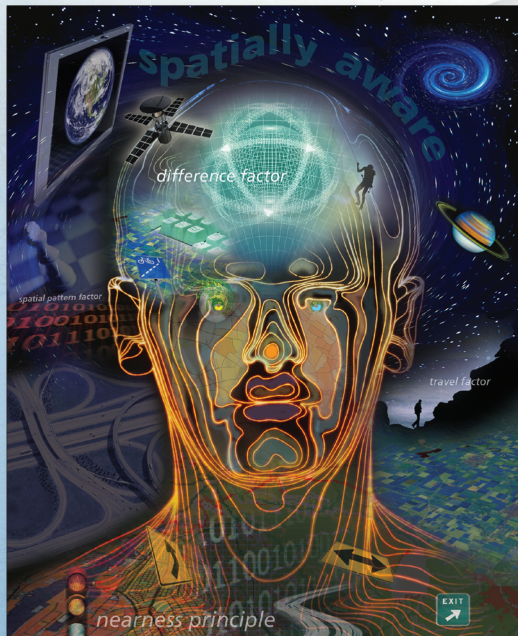
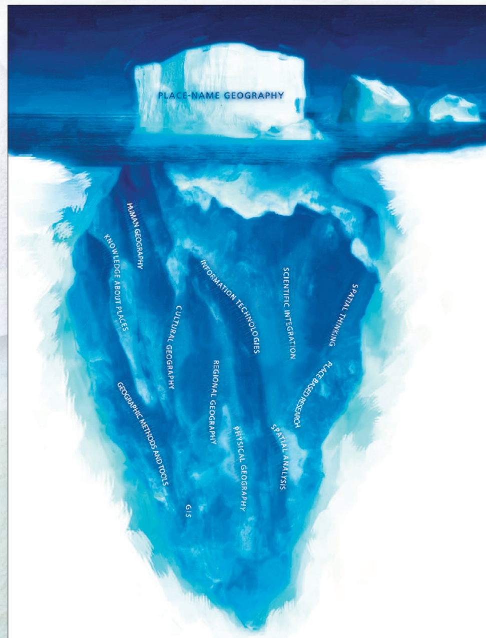
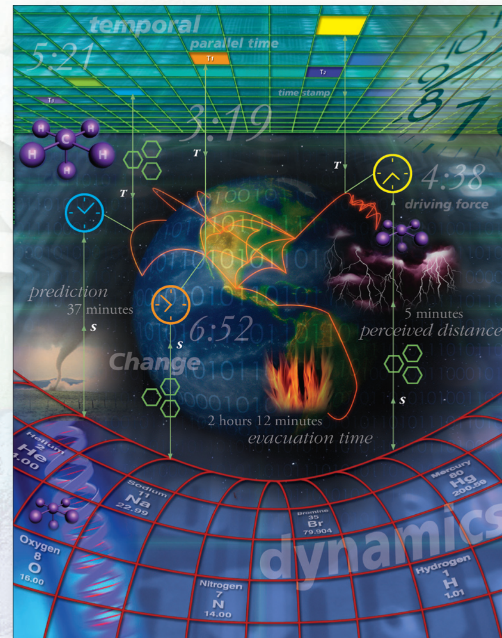
GIS Best Practices

Essays on Geography and GIS







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What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

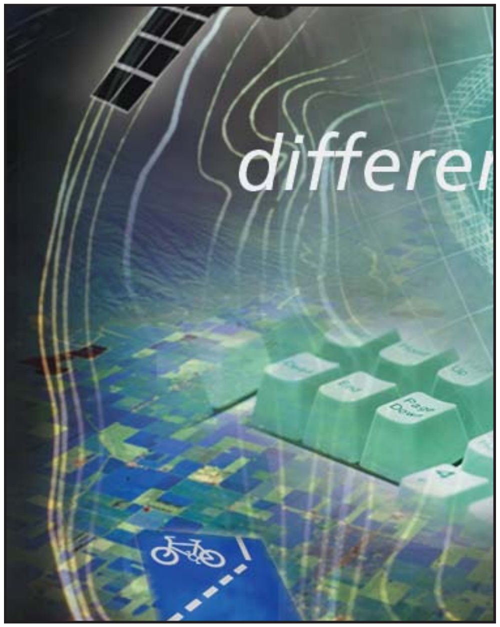
GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

What Holds Us Together

By Arthur Getis

When did you realize that maps and mapping were truly interesting things to create or use? The tremendous response to GIS over the last 20 years did not happen by chance. As children, when we matured from being self-centered individuals to externally oriented people, we developed a strong sense of place and a strong curiosity about the world around us. The spatial point of view was latent within us. Educational theorists have always said that a spatial perspective exists among all normal people. When we are still in diapers, we begin to sense where things are relative to where we are. But for most of us, as we develop into children and young adults, the spatial perspective is not tweaked. If no friend, teacher, or relative helped stimulate that natural tendency, or our circumstances limited the world that we could have possibly known, we might have said, as so many people have said in the past, "Geography is not one of my strong subjects" or "Maps don't mean much to me." Unfortunately, most people lacked that stimulus, but the readers of this article have been fortunate to have discovered GIS.



GIS; GPS; and the marvelous gizmos, gadgets, software, hardware, and Internet sites virtually make the earth come alive. We have been exposed to this wonderful new technology and the software that allows us to explore our environments. Now we can't get it out of our systems. If it is a location we are talking about, usually our first inclination is to check it out on a map. We have become spatially conscious, spatially aware, and geographically sensitized. We are thinking geographically. Our world is much fuller for these experiences. We better understand the land, streets, paths, streams, patterns, networks, hills, and slopes. They are ours. We meet a colleague or fellow worker and immediately launch into a discussion of how we can do something on the computer that will bring us even more understanding. This is done without skipping a beat. No need to start with first principles. One spatial thinker is interacting with another spatial thinker.

GIS and all of its related techniques and methods have helped open our geographic door. Now we "see everything," manipulate it, overlay it, add to it, and make great prints of what we have created. One of the wonders of these discoveries and activities is that many of us earn our keep being professional spatialists. I use the word spatialists purposefully, because it is by virtually manipulating earth space that we have tweaked our natural tendency to develop our spatial cognitive abilities. "Spatial" has meaning to the extent that it is spatial concepts that hold us together and allow us to skip all the preliminaries and get right to our interactions with the earth, with maps, and with colleagues.

It is easy to say that we are in the same geographic boat, but it is a challenge to try to deconstruct that boat and find what keeps it floating. What elements of spatial structure let it sail unimpeded? I am going to give it a try, attempting to put into words why we are all in this together.

The first construct is our development, by nature and experience, of a sense of distance and direction that corresponds to real distances expressed as some measure, such as in the next block, halfway down that road, 200 feet north, second light on the left, 100 kilometers after the intersection, east for about five minutes, and so on. If we are called on to express these distances time and again, we become better and better at it and thus become more accurate and more concise. We develop a vocabulary of locations and distances. It may include latitude and longitude, cardinal or polar projection directions, or some specialized coordinate language. If we are rarely in a position to think of distance and direction, we will not develop our ability to be anything more than general and thus will often be mistaken in our perceptions. But when we view maps day after day and are called on to estimate or give the exact distances from here to there, we become good at it. When we have marvelous technological tools to help with the process, we no longer say "100 meters south" when we mean "125 meters at 210 degrees." So the experience of working with maps leads to our discovery of spatial relations, which in turn gets our spatial perspective going in high gear.

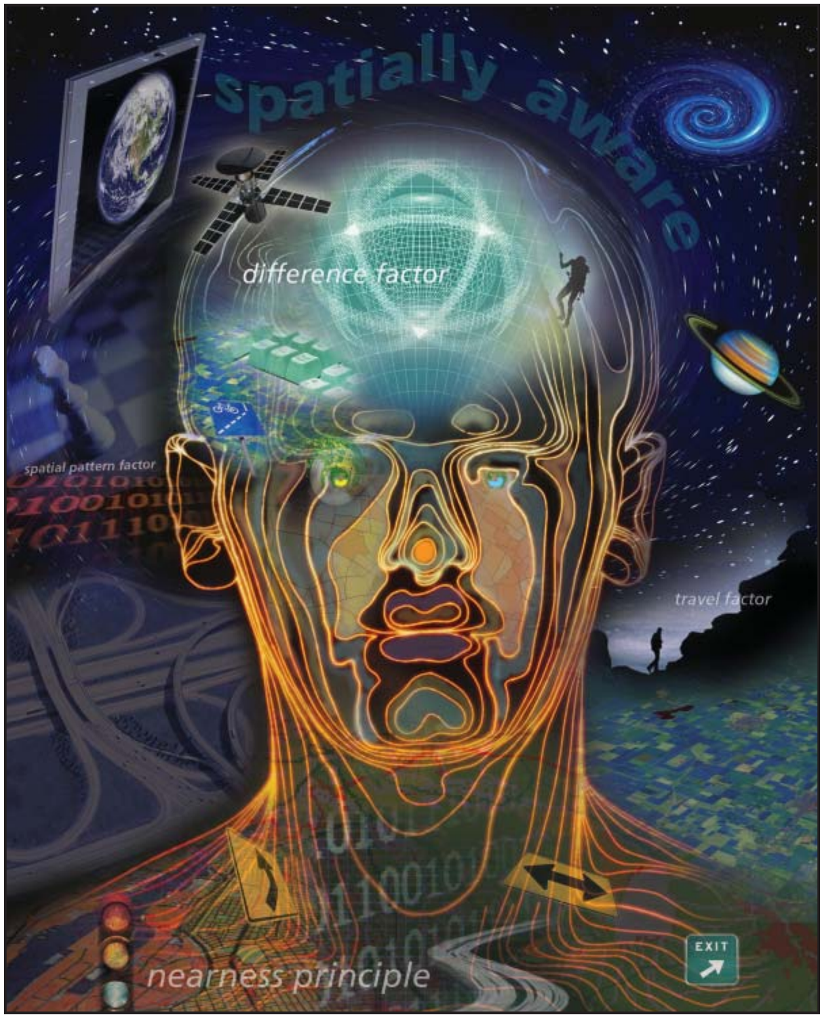


Illustration by Suzanne Davis, ESRI.

The second construct is what might be called the "nearness principle." We are better at discussing nearby conditions and situations than those far away. This might be considered the experience or repetition factor. If you see it enough, read about it enough, or hear about it enough, it becomes part of your psyche. Of course, that has always been the case, but now, with all of the tools available to us and our newfound appreciation for distance and direction, the nearness principle takes on great meaning. Many of us have become specialists in ferreting out the problems of our home area, such as environmental issues, public service issues, planning issues, and so forth. We are entrusted with making these issues clear so that they can be acted on. Our knowledge of place, especially our home place, has increased significantly. We see spatial relations, such as the effect that a new highway might have on drainage, in clear, concise ways.

The next construct comes from field experience: the travel factor. Some children are glued to their handheld devices as their family vehicle winds its way through the countryside. Traveling at 75 miles an hour in a car does not lend itself to gazing out the window. But distance and direction, the nearness principle, and our more conversant knowledge of the landscape have led us onto trails and into never-before-seen towns and city neighborhoods. The number of campers, hikers, sailors, and tourists has increased greatly in the last 20 or so years. Much of that increase corresponds to the ever-increasing use of the computer hardware and software related to our GIS interests, including portable GPS instruments. Hikers with this technological experience do more than identify elements of the landscape. They observe differences in the land due to changes in elevation, rainfall, geologic structure, new buildings, changed traffic patterns, networks of interaction, and so forth. Consequently, those of us fortunate enough to use GIS regularly get so much more from field experiences than those unable or unwilling to put down their cell phones or other distractions.

Next is the spatial pattern factor. Dealing with maps on a regular basis stimulates thinking about the peculiar configurations of our environments. We are aware of flows between places, clustering of objects, densities, intensities, and magnitudes. This leads naturally to an appreciation of spatial relationships. What kinds of things are associated with other things and to what extent is there interaction between them? An example of this is a traffic pattern—the need for commuters to live within a reasonable distance of their homes. What spatial associations and spatial interactions occur because of the need to go to work? When we view the complexity of commuting for a single person or for many individuals, our GIS background allows us to view this in a spatial framework. No wonder traffic experts have strong GIS experience.

We have what we might call the difference factor. Of course, everyone knows that Mumbai, India, differs in many ways from New York City. GIS puts us in a better position to define those differences. Because we better understand our local environment, we have meaningful benchmarks. Our knowledge of water levels in our streams during high runoff periods, temperatures in the canyons at 2:00 p.m., traffic tie-ups at rush hour, land values across town, local government dealings with various interest groups, and so on, helps us—when we are faced with the facts of the other place—assess the differences between here and there. This is our newfound ability to become comparative spatialists. Knowledge of an issue is not complete until we have some way to evaluate it. Let's use an Internet mapping tool or manipulate our GIS functions to bring this "extra knowledge" to bear on the problem. Spatialists are open to comparisons, since their perspectives allow for a sense of what it is like elsewhere.

Finally, I must include a particularly important nonspatial factor: computers. Were it not for our ability to manipulate this ever-advancing technology, and our constant use of computers, the chances of developing our spatial tendencies would be limited. But when the entire package is put together, we find a level of congeniality that brings a high amount of enthusiasm and dedication.

In the field of geography, the spatial principles and factors come under headings of spatial interaction, distance decay, gravity models, spatial autocorrelation, scale, and others. All of these can be formalized into topics, subtopics, statistics, and models. Geography is like many subjects, such as economics, where supply and demand can be reduced to a series of equations. What is important, however, is that the foundation is laid for any further study of a field of knowledge. We are, or are becoming, GIScientists. Before the advent of the GIS revolution, our task in ferreting out the complexities of the world was very difficult, but now we have laid the spatial foundation. We think spatially. We are on the same ship held together by the same structures.

About the Author

Arthur Getis, distinguished professor of geography emeritus at San Diego State University in California, is author of many books and papers ranging across the geographic spectrum. He was awarded distinguished scholarship honors by the Association of American Geographers and the North American Regional Science Association. He served as president of the University Consortium for Geographic Information Science and as editor-in-chief of the Journal of Geographical Systems.

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Exploration in the Age of Digital Earth

By Dawn J. Wright

What might the concept of exploration and the notion of discovery mean to geographers and GIS practitioners today? Exploration of our planet through fieldwork and, hence, discovery of new places is still ongoing, but so is the exploration of environmental databases, even information spaces that do not necessarily include spatial data. Therefore, "discovery" of a place does not necessarily mean having to "be there" in the field. Presented in this context are the themes of data sharing and the benefits thereof in the United States and the emergence of cyberinfrastructures (i.e., the use of high-end information technology in day-to-day activities, not just for the occasional supercomputer job), which are taking hold in basic and applied research and also within the realm of digital government. Under the umbrella of cyberinfrastructures, exciting new research topics are being developed in the areas of Web GIS (e.g., modeling, algorithms, data structures, stability, performance, and other computing issues), ontological libraries and semantic interoperability within Web GIS, and networks of data and metadata clearinghouses that are being built with open-specification Web mapping services and Web feature services.

Explornography is an interesting term that was first coined by John Tierney in a 1998 *New York Times* article. It was defined there as "the vicarious thrill of exploring when there is nothing left to explore." His discussion of the term was actually meant to be a critique of the Peary expedition to the North Pole in particular and of some forms of extreme tourism to exotic or dangerous places in general. But if one extends this beyond the notion of just exploring physical places on the Earth's surface, one can think of exploration and discovery in a new way. We are now in what many call a second age of discovery, where virtual worlds of real and imagined phenomena may be explored through computers on a desktop, in large visualization theaters, on small handheld devices, or soon even through small devices on our clothing or eyewear. But, thankfully, there is still much left to explore physically. For example, in terms of surveying and mapping of the Earth's surface, very little is known about the fine-scale topography and structure of the global seafloor. There now exists satellite altimetry covering all the world's oceans from which low-resolution bathymetry can be derived. But slower, more spatially restricted shipboard measurements must still be made at sea to gather the higher-resolution data required for tectonic studies or the baseline framework datasets needed for a host of applications from laying marine cable to conserving marine protected areas. Only 35 to 40 percent of the entire Earth's surface (including the seafloor) has been mapped at a similar resolution of a common hiking map or topographic maps of other planets, such as Mars and Venus.

So in our quest to build a "digital earth"—global access to all possible geographic data about places on the surface and the subsurface—researchers and practitioners face many enticing challenges, including the development of visualization systems with user-friendly interfaces that enable the analysis, modeling, and simulation of data, as well as just the simple viewing of it.

For several years, the National Aeronautics and Space Administration (NASA) led a Digital Earth Initiative that included the development of a prototype visualization system, a large globe that a user could manipulate with special gloves and glasses, "a very visual earth explorer that lets scientists, both young and old, examine information about the earth to learn how the forces of biology and geology interact to shape our home planet." In a parallel effort, Google Earth has now essentially taken up this mantle and led the way with its high performance, seamlessness, and a de facto exchange standard in Keyhole Markup Language (KML) and KML, Zipped (KMZ).

The GIS world is following suit with the addition of better integration and leveraging of models, analyses, and metadata, in addition to the 3D data. These are examples of helping to build the second age of discovery through geographic information science, recognizing that technologies give rise to questions about their appropriate and most efficient use, questions that need theoretical frameworks to be solved. For instance, interoperability is one of many research topics that geographic information science, computer science, and others still grapple with. At times we pay the price for building technology in the absence of good theory.

In the United States, the term *cyberinfrastructure* is being used with greater frequency to refer to how the traditional modes of scientific research (e.g., experimentation in the lab, observation in the field, processing/analyzing on a single calculator or computer, calculating on the back of an envelope) are being extended or replaced by information networks. Indeed, just as physical infrastructure has represented roads, bridges, railroad lines, power grids, etc., as fundamental components of modern communities, cyberinfrastructure now refers to the fundamental components of modern scientific and engineering methodologies (i.e., information technology, digital communications, and distributed computing). As stated by a recent blue ribbon advisory panel of the U.S. National Science Foundation (NSF), one of the primary funders of basic and applied research in the United States, "Cyberinfrastructure will become as fundamental and important as an enabler for the enterprise as laboratories and instrumentation, as fundamental as classroom instruction, and as fundamental as the system of conferences and journals for dissemination of research outcomes."

Distributed computing is a particularly important part of the equation, as the computing power in cyberinfrastructure for serving, rendering, analyzing, and simulating may be as distributed as the datasets themselves (and this distribution often implies that data producers and providers are willing and able to share their products, often in near real time). As such, research in cyberinfrastructure deals with the interoperability of technologies, as well as their efficiency, connectivity, and usability, within the realms of large systems, such as university consortia, large research collaboratives, and local/county/state/federal governments.

Illustration by Jay Merryweather, ESRI.

Current Initiatives in the United States

NSF now provides federal dollars through an Office of Cyberinfrastructure, with a focus on acquisition and upgrading of supercomputing facilities, high-capacity mass storage systems, enterprise software suites and programming environments, support staffers, etc., for the academic community. It may soon become one of the most important funding programs at NSF for geographic information science. Related to this is the NSF Digital Government Web portal (www.digitalgovernment.org) with a mission to link academic research in information technology (including cyberinfrastructure) to the mission, directives, and activities of government at the federal and state levels and to evaluate the overall resulting impact on governance and democracy. These "e-science" programs point to the priorities placed by our government on these areas and the recognition that new subdisciplines may be created as a result. There has also been great interest expressed regarding funding collaboratives between U.S. researchers and European partners and that cyberinfrastructure developed in the United States be interoperable with that being developed and deployed elsewhere.

There are many examples of cyberinfrastructure projects in development, far too numerous to highlight, but one currently under way in the United States, the Oregon Coastal Atlas (www.coastalatlas.net), has many connections to the Marine Irish Digital Atlas (MIDA). The Oregon Coastal Atlas was funded primarily by the NSF Digital Government Program and is a collaboration between the State of Oregon's Ocean-Coastal Management Program (state government), Oregon State University (academia), and Ecotrust (nonprofit environmental organization). The heart of the atlas is an interactive map, data, and a metadata portal for coastal zone managers and coastal planners, with additional outreach sections for scientists, secondary school educators, and the general public. The portal enables users to obtain datasets, understand their original context, and use them for solving a spatial problem via online tools.

The design of the atlas draws from the reality that resource decision-making applications require much more than simple access to data. Resource managers commonly make decisions that involve modeling risk, assessing cumulative impacts, and weighing proposed alterations to ecosystem functions and values. These decisions involve pulling together datasets and, thus, knowledge from such disparate disciplines as biology, geology, oceanography, hydrology, chemistry, and engineering. Practitioners within each one of these disciplines are often vested in the technologies that dominate the market within their particular field. This presents significant data integration difficulties for investigators involved in management decisions that are as inherently interdisciplinary as those in the coastal zone. The goal of the atlas effort is to address these problems by incorporating a variety of geospatial data coupled with analysis tools that the data can be applied to that are run on the Web within the atlas itself or downloaded to the desktop. Advanced GIS tools to date that are available within the atlas include the Coastal Erosion Hazard Suite, Coastal Inundation Visualization tool, Watershed Assessment tool, and Coastal Access and Beach Water Quality viewers. In this way, the collaborative seeks to improve universal participation in coastal decision making among communities within the state of Oregon by extending infrastructure to public offices that would otherwise face difficulties accessing these services and resources.

The Oregon Coastal Atlas and Marine Irish Digital Atlas were discussed in detail at a recent Transatlantic Workshop on Coastal Mapping and Informatics (funded by the Marine Institute of Ireland, National Development Program of Ireland, and NSF), along with similar coastal atlas efforts in Belgium, Canada, France, the United Kingdom, and other parts of the United States (workshop1.science.oregonstate.edu). Workshop 1 (Potentials and Limitations of Coastal Web Atlases) took place in Cork, Ireland, July 24–28, 2006, and brought together more than 40 key experts from academia, government agencies, and conservation organizations on both sides of the Atlantic to share technologies and lesson learned from the development of coastal atlases. Workshop 2 will be held at Oregon State University, July 16–20, 2007, and will focus on building a common approach to managing and disseminating coastal data, maps, and information within these atlases, including an agreement on initial common vocabularies and thesauri to facilitate database searches in Europe and North America. As an example of a cyberinfrastructure that will be developed on a much broader scale (regional to national), the workshop participants are considering the formation of an international network or federation of coastal atlases. This has important implications for maritime policy throughout the European Union, as such mapping plays a critical role in issues of national sovereignty, resource management, maritime safety, and hazard assessment.

With the release of the Pew and U.S. Ocean Commission reports, there is growing public awareness in the United States of the critical state of our coastal zones and fisheries. Government agencies, businesses, academic institutions, and even nonprofit organizations all have a tremendous stake in the development and management of geospatial data resources, especially in the coastal zone, since, worldwide, 20 percent of humanity live less than 25 kilometers from the coast, and 39 percent, or 2.2 billion people, live within 100 kilometers of the coast.

Other broad-scale cyberinfrastructure examples include the Biomedical Research Network, a collaboration of three U.S. West Coast universities (California Institute of Technology [CalTech]; the University of California, Los Angeles [UCLA]; and the University of California, San Diego [UCSD]) with Duke University on the East Coast to distribute and integrate multiscale biomedical data for human disease studies. GEONGrid (www.geongrid.org) is a large, five-year collaborative effort spearheaded by the Pennsylvania State University, San Diego State University, and San Diego Supercomputer Center to foster interdisciplinary research among geologists and geophysicists. These and many other collaboratives all participate to some extent in geodata.gov, the reincarnation of the nationwide network of geospatial metadata clearinghouses at the heart of the U.S. National Spatial Data Infrastructure. Geodata.gov's Geospatial One-Stop Initiative (toward one-stop "shopping" for free government and academic data) is part of the ongoing technological and e-government trend toward collecting and maintaining datasets locally or regionally and sharing them nationally or internationally (in some cases as fulfillment of a grant deliverable or contract, which must be completed before an organization becomes eligible to apply again for future funding).

A Concluding Eye to the Future

The following is a small sampling of compelling cyberinfrastructure research topics being undertaken within the GIS/geographic information science (GIScience) community. Further explanation and references may be found on the Web sites of the University Consortium for Geographic Information Science (UCGIS) (www.ucgis.org) and the GIScience 2006 conference in Münster, Germany (www.giscience.org).

- Ontology and ontology cataloging, where ontology is briefly defined as the formalization of concepts and terms used in a practice or discipline. Ontologies can thus provide the semantic aspects of metadata, including lists of terms with definitions, more complex relationships between terms, rules governing those relationships, and potential values for each term.
- Closely related is the area of semantic interoperability and the semantic Web. Despite ontologies, words may still mean different things to different people within an interdisciplinary community, and how does one, for example, search effectively through shared databases based on the words in the metadata (e.g., coastline vs. shoreline, seafloor vs. seabed, engineering vs. ecological resilience, resilience vs. robustness, scale vs. resolution, wetland buffering vs. GIS buffering)?
- Spatialization, or the process of mapping out nongeographic information, again, in an attempt to improve distribution, search, and visualization of data and information.
- Development of domain-specific data models, with their accompanying distribution protocols and toolsets, and data models for Web GIS.
- Grid computing (Grid GIS, distributed agent GIS, peer-to-peer [P2P] GIS), where the computing power may be as distributed as the datasets themselves (e.g., one might execute data on one machine, render it on another, send it back to another machine for GIS analysis and mapping, then deploy a prototype that ties all these processes on all these servers together in a seamless interface):
    - Stability, performance, and connectivity issues

- Design, architecture, algorithmic, and data structure issues
- Data mining/Knowledge discovery, visualization
- Distributed GIS education (distance)

As work continues in these areas, and collaborations and funding levels remain at least at the present levels, the future appears bright for a new kind of exploration and discovery (even productive rediscovery) of physical places, environmental databases, information spaces, spatial data infrastructures, and the like, through cyberinfrastructures.

About the Author

Dawn Wright (a.k.a. "Deepsea Dawn") is a professor of geography and oceanography at Oregon State University, where she has been on the faculty since 1995. Dawn has explored some of the most geologically active regions of the planet on more than 20 oceanographic expeditions. She has published five books and more than 70 papers. In 2005, she received the Milton Harris Award for Excellence in Basic Research.

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Dynamics GIS: Recognizing the Dynamic Nature of Reality

By May Yuan

Reality is dynamic. In fact, dynamics is so essential to reality that a static world is difficult to imagine. Space and time penetrate physical, biological, social, and humanistic inquiries. The accumulative nature of sensing and knowing our world arises through spatiotemporal experiences and interpretations. Some disciplines, such as geography and landscape ecology, emphasize the spatial dimension of world knowledge, and other disciplines, such as history and climatology, take timecentric approaches to organize evidences of reality. However, it is the space-time integration that provides the explanatory power to understand and predict reality. In this article, I advocate for the concept of dynamics GIS to fundamentally rethink the role of geographic information science as a means to improve our understanding of reality and, through that understanding, to develop geographic information systems that enhance our ability to formulate interpretations, make informed decisions, and develop adaptation strategies for this ever-changing world. Before continuing, I would like to clarify my use of dynamics GIS instead of dynamic GIS. The emphasis refers to the fact that a GIS can represent, analyze, and model geographic dynamics, not that a GIS is dynamic.

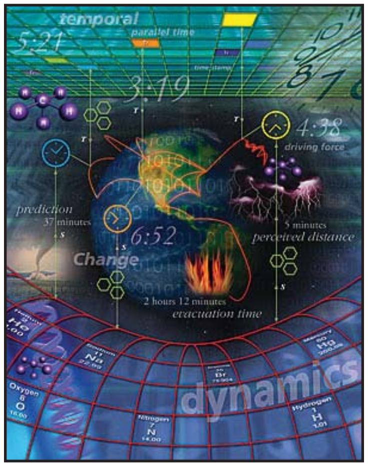

Illustration by Suzanne Davis, ESRI.

Exploring the Background

Dynamics is by definition an integration of space and time. Hence, let me start with a brief history of research that integrates time with GIS. The development of temporal GIS in the late 1980s marked a significant period of GIS research in dynamics. The importance of capabilities to handle temporal information in GIS has long been recognized by the GIS research community. I consider 1988 as the year that temporal GIS research took a significant leap with Gail Langran and Nicholas Chrisman's article "A Framework for Temporal Geographic Information" in *Cartographica* and Marc Armstrong's presentation on temporal GIS at the GIS/LIS international conference. Soon after, in 1992, Andrew Frank, Max Egenhofer, and Reginald Golledge chaired the National Center for Geographic Information and Analysis (NCGIA) specialist workshop entitled Time in Geographic Space and Methods of Spatio-Temporal Reasoning in GIS. In 1994, two publications laid the conceptual and computational foundations for temporal GIS development: Donna Peuquet's article, "A Conceptual Framework for the Representation of Temporal Dynamics in Geographic Information Systems," in the *Annals of the American Association of Geographers,* and Michael Worboys' article, "A Unified Model of Spatial and Temporal Information," in *Computer Journal.*

Several academic publications review the development of temporal GIS. Most research efforts emphasize the integration of temporal data into GIS databases. Change and movement are two fundamental elements in temporal GIS research. Several temporal logic and reasoning schemes have been proposed. Research also discussed different kinds of time (e.g., world time and database time) or different topologies of time (e.g., cyclic time, branching time, and parallel time). Starting in the mid-1990s, temporal GIS researchers made laudable progress toward the development of spatiotemporal representation, data models, and query languages (e.g., the event-based spatiotemporal data model, field-based temporal GIS, object-oriented temporal GIS, event modeling language, and Arc Hydro data model). Recently, major progress has been made in modeling moving objects, spatiotemporal analysis, and geostatistics, as well as in visualization and geocomputation, especially agent-based modeling. Outcomes from these research efforts are being realized in various research-grade or commercial software programs, such as 4DataLink, Arc Hydro, EMBLib, GeoTime, STARS, STEMgis, Tempest, TerraSeer, and TimeMap, just to name a few.

Temporal GIS research has prospered in many applications, such as map animation; change detection; movement tracking; and spatiotemporal clusters, simulation, and visualization. A later emphasis on processes and events set forth the basis for a dynamics GIS to reveal the causes or driving forces responsible for change and movement and the mechanisms by which the change or movement proceeds. After all, change and movement are observable elements of dynamics. If there is no change or movement, we would not be able to perceive dynamics. However, change and movement alone only partially address dynamics. Components, functional relationships among components, driving forces, and feedback mechanisms are all essential to understand dynamics; therefore, the concepts of a system and system dynamics constitute the foundation for dynamics GIS. Change to one component is likely to subsequently affect other components in the system. Movement of an element may induce adjustments to the positions of others. Dynamics GIS considers space-time integral to developing representation and methodology that treat reality as a system of systems cascading across scales of geographic dynamics.

So what will a dynamics GIS be like? Since dynamics needs to be investigated from a system's perspective, we should first ask what a system is and then how system concepts can be embedded in GIS data and analysis. Let's look at system from the perspectives of general system theory and Ludwig von Bertalanffy's paper entitled "An Outline of General System Theory" published in the *British Journal for the Philosophy of Science* in 1950. He highlighted some general conceptions and viewpoints that cut across multiple disciplines, including wholeness, isomorphism, and organization. Now it is common knowledge that the whole can be greater than the sum of its parts. The conception of wholeness is in fact a different, yet complementary, perspective to the reductionist's approach to understanding phenomena by dividing a phenomenon into individual elementary units and examining these elementary units and their interactions individually.

The conventional GIS framework is more or less a reductionist's approach by resolving geographic phenomena into feature classes of elementary units (what may also be called geospatial data objects) in the forms of points, lines, polygons, and their attributes. Furthermore, the geometric characteristics or attributes of these elementary units remain the same regardless of whether they are investigated in isolation or in a complex. Reality is that an urban complex cannot be fully understood by merely examining its communities individually; also important are the spatial and social organizations among and within its communities and their social interactions and functional dependencies. General system theory emphasizes that the whole is not a simple summation of elementary units and is governed by dynamical laws. Isomorphism denotes that dynamical laws can be isomorphic (i.e., applicable across systems in various domains). I was fascinated when I first learned about field- and object-based conceptualizations in GIS and was able to make an analogy with the field and particle views of light in physics.

From a different angle, Gerald M. Weinberg's book entitled *An Introduction to General Systems Thinking,* published by Wiley in 1975, suggests three types of systems:

- Small-number simple systems—The behaviors of elementary units can be accounted for individually by mathematical means or qualitative descriptors. Examples are the solar system and a class of students.
- Large-number simple systems—Collective characteristics can be considered through statistics. The large number of elementary units in a system ensures that statistical parameters (means, variances, etc.) are representative of general characteristics in the system, due in part to central limit theory. That is, when we collect a large number of independent observations from a population, the means of independent samples from these observations (which are also representative of the population mean) will approach a normal distribution. Examples are the heights of individuals and the property values in a region. In these systems, phenomena are sums of a large number of independent random effects and hence are approximately normally distributed by the central limit theorem.
- Middle-number complex systems—The number of members is too small to make statistical measures representative but is too large to account for individuals. Therefore, middle-number complex systems require attention to members both individually and collectively.

Hierarchy theory is a subsequent development of General System Theory to address middle-number complex systems in which elementary units are few enough to be self- assertive and noticeably unique in their behavior, and meanwhile, these elementary units are too numerous to be modeled one at a time with any economy and understanding. Echoing von Bertalanffy's emphasis on organization, Herbert Simon argued in his 1973 paper, "The Organization of Complex Systems" (in H. H. Pattee, ed., *Hierarchy Theory,* pp. 3–27. New York, NY: G. Braziller), that any complex system in the world must be hierarchical; otherwise, we would have no way to acquire and understand it. He further elaborated on the importance of hierarchical structures to the sustainability of a complex system, for only hierarchies can evolve efficiently and successfully in a consistently changing world.

Illustration by Antoinette Beltran, ESRI.

Simon's argument is not without criticisms, especially for imposing hierarchical organizations over markets. However, his emphasis on hierarchy as a structure to connect subsystems and supersystems in a complex system is well accepted in hierarchy theory. Indeed, reality may or may not be hierarchical, but a hierarchical structure facilitates observations and understanding. A complex system is more than simple aggregation of lots of little bits of information about individual entities. A good understanding of intrinsic relationships among parts and wholes (or individuals and groups) is necessary in the study of a middle-number complex system. In Simon's book entitled *The Architecture of Complexity,* published by MIT Press in 1969, Simon emphasized that hierarchy is profoundly natural and emerges through a wide variety of processes that drive the evolution of the system through self-organizing interactions and dependency among elementary units to reach stability and sustainability in the system.

Dynamics is, hence, the working of these evolutionary processes and responses from elementary units, individually and collectively at various scales. At a lower level in a hierarchy, elementary units (or entities) operate at a higher degree of frequency (or have higher activity rates) but have a higher degree of variability than those at a higher level. A good example is climate and weather. Weather may be capricious within a day or over a few days, but climate variability is much lower than weather variability because a climate system corresponds to a longer-term pattern over a broader region. Nevertheless, elementary units and their associated processes in a subsystem (or at a lower level of the hierarchy) support unit activities and processes in its supersystem. Meanwhile, elementary units and associated processes of a supersystem constrain the bounds of activities and processes in its subsystems. A tropical climate zone sets the range of possibilities for weather systems to develop in the zone. In this context, scale is the function that relates elementary units and the interconnections of their behavior across levels of systems in a hierarchy. Recognition of their behavior and interconnection can facilitate identifying subsystems, their hierarchy, and the manifestation of dynamics at and across multiple scales.

Embedding Dynamics in a GIS

Now we can consider how dynamics may be embedded in a GIS. In the framework of general system theory and hierarchy theory, we need to consider wholes and parts and apply system concepts to develop GIS data models. We can start with a whole, then identify its parts. Alternatively, we can start with elementary units to recognize wholes. The concepts of aggregation and disaggregation apply well here. The use of aggregation and disaggregation tools is becoming more and more common in GIS analysis for upscaling and downscaling geospatial data from local to regional (such as spatial interpolation) or from global to regional (such as multivariate spatial allocation). What has not been common is to store the data objects and their associations across spatial and temporal scales in ways that correspond to the proper underlying processes.

In addition, we should be attentive to additional properties that emerge through aggregation, not just grouping points, lines, or polygons together. Systems or objects formed by aggregation should be characterized with additional properties appropriately. For example, geospatial data and weather data observed from a severe storm system at a mesoscale can be linked to data representing seasonal patterns at a synoptic scale. A severe storm system has objects at several levels of granularity, from data bits of in situ ground observations to Geostationary Operational Environmental Satellite (GOES) images from a meteorological remote-sensing satellite. Aggregation of these data bits over space and time form a temporal sequence of footprints from a storm. In addition to data bits, each storm object has attributes of size, rate of movement, direction of movement, precipitation intensity, wind speeds, etc. Within each storm object, there are features signifying rotation, hail formation, downdrafts, etc. Each of these features is a data object at this scale and should be associated with proper attributes. Eventually, the spatiotemporal aggregation forms a narrative of the storm to characterize the storm development and lifeline.

With the linkages to form hierarchies of synoptic weather systems and localized storm events, spatiotemporal analytical and computational tools can be developed to support queries and knowledge discovery about composition, organization, and interconnections among these super- and subsystems. For example, it will be possible to query synoptic weather systems associated with certain types or behaviors of local severe storm events. It is also possible to compare local severe storm events and evaluate synoptic conditions that promote or suppress their development. We will be able to mine data on higher-level concepts, like storms or lake-effect snow events, than data records or clusters. The approach can also enable linkages among systems across domains, such as weather systems and transportation systems, to allow information analysis that leads to new insights into and a closer understanding of the wholeness of reality.

Hence, aggregation is more than just grouping objects over space and time but brings about higher-level geospatial objects with emergent properties and behavioral characteristics. Besides aggregation, there are processes of agglomeration and narration that can form abstract objects at a higher level in a system. The concept of agglomeration has been used mostly in reference to a metropolitan complex in which cities and towns are connected to form a greater urban area. While definitions of aggregates and agglomerates vary, it may be useful to consider that aggregates reference systems of individuals of the same type and agglomerates, systems of individuals of multiple types. For example, a flock of sheep is an aggregate, but an urban system is an agglomerate. If we can identify and formalize structures and functions that form aggregates and agglomerates, as well as model their behavior, we can incorporate these structures, functions, and behavior models into GIS to automate the processes of forming aggregates and agglomerates. Subsequently, we can model their behavior and analyze the constraints that they pose to objects at a lower level, as well as their support of (or influence on) objects at a higher level in the associated hierarchy.

In contrast to aggregation and agglomeration, narration produces narratives that play out a story in space and time. A narrative system connects geospatial lifelines via spatial and temporal markers to tell us what has happened, how it happened, and what could have happened. Constructing narratives from spatial and temporal data is very challenging, but its potential for understanding dynamics cannot be underestimated. Storytelling is said to be one of the most effective ways of learning, sense making, and communication, and some consider humans the only species with the intelligence to construct narratives. Regardless of the validity of these claims, maps—as the most popular communication means of geographic information—can be greatly enriched with narratives (perhaps semiotic forms) to add dynamics that shape reality.

When a GIS is able to capture and handle information about geographic dynamics, we are empowered to study the world not just spatially or temporally but holistically from a system's perspective. A dynamics GIS needs to make the connections across multiple themes and scales through spatiotemporal integration and summarize discourses and mechanisms by which dynamics manifest and narratives unfold. Think about a GIS not only to show where things are but how geographies become.

About the Author

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Living Inside Networks of Knowledge

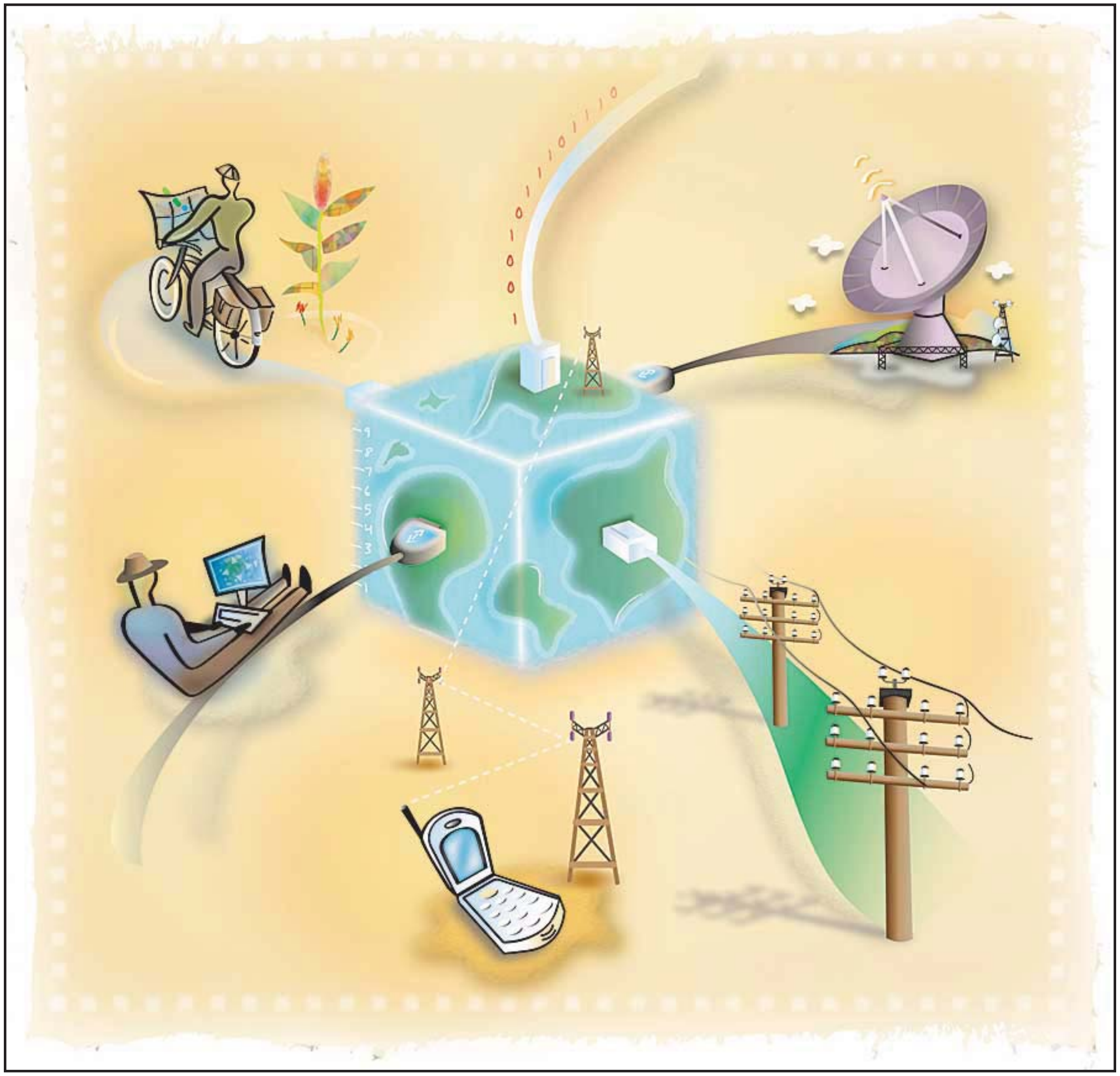
By Nick Chrisman

Nearly every article on technological change begins by saying that recent changes are unprecedented. As I begin this essay about new directions and choices, I remember the overblown prose of the manual for a 1974 data conversion program. It began: "Recent years have witnessed the upsurge . . ." After 33 years, the upsurge becomes just a matter of daily life. Been there; time to break the habit.

Instead of saying that the present is different, I am going to argue that networks have always been important, just not very clearly identified as powerful elements. Around 1974, I started working on a computer at Harvard that had a freezer-sized box to connect it to other computers across the continent. It was node "9" on the ARPANet. This box enlarged our e-mail to the dozen or so other network boxes, but e-mail was pretty selective in those days. In my practical application, it took another 13 years before I could reliably expect to contact a colleague through e-mail. By 1986, in planning for AUTO-CARTO 8, I could reach most of the authors and reviewers through e-mail, with a bit of care in how it was sent. Each network needed special addressing; for example, British addresses were inverted (uk.ac.bristol and not bristol .ac.uk as it is now). Still, it was possible to reach the community. The lesson is that a network of communication has to become nearly universal before it supplants the prior technology.

I am not going to spend any more time talking about the early days of the pre-Internet, since they have little bearing on the bigger future revolutions that have already begun. Am I exaggerating? What can be bigger than the planetary communication system that has emerged in the past decade? The Internet was not unprecedented. Connecting a significant portion of the world's population to an integrated network of communication is something our society has done over and over again. The telegraph system was one such system. From its inception in the mid-19th century, the telegraph provided light-speed communications from place to place. It remained centralized, and the last mile involved boys on bicycles, but the overall increase in speed was enormous. The telegraph was followed by the telephone, bringing the equipment right into each house. In a sober analysis, the Internet, as most people use it, simply makes another transition in the details of the connection. The network technology offers some new possibilities, but we have barely begun to figure them out. The real trouble is that as each new technology emerges, the first reaction is to use it to implement the previous technology, only a little bit faster or cheaper. Our conceptual models have not evolved as fast as our infrastructure.

In the world of GIS, we are still living out the original dreams of the 1960s. An institution would spend great time and effort to develop a geographic information system. Note that the term is singular. It implies one integrated system, a centralized one, built by experts to respond to specific needs. There is some vague hope that others will beat a path to the door of the big centralized system. If one of these users wants the data, they will be offered 1974 technology: a File Transfer Protocol (FTP) to take a copy. FTP has survived virtually unchanged for more than 30 years. Now implemented as a Web-based portal under the disguise of a download, this looks modern and sophisticated, but it leads to the most horrible duplication and proliferation of unsynchronized data holdings. We have a worldwide communication network, but we are still managing it with some elements of the telegraph mentality of centralization. Somehow the official-looking professional presence of a clearinghouse inspires confidence, even if the business model fails to grasp how the world has changed.



In the movement to build "spatial data infrastructures" as a new form of activity, it is rather curious that a key message of the original work by Barbara Petchenik and colleagues at the National Research Council has been forgotten. Her point was that we already had a spatial data infrastructure, one that needed to be rethought and reengineered. The simple transfer from one medium to another preserved the institutional structure that needed to be overhauled. In place of the one-stop shop metaphor, we should be expecting to hear from many sources. In place of relying on a single integrator to produce the safety of a 1960s unitary GIS, we should learn to live with multiple sources and conflicting viewpoints.

The geographic technology that challenges the old ways of thinking is not simply the communication backbone of the Internet. The new world goes under various terms: distributed sensor networks, sensor webs, and some other buzzwords. Let's paint a picture of what these networks mean in a nested scenario. In my textbook *Exploring Geographic Information Systems* (Wiley: 1997, 2002), I start out with a simple case of geographic measurement: a stream gauge (or a tide gauge).

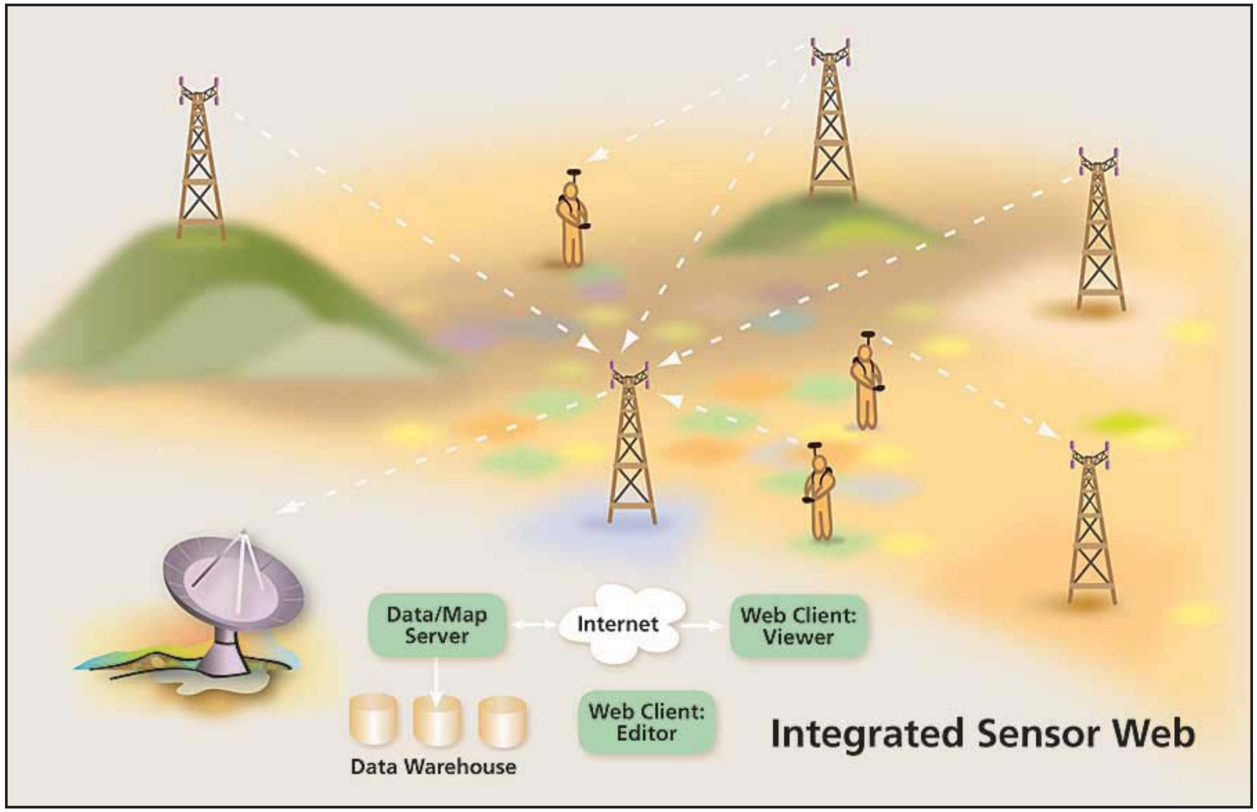
At a particular place, whose position is established by other means, a float rides up and down on the water's surface. A recording device can capture the height of the water at a given time. But then what happens? In the old days, a guy drove up in a pickup truck, changed the roll of paper, and drove it back to the office. There are a lot of hidden steps to make the basic measurement accessible. We have to include all those procedures of inscription, reinscription, digitizing, and storage before we make a stream gauge functional. As the technology changes, someone comes up with the bright idea of installing a communication link. It could be a telephone or a wireless link of some sort. The motivation of the processing agency that sent out the guy in the pickup would be to save labor costs, reduce the time lag in processing, and make a host of other improvements. A computer would probably be installed to manage the sensor and the communications, but the command from the central authority would still be "send all your data." The computer simply replaces the roll of paper. What a waste!

The computer at our stream gauge becomes a part of a distributed sensor web when we expect it to actually do some work, not just act as a roll of paper in the old arrangement. Linked by a communication network that does not simply act as a star, feeding data into the maw of the all-knowing centralized database, our stream gauge can communicate with other stream gauge installations to determine the water levels at other locations. An event like a flash flood could be detected in the field as it happens, rather than waiting for the rolls of paper to be processed at the central office (weeks later). After all, the information is driven by the water levels, not the acts of humans to recode the data and run the analysis. These agents in the field will of course be looking for whatever their programmers foresee. Detecting a flash flood requires some idea of the hydrological network, the neighborhood in which the sensor is deployed. Rising water levels upstream propagate downstream at a specific time lag that depends on slope and distance along the channel. These details can be captured, and deviations above some threshold reported. Ah! Reported to whom?

The agency with the pickup trucks that stock the rolls of paper might still exercise control over its equipment. This institution's survival depends on guarding its role as custodian of the stream gauges. But this would be somewhat like expecting the telegraph boy on his bicycle to deliver our Web pages on strips of yellow paper. It would make more sense to give the computer at the gauge more of a role. It holds the archive of water levels over time; why ship it off somewhere else? The issue becomes "bandwidth"—the capacity of the network connection, which is influenced by power supply as well as the communication link. Rather than sending in a dump of water-level data and waiting for it to be integrated at some control center, the neighboring gauge computers could share their recent water readings and provide a value-added product, such as alerts of impending floods to subscribers or relevant parties (dam operators, kayak clubs, and downstream residences).

This sketch of a revised business model for simple sensors inverts the old hierarchy. The old GIS looks like a telegraph business with its bicycle messengers. But like the anarchic and turbulent world of Web 2.0, it is not clear how we make the transition to the world of distributed sensor networks. There is a lot of programming to be done, and business models to be shredded by the competition. The sensors we currently have around the city and the environment are much more complicated than a simple float in a pipe. We have video cameras pointed at every public place. But when London needed to trace backpack bombers, they resorted to brute force: people looking at videotape for hours looking for recognizable people. In George Orwell's *1984,* the cameras enforced the state's will, but that 1949 novel's author had people behind the screens. If it takes one police officer to watch each citizen, the overhead costs are pretty high. And, as always, who watches the watchers?

From his observation of the observers in Paris, French sociologist Bruno Latour found that each agency has its particular reason for being and hence its own manner of observation. The watchers do not see everything, just as we do not expect our stream gauge to record passing moose. Sensors fulfill a particular purpose and measure within a framework that the equipment imposes. An optical camera captures little at night unless the scene is properly lit. And the measurements of gray by pixel are still not really what any user wants. The images require substantial processing to recognize a specific person—or a moose, for that matter; however, this trick is no longer the wild dreaming of a sci-fi writer.



Just as the Internet grew in a given historical setting, the distributed sensor network of the future will emerge from the little bits we already have. It will not get integrated and coherent until somebody makes the effort and has the access. I do not doubt that it can be done technically, but such a revolution will destabilize many existing institutions. There will be growing pains, resistance, and the usual shortsightedness.

As long as the current distribution of geographic power revolves around being a gatekeeper, a custodian of data, the potential of the distributed sensor network is diminished. What is required is an escape from the "Prisoner's Dilemma." [Note: This dilemma comes from game theory: many situations are structured to disfavor cooperation.]

And there are glimmers of hope in this regard. In the tightest of information economies, there are "Free Data Movements." Institutions can be motivated by their original mandate—protect the environment—to cut loose from the habits of centuries forced on them by the processing technologies of the past. Old habits die slowly, but there is some movement.

The biggest trend that will support the conversion of the data economy will come from the human—not technical—side. Knowledge networks have escaped from the hierarchical structure. Citizens are making their own maps, integrating their own evaluations of the world they inhabit. Yes, some of this has started as user ratings of motels and restaurants, but that is a start. Each new social networking Web site (YouTube, Facebook, Wikipedia, and so on) may appear to be a simple craze, but collectively, these sites amass the power to address pressing issues of the world as much as the popularity of rock stars.

In the GIS community, the movement was first heard under the title of Digital Earth—the idea that libraries of information could be referenced by location as a special kind of content index. The term also tied in a real-time camera pointed at the Earth from orbit. Although Al Gore did not invent the Internet, his name and office were used to validate the Digital Earth vision. The term geoweb is perhaps a better term for the technical trick to search for content based on location. Certainly the emphasis on spatial search is the key to Google Earth and Microsoft's Virtual Earth. Yet these initiatives miss the social side of networking. One of the key elements of the technology is the empowerment of citizens to produce their own spatial information, then to present it publicly. This overthrows the specialist model of the centralized model from decades past.

Knowledge networks do not have their origin in Web technology. Scholars and specialists have developed tools like journals, conferences, and peer review over the centuries. Some of these tools are attuned to the exigencies of printing or face-to-face meetings, but each has evolved to a new hybrid form. While some people focus on the wiki movement as a way to decentralize knowledge, that kind of work remains at the level of the encyclopedia, a rather superficial one.

The collective problems of the planet also require the concerted efforts of the science community. In my role as scientific director of the Geomatics for Informed Decisions (GEOIDE) Network, which links geomatics research across Canada, I have come to see the power of reorganizing our scientific expectations, of giving greater room for interdisciplinary collaboration.

Funded under the Canadian Networks of Centres of Excellence (NCE) program, the idea is to build a community of interest that includes user communities in the research process from the start. Rather than talking about "technology transfer"—a process that implies that the user does not matter until the research is finished—the NCEs engage in knowledge translation as an active process as researchers advance in collaboration with partners from industry, government, and other community participants. A few countries in the world have taken similar steps, each attuned to their particular background and history. I can point to the Cassini group in France, which has reconstituted itself as the SIGMA Groupe de Recherche and will continue to find new administrative ways to carry on useful networking. Its next phase may be under the title Géoide à la française. In Australia, the Cooperative Research Centre–Spatial Information (CRC-SI) has built a strong linkage between industry and the research community. In the Netherlands, RGI (Space for Geo-Information) has an ambitious program of research to result in direct benefits to citizens and the economy. These groups, nine of them in all, have begun to share their experiences, a long and complex process that began last year in Banff, Alberta, Canada. New groups have emerged since then; the network structure quickly accommodates them. In the end, I expect to see that these collaborations will provide the firm foundation for a knowledge network to understand the complex interactions that constitute the world in which humankind must learn to prosper sustainably.

Knowledge networks happen at a finer scale than national ones too. Each reader should think about how they already communicate in a network of interactions, locally and in their professional roles. How do we decide what is trustworthy information? Do we do our own tests, or do we trust another person or institution? How can we be sure the guy with the pickup did not switch rolls of paper between two stream gauges? It clearly saves a lot of effort once we can fully trust the work of others, but that trust should not be handed out without careful consideration. Some of the community wants to install a closed shop, using licensing to decide who can work with GIS. The problem is that these groups want to legislate away the breadth and diversity of the current user community. It is no time to restrict access to the tools of GIS; the tool is out of that stage anyway, firmly in the realm of the whole population.

The distributed sensor webs will mix up humans and robotic sensors in a new and complex set of interactions. Trust will become a more and more important commodity, one that we will learn new ways to validate.

About the Author

From 1972 to 1982, Nick Chrisman was a researcher at the Harvard Laboratory for Computer Graphics and Spatial Analysis. He is now professor of geomatic sciences at Université Laval in Québec City, Canada, and is scientific director of GEOIDE. He is the author of *Charting the Unknown: How Computer Mapping at Harvard Became GIS,* published in 2006 by ESRI Press, and the textbook *Exploring Geographic Information Systems,* published by John Wiley & Sons, 1997 and 2002.

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What Historians Want from GIS

By J. B. "Jack" Owens

An increasing number of historians, particularly those dealing with world history or the history of large geographic regions, are becoming interested in using geographic information systems for research and teaching. Historians are noticing GIS because they normally deal with processes in complex, dynamic, nonlinear systems and, therefore, demand a means to organize a large number of variables and identify those variables most likely implicated in the stability and transformation of such systems.

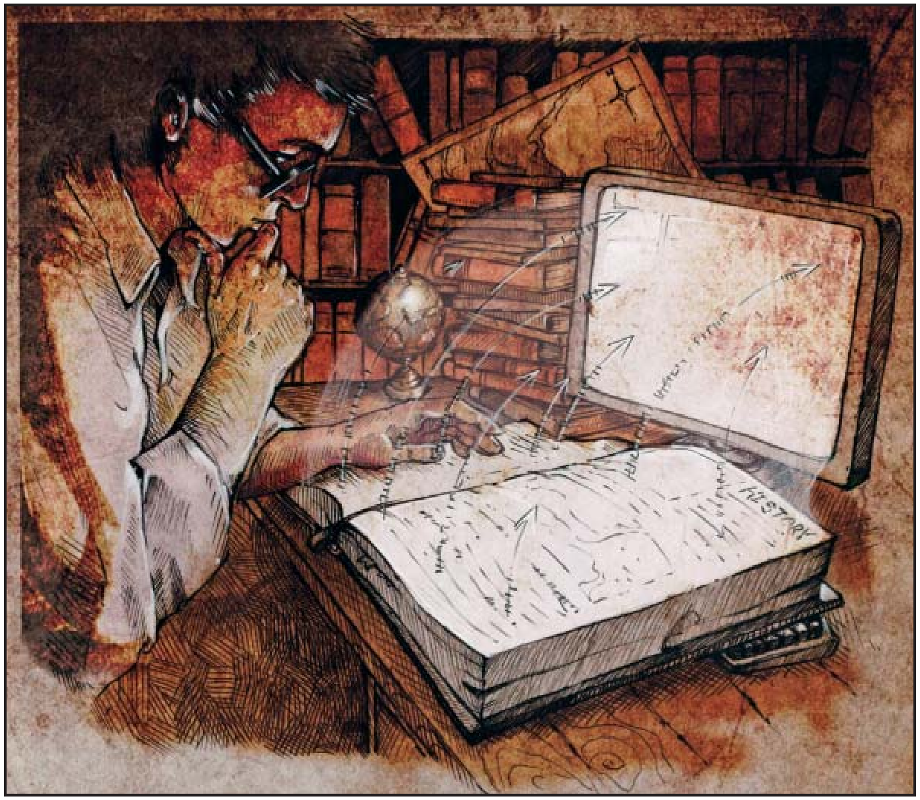

Illustration by Jay Merryweather, ESRI.

However, GIS remains largely unknown among the vast majority of professional historians, and a significant percentage of those who believe they know about the technology think it is something they can buy with their next car so that they will not become lost. Even those interested in some sort of *geographically integrated history,* a term I prefer to escape some of the limitations of the more familiar *GIS history,* would justifiably categorize the title of this article as pretentious.

GIS and History

I am often the only historian at geographic information science (GIScience) meetings, and my presence provokes the obvious question. A story will explain why a historian would become interested in GIS. At the beginning of my graduate studies, I read Fernand Braudel's *La Méditerranee et le monde méditerranéen a l'époque de Philippe II* because I was studying the western Mediterranean in the 16th century and plunged into this 1949 book with considerable enthusiasm despite its imposing length. As I read Braudel's attempt to integrate the slow changes in the Mediterranean's geographic form, climate, flora, and fauna with the faster alterations in human socioeconomic relations and the specific wars, political alterations, and other events of the 16th century, I struggled to understand how these different layers of the account, which were discussed in sections characterized by the variable speeds of temporal process, fit together. At the time, I tried tracing maps of human cultural features, such as cities and centers of economic activity, over topographic maps in an effort to integrate better the elements of Braudel's history. This work produced nothing more than a visual mess, which also failed to capture the considerable dynamism of Braudel's account. Moreover, I repeatedly felt frustrated that I could not easily examine particularly interesting segments of my visualizations at a larger scale.

Many years later, on a hot, sleepless night in Murcia, Spain, in 1983, I used my daughters' tracing paper and colored pencils to try this technique again. This time, I was investigating the development of a cohesive oligarchy in southeastern Castile and wanted to see, literally, how my different types of data went together. I was particularly interested in the evolution of social networks among individuals, families, and communities within a regional social and cultural environment. Alas, even for this more spatially restricted story, no useful result emerged from the tracings that captured the dynamism and complexity of the processes involved.

Fernand Braudel sought ways to shake historians into an awareness that they needed to focus on geography. The second edition of La Méditerranee *(1966) featured a striking image designed by famed cartographer Jacques Bertin. Maps of the Mediterranean Sea often show how much of Europe is only a tiny slice of North Africa. To emphasize the importance of Africa to the Mediterranean, Bertin oriented the map toward the south,* **showing Africa looming over the Mediterranean with a relatively small Europe on the other side of the sea,** *much as this satellite image conveys this geographic relationship. (Image courtesy of NASA.)*

Again, after the passage of many years, when I told this story during an online discussion of possible titles for Andre Gunder Frank's 1998 book *ReORIENT: Global Economy in the Asian Age,* I learned from other participants, Martin Lewis and Kären Wigen, that a method existed to undertake the type of visualization I had earlier attempted. They recommended that I try GIS as an integration and visualization tool, and I participated in my first GIS workshops with great aesthetic and intellectual satisfaction.

It so happens that Frank's book, which focuses on the first global age, 1400–1800 CE, formed part of a body of work produced by Braudel, Immanuel Wallerstein, and others on historic "world systems," which were geospatially large, interconnected, dynamic entities of considerable complexity. Although Frank rejected existing linear, civilizationalist, and Eurocentric social science theories of historical development, as well as his own pioneering work in economics on dependency theory, he admitted that he did not know how to undertake the type of data organization and analysis that would be necessary to understand such complex systems. He, therefore, limited his book to a path-breaking discussion of the world economy, for which he received the inaugural Best Book prize of the World History Association in 1999. Since early 1995, Frank had been pushing me to figure out how such a comprehensive "holistic global analysis" (his phrase) could be done. It increasingly appeared to me that GIS, with its capacity for the aggregation of data on the basis of geographic location and spatial analysis, provided a tool for the work that Frank had wanted to do before he died in April 2005.

GIS and Disciplinary Crisis

It is difficult to convey to readers of a written text a complex, multidimensional history, even a linear one. Because such a high percentage of the human brain becomes engaged by visual tasks, visualization must be a component of any account of this type of historical system, and with its tie to cartographic forms of representation, GIS visualizations can play a particularly valuable role in increasing the understanding of geographically vast subjects like the histories of major world regions or of the world itself. For this reason, GIS offers great promise as a means to develop high-quality classroom materials for history teaching.

Therefore, beyond its integration, visualization, and analytical potential, I began to look on GIS as the central piece of a response to the serious and worsening crisis in which the discipline of history had been enmeshed throughout my teaching career. Through a failure to adapt, history surrendered its place in a curriculum designed by Renaissance educators to prepare students for *humanitas,* effective leadership. For 35 years, the discipline has suffered from a tight higher education job market, the relatively low position of history departments in the development plans of most colleges and universities, a lack of appreciation by university administrators for the discipline's traditional publication emphasis on the individually authored monograph, and the growing weakness and instability of history in K–12 curricula. Over the past decade or more, the disciplinary crisis has become dangerous because leaders of four-year and graduate institutions have confronted a rapidly changing U.S. higher education environment. Levels of federal and state support have fallen, and public and private institutions recognize limits on tuition increases to cover budget shortfalls. Higher education cannot easily reduce expenditures because students must be prepared to deal with constantly shifting, globalized environments whose developments are driven by rapid changes in communications and information management.

The discipline will either contribute to the painful readjustment of U.S. higher education that is currently under way, or history departments will decline further in terms of resources and internal administrative influence within their respective institutions. In the midst of some institutional crises, existing history departments may disappear as the remaining history courses will be housed within other units, such as education, which will undermine the discipline's contributions to critical, research-oriented thought. It does not take much imagination to envision education programs, without coherent history departments, organized to produce teachers of the sort of uncritical, "patriotic" K–12 history curriculum advocated in the 1990s by some opponents of the national standards for U.S. and world history. What solution does the use of GIS offer?

Collaboration and GIS

Leaders of the discipline of history have long resisted collaborative forms of research, and they have been slow to adopt contemporary communications and information management technologies. Working alone, historians frequently extract data from sources that are difficult and time-consuming to discover and use, and thus, their research usually has a relatively narrow geographic and temporal focus. As one result, synthetic studies of cultural, institutional, and economic evolution over long historical periods often badly distort reality because this type of work has frequently been left to scholars from other disciplines who are largely unfamiliar with the nature, limitations, and uncertainty of the poorly structured, fragmented, messy data used by historians in their individual research. The failure to transform research practices and graduate training has crippled the ability of historians to respond effectively to major problems in world history and increasingly marginalized the discipline at major research universities.

GIS offers historians who specialize in the histories of different places and chronological periods an effective vehicle for collaborative research among themselves and for involving researchers from other disciplines. At any point in its work, a research team can visualize its available data and decide what additional information is required. Such research will often produce and be based on digital, shared databases, archived in public, online repositories, which will constitute a body of knowledge capable of expansion and the correction of errors. The cumulative results will allow us to better address the complexity of history by melding diverse voices and stories and a wide variety of sources. This capacity for collaborative work will enable historians to join research teams able to submit more ambitious proposals to a greater variety of funding sources and will lead to jointly authored papers addressing a broader range of problems and readers. By escaping their self-imposed disciplinary isolation, historians will enhance an already dynamic discipline at the same time they will make themselves an important part of the solutions to institutional budget difficulties.

The Future of History at ISU

In response to these many factors, and to produce leaders for this exciting future for historical research and teaching, the History Department of Idaho State University (ISU) developed a new internship- and GIS-based master's degree program in geographically integrated history, known officially as the M.A. in Historical Resources Management (MHRM). This appears to be the first history program of its kind in the world (see the Fall 2005 *ArcNews* article on the program, "Idaho State University Creates Innovative Program in History and GIS"), and it is one of the fundamental building blocks of ISU's proposed interdisciplinary Ph.D. in social dynamics and human biocomplexity. These developments are supported by ISU's GIS Center. Because the university has never had a geography department, the center's director reports directly to the vice president for research, and its oversight committee has representatives from all interested academic units, including the History Department.

During the process of creating the master's degree program, we transformed our undergraduate history curriculum to give it a distinctly geospatial focus. For example, we may be the only history department to state as a core objective that students will understand cartographic design and maps as historic sources. With the kind assistance of Waldo Tobler, I introduced a course on this subject to history undergraduates in the fall of 2006.

Spatial, complex economic models, like this one of a choppy-growth pattern, can be projected cartographically. The bottom sheet shows alternating growth and decline areas projected to a regional map. Adapted from T. Puu, Mathematical Location and Land Use Theory *(2nd ed.; 2003: 276), with permission from the publisher Springer Verlag.*

Although the first students only began their master's studies in August 2007, the program has already permitted the department to submit major multiyear funding proposals to support our own research and the educations of the master's students and participating undergraduates. We have under consideration a proposal for an ambitious multidisciplinary, comparative study of the impact of public policy on rangeland health in 20th-century Idaho, Mongolia, and Spain, and we are in the preliminary proposal stage of a project to develop GIS-based support for the high school U.S. history standards and to train public school teachers for this type of teaching.

We are also part of a campus group that is preparing a funding proposal for a temporal GIS. The National Science Foundation (NSF) has provided $394,000 to support for three years my participation and that of my graduate research assistants in a large GIS-based, multinational, multidisciplinary, collaborative research project entitled Dynamic Complexity of Cooperation-Based Self-Organizing Commercial Networks in the First Global Age (DynCoopNet). I designed DynCoopNet to address a program of the European Science Foundation's (ESF) European Collaborative Research (EUROCORES) Scheme, The Evolution of Cooperation and Trading (TECT), which was devised by evolutionary biologists and economists. The DynCoopNet collaborative research community investigates the evolution of cooperation among merchants and between merchants and other groups, with particular attention to the commercial networks of importance to the global domains of Iberian monarchies, 1400–1800 CE. In addition to the NSF support, I also receive generous travel support from EUROCORES, and I was named to the Scientific Committee, which will guide the entire TECT program.

After years of administrative neglect and failure to provide the History Department with necessary resources in the face of greatly increased enrollments, our GIS activity has drawn significant attention from ISU's administration. As one direct consequence, my department received approval to hire Sarah Hinman for a new position. She is a recent Ph.D. (of Louisiana State University's Geography Department) who uses GIS to study historic public health problems of U.S. cities. She will provide us with significant support as we strengthen our research and teaching programs. To help us maintain our momentum, we have reason to hope that we will soon be permitted to hire a historian of modern Europe with a strong programming and GIS background and to receive support for the graduate GIS teaching laboratory and classroom we have designed.

Challenges for GIS

As exciting as these new triumphs and opportunities are, we nonetheless recognize that there is much more to do to adapt GIS to a discipline, such as history, for which time is significant. I prefer to describe what we advocate as geographically integrated history because we cannot be locked into the questions and analytical techniques dictated by the available GIS software. Yes, of course, there are applications and combinations of applications that will take us partway down the required paths of dynamic history. To make further progress, though, it is clear that historians must concentrate on developing, in collaboration with other disciplines, process models that capture the importance of geospatial relationships and variations.

Because of the importance of time to their discipline, historians especially require a spatial-temporal GIS built on the basis of mathematical models that will permit an evaluation of the fit between data and theory, compensate for gaps in the data or missing data types, and facilitate the analysis of the emergence of new forms in complex systems and of object/field dynamics, such as the diffusion of innovations. These models must be appropriate for dealing with complex, dynamic, nonlinear systems, which are probably a great deal more common than simple, linear ones, and with the geospatial aspects of these systems.

The existing forms of GIS visualization usually involve some sort of cartographic representation, and these lend themselves well to presenting research results, engaging the public in discussions, and teaching. A spatial-temporal GIS should also provide effective means of visualizing the dynamics of complex systems because the visualizations produced by the mathematical expressions used to model nonlinear dynamics, while often aesthetically pleasing, are too difficult to grasp for policy makers or other audiences whose mathematical skills do not extend to partial differential equations.

In economics, both these concerns, nonlinear dynamics and geographic space, have been marginalized in recent decades in preference for simpler, linear economic models, which offer the illusion of confident predictability without reference to geospatial variations. As a consequence, around 1990, leaders in the field were predicting the universal benefits of a globalized economy from which all the planet's inhabitants would enjoy increased well-being. Many of them have begun to recognize the error in their prediction. If they had used nonlinear, spatial models, they would have warned policy makers that pushing locally stable economies into a world one would likely produce local chaos, resulting in environmental degradation, famine, disease epidemics, wars, and other forms of terrible human suffering with planetary impacts. But at least a number of useful spatial models already exist in economics, and major figures continue to develop these, such as Swedish economist Tönu Puu of Umeå University's Centre for Regional Science.

GIS Research Opportunities

Because other social sciences, especially political science and sociology, have remained more faithful to the 19th-century linear theories around which they were developed, the number of available, useful models, which can be expressed in mathematical terms, is much more limited. However, there are researchers working to develop such models, such as Michael Sonis of the Geography Department of Bar-Ilan University in Israel. He is writing a book on the diffusion of innovations for which he models sociological theories to account for the diffusion of ideological innovations producing "aggressive intolerance." A great many exciting research possibilities are open to historians interested in the nonlinear dynamics of human ecology, social organization, and political institutions and the interpretive schemes of the cultural environment to create such models and to GIScientists interested in integrating such process models into GIS. Moreover, except to assert the supremacy of a European pattern of development as the model for understanding and "modernization," these 19th-century social science theories and their 20th-century descendants largely ignored geographic differences and spatial questions, which means that there is much that geographers can do to expand the horizons of the social sciences.

Because of humans' weak cognitive capacity to grasp spatial relationships, it is helpful to historians to make "snapshots" of their data at various intervals in the historic chronology, as we do now, but more must be done if GIS is to fulfill its promise for historical research and teaching. Historians require distinctly temporal forms of GIS and must collaborate with experts in GIScience and mathematical modeling. The DynCoopNet project of TECT is addressing these issues.

Getting What Historians Want

In his book *ReORIENT,* Frank argues that the history of no place can be adequately understood without integrating into the analysis environmental, economic, political-social, and cultural information about it or taking into account how that place has been connected to other places. All locations were parts of geospatially large systems, which, after the 15th century CE, constituted a single world system whose dynamics continuously shaped what happened in these places, while at the same time local developments influenced systemic processes.

In 2000, the authors of the Organization of American Historians' *LaPietra Report* (www.oah.org/activities/lapietra/final.html) emphasized that, for reasons similar to Frank's, you cannot make sense of U.S. history without taking into account the ways in which the country has been linked to other places in the world and the changes in the pattern of those interactions over time.

In fact, because for thousands of years most of the world's people have been connected throughout large geographic regions, the history of any place, including large countries, can only be understood by grasping how that history has been shaped by the way the place has been connected to other places. Since the 15th century and the development of some sort of truly global, dynamic, nonlinear system, the histories of the places within the system have been shaped by the nature of the system and the way they have been linked to it. The common practice of writing and teaching history on the basis of the political boundaries of modern countries is antithetical to such a connected history, and it will be necessary to conceptualize geographic regions on the basis of additional variables. Because the spatially large systems have undergone systemic transformations, which fundamentally alter human cultural perceptions and values, models for understanding process within one historic system, even ours, may not be easily adaptable to others.

Therefore, to create a GIS for data organization and visualization that is fully useful for historical research and teaching, many new models will be required, and this demand should stimulate research capable of profoundly changing a number of academic disciplines. In exploring the evolution of cooperation-based commercial networks in the first global age, which requires understanding the pattern or form of these networked interactions and the processes of a dynamic, nonlinear world system, the DynCoopNet project will create the spatial-temporal GIS to implant GIS as a significant component of historical research and teaching.

About the Author

J. B. "Jack" Owens is professor of history at Idaho State University. He is the cocreator of ISU's GIS-based master's program in geographically integrated history, the M.A. in Historical Resources Management. The U.S. National Science Foundation has funded his work on the DynCoopNet project for three years. Owens' understanding of complexity, nonlinear dynamics, and temporal GIS has been shaped by reading papers by the computer scientists, economists, geographers, and mathematicians of the DynCoopNet research team, including professors Puu and Sonis (identified above) and professors Monica Wachowicz and May Yuan, and he wishes to thank them for their patience in responding to his endless questions about their work.

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Bring Back Geography!

By Jerome E. Dobson

Quiz after quiz has shown that kids today don't know where any place is. How often have you heard this lament about "geographic ignorance" or "geographic illiteracy," as it is commonly called?

Illustration by Jay Merryweather, ESRI.

Now, take that complaint and turn it around. What does it say about geography? It says geography means knowing where places are. That's what geographers call "place-name geography." It's vital, but it's the least of what we expect budding geographers to learn.

Geography is more than you think. Geography is to space what history is to time. It is a spatial way of thinking, a science with distinctive methods and tools, a body of knowledge about places, and a set of information technologies that have been around for centuries. Geography is about understanding people and places and how real-world places function in a viscerally organic sense. It's about understanding spatial distributions and interpreting what they mean. It's about using technology to study, in the words of the late professor J. Rowland Illick, "why people do what they do where they do it." Geography is a dimensional science and humanity based on spatial logic in which locations, flows, and spatial associations are considered to be primary evidence of earth processes, both physical and cultural. Its hallmarks are spatial analysis, place-based research (e.g., regional studies, area studies, urban studies), and scientific integration.

The familiar litany also implies that geography is just for kids, something you learn in elementary school or high school if you're lucky, and use for the rest of your life without any need for new learning. Does geography really matter for grownups? Of course it does. Geographic knowledge, understanding, and skills matter, for instance, in formulating foreign policy, designing and using GIS, and just about everything else in society that involves locations, movements, and flows.

An Excellent Invention

Geography was founded at least 2,500 years ago and advanced by Greek, Roman, and Chinese scholars throughout the Classical Age. Prior to the Renaissance, geography and astronomy—interrelated, spatially oriented disciplines—were preeminent sciences. For a thousand years, geography was recognized and valued. "How excellent inventions are geography, arithmetic, astrology, and the rest!" wrote Saint Augustine in *The City of God* in the early 5th century.

Then came the Great Interruption of the Middle Ages, and geography became a fantasy. For a thousand years, its real body of knowledge was preserved by Irish monks and advanced by Arab and Persian scholars. Its rediscovery by European scholars was central to the enlightenment of the Renaissance. It thrived from c. 1450 to 1948 based on exploration, from c. 1600 to 1900 based on the information needs of westward expansion, and from c. 1915 to 1947 based on geopolitics. Its accomplishments include the following:

- The first proposal of continental drift was published by geographer Abraham Ortelius in 1596. Its most famous champion, Alfred Wegener, was a climatologist (climatology is a subspecialty of geography).
- Biogeographer Alfred Russell Wallace codiscovered evolution in 1859. By today's rules of precedence, he would be considered the principal discoverer because he published first, but Charles Darwin's friends made sure his paper was read ahead of Wallace's at a meeting of the Royal Society.
- President Woodrow Wilson's geographer Isaiah Bowman was the author of America's globalization policy, which proclaimed that America could lead the world through political and economic means rather than military conquest. Bowman went on to become president Franklin D. Roosevelt's geographer, as well, and one of the top six architects of the United Nations.
- Geographer Carl Sauer led the way toward new understanding of the ancient Americas and the vast populations they once contained. His first inklings were published in the 1930s; geographer Bill Denevan discovered massive supporting evidence in 1961; geographers widely accepted their findings by the 1970s; and science journalist Charles Mann's *1491* announced those findings to the public, to great acclaim, in 2005.
- Geographer Roger Tomlinson is universally recognized as the father of GIS in the early 1960s. Duane Marble and other geographers were instrumental in laying the groundwork for GIS and have been heavily involved ever since. Geographer John K. Wright of the American Geographical Society published the earliest known expression of points, lines, and areas—concepts now central to GIS—and pioneered quantitative techniques, such as dasymetric interpolation, that serve vital GIS functions today.

The Purge of Geography

Soon after World War II, however, geography was purged in the United States, and the impact continues today. From 1948 to 1988, the discipline was expunged at the University of Chicago, Columbia, Harvard, the University of Michigan, Northwestern, Stanford, Yale, and other esteemed American universities, oddly even during periods when universities were expanding faster than at any other time before or since. In truth, nobody knows why geography was targeted on such a broad scale. For decades, there have been no geography departments in the Ivy League, except Dartmouth's undergraduate department. Of the top 20 private universities in the United States, only two currently have geography departments, though 15 of the top 20 public universities do. The purge was an American phenomenon. In the United Kingdom to this day, Oxford and Cambridge universities continue to have strong academic programs offering doctoral degrees in geography.

Lately, geography is enjoying a resurgence due to the phenomenal success of GIS and the need for better understanding of foreign lands and peoples in this age of globalization and geopolitical turmoil. Peers in other disciplines now respect, and some are adopting, our hallmarks—spatial analysis, place-based research, and scientific integration. What this resurgence means is that existing geography departments are adding faculty and new graduate degrees. Unfortunately, however, only four new undergraduate degree programs have been added in the past 10 years, and only one new department is being discussed at present in a serious way. As incredible as it may seem, the purge continues, and there will be a net loss this year as Southern Oregon University closes its geography department.

The panoply of disciplines must evolve, of course, and obsolete ones should disappear. Geography, however, was cut down in its heyday, just as it was shortly after Saint Augustine's effusive compliment. This not-so-great interruption from 1948 to the present is disturbingly reminiscent of the great one in the Middle Ages. I, for one, take enormous pride in how my discipline handled its fate. For half a century, geography's body of knowledge and pool of expertise have been preserved and advanced by American scholars in state universities and a few private universities and by foreign scholars. These geographers in exile have, in effect, "preserved the scrolls" as Irish monks did in the Middle Ages. Better yet, they continued to advance the field and contribute to science and society in impressive fashion. Their collective impact is far greater today than one would expect based on their diminished numbers and institutional base.

Meanwhile, geographic education has been nearly eliminated from K–12 curricula in the United States. In elementary school, it has been lost in a mishmash called "social studies" that neglects physical geography and spatial thinking. Each semester, I ask my students in a large introductory class how many of them have ever had a geography course before at any level, and less than 10 percent raise their hands. Advanced Placement (AP) enrollments in geography are rising in high school, but the absolute number remains small (21,000 in 2006). Most matriculating students do not even know it is possible to earn a college degree in geography. The No Child Left Behind program provides funds to improve the teaching of all the essential subjects identified—except geography. Congress said geography is essential and then provided not a single dollar for it.

Illustration by Jay Merryweather, ESRI.

The situation in government reflects what happened in academia. In ancient China, the Chou emperor had his geographer-royal. Louis XV had his geographer. The Continental Congress appointed its official geographer. President Wilson had his geographer (Bowman). President Roosevelt had his geographer (also Bowman). Since World War II, however, no U.S. president has had a geographer. Again, the deficiency is a distinctly American phenomenon. In the United Kingdom, Prince William, heir to the throne, is himself a geographer, having graduated from St. Andrews University in 2005 with a master's degree in geography.

In the first half of the 20th century, geopolitics was a major focus of academic research, especially by geographers, and its influence on real-world politics was enormous. In the second half of the century, geopolitics gave way to political science and international affairs. Now, 9 of the top 15 schools of international affairs in the United States reside in universities without geography departments. The late Bill Wood, geographer of the United States, compiled a list illustrating that point and shared it with me shortly before he died. He was deeply concerned by the lack of geographic knowledge among graduates in international affairs and a similar lack of political understanding among geographers. He wanted to hire people with a broad understanding of geopolitics—both geography and politics—at the U.S. Department of State and could not find them in the labor pool.

As one indication that geopolitics matters, consider geographer Bowman's warning in 1949, "we can lose our shirt in the swamps and canyons of the hinterlands" of Southeast Asia. Two decades later, the United States went to war in Vietnam fully committed to George F. Kennan's doctrine of containment, but Bowman's "scroll" was lost, and his warning never entered the debate.

During my 26-year career at Oak Ridge National Laboratory and 6 years at the University of Kansas, I have participated in scores of meetings among insiders who provide decision support to foreign policy makers and military strategists. For about 2 years, I've sensed an historic opening for the restoration of geography. Many insiders now openly admit that geographic understanding is sorely missing from their deliberations, though only a few know to call it geography. As I listen to their concerns, I sense a striking similarity to the situation that Woodrow Wilson faced in World War I and Franklin D. Roosevelt in World War II. Yet those wars ended in victories viewed today as intelligence triumphs. They found a solution in their day, and current leaders would be wise to ask what it was.

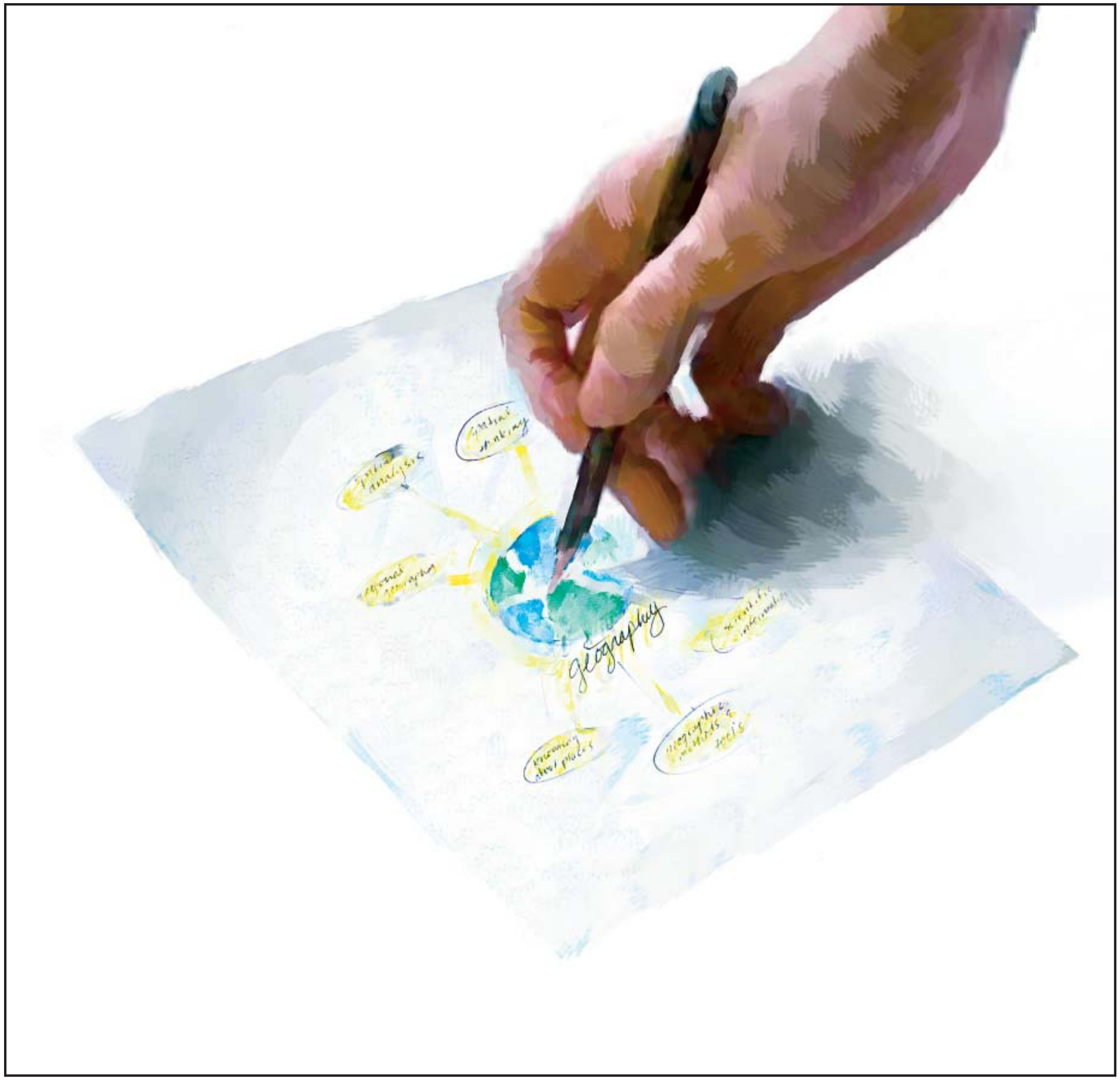

Illustration by Jay Merryweather, ESRI.

Wilson's plight is especially instructive. On the eve of World War I, he knew the United States was poised to become a world power. The Great War and subsequent peace would be his nation's debut on the global stage. He relished the role of leading man, but who would play his supporting cast? For 140 years, America had practiced isolationism. No one in government—not even the officers and analysts of the Department of State or Military Intelligence—was ready to analyze foreign intelligence or face sophisticated European negotiators. Wilson, scholar that he was, recognized his problem as being geographic and called on the American Geographical Society (AGS) for help.

AGS director Bowman led The Inquiry, a massive analysis of foreign intelligence staffed by 150 scholars from geography and other disciplines. Their task was to collect and analyze the information that would be needed to establish a "scientific" peace at war's end. As part of The Inquiry, the American Geographical Society was responsible for drafting Wilson's famous Fourteen Points, one of the most reassuring and effective policy statements ever written. When Wilson and the American delegation left for France aboard the USS *George Washington,* Bowman sailed with them. On arrival, Bowman pulled off an amazing bureaucratic coup, and Wilson decreed that analysts from the Department of State, Military Intelligence, and Central Bureau of Statistics would report to him through Bowman. In January 1919, AGS geographers and cartographers, led by Mark Jefferson, turned out more than 300 maps per week based on geographic analysis of The Inquiry's massive data collections covering language, ethnicity, resources, historic boundaries, and other pertinent information. America's delegation became the envy of Versailles.

President Roosevelt, too, appreciated geography and even served on the Council of the American Geographical Society for more than a decade. During World War II, Bowman was his closest advisor and one of the top six architects of the United Nations. Bowman was the only individual present from the beginning to the end of the effort to establish the United Nations, and he personally convinced Winston Churchill that one global organization would be better than three regional organizations.

During that war, one-third of all academic geographers were called to Washington, D.C., to serve in the Office of Strategic Services (OSS) and other agencies essential to the war effort. Their service, and especially Bowman's powerful role in both wars, adds to our puzzlement over why geography was purged just three years after the war ended and one year after the United Nations' charter.

Today, considering our nation's new capacity for rapid warfare, it is worth noting that the American Geographical Society's role in World War I and Bowman's role in World War II had far more to do with peace than war. Knowing the field of peace ahead of time is more important than ever.

Aliased Geography

If geography did not exist, it would have to be invented. Indeed, there are four high-profile cases in which it was reinvented by authoritative bodies purportedly unaware of its existence:

- Ten years into the purge of geography, Congress passed Title VI of the National Defense Education Act (NDEA) of 1958, which authorized funding to build "area studies" programs at U.S. universities to ensure "trained expertise of sufficient quality and quantity to meet U.S. national security needs."
- Forty years into the purge, three federal agencies signed on to a proposal for a "new" scientific discipline called "earth system science." Days after the Bretherton Report appeared in the late 1980s, I read the definition in a plenary session at an international conference of geographers, and they recognized in an instant that geography had been reinvented yet again. The auditorium erupted in laughter.
- Columbia University disbanded its geography department in 1986 and nine years later established the Earth Institute "for the integrated study of Earth, the environment, and society." Geography is not listed among its "core disciplines."
- Harvard University discontinued geography in 1948, and the results showed in its curricular review of 2004. The report called for bold remedies including certain hallmarks of geography—broader knowledge of diverse sciences and a better understanding of foreign cultures, economies, and policies—without mentioning its name.

All four sound like manifestos for geography, but the word itself is assiduously avoided even where it normally would be used in common language.

In 2005, Harvard University announced that it will reintroduce GIS but not geography. The new Center for Geographic Analysis recognizes the demand for GIS throughout all disciplines without granting academic stature to its home discipline. That's much like building a word processing center without an English department, and it's a mistake the university has made before. Harvard was one of a handful of key centers advancing GIS in the 1970s. Lacking an academic home, however, its groundbreaking GIS developments were mislabeled "computer graphics," and a grand opportunity was lost.

Years ago, I warned, "Advances in geography could position our discipline to play a major role in important issues, such as global change or the restructuring of east European economies and societies. In contrast, advances in GIS alone are likely to cast us as clerks handling data for the ecologists, political scientists, economists, and other current leaders in these topics." Harvard's previous experience with GIS and its current direction are proving my point. Only by joining the fray of science theory ourselves and occasionally "drawing blood" will we establish ourselves as a respected force in the upper echelons of science, science policy, and public policy influenced by science. Meanwhile, many conventional theories—developed in isolation by specialized disciplines with little thought for geographic relationships, spatial logic, or integration—have stood unchallenged for decades.

Harvard administrators have opened the door to a possible return of geography, but the process is slow and uncertain. Can it possibly be in anyone's interest for information technology of such power to exist, devoid of intellectual leadership, even temporarily, at the nation's most influential university? Geography is the intellectual force behind GIS and its natural academic home. Of the 80 institutional members of the University Consortium for Geographic Information Science, for instance, about 85 percent are led or co-led by geography departments.

Gaffes, Laughs, and Downright Insults

A laughable event from the past illustrates, in reverse, the state of geographic knowledge today. In 1897, the House of Representatives of the State of Indiana unanimously approved bill no. 246, which inadvertently would have changed the value of pi. Fortunately, the bill died a quiet death and never came before the Senate. The immediate agent of its defeat was Clarence A. Waldo, a professor of mathematics at Purdue University, who happened to visit the legislature; he was shown a copy of the bill and ridiculed its claims. Even if the good professor had not appeared, surely other voices would have materialized from mathematically informed government officials and staffers, journalists, educators, and the public.

Today, however, politicians and pundits can make whatever pronouncements they please about geography, no matter how absurd, and there aren't enough geographically informed people to counter their claims. Geographically smart people exist, of course, in government offices, schools, businesses, and homes across the land, but they are too few. There's no sizable constituency to carry the day. Not even journalists ask the questions that should be asked.

Worst of all, geography has slipped so far beneath the public consciousness that no politician or journalist is likely to seek an informed geographic opinion, even on matters of war and peace.

There is today no greater gulf of knowledge than that which lies between the public understanding of geography and the reality of what geographers actually do. Every geographer endures frequent reminders from people who suffer from honest misunderstanding. Some are funny, some downright insulting. For example, I once fell into conversation with a salesperson in an upscale shop in Kansas City, a sophisticated woman whose daughter attended my university. She asked what I teach. I answered, "Geography," and she said, "Oh, they don't teach that in college, do they?" I said, "Certainly. We offer B.A.s, M.A.s, Ph.D.s." Then came the cruelest cut of all: "Well, what do they call it?" she asked incredulously.

Believe it or not, some people really do think geography is just knowing your states and capitals. Some think it's just about borders. Some think it's purely physical. Others think it's purely social. Actually, cultural, social, and economic topics comprise 47 percent of declared specialties in geography; geographic information science, 21 percent; physical, 10 percent; regional, 8 percent; methodology, 5 percent; and combinations of all the above, 9 percent.

Most individual gaffes are insignificant, and we are accustomed to fending them off. Collectively, however, they doom society to the kind of misunderstanding that makes bad policy, bad business, and bad science. Some individual comments are dangerous and worth fighting. Harvard's assault, for instance, began in 1948 when president James Conant declared, "Geography is not a university subject." His institution's influence is such that his words and associated actions triggered a national purge of historic proportions.

In spite of all that's happened to prove Conant wrong, some people still don't get the message. Recently, the vice president of a highly respected liberal arts college in California publicly questioned the legitimacy of human geography as an Advanced Placement course. Many eloquent letters have been written by geographers to the college's administrators, and selected ones will be published in the American Geographical Society's publication *Ubique.*

Solidarity

Restoring geography is in your best interest as a citizen of the world and especially as a GIS professional, regardless of your home discipline. We are your natural ally, whether you yourself hold a degree in geography or not. No discipline should rest easy until the one that was lost is restored. Every scholar should be clamoring for geography's return as proof that future purges will not be tolerated, and that holds true even for those who do not like geography.

What protects other disciplines from onslaughts like those that beset geography? You may imagine that public opposition would be fierce, and legions of academic peers would rise up in arms, but that did not happen in our case. You may imagine that your own discipline would not go down without a fight, but geographers accepted their fate far more graciously than they should have. Earlier this year, when I published an op-ed piece questioning how and why the nationwide purge had occurred, all but one of the public replies came from geographers, and several blamed the discipline itself. Yet every reason they offered was characteristic of many other disciplines, none of which were punished as we were.

As passionate as I am about my discipline, my advocacy is not chauvinistic. I fully recognize that geography is not the only answer. The GIS revolution never could have happened without massive contributions by computer scientists, landscape architects, mathematicians, electrical engineers, and many others. The same is true for geography as a body of knowledge about places. Cultural anthropologists, for instance, understand as much about culture as we do, and they teach it just as well. Indeed, I support all those other disciplines as much as I do my own, but they were not purged as geography was.

My first point is that geography has an essential viewpoint and methodology that are at least as important as those of other disciplines. Geography was purged, aliased, and fragmented, and none of the fragments add up to the whole. Area studies programs, for instance, bring together specialists of all sorts who know much about each region, but they do not inherently contain the glue that holds those regions together. Their faculties do not inherently think about space and define it as geographers do. That's why, despite all the federal dollars they have received since 1958, area studies programs were not major contributors to GIS development while geographers were.

My second point is that geography has been neglected to an extent that no other discipline has faced in modern times. Not a single Ivy League university tries to get by without anthropology, biology, history, mathematics, and sociology, for example. Indeed, you will find Ph.D. programs for all of those disciplines, and usually multiple Ph.D. programs for their subspecialties, in every Ivy League university (except, in some cases, Dartmouth, which emphasizes undergraduate education). Only geography is missing.

What Can You Do to Help?

Say the word—Nowadays, there is a conspicuous reluctance to say the G word. *Spatial* or *geospatial* are more acceptable than *geography* or *geographic*. When geographers discover anything new, they are likely to be identified with the closest thematic discipline rather than geography, even if geographic methods were absolutely essential to the discovery. Geographers are routinely misidentified as geologists, though only 10 percent of them claim physical specialties that could possibly be confused with geology.

Tell people what geography really is—The vast majority of geographers define their discipline based on spatial perspective and methods rather than content. Tell everybody that geography is to space what history is to time. No one would seriously suggest that a university should exist without a history department. Why should any exist without geography?

Make administrators accountable—If your favorite university does not have a geography department, ask why. If it has one but it's combined with another discipline, ask administrators to explain the reasoning behind its placement. Together, we must send the clear message that every discipline that helps explain our world matters to every one of us. We and those who support us throughout society must draw a line that no politician or administrator can cross without pain. Every individual who crosses that line must face accountability. The hardest part, of course, will be to set aside your own discipline's short-term interests in favor of the greater good, but solidarity is our best hope to staunch the purge of disciplines. Together, we must oppose every threat, starting with the one that has already occurred.

Lobby for a rational legislative agenda—Funding for geographic education, development, and research must be increased by at least two orders of magnitude, partly to solve the labor shortage in GIS and partly to educate the general public. These funds are needed to fulfill six modest principles:

1. Every elementary and high school student must have the opportunity to learn basic geography and experience GIS technology.

2. At a minimum, every freshman should reach college knowing that geography is a viable major with solid career prospects after graduation.

3. Every college student must have access to a full geographic curriculum—thematic, regional, methodological, and technological—within the set of college destinations among which he or she normally would choose.

4. Scholarships must be available to support the best and brightest students who choose to pursue undergraduate and graduate degrees in geography.

5. Research grants must be available to encourage substantially increased geographic research, including fieldwork, both foreign and domestic, by faculty and students.

6. Development grants must be available to upgrade or create geography faculties throughout the nation; to ensure topical, regional, methodological, and technological coverage; to upgrade GIS facilities; and to promote community outreach.

Aim big—In a rational world, Congress would urgently fund a crash educational program to rush society ahead in this vital discipline as it did for science and math in the 1950s. Instead, the powers that be in the highest realms of education, science, and science policy have done precisely the opposite for six decades. Now change is coming, but will it be enough? Will it happen fast enough? Will geographers and GIS professionals have much influence on the outcome?

Restoring Geography

Actually, I don't think such a crash program is out of the question. Society may well recognize the folly of its ways and try to restore geography through remedies such as those I recommend. National leaders may suddenly recognize what's missing in foreign intelligence, foreign policy, information technology, and other vital aspects affecting national interests. Everything depends on getting our message through to the right people. Once it's there, anyone with a sound, open mind can grasp the point.

One reason for my cautious optimism is that I have seen how quickly individual leaders can modify their personal impressions of geography whenever I've had a chance to talk with them one on one at length. Over the past year, for instance, I had occasion to speak three times with General David H. Petraeus, now commander of American forces in Iraq, and he exemplifies an excellent case in point. He holds a doctorate in international relations from Princeton University's Woodrow Wilson School of Public and International Affairs, and he's every bit as smart as you've heard. His innate sense of geography comes through in his 14 observations from soldiering in Iraq. Observation no. 9 says, "Cultural awareness is a force multiplier," and he adds, "knowledge of the cultural 'terrain' can be as important as, and sometimes even more important than, knowledge of the geographic terrain." The first time we spoke, I passionately advocated sending geographers to conduct foreign fieldwork specifically to address America's foreign policy crisis, as the American Geographical Society is now doing with its Bowman Expeditions. His immediate reaction was, "You'd better send someone who understands culture, too." Both statements imply that geography is purely physical, and he is not alone in that impression. Later, the AGS Council was privileged to meet with him for nearly two hours. At the conclusion of our visit, he said he had a new appreciation for geography as a source of such understanding and offered to clarify the wording of observation no. 9 in the future. Princeton does not teach that lesson because it does not have a geography department, but he was receptive when our message came before him.

The challenge, of course, is to deliver that same commonsense message to a critical mass of opinion makers and decision makers.

No More Dr. Nice Guy

Geographers have been gracious in exile far too long, and now it's time to fight. It is high time, as well, for the overwhelming majority of GIS professionals to embrace geography and fight for its return. All we seek is parity with other disciplines and fields. Surely that's not too much to ask, and it's in the nation's interest, not just our own.

About the Author

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The Fourth R? Rethinking GIS Education

By Michael F. Goodchild

When Ross Newkirk and I started a course in GIS at the University of Western Ontario in Canada in 1975, we hoped to introduce some of the students in the undergraduate geography program to a new kind of computer application, one that seemed to have enormous promise. Thirty years later, that promise has been realized in spades. GIS courses are available at almost all universities and colleges and are enthusiastically received by students in majors ranging from geography to criminology, from environmental studies to civil engineering. It would be hard for anyone majoring in any of the sciences dealing with the earth's surface to avoid at least hearing about GIS, and courses are even available in some of the humanities—at the University of California, Santa Barbara (UCSB), for example, one can learn about GIS applications from a professor interested in the sacred meanings of space in Japanese culture. The number of students taking GIS courses each year in the United States alone is certainly in the tens of thousands and worldwide may exceed 100,000.

Who takes these courses? Students headed for careers in planning and the environmental sciences see GIS as a definite asset on a resumé, whether they eventually work in the private sector, in government, or in research. The military and intelligence communities are hiring students trained in GIS as fast as they can find them. But in other cases, the motivation is more abstract and altruistic and more in line with the traditions of liberal education: GIS is seen as something that every educated person should know about, a set of tools that allow us to see and interact with the world in new and stimulating ways, a contemporary way of satisfying a deeply felt love of maps and geography, and a way of expressing concern for the future of the planet.

It's that last set of motivations that I would like to address, because it seems to me that we are currently at a critical point in the evolution of GIS education. In the past year or so, there has been a dramatic increase in the availability of GIS in society, in its importance in the everyday lives of citizens, and in its value in a host of human activities. No one following the events of August and September 2005, in the days immediately before and after Hurricane Katrina, could have missed the message that GIS and spatial data were of absolutely critical value. Anyone with Internet access could download a thin client and use the Google Earth service to see the situation in New Orleans, Louisiana, at submeter resolution wherever they were located on the planet. Since the advent of Google Earth in early 2005, along with many other equally compelling and accessible services, such as ESRI's ArcGIS Explorer (www.esri.com/arcgisexplorer), Microsoft's Windows Live Local (local.live.com), Amazon's A9 (A9.com), satellite navigation systems, and online maps and driving directions, the general public has become far more aware of the power of spatial data and the degree to which technology now allows easy sharing, visualization, and exploration of information about the planet's surface. When *Nature* ran a cover story on Google Earth earlier this year, I was quoted as saying that Google Earth represented the democratization of GIS, just as the PC had democratized computing 25 years previously.

While we recognize these services as the accessible and highly visible version of the technology we call GIS, to the general public they are simply useful services that may or may not be perceived as having anything in common—and very few will link them to the familiar acronym. But all of them represent spatial ways of viewing the world and solving day-to-day problems, and they demand certain abilities on the part of the user, for example, an ability to capture and communicate knowledge in the form of a map, understand and recognize the world as viewed from above, recognize and interpret patterns, know that geography is more than just a list of places on the earth's surface, see the value of geography as a basis for organizing and discovering information, and comprehend such basic concepts as scale and spatial resolution. Together, these amount to what one might term spatial literacy, a set of abilities related to working and reasoning in a spatial world and to making a picture truly worth a thousand words. Children grow up to function as adults in a world in which the three Rs—reading, writing, and arithmetic—are considered essential as much to basic functioning as to the realization of life's higher objectives. Today, we surely have to add spatial literacy to the list.

This theme seems to be striking a chord in many places around the world. In the United Kingdom, three universities are collaborating in SPLINT (www.spatial-literacy.org), and have had some success in reaching this new, much broader audience. In the United States, the National Research Council (NRC) recently released a long-awaited report *Learning to Think Spatially* (www.nap.edu/catalog/11019.html), which includes many useful ideas about how to promote spatial literacy in the K–12 world. Google Earth has stimulated a large and growing community of hackers and bloggers who are feverishly adding value to the service through mashups, commentaries, and extensions—and many of this new community have no background in GIS whatsoever.

What might all this mean for GIS education? It seems to me that it demands a new approach in which spatial literacy is recognized along with other basic abilities—that maps, pictures, and spatial data need to rank with numbers, text, and logic as essential ways in which humans function, both on and off the job, as they reason, interact, and generally live their lives. In the tradition of U.S. liberal postsecondary education, this makes spatial literacy part of what is variously known as the core curriculum or general education—the set of courses available to everyone and from which every student is expected to choose a significant fraction of their course load.

Illustration by Jay Merryweather.

What would a course in spatial literacy look like? I think it would cover a minimal set of the basic concepts of spatial thinking and reasoning: location and place, distance and direction, topological relationships, wayfinding, map reading, etc. The course should discuss fundamentals of geographic understanding, including concepts of neighborhood, spatial interaction, competition for space, territory, migration, and spatial context. Visualization, cartography, and the ways in which humans express themselves visually would also form a major part of the content. The course would be grounded firmly in technology and would introduce students to some of the basic concepts of GIS—rasters and vectors, layers and overlay, points, polylines, and polygons—as well as to the world of geospatial data and infrastructure. It would cover the fundamental ways in which humans describe and record the world using coordinate systems, datums, and map projections. Finally, it would be good to include coverage of the special properties of geographic data, particularly spatial dependence and spatial heterogeneity.

If this sounds familiar, it is because these are all topics covered in the education of today's GIS professionals. But the emphasis here is very different, focusing on what every member of tomorrow's society should know rather than on the very specialized skills that we teach in GIS courses today. The objectives are very different, also—this is spatial literacy for everyone, or at least everyone who has the opportunity to take undergraduate general education courses, rather than for the few.

It seems to me that the situation today with respect to the fourth R is similar to the situation in the late 1980s with respect to GIS: there is plenty of interest, but there are very few models of how such a course might be constructed and taught, and there are no textbooks. In 1988, a collaborative effort by the GIS community produced the National Center for Geographic Information and Analysis (NCGIA) Core Curriculum (www.ncgia.ucsb.edu/pubs/core.html), which filled a critical gap and allowed many universities to define the content of new courses. Something similar today might produce an equivalent set of materials for courses in spatial literacy, to fill the gap before suitable textbooks appear.

I have focused on undergraduate education because my experience is in the postsecondary world, but it is clear that the development of spatial literacy needs to begin much earlier. The NRC report has already laid much of the groundwork, and is full of practical ideas, but many issues remain. Not least among them is the question of where spatial literacy belongs in the curriculum. Should it be taught as part of geography, which is a comparatively minor part of the content of social studies courses in most schools? Perhaps it should be developed in mathematics, where it is invaluable in the teaching of geometry, set theory, and calculus. In fact it is easy to see how spatial literacy can be helpful in just about any area of the curriculum. But this is both good news and bad news—good in the sense that it provides an immensely strong argument for spatial literacy, but bad in the sense that no single discipline is clearly responsible for adopting and promoting it.

These and many other issues will be the subject of increasing debate in the next few years. What is clear, however, is that GIS education needs to think about its future and about scaling up to an entirely new concept of its role. One hundred thousand students taking GIS courses worldwide is impressive, but it represents no more than 0.1 percent of all of the students passing through the world's educational system in any one year. Postsecondary education is notoriously resistant to change, and yet pressures for change are overwhelming, particularly in rapidly developing countries, such as China. Moreover, any educational system has its pressure points where change can be initiated effectively. Graduate students can be very effective at embarrassing their stuck-in-the-mud professors to accept new ways of thinking; funding agencies and foundations can provoke change by well-directed infusions of resources; and collaborative efforts across an interested community can work wonders. Together we can make this happen.

About the Author

Michael F. Goodchild is professor of Geography at the University of California, Santa Barbara. He was elected member of the National Academy of Sciences in 2002 and has received honorary doctorates from four universities. In 2001, he received a Lifetime Achievement Award from ESRI. He has published 15 books and more than 350 papers.

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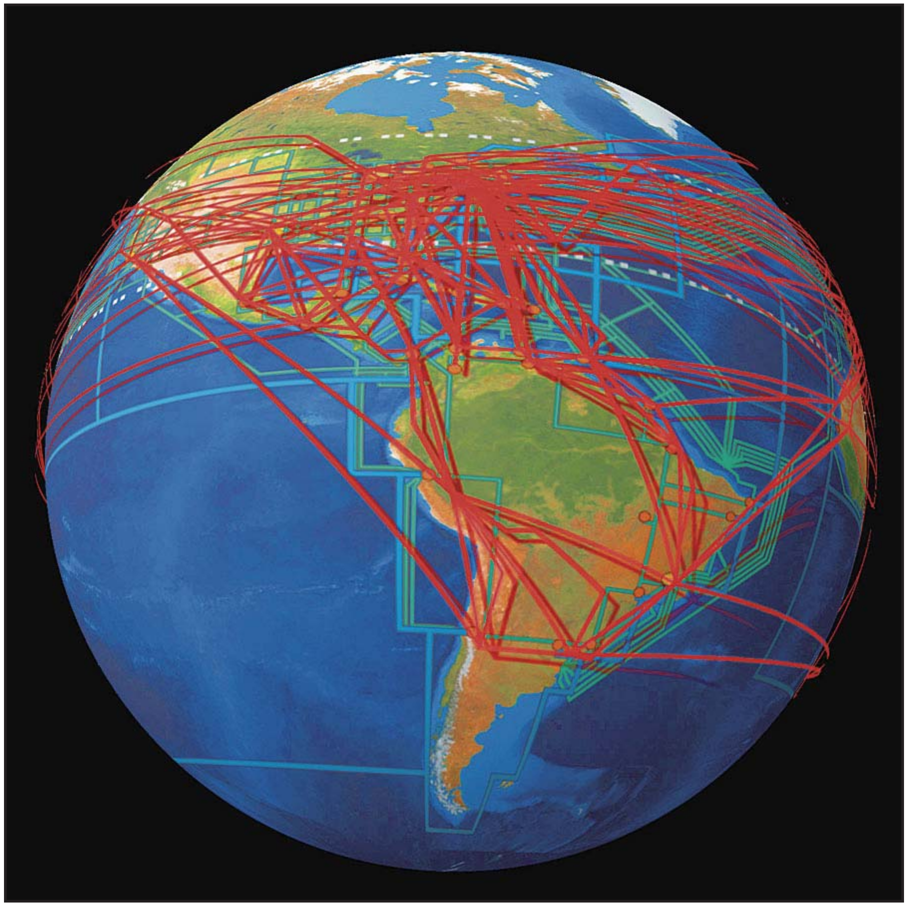
Nature, the Human Network, and the Role of GIS

By Gary Moll, Michael Gallis, and Heather Millar

The environment is a seamless, interactive system that wraps the earth. At some level, everyone understands that what happens on the land affects the health of the air, the waterways, and so on.



The global human network.

Amazingly—since we all intuitively understand that the environment is a system—business, government, and even watchdog groups have never truly addressed the environment this way. Business has seen the environment as a resource. Government has tried to create legal frameworks to manage its use. The activist community has tried to protect it. Because of their conflicting goals—development versus protection—businesses and activists have approached environmental problems from opposite directions. Government actions have ranged widely, depending on the political climate, from laissez-faire to inflexible regulation. The outcome is a piecemeal, ad hoc, and inconsistent environmental policy.

Whether these actions have involved setting aside wilderness, protecting endangered species, or regulating air and water quality, all efforts to minimize environmental damage have been split up into a crazy quilt of separate projects and problems: this endangered species, that critical place, this pollutant, and so forth.

People-Nature: A New Framework

We at American Forests, the nation's oldest citizen's conservation organization established in 1875, believe that we need to try to begin to fit these pieces together within a common framework. People must find the means to rebuild and reconnect the fragmented parts of the environment. The environment is not the problem. Humans are the problem. How we create a framework for development, or don't, is the problem.

Unless we all begin to approach the environment as a system, we will not preserve it. Unless we try to solve environmental challenges within the context of a system, we will only address part of the problem. In the face of inevitable, continued urban and economic development around the world, such partial solutions will be disastrous. Unless we create a new framework that includes the environment and guides the growth of our cities and our economy, we will destroy the environment. If we cripple nature, then we also lose our prosperity and all that goes with it.

This new framework needs to be built on the understanding that the environment is a living system, continuous and interactive. Building on this idea, we need to treat nature as a system and maintain it like all the other systems we manage: urban systems, transportation systems, economic systems.

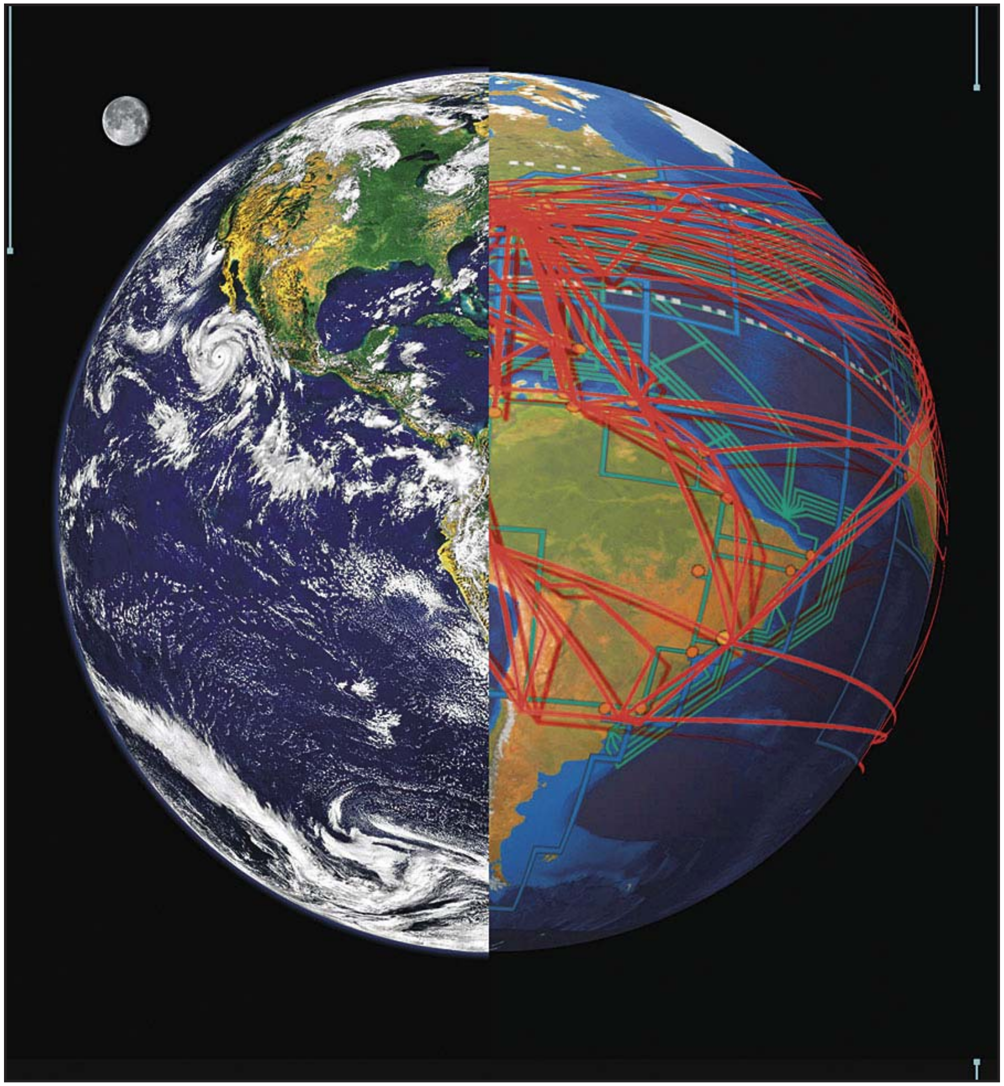
Over the next year, American Forests hopes to sketch out how this new initiative and new framework can grow from a new public, private, and institutional coalition. We hope to explain why this coalition must embrace the environment as a living, planetary system. We hope to suggest ways that communities, industries, business, and government can come together to devise systemic solutions. We believe that GIS data and companies can be integral to fashioning system-based solutions to our environmental challenges.

A broad coalition can begin this initiative, but we hope to make clear that only a more active and informed federal leadership and framework can achieve this goal. American Forests played a central role in 1905 when Teddy Roosevelt formalized the federal government's involvement in the conservation movement, and we hope to play a similar role as we move forward with the building of the new framework for the environment/network.

Humanity and Nature Collide

The need to reach out for new forms and new solutions has never been more critical. Within the next few years, more of humanity will live in cities than in the countryside; we will become a predominantly urban species. The United Nations projects the world population will be nearly nine billion by 2050, and the demand for resources is projected to increase from 400 to 700 percent its current level (according to the Goldman Sachs Group, Inc.).

At the base of every environmental issue, every local leader's quandary—whether it's tree canopy, water pollution, biodiversity, or invasive species—lies a fundamental competition and collision between two systems, between two "networks": the natural network and the human network. When forests and other resources seemed limitless, we didn't need to think or work within a framework that balanced and integrated the needs of both systems. We just planned and constructed our cities, our industries, and our transportation networks as we pleased. Human networks—cities, roads, and businesses—could occupy separate territory. We could delude ourselves that nature was "out there," somewhere else, in a park or remote wilderness.



When the astronauts view the earth or globe from space, they see the natural system (left) which is the product of four billion years of evolution. The human network (right), the system of communications and trade we have developed to fuel our lifestyle, has been charted over the globe with the aid of computer graphics. The red lines are major transportation routes, and the green lines are land communication networks. Not shown are the satellite communication paths. (All of the graphics were produced by Michael Gallis and Associates.)

Yet today, the conflict between man and nature is becoming impossible to ignore. Consider that the Chicago suburbs provide habitat for more threatened species than any other area in the state of Illinois. The world economy is growing at an astounding rate. According to World Bank figures, the economy reached $30 trillion in annual value by the year 2000. Just four years later, in 2004, that figure had soared to $41.6 trillion. Economic growth is beginning to outstrip population growth, creating a conflict between humanity's desire for the "good life" and nature's ability to support it. Megacities, like New Delhi, India; New York City, New York; and Sao Paolo, Brazil, expand on every continent, strengthening their connections to each other and thereby improving their ability to obtain the resources they need and want.

Urban regions demand more food, more cars, more housing, more furniture, and more concrete and asphalt as their populations grow. Satisfying these demands requires that vast amounts of raw materials and manufactured goods be pulled through a giant global network that reaches into ever more remote parts of the globe.

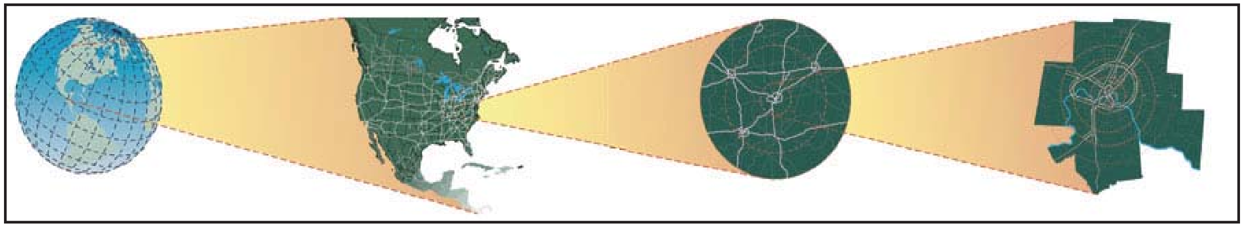
Think of this network as the summation of all the things that move people, goods, and information around the world. It's the foundation of civilization. We talk about the physical parts of the network all the time: the Internet, the phone system, the transportation system. But we seldom think of the network as a totality, as the physical and technological means by which globalization occurs.

It is not the physical infrastructure of roads, shipping lanes, and airlines that is the most important to consider in this case. What most impacts the environment is the vast stream of resources and products that travel through these avenues of commerce: plates and silverware and animal carcasses and oil. When the world was divided between the Communist and free world blocs, human networks were also divided. Now, since the collapse of the Soviet Union, the network has reunified and is becoming truly global. It wraps the entire planet like a giant spider web—obvious to see from any large-scale GIS image.

It is precisely because this network appears so mundane, so ordinary that it remains largely invisible and entirely misunderstood. Most people don't think of the world in these terms. Environmentalists don't know how to approach the network and tend to see everything associated with it as a problem. Business and political leaders see only the part of the network that affects whatever their interest happens to be at a given time. We must integrate the network into our thinking about people and nature.

This is urgent because across the world our exponentially increasing demand for nonrenewable resources decimates natural areas. Nationwide in the United States, only 6 percent of the once vast, old-growth forests remain, for example. In addition, timber companies are clear-cutting huge swaths of the Canadian Rockies.

In Atlanta, Georgia; Chicago, Illinois; Los Angeles, California; Memphis, Tennessee; Orlando, Florida; and other urban regions, the expanding network is leading to greater urban sprawl. As regions grow, they erode the natural landscape. East of the Mississippi River, urban areas have lost 30 percent of their tree cover, according to American Forests' Urban Ecosystem Analysis (UEA). The association has conducted UEAs in more than 40 metropolitan areas in the United States. The analysis combines remote sensing, GIS technology, and ecological modeling to calculate changes in land cover over time, as well as determines the financial impact of these changes.



We need to understand our cities in context. Urban and economic activity operate and impact the environment at different scales. This diagram shows how Cincinnati, Ohio, is part of, from left to right, the global network, the North American trading bloc, a super region, and a metro region.

Sadly, because of the way our business and political institutions are set up, most places do not embrace regional, systemic planning that effectively reconciles the needs of both humanity and nature.

It Doesn't Have to Be This Way

Yet, in many quarters, there is a growing recognition that we've got to try to do things differently because business as usual isn't working. Consider, for instance, that municipalities nationwide now quite commonly band together in regional associations rather than laboring alone on problems like transportation or air quality. While most of these groups lack enforcement power, and many are plagued by internal disputes, at least they are trying to start some sort of regional dialogue on issues of common concern.

See Systems, See Solutions

Places that have begun to recognize human systems and ecosystems are crafting creative solutions to their problems. In the Cincinnati, Ohio, and Memphis, Tennessee, metropolitan regions, leaders are developing strategies that reach across three states. In the Orlando, Florida, area, an online framework—Myregion.org—allows 150 communities across seven counties to work together on a variety of issues.

As they have worked together, Florida leaders have begun to understand that Orlando's environment is also part of a natural network, a global ecology. Central Florida is flat and not as scenic as, say, Boulder, Colorado, or San Francisco, California. Yet the Orlando area is unique and has tremendous ecological importance: it is the only place in North America where tropical ecologies overlap with temperate ones. Hidden in all that flatness and in the murky swamps and estuaries, incredible biodiversity thrives: more than 400 species in the Indian River Estuary alone.

Orlando leaders began to recognize that preserving this natural richness was inextricably linked to creating value in real estate, creating ecotourism businesses, and building the rest of the economy. Policy makers slowly learned to stop thinking of the environment simply as a new park or nature area and to see it as a continuous system woven into their region. As a result, they began to link the region's growth to the environment, form a more integrated strategy that takes into account all the swamps and rivers, and publicize the region as a birding destination. Indian River Estuary birding ads now appear in magazines like *Sierra* and *Audubon*.

In Cincinnati, the idea of linking human systems and natural systems inspired leaders to create a vision much larger than a downtown riverfront park. They embraced the concept of a 160-mile-long environmental corridor along the Ohio River.

In Rhode Island, Kip Bergstrom, the executive director of the Rhode Island Economic Policy Council, is leading an initiative to preserve the "Gap," the last large tract of natural landscape in the Northeast. Bergstrom and other leaders believe in the Gap's value for the state and for the region.

In the West, a coalition of nongovernmental organizations has conceived of a regional system on a grand scale: a network of wildlife corridors connecting the large wildlife parks and reserves that already exist, stretching nearly 2,000 miles from Wyoming's Yellowstone National Park to Canada's Yukon Territory. As imagined, the Yellowstone to Yukon (Y2Y) Conservation Initiative would create an "animal superhighway," a wild heart of North America where grizzlies, wolverines, redband trout, and other threatened species could skirt developed areas and coexist with human settlements and industries.

The Y2Y initiative has made some headway in realizing its vision. Some 16 million acres of the Muskwa-Kechika Management Area in northeast British Columbia have been protected from development. Work is under way to restore and maintain wildlife corridor connectivity across the Trans-Canada Highway in Banff National Park. The Y2Y initiative also focuses on supporting scientific research and gathering data—much of it GIS data—to support its efforts.

A sleepy Seattle suburb just a few decades ago, Bellevue, Washington, has grown to be one of the largest cities in the state, with its own soaring skyline and a business community anchored by technology giants, such as T-Mobile and Expedia. But it's also a place that people call "a city in a park." It's a place that has managed to keep chinook and sockeye salmon running through suburbia; created wildlife corridors through the subdivisions; and preserved 2,500 acres of forest, wetlands, bogs, and parks within a stone's throw of the skyscrapers. In some of the city's watersheds, one-quarter of the land remains wild. There, the otter, beaver, coyote, and osprey go about their lives with the soft hum of urban life in the background.

Bellevue has embraced GIS to better reconcile man with nature. For example, the city is teaming up with nearby communities to acquire advanced satellite data that will enhance the GIS data that the cities already use. This enhanced GIS data will make it possible for planners and developers in several municipalities to quickly calculate what percentage of a watershed is covered by asphalt or to see how natural systems, such as forests, flow through their communities.

People often argue that human society and the environment are too big, too mutable, and too complex to be planned as systems. Of course, local planners and leaders don't know, and can't do, everything. But together, people have made a start. Once the environment is seen as a system, big things begin to happen. Leaders and citizens start to see that they can make a difference.

Time to Act

GIS technology is part of the story in every successfully growing region of the country, and it can be the cornerstone for building the "new framework" in your region with your help. The two fundamental elements for building a new framework are visualizing your region or place and analyzing the systems at work in that area. There is a third step to be touched on last.

Your action as a GIS user is the critical first step. To start building a new framework, you need to first answer the question, Where? Your region needs to be defined, and thinking of the region in connection with a metropolitan area will likely be the most useful. This is done by creating a project in ArcGIS that identifies the metropolitan region where you live. It needs to encompass major natural areas, like watersheds, and will include several smaller cities and towns. For example, the Cincinnati region stretches into three states while the region around New York City consists of five subregions (Connecticut; Long Island, New York; New Jersey; and New York City, New York). The metropolitan area will range in size from a couple hundred square miles to more than a thousand square miles depending on its location and the size of the systems involved. It is not critical that you identify the regional area of interest (AOI) perfectly the first time you outline it (make a shapefile) but, rather, that you create a palette for visualizing the systems that form the framework for your region.

Step two is to find the data that identifies the systems that make up the region. This is where your knowledge of the technology and the data sources is paramount. You need natural system data that identifies the land, water, and air systems as well as the elements of the built network, like transportation, education, medical resources, culture, and governance, to name a few (the full list is available at www.Americanforests.org). You will find some data ready to use and available over the Web. We suggest using it when possible so that the procedures you use in your region can be easily shared with users in other regions.

The third and final step requires you to step away from the computer and the GIS procedures and introduce decision makers to your project. The local leaders that need to work with the project you have started reach well beyond the elected officials and must include members of business and industry. A good place to start is an area or regional chamber of commerce. Take your project to the chamber and have a workshop where members of the chamber can see the region you have identified and can ask you to run scenarios.

We need to build a new framework that weaves nature and the network together starting today. GIS users need to play a central role in this effort. It should be obvious to all thinking people that the capacity of natural systems, which make this a living planet, cannot sustain the growth of the network over the next 40 years. We have provided a recipe for you to start building the new framework in your region; we look forward to joining you in this effort.

About the Authors

Gary Moll is the leader of the Urban Ecosystem Center at American Forests. The center has conducted ecosystem analysis on more than 40 metropolitan areas. In 1996, the center produced CITYgreen software to assist GIS users in analyzing their local ecosystems. Michael Gallis is a member of the board of directors for American Forests, an ESRI Business Partner, and is a strategist and principal of Michael Gallis and Associates in Charlotte, North Carolina, a strategic planning and design firm. Heather Millar is a Brooklyn-based writer who has written for many magazines, including the *Atlantic Monthly, National Wildlife, Sierra,* and *Smithsonian.*

More Information

For more information, visit on the Web www.americanforests.org.

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People–Nature: The Human Network

By Michael Gallis, Gary Moll, and Heather Millar

Imagine you're a sea captain or a truck driver, a pilot, or a mother driving your child to preschool. You're focused on the people or goods you're moving and the easiest and quickest way to get where you want to go. As your cell phone rings or your BlackBerry buzzes, you concentrate on what the caller is saying.

You don't spend time pondering how your trip, or your phone conversation, is part of a much larger network of shipping, air, road, rail, and digital lines that wrap the earth. You may only be vaguely aware of how the network has evolved through many stages, relying on sail power; then steam; oil; and, more recently, the energy of computers, rockets, and other advanced technologies. You probably won't consider that during the last 50 years, this network that moves goods, people, and information around the globe has grown with lightning speed. You may not realize that this network continues to expand at an ever-accelerating rate.

But paying attention to the global network, and to the continental network where you live within it, is quite possibly the most important thing you could do. The human network has created unprecedented wealth and has allowed society to connect and evolve in new ways. Yet its growth is uncontrolled and chaotic. This has not only created social and economic dislocation, but it has also placed relentless pressure on the world's ecosystems. The network cuts through the last natural areas on earth, continuing to fragment farms, forests, and wilderness into ever-smaller shards. This network of trade, transportation, and information is so much a part of your life that you, like everyone else, remain blind to it.

We need to create a new science, a new political and business structure that will help us understand the fundamental needs of human and natural systems and allow them to coexist. As environmental advocates, we must understand and reach out to those who build the network. We must help them understand, in detail, how this network destroys natural systems. Then, we can begin to devise a new framework that will rebuild what we have destroyed.

As many recognize, reconciling people and nature is now one of society's central challenges. If we hope to meet this challenge successfully, we must not assume that we already know all about the problem. If we hope to manage our infrastructure in harmony with natural systems, we must cultivate a whole new point of view. Both the environmental community and society at large have become increasingly specialized. As a society, we focus too much on bits of the problem: this endangered species, that development proposal, that carbon credit initiative, this road project, or that flood levee. We spend far too little time looking at how they all fit together. Of course, anyone who makes a daily to-do list knows that problems need to be broken down into manageable pieces. The trick, however, is to not lose sight of the big picture while working out the details. We must stop being afraid of generalists.

How do we start to build this new framework? First, we need to look closely at the network that humanity has built to meet its needs. Before we can talk in detail about solutions, we need to fundamentally alter the way we see our situation. We need to rise above all the details, to see our problems in the big picture. We need to stop trying to fix the environment and figure out how to manage the network. To do that, we need to understand the network: How has it evolved? What does it look like now?

Today, the network that has formed across North America is denser, faster, and more complex than is usually imagined by politicians, business leaders, or environmentalists. As the 20th century began, the country had few paved roads or automobiles. By 1960, 1.2 million miles of paved roads had been built to serve 61.6 million cars. By 2004, those same numbers more than doubled: to more than 2.5 million miles of paved roads and more than 136 million vehicles.

The recent increases in the network's complexity and speed have been so fast, and the changes so profound, that it's difficult to remember how things used to be not so very long ago. In the late 1940s, a superhighway meant a four-lane road with unlimited access: no on-ramps, no off-ramps, no overpasses. Propellers powered planes, which had to stop for gas on their way across the continent. Bulk cargo made its way across the oceans on freighters; container ships did not exist. In the mid-20th century, egrets in the millions used to nest in the Florida Everglades. Now birders exclaim when seeing just a few dozen egrets at one time. In the Pacific Northwest, salmon used to run in such numbers that anglers joked it was possible to walk across rivers on the backs of the salmon. Today, 40 percent of those streams have no fish at all. Air laden with mercury and other pollutants remained the exception rather than the norm. In those days—though things weren't perfect—there were still places humanity didn't reach.

The Beginning of the American Network

To fully understand the development of the United States' Northeast, we need to understand that the human network is not new. It has been evolving since people first set foot on the continent.

Northeast Urban Lattice Evolution 1945: Stage One—The traditional Northeast

For centuries, a spider web of two-lane roads and regional transit systems linked the few large Northeast cities to a scattering of towns set in a rural countryside. During World War II, the network began to expand and strengthen as the first four-lane divided roads—then called "superhighways"—began to facilitate traffic flows and connect the major urban centers. As the map shows, the Northeast remained primarily rural: Cities were still dense. The automobile had not yet allowed them to decentralize and sprawl.

It began slowly. In America, native footpaths through the wilderness formed the first tendrils of the network. Then, nearly 400 years ago, European settlers landed. As colonial settlements gradually took form, the French, the Spanish, and the English widened the tracks into dirt roads and established shipping routes and ports on the coasts and along the rivers. For more than two centuries, dirt roads and rivers formed the North American network. The few "turnpikes" were nothing more than log roads to help foot travelers and lumbering Conestoga wagons avoid the mud. Waterways remained the most convenient highways through the new nation.

With the development of the steam engine in the late 18th century, the network's development began to accelerate. Less than 50 years later, steamships were crossing the oceans and plying the rivers. Railroads crossed the landscape, linked the cities, and pushed inland, deep into the Midwestern plains. With great fanfare, Union Pacific and Central Pacific track crews in 1869 drove the last spike into the transcontinental railroad at Promontory, Utah, thus linking the east and west coasts. The nation's entire rail system only comprised 52,922 miles then. Within 30 years, more than 163,000 miles of track crisscrossed the country. Telegraph lines followed the railroad lines, initiating the first communications revolution. These corridors of transportation and communications rapidly spread and transformed the continent, as booming cities reached farther and farther into the wilderness for raw materials.

Steam engines and telegraphs began an ever-accelerating process of massive environmental impact that continues today. Railroads fragmented the landscape. As railroads conquered distance, depletion of natural resources accelerated. Timber was extracted from what was believed to be endless virgin forests. Pollution increased as the network grew. Factories demanded more energy to fuel the same steam engines that had changed the methods and finances of manufacturing. As population and incomes grew, the demand for food and new homes eroded the landscape, changing fields and forests into farms and farms into suburbs. All these developments hastened extinction. Ladies' fashion doomed the carrier pigeon and the flamingo. Railroads brought sportsmen to the prairie, where they slaughtered millions of buffalo and left them to rot. Later, as the network developed, tons of domestic beef traveled by rail to markets in Chicago, Illinois.

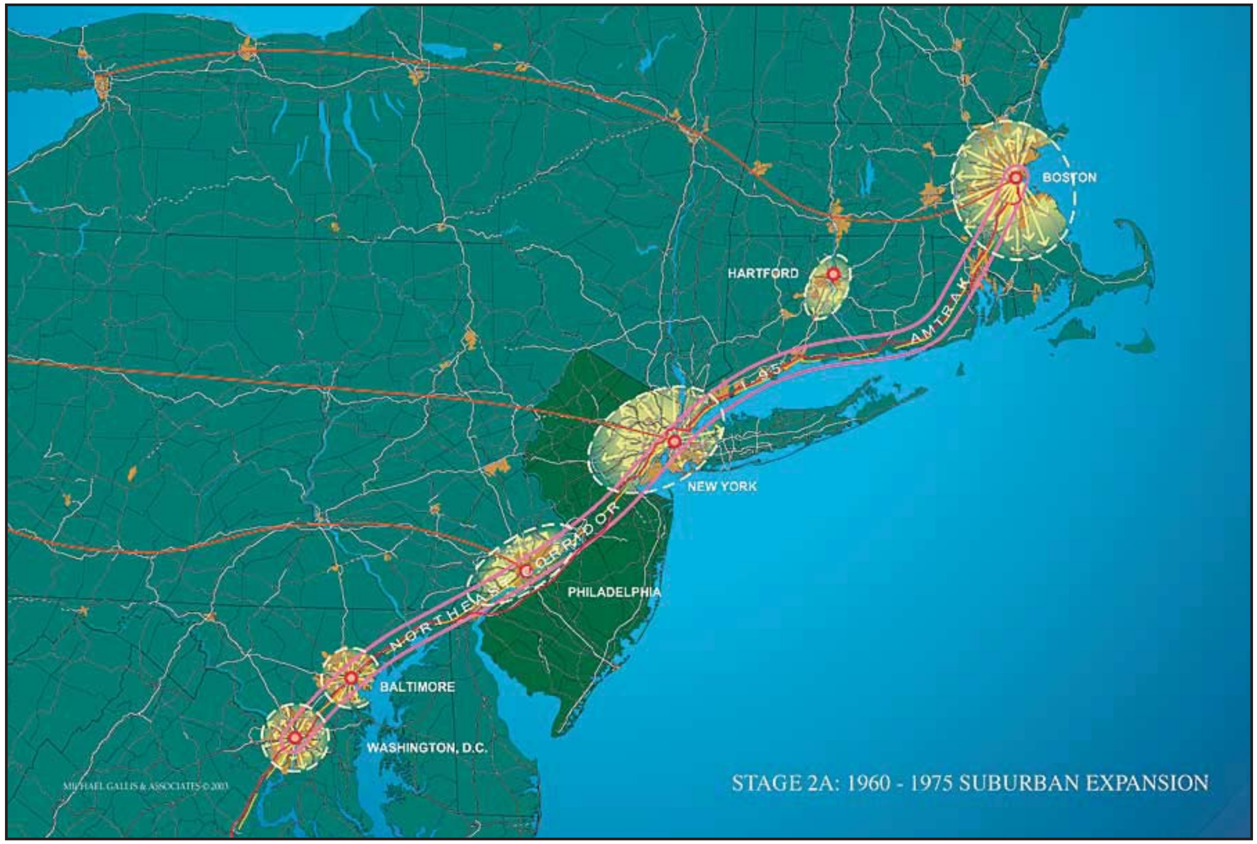
Again and again, throughout the 20th century, this cycle of environmental destruction has repeated itself as the network has added new "layers" and developed new capacities: Railroads led to roads, which then led to airplanes. Telegraphs led to telephones and computers and satellite communication. Each development increased the efficiency and the reach of the human network.

As it has developed, the network has added more layers, each of which has become more specialized. As autos and air took over passenger traffic, railroads and steamships increasingly hauled only freight. This increased specialization has more tightly linked the network and made it more interactive. It exerts an ever-greater influence on our lives, businesses, governments, and institutions, which have also dissolved into a mosaic of disciplines and subdisciplines.

We need to get beyond our own communities, our interest groups, our specialties. If we try to see our nation as an integrated whole, it becomes obvious that cities and metropolitan areas are the smaller and larger networks that have grown at the interstices of a great continental network. At key access points that link the United States to the larger global network—Atlanta, Georgia; Chicago, Illinois; Los Angeles, California; New York, New York; or San Francisco, California—large urban areas have grown up like spider webs between the branches of an enormous economic tree.

The Interstate Transformation

So let's take an example so familiar that we think we know all about it: the Northeast corridor of the United States, the area from Washington, D.C., to Boston, Massachusetts, the nation's oldest urbanized region. In 1960, this region had already been labeled a megalopolis, a seemingly borderless urban region that reached beyond traditional city boundaries. Since then, the eastern seaboard has urbanized much more quickly and in a much different pattern than predicted or broadly understood. The East Coast is not the linear corridor and continuous urban smear that was predicted and that most of us imagine. Rather, the region has morphed into an urban lattice composed of metropolitan centers and corridors extending westward.



Northeast Urban Lattice Evolution 1960–90: Stage Two—Northeast Corridor
The Interstate Highway Act of 1956 created a macro-scale pattern of highways, forming a new framework that increased accessibility and mobility. The first phase of this new network developed in a linear pattern along the Northeast Corridor, a combination of I-95, New Jersey Transit, and the Amtrak line that connected the region's cities. The second phase of the network began in 1975 as the first urban beltways provided a new framework for even greater suburban expansion and connectivity.

When World War II ended in 1945, the cities from Washington, D.C., to Boston remained almost as highly dense and clustered as when they first had been settled four centuries earlier. A series of parkways and turnpikes had begun connecting the seaboard's cities, but these were single-purpose segments. The Pennsylvania Turnpike, for instance, had been built to link Philadelphia to the Midwest, not to intersect with the New Jersey Turnpike and throughways to form a network. Consequently, these roads had not formed a large-scale grid. New Jersey, in the center of the 11 states that make up the region, remained an agricultural area. Its nickname, the Garden State, had not yet become an irony.

The Interstate Highway Act would change all that. Passed in 1956, the act created a new foundation for growth: an interstate grid that connected the six large metropolitan areas of the Northeast. Planners sought to create a passage, now known as the Northeast Corridor, that would link these urban centers, reducing intercity travel times and increasing economic synergies.

Their strategy worked. However, the interstates' initial phase also created a platform for suburbs to spread across the land gobbling up wildlife habitat and resources, extending the fragmentation, depletion, pollution, erosion, and extinction of natural systems. Work began on the New Jersey Turnpike in 1950 and later merged with the construction of I-95 to complete the Northeast Corridor by 1960. Between 1950 and 2000, New Jersey's population doubled, and by the dawn of the 21st century, only two million of the state's six million acres remained undeveloped.

The new roads made it possible for ever-greater numbers of people and goods to move around the state. Population density increased. Suburbs more than doubled the urban area surrounding the cities of Philadelphia, New York, and Boston. As growth continued, New Jersey housing became highly desirable. Not only could the state offer an exceptional landscape of mountains and shores, it lay between Philadelphia and New York, the region's two largest cities. The new highways transformed the Garden State into an urban state. The state's myriad small towns no longer dotted a rural countryside. Instead, in the north and south, they had grown together.

High-capacity interstates created a new kind of transportation corridor that provided greater accessibility and visibility for businesses. This, in turn, changed the pattern of economic activity. The new corridors attracted commercial development and evolved into long strips of restaurants, hotels, office buildings, industrial parks, movie theaters, and shopping centers. New urban centers—unrelated to the usual geographic features like ports or rivers—formed at key points and intersections of the interstate network, like Tysons Corner, Virginia, outside Washington, D.C., or the Meadowlands in New Jersey.

Two years after the first interstates opened, the first commercial jets entirely changed the pattern of long-distance travel. Airports provided the most efficient access to regional, national, and international markets. This ended the grand era of train travel as people flocked to the airports for quick connections to distant locales. This proved a great advantage to the larger cities with well-developed airports and a terrible disadvantage to the small cities with limited air service like Hartford, Connecticut; Harrisburg, Pennsylvania; Wilmington, Delaware; and Danbury, Connecticut.

The City Gets a Belt

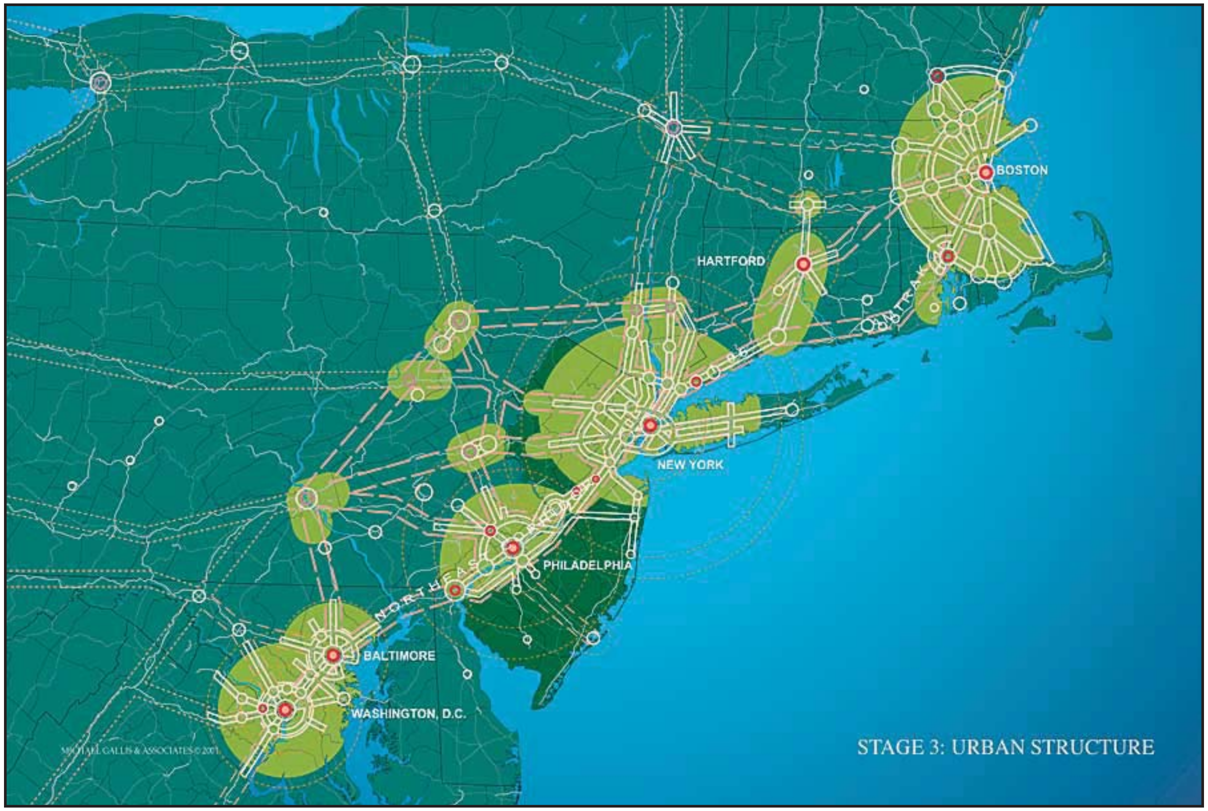
Those who envisioned the interstates saw them as a strategic tool to connect cities, moving not only goods but also tanks and other weapons in case of war. Yet the roads themselves became linear cities as more homes and businesses clustered around these high-speed corridors. They also became the habitat of bumper-to-bumper traffic. To relieve this pressure, metro areas began to construct beltways around urban areas. But these new ring roads did far more than ease traffic congestion. They greatly expanded the urban edge, opening up thousands of square just happened.

In Boston, for instance, the first ring, Route 128, was built 5 miles out from the city. Then a second ring, I-495, went in about 30 miles out. A third ring, a combination of I-195 and I-90, now lies approximately 45 miles from downtown. While the population of Boston's city center had declined from 800,000 to 500,000 since 1970, the population of the Boston metro area has grown by 5 times to 4 million. During this period, the amount of space these people take up has increased to 10 times the area of the original city. As this pattern repeated throughout the Northeast, the natural landscape was disappearing faster than at any time in history.

Strangely, as the human network became more complex, the engineers and policy makers who planned it became more specialized. While the designers of the interstate system looked at the continent as a system, those who followed them did not. Increasingly, planners did not emphasize network performance, how each segment or component fit into the larger system. Instead, they focused on each segment, such as the links between New York City and Albany, the state capital. They defined performance narrowly: by capacity alone. They gave little attention to the patterns of urban growth, the economy, or our quality of life. As a result, transportation planning became reactive, responding to congestion and safety issues. We no longer set any proactive goals: When we plan a road, we do not try to achieve a better network, a stronger economy, or a healthier environment. The same is true of other growth and development issues, such as zoning and water management.

A Lattice over the Landscape

We have become more narrowly focused while our reach has become almost impossibly wide. Since 1990, this network has morphed into a massive urban lattice linked by a series of centers and corridors like a gigantic Tinkertoy. The breakup of Conrail and the introduction of e-commerce redefined the pattern of distribution, transportation, and logistics across the Northeast. Conrail's subdivision introduced two rail systems—CSX and Norfolk Southern—into the region, each of which sought to develop its own system of hubs. The introduction of e-commerce created a single integrated marketplace.



Northeast Urban Lattice Evolution 1990–2007: Stage Three—The Lattice

After 1990, global integration, the formation of the North American trading bloc, the breakup of Conrail, and e-commerce resulted in a new configuration in the pattern of the network. The previous linear pattern of development began to transform into a parallel north-south set of growth points connected by a set of east-west interstates. This lattice is evolving into a pattern with multiple nodes and connections, each with an increasingly specialized role in the urban, economic, and transportation structure of the Northeast. This new lattice is generating a much broader pattern of urbanization across an even larger landscape.

Yet a new pattern emerged: The older urban centers of Scranton, Allentown, Bethlehem, and Harrisburg, Pennsylvania, and Wilkesboro, North Carolina, began to play important roles as inland hubs. The Norfolk Southern Railroad concentrated on these cities as new distribution points. At the same time, the Internet and global positioning systems made "just-in-time" delivery and e-commerce the norm. Retailers no longer shipped goods to one place and hoped that they would sell. If an item was moving sluggishly at one outlet, it could be "redeployed" to where shoppers demanded it. Or, through e-commerce, the item could be shipped directly to consumers. This fueled a boom in the freight industry.

Suddenly, erstwhile Rust Belt towns enjoyed a competitive advantage as they could receive goods from inland locations, West Coast ports, the Southeast, and Mexico and distribute them up and down the eastern seaboard. Bypassed for a century, these towns now enjoyed a renaissance as they grew into trucking and rail hubs with "fulfillment centers" that transferred goods from mode to mode (e.g., air to rail to road). Places like Harrisburg, Pennsylvania, could now serve Baltimore, Maryland; Philadelphia, Pennsylvania; and Washington, D.C. In Upstate New York where I-84 crosses the Hudson River, Newburgh could now serve New York, New York; Hartford, Connecticut; Boston, Massachusetts; and Providence, Rhode Island.

While these smaller metro areas began as distribution hubs, they quickly added "back office" data processing operations, housing, retail, and industry. Each created its own network of roads, water mains, and power systems. East Coast development no longer centers on the Northeast Corridor but extends westward to places like Scranton, Pennsylvania, and north to places like Newburgh, New York. The system of interstates that now extends west from Washington, D.C.; Baltimore; Philadelphia; New York; and Boston—together with the interstates that extend north and south between I-81 and I-95—now forms a gigantic lattice. That provides a new framework for growth that is now not just concentrated along I-95 but extends inland to the Lehigh Valley, north up the Hudson River, and south into northern Virginia. The individual metropolitan markets of the mid-20th century have transformed into a huge consolidated urban market serving the 52 million people who now live in the Northeast.

Where We Are Now

In the space of just a few decades, the landscape of the Northeastern Corridor has changed dramatically. What was once a region with dense cities separated by farms and natural areas has become a nearly continuous urban region that is extending inland to smaller hub cities. This new urban superstructure took form in response to the forces that were generated as the continental grid integrated with the global network. This, in turn, has sent the global economy into overdrive, growing at the fastest rate in human history according to World Bank figures. This ever-growing lattice of development also presents new and massive threats to the environment. More and more roads slice across ecosystems and migration routes. More and more people demand more resources and create more pollutants. More and more species are finding that they just can't survive within this human network.

While the story of the Northeast provides the most advanced example of this problem, it is not the only example: It has analogues across the continent. Chicago's metro area now extends across five states. Denver, Colorado Springs, and Pueblo, Colorado, are growing together and even reaching out north to Cheyenne, Wyoming. Other metro areas like Los Angeles, California; Houston, Texas; Miami, Florida; and Atlanta, Georgia, keep expanding with no end in sight. The same is true of smaller cities like Lexington, Virginia; Charlotte, North Carolina; and Memphis, Tennessee.

As these metropolitan spiderwebs continue to grow ever larger, the continental grid grows stronger. More and more goods flow through these thruways. And as a result, the land between them is being further fragmented, depleted, polluted, and eroded, and more species are becoming extinct.

Even more damaging, the densest human developments often grow up in the areas of greatest biodiversity, such as coastal regions and river valleys, where cities were originally located to have access to the water. In desert cities like Phoenix or Tucson, Arizona, the growth of the network has led to the desire to re-create the green cities of the Midwest and East. This has altered the natural landscape and upset the fragile ecological balance.

The growth of this network remains almost wholly uncoordinated and unplanned and is the biggest problem facing the environment. Our current framework is inadequate to meet this challenge. For instance, a city like Portland, Oregon, may try to curb its growth, defining strict city limits and lot sizes. But Portland can't control the growth that goes on across the Columbia River in Vancouver, Washington, or south in between other Oregon cities. What about smaller urban hubs? How will we integrate their development? As a society, we talk far too little about these questions.

We Must See It to Manage It

Seeing this network is the first step to recognizing that we must better manage it. Take the situation in the Highlands of northwestern New Jersey, where northern forests overlap with the southern Piedmont. Development pressures in the Highlands, once a pristine pocket in an overdeveloped state, have become extreme. How will we resolve this?

We can't do it if we continue our old ways of seeing.

While the planners laid out the interstate system with an eye toward a continental system, they never applied the same kind of thinking to metropolitan areas. Instead, planners focused on one project at a time, each in isolation from the others. Our bureaucracies and businesses have become increasingly specialized. So have the academic institutions that train our leaders. Like in medicine, a discipline that has subdivided again and again, the generalist has disappeared from our environmental, economic, and planning discussions.

As a result, we have lost any understanding of the entire network—just at the time when this insight is most crucial: today, the human network's reach and complexity have nearly exceeded our ability to understand what we are creating and how it affects us.

Most of us don't even see the network that has come to dominate our society, our economy, and our environment. Today, the network has come to dominate our way of life: Transit schedules and digital clocks orchestrate our days, not the ebb and flow of natural systems. We carry cell phones everywhere, living lives of perpetual motion made possible by the network.

We all exist within this complex network of human development that has a stranglehold on natural systems. Most now acknowledge the reality of global warming. But while that massive problem certainly demands attention, we must also address the root cause of rising temperatures and every other environmental problem: that root cause is the human network in which we all live.

So far, we have reacted to environmental damage in two ways: either by adapting to it or by trying to mitigate it. American Forests now promotes a third solution: strategic environmental development. We are dedicated to beginning this process. If we begin to see the network and how it affects our cities, regions, and continents, we can begin to figure out how best to design and build it. We can begin to weave human and natural systems together. We can begin to build links between business communities and environmental groups. We can develop a new science to guide these efforts, building up the environment as we build the human network. We can begin to be part of a big-picture solution.

About the Authors

This is the second in a series of articles focusing on the need for decision makers to understand that nature and humans must work together. Gary Moll is the leader of the Urban Ecosystem Center at American Forests. The center has conducted ecosystem analysis on more than 40 metropolitan areas. In 1996, the center produced CITYgreen software to assist GIS users in analyzing their local ecosystems. Michael Gallis is a member of the board of directors for American Forests, an ESRI Business Partner, and a strategist and principal of Michael Gallis and Associates in Charlotte, North Carolina, a strategic planning and design firm. Heather Millar is a Brooklyn, New York-based writer who has written for many magazines, including the *Atlantic Monthly, National Wildlife, Sierra,* and *Smithsonian.*

More Information

For more information, visit www.americanforests.org.

(Reprinted from the Summer 2007 issue of *ArcNews* magazine)

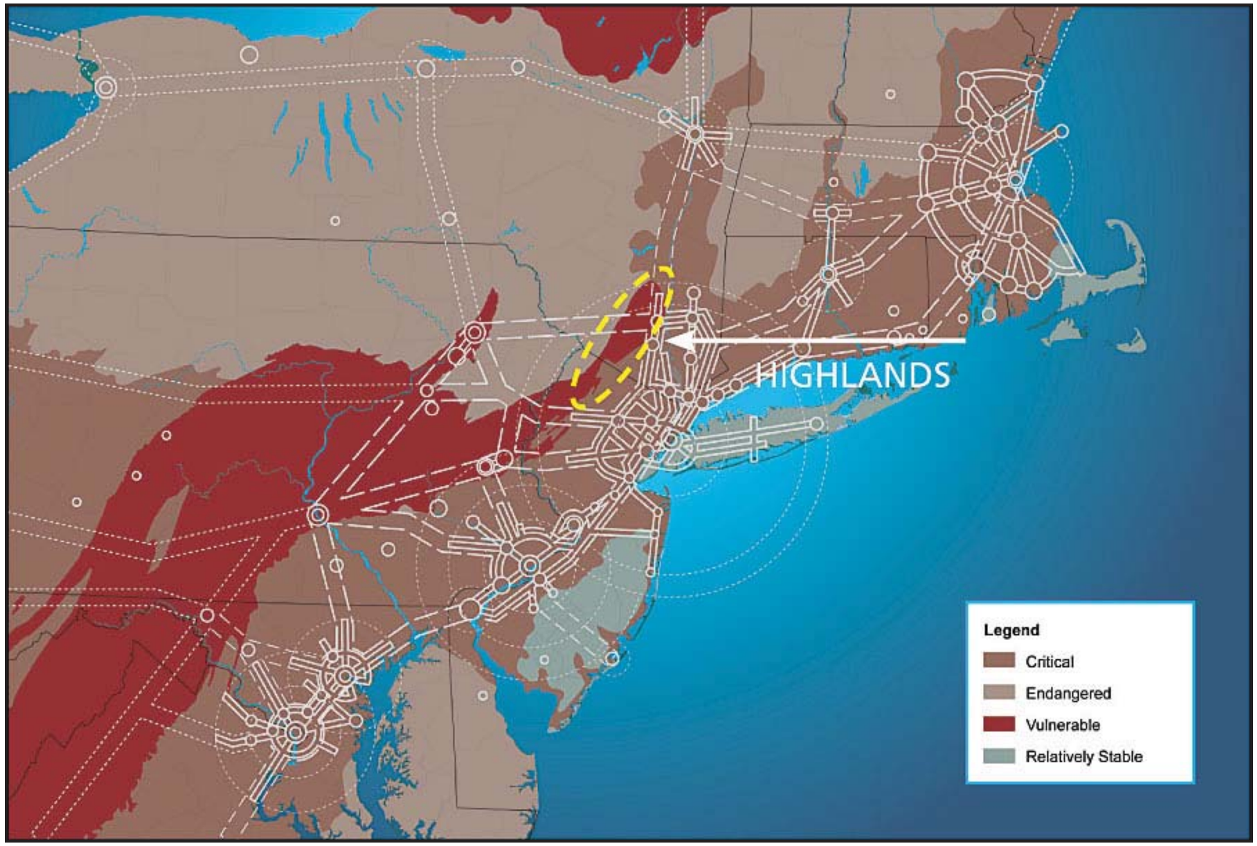
People–Nature: The Natural Network

By Michael Gallis, Gary Moll, and Heather Millar

In our previous two ArcNews *articles, we discussed how the human network affects nature and how the global network needs to be recognized and factored into decision making. This big picture, or macro view, is absolutely important, but it's also important to understand that while problems can sometimes be solved locally, just solving things locally often doesn't work, and a regional approach that integrates an understanding of the human network is needed. This article could have been written about any state in America: It could have been written about the high plains north of Denver or the Florida wetlands or the forests of the Pacific Northwest. We picked the Highlands of New Jersey because we had focused on the northeast portion of the United States in the preceding article (Summer 2007* ArcNews*) and also because the difficulties surrounding the Highlands are an example of how humans are failing to see the human and global network consequences of policy/environmental/economic drift. The attempts to save the Highlands are well intentioned, but as now structured and implemented, the regional approach to a solution remains elusive.*

On a warm August day in 2004, Jim McGreevey, then governor of New Jersey, climbed the wall of the Wanaque Reservoir, part of a network of holding pools and aqueducts that flows from the northwest, supplying drinking water to the suburbs that ring New York City, New York, and Philadelphia, Pennsylvania. There, flanked by well-wishers, publicity handlers, and lawmakers, the governor signed legislation aimed to protect hundreds of thousands of acres in the Highlands, perhaps New Jersey's last large, intact ecosystem.

"The Highlands has been one of the missing jewels . . . in our preservation efforts . . . ," McGreevey said. "Today is a wonderful day . . . for our environment and our children." Meanwhile, many of the state's foremost environmental leaders—the executive directors of the state chapters of the Audubon Society, the Sierra Club, and many others—boycotted the dam event. Concerned by the signing of a bill that could "fast track" development in other parts of the Garden State, the "greens" held a competing press conference and went hiking in the woods.



When the human network from Washington, D.C., to Boston is superimposed on the natural ecological system, it reveals important decision-making factors that are presently not part of the planning process. The Highlands is the northeast arm of this vulnerable North American ecosystem.

The hardwood forests of the Highlands where the activists walked that day stretch for nearly 3.5 million acres, over folds of gneiss and granite that undulate north from Pennsylvania, through New Jersey and New York, to Connecticut. This world, occupied for now by the bobcat, black bear, bald eagle, and about 3,000 other species, plays a key ecological role within North America. In the Highlands, several continental-scale ecoregions come together: Here, the Appalachian/Blue Ridge ecosystem that reaches up from Alabama and Georgia ends, mixing with northern ecologies. In this transition zone, the plant and animal species from north and south meet and mix. Ecosystems and species occur here that exist nowhere else.

The Highlands, covered with oak, hickory, and ash, or hemlock and red maple in moister spots, provides an important way station for birds migrating up from Central and South America. Warblers, vireos, tanagers, and dozens more stop over here. The Highlands houses more than 300 plant and animal species that the U.S. Fish and Wildlife Service judges of "special emphasis." These hills contain some of the richest ecological communities on the continent: their biodiversity rivals that of the Florida Everglades.

While lesser known, the Highlands is even more threatened than Florida's beleaguered wetlands. In part, this is because these low mountains form the backyard of the urban Northeast: More than 15 million people live within one hour of this patchwork of glacial lakes, wetlands, and forested valleys. Each year, more people visit the Highlands for outdoor recreation than all the visitors to Yosemite, Yellowstone, and the Grand Canyon combined.

"We don't have the luxury of time in the Highlands," Jeff Tittel, the state's Sierra Club director, has told the press again and again.

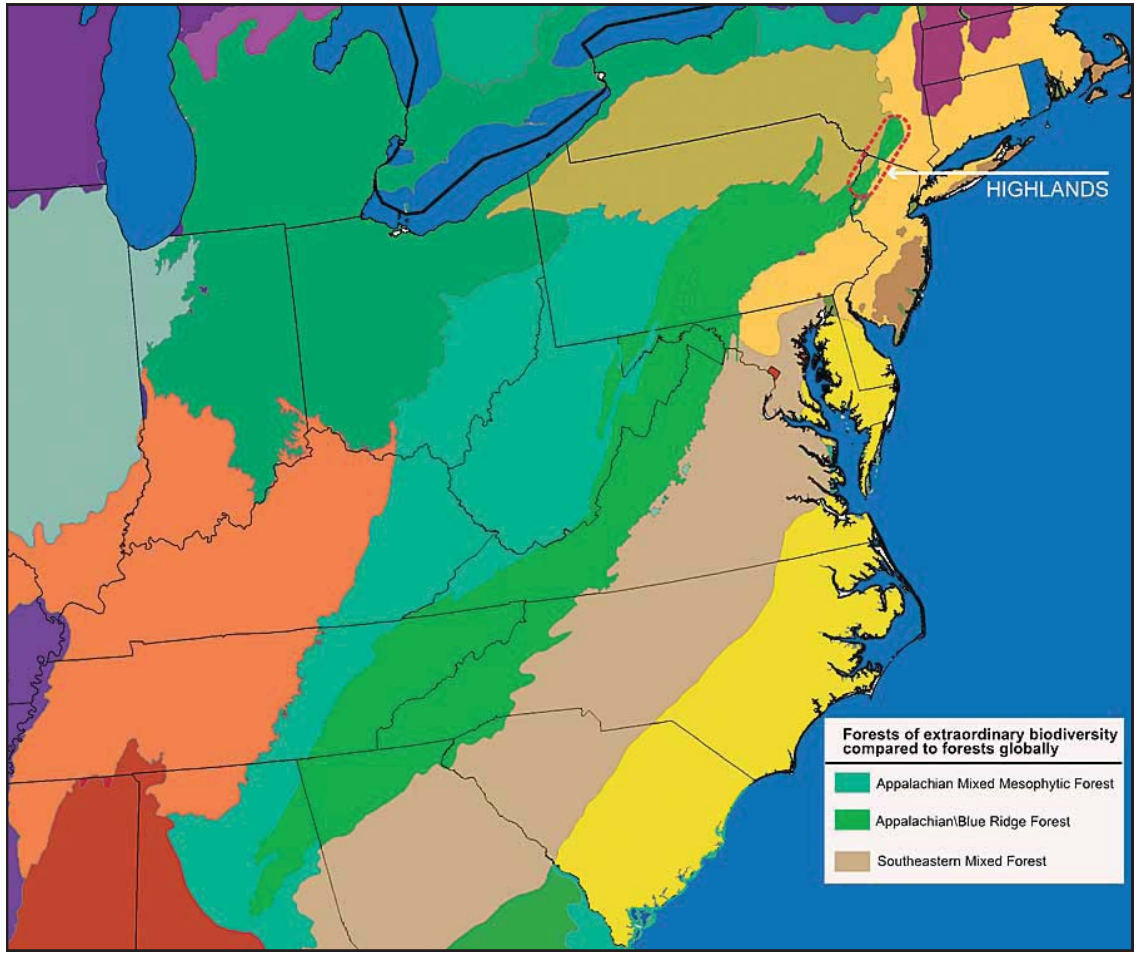
Nearly everyone—farmers and politicians, developers and ecologists—agrees that the Highlands is important, especially in a state that gets the majority of its drinking water from small rivers that originate in these low mountains. Arguments about preserving the Highlands began almost a century ago. In the last two decades, the debate has grown more strident and polarized: the defenders of private enterprise and property rights on one side, the opponents of sprawl on the other.

Really, both sides are right: New Jersey needs key swaths of the Highlands to remain wild. New Jersey also needs affordable homes. In the Highlands and across the country, these competing goals must somehow be reconciled. Yet this will never happen unless voters, businessmen, politicians, and other leaders fundamentally change how they perceive problems like species extinctions, air and water pollution, urban sprawl, global warming, and dwindling resources.

Three years after the ceremony at Wanaque Reservoir Dam, the future of the Highlands is far from clear. The state bill remains underfunded: State lawmakers set aside $500,000 for Highlands preservation in 2005 and 2006. However, the Regional Plan Association, a nonprofit organization dedicated to improving life in New York, New Jersey, and Connecticut, says as much as $1 billion may be needed by 2014 to save critical parcels.

Lack of money may be the most obvious problem. But these budget shortfalls would not be tolerated if not for something that threatens the Highlands even more: lack of vision and understanding. If we're going to save the Highlands, or any other threatened ecosystem in

North America, we need a fundamental shift in perception. We need to place these regions in their larger contexts, to recognize that they are not islands. How does the Highlands fit into the continent's ecology? How do regional and continental human systems—roads, real estate, economic corridors—overlay the natural systems? These sorts of big-picture questions are missing from the dialogue.



The Highlands in New York and New Jersey is the most northern part of the Appalachian/Blue Ridge Forest ecosystem that reaches south to Alabama. This ecoregion has been classified as globally outstanding.

Though more than 150 environmental groups have joined the Highlands Coalition—a group of organizations fighting to preserve the region—and dozens of scientists are studying the ecosystems and impacts of development there, none of these efforts takes on the region's natural and man-made systems as a whole. None examines how the region might work as an integrated system, both ecologically and economically. Studies of environmental impacts examine problems species by species, place by place, or problem by problem. They form a patchy mosaic of information, not a coherent scientific picture. Even the Highlands Coalition divides its efforts by state. Development, while mapped by region, is approved and funded one project at a time.

Yet the Highlands desperately needs an overarching vision: More than 80 percent of the critical open land in the Highlands is already fragmented into private parcels and thus more vulnerable to development. Meanwhile, the Highlands' population is growing 50 percent faster than the statewide rate, according to the state Department of Environmental Protection (DEP). A Forest Service study has shown that each year, 5,000 acres of the Highlands succumb to bulldozers.

The suburbs loom ever closer.

What's most needed is a framework that ties together all these well-known challenges. We need to do more than decry sprawl or fret about new condos and toxic runoff in the Highlands. We need to understand how human systems fit into the Highlands' natural pattern of wildlife and water flow, and so on. We need to analyze the economic, social, and transportation patterns that encompass the region. How do these human activities in the Highlands connect to other parts of New Jersey and beyond, to other states and to other countries?

A New Framework: Nature and the Network

As we've outlined in previous articles, we believe that the global network is the most useful framework for understanding the pressures on ecosystems and human systems around the country and around the world—including New Jersey's Highlands. While infinitely complex in its details, the network is really a simple idea: It's the patterns of trade, transportation, and information that people use to meet their needs—roads, shipping routes, economic regions, digital systems. This network forms a pattern of centers and corridors that reaches around the world like a web. Looking at the world this way makes it possible to break down problems and start to identify goals and strategies.

In the Winter 2006/2007 issue of *ArcNews,* American Forests, in partnership with Michael Gallis and Associates, explained how this new vision has transformed regional plans in North American cities like Memphis, Tennessee, and Cincinnati, Ohio. In the Summer 2007 issue of *ArcNews,* we explored how the network in the Northeast has evolved: changing from rural landscape to the well-known corridor traveled by Amtrak trains to the bull's-eye patterns of late 20th-century, metro ring roads. Today, the network has begun to form a new pattern: a lattice of transportation and economic nodes that reaches westward.

We believe that seeing and understanding the network could lead to effective ways to integrate human systems and ecosystems in the Highlands and elsewhere. If we see the problems in a new way, the Highlands could be a hopeful example of how we can manage growth.

How the Network Covered New Jersey

Millennia ago, the network began as simple trading paths. Over the centuries, it evolved and became stronger and more complex: Trails turned into roads. Roads led to ports and shipping routes. Later, trains, planes, spacecraft, and digital technologies added new layers to the network's web. While the network has always impacted the environment, it's only in the last 50 years that it has become so powerful and widespread that those environmental impacts have threatened human society.

Suburban New Jersey—the ring communities around New York City and Philadelphia and the nether regions in between—has been battered by these problems. It's a poster child for the problems of network growth: five federally endangered species have become extinct in the state, wetlands have been filled in, forests have been cut, groundwater pollution has increased. Unplanned development has continued until the state DEP has warned that New Jersey could run out of drinking water by 2040.

We find it useful to think of five major environmental impacts of the human network:

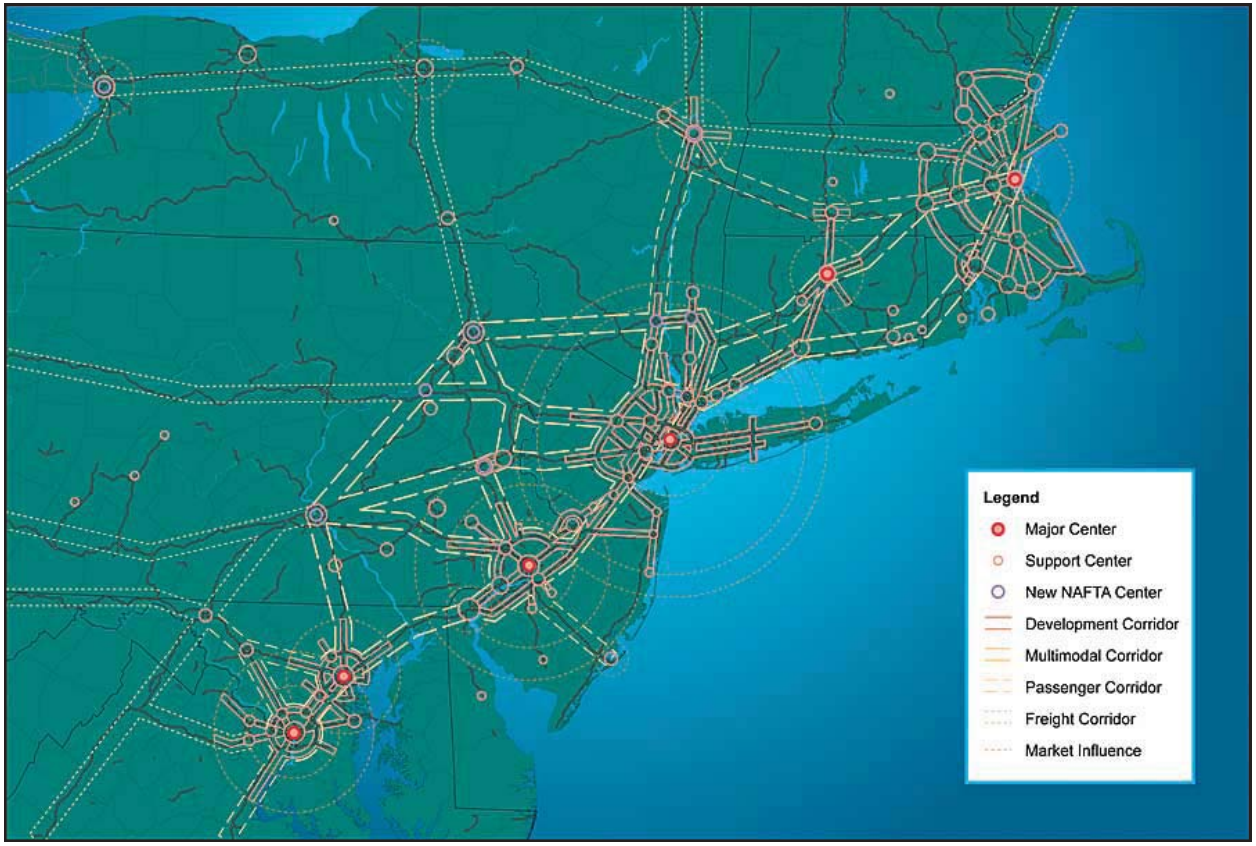
- *Fragmentation*—Much of the geography of New Jersey has been divided and subdivided, a fact that is not necessarily conducive either to environmental interests or development. It's easier to site roads along rivers or through wetlands, areas of the greatest biodiversity: Interstate 95 parallels the Delaware River, then cuts across the marshlands that border New York Harbor. The Palisades Parkway runs along the cliffs north of Manhattan in New York City, cutting off the Hudson River. The Garden State Parkway cuts off the southern barrier islands from the rest of the state.

- *Depletion*—More than other states, New Jersey relies on the flow of many small rivers to supply its water. Even one season of drought can upset this delicate balance: In 1999, toward the end of a spring drought, water managers had to hold back reservoir waters as insurance. Soon, the only water in the Passaic River was treated effluent from the more than 30 sewer plants that lined its banks.
- *Pollution*—Being the site of many oil refineries, factories, shipping terminals, and ever-growing suburbs has made pollution a big issue in the Garden State for half a century. Today, cleanup efforts continue for at least 8,900 hazardous waste sites, including more than 100 active Superfund sites, according to a state DEP report. Many watersheds are plagued by pollution, overgrown with weeds, or filled in with sediment, the DEP report found. Fish kills sometimes occur.
- *Erosion*—Development of New Jersey's farmland has eroded the remaining ecosystems. Invasive garden species, like the Japanese barberry, began to overwhelm native woodlands. Invasive Asiatic earthworms gobbled up the forest leaf litter upon which native ecosystems depended. Meanwhile, whitetail deer populations exploded: unchecked deer populations pose one of the greatest threats to native ecosystems, a 2005 New Jersey Audubon Society report found. Because they're open and flat, wetlands have been attractive places to New Jersey developers. The state DEP estimates that 40 percent of New Jersey's wetlands have been lost.
- *Extinction*—Approximately 15 percent of New Jersey's 2,100 native plant species are listed as endangered, a 2006 DEP report found. Of those that have disappeared since 1980, the majority vanished from the parts of the state that had had the most development during that time.

The Network Pressures the Highlands

Developers in the Highlands like to defend their plans for a new golf course or condo complex by pointing out that the forests that now cover the northwestern part of New Jersey are hardly untouched wilderness. Dutch settlers first came to these hills and narrow valleys in the 17th century. They, and the Scots and Huguenots who followed, created a patchwork of fields, forest, and compact villages. When high-grade iron ore was discovered, the farms gave way to mines. Ore from the Highlands provided metal for the cannonballs used in the Revolutionary War. By the 1830s, most of the region's trees had been cut down to feed the iron-smelting furnaces. Almost no native animals remained. By the late 1800s, the sighting of eight deer in the Highlands made front page news.

Yet these depredations did not totally destroy the Highlands. Gradually, people turned their attention elsewhere. A few farms held on, but the rough, craggy terrain discouraged large-scale urbanization when so many easier places still hadn't been developed. The forest grew back over the last century or so, again providing key habitat for 150 kinds of birds, as well as endangered species like the woodland turtle, timber rattlesnake, and woodland rat.



Michael Gallis and Associates has developed a technique for accurately analyzing human networks and graphically displaying them on maps. Above: The lattice of hubs and corridors that connects the major centers of the Northeast resulting from the analysis.

The full force of the human network did not reach into the Highlands until the early 1980s, when the completion of Interstate 80 opened up an east–west corridor through the region. Suddenly, the trip from Parsippany, then a bucolic little town at the foot of the Highlands, to Manhattan dropped from more than an hour to about 30 minutes. Soon after, Interstate 78 opened another east–west corridor to the Bethlehem, Pennsylvania, area. As the 1980s progressed, campus-style offices followed the subdivisions. Multinational corporations built headquarters in the Highlands and helped fuel New Jersey job growth during the slump of the late 1980s. Then Interstate 287, running north–south, connected I-80 and I-78 in 1993. Suburban-style development marched into the Highlands.

In the early 1990s, a study by the Forest Service sounded the alarm about the Highlands, calling for a regional planning authority and warning that unchecked development could threaten water quality, wildlife habitat, and recreational resources.

In reaction, the state took steps, mostly buying up parcels around the large reservoirs. The Forest Service updated its report in 2003, again issuing warnings and identifying 100,000 acres of prime Highlands forests, watersheds, and wildlife habitat that were in danger of being lost to development. The Forest Service also found that 25,000 acres of forest had been lost between 1995 and 2000.

The bill signed atop Wanaque Reservoir Dam on that summer day in 2004 has by no means "saved" the Highlands.

The Regional Highlands Planning Council doesn't have enforcement authority, and green groups worry about a recently signed fast track bill that requires any permit not acted on within 45 days to be automatically approved, and there's disagreement about whether this bill applies to the Highlands.

A New Process

Obviously, what we're doing in the Highlands isn't working. The development that now threatens the Highlands is different from the extractive industries that rolled through the region in the 18th and 19th centuries. Loggers and miners may have devastated the Highlands, but they left the ground open. Eventually, it regenerated. Modern development paves over natural regions with asphalt and lawns, subdivisions, office parks, and malls. That will entirely upset the Highland's ecology, changing soil chemistry, plant cover, and all the natural processes that make the Highlands work both for wildlife and for humans.

"Habitat is being altered so fast and so thoroughly that we have no idea what's happening to many species," says Emile DeVito, manager of science and stewardship for the New Jersey Conservation Association.

We need a new process, a new perception of the dangers and the possibilities.

First, people need to understand how the Highlands fits into the global network. Those on both sides frame the debate as if the Highlands were on the edge of ever-expanding circles of development reaching out from Philadelphia; New York; and Hartford, Connecticut. Actually, the Highlands is not on the edge. It's in the middle, both ecologically and economically.

The Highlands occupies a swath of territory that crosses the lattice developing between these reenergized cities to the west and, to the east, the metro centers from Washington, D.C., to Boston, Massachusetts. Development is not only spreading west from the big cities, it's spreading east from smaller centers like Scranton, Pennsylvania. It's as if the Highlands is caught in a nutcracker.

Rather than fighting these developments, we could have predicted them if we had looked at the Highlands in the context of the network. Yet, like generals fighting the last war, politicians and planners have in the last two decades focused on the sprawl emanating from New York and Philadelphia. They failed to recognize the importance of Interstate 81, an inland parallel to the coastal Interstate 95. They failed to appreciate the impact of Interstate 78, which links New York to Bethlehem-Allentown, Pennsylvania.

If expansion of the human network is inevitable, how do we manage its impact?

We must bring all parties to the table to discuss this question. For example, the New Jersey Builders Association is concerned that preservation plans have not put the Highlands in the context of regional economic activity. It's a criticism worth pondering. Then again, while the nonprofit Highlands Coalition's Critical Treasures report tried to take a more regional view and identify key ecosystems in the Highlands, the region still has no federal designation or protection that would allow preservation on a regional level. Efforts to protect the Highlands are divided into dozens of groups and municipalities. These efforts should be brought together. It bears repeating: it would help if everyone sat down and tried to figure out how the human network can move through these beautiful hills without destroying them.

If the species and ecosystems disappear in the Highlands, what will replace them? How will the quality of all life support systems suffer? How do these species and ecosystems fit into the larger tableau of North America? Beyond supplying water, what is the ecological function of the Highlands? These are the questions that policy makers and developers should be asking and answering.

Concern and Resources

When Michael Gallis and Associates (MGA) has consulted in cities like Memphis; Orlando, Florida; and Cincinnati, we brought all interest groups together. Then we divided human society into areas of concern and resources. We used nine categories:

- Environment
- Infrastructure
- Economic development
- Culture
- Sports
- Education
- Medicine
- Urbanization and demographics
- Governance and public management

Taking one category at a time, we asked these kinds of questions: What economic and social patterns are driving the development of the region? Where are the transportation corridors? Where are the economic corridors? What metro areas are nearby? How are they linked? How is expansion and change happening?

While it's not usually brought together in this macro way, the data to answer these questions is out there: in government databases; GIS databases; and academic atlases of soil, geology, vegetation, and animal life. GIS technology can read these complex sets of data and create maps on the fly. Software like American Forests' CITYgreen can model how air and water move through these ecosystems. We can create trend diagrams that model how human activity and natural systems may evolve in coming decades.

Eventually, we can create two sets of diagrams: one that outlines the human network and one that describes the natural systems. Then we overlay the pattern of the human network over the pattern of ecosystems and ask: How can the natural environment fit into regional patterns and resources? How can the environment enhance the economic goals of the region? Seeking these diagrams and asking these questions must be an ongoing process.

Apply This Process Elsewhere

Yes, environmental and economic development issues are complex. But using this process to break down problems and devise strategies has worked in Rhode Island and Memphis, Tennessee; Orlando, Florida; and Cincinnati, Ohio. Together, MGA and American Forests will make the process work better: MGA brings strategic planning expertise to the table; American Forests examines the environmental systems with more intensity.

It can work in the Highlands and across the rest of the country as well.

About the Authors

This is the third and last in a series of articles focusing on the need for decision makers to understand that nature and humans must work together. Gary Moll is the leader of the Urban Ecosystem Center at American Forests, an ESRI Business Partner. The center has conducted ecosystem analysis on more than 40 metropolitan areas. Michael Gallis is a member of the board of directors for American Forests and a strategist and principal of Michael Gallis and Associates, a strategic planning and design firm in Charlotte, North Carolina. Heather Millar is a Brooklyn, New York-based writer who has written for many magazines, including the *Atlantic Monthly, National Wildlife, Sierra,* and *Smithsonian.*

More Information

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