic, and environmental conditions.

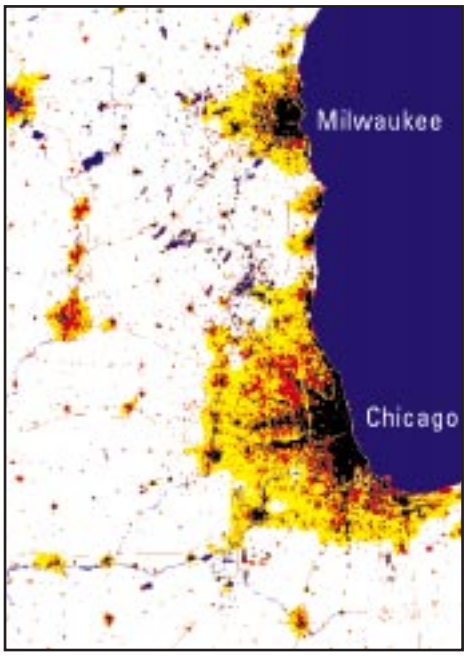
This analysis requires understanding a region's land use history. Population data, timelines of historical events, and related information are all used to explain the mapped changes. Population data are correlated with the temporal database so that human movement can be tracked and factored into these interpretations. Population increases suggest economic growth and the availability of jobs in an area, and population declines suggest a decline in livability or economic issues that cause people to leave a region. Timelines of past events and other historical compilations aid in identifying the issues that affected the development of the region.

In addition to gathering statistical and historical information, scientists must have a physiographic understanding of the place and its greater region. Topographic features, climate, and adequate supplies of water and other natural resources can limit or encourage growth and change.

The existence and accessibility of transportation routes have often dictated patterns of urban growth. Urban areas that were established in the 18th and early 19th centuries were usually located along waterways, reflecting dependence on shipping for the transport of goods and people. By the middle of the 19th century, railroads began to connect existing towns and spurred the growth of new urban areas.

The post-World War II era saw not only an increase in the population of most metropolitan areas, but also the emergence of a society dependent on the automobile. The proliferation of the private automobile led to expansive development at the edges of many urban areas. The development of the Interstate Highway system in the 1950's spurred the widespread construction of roads. As road networks expanded and became more complex, urban development followed. As in the past, most recent urban growth has occurred along transportation corridors.

The UDR program provides the data and geographic information necessary to document past land use change. By looking to the past, communities and regions are better informed and



This preliminary interpretation of urban land use change for Chicago-Milwaukee shows urban growth in 1955, 1975, and 1995. Each time period is represented by a different color. Black shows the extent of urban growth in 1955, red represents 1975, and yellow represents 1995.

equipped to plan and prepare for the future.

Land Use Change Modeling

Historical land use patterns, together with current trends in a region, are used to model future land use. Results from modeling urban growth and land use change can be used by the public, land use planners, and policy makers to anticipate and plan for the future. Land use change models can also generate alternative landscape predictions on the basis of different land use policies and environmental constraints.

These land use change models use simple parameters including present urban extent, major transportation routes, topography, and protected lands. Other factors, such as employment opportunities, land prices, and the millions of personal decisions people make, are not considered in this modeling approach. The primary focus of the modeling effort is to account for physical controls on land use. Acknowledging the uncertainties of models, the USGS uses statistical methods to predict probabilities of urbanization.

Impacts of Land Use Change

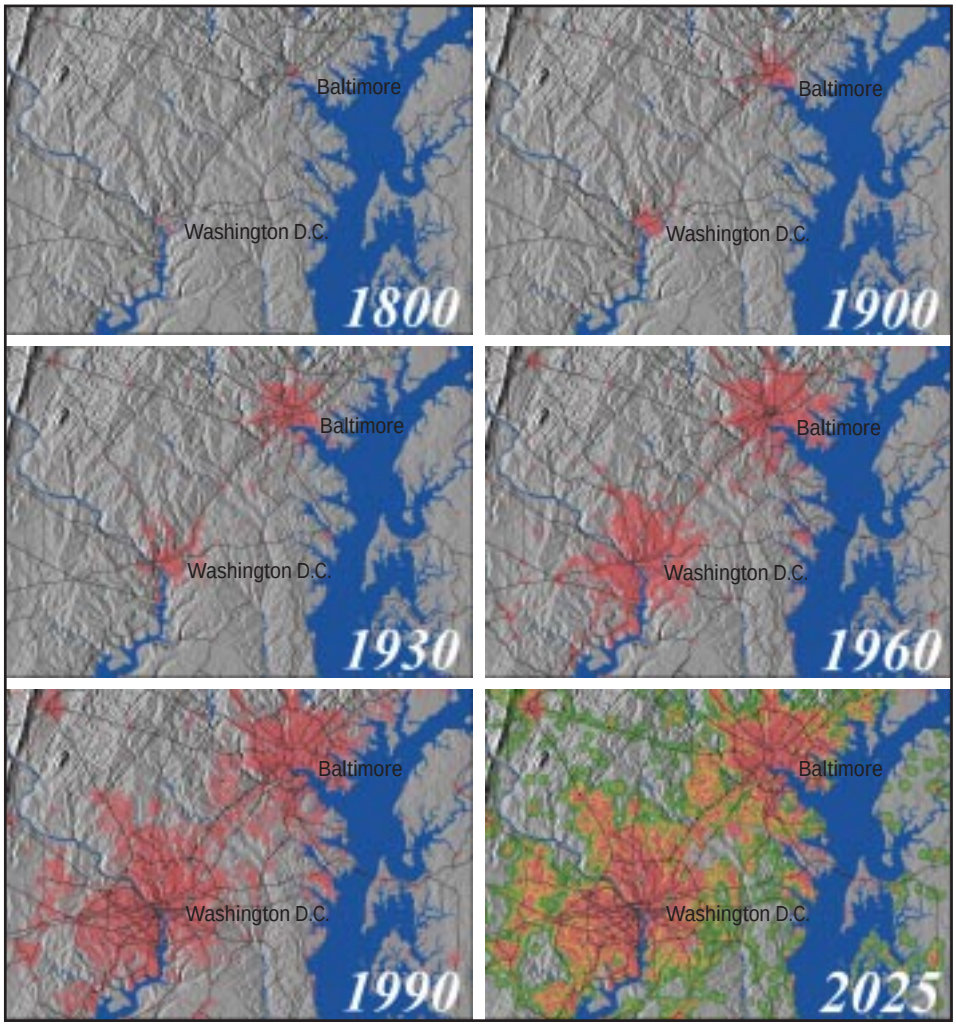
Urban Dynamics research in landscape characterization, urban growth models, and geographic understanding provides the data necessary for analyzing the impacts of population growth and land use change. This information can be used to analyze the causes of urban congestion, pollution, and loss of natural resources. Each of these impacts is linked to changes in the extent of urban, agricultural, and forested lands, and (or) transportation systems.

Planners use Urban Dynamics data to evaluate environmental impacts, to delineate urban growth boundaries or service areas, to develop land use zoning plans, and to gauge future infrastructure requirements. Traffic congestion, a common malady of urbanization, is the result of urban growth, increases in population density, and out-dated transportation infrastructure. By evaluating trends associated with land use change over time, solutions to traffic congestion may be obtainable.

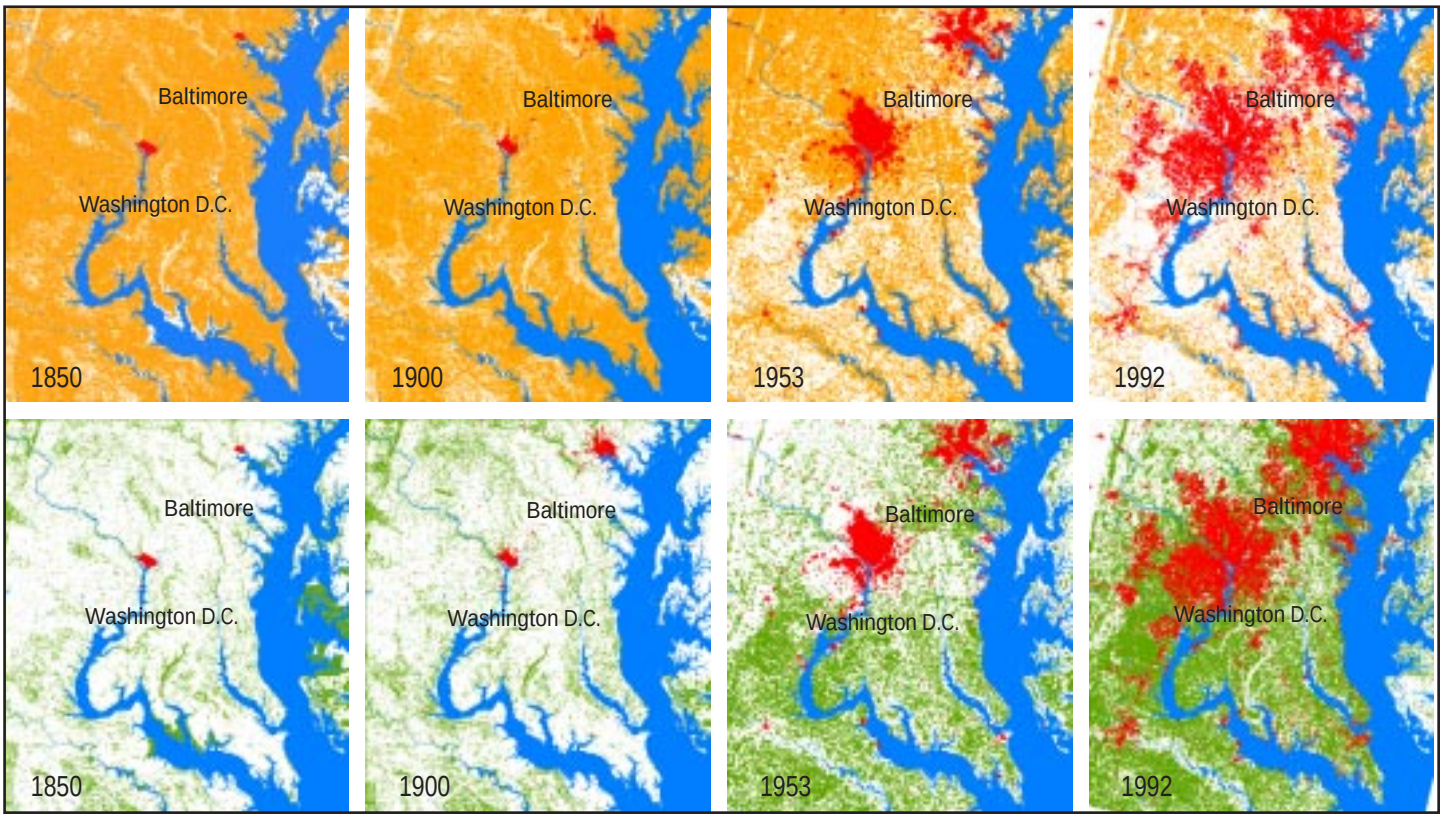
Another specific application of UDR data is the correlation of air pollution records with the temporal database to determine if control strategies for reducing pollution have been effective. Many pollution control strategies have been used in the past three decades. Correlation between land use change and pollution helps researchers establish positive or negative trends that indicate whether pollution control strategies have been successful. With this information, policy makers, resource managers, and the public can make appropriate changes for the future.

Hydrologists can use Urban Dynamics data to evaluate new water sources for future urbanization and to analyze water pollution – a problem common to urban areas, industrial sites, and agricultural lands. The amount and degree of water pollution in rivers, lakes, and bays can be predicted on the basis of past and future trends in land use change. A study currently underway in the Patuxent River Basin in Maryland focuses on the sources of water pollution over time. In this study, temporal change maps of urban, agriculture, and forest lands are used to identify and quantify historic trends in sediment and nutrient loads in waters draining into the Chesapeake Bay.

Geologists use data on land use change to evaluate the availability of building materials, such as sand, gravel, and cement. Geologists also use data on existing hazards to correlate with the UDR data to predict the impacts of future natural disasters and the potential damage they may cause.



This series of maps shows more than 200 years of urban growth in and around the Washington, D.C. area. The background in each map is a shaded-relief image. The red areas represent urban extent for each time period and the blue is Chesapeake Bay. Projections for 2025, made with a land use change model, show likely areas of new urban growth in yellow (high probability) and in greens (light green is moderate probability; dark green is low probability).



This series of maps compares changes in urban, agricultural, and forested lands in the Patuxent River watershed over the past 140 years. The top series shows the extent of urban areas (red) along with agriculture (gold), which was at its peak in the mid-to late-1800s. Since 1900, the amount of agricultural land has declined as urban and forested land (green) has increased.

Policy makers can then use these damage or hazard projections to direct future development away from the most at-risk areas.

Finally, biologists also use land use change data to compile maps on habitats, species distribution, and land management. Predictions about future urbanization are critical to the protection of ecosystems and the sustainability of communities.

Products

The UDR program provides temporal land use databases, analyses of land use change, and landscape change predictions. Databases for study sites contain digital maps of urban extent, transportation routes, water features, and other significant land uses compatible for use in geographic information systems (GIS). Digital animations are available to help visualize the temporal patterns inherent in the data. A land use change model and documentation are also available. Interpretive papers and maps based on the data and models are published in a variety of formats.

Study Sites

UDR projects are underway in the metropolitan regions of Washington, D.C., Baltimore, Chicago, Milwaukee, Portland, Vancouver, New York, Philadelphia, San Francisco, and Las Vegas. Additional work is being done in the Detroit River corridor, California's Central Valley, the Front Range corridor of Colorado, South Florida, and in the Middle Rio Grande Basin in New Mexico.

Collaboration

The UDR program is a joint activity between the USGS and the University of California, Santa Barbara. The Baltimore-Washington study was also supported by the University of Maryland, Baltimore County, NASA's Mission to Planet Earth, U.S. Census Bureau, Library of Congress, Smithsonian Institution, and Maryland Historic Trust. We are actively seeking the participation of organizations in new project areas as partners and clients.

Information

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Project descriptions, plans, and information generated by the program are available at

http://edcwww2.cr.usgs.gov/urban.

For information on other USGS products and services, call 1-888-ASK-USGS, use the ASK.USGS fax service, which is available 24-hours a day at 703-648-4888, or visit the general interest publications web site on mapping, geography, and related topics at http://mapping.usgs.gov/www/products/mappubs.html.

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