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Essays on Geography and GIS

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The Power of the Map

By John Calkins, Esri

Maps mean different things to different people. So what is a map?

My definition is simple: a map is an answer to a question.

There are three basic kinds of maps that answer three basic types of questions:

- The Location map answers the question, "Where am I?"
- The Navigation map answers the question, "How do I get there?"
- The Spatial Relationships map answers the question, "How are these things related?"

It's this third type of map—a map that helps in our understanding of spatial patterns and relationships—where we as GIS professionals spend most of our time. We work hard making our maps. Our maps can be beautiful works of art, but that's not why we make them. We make them to answer a question, to solve a problem, and to advance our understanding. And therein lies the power of the map.

Even the best maps have no power by themselves; they just exist, like the maps you hang on your office wall, or the maps in the world atlas sitting on your bookshelf. But depending on how they are created, and how they are used, maps can have tremendous power.

For maps to become truly powerful requires two things. First, they need to **tell a story**. Second, they need to be **put in people's hands**.

Telling Stories

Almost anyone can publish a map or spatial data, or put dots on a map, or create a cool web mapping app. But today we are seeing a shift to the desire and the need to communicate more effective stories, not just the data. We need the rest of the message beyond the data on the map. We need to craft these maps into more useful information products. Because *maps only have power when they tell a story*.

A map represents geographic data and includes other features, such as annotation, legends, and pop-ups, to help us understand the map. The next step is adding a new feature to this list: narratives. We need to turn our maps into storytelling devices. A map that tells a story doesn't simply answer a question or solve a problem; it's a map with a definite purpose, a direction, and a message: it's a map that can drive action.

Create a map that tells a story, and you've created a much more powerful map. But once you've done that, how do you put your map—your *story*—in the hands of the people that will use it to create a better world?

Power in Your Hand

We often make maps, but are they reaching the right people? Our colleagues, the decision makers, the public? Others who can collaborate with us?

Maps only have power when we put them in the hands of people.

GIS has traditionally been a back-office technology, and many of the maps created by GIS professionals only reach the hands of a few people. But all that is changing, and it's changing very rapidly.

What is changing is *how* we put maps in the hands of the people. Do you remember how maps used to be shared? You would print out your map on a giant color plotter, roll up the paper map, and hand it to someone. It wasn't the most effective way of leveraging the full power of all your hard work.

Today, thanks to advances in computing and geospatial technologies, you have a much wider variety of options available for extending the reach of your map. For example, you can now put your map in a web app. Or you can put it on a mobile device.

This evolution is changing the discussion; it's changing how we interact among ourselves, our organization, and the much larger world.

Power to the People

Gone are the days when information was inaccessible; when our maps were difficult to create, and even more difficult to share.

Thanks to the rise of mobile computing, today almost anyone can use your map from practically anywhere.

Be it your coworkers, your constituents, or your fellow world citizens, today almost anyone can use your map from practically anywhere. They can use it to be more productive, make better decisions, and help others. They can use it to make the world a better place.

Now *that's* what I call *power.*

(This blog post originally appeared October 9, 2012, in *Esri Insider.*)

Geography: A Platform for Understanding

By Jack Dangermond, Esri

At the Esri International User Conference this summer, I shared the context that GIS professionals are working in today: living on a small planet; breathing the same air and becoming increasingly concerned about our future—our personal future, the future of our families and communities, even the future of life on the planet. The evidence suggests that our world is changing rapidly,

Jack Dangermond speaking at the 2012 Esri International User Conference. Watch his opening talk.

with many trends that will be challenging for us personally and our organizations for the rest of our lives.

At the same time, we are living in an amazing time when scientific discovery and technological advancement are accelerating dramatically. We are making huge scientific discoveries and creating unfathomable volumes of data in the process. But these advances and the simple volume of data aren't enough. Clearly we need more integrated knowledge and ways to be able to make better decisions and create better outcomes. We need to harness our technology and our brainpower to create a more sustainable future.

Geography

The role of geography is a platform for understanding the world. GIS is making geography come alive. It condenses our data, information, and science into a language that we can easily understand: maps.

These maps help us integrate and apply our knowledge. The same maps tell stories—stories about almost everything in our world. We need to better harness the power of GIS maps to engage everyone, telling the stories of what's happening to the world and creating maps that create a better future, a future with better outcomes.

I'm increasingly confident that our GIS community will do this. One reason is that GIS itself is advancing; it's getting more powerful and easier to use. It's evolving with lots of new capabilities. It's also moving to a new web/cloud based platform; one that will make GIS pervasive. GIS will evolve to a new level, creating "geography as a platform."

Cloud GIS enables pervasive access, integrating traditional GIS with a whole new world of applications.

Reimagining Our World

This new platform allows geographic knowledge to be widely shared, enabling widespread access and use of GIS.

At the same time, other trends, such as widespread measurement, big data, and ubiquitous computing, are advancing rapidly, including Software as a Service computing, device computing with lightweight and locationally aware applications, as well as supporting scientific exploration and innovation.

The convergence of GIS with these trends will enable us to integrate geographic knowledge into everything we do.

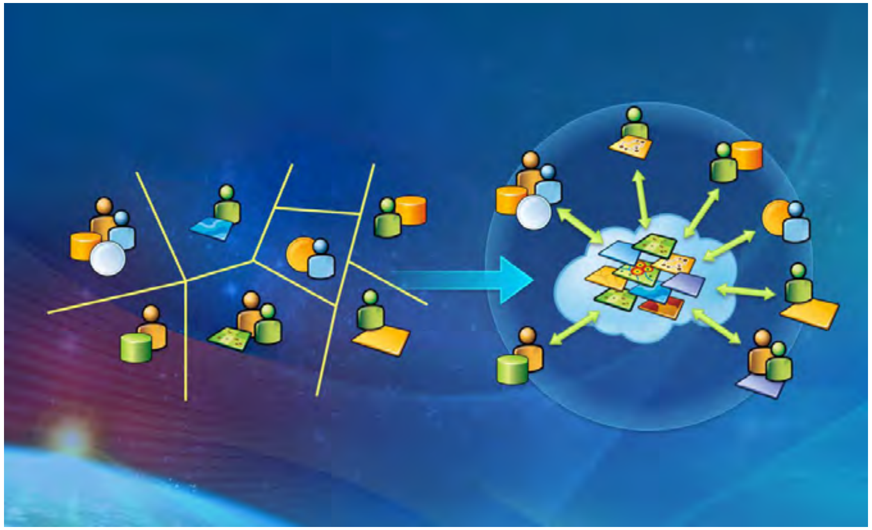
This new pattern integrates all types of geographic information—maps, data, imagery, social media, crowdsourced information, sensor networks, and much more.

Cloud GIS enables ubiquitous access and integrates the traditional work of geospatial professionals with a whole new world of GIS applications. It takes what have been relatively scarce commodities—stories and actionable geoinformation—and makes them abundant. Web maps provide the medium for integration and understanding and make this information widely accessible in simple forms. This widespread, easy access to geographic knowledge is what we mean by providing geography as a platform for understanding.

A New Pattern

This new pattern breaks down the barriers between different workflows and disciplines and brings them together. This will enable us to better collaborate and share, as well as approach problem solving and decision making more holistically.

We are already starting to see organizations rapidly adopt this new pattern. The European Environment Agency, the United Nations Environment Programme, the World Bank, and many United States government agencies are adopting it. They are using cloud computing to support their own mission and, at the same time, sharing their knowledge with others. By sharing their geospatial knowledge in common cloud environments, they are creating a new kind of spatial data infrastructure.



Cloud GIS changes the discussion, breaking down barriers between workflows, disciplines, and cultures.

Enabling the Platform

The sharing of geospatial knowledge will open our world and create a new level of understanding. As more organizations embrace this idea and adopt a culture of collaboration and sharing, the GIS community will benefit greatly. GIS practitioners will be able to do their work better and elevate the role of GIS in our organizations.

Our work at Esri is about enabling our users to do their important work. We take that responsibility very seriously. I thank you for entrusting us to do that.

(This article originally appeared in the Fall 2012 issue of *ArcNews*.)

A Business Plan for the Planet

By Rachel Kyte, World Bank

The World Bank, a cooperative of 187 member countries, provides financial and technical assistance to developing countries around the world to help reduce poverty.

Conventional governance methods can't cope with the speed and scale of the technological, social, and environmental changes sweeping the world. Governments and international development organizations have to adopt a more holistic approach to the challenge—in essence, to draw up a "business plan for the planet."

Such a plan would require a comprehensive redesign of economic policies, broadening the way we calculate national products and services. It would include a more comprehensive form of wealth accounting that puts quantifiable values on natural capital and ecosystem services. The least developed countries need investment flows to speed up green and inclusive growth, while middle-income countries need to shift the pattern of their growth with resource efficiency and inclusivity at the fore. The developed world needs to play its part by shrinking the footprint caused by inequity and resource inefficiency. It's a global business plan for a multispeed world.

This can only be achieved with better data and, more important, the better application and use of that data. Data without purpose is clutter. We have learned over 65 years of serving our clients that, to be effective, development programs must be based on firm evidence and driven by reliable data.

Since the first Earth Summit in Rio de Janeiro 20 years ago, the debate on sustainable development has shifted focus to the sustainability of growth. Growth is essential for poverty eradication, but for growth to be sustainable, it needs to be greener and more inclusive.

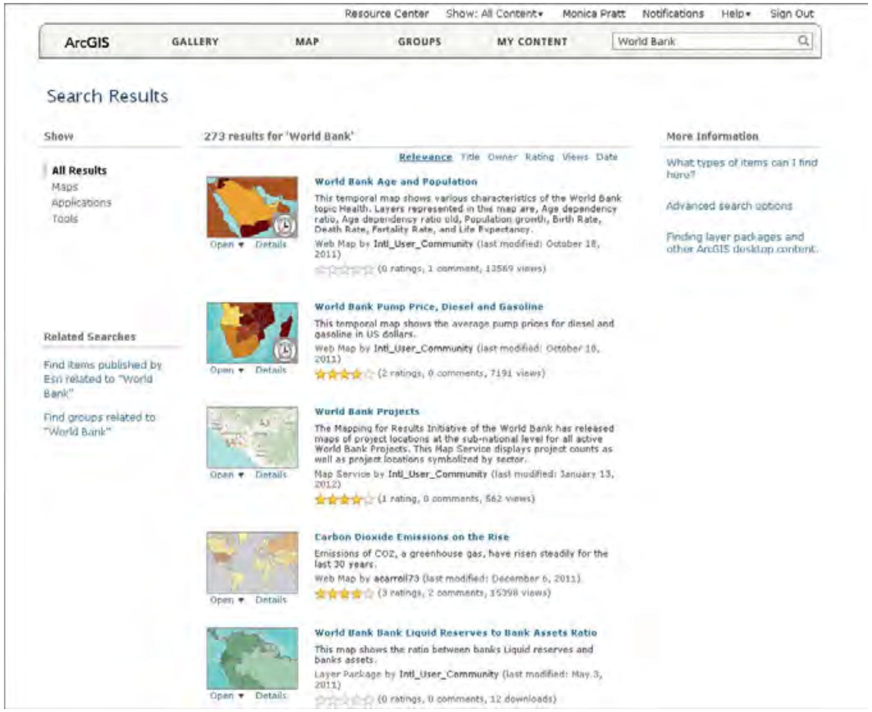
Climate change threatens to undo much of what we've accomplished for the poorest and most vulnerable in developing countries and sharpens the need for integrated solutions across the economy. We calculate that climate change is already costing Africa 5 percent of its gross domestic product (GDP) growth per year. The need to find solutions that improve food security, provide energy access, balance water supply and demand, can cope with rapid urbanization, and bring climate adaptation to the fore demand lateral thinking and planning.

With these challenges, no country can afford the luxury of not empowering its most significant market and productive sector: women. In some countries in Africa, women compose the majority of small farmers and business owners, but access only about 5 percent of the bank credit. Underinvesting makes no sense.

The good news is that technology exists to enable more evidence-based, data-driven development. Technology is evolving rapidly, and data is becoming more accessible. Technology can become a source of empowerment that improves and strengthens growth programs through popular engagement.

We at the World Bank value open, accessible data and believe in its effectiveness. We have seen that it can help reduce poverty, restore ecosystems, and generate growth. Of key importance, though, is how data is collected; who keeps, analyzes, and shares it; and how this is done. At the bank, one of the most important tools for collecting, applying, and sharing data is GIS.

We have used GIS operationally since the early 1980s. Many teams are using and developing GIS tools and maps for a wide range of applications including assessing the viability of current development projects or the location of planned ones. A map might show human settlement densities in a country relative to its clinics, hospitals, and schools to indicate areas of greatest need.

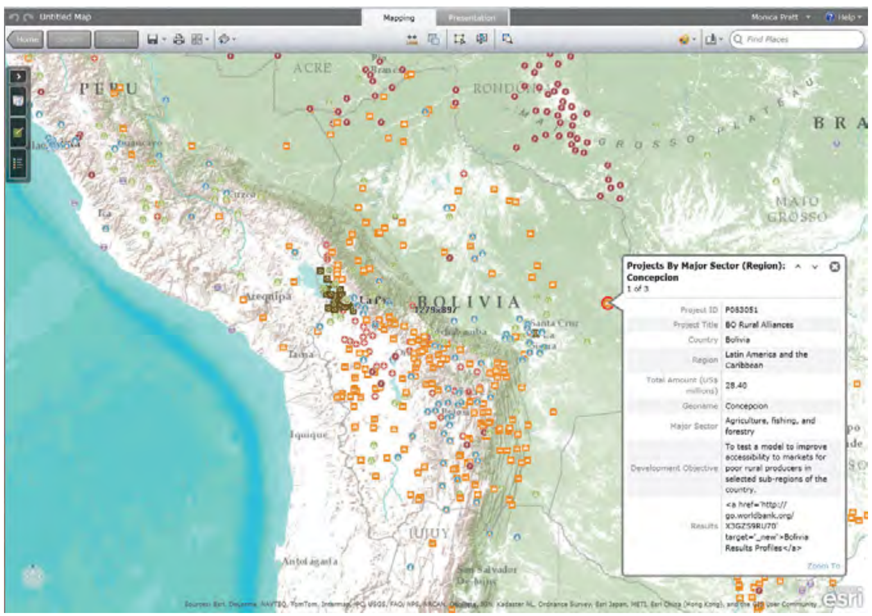


World Bank makes its extensive data holdings readily available through maps on ArcGIS Online.

A map could also be used to ascertain that there are sufficient service roads in the right places. Or a map could help determine how many people are at risk from flooding or earthquakes.

Projects benefiting from such spatial analyses include the bank's Climate Change Knowledge portal. In addition, the bank's spatial development infrastructure team has set up a high-priority rapid-mapping service for its natural disaster risk management situation room. A series of 49 interactive, country profile maps shows climate change priorities. The bank also performs urban growth analysis for more than 100 cities worldwide using remote sensing.

The World Bank Institute's Innovation Team has geocoded and mapped more than 30,000 geographic locations for more than 2,500 bank-financed projects worldwide under its Mapping for Results initiative. All new World Bank projects are now georeferenced to ensure that development planners can track and deliver resources more efficiently and effectively and avoid



The World Bank launched the interactive Mapping for Results (M4R) platform in October 2010 which visualizes the location of World Bank projects to better monitor projects and their impact on people, enhance transparency and social accountability, and enable citizens and other stakeholders to provide direct feedback. View this map on [ArcGIS Online](#).

work duplication. Since the data is publicly accessible, it also empowers citizens to follow the progress of projects and service delivery in their countries.

The bank's Development Research Group uses GIS methods extensively to carry out policy research and provide support to bank operations. As part of its environmental policy research, the bank uses overlay mapping techniques to track the spatial distribution of potential environmental impacts and calculate the probable effects of climate change.

In our Global Facility for Disaster Reduction and Recovery (GFDRR), geospatial risk assessments are central to the World Bank's disaster reduction strategy. The bank does not engage directly in disaster response but focuses on risk reduction. In the event of a disaster, we do assist humanitarian agencies and postdisaster reconstruction (as in Haiti after the January 2010 earthquake). GFDRR has identified 31 priority countries deemed most at risk of disasters. The GFDRR lab has magnified its impact by inviting specialists in GIS and related fields to help map risk profiles in these countries under the Open Data for Resilience program.

Meanwhile, many countries are turning to GIS for planning and service delivery. Ghana is using GIS to map its extractive industries and assess their economic value. Jamaica has embraced the technology for similar reasons. Mali is using GIS to help adapt to the challenges of climate change. GIS has also helped revitalize Rwanda's coffee-growing industry. The value of GIS in poverty reduction was thoroughly explored in the World Development Report 2009 entitled *Reshaping Economic Geography*.

Cost was a major inhibitor in the early use of GIS. But, as the technology has become more affordable and commercially available, its use has expanded exponentially. Many proprietary technologies that used to be prohibitively expensive are now open source. The World Bank itself has opened many of its data banks to public access. It is crucial for the sustainability of GIS that its data is not lost but becomes permanently incorporated into national and international operations as spatial data infrastructure.

To an increasing degree, governments, aid agencies, and commercial enterprises are joining forces around GIS technology, particularly on issues, such as climate change, that are too big and complex for any one institution to handle. The World Bank recently entered into a partnership with the European Space Agency to incorporate satellite data—under the rubric Earth Observation for Development—into the bank's lending operations in sustainable development.

Collaborations such as these are bound to grow as more organizations tap into the power of GIS. This will bring the data necessary for a business plan for the planet one step closer to reality.

About the Author

Rachel Kyte is the vice president for sustainable development at the World Bank.

(This article originally appeared in the Spring 2012 issue of *ArcUser*.)

Geoliteracy: So What?

By Charlie Fitzpatrick, Esri

Trooping into my room on the first day of school, my 8th grade geography classes would look above the board and see a sign:

Geography is:

1. What's where?
2. Why is it there?
3. So what?

I would tell them that they didn't need to know a lot of facts for my class; primarily they needed thinking skills. They would build up their background knowledge by exercising those skills endlessly. We quickly began exploring.

Their growing background knowledge and thinking skills would allow them to answer the first and second questions. But to answer the third question they needed to always be alert, not just "go through the day." They needed to be attentive wherever they were, look for patterns and relationships at various scales, and pay attention to what they heard adults talking about, as well as what they saw/heard/read in the news. I told them it was okay to ask "So what?" in class, any time they wanted, and such diversions happened often.

True literacy—about words, numbers, graphics, personal finance, social relationships, etc.—means more than simply reciting facts and rules committed to memory. It means being able to understand situations and relationships, and handle questions not previously encountered—and to do so with increasing sophistication.

For geographic literacy, or "geoliteracy," this means far more than knowing the states and capitals in the US or the directions around a compass. Such facts are handy, for sure, but insufficient by themselves.

So what does geoliteracy mean?

- It means being able to detect patterns that vary across space, and to understand how phenomena in one place and time relate to other phenomena.
- It means looking at a map, a classroom, or an athletic field and seeing patterns with similar clarity.
- It means looking at a label on a piece of clothing and understanding how an item made in a distant land might have gotten to this location, and being able to describe some possible related conditions and effects of such a journey.

- It means understanding how different groups might see and describe the value of a specific tree, a species, or an ocean differently.
- It means looking at a billboard next to a vacant lot on the way home from school and being able to describe some of what "Future home of BigBox SuperStore" might mean to the community beyond just one less place to play catch.

Things are different between "here" and "there." Geoliteracy helps people understand the world and helps students see relationships.

- It means hearing a discussion about labor, economy, local resources, and global patterns, and being able to talk about what different sides might value.
- It means carefully choosing which ideas to support and discard, and knowing how to learn about new things, including deciding why certain bits of information might be more appropriate than others.

Geoliteracy helps people to navigate through life and to cope with overlapping and often competing information and values, at scales from micro to cosmic. It means being able to describe for new situations "what's where," postulate "why it's there," and being interested enough to wonder and skilled enough to resolve "so what." Geoliteracy fosters skills in managing disparate information about complex problems. And this is exactly what employers are seeking today—workers accustomed to thinking critically, learning insatiably, collaborating naturally, and using technology to analyze and integrate more efficiently and powerfully. Geoliteracy opens doors to a better future for individuals, communities, and the planet.

(This blog post originally appeared October 29, 2012, in *Esri Insider*.)

Quo Vadimus?

By Brian J. L. Berry, University of Texas, Dallas

Where are we going?

I doubt that the young "quantitative revolutionaries" who, 50 years ago, were working to trick line printers to reproduce boundary files and produce choropleth maps would have been able to answer that question. Although we were full of hope, as Neils Bohr said, prediction is very difficult, especially if it is about the future. What we used to call *computer graphics* was held at bay by manual cartography aided and abetted by hardware limitations during the 1960s and 1970s, when the spatial analytic paradigm reshaped human geography, and by the ideological predispositions of Marxist geographers and critical social theorists in the 1980s and early 1990s. It was not until the IT revolution brought new hardware and software, removing earlier constraints, that hopes could begin to be realized and modern GIS could take shape. And take shape it has, creating the extraordinary new interdisciplinary area of geospatial information science, now firmly established as the leading edge of scientific geography and critical to many applied arenas, among them urban and regional planning and environmental analysis and regulation.

But the full potential of the revolution has yet to be realized. The majority of Americans are geographically illiterate, and as a downside of the IT revolution, the widespread availability of GPS devices makes it even less likely that they will engage in even the most rudimentary road map reading. Few schools provide any preuniversity GIS experience, and few universities provide even "driver ed" introductions to GIS software.

Is there a path to a different future? I believe the answer is yes and that it resides in the millennial generation, born in the 1980s and 1990s and now entering young adulthood. The Pew Research Center has undertaken detailed survey work on the millennials in the United States. It concludes that they are history's first always-connected generation, steeped in digital technology, social media, and handheld gadgets. Via texting, Twitter, Facebook, YouTube, Google, and Wikipedia, they are in instant communication with each other and with sources of information, although not always with the means to evaluate the validity of that information. More ethnically and racially diverse than previous generations, less religious and more educated, they are more culturally liberal than their generation X parents and embrace multiple modes of self-expression using the new media, valuing a wide range of lifestyle choices.

Importantly, they are among the one-fourth of US Internet users who play games on social networks (a segment that is growing). The potential of online social gaming has, I believe, yet to be realized by geospatial analysts. Observers of the "serious gaming" industry argue that new generations of games, particularly what they call "life-and-style" games, "games-for-change," and "behavior change" games, have the potential to attract participants to work on real-world problems and craft potential

solutions. Tens of millions of players have been attracted to Zynga's Cityville and Farmville games, managing small cities or virtual farms, proceeding from level to level via collaborative development activities. The fun is in the gaming; the opportunity comes in focusing on real problems in real places rather than on virtual worlds. It is the real place component that carries with it the means to counter geographic illiteracy.

How might this be accomplished? I revert to designer-planner lingo as I envisage new types of "charrettes" that marry GIS via cloud computing with gaming on social networks, providing the opportunity for the broadest array of participants both to compete and to participate in developing collaborative solutions to problems requiring structured solutions in which conflicting goals are resolved via the gaming process. The real excitement for the millennial generation comes from being plugged into gaming and is likely to be enhanced if the problem is real, not virtual, and the solution is of consequence. GIS, if it is equal to the task—and I believe it can be—can provide that reality. I envisage some games that are national in scope, even global, but many more that substitute new online charrettes for the classical limited stakeholder confrontation. In an earlier article, Harvey Miller talked of "meeting grand challenges with GIScience." I believe one path to meet such challenges and enhance both geographic education and planning practice is to take advantage of the passions of the online gaming generation by adding dynamic reality to new forms of social network charrettes.

About the Author

Brian J. L. Berry is the Lloyd Viel Berker Regental Professor in the School of Economic, Political and Policy Sciences at the University of Texas, Dallas (UTD). One of geography's earliest mid-1950s quantitative revolutionaries, he has been an active participant in the development of spatial analysis and GIScience ever since. A member of the National Academy of Sciences and a fellow of the American Institute of Certified Planners, he headed Harvard's Laboratory for Computer Graphics and Spatial Analysis from 1976 to 1981. Recently, he helped craft UTD's pioneering PhD program in geospatial information science.

(This article originally appeared in the Spring 2012 issue of *ArcNews*.)

GIS and The City 2.0

By Jack Dangermond, Esri

Seven billion. That number has received a lot of attention recently as the global population has grown past this mark. But lost in the media coverage of this milestone was another, perhaps even more fascinating, global statistic: more than 50 percent of those 7 billion people now live in cities, a number projected to grow to more than 75 percent during this century. In fact, there will be at least 19 cities in the world with a population greater than 20 million people by the end of the 21st century. Cities are human destiny.

This growing recognition of cities as the center of the human world was further highlighted when The City 2.0 was awarded the 2012 TED Prize. "For the first time in the history of the prize, it is being awarded not to an individual but to an idea," the Technology/Entertainment/Design (TED) committee stated. "It is an idea upon which our planet's future depends."

Clearly, cities will play an increasingly important role in our survival. Cities offer easier access to services, and urban dwellers are more efficient consumers of limited resources. But as our cities become more populated and more numerous, how do we best manage this complexity?

We need to start thinking about cities in a different way.

Reimagining the Canvas

Fundamental to changing the way we think about cities is a reimagining of the way we abstract them. Maps are abstractions of geography and have proved to be particularly useful throughout our history. But traditional maps have limited our ability to manage and design in a holistic, comprehensive manner.

GIS technology has given us a powerful new context for extending our traditional methods of abstracting geography—a new canvas that includes everything that lies below, on, above, and around the city, including what exists inside and outside buildings, as well as how things connect to the city and how all these things change through time.

Cities as Ecosystems

Cities are the places where most of us now spend the vast majority of our lives. They have in fact become man-made ecosystems—vast assemblages of interdependent living and nonliving components—the primary habitat for the human species.

Tall structures can have a huge shadow impact on a city, as modeled here in CityEngine.

The recognition of cities as a habitat for modern man is leading to new approaches to their management and design. GIS technology has long been used to map, study, analyze, and manage natural ecosystems. It only seems logical to manage, model, and design our new man-made ecosystem with the same tried-and-true tools used for traditional ecosystems.

Buildings as Microcities

As our cities are growing in size and complexity, so too are the buildings that compose much of the fabric of the city. In effect, many buildings and facilities are becoming small cities themselves, and they need to be designed and managed as such.

GIS tools, used successfully for many years in fields such as environmental analysis and landscape planning, also support a broad range of applications inside and outside buildings and facilities. In fact, GIS can be used throughout the life cycle of a facility—from siting, design, and construction through ongoing use, maintenance, and adaptation, ultimately through closing, repurposing, and reclamation.

An Engaged Citizenry

Smart cities of the future will be those where the citizenry is engaged in city design and evolution, where we fully leverage the collective intelligence of the masses and allow everyone to actively participate in shaping our communities. Today, social media and mobile citizen engagement applications are enhancing a variety of government-citizen interactions involving public information, requests for service, public reporting, citizens as sensors, unsolicited public comment, and even volunteerism.

Geospatial technologies have already proved to be effective tools in supporting citizen engagement. Intelligent web maps are acknowledged as a catalyst for solving key challenges in creating a dialog through informed citizens. As web- and cloud-based GIS continues to evolve and social media and mobile devices become more pervasive, governments will continue to deliver innovative forums through interactive information and participatory citizen applications.

Designing The City 2.0

Geography is constantly changing—from wind and water erosion, natural climate shifts, tectonic and volcanic activity, and the dominance and extinction of species and ecosystems. But recent changes to geography as a direct result of human activities are threatening the survival of many species, including our own. And while the actions causing these monumental changes are often deliberate, much of the change to geography has been an unintentional by-product of poor planning and unsustainable actions—change that I call *accidental geography*.

In my talk at TED 2010, I introduced the idea of geodesign—a concept that enables architects, urban planners, and others, to harness the power of GIS to design with nature and geography in mind. Geodesign results in more open participation through visualization, better evaluation of proposed scenarios, and a deeper understanding of the implications of one design over another. Combining the strengths of data management and analysis with a strong design and automation component is fundamental to designing The City 2.0.

Jack Dangermond at TED 2010 in Long Beach, California.
(Credit: TED/James Duncan Davidson)

A New Direction

Cities are intricate collections of materials, infrastructure, machinery, and people, with countless spatial and temporal relationships and dependencies, and require progressively more sophisticated tools to help us design and manage them. They are complex systems where we humans spend an increasing amount of our lives.

"This idea is capable of inspiring millions of people around the world to contribute to one of the biggest challenges and opportunities humanity faces," the TED committee stated when announcing the award of the 2012 TED Prize. "The City 2.0 is not a sterile utopian dream but a real-world upgrade tapping into humanity's collective wisdom."

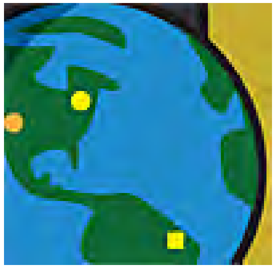
Our challenge is to design our man-made ecosystems to achieve the maximum benefit to society while minimizing short- and long-term impacts on the natural environment. As an integrative platform for management and analysis of all things spatial, I believe that GIS technology can help meet this challenge.

Cities are our new man-made ecosystems, and it's time we start to think about them, manage them, and design them as such.

(This article originally appeared in the Spring 2012 issue of *ArcNews*.)

Strengthening the GIS Profession

By David DiBiase, Esri



Is GIS a profession? If so, what's its relationship to other professions in the geospatial field? How can you tell if someone who calls herself a GIS professional—or a GIS educator for that matter—knows what she's doing? You might be surprised to learn that these are contentious questions in the United States and other parts of the world. They're contentious because the demand for GIS work has surpassed the demand for other kinds of geospatial work, despite the fact that GIS is a relatively new branch of the field. The rightful roles and qualifications of GIS pros are in dispute, and there's competition for who gets to decide.

Do you consider yourself a GIS professional? Or are you thinking of becoming one? By *GIS professional*, I mean someone who makes a living through learned professional work *(see table at right)* that requires advanced knowledge of geographic information systems and related geospatial technologies, data, and methods. If that's what you do, or what you might want to do, then you have a stake in the dispute. Your right to make a living doing GIS work, your ability to be part of an open and innovative GIS community, and your chance to be part of something big that's making a difference in the world all depend on how those contentious questions are answered.

Occupation	Estimated Employment (2010)	Projected Growth (2010–20)	Projected Growth Rate (2010–20)
Geospatial Information Scientists and Technologists*	210,000	51,600	3%–9%
Geographic Information Systems Technicians*	210,000	51,600	3%–9%
Remote-Sensing Scientists and Technologists*	30,000	13,300	3%–9%
Remote-Sensing Technicians*	62,000	33,500	10%–19%
Precision Agriculture Technicians*	62,000	33,500	10%–19%
Geodetic Surveyors*	51,000	24,200	20%–28%
Surveyors	51,000	24,200	20%–28%
Surveying Technicians	57,000	20,000	10%–19%
Mapping Technicians	57,000	20,000	10%–19%
Cartographers and Photogrammetrists	14,000	6,100	20%–28%
Totals	**~424,000**	**~148,700**	

Estimated 2010 US employment for 10 geospatial occupations, along with projected employment growth through 2020. (Source: US Bureau of Labor Statistics, available at onetonline.org)

I've been interested in the professionalization of GIS work since Bill "Hux" Huxhold and others raised these questions in the 1990s. Hux was, and is, a respected member of the GIS old guard. With his piercing blue eyes and close-cropped white hair, Hux looks a bit like Mr. Clean with eyeglasses. But unlike that cheerful ally of housekeepers everywhere, Hux was mad in the late 1990s, and he wasn't going to take it anymore.

Hux was angry that there were no standards to ensure the qualifications of GIS professionals. "Can it be," he asked, "that anyone can pass himself off as a 'GIS professional'?" Hux also railed at the absence of a formal quality control mechanism for GIS education. "Can it be that anyone can pass herself off as knowing what to teach GIS students?" To fill these gaps, Hux, Nancy Obermeyer, and a few others crusaded for a formal professional certification program for GIS professionals. Hux convinced the Urban and Regional Information Systems Association (URISA) to establish a certification committee to study the problem and recommend a solution. He also argued for a formal accreditation program for GIS in higher education.

Creating the GIS Profession

I was an educator at Penn State University at the time, and these arguments made a strong impression on me. Like many other educators, I was skeptical about the potential of certification and accreditation to ensure competence and quality. But the more I read and thought, I became convinced something more than competence is at stake. What's at stake in the professionalization of GIS is the right of GIS practitioners—some of whom are my students—to work side by side as respected peers with other geospatial professionals.

From the time that the US Department of Labor Employment and Training Administration (DOLETA) showcased geospatial technology as a high-growth industry, it warned that the absence of a coherent definition and public awareness of the field posed an obstacle to its growth. As the philosopher Michael Davis said, "Just as nobody likes a wise guy, nobody likes a definition" (2002). But to define something is, in a sense, to create it. I believe that the early crusaders and their successors have helped create a flourishing GIS profession that is just now coming of age.

The Geospatial Work Force

Until recently, we had to be content with anecdotal evidence about the GIS profession's size and scope. Reliable estimates of GIS employment didn't exist in the United States or most anywhere else. However, the anecdotal evidence was enough to worry DOLETA and others that work-force needs were growing faster than the capacity of the geospatial education infrastructure. Good students tended to get good jobs. Then confidence waned somewhat during the recession, when good jobs of every kind became much harder to find and keep.

The size and scope of the GIS work force came into sharper focus when DOLETA established two new GIS occupations—geographic information scientists and technologists and GIS technicians—in late 2009 and when it identified the core competencies of geospatial professionals in 2010. Along with the new occupation definitions came the first rough estimates of the size and growth of the US GIS work force.

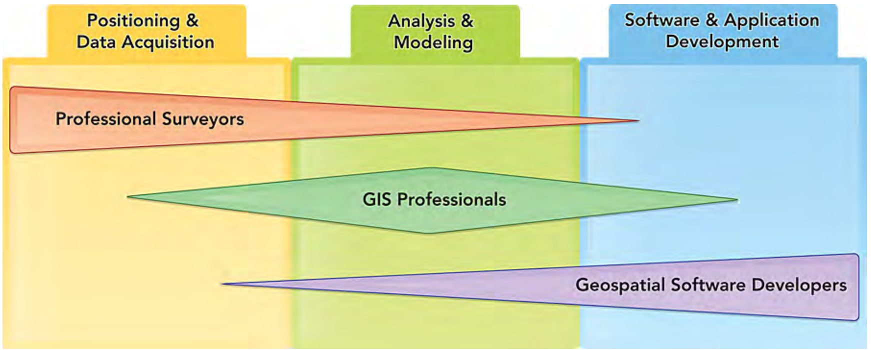
The employment estimates and growth projections in the accompanying table don't add up because some estimates overlap. However, even when the overlaps are accounted for, the estimates are still impressive: nearly 425,000 geospatial professionals were employed in 2010 in the United States, DOLETA work force analysts say, and almost 150,000 additional positions will be created by 2020. Significantly, the two GIS occupations account for the largest share of those employment estimates—about half of all US geospatial workers in 2010, and nearly more than one-third of new positions to be created by 2020. Estimates of the size of the geospatial work force beyond the United States are harder to find, but some reckon that there were about two million professional GIS users worldwide in 2005 (Longley et al. 2005).

Meanwhile, GIS employment prospects are good in many locations. According to Richard Serby, president of GeoSearch Inc., a leading personnel recruitment firm specializing in the geospatial industry, employment opportunities in most sectors have already rebounded to prerecession levels in the United States, recovering faster than most other industries. Serby points out that Indeed.com, which aggregates job postings worldwide, listed more than 11,000 geospatial jobs just for the period February 15 to March 15, 2012. Half of the geospatial jobs had GIS in their titles, and all but a few jobs included GIS in their requirements.

Scoping the GIS Profession

In 2010, DOLETA issued a Geospatial Technology Competency Model (GTCM) that identifies the specialized knowledge and abilities that successful geospatial professionals possess. The GTCM is useful for geospatial workers, who can use it to guide their continuing professional development plans. Employers can use it for job descriptions and interviews. Students can use the GTCM to assess what they know, what they need to learn, and which educational programs fit their needs. Educators can use it to assess how well their curricula align with work force needs. And certification and accreditation bodies can use it as a basis for their requirements. The GTCM is freely available for use and reuse, without restriction, at www.careeronestop.org/competencymodel.

In addition to 43 essential competencies common to most of the geospatial occupations, the GTCM identifies 19–24 essential competencies for each of three industry sectors: positioning and data acquisition, analysis and modeling, and software and application development. The sectors represent "clusters of



The work roles of three geospatial professions cross boundaries of the geospatial industry sectors and overlap one another. Each profession has a "center of mass" within one sector. Not all geospatial professions are depicted.

worker competencies associated with the three major categories of geospatial industry products and services." The diagram above shows the scope of responsibilities for three geospatial professions in relation to the industry sectors and to one another.

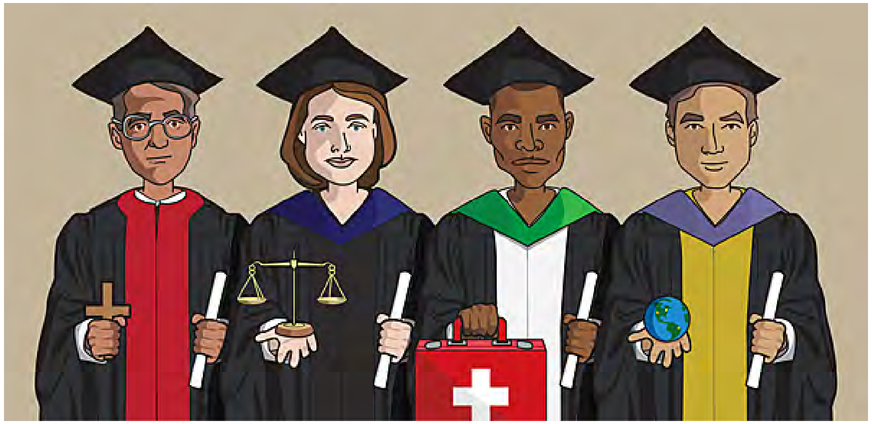
Debates about the rightful roles of GIS professionals arise because their activities tend to overlap those of other geospatial professions. Overlaps cause tensions but also afford opportunities for cooperation. J. Alison Butler, an experienced and outspoken champion of the GIS profession, points out that overlaps tend to be complementary. For example, professional surveyors and GIS professionals do many similar things but usually at different geographic scales ("Surveyors work at a 1:1 scale," Butler says, in contrast with GIS professionals, who "work at smaller scales and do not need to be so precise."). And although professional roles overlap, each geospatial profession exhibits a distinctive "center of mass," or concentration within one sector *(see diagram at left)*.

The GIS profession's center of mass is analysis and modeling. GIS professionals tend to be end users of geospatial data and software. They're employed in a wide range of allied industries, such as natural resources, government, and defense and intelligence. The character and geographic distribution of GIS employment differs from one industry to the next. However, the core responsibility of most GIS professionals is to use specialized software technology to render actionable information from geospatial data. In addition, many GIS professionals also acquire and process geospatial data (within the constraints of government regulation over data collection activities that pose risks to public safety and welfare). Others design and implement geospatial databases or develop customized software applications.

In this article, I define *GIS professional* narrowly, as one who makes a living doing GIS work. Some object to scoping the field so narrowly. Directions Media editor in chief Joe Francica points out that "non-GIS people are becoming more 'location aware' and thinking spatially." Gone are the days, Francica and others observe, when knowledge workers had to rely on "the map guy" to provide location-based information. Now "everyone is becoming a 'map guy.'" Even so, neither widespread access to mapping capabilities nor crowdsourced or "volunteered" geographic information have displaced GIS professionals. On the contrary, as the employment estimates above suggest, the demand for GIS professionals seems to be increasing even as location awareness proliferates.

GIS as a Learned Profession

Not everyone agrees that a GIS profession exists. Debates about whether GIS qualifies as a true profession date back more than 20 years. Today, however, by almost any definition, there's not much room left for debate. Consider, for example,



the definition of *learned professional* in the US Department of Labor's Fair Labor Standards Act (FLSA). To qualify as a learned professional under FLSA, a worker's primary duties must require advanced knowledge, involving the "exercise of discretion and judgment." Advanced knowledge "must be in a field of science or learning" (comparable to the traditional professions of medicine, law, theology, accounting, engineering, teaching, and others) and "must be customarily acquired by a prolonged course of specialized intellectual instruction."

Advanced Knowledge

The advanced knowledge that distinguishes the GIS profession is now well defined. The first comprehensive attempt to specify the knowledge that characterizes the broad geospatial field was the University Consortium for Geographic Information Science's (UCGIS) Geographic Information Science and Technology Body of Knowledge (2006). Building on that foundational work, DOLETA issued the GTCM in 2010. As discussed above, DOLETA also provides detailed descriptions of 10 geospatial occupations, including geospatial information scientists and technologists and geographic information systems technicians.

Specialized Education

Formal, specialized education is commonly included in GIS job requirements and is required for GIS professional (GISP) certification. Many thousands of students now pursue specialized certificates and degrees in GIS at colleges and universities worldwide. Some 7,000 colleges and universities worldwide—including over 85 percent of the institutions included in *The Times* of London's ranking of the top 400 institutions—maintain low-cost education licenses of Esri's ArcGIS software. And since

Esri made free, one-year educational software licenses available for individual student use in fall 2005, over 450,000 students worldwide have requested DVDs or downloaded the software. The availability of no-cost ArcGIS software that students can use on their personal computers has helped educational institutions offer advanced GIS education online for adult learners who can't put their lives on hold to participate in traditional campus-based education.

GIS seems clearly to qualify as a learned profession under the FLSA definition. The advanced knowledge that distinguishes the profession is well defined. Prolonged courses of specialized intellectual instruction are widely available, attracting large and increasing numbers of enrollments.

Professional Ethics in GIS

Professions are more than just occupations, and the distinction involves more than just specialized knowledge and education. One of the distinguishing characteristics of a profession is its specialized code of professional ethics.

In the early 1990s, Will Craig—another pioneer of urban and regional information systems and GIS—pointed out the need for a code for the GIS profession and set out to write one. Craig began by examining the existing codes in use in other fields. He found "surprising similarity" among them. Most reflected a "duty-" or "obligations-based" approach to ethics. "Obligations to society," he observed, "usually override other considerations" in the codes he studied. At its founding in 2004, the GIS Certification Institute (GISCI) endorsed the GIS Code of Ethics he completed (with help from many members of the GIS community) and later developed its own complementary Rules of Conduct. To qualify for certification as a GISP, applicants must pledge to uphold the code and rules. Coming to terms with its ethical challenges is another sign of a profession that is coming of age.

Certification and Licensure

Another distinguishing characteristic of professions is specialized certification or licensure. We typically think of these as mechanisms to ensure that individual practitioners are competent and trustworthy. However, another way to think about certification is as a road map for continuing professional development. GISCI has conferred its GISP certification on more than 5,000 professionals who document sufficient formal education, experience, and contributions to the profession. To qualify for renewal of certification, GISPs must document continuing formal education and contributions. These requirements strengthen the profession by ensuring that professionals "keep current in the field through . . . professional development" (GIS Code of Ethics Item II. 1.).

Unlike the state licensure required for professional surveyors in the United States, GISP certification remains voluntary (though one state, South Carolina, requires that surveyors who use GIS be licensed as "GIS surveyors"). In part, this difference is due to the fact that GIS is a much younger profession than surveying. However, recent developments suggest that GIS certification may not remain voluntary for long. According to Max Baber of the US Geospatial Intelligence Foundation, the US undersecretary for defense intelligence has mandated a formal policy for certification of geospatial analysts. The policy is to be in place at the National Geospatial-Intelligence Agency by September 2012. Baber believes that GIS professionals in the civilian side of government may be affected in the longer term. It appears that GIS certification is finally taking root.

GIS Professional Organizations

Another characteristic of GIS and other professions is specialized membership organizations dedicated to advancement of the profession. Such organizations typically aim to serve members through continuing professional development opportunities and through advocacy on their behalf in the policy arena. (A list of organizations for geospatial professionals is available at edcommunity.esri.com.) Voluntary, active participation in such organizations is one example of what GISCI means by "contributions to the profession."

Toward a Moral Ideal for GIS

The GIS field has all the trappings of a profession, including a distinctive body of advanced knowledge, specialized educational offerings, a code of professional ethics, mechanisms for professional certification, and specialized membership organizations. What's lacking is a certain ethos—a characteristic spirit evident in the shared beliefs and aspirations of mature professions like medicine, the law, and even accounting. Darrell Pugh, the author so often cited for his checklist of the defining traits of professions, includes one he calls a "social ideal." For Michael Davis, serving a shared "moral ideal" is a defining characteristic of all professions. Physician and ethicist John W. Lewis argues that a profession's "core product and service is [its] pledge to put the interests of others ahead of [its] own while providing [its] specific services." At the 2012 Esri Partner Conference, Jack Dangermond reminded attendees "we have a driving purpose to make a difference in the world."

How can the GIS profession advance society's interests? What is the GIS profession's moral ideal? For starters, here's my suggestion:

The GIS profession's moral ideal is to apply geospatial technologies and spatial thinking to design sustainable futures for people and places everywhere.

Challenges

The GIS profession is relatively young. It has weaknesses and faces some very real threats. Some critics question the profession's legitimacy, citing the facts that GIS professional certification remains voluntary and that no formal GIS accreditation process is in place to hold colleges and universities accountable. Others seek to monopolize the use of GIS and related technologies through government regulation. Given these challenges, GIS professionals need to do everything we can—individually and collectively—to strengthen our profession.

Seven Things Every GIS Professional Can Do to Strengthen Our Field

1. Become certified as a GISP or its equivalent (depending on where you are and what you do). Professional certification is a public commitment to competence, ethical practice, and continuing professional development. (Technical certifications like Esri's are valuable, too, but are no substitute for professional certification.) Formalizing that commitment, and fulfilling it throughout your career, is one of the most significant things you can do to strengthen your profession. And the larger your GIS professional community grows, the better your chances to control your own destiny.
2. Map out a professional development plan that includes continuing formal education and contributions to the profession. Whether you opt in to certification or not, use the requirements for renewal of GISP certification—and the GTCM—as guides.
3. Join and be actively involved in one or more organizations that advance the interests of the GIS profession. Wise employers will help support your participation. If you don't enjoy such support in your job, participate anyway and look for a better job.
4. Be able to explain the nature of your profession, its history, and its code of ethics.
5. Cultivate respectful working relationships with colleagues in kindred professions. Participate in efforts to increase cooperation among the geospatial professions but stand up for your profession when its legitimacy is challenged. Keep in mind that your adversaries are usually not your professional colleagues but rather the lobbyists and lawyers who stand to gain the most by monopolistic regulations.
6. Volunteer for GIS activities that benefit society. Help increase public awareness on GIS Day. Become a mentor for a schoolteacher who wants to teach with GIS. Volunteer to serve on an industry advisory board for a GIS certificate and/or degree program at a nearby higher education institution. Encourage such programs to use the GTCM to assess their curricula and students and to embrace accreditation.
7. Articulate a "moral ideal" for GIS that expresses your professional commitment to society.

So, what's your moral ideal?

About the Author

David DiBiase is Esri's director of education industry solutions. Before joining Esri in 2011, he founded the Penn State Online master's degree and certificate programs in GIS. As a member of URISA's Certification Committee, he helped design the criteria by which more than 5,000 GISPs have been certified. He is a past president of GISCI.

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URISA at 50

An Interview with Jack Dangermond


Jack Dangermond

URISA—the Urban and Regional Information Systems Association—will celebrate its 50th anniversary at the 2012 GIS-Pro Conference in Portland, Oregon, September 30–October 4. Here, Jack Dangermond shares memories of URISA's early years, as well as thoughts about its future. Dangermond earned URISA's Horwood Distinguished Service Award in 1988.

URISA—How and why did you get involved with URISA?

Dangermond—I was a young graduate of the Harvard Lab when Alan Schmidt advised me to attend the 1969 URISA meeting in Los Angeles. I wasn't really sure what URISA was, but I traveled to the meetings for three days and met many interesting people. It was there I first met Ed Horwood, Tom Palmerlee, Bob Aangenbrug, Bob Dial, and other people who introduced me to early concepts of urban information systems.

At that time, there were a lot of innovative people and organizations thinking about urban information systems in the Los Angeles area, and many of them showed up at the URISA meeting, for example, the Community Analysis Bureau (CAB) in the city and the Southern California Regional Information Study (SCRIS), an outgrowth of the Census Use Study activities sponsored by the Census Bureau in New Haven, Connecticut. People I remember meeting were Caby Smith, Matt Jaro, Ross Hall, Lee Johnson, Al Evans, Ken Duecker, and Mike Kevany. They were playing around with everything from the first generation of ADMATCH address geocoding and census DIME files to transportation modeling. I realized this was a special meeting where public-sector people, private consultants, and entrepreneurs were mixing and sharing ideas about applications of computers and information systems within local government.

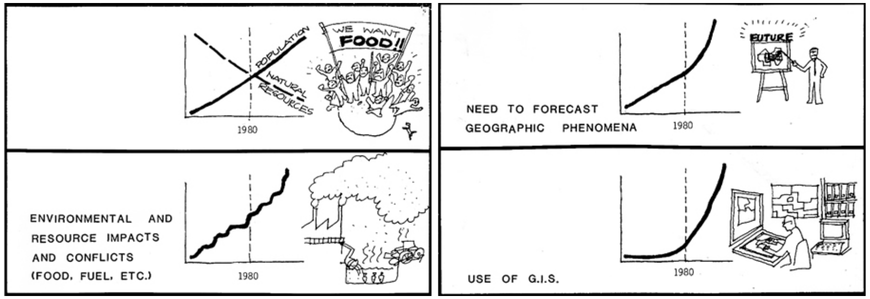
I discovered that URISA wasn't just another academic conference. It was a place where professional relationships were established and new concepts were discussed. In those days, the atmosphere of the meetings was highly charged and competitive. People were actively trying to forward their vision, create business, and get business. At least a third of the participants were consultants like me, who talked about their offerings and wares in various sessions.

I got one small computer mapping job for the 1970 election campaign for George Leyland, with whom I'd worked at Harvard and who later became head of the Federal Emergency Management Agency.

URISA—How did URISA evolve as the GIS industry matured?

Dangermond—I liked URISA because it provided a forum of colleagues where a young professional and entrepreneur like me could share my work. People were genuinely interested and would give me feedback. We talked about technology and approaches to the kinds of problem solving that eventually became known as urban GIS. This kind of open culture of sharing and learning flourished, especially during the 1970s and early 1980s. Around 1982 or 1983, URISA decided to invite vendors to exhibit at the annual meeting. At that point, the complexion of URISA began to change.

By the late 1980s, URISA had become identified with local government GIS. The membership grew dramatically into the thousands. But at the same time, the association took on a more commercial aura with a strong trade show emphasis. And as the GIS industry began to shake out, the trade show business fell off, and attendance also declined. Discussions shifted to planning, organization, implementation, and policy issues. Likewise, the original core people who had founded or nurtured URISA as a



Jack Dangermond produced these drawings by hand for the 1979 URISA conference. Here he looked into the future with 1980 as a near-future milestone.

venue for sharing ideas and best practices continued to come and dialog. I liked this. URISA gradually became one of the homes where GIS professionals could get together and discuss issues.

URISA—Which URISA people come to mind who really made a difference in the GIS field?

Dangermond—URISA's founder, Horwood, was a big influence on me. He was also a really fun guy. Horwood liked the idea of using computational methods for doing transportation planning. He especially liked getting people together to share their experiences in urban information systems.

Dial was another key visionary and influencer. He pushed some of the early thinking about urban information systems. His thinking, writing, and presentations led to a Housing and Urban Development program that funded experiments in implementing automated methods within cities around the country. This got the private sector interested in selling hardware, software, and services to build these experimental systems.

Dial was one of the first to envision how the multiple fiefdoms in cities could share common databases. I grabbed that notion personally to drive some of the concepts of urban GIS in the early days of ArcInfo, and it really worked. I credit Scott Morehouse for listening to my rants and systematically implementing a toolbox of tools that could be customized (using ARC Macro Language) to build application views to a common, shared database. We saw eager adoption—by planning departments, public works, land records organizations, and environmental agencies—of this vision of sharing a common GIS database.

Duane Marble was another early leader. Marble brought in systematic user needs assessment methodology and later the whole concept of doing geographic and GIS research in the academy. All this activity eventually led to the National Center for Geographic Information Analysis at Santa Barbara, California; Buffalo, New York; and Maine. Marble's research thinking, together with that of Aangenbrug and Roger Tomlinson, and others, helped balance out the somewhat aggressive commercial forces that were pushing URISA along.

URISA—Why did URISA gravitate to GIS?

Dangermond—URISA was, in a sense, one of the birthplaces of information system technology for local governments. This was a hot topic at the time—kind of like social networking is today. Remember that the best computers we had were huge, very expensive mainframes, and there really wasn't much of a database management technology at all. IMS [IBM's mainframe system] was a hierarchical data structure and considered the best of breed. This technology was designed primarily for accounting systems and financial back-office work. In those days, if you put simple things like property records into a database and could get lists of them, it was rocket science. So there was a need for a forum where people could come together and share, because computers and information systems were so new. Only a few people in transportation and urban planning were interested in computational approaches and database approaches. URISA brought these people together.

When GIS began to emerge as a commercial product in the late 1970s and early 1980s, it attracted more people from more organizations. They were excited to discover that GIS was a real information system just like an accounting system or a financial system or a permitting system, all of which had already been commercialized. So the introduction of a commercial off-the-shelf platform for sale from multiple vendors caused a stir and a lot of common interest. People and organizations wanted to buy these products because they saw their value, and there was lots of competition during the 1980s and 1990s for brands from different vendors.

URISA—Do you think Esri's User Conference has affected URISA?

Dangermond—Perhaps. As more organizations purchased and implemented this software, some of those who attended URISA to help select a platform now attend our conference because of its strong emphasis on supporting users with technology refreshers and training. What the User Conference does not replace is a forum for discussion of data policies, professional standards, new methods, new approaches—the kinds of conversations that URISA was known for.

URISA—Looking ahead, URISA has proposed a new emphasis on GIS management. What's your perspective on this potential new role?

Dangermond—Today, GIS is maturing as a technology and as a profession, and GIS operations within organizations are maturing as well. There's a need for a forum to bring together the professionals who are responsible for managing large, complex GIS operations. URISA is the logical place where managers come together to talk about how to use new technology and new methods to make cities better places.

I have, year after year, supported URISA because I believe it's one of the best places where local government professionals can get together and discuss their common interests with respect to information system technology. It was certainly one of the birthplaces of urban GIS and continues to have much to offer its members.

During URISA's first two or three decades, there was perhaps a greater spirit of excitement when the meetings were held. URISA's number-one asset was its ability to get people together to share ideas, renew old friendships, have a chance to share their work, get acknowledgment from friends, network, and also have a great party. These were the magical ingredients that kept URISA alive through thick and thin. Reengaging that spirit is what's needed. And the 50th anniversary conference in Portland this October is a good time and place to start.

See also "URISA's 50th Anniversary."

(This article originally appeared in the Summer 2012 issue of *ArcNews*.)

Sustainability in Africa

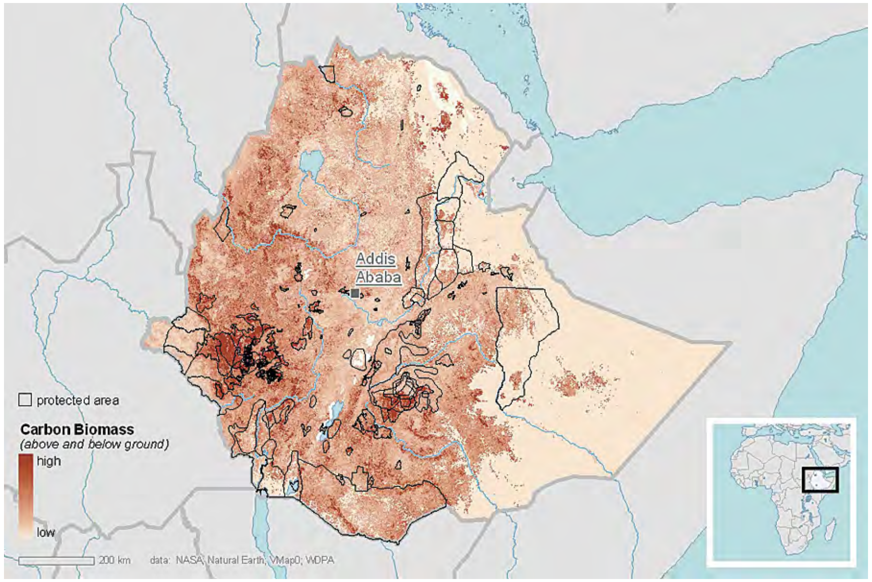
Peter A. Seligmann and Sandy J. Andelman, Conservation International

> *We need to take stock and attach value to our natural resources and ecosystems, such that we may include their value in planning and decision-making processes, as well as in our national accounts and balance sheets.*

Although His Excellency President Ian Khama of Botswana was speaking about Africa in his opening remarks to the first Summit for Sustainability in Africa, his words apply equally to the rest of the globe.

The goal of the summit, hosted in Gaborone last May by the government of Botswana and Conservation International, was to demonstrate how African nations and their investment partners understand, manage, and value natural capital to support and improve human well-being. The aim was to take a practical, results-focused approach, with African nations leading and encouraging investment partners to provide support in a coordinated and coherent fashion.

The term *natural capital* refers to earth's natural assets (soil, air, water, plants, and animals) and the ecosystem services resulting from them (e.g., food production, climate regulation, pollination, flood protection) that sustain human life.



This map was part of a series created for the first Summit for Sustainability in Africa, held in Gaborone in May 2012 to demonstrate the natural capital of participating countries. In this example, the ecosystem service of climate regulation through carbon storage is shown, along with the country's protected area network.

The visionary heads of state and ministers of 10 African nations—Botswana, Gabon, Ghana, Kenya, Liberia, Mozambique, Namibia, Rwanda, South Africa, and Tanzania—unanimously voiced their support for the value of natural capital in national accounting. These nations reached two key conclusions. First, there was unanimous consensus that the historical pattern of resource exploitation has failed to promote sustained growth, environmental integrity, and improved social capital and has, even worse, been counterproductive. Second, they agreed that the value of natural capital—the wealth of benefits provided to people by biodiversity and ecosystems, like watersheds, forests, coral reefs, and grasslands—must be fully accounted for and integrated into national and corporate planning, as well as reporting practices, policies, and programs.

The message resulting from the summit—the Gaborone Declaration—reaffirmed a commitment to sustainability already shared by these visionary leaders. The declaration signaled a new era of leadership, rooted in Africa, that understands, values, and manages the natural capital that sustains all of us: a platform on which we can begin to build a sustainable future.

Summit participants included Sam Dryden, director of agricultural development at the Bill & Melinda Gates Foundation; Laurene Powell Jobs, chair and founder of Emerson Collective; Rachel Kyte, vice president of sustainable development at the World Bank; Rob Walton, the chairman of Walmart; and numerous other private- and public-sector partners from within and outside Africa. These participants also issued a communiqué to draw attention to what they described as "the limitations of GDP [gross domestic product] as a measure of well-being and sustainable growth that values environmental and social aspects of progress."

In closing the summit, President Khama emphasized the importance of following through on these commitments. "This meeting will not be of any value to our peoples if we fail to achieve the objectives that formed the core of this summit, that is, integrating the value of natural capital into national and corporate accounting and planning," he said. "We must continue building social capital and reducing poverty by transitioning agriculture and extractive industries to practices that promote sustainable employment and the protection of natural capital while building the knowledge, capacity, and policy networks needed to promote leadership and increase momentum for change."

This is true leadership and an example we should celebrate and follow.

The Gaborone Declaration marked an important step in paving the way toward mutually beneficial partnerships between governments and businesses. A month later, at Rio+20—the United Nations Conference on Sustainable Development—these 10 African nations united under the Gaborone Declaration and emerged as global leaders. They urged others to join them in taking the first steps to correct what has been, up until now, a misguided development trajectory. They were followed by 49 other nations, developed and developing alike, along with nearly 100 public, private, and civil society partners, including ArcelorMittal, the Coca-Cola Company, the Bill & Melinda Gates Foundation, the German Development Institute, the MacArthur Foundation, the United Nations Environment Programme, the

United Nations Permanent Forum on Indigenous Issues, Walmart, Woolworths, the World Bank, and World Vision.

Measuring Sustainability: Getting the Metrics and Measurements Right

The recent Stiglitz-Sen-Fitoussi Commission on the Measurement of Economic Performance and Social Progress (2009) put it very clearly:

> *What we measure affects what we do; and if our measurements are flawed, decisions may be distorted. . . . Those attempting to guide the economy and our societies are like pilots trying to steer a course without a reliable compass. The decisions they make depend on what we measure, how good our measurements are and how well our measures are understood. We are almost blind when the metrics on which action is based are ill-designed or when they are not well understood. . . . We need better metrics.*

Ecosystem goods and services from natural capital provide an enormous contribution to the global economy, but natural capital has not been factored into conventional indicators of economic progress and human well-being like GDP or the human development index (HDI). Neither GDP per capita nor the HDI reflect the state of the natural environment. Both indicators focus only on the short term, giving no indication of whether current well-being can be sustained for future generations.

Many economists and politicians have become convinced that the failure of societies to account for the value of natural capital—as well as the use of indicators of well-being that don't reflect the state of natural capital—have contributed to degradation of the natural environment. We are using a flawed measurement approach to guide policy and decision making, and one key step toward achieving healthy, sustainable economies is to begin accounting for our use of natural capital. We must recognize and report the true cost of economic growth and our ability to sustain human well-being, both today and in the future. By incorporating the value of natural capital and ecosystem services, such as water provision, climate regulation, soil fertilization, or plant pollination, into our balance sheets, governments and businesses will be able to see a more holistic and accurate picture of natural and national wealth.

Sustainability and Food Security: Grow Africa and the G8 New Alliance for Food Security and Nutrition

Ann's story that follows is representative of hundreds of millions of farmers across sub-Saharan Africa. The continent's smallholder agricultural systems have inadvertently degraded vital ecosystem services like flood protection, water supply, and soil nutrient cycling:

Ann is 75 years old, a feisty grandmother in Wasare, Kenya, near Lake Victoria. She remembers five decades ago as a fish trader, when the water was clear, fish were abundant, the hilltops were green and lush, and harvests were plentiful. Now, she barely ekes out a living on her family farm. Like all her neighbors', Ann's field is planted with corn, but the soil underneath the rows of corn is gravely wounded and pale, drained of vital minerals. Gulleys scar the landscape, evidence of sustained hemorrhaging of fertile soils.

According to Jon Foley of the University of Minnesota, feeding the growing world population in the next 40 years will require producing as much food as we have produced in the last 8,000 years. This equates to a 70–100 percent increase in food production through agricultural intensification and expansion, mainly in developing countries. In this context, Africa is central to solving the world's food security and sustainability challenges. Africa contains 12 percent of the globe's land that is suitable for agriculture, but only 33 percent of this land currently is cultivated. Africa also offers significant opportunities to increase production on existing agricultural lands by filling yield gaps (i.e., the difference between current crop yields in a given location and the potential yield for the same location) using improved agricultural management and new technologies.

The harvesting of amaranth greens. (Photo courtesy of Conservation International. Copyright © Benjamin Drummond.)

Two other processes that focus on food security and involve many of the same governments and private-sector players are the World Economic Forum's Grow Africa Initiative and the G8 New Alliance for Food Security and Nutrition. These initiatives have been moving forward, largely independently of and parallel to the Summit for Sustainability in Africa and Rio+20, yet they underscore the importance and timeliness of the Gaborone Declaration.

Building on public-private partnership models piloted by the World Economic Forum's New Vision for Agriculture Initiative, Grow Africa is a public-private partnership platform. It aims to accelerate investments and transform African agriculture in accordance with national agricultural priorities and in support of the Comprehensive Africa Agriculture Development Programme, a program of the New Partnership for Africa's Development established by the African Union in 2003. At the Grow Africa Investment Forum last May, held at the glamorous African Union Conference Centre in Addis Ababa, seven African governments presented opportunities for multinational, private-sector investment.

Also in May, at Camp David (the US president's retreat in Frederick County, Maryland), the G8 countries announced the New Alliance for Food Security and Nutrition. The New Alliance, also a public-private partnership, is being promoted as a mechanism to raise 50 million people in Africa out of poverty over the next 10 years. The G8 committed $1 billion, together with $3 billion in pledges from 45 agribusiness companies, and is initially targeting Ethiopia, Ghana, and Tanzania. While applauding the focus on lifting 50 million people out of poverty, several African civil society groups and international organizations, such as the agency Oxfam, have criticized the alliance's top-down approach and its failure to bring smallholder farmers—particularly women—to the table. They have also voiced concern about its lack of attention to environmental sustainability.

We are clearly gaining traction and attention on these critical challenges, but we need to integrate our efforts to strengthen our collective impact.

Looking Ahead to Increased Sustainability

As stated by Kenyan Alex Awiti, director of the East African Institute at Aga Khan University in Nairobi, "A fundamental question underlies Africa's socioeconomic and environmental sustainability: How can smallholder farmers increase land productivity, profitability, and human well-being outcomes without causing irreparable damage to the natural world on which they depend?"

Africa's smallholder production systems, like global agricultural production systems, depend on essential natural capital—the ecosystem services produced by ecosystems at many spatial scales, such as rainfall and water captured by forests or from underground aquifers or vegetation from grasslands and savannas to feed cattle, goats, and sheep. As a result, solutions to the challenges faced by smallholder farmers require a landscape-level approach.

However, much of the existing knowledge of ecosystems and agricultural systems in Africa is local, fragmented, often inaccessible, and seldom mapped at the scales relevant for decision making. As a result, policy makers, farmers, and investors often make important land-use and land management decisions based on partial and incomplete understanding of landscape-level interactions and feedback.

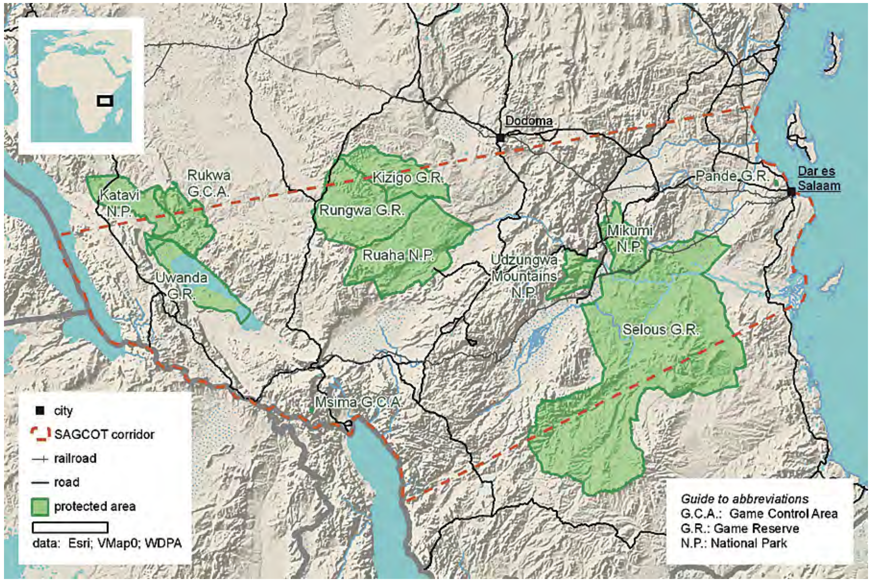
Without concerted investments in a framework with the right metrics, indicators, and data to track changes in ecosystem services and human well-being, gains in food production are unlikely to be sustainable in the long run. At worst, they may unintentionally degrade the environment.

Conservation International and partners have argued, therefore, for a new, holistic, evidence-based approach to supporting African agriculture, one that improves decisions on sustainable land use and land management and provides a holistic understanding of ecosystem health and human well-being.

Africa needs an integrated diagnostic and monitoring framework to generate data and information at appropriate scales to support decision making at household, national policy, and international and global investment levels: an instruction manual, if you will, to ensure that communities, investors, growers, and decision makers are operating in sync. Such a framework requires a strategically selected set of indicators that integrate information about land productivity, soil and plant health, biodiversity, water availability, and human well-being in a scientifically credible way. At the same time, the set of indicators must be small enough that decision makers aren't overwhelmed with too much information.

Farmers like Ann, African governments, and investors like the G8 and multinational corporations need a system of metrics and indicators that provide information at the right scales. These indicators are the missing piece that will help minimize environmental impacts of food production, as well as ensure that the well-being of Ann and millions of farmers like her across sub-Saharan Africa can be improved in a sustainable manner.

Over the last two years, with funding from the Bill & Melinda Gates Foundation, Conservation International has worked together with a broad set of science and policy partners to identify the right set of metrics for measuring natural capital. These metrics are intended to map the flow of ecosystem goods and services to people and to quantify the contributions of



Map showing the Southern Agricultural Growth Corridor of Tanzania (SAGCOT), where the government is attempting to transform agricultural development, increase food production, and reduce poverty through a targeted program of public-private partnerships. The corridor is critically important for maintaining natural capital and contains important protected areas that also provide revenue from ecotourism.

these services to human well-being. We tested this framework in southern Tanzania, including the Southern Agricultural Growth Corridor of Tanzania (SAGCOT), where the country's government is attempting to transform agricultural development, increase food production, and reduce poverty through a targeted program of public-private partnerships. The corridor [see ArcGIS map on previous page] is critically important for maintaining natural capital and contains important protected areas that also provide revenue from ecotourism. As with Grow Africa, some questions and concerns are being raised with respect to SAGCOT: whether it is commercially viable, whether large commercial farms will dominate the landscape at the expense of the region's poorest farmers, whether investments will be transparent, whether fears of land grabbing will be addressed, and whether there will be transparent processes for investments and auditing. Without access to integrated information on the socio-agroecosystems within the corridor—information that can gauge the success of the agricultural investments and the environmental and socioeconomic outcomes—there is significant risk that SAGCOT will fall short of its transformational goals.

Vital Signs Africa

Having identified the metrics and demonstrated the feasibility of making the necessary measurements at the right scales, we're ready to think bigger, act bigger, and dramatically scale up. Recently, Conservation International, in collaboration with Columbia University, the Council for Scientific and Industrial Research in South Africa, and the Earth Institute, launched Vital Signs Africa, an integrated monitoring system for agriculture, ecosystem services, and human well-being. The first phase of Vital Signs, funded by the Bill & Melinda Gates Foundation, focuses on regions in five countries in sub-Saharan Africa, including Ethiopia, Ghana, and Tanzania. These regions were selected because they are where agricultural transformation is targeted to meet the needs of Africa's growing population. Measurements will be collected through a combination of ground-based data collection, household surveys, and high-resolution and moderate-resolution remote sensing.

Currently, no African countries have environmental monitoring systems, and Vital Signs aims to fill that gap. The system emphasizes capacity building, working through subgrants to local scientists who will collect information and partnerships with existing data collection efforts, such as the Tanzania National Bureau of Statistics. It focuses on building local capacity for analysis and synthesis of spatial information, as well as on the capacity of African policy makers and institutions to understand and use this kind of information.

Data collection will happen at multiple scales to create the most accurate possible picture: a household scale, using surveys on health, nutritional status, and household income and assets; a plot scale to assess agricultural production and determine what seeds go into the land, where they come from, what kind of fertilizer is used, what yield of crops they deliver, and what happens after the harvest; a landscape scale (100 km^2) measuring water availability for household and agricultural use, ecosystem biodiversity, soil health, carbon stocks, etc.; and a regional scale (~200,000 km^2) that will tie everything together into a big picture to enable decision makers to interact with the information at the scales on which agricultural development decisions are made. High-resolution (e.g., QuickBird, WorldView-2) and moderate-resolution (e.g., Landsat, SPOT) remote sensing will provide wall-to-wall coverage.

Vital Signs aims to fill the crucial information gap, providing a set of metrics to quantify the value of natural capital for agriculture and for human well-being; using the right measurements at the right scales; and offering a set of indicators and tools to provide policy makers, farmers, and investors with the holistic understanding they need for better decision making.

These are long-term endeavors that will take time to realize but offer a smarter way forward as we work to build healthy, sustainable economies that support people and our planet.

The Geospatial World of Conservation International

Armed with an Esri nonprofit organization site license, for many years Conservation International (CI) has partnered with Esri and Esri Partners and users to provide data and geospatial analysis that has made a world of difference. To name merely a few, CI uses ArcGIS for the following:

- As the core analytical engine for its automated near real-time monitoring systems, serving more than 1,200 subscribers in Madagascar, Indonesia, Bolivia, and Peru
- To analyze trade-offs between multiple ecosystem services and stakeholders linked to land use and water quality management in the Great Barrier Reef, Australia
- To define site- and landscape-level conservation priorities in collaboration with regional partners to guide conservation action and funding in the Mediterranean Basin, Caribbean, Eastern Afromontane, Indo-Burma, and East Melanesian Islands biodiversity hot spots
- To analyze land use and natural resources to inform various development scenarios in the Cardamom Mountains of Cambodia to guide government policy makers

About the Authors

Peter A. Seligmann is chairman and chief executive officer of Conservation International and has been a leader in creating conservation solutions for the past 36 years. Since he founded the organization in 1987, Conservation International has earned a reputation as an organization on the cutting edge, creating innovative and lasting solutions to the threats facing humanity, biodiversity, and the natural systems that sustain us all. Dr. Sandy J. Andelman is the executive director of the Vital Signs Monitoring System and is a vice president at Conservation International. Vital Signs fills a critical unmet need for integrative, diagnostic data on agriculture, natural capital, and human well-being. Andelman has pioneered the creation of global monitoring and forecasting systems for climate change and ecological change.

For more information, visit conservation.org or vitalsigns.org.

(This article originally appeared in the Fall 2012 issue of *ArcNews*.)

The Geoscape: A New Canvas for Understanding

By Matt Artz, Esri

For many years, Bill Miller directed the development of Esri's training and support infrastructure. Later as an engineer/architect, he was intimately involved in the design of Esri's state-of-the-art corporate headquarters and conference center. Perhaps his best-known contribution to the GIS community was development of the ModelBuilder environment released as part of the ArcGIS Spatial Analyst extension. More recently, he came out of retirement to rejoin Esri and head up a new Geodesign Services effort.

Miller's vision for the integration of geospatial technologies with the design process was long shared by a group of people that included UC Santa Barbara's Michael Goodchild, Esri President Jack Dangermond, Harvard University's Carl Steinitz, and a handful of others. Miller took the first step toward making this vision a reality when he assembled a small team to develop ArcSketch, a free sample extension that allowed users to quickly sketch features in ArcGIS. ArcSketch was Esri's first small step toward what is now commonly referred to as "geodesign."

Beyond Landscape

While identifying the technology hurdles the geospatial industry needed to overcome in order to advance the concept of geodesign, Miller noted a fundamental contextual obstacle as well: our traditional approach to abstracting the landscape severely limited our ability to move forward with geodesign. We couldn't fully realize the vision of geodesign without a framework for a more holistic, comprehensive understanding of the world around us.

Different levels of understanding often require different levels of abstraction, and it's clear that's what was happening with geodesign. As TED founder Richard Saul Wurman has so succinctly stated, "Understanding precedes action." Design is action. Before we can design, we must understand. Geodesign—the act of thoughtfully creating the future for the mutual benefit of humans and the natural environment—requires a heightened level of understanding.

Understanding the world for the purpose of geodesign necessitated extending our view of geographic space. "This meant moving from 2D to 3D and to 4D, coupled with the idea that most data, at some level, is spatial and that all types of spatial data (physical, biological, social, cultural, economic, urban, etc.) can be georeferenced," states Miller. "This ultimately led to an expanded view of what is typically envisioned, or imagined, when referring to the *geo* portion of *geodesign*." He likes to call this new context for understanding our world "the geoscape."

Bill Miller shares his vision at the 2012 Geodesign Summit.

A New Context

Extending our traditional methods of abstracting the landscape to include 3D "provides us with the ability to georeference what lies below, on and above the surface of the earth, including what exists inside and outside buildings, as well as 4D geographic space, or how things change through time," Miller notes. "This gives us the added ability to georeference time-dependent information such as population growth or the migration of a toxic plume through a building."

Miller defines the geoscape as the planet's "life zone," including everything that lies below, on, and above the surface of the earth that supports life. The geoscape expands the view of what constitutes the content of geography as well as the dimensional extent of the geographic space used to reference that content. It gives us the context we need to actually do geodesign, "ensuring that our designs consider everything that supports or inhibits life."

Designing a Better World

The concept of the geoscape gives us the framework to extend our thinking and understanding of the world around us. As we move from thinking about only the surface of the earth to now including what's below and above the surface, we take into consideration the full spectrum of the earth's life support system. This represents a significant transformation in the way people think about geography, geodesign, and the application of geospatial technologies.

The geoscape gives us a new canvas for understanding, moving beyond traditional mapping for navigation and location toward using our maps for active designing and decision making. Moving from the landscape to the geoscape gives us the canvas we need for designing a better world. After all, as Miller is fond of saying, "The purpose of design is to facilitate life."

Read Miller's new paper, "Introducing Geodesign: The Concept."

(This blog post originally appeared July 30, 2012, in *Esri Insider.*)

Unlocking the Educational Potential of Citizen Science

By Daniel C. Edelson, Vice President for Education, National Geographic Society

I have been a fan of citizen science for many years, but I do not think the citizen science movement has had the educational impact that it could. *Citizen science* is the name for scientific research projects that engage members of the public in some aspect of their research. There have been some high-profile citizen science projects recently in which members of the public have conducted image analysis and solved protein-folding problems, but the overwhelming majority of citizen science projects involve crowdsourced data collection.

For example, some of the largest and longest-running citizen science projects are in ornithology. In projects like the National Audubon Society's Christmas Bird Count and the British Trust for Ornithology's Garden Birdwatch, birders contribute their observations to databases that scientists use to track trends in bird populations and species distributions.

These two projects, like many others, fall into a category of citizen science project that I call *community geography*. In community geography projects, the data is georeferenced and used for spatial analysis.

Community geography projects can be a boon for researchers. Volunteer data collectors provide investigators with the opportunity to obtain a quantity and geographic range of data that would not be practical through any other mechanism. They are also a boon to participants, who get to join a community; participate in something meaningful; and, in many cases, learn some new science.

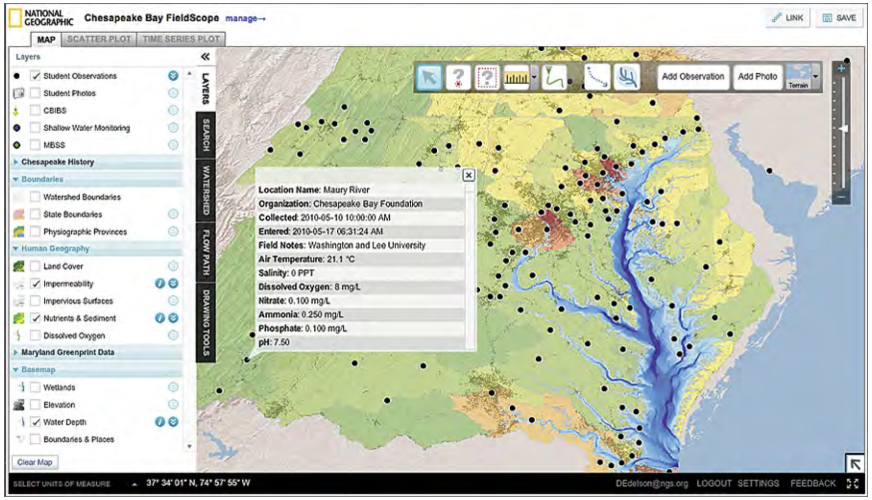
For as long as I've known about them, I've been fascinated by the educational possibilities of community geography projects. I'm a big believer in both inquiry-based learning and breaking down the boundaries between school and the real world. Community geography does both—except for one thing. Collecting data is only one part of the scientific process, and most community geography projects only engage participants in data collection.

In the stereotypical community geography project, participants take measurements or record observations and submit them to a central database for scientists to analyze. In some cases, participants are able to see a map of the data that has been submitted or see results of previous analyses that have been conducted by scientists. However, it is very rare that participants have a chance to create and interpret visualizations or analyze data themselves.

After talking to organizers of community geography projects, I've learned that most of them would prefer to provide their participants with opportunities to work with the data, but they lack the resources or expertise to create tools that would enable their participants to do their own visualization or analysis.

So, a few years ago, National Geographic—with support from Esri and others—set out to create a web-based platform for community geography that would provide participants with the ability to visualize and analyze their own data using GIS. We call this platform [FieldScope](). The idea behind FieldScope is that it is designed specifically to support citizen scientists—individuals who are interested and invested in researching a specific scientific question but who lack the training or technical skills of a scientist. This has required that we create easy-to-use interfaces and offer users a set of analytic tools that are either familiar or easy for a novice to grasp.

One of the first FieldScope projects that we deployed is dedicated to studying water quality in the tributaries to the Chesapeake Bay. Working together with environmental educators throughout the Chesapeake Bay watershed, we identified a set of water quality measurements that could be done by students and teachers across a wide range of grades, and we created a FieldScope application that displays not just student-collected water quality data but also a wide variety of data layers describing the land in the watershed, including land use, impermeability, and nitrogen yield.



A FieldScope map from the Chesapeake Water Quality Project showing a student's water quality measurement.

We also provided users with analysis tools that enable them to create time plots and scatterplots for the data that they have collected, and we implemented a set of hydrologic analysis tools that will help them understand the underlying dynamics of the watershed. For example, we have provided users with a flow path tool that allows them to click anywhere in the watershed and see the path that water will flow from that point to the bay. Users might employ this tool to see the portion of the river system that would be affected by a point source of pollution.

This Chesapeake water quality project has proved very popular in public schools; in the two years that it has been active, more than 600 teachers have received training on the software, and we have recorded more than 40,000 visits to the site. It is also succeeding in engaging users in analysis. In the first three quarters of 2011, we recorded more than 75,000 geoprocessing events and more than 45,000 uses of the query tools.

In the 2011–12 school year, both Fairfax County, Virginia, and Anne Arundel County, Maryland, have incorporated the project into their science curricula for all middle school students.

With support from the National Science Foundation, we are currently in the process of expanding FieldScope's functionality and creating authoring tools that will enable the broadest possible community of citizen science projects to build FieldScope applications for their own users. This spring, we will be launching FieldScope applications for two national community geography projects: Project BudBurst, which is studying plant phenology, and Frogwatch, USA, which is studying the distribution of amphibian species.

FieldScope, with its carefully designed user interface and specially selected GIS tools, is beginning to unlock the potential of citizen science as a learning experience. Teachers and students have responded enthusiastically to the opportunity to participate in geospatial analysis of data. In part, their enthusiasm stems from the fact that it's data about their own community that they helped collect. Administrators, in turn, are seeing that the entire experience of community geography is enabling them to achieve important learning outcomes for both science understanding and science skills.

Our goal over the next few years is to bring this powerful educational experience to as broad an audience as possible, young and old, in school and out.

For more information about National Geographic FieldScope and the Community Geography Initiative, visit natgeoed.org/fieldscope.

(This article originally appeared in the Spring 2012 issue of *ArcNews*.)

Thinking Outside the Map

Matt Artz, Esri

"That's another thing we've learned from your Nation," said Mein Herr, "map-making. But we've carried it much further than you. What do you consider the largest map that would be really useful?"

Source: http://archive.org/

"About six inches to the mile."

"Only six inches!" exclaimed Mein Herr. "We very soon got to six yards to the mile. Then we tried a hundred yards to the mile. And then came the grandest idea of all! We actually made a map of the country, on the scale of a mile to the mile!"

"Have you used it much?" I enquired.

"It has never been spread out, yet," said Mein Herr: "the farmers objected: they said it would cover the whole country, and shut out the sunlight! So we now use the country itself, as its own map, and I assure you it does nearly as well."

–Lewis Carroll, Sylvie and Bruno Concluded, 1893

Nothing beats the experience of directly interacting with the outside world. All five senses are involved: we see, we feel, we smell, we hear, and we taste our way through our world.

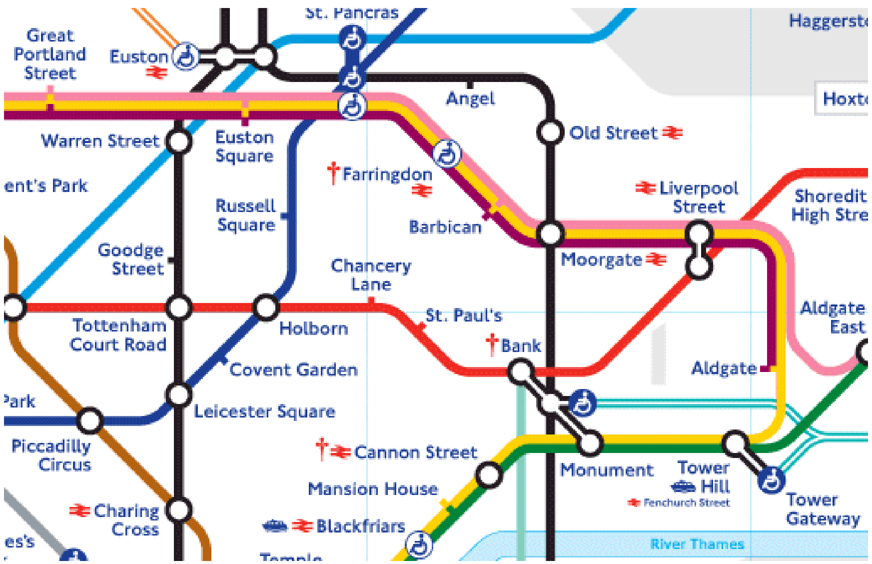
However, sometimes it's necessary for us to create *abstractions* of reality. These abstractions simplify things, letting us focus on the information that's most important for the task at hand without sacrificing understanding. Removing the extraneous elements helps us to cope with complexity. Think of a short story told to teach an important lesson; a simple diagram drawn to explain a complex system; or an elegant map created to demystify confusing geography.

By definition, maps are abstractions of geography. For centuries, these abstractions have proved to be invaluable to humans: information stored in map form has helped us communicate geographically and make better decisions. Maps have certainly played a key role in the advancement of humankind.

As fellow *Esri Insider* blogger and map lover [Bern Szukalski](#) pointed out in his recent post "[There's Something about a Map…](#)," maps have a number of advantages, such as:

- Maps are portable and reliable.
- Maps are not dependent on other technology.
- Maps are a platform for communication and collaboration.

Maps are both useful and wonderful; they can be highly utilitarian and amazingly beautiful at the same time. They have proven their



A tube map is invaluable, until you step outside of the tube.
Source: http://www.tfl.gov.uk/

usefulness, but they are not without their limitations. Many maps are context-specific. For example, a map of the [subway](#) system can be completely useless once you step out of the tunnel and try to navigate the remaining half mile to your destination on foot. Maps also have extent and scale. If you need to see an area just outside the map border, or need a higher level of detail for a particular area, then you need a different map.

While maps are still the dominant medium for sharing geographic intelligence, their usefulness has become strained as the world around us continues to increase in complexity. Enter geospatial technologies, which give us exciting new ways of abstracting and interacting with geography, allowing us to step outside of the limiting paradigm of a map.

With GIS we are not simply replacing paper-and-ink-based maps with maps on computer screens, but we are evolving and extending the definition of what "maps" are and how we use and interact with them. [At our fingertips](#) we have both vast collections of data describing our world at tremendous levels of detail, and the tools to quickly and easily create a virtually limitless number of custom "maps" for a multitude of purposes. The screens of our computers, smartphones, and tablets become windows into the wonderful world of geography, giving us access to the real-world platform beneath our feet. This concept of geography as a platform is creating a revolution in how we understand our world and plan for the future, all while avoiding the "paradox of the complete map" that Lewis Carroll so eloquently described back in 1893.

(This blog post originally appeared July 9, 2012, in *Esri Insider.*)

Place-Based Knowledge in the Digital Age

By Thomas Fisher, University of Minnesota

In Victor Hugo's *The Hunchback of Notre Dame*, the archdeacon holds up a book before the cathedral and says, "This will kill that. The book will kill the edifice."[1] Of course, we know that the printing press did not "kill" buildings. We still have cathedrals and books, and indeed, most books wouldn't survive very long unless stored in buildings.

But we also know that the book changed cathedrals, which had been thought of as "books in stone," with the stories of the Bible depicted in the statuary and stained glass of those buildings. We still have cathedrals today, but they no longer have to serve also as books, and so they have changed in fundamental ways, becoming more abstract in form, more diverse in function, and largely shorn of their didactic ornament.

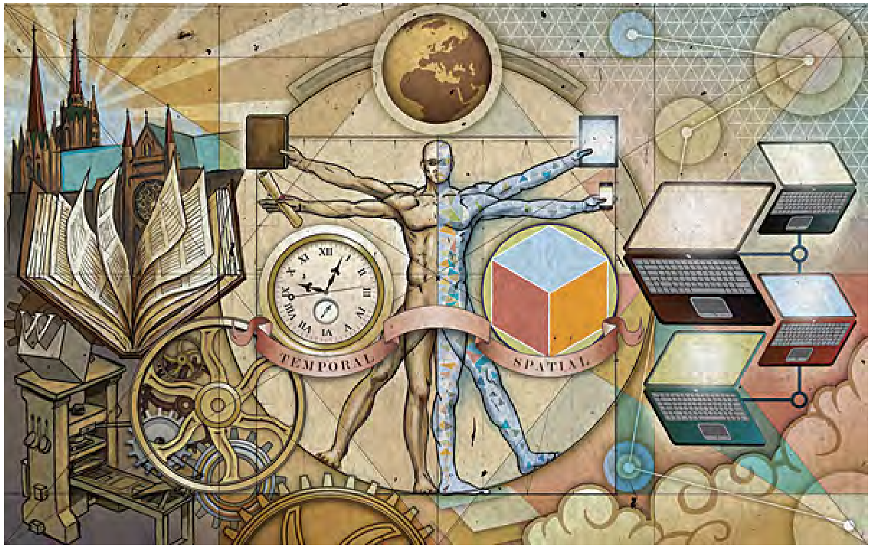
I mention this because we find ourselves at another moment in time where we could hold up a digital device—a laptop, tablet, smartphone, or e-reader—and declare, in front of either a book or a building, that "this will kill that." While we know that such devices will not "kill" books, or buildings for that matter, we have also gone far enough into the digital revolution to sense that digital media—and spatial media like geographic information systems—seem destined to have the same kind of effect as the printed book did beginning some 500 years ago.

This brings to mind the observation of Marshall McLuhan that each new technology "turns its predecessor into an art form."[2] Books will indeed survive the onslaught of downloadable e-books, but as we depend less and less upon books for information or even as the most convenient way to access information, we will increasingly value them as an art form, as McLuhan put it—as beautiful objects and works of great craftsmanship, exemplified in the rise of popular institutions such as the Minnesota Center for the Book Arts.

And what about Victor Hugo's claim that books ultimately trump buildings? Downloadable e-books have not "killed" the library as a building type, but as happened with the cathedral after the widespread adoption of the printing press, libraries have increasingly become places where people go to have experiences that they cannot find anywhere else. Like the modern cathedral, the modern library will likely have a greater array of functions; play a more social and less didactic role in people's lives; and, at least partly, lose the primary purpose they once served of storing large quantities of books. It may be that, in the future, we will go to libraries to admire the craftsmanship of books and then interact with others about what we have learned from the information we have downloaded on our portable devices.

The biggest effect of the digital revolution, though, may be less material and more metaphorical. As McLuhan argued, the "medium is the message," with major changes in media leading to changes in our metaphors and to the meanings that we ascribe to the world.[3] The mass-produced book led to a view of the world as a kind of machine, a metaphor that reflected the very thing that made this new media possible: the printing press. And that change in metaphor, in turn, led to many of the revolutions that followed: the Protestant Revolution in the sixteenth century, the Scientific Revolution of the seventeenth century, the Democratic Revolutions of the late eighteenth century, and the Industrial Revolution of the nineteenth century.

The machine metaphor lasted well into the twentieth century and paradoxically gave rise to the very technology—computers—that would ultimately overturn that metaphor. In the early twentieth century, we still heard people talk about the world in mechanistic ways, with intellectuals like Leo Tolstoy calling the body "a living machine"[4] and Le Corbusier calling the house a "machine for living in."[5] Later in the last century, we still heard such mechanistic analogies, such as the physicist Stephen Hawking regarding the "brain as a computer."[6]



Computing, though, also gave us the Internet. And with that, along with the miniaturization of computing in mobile devices, we have gradually realized that computers represent not just a faster form of computation but an entirely new medium, which has brought with it a new metaphor that increasingly dominates our view of the world. It took machines, in other words, to move us from a mechanistic view of reality to a networked one. We no longer view the brain as a kind of computer, but instead as a neural network; no longer speak of society as a well-oiled mechanism, but instead as a social network; and no longer see the human body as a machine, but instead as part of the web of life.

This shift in metaphor matters even more than the media that has prompted it. We will, of course, continue to use machines just as we will continue to use books, and so our material world will remain layered with technologies of the past as well as the present. But when we start to think of ourselves and see the world differently, big things begin to happen, as we saw in the wake of the printing press. Human relationships and social structures change, as we have already seen in the "Arab Spring" revolutions taking place in areas like North Africa, fueled by the crowdsourcing capabilities of cell phone technology; in the micro-lending revolution in the developing world, enabled by the financial transfers possible through social networks; or in the green revolution going on around the world, empowered by our access to information formerly out of reach of ordinary people. The metaphor may ultimately be the message that matters.

The Ecology of Being

This metaphor of the world as a network or web will alter our intellectual lives as well. The old machine metaphor privileged physics, mechanics, and engineering—three of the fields most closely associated with mechanisms. The new web metaphor, instead, draws from fields like biology and ecology, seeing in their understanding of how natural ecosystems work a parallel to the networked world we now occupy and informing us about human ecosystems and how they relate to each other in particular places.

The increasingly weblike way of seeing the world, in turn, has profound implications for how and in what form we will seek information. The printed book offers us a linear way of doing so. We begin at the beginning—or maybe at the end, with the index—and work forward or backward through a book, or at least parts of it, to find the information we need. Digital media, in contrast, operate in networked ways, with hyperlinked texts taking us in multiple directions, social media placing us in multiple communities, and geographic information systems arranging data in multiple layers. No one starting place, relationship, or layer has privilege over any other in such a world.

The linearity of the book, compared to the multiplicity of the web, leads to an even more fundamental shift in how we assess reality: from a temporal to a spatial one. Like reading a book, we see time as an arrow, a linear path with starting and ending points. While we learned from Albert Einstein that we could slow time down depending upon how fast we accelerate, we cannot reverse time or occupy different speeds of time at the same time. But that is not the case with space. Like the web, we can manipulate space, move in multiple directions within it, and reverse it—tear a space down, for example—if we choose.

The worldwide web, of course, often seems aspatial. It connects us to people and places not in, and often far from, the actual spaces we occupy. Indeed, this new weblike way of engaging in the world appears to have collapsed both time and space, making everything that ever existed anywhere in the world immediately available to us, as if temporal or spatial distance no longer mattered. Such effects, however, disguise the essentially spatial nature of digital media. The laterally linked and complexly networked nature of the web gives it a spatial form, conceptually if not always physically. And the layering of data and simultaneity of information through the web makes it place-based, even if that "place" exists in virtual space.

This line of thinking, in turn, suggests that the current way we store information—through digital documents and files—and distribute it—through e-mail, e-books, e-zines, and the like—may represent a transition stage in this technology. Such formats mimic the forms that emerged from the printing press and paper technology and, because of their familiarity, have enabled us to adapt to the access of digital information more easily. But they also reinforce a linear way of thinking about information inherently at odds with the weblike way in which we increasingly see the world.

GIS will eventually become a major way—perhaps the dominant way—in which we will access information in the future because of the essentially spatial nature of that software. Rather than see information as discrete bits, accessed linearly and temporally, like moving along a necklace of data, GIS layers information spatially, linking it according to its relevance to other data on a given layer and according to its relevance to all the other layers in a given place. It allows us to "map" information, which may become the primary way we organize, access, and distribute knowledge in the future.

This use of spatial tools to match the spatial nature of a web will have a profound effect on how we think about information itself. The book led us to see information in highly discrete ways. By packaging related content between two covers, books encourage us to see knowledge as a set of distinct disciplines, each with its own discourse and eventually its own set of assumptions and use of language that made it increasingly hard for anyone else not in that discipline to understand. And by sorting information according to disciplines, books enabled us to think of knowledge divorced from any particular physical or conceptual space. As a result, we can take almost any subject—say, water—and find that topic addressed in myriad ways by many disciplines—the sciences and social sciences, literature and history, art and poetry—all located in different places in a library and all addressed in different ways through different disciplinary lenses.

That way of organizing knowledge has served us well in the last several centuries as we have sought to understand and control the world around us. But it's gotten in our way in recent decades, as we have come to realize the damage we have done to the world and the threat that that poses to our civilization and to us. It has led, for example, to what Adam Smith called the paradox of value, when he asked, at the beginning of *The Wealth of Nations*, why we so value diamonds that have so little real use, and why we don't value water, without which we cannot live.[7] By dividing information into discrete, disciplinary units, we have created what we might call the paradox of knowledge: in which we have so much information about the world and yet remain so ill informed about our effect on the world.

This suggests that we may need to arrange knowledge differently in the future, not according to disciplinary categories, but instead according to spatial phenomena and, as Smith would say, to the things without which we cannot live. GIS offers one way of doing so. While the data-rich digital mapping of GIS arose, initially, to ease geographic analysis and enhance spatial decision making, it has the potential to organize knowledge in ways that align more closely with the ways in which the world itself is organized: spatially.

That may make sense in spatially oriented fields, like geography, forestry, or planning, but how, you might ask, does that make sense for fields that appear to have no spatial equivalent: philosophy or pharmacy, history or histology, literature or linguistics? It's a good question, but maybe the wrong one to ask. It may be that we need to stop asking how to preserve our disciplines, which, for all their value, remain abstractions of or at best partial views of the world, and instead start asking how to preserve what remains of the natural world, which our disciplines, if they have any value, need to serve.

Spatializing Knowledge

How might GIS help us spatialize knowledge? Rather than organize knowledge by type or discipline, we could use GIS to embed all the knowledge relevant to a place in the myriad layers of information about it. And as we scroll over a place, we can select the pertinent layers and begin to see the relationships among disciplines and the connections among data. So many talk about the need for interdisciplinarity, but as long as we organize knowledge in disciplinary silos, the connections among disciplines will continue to elude us. When we instead begin to organize knowledge spatially, the connections come to the fore, as we focus less on the layers and more on the overlay of them and on their relevance to particular situations.

This, of course, may seem too much to ask: the reorganization of knowledge and the spatializing of education. We have, however, managed over the last couple of centuries to temporalize education. Every field has a history, and almost every one requires that students study the history of the discipline as part of knowing it. Indeed, historical understanding has become such a part of what we define as an educated person that we take it almost for granted, but it wasn't always so. It wasn't until the nineteenth century that we assumed, as Georg Hegel argued, that we couldn't fully comprehend anything without knowing its history.

In the first decades of the twenty-first century, we need to see that the same holds true for space as much as it does for time. We cannot fully understand any field without also spatializing it, without also seeing how it relates to every other discipline as they come together in particular places, with a given group of people, in specific social and environmental contexts. We need to know how disciplines evolved over time, but we also need to know how they, so to speak, hit the ground and how they play out as part of the web that constitutes the whole of a place and of the people there.

This does not mean that we should see such spatial analysis as an end in itself. Except for historians, we rarely study temporal phenomena—history—as an end in itself. In most fields, history serves as a means to an end, as a way of better understanding how the present came to be and what the future might hold. The same is true for a spatial understanding of our fields. Except for a few fields, like my own field of architecture, which does study space as an end in itself, most disciplines will likely see this weblike, spatial turn in our thinking as a means of understanding their subject in new ways. Space represents, like time, an a priori condition, as Immanuel Kant argued—a precondition to everything else, and so having a sense of the relationship of space and time—how a field evolved spatially as well as temporally, what happened where as well as when—will increasingly become necessary to fathom how we have done so much damage to so many places and to the cultures of so many people on the planet even as we purportedly know more about them.

The spatializing of knowledge via its mapping onto places has another advantage as well: it becomes a visual way of conveying information across the barriers of language and to the growing percentage of the human population that remains illiterate. The book divides the literate and illiterate and, as such, has helped reinforce the power of the former over the latter. Hugo understood that when he had the archdeacon hold up the book as killing the building. The medieval cathedrals spoke to both the literate and illiterate and, in some respects, the book made large stores of knowledge inaccessible to the latter.

The digital divide threatens that as well, with the wealthier parts of the world having much more access to information than the poorer parts. The web and cloud computing may help end that division by making most of what we need to know available at low cost, with "dumb" devices able to access information anywhere in the world. But there remains the problem of literacy, as well as translation, and so closing the digital divide through such devices will only partly close the gap that exists between those who have access to knowledge and those who don't.

We may never close the latter until we spatialize knowledge through the use of visual tools like GIS. Enabling people to see the information relevant to their lives, whether or not they can read, and to map it to the places they know to understand the conditions that affect their lives, could have a transformative effect in empowering those who have been left behind by the book and even by the early incarnations of the computer.

GIS may represent the leading edge of computer mapping and visualization technology, but it also signifies, in some respects, a return to the world that Hugo's archdeacon saw as threatened. This brings to mind the observation of the novelist and semiotician Umberto Eco—that modernism represented a premedieval condition, which suggests that our post-postmodern world may have more characteristics in common with the medieval world than we have recognized.[8]

If the medieval cathedral tells its stories in stone and glass, GIS tells them through layers and overlays. Both do so visually and spatially, both speak to viewers whose language or even whose literacy may not matter, and both reveal relationships and meanings that no book could ever capture. At the same time, the medieval cathedral and digital cartography both have the power to move us to action, to help us see things with our own eyes and without the interpretation of an author who might want to edit what we know or affect what we think.

Just as the book helped give rise to the Protestant Revolution, in which people wanted to read the Bible for themselves and make up their own minds, so too might the visual and spatial power of GIS someday give rise to a secular version of the same, in which people, protesting the power of a few to control so much of the knowledge about the world, will want to see that information for themselves and make up their own minds.

Geodesigning the Future

This leads to my final point about the spatializing of knowledge. The temporalizing of knowledge has, through the agency of history, helped us understand the past and possibly comprehend how the present came to be, but rarely do we venture very far into the future. We call that science fiction or fantasy to set such future-oriented thinking apart from what we can reliably know about the world as it is or as it once was. And we tend to see such work as somehow of lesser quality or validity than what the sciences, social sciences, and humanities offer.

But spatial understanding has a different relationship to the future, as well as the past and present. Spatial knowledge recognizes place, rather than time, as the ultimate continuity in our lives. And while none of us can see the future as a temporal idea, we continually imagine the future of places, projecting possible spatial arrangements based on what we see around us.

The design disciplines do this all the time, using spatial means to imagine what could be, envisioning the future of a place, product, or environment, and depicting that visually for others to see. We commend or criticize a design and accept or alter it to fit our idea of what should happen in a particular place or with a particular product. We don't consider design a lesser discipline, simply a different one, operating according to its criteria and assumptions.

I mention this because the leading edge of GIS rests with the idea of "geodesign," the use of geographic analyses of what is as the basis of making design decisions about what could be. Rather than see future-oriented thinking as somehow fiction or fantasy, geodesign allows us to connect what we know about the world with what we might want the world to be. Just as GIS can serve as a means of organizing knowledge spatially, geodesign might serve as a means of projecting that knowledge into the future and assessing its merits based on what we know about a place.

Why does this matter? Because we stand on a similar precipice as Hugo's archdeacon, with even more drastic implications. We might well say that "this will kill that," but in our case, "this" represents modern civilization and "that," the natural world. Since the rise of the book, although not necessarily because of it, we have devised a Ponzi scheme with the planet over the last couple of centuries, exploiting natural resources, other species, foreign cultures, and even future generations to keep those at the top of this pyramid scheme enriched.

As we know from the collapse of other, smaller Ponzi schemes, such frauds cannot last. They tend to collapse suddenly and without warning, and those most enriched by the scheme—us—have the farthest to fall. The only way we can avoid such a fate is to realign our relationship with the natural world, to reorganize our considerable knowledge about it to reveal the forces that lead to our unsustainable practices, and to relearn how to steward what remains of the planet we have so altered. And if we don't, we have only to alter the terms of Hugo's observation only slightly. *This*—the collapse of our Ponzi scheme—will kill *that*—the civilization we have built up over the last 200 years.

The spatialization of our knowledge, in other words, isn't just an academic exercise or the result of some arcane interest of a few spatial thinkers or GIS specialists. With it, we can begin to set the foundation for a more sustainable future for ourselves as we see the impact of our actions and the relevance of our knowledge to the particular places in which we live. This will not kill anything except the ridiculous illusion that we can continue to live beyond the carrying capacity of our planet. And doing so is not just about space; it's about time!

About the Author

Thomas Fisher is a professor in the School of Architecture and dean of the College of Design at the University of Minnesota in the Twin Cities. This paper is based on Fisher's keynote address to the GeoDesign and Spatializing the University meeting of the Big 10 university librarians, May 2012.

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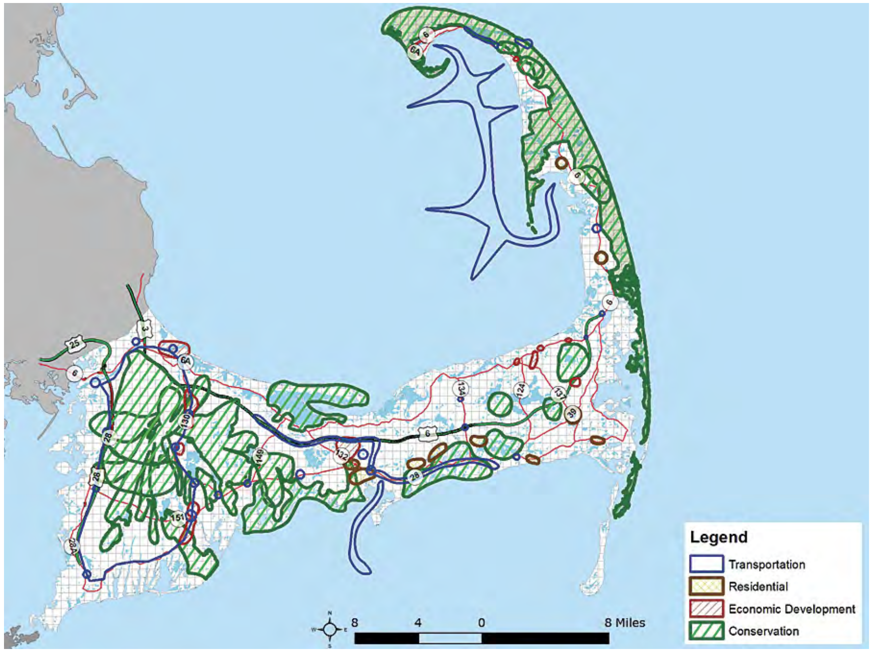
Can Geodesign Help Us Adapt to Climate Change?

By Jack Dangermond, Esri

The earth's climate is changing, leading to serious problems for humanity in areas such as food security, health, and public safety. We need to adapt swiftly. But where do we start? Should we reinforce or rebuild existing structures? Or should we abandon existing settlements and relocate the population in some cases? And how can mass rebuilding/relocation efforts be best accomplished from human, environmental, and economic perspectives?

Geodesign is a framework for understanding the complex relationships between human-designed settlements and the changing environment, for quickly planning ways to adapt existing communities and build new ones in a more sustainable manner. This methodology helps us assess risk, identify change, create synergies, develop strategies, adapt to change, and monitor the results. Geodesign takes an interdisciplinary, synergistic approach to solving the critical problems of future design—to optimize location, orientation, and the features of projects at local and global scales.

How can geodesign help us adapt to climate change? I recently asked this question at the Spatial Roundtable (www.spatialroundtable.com), where geospatial industry thought leaders share their perspectives about concerns, trends, challenges, and technologies. Participants in the Spatial Roundtable offered thought-provoking insight into the role of geodesign in climate change adaptation, and I would like to share some important points made by several contributors.



This climate change scenario planning study for Cape Cod demonstrates the communicative power of geodesign using spatially informed models, fast feedback, and a large format sketching environment.

Designing Our Future

"Geodesign proposes to support decisions about the surface of the Earth through a combination of two sets of tools: one to allow designers to sketch proposals as they appear in map form, and the other to provide scientifically sound assessments of proposals through the execution of computer-based models," said Dr. Michael Goodchild, professor of geography, University of California, Santa Barbara. "For example, a designer should be able to sketch a design for a development near a coastline, and to evaluate it based on scientific models of sea-level rise, as well as pollution of air and water, impacts on traffic congestion, and other environmental and social dimensions. By including projections of the effects of climate change, this approach offers a coherent and scientifically based way of addressing key decisions about development and land-use change."

A Global Dashboard

"If we really want to feed 9 billion people by the middle of this century, we need spatial data systems with real-time monitoring capacity and a data dissemination capability that can reach all stakeholders directly," said Dr. Wim Bastiaanssen, cofounder, eLEAF. "Without daily updates of intelligent, pixel-based data components, the great capacity of geodesign will not reach its full potential to support daily decisions in natural resources management—and become more climate resilient across the world. A data-enriched geodesign system supports authorities, policy makers, water managers and individual farmers to make firm decisions. Geodesign principles fed with quantified crop, water, and climate data components must become one click away for everybody."

Scenario Development

"I am especially interested in the role geodesign might play in environmental scenario development," said Dr. Elena Bennett, assistant professor, McGill University. "Scenarios, sets of stories about the future, can be a useful technique for thinking about a range of potential futures. In the environment, scenarios are often used to understand situations of uncontrollable or unpredictable futures, of which climate change is a classic example. Environmental scenarios can be qualitative or quantitative, and are often associated with images, but rarely with maps. I am interested in the potential for mapping scenarios, and for using geodesign as a way to bring together multiple disciplines to improve development and understanding of environmental scenarios in situations of climate change."

Integrating Knowledge

"Geodesign, by bringing multiple disciplines into a common geographic perspective, is the ideal integrator—helping societies identify those regions and policies where the interactions between climate stress and differing socioeconomic conditions are likely to make the most difference," said Dr. James Baker, director, Global Carbon Measurement Program, William J. Clinton Foundation. "The resultant visualization and modeling will give guidance on the most efficient and effective ways to adapt both in the short and the long term. The long-term impact of climate change looms large—the sooner we can begin to adapt with tools like geodesign, the more resilient our societies will be in the future."

The Issue of Scale

"GIS, as a spatially based technology, offers a powerful approach to both the sketch and assessment aspects of geodesign, allowing decisions and their impacts to be investigated at a full range of scales from the very local to the global," said Goodchild. Dave Williamson, founding partner, Cascade Environmental Resource Group, agreed that scalability is a key issue: "Climate change is a global issue, and the models tend to operate at a global scale. However, planning decisions must consider meso-scale influences, while implementation generally takes place at a regional or local scale."

A Responsive Framework

"Geodesign should strive to provide a systematic and consistently applied methodology for assessing risk and potential outcomes," added Williamson. "The current state of the science of climate change is such that new information is coming to light on a regular basis and yesterday's accepted fact is tomorrow's fallacy. Geodesign should provide a dynamically responsive framework that can accommodate the ongoing shifts in the climate change model. When it comes to planning in response to climate change, the future will belong to the speedy and the integrated."

Moving Forward

"The geodesign framework is to be welcomed as another powerful arrow in the quiver of approaches and tools that will help us to plan and implement climate-smart development measures," said Gernot Brodnig, geographer, World Bank. "The time for implementation of strategic and tactical projects based upon this understanding is now," added Dr. Nguyen Huu Ninh, Nobel Prize winner and chairman of CERED. "Making wise decisions to accommodate emerging changes will have major positive impacts on the health, security, and prosperity of populations in high risk areas around the globe."

I'd like to thank all of the Spatial Roundtable participants for their valuable insights on this important topic. You can read the complete responses here.

(This blog post originally appeared April 23, 2012, in *Esri Insider*.)

Break-the-Mold Approaches to Geography Learning

By Daniel C. Edelson, Vice President for Education, National Geographic Society

Before you read this column, I want you to pause for a moment to consider the following question: How could we make geography learning more enjoyable for young people?

My nonscientific research indicates that about 1 percent of the general public enjoy learning geography so much that they cannot imagine a way to make it more enjoyable (you know who you are). The rest of us tend to generate ideas like making geography learning into a game, making it more relevant, or adding rewards.

I don't think people's answers to the question are nearly as interesting as what flashes into their minds when asked to think about geography learning. My nonscientific research on this reveals that most of us picture very traditional classroom activities: memorizing place-names and locations, learning to interpret maps, reading about foreign cultures, analyzing population pyramids, and tracing migration paths. Two things tend to characterize that image: it doesn't feel relevant or useful to the learner, and it doesn't feel inherently enjoyable. So when we think about improving geography learning, we think about how we can change those experiences.

There are a small number of people out there, however, who summon up very different images when they think about geography learning. Maybe they never experienced traditional geography education, or maybe they experienced it and have completely rejected it as a model for learning. They envision activities that feel both relevant and enjoyable. These are the people we need to find and listen to, because they don't think about improving geography education by incrementally improving traditional approaches. They think about completely new approaches to geography teaching and learning.

One place where you can find people like that is in the Geography Collective, a group of innovative thinkers in the United Kingdom. They describe themselves in the following way: "We are a collective of geography activists, teachers, therapists, academics, artists, and guerrillas. We've come together to encourage [young] people to see our world in new ways."

The Geography Collective's Mission:Explore website.

The members of the Geography Collective characterize themselves as "guerrilla geographers," and their goal is to engage others in guerrilla geography. By their definition, guerrilla geography consists of "operations carried out by small, independent geographers to cause thought [and] connected thinking, stimulate the public, and to wear down public resistance to geography, usually carried on by a number of small groups behind public lines or in occupied spaces. . . . Guerrilla geography is irregular [direct action] educating."

Its approach to engaging people in guerrilla geography is through a set of miniadventures that are designed for young people to do by themselves or with adults. These adventures—or "missions," as the Geography Collective calls them—encourage exploration. They challenge participants to explore either new or familiar places with new perspectives.

These missions are always quirky and often have a sense of playful mischief about them. One mission asks explorers to locate places where one neighborhood ends and another begins and then explain how they know. Another asks them to "go outdoors in search of the most beautiful poo you can find [it's a kid thing]. When you discover it, take a picture of it." A third asks them to explore the world from a bug's-eye view by taking macrophotographs. And a fourth, called Avoid Seeing Red, instructs explorers, "If you see red, shield your eyes, look irritated, and walk in another direction."

The Geography Collective shares its missions with children, parents, and educators through a series of books and a website, Mission:Explore. The website offers points for completing missions and allows explorers to collect points toward "badges" as rewards.

Behind the playfulness and quirkiness of the Geography Collective's missions are carefully considered philosophical and educational stances. One is that young people should be encouraged to explore their surroundings and express their own opinions about the positive and negative aspects of different spaces. Another is that they should recognize their own role in shaping the world. Underlying all of what the Geography

Collective does is the goal of teaching geography as a method for observing the world and deciding how to act in it.

The Geography Collective does not position its approach to geography learning in opposition to traditional geography or even as an alternative. It presents its approach as providing an additional set of experiences that are disappearing from the modern world, where children are taught that all the interesting things in the world have already been discovered and adults believe it's more important to protect young people from the hazards of the world around them than to give them the chance to explore it.

The Geography Collective is one of the most creative groups in geography education today, and every time I learn more about its work, I get more excited about it. However, I do find myself wishing that creative approaches to geography teaching and learning were not so unusual. This is just one transformative approach to geography learning, and it is not going to resonate with everyone. Where the Geography Collective's approach is quirky and playful, others might be practical and serious—but equally effective and motivating to learners.

I can't help feeling that truly creative approaches to geography learning are discouragingly few and far between right now. Too few people are even thinking about geography education, and those who are still focus too much on incremental improvements rather than entirely new approaches. We should take the Geography Collective members and others like them as inspiration. We must challenge ourselves to think more creatively and seek out and promote the creative ideas of others.

(This article originally appeared in the Fall 2012 issue of *ArcNews*.)

Monitoring Our Planetary Pulse

Global Dashboards Help Us Make Sense of the Sensor Web—and Our Planet

By Matt Artz, Esri

Geography has for many years been concerned with exploring and describing our world. Historically, explorers commanded grand expeditions to the farthest reaches of the globe. This golden age of exploration contributed greatly to our understanding of how our world works.

This was followed by the space age—an era where we left the planet and turned our cameras and sensors to look back on our home, giving us an entirely new perspective. Bound to the surface of earth for millennia, humankind was getting its first opportunity to look at our planetary system as a whole—from a few hundred miles up in space.

While data remotely sensed from satellites continues to play an important role in monitoring and understanding our planet, "earth observation" has more recently taken on a whole new dimension thanks to deployment of an increasingly complex and pervasive network of earthbound sensors. These sensors are practically everywhere you look—as well as in places you could never imagine. From stream gauges to seismographs, from weather stations to air quality monitors, from ocean buoys to even our cell phones, countless sensors are measuring and collecting important data about our planet at a rate that seemed impossible just a short time ago.

We're collecting more information about the geography of planet earth today than ever before. New data sources, along with the sheer volume of data being collected, are spawning a new age of exploration. But the new explorers are navigating a vast, uncharted sea of data. What do we do with all of this sensed data? How can we make sense of the sensor web?

A Global Dashboard

Modern science and advanced technology have resulted in unprecedented access to global environmental information through the placement of countless sensors across the planet—and the linking together of this information through the Internet. The sensor web has inundated us with data that needs to be stored, managed, analyzed, and used to inform better decisions about our many social and environmental challenges. Integrating and synthesizing all this disparate sensor data into a single, comprehensive view—a global dashboard—is our next great opportunity for exploring our world.

The dashboard of your car presents you with high-level feedback on the current status or "health" of various subsystems that make up your vehicle. It's designed such that a simple glance gives you a quick summary of the status of the entire car. This leads to an understanding that informs your driving decisions and determines your actions.

As our planet speeds toward the future, all passengers on 'spaceship earth' can benefit from a simple, easy-to-understand, dynamic overview of the health of our planet. A "global dashboard" is a decision support tool to help us monitor current conditions, identify change, and drive informed action. This tool would operate as a framework for taking many different pieces of past, present, and future data from a variety of sources, merging them, and displaying them in an easy-to-read-and-interpret format that indicates where action needs to be taken. It enables exploration at scales from global to local, allowing us to visualize large, complex global spatial information in the context of our neighborhoods, our streets, and our houses.

Technology Is the New "Natural"

In the twenty-first century, information technology is becoming our most valuable tool for managing complexity and designing a better world. We tend to think of "environment" and "technology" as two opposing, almost mutually exclusive ends of the spectrum. But as technology becomes more pervasive in our world and more tightly integrated with our very existence, in fact the opposite is true. If we do it correctly, this integration will allow humans to enter a more mutually beneficial relationship with the environment.

"Technology offers a continually, if unevenly, expanding domain of increasing human control and power in the world, and in the process, technology continually transforms the natural and social worlds," say Braden Allenby and Daniel Sarewitz. "Technology embodies the modern ideal of applying rationality to the betterment of humankind."[1]

At its core, technology extends human abilities. As Marina Gorbis has said, technology amplifies our capabilities, "enabling us to do things we never dreamed of doing before."[2] To meet the monumental challenges of the future, David Kirkpatrick states that "we will only be successful if we unreservedly embrace technology and innovation as essential tools."[3]

We now live in a new era where technology is redefining man's relationship with the environment. Perhaps nowhere was this more eloquently predicted than in Richard Brautigan's 1967 poem "All Watched Over by Machines of Loving Grace," where he painted a vivid picture of a future where nature and technology are inextricably linked in a mutually beneficial relationship.

> *I like to think (and*
> *the sooner the better!)*
> *of a cybernetic meadow*
> *where mammals and computers*

live together in mutually
programming harmony
like pure water
touching clear sky.

I like to think (right now please!) of a cybernetic forest filled with pines and electronics where deer stroll peacefully past computers as if they were flowers with spinning blossoms.

I like to think (it has to be!) of a cybernetic ecology where we are free of our labors and joined back to nature, returned to our mammal brothers and sisters, and all watched over by machines of loving grace.[4]

This prophetic vision of our utopian environmental future may seem quite frightening to some people, but I would suggest that it is already here. The computers are here, the sensors are here, and the data is here. Our next challenge is to turn the data into actionable information and use it to create a better future for ourselves and the environment. But those worried about the "Big Brother"-ness of such a vision may look toward Adam Greenfield's essay for help in establishing ethical guidelines for user experience in ubiquitous-computing settings. Taking part of its title from Brautigan's poem, the essay provides a useful example of five principles that meet the dual requirement of being both useful and humane:

- Default to harmlessness.
- Be self-disclosing.
- Be conservative of face.
- Be conservative of time.
- Be deniable.[5]

Greenfield's focus is weighted toward doing no harm to humans, but still presents us with valuable concepts such as transparency and reversibility, which can be applied to the use of global dashboards.

Moving Forward

We live in a world full of sensors. Thanks to the rich information flow they provide and the availability of new mapping tools to display and analyze this information in context, now everyone can be an active participant in the journey of spaceship earth. This has far-reaching benefits to both society and the environment, ushering in a new era of understanding and leading us toward more informed, equitable, and sustainable action.

The global dashboard is already here; it's just not in the form we expected. It's not a single, massive, integrated system, but a distributed system of published services that can be consumed by anyone on the Internet. These services can then be combined, visualized, and analyzed using a variety of applications across different mediums. The result is not a single global dashboard, but a multitude of dashboards designed to help us monitor and address a plethora of specific problems and issues.

As technology becomes more tightly integrated into virtually everything we do, we need to understand that it's not a blessing, nor is it a curse—it's simply a tool of our own creation, a tool to help us move down the path toward our destiny. Or, as Allenby and Sarewitz note, "technology is neither the answer nor the question, it's just the condition."[6]

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Geo-Education: Preparation for 21st-Century Decisions

By Daniel C. Edelson, Vice President for Education, National Geographic Society

Geo-education is about preparing people to make the important decisions we will all face in the 21st century. At National Geographic, we call people who are prepared to make these decisions geo-literate.

Geo-literacy requires three kinds of understanding:

Interactions—A geo-literate individual understands that the world is composed of interacting systems that move and transform resources. These may be social systems, like political, economic, and cultural systems. They may be technological systems, like transportation, energy transmission, and communications systems. Or they may be environmental systems, like hydrological, atmospheric, and ecological systems.

Interconnections—A geo-literate individual understands that these systems connect people and places to each other. This means that events that happen in one location affect other people and places. It also means that our actions affect other people and places.

Implications—A geo-literate individual is able to use his or her understanding of interactions and interconnections to make well-reasoned decisions. This means being able to anticipate the cascading consequences of actions that result from systems interactions and interconnections among people and places. It also means being able to weigh costs and benefits for oneself, for one's community, and for other people and places when making decisions.

More important than what it requires is what geo-literacy enables you to do. Here are six categories of critical decisions that geo-literacy prepares people to make:

Community life—A geo-literate individual understands the factors that improve or degrade the quality of life in a community. These factors include everything from walkability to cultural resources to housing stock. A geo-literate individual is able to use that understanding to (1) make good personal choices about where to live and spend time, and (2) make good civic choices about how to improve the quality of life in his or her community.

Location and transportation—A geo-literate individual is able to reason through problems involving site selection and transportation planning. These problems come up in personal, professional, and civic life, but they are particularly important in professional life in the modern world. Individuals with geospatial reasoning skills are in high demand in fields as diverse as military logistics, intelligence, natural resources management, and supply-chain management.

Interactions across cultures—Our local communities are increasingly diverse, and our daily lives increasingly involve interactions with people in faraway places. Both of these trends make it important that members of our society be culturally literate, meaning able to communicate and collaborate effectively with individuals from different cultures.

Environmental and social impacts—Both the connections that knit together our world ever more tightly and the growth in our global population mean that the impacts of our actions on the environment and on other people are amplified. This makes it all the more important that we all be able to anticipate the potential environmental and social impacts of our actions and make decisions accordingly.

Global affairs—While most individuals' direct influence on global affairs is limited, people throughout the world have growing opportunities to shape global affairs through participation in political processes and public opinion. So geo-literacy is important to be able to participate in the public debate about trade, diplomacy, military action, and foreign aid.

Acts of caring—By "acts of caring," I mean actions to improve the lives of other people or care for the world that we share. This includes efforts to alleviate poverty, reduce hunger, or improve health care and education. It also includes wildlife conservation and environmental restoration. Whether one is taking action oneself or providing financial support, it is important to be able to make informed decisions about what actions are most likely to have a meaningful and lasting impact. This requires geo-literacy.

The challenge of geo-education is weaving the knowledge and reasoning skills required to make these six categories of critical decisions into the written curriculum of schools and the unwritten curriculum of home and community life. This is a challenge that we have not yet taken on explicitly in our modern society, but we must all take it on if we are to prepare today's youth for the world they will inherit.

(This article originally appeared in the Summer 2012 issue of *ArcNews*.)

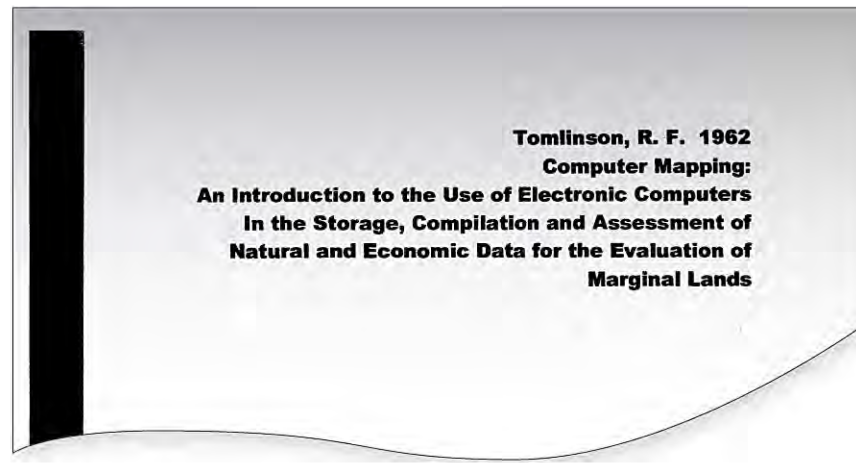
The 50th Anniversary of GIS

By David DiBiase, Esri

Roger Tomlinson

Some events, like birthdays, weddings, and graduations, are easy to mark on the calendar. Others, like the beginning of a social movement or a language—or the invention of GIS—are harder to pinpoint. However, the confluence of three pivotal events in 1962 and 1963 makes this as good a time as any to celebrate a half-century of GIS.

The first event was the establishment of the Canada Land Inventory (CLI) in 1962. CLI set out to produce about 1,500 maps of land use and land capabilities at 1:50,000 and 1:250,000 scales. Though the maps were made by traditional manual methods, Roger Tomlinson (then employed by Spartan Air Services of Ottawa) convinced the head of CLI that computers could be used to automate map analysis. CLI invited Tomlinson to define the functional requirements of what would later be called the Canada Geographic Information System. His carefully considered use of the qualifier "geographic" caught on and has created opportunities and challenges for the discipline of geography ever since.



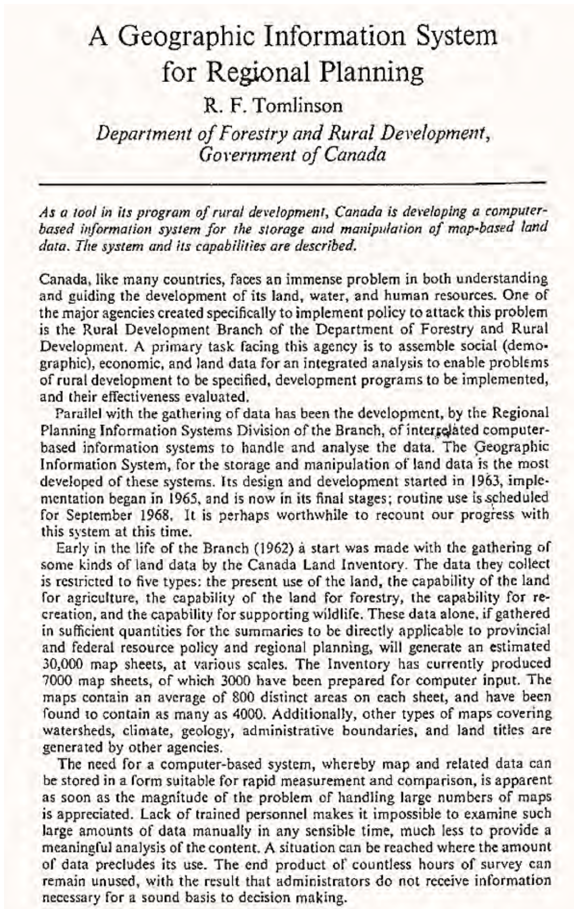
Tomlinson, R. F. 1962
Computer Mapping:
An Introduction to the Use of Electronic Computers
In the Storage, Compilation and Assessment of
Natural and Economic Data for the Evaluation of
Marginal Lands

The title page of Roger Tomlinson's 1962 paper that started the work on GIS in the Government of Canada.

In August 1963, just as Tomlinson delivered his feasibility report to CLI, Edward Horwood of the University of Washington organized the First Annual Conference on Urban Planning Information Systems and Programs. Within a few years, that event became the annual conference of a new organization called the

Urban and Regional Information Systems Association (URISA). Urban and Regional Information Systems eventually became known as geographic information systems, and the 50th annual URISA conference—now called GIS-Pro—took place in 2012.

Horwood spent most of a month at Northwestern University in 1963 teaching a short course about computer handling and mapping of census data. One participant in that course was Howard Fisher, an architect who taught planning and design at Northwestern. Fisher was inspired to develop his own computer mapping system and, with the help of programmer Betty Benson, soon developed a working prototype called SYMAP. With a grant from the Ford Foundation, Fisher later founded the Laboratory for Computer Graphics at Harvard, where he oversaw an important strand of the evolution of computer mapping into GIS.



A Geographic Information System for Regional Planning

R. F. Tomlinson

Department of Forestry and Rural Development, Government of Canada

As a tool in its program of rural development, Canada is developing a computer-based information system for the storage and manipulation of map-based land data. The system and its capabilities are described.

Canada, like many countries, faces an immense problem in both understanding and guiding the development of its land, water, and human resources. One of the major agencies created specifically to implement policy to attack this problem is the Rural Development Branch of the Department of Forestry and Rural Development. A primary task facing this agency is to assemble social (demographic), economic, and land data for an integrated analysis to enable problems of rural development to be specified, development programs to be implemented, and their effectiveness evaluated.

Parallel with the gathering of data has been the development, by the Regional Planning Information Systems Division of the Branch, of interrelated computer-based information systems to handle and analyse the data. The Geographic Information System, for the storage and manipulation of land data is the most developed of these systems. Its design and development started in 1963, implementation began in 1965, and is now in its final stages; routine use is scheduled for September 1968. It is perhaps worthwhile to recount our progress with this system at this time.

Early in the life of the Branch (1962) a start was made with the gathering of some kinds of land data by the Canada Land Inventory. The data they collect is restricted to five types: the present use of the land, the capability of the land for agriculture, the capability of the land for forestry, the capability for recreation, and the capability for supporting wildlife. These data alone, if gathered in sufficient quantities for the summaries to be directly applicable to provincial and federal resource policy and regional planning, will generate an estimated 30,000 map sheets, at various scales. The Inventory has currently produced 7000 map sheets, of which 3000 have been prepared for computer input. The maps contain an average of 800 distinct areas on each sheet, and have been found to contain as many as 4000. Additionally, other types of maps covering watersheds, climate, geology, administrative boundaries, and land titles are generated by other agencies.

The need for a computer-based system, whereby map and related data can be stored in a form suitable for rapid measurement and comparison, is apparent as soon as the magnitude of the problem of handling large numbers of maps is appreciated. Lack of trained personnel makes it impossible to examine such large amounts of data manually in any sensible time, much less to provide a meaningful analysis of the content. A situation can be reached where the amount of data precludes its use. The end product of countless hours of survey can remain unused, with the result that administrators do not receive information necessary for a sound basis to decision making.

The first known published use of the term *Geographic Information System* in August 1968.

Whether we choose these milestones or others as the origins of GIS, the fact remains that GIS has come a long way, baby, in a relatively short period of time. Its impact extends far beyond the hundreds of thousands of GIS professionals at work around the world. The recent Penn State-Public Broadcasting video series *Geospatial Revolution* dramatizes the far-reaching impacts of GIS and related technologies on how we think, act, and interact. At its 50th anniversary, GIS has itself become a kind of movement and a kind of language.

Original Documents

Digital copies of Roger Tomlinson's original feasibility report and related documents are available (by kind permission of the author) at the links provided on the following page.

(This article originally appeared in the Fall 2012 issue of *ArcNews*.)

Sources

Chrisman, Nick. 2006. *Charting the Unknown: How Computer Mapping at Harvard Became GIS*. Esri Press.

Tomlinson, Roger. 1998. "The Canada Geographic Information System." In Timothy Foresman, ed. *The History of Geographic Information Systems: Perspectives from the Pioneers*. Prentice Hall.

Further Reading

The following are some of Roger Tomlinson's original documents from which grew the important and exciting field we know today as GIS, as well as a new article written by him about the origins of the Canada Geographic Information System:

An Introduction to the Use of Electronic Computers in the Storage, Compilation and Assessment of Natural and Economic Data for the Evaluation of Marginal Lands [PDF], by Roger Tomlinson. 1962. "This is the paper that started the work on GIS in the Government of Canada."—Roger Tomlinson

Feasibility Report of Computer Mapping System [PDF], by Roger Tomlinson. Agricultural Rehabilitation and Development Administration, Department of Agriculture, Government of Canada, August 1963.

An Introduction to the Geo-Information System of the Canada Land Inventory [PDF], by Roger Tomlinson. 1967.

A Geographic Information System for Regional Planning [PDF], by Roger Tomlinson. August 1968.

Origins of the Canada Geographic Information System

By Roger Tomlinson

This article has been paraphrased from Roger Tomlinson and M. A. G. Toomey, "GIS and LIS in Canada," chapter 15 in Mapping a Northern Land: The Survey of Canada 1947–1994, *Gerald McGrath and Louis Sebert, eds. (McGill-Queen's University Press, 1999).*

At the heart of the innovations that led to the Canada Geographic Information System was the fundamental idea of using computers to ask questions of maps and to render useful information from them. To do this, maps had to be in digital form. This led to the idea that many digital maps could be stitched together to represent the whole of Canada and that the maps could be linked intelligently to digital databases of statistics, such as the Census. Fifty years later, this brief article recalls the people, organizations, and circumstances that gave rise to these original ideas, and how the ideas played out.

In 1960, Spartan Air Services of Ottawa, Canada, was a large surveying and mapping company whose business included topographic mapping, geophysical surveys, land resources surveys, and other projects worldwide. Some projects required manual analysis of mapped data. However, since manual analysis was almost as costly as the surveys themselves, not infrequently the proposals for map analysis were rejected by both clients and Spartan's management because they were too costly.

George Brown, chief of Spartan's land resources division, permitted me to try digital methods as a potentially cost-effective alternative. I created two small test maps in numerical coordinate form—each 5 x 5 inches and containing five polygons. I found that these could be digitally overlaid and that I could measure the resulting areas from the digital record.

Efforts to interest Ottawa computer companies (Computing Devices of Canada, IBM, Sperry, and Univac) to partner with Spartan for future development were not successful. However, in 1962, at an ASPRS conference in Washington, DC, John Sharp, a consultant to IBM, introduced Spartan to the digital photogrammetric research being done at IBM in Poughkeepsie, New York, in the United States. That, along with subsequent contacts with the previously reluctant staff in the IBM office in Ottawa, was the beginning of a pivotal relationship that was to grow significantly over the years. IBM brought early experience with computers and programming to the table. I brought an understanding of the needs, as well as the geographical training needed to formulate the new concepts and to spell out the requirements for the system.

Another pivotal encounter was a chance meeting with Lee Pratt in 1962. Canada had recently passed into law the Agricultural Rehabilitation and Development Act. That legislation created a need for an inventory of land use and land capability across Canada. Thus was the Canada Land Inventory (CLI) established in 1962. Pratt was the new head of the CLI. The CLI planned to create about 1,500 maps of the commercially productive parts of Canada at scales of 1:50,000 and 1:250,000. These were to show the capability of land for agriculture, forestry, wildlife, and recreation, as well as present land use and the boundaries of census subdivisions. Like Spartan and me, Pratt and the CLI faced the problem of how to efficiently analyze a large number of maps. The idea of using computers to do this was very attractive.

Pratt urged me to write a paper entitled *Computer Mapping: An Introduction to the Use of Electronic Computers in the Storage, Compilation and Assessment of Natural and Economic Data for the Evaluation of Marginal Lands*. I presented the paper to the National Land Capability Inventory Seminar in Ottawa in November 1962. It was well received. The Department of Agriculture subsequently awarded a contract to Spartan to carry out a technical feasibility study for the CLI. The outcome of that study was the *Feasibility Report of Computer Mapping System* that I prepared and delivered to the Agricultural Rehabilitation and Development Administration (ARDA) in August 1963.

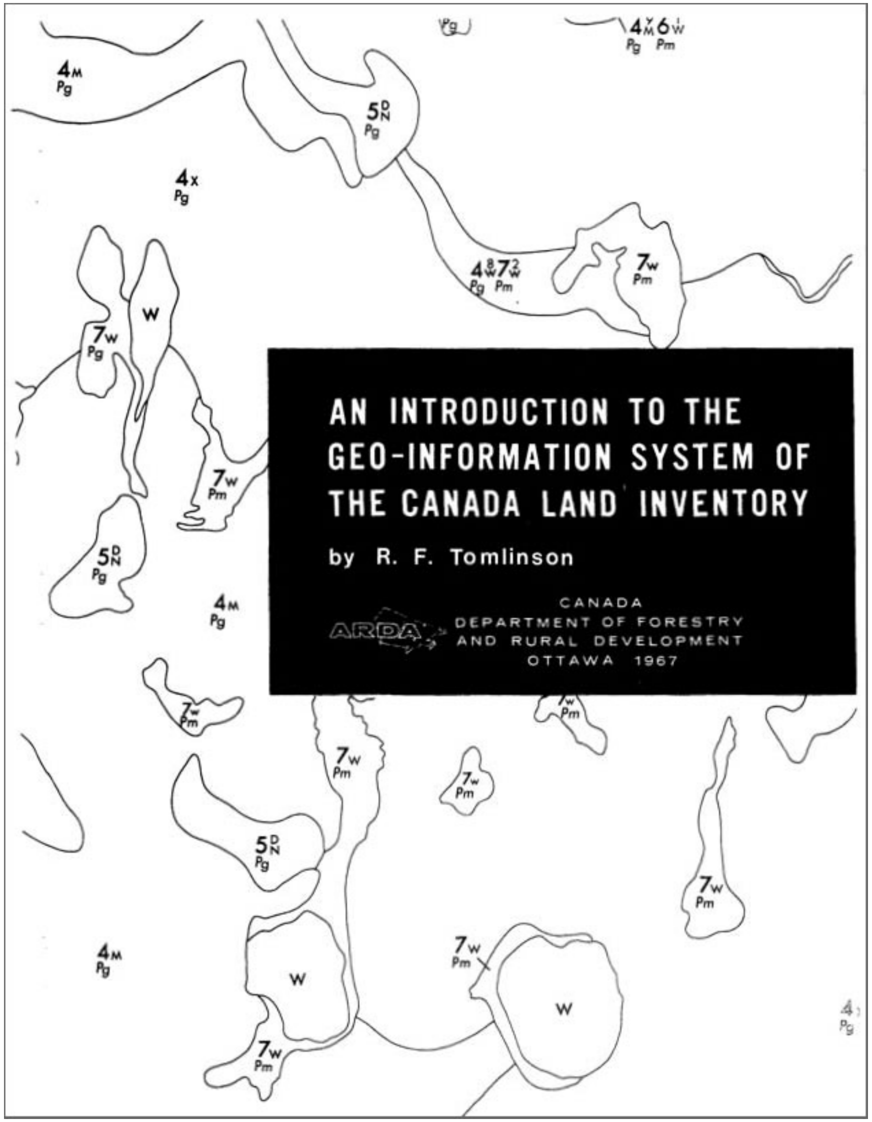
In retrospect, the feasibility report seems remarkably prescient about the functional requirements of a comprehensive GIS. The system's purpose was to enable analysis of geographic data over any part of a continent-wide area. Results were to be provided in tabular or map form, or both. Many different kinds of maps needed to be put into the system. The report specified a seamless, nationwide data structure. The recommended structure separated the descriptor data (attributes) from image data (points and polygon boundaries). The report addressed the task of converting many maps to digital form. The need for various data inputs optimized for different data types was anticipated, including automated scanning for polygon boundaries, digitizing for selected points as identifiers inside the polygons, and keypunching for descriptor and statistical data. These data types were to be input separately and linked logically later. The coordinate system requirements were examined, and the concepts of error in subsequent area calculation considered. Image data compaction requirements were identified to reduce data volumes to be stored on magnetic tape. The need to combine socioeconomic data with mapped data was also prescribed. Data analysis capabilities included area measurements and multiple topological overlays. The vision of a comprehensive GIS is clearly evident in this report.

The Department of Agriculture (Pratt and Al Davidson) accepted the proposal and awarded contracts to Spartan and IBM to develop the system. I was asked to join the ARDA team and direct system development. More than 40 people worked on the development teams throughout the rest of the decade. One key contributor was Guy Morton, who devised a brilliant tessellation schema that was fundamental to the system data structure. The schema is now known as the Morton Matrix. Don Lever was responsible for most of the logic and for converting the scanner data to topologically coded map format. Bruce Sparks and Peter Bedárd developed the system's edgematching capability. Art Benjamin designed the links between image data and descriptor data. Bob Kemeny developed the map data compaction methods using the eight-directional coding originated by Galton and later called Freeman codes. Frank Jankaluk devised the reference coordinate system and error calculation algorithms. Bob Whittaker designed the system for error correction and updating. Peter Kingston designed the data retrieval system and the polygon overlay process. Also incorporated in the system were map projection change, rubber sheeting, scale change, line smoothing and generalization, automatic gap closing, area measurement, dissolve and merge, buffer generation, and new polygon generation, all operating in the topological domain. A very important part of the system was a computer command language that recognized geographic analysis terms that could be understood by a wide range of potential users. The command language was designed by Peter Kingston, Ken Ward, Bruce Ferrier, Mike Doyle, John Sacker, Frank Jankaluk, Harry Knight, and Peter Hatfield.

The Canada Geographic Information System (CGIS) gave rise to several developments in cartographic instrumentation. D. R. Thompson at IBM in Poughkeepsie engineered the first cartographic-size digital scanner specifically for the project. It was delivered in 1967 at a cost of approximately $180,000 and worked well for 15 years until replaced by a newer model. The original is now in the National Museum of Science and Technology in Ottawa.

Another technical innovation was the first high-precision 48 x 48 inch free-cursor digitizing table ever produced. Ray Boyle, then working for Dobbie-McInnes (Electronics) Ltd in Scotland, designed and built these especially for the CGIS.

Names matter, so it seems worthwhile to reflect briefly on the origins of the term *geographic information system*. Though the original proposal to the CLI was entitled "computer mapping," that term seemed inappropriate by the end of 1963. At that time, we referred to the system as the ARDA Data Coordination System. As time went on, we considered various alternatives. The term *spatial data system* seemed too general, and the term *land information system* too restrictive considering the data types that were to be involved. The term *geo-information system* or *Geo-IS* eventually came into use in the office and appears in a 1967 paper entitled "An Introduction to the Geo-Information System of the Canada Land Inventory." Finally, we settled on the term *Canadian Geographical Information System*, which a wise politician in the cabinet shortened to Canada Geographic



The term *geo-information system* or *Geo-IS* first appears in the 1967 paper shown here.

Information System to reflect the then-popular use of Canada as a synonym for the federal government.

The first published uses of the term GIS may be a 1968 paper prepared for the Commonwealth Scientific and Industrial Research Organization (CSIRO)—Australia's national science agency—entitled "A Geographic Information System for Regional Planning" and in a film produced that same year by the Canadian Film Board called *Data for Decisions*. On reflection, the name perfectly defines the system's capabilities. It has since been widely adopted for many other systems worldwide.

See also "The 50th Anniversary of GIS."

(This article originally appeared in the Fall 2012 issue of *ArcNews*.)

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