# Decision Support Systems and the Changing Landscape

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## Summary

Throughout the United States and the world the natural landscape is changing rapidly as the human population grows and open space is replaced with the infrastructure of civilisation. Although population growth is considerably slower in the United States than in many other parts of the world, the American landscape is declining as a consequence of urban sprawl and short-sighted land use practices. Public concern about the loss of open space and wildlife habitat is mounting as evidenced by the more than 200 ballot initiatives addressing this issue in states and communities across the country in the 1998 election.

Urban planners, government officials, concerned citizens, and others are in need of information and tools to guide their efforts to stem urban sprawl and the decline of the natural landscape. Geographic information systems (GIS) offer a mechanism to organise data on a wide range of themes, from land use, vegetative cover, and hydrology to infrastructure and natural hazards. Coupling GIS to models of various kinds, visualisations, and other analytical tools results in decision support systems (DSSs) that can be used to depict future growth scenarios and patterns of land use.

The rapid advance of remote sensing, global positioning, and other technologies in parallel with the development of increasingly sophisticated GISs and DSSs offer opportunities to fundamentally change the way we think about human activities and their impacts on the landscape. Opportunities now exist to build DSSs, link them with other emerging technologies, and apply them in ways that will facilitate more informed, science-based land use planning. DSS development can be advanced most efficiently through public-private partnerships. This includes informal collaborations to more formal relationships such as cooperative research and development agreements (CRADAs), contracts, and grants. Government policies should encourage open access to data, interoperability of data systems and models, and incentives for partnering across societal sectors both within and among nations.

## Natural resource challenges and the importance of geospatial data

The global landscape is rapidly changing as the human population grows and the natural world gives way to the demands of civilisation. The world population, now more than 6 billion, is projected to grow to 8.5 billion by 2025[1], a staggering growth rate that will fuel urban sprawl, increased resource use, declines in biodiversity, increased solid waste production, and large-scale modification of the physical environment. Some 60 percent of the world's population is projected to reside in urban areas in 2025, compared to 40 percent in 1990[2]. This shift is giving rise to major urban centres that become sinks for minerals and materials and a source of massive quantities of solid waste as well as water and air pollutants. The expansion of these centres has impacts well beyond their urban boundaries as minerals and materials are mined, produced, and transported into urban areas and waste products are transported outside.

Just over the last 25 years, Landsat images have documented dramatic changes in the global environment, a rate of change that will undoubtedly increase in the coming decades. Although calls for sustainable development have been made and governmental policies are changing, much greater attention must be focused on land use patterns and approaches to preserving and restoring the natural landscape. GISs and DSSs will be central to these efforts.

Addressing the natural resource challenges of the decades ahead will increasingly require multidisciplinary research and monitoring efforts that evaluate ecosystem structure and function from an integrated perspective. Understanding the implications of changes in vegetative cover, for example, requires not just biological studies, but geological, hydrological, atmospheric, and socioeconomic evaluations. And even biological studies must involve a broad range of expertise including microbial, aquatic, fisheries, and population biology as well as systematics, botany, zoology, and ecology.

Regardless of the scientific discipline, place-based, geo-referenced data are central to research and monitoring programs. Consequently, mapping capabilities are critically important. The organisational structure of the U.S. Geological Survey is instructional in this regard. It has four major operational divisions: Geologic, Water Resources; Biological Resources; and National Mapping. The capacity to work across divisions and integrate the physical, biological, and mapping sciences allows the Survey to evaluate issues from a comprehensive perspective. The Mapping Division often plays an integrating role, offering tools to bring the physical and biological sciences together.

GISs have revolutionised the way natural resources data are organised, transferred, and presented. Once a system accessible only to technically trained experts working on high-end computer systems, GIS has become a standard tool used by individuals in many different fields of work with varying educational backgrounds. The rapid diffusion of this tool can be attributed to several advances including new low cost powerful computers capable of running GIS software, inexpensive GIS software, accessory software packages extending the uses of GIS, and the successful application of GIS in addressing a host of practical issues.

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1. United Nations, Population Division, *Demographic Indicators 1950 – 2025* (the 1992 revision).

2. United Nations, Population Division, *Urban and Rural Places, 1950 – 2025* (the 1992 revision).

GIS is now being used worldwide to guide decision-making related to transportation systems, natural resource use and conservation, and environmental protection. It is emerging as a tool in other areas of public policy including law enforcement, telecommunications, energy supply and demand, and consumer product marketing.

Individuals in a wide range of professions are making use of GIS and related applications: from elected officials, resource managers, and scientists, to architects, urban planners, and the public. Nearly all governmental and private sector activities influence resource use and the environment to some degree. Understanding these influences requires the use, and often the integration, of a wide range of physical, biological, and socioeconomic placed-based or geo-referenced data. Consequently, GISs will increasingly become the focal point for storing, manipulating, and transferring data critical to future policy-making.

GIS has transformed the way natural resource science is undertaken. It is now a standard tool in field ecology, essential in mapping habitat and the location of plant and animal species. It is used by earth scientists to map geologic structures, mineral deposits, soils, and hydrological characteristics. And it can serve as a unifying tool among scientific disciplines. Through the overlaying of data themes or layers, the products of research and monitoring can be readily integrated, providing a more comprehensive depiction of the condition of and stressors on an ecosystem.

## The advancement of enabling information and related technologies

The digital age opens the door to a broad array of technologies that enable the gathering, storage, analysis, and transfer of data on the environment and natural resources. Rapid improvement in the storage capacity and processing speed of computers, together with advances in global positioning system (GPS) and related software have not only aided the traditional GIS community, they have opened the door to a whole new set of users. Powerful GIS software can be run on personal and laptop computers making GIS and its applications accessible to virtually anyone. These advances have also transformed field biology, hydrology, and geology. Laptops loaded with databases, GIS, and other analytical software, and visualisation tools are becoming standard gear in the field.

Emerging telecommunications, digital photography, GPS, and other technologies extend natural resource science capabilities even further. Today, data can be gathered, analysed, and reported in hours instead of weeks or months, significantly advancing the capacity to respond to the needs of government officials, resource managers, the private sector, and the public. The Internet and World Wide Web now allow rapid dissemination of data locally, nationally, or globally allowing colleagues to contribute to the analysis or quickly make use of the results. Tools are emerging that allow individuals to identify and merge data themes on the Internet and download a final integrated map product. In the near future this capability is likely to be coupled with various analytical tools allowing on-line development and use of customised DSSs.

Other tools that extend the capabilities of GIS either exist or are on the horizon. Real time monitoring systems of water and air quality, streamflow, earthquakes and other natural hazards, as well as the status of the biological conditions will allow the rapid integration of data and depictions of ecosystem change over time. Satellite telephones will allow the instant transmittal of data to and from remote locations. Clearly, technology is rapidly changing the way the science is done.

New satellite imaging systems will result in an explosion of data that will allow better monitoring of natural and human impacts on the global environment. The recent launch of Landsat 7, for example, will allow ready access to imagery with 15 meter resolution, twice the resolution of Landsat 5. And commercial satellites will soon be launched with imagery capabilities of 1 meter resolution that will allow detailed analysis of the Earth's surface. Future DSSs will benefit greatly from the availability of these emerging monitoring technologies.

## Evolution of decision support systems from geographic information systems

GISs are becoming more sophisticated over time as applications and analytical tools are added to core GIS capabilities. These include three dimensional visualisation tools, scientific models, depictions of population growth and urban expansion, as well as projections of future natural resource uses and impacts. In this sense GISs are gradually evolving into decision support systems (DSSs), sophisticated systems comprised of a series of interrelated, compatible modules that offer users a wide range of analytical assistance.

As an example, consider the Yellowstone ecosystem, a 30,000 square mile area encompassing two national parks, seven national forests, 22 counties, and parts of three states – Wyoming, Montana, and Idaho. Through a collaborative public-private effort called the Aurora Partnership, individuals from the federal government, academia, and the private sector are developing a prototype decision support system comprised of multiple modules that will aid land use planning, resource management, and response to natural hazards, including floods, earthquakes, and fires. The approach is not to build a large centralised system, but to encourage the advancement of a series of distributed, interoperable modules that, taken together, comprise a DSS. A module may be a hydrologic or fire model, an analytical package, visualisation software, or virtually any tool that one may draw upon to store, manipulate, or transfer data. The DSS as a whole allows the user to rapidly perform a wide range of functions. In addition, it will allow the public access to information that will encourage greater participation in decision making activities.

Compatibility or interoperability of data and data systems is the key to the advancement of DSSs. Fortunately, considerable progress is being made on this front. The Federal Geographic Data Committee and other organisations have developed a series of data standards. And software advancements are making it easier to reformat and transfer data. Just a few years ago, it was difficult and time consuming to transfer files from one word processing system to another. In the next few years transferring geospatial data from one system to another will become easier – hopefully routine. This will facilitate the construction of modular information systems.

The modular approach to advancing DSSs is key because it builds on existing data systems and encourages their developers and sponsors to continue supporting these activities. DSS development is largely a two-fold process:

1. encouraging the advancement of interoperable modules; and
2. linking the modules in such a way that they are accessible and useful in broader problem solving.

The Aurora Partnership was only recently initiated. It encourages individuals and organisations in particular regions – for example, a defined geographic area, an ecosystem, watershed, or county – to collaborate in developing DSSs. At some point this could be extended to an international partnership. For example, a multinational system that allows the rapid identification of areas of high biological diversity that should be protected from development, a system that depicts current and projects future land use patterns on a global scale, or a system that tracks current and projects future point and nonpoint sources of air and water pollutants that may impact a neighbouring country. Often international conflicts arise and become difficult to resolve because of disagreement over fundamental information about the source and impacts of a particular environmental stressor. A common set of data and agreed-upon analytical tools can greatly facilitate the avoidance or resolution of environmental conflicts.

## Emerging decision support systems and their application

Developing sound land use policies requires a solid foundation of scientific data, yet there is typically a gap, or even chasm, between science and management. Bridging the two requires communication in both directions. Resource managers must articulate challenges and needs and scientists must not only respond to but also help managers shape the questions they ask and understand what science can realistically offer. DSSs can be a useful bridging tool in that they clarify and raise the level of this two-way dialog.

Government officials and the public often complain that they are inundated with information – that they cannot make use of the data that they already have, much less find a way to consider more. Nevertheless, natural resource decisions are regularly made with incomplete or misleading information. Take a practical example: water consumption and conservation in California is major statewide challenge, particularly in the southern portion of the state. California simply does not have sufficient water resources to support its present rate of growth in the decades ahead. Most Californians are well aware that water supplies are dwindling and that they must place more emphasis on conservation. Ironically, however, the public has little idea of how much water a typical family uses in a day. Recently, the California Department of Water Resources undertook a first-ever public survey on water consumption[3]. More than 90 percent of the respondents agreed that conservation is needed and that water must be used more wisely to protect the environment, yet very few respondents had any sense of how much water they were using. Residential water users guessed that a household of three individuals was using only 73 gallons of water a day. Yet, the actual average was 402 gallons a day – an underestimate of use by 450 percent. More than 40 percent of the respondents indicated that they believed they could reduce their water consumption by 20 percent with little difficulty. In actuality, doing so would require an average reduction of 80 gallons per day – more than what they guessed they were using.

3. *Citizens Send Mixed Signals About Water*, Wall Street Journal (California Edition), 31 March 1999.

This example points to a fundamental problem in natural resources decision-making: the gap between availability and use of natural resources data. People cannot appropriately respond to a natural resource challenge if they are not able to measure and understand the results of their actions. Using this example, a simple DSS could be constructed that would allow citizens to make informed choices about water use in their homes. It could be linked to monitoring devices that provide real-time feedback on consumption. The system could provide projections of future consumption under alternative scenarios and could retrieve information via the Internet on community and statewide consumption so that individuals could relate their use patterns to those of others. Here a simple DSS becomes a powerful tool for resource conservation.

Similarly, urban sprawl and poor land use decision-making more broadly stems from an inability to put individual decisions in a larger context. For example, when citizens are presented with a visualisation showing the growth of urban centres over a two hundred year period they are typically shocked at how rapidly the landscape has changed. The larger context catalyses concern and action. The U.S. Geological Survey recently initiated an urban dynamics program that is using various map products and visualisations to describe the growth in urban centres throughout the United States. A video of growth in the Baltimore-Washington urban corridor developed in cooperation with the University of Maryland, the University of California, Santa Barbara has proved to be a powerful tool in fostering public understanding of land use trends.

The lack of comprehensive information about the status and trends of ecosystem health and the impacts of multiple stressors often hinder environmental decisions. The discipline-by-discipline approach to environmental studies frequently leads to incomplete or misleading depictions of ecosystem status. DSSs can be designed in such a way that hydrological, geological, biological, and socioeconomic data are presented in an integrated fashion. This type of depiction encourages – perhaps even forces – collaborative studies across fields of scientific study, fostering the kinds of holistic ecosystem studies that will be critical to addressing the challenges of the future.

## Democratising decision making

GISs and DSSs offer an opportunity for greater public participation in the decision-making process. They do more than convey data; they present information in a usable format. GISs and DSSs make data both accessible and understandable. Data once published solely in technical journals, kept in archives, or even stored in file cabinets are now available to a broad range of users. And the organisation of data in a geographic context makes it more understandable to users. DSSs build on GISs by allowing the visualisation of complex data sets, sometimes in a realistic 3-D format. The integration of data of various kinds – whether biologic, geologic, hydrologic, or socioeconomic – allows for more comprehensive thinking about problems and potential solutions. This is particularly helpful in thinking about ecosystem structure and function and the impacts of human activities on the landscape.

In a sense, GISs and DSSs can be called ‘Jeffersonian Technologies’ – technologies that enable greater public participation in the decision making process. Jefferson’s view was that citizens given access to adequate information will make informed judgements about public policies. The process is therefore more democratic because more individuals are able to participate in the decision-making process. A logical extension of this argument is that experts and government officials do not have sole access to the information for decision-making. Consequently, the decision-making process is more decentralised and pluralistic.

Throughout the United States, individuals are organising to protect the environment, stem urban sprawl, and ensure the livability of their communities. For example, more than 1000 citizen-based watershed councils have been organised across the country to find ways to limit water pollution, and preserve and restore wildlife habitat. These councils seek a wide range of information on environmental conditions and stressors within their and neighbouring watersheds. Many are using and others are discovering the utility of GISs and DSSs in organising, evaluating, transferring, and presenting data. These tools have helped the councils build their management initiatives on a firm scientific foundation and have allowed them to monitor progress over time.

The Federal Geographic Data Committee, chaired by Secretary of the Interior Bruce Babbitt, along with the National Association of Counties, National League of Cities, and others has developed an initiative to enable communities to build their GIS and geospatial data capacities. The Community/Federal Information Partnership (CFIP), if funded by Congress, will provide grants to communities on a competitive basis to support the purchase of hardware or software, or to support training, data development, or related activities. It will also support efforts within federal agencies to make geospatial data more accessible to communities. Six pilot projects are presently underway in counties and watersheds across the United States to demonstrate the value of such a initiative. The broad goal of the initiative is to advance the development of the National Spatial Data Infrastructure.

## Conclusion

Advancing decision support systems requires policies that encourage the ready sharing of data and the interoperability and modular development of systems. Open access to scientific data is very important, otherwise the rate limiting step in developing DSSs will shift over time from technological and analytical advancement to data access. Public-private partnerships are essential in ensuring the development complementary decision support modules, the major elements of DSSs. Government policies and economic incentives that promote partnering across societal sectors within and among nations are key in this regard. Regional collaboration efforts to advance DSSs, together with periodic opportunities to report on progress and share information across regions, is a useful approach to promoting the development of advanced GISs and DSSs that will aid in natural resources management.

The future of GIS and DSS is very promising. The capacity to improve the way decisions are made about the environment, natural resources, and land use is at our doorstep. Through data sharing and collaborative advancement of analytical tools, the next decade has the potential to be a remarkably productive period in which a range of new decision making tools emerge that will help improve our quality of life, sustain economic growth, and help preserve the natural landscape for the enjoyment and prosperity of future generations.

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