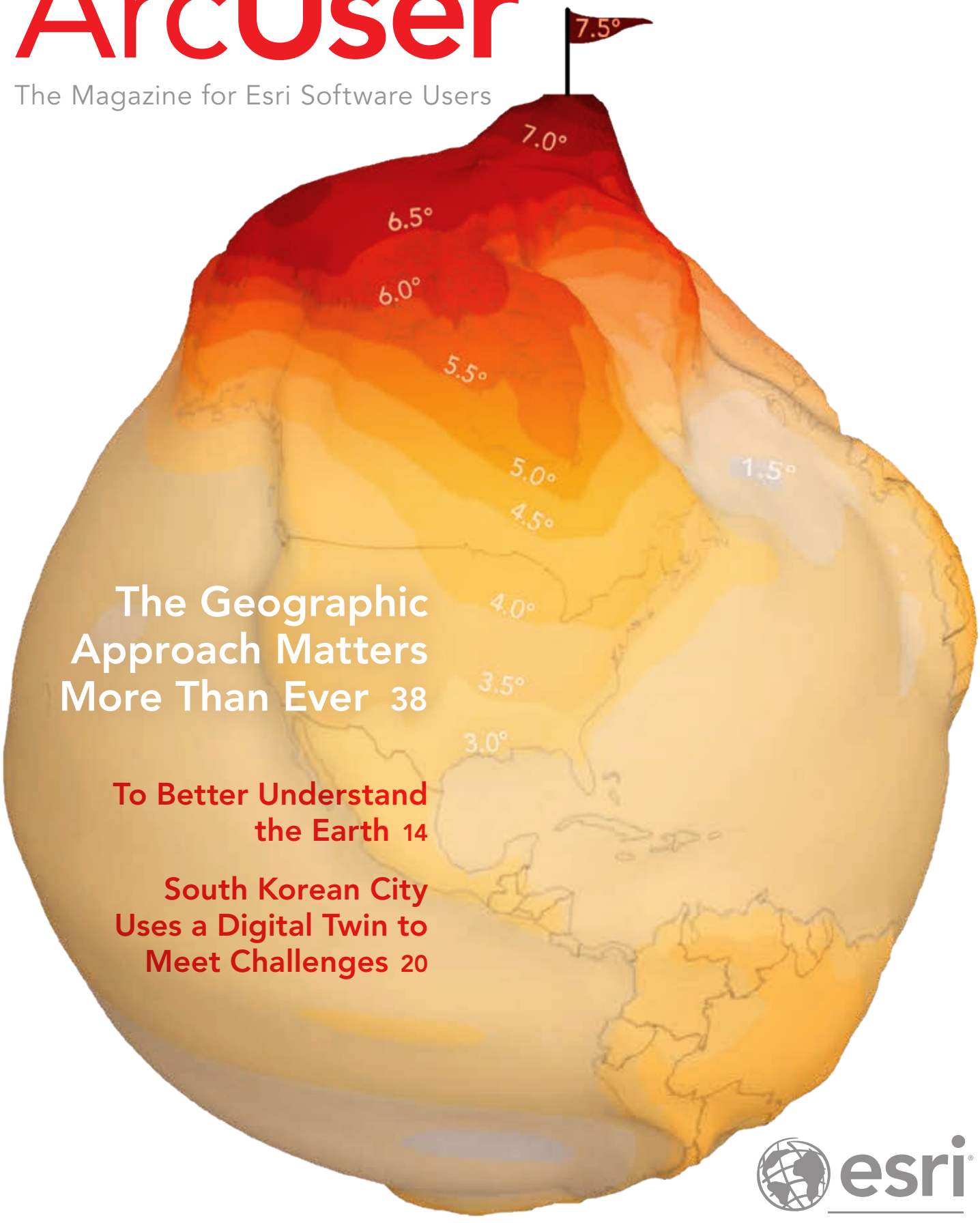
Summer 2021

ArcUser

The Magazine for Esri Software Users



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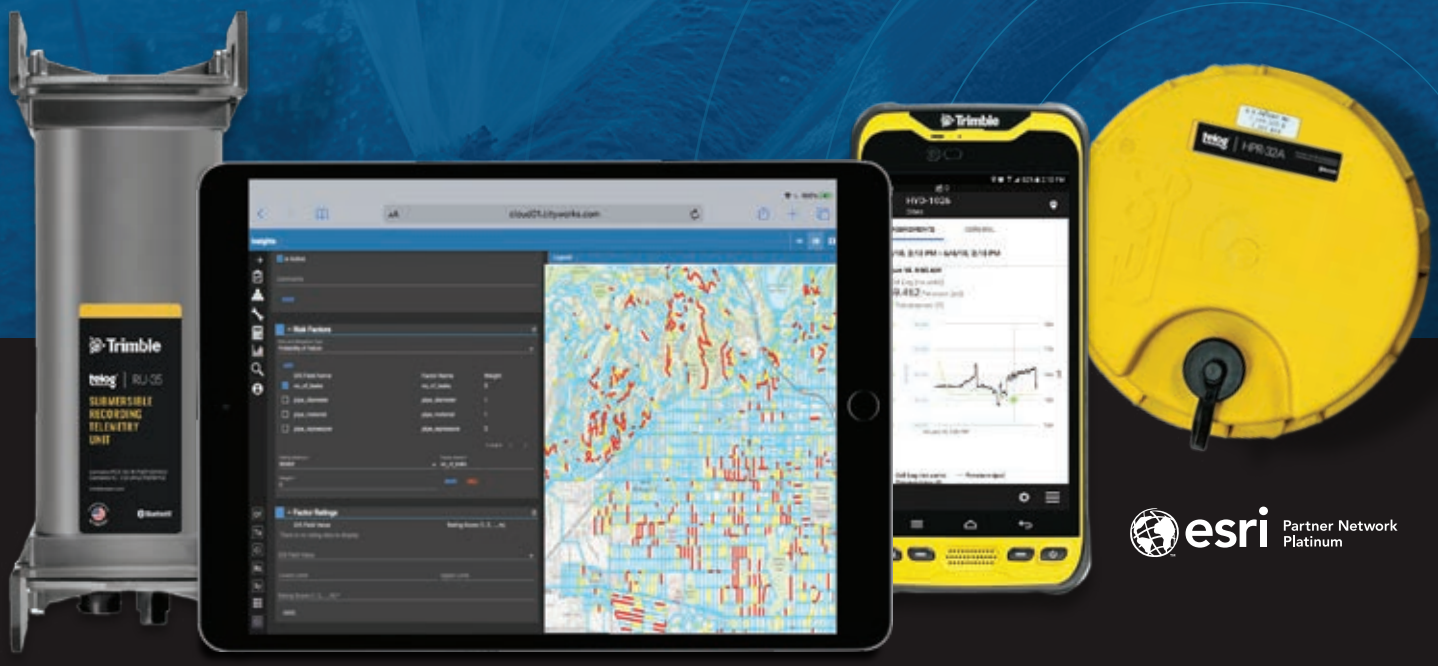

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On the Cover

Disproportionate Warming of the Artic, is an award winning entry in the Most Innovative Map category of the 2021 Esri User Conference Map Gallery. The map, in both static and animated versions, was created by Greg Fiske of Woodwell Climate Research Center using ArcGIS Pro. It visualizes temperature change as a substitute for true elevation in a 3D map, illustrating the disproportionate effect of climate change on the Arctic using the Representative Concentration Pathways (RCP) worst-case scenario RCP8.5. This scenario models very high baseline emissions to show a possible—though not the most likely—outcome in the absence of climate policy. The distorted globe represents the mean temperature difference (C°) projected temperatures for the 2040–2060 time frame (under RCP8.5) minus temperatures for the 1880–1920 time frame. The map uses data from the KNMI Climate Explorer, a web-based tool for researchers developed by the Royal Netherlands Meteorological Institute (KNMI), the Dutch national weather service.

Act Now for the Future

"Today our world is being challenged because humans are living recklessly and unsustainably, and this is threatening our future."

Jack Dangermond
Esri President and Founder
2021 Esri User Conference

We now live in an era that geologists and others have dubbed the Age of the Anthropocene because the imprint of human activity is so pervasive and so deeply etched into the Earth.

GIS professionals are uniquely equipped to appreciate this threat to our collective home and respond to it. They possess the geographic perspective needed to deeply understand the complexity and interconnected nature of life on Earth and the creativity, knowledge, and skills needed to develop strategies for dealing with these challenges.

This process starts with a greater understanding of the Earth than we currently possess. GIS is a fundamental tool for building this understanding. An article in this issue describes the release of the completed global ecological coastal units map, the third in a series of comprehensive maps that are defining the Earth's ecosystems with data that is standardized in scale and quality. The maps provide a framework for critical additional research on Earth's vast but understudied life and processes.

During his keynote presentation at the Esri User Conference (Esri UC), Dr. Enric Sala described the work of the National Geographic Pristine Seas team he leads. Its mission is to protect 30 percent of oceans in marine reserves by 2030. Protected areas not only safeguard biodiversity but underpin economic viability. By transforming overfished ocean "deserts" into thriving sources of fish, these marine reserves provide livelihoods for people through tourism and fishing in adjacent areas where reestablished fish populations have spilled over.

A keynote presentation by La June Montgomery Tabron, president and CEO of the W.K. Kellogg Foundation, explained how GIS supports the foundation's work in creating a more sustainable society by identifying those societal structures that cause racial inequality. The foundation engages communities through planning, intelligent study, and group action to produce better outcomes.

In closing his presentation on the Esri UC theme, GIS—Creating a Sustainable Future, Dangermond urged the GIS community to become involved. "The human population generally and the GIS community specifically are collectively responsible for the Earth's future. That future could go in many directions. Achieving a sustainable future will require changing our priorities and applying the best science, technology, and creative thinking."

Monica Pratt
ArcUser Editor

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Summer 2021 Vol. 24 No. 3

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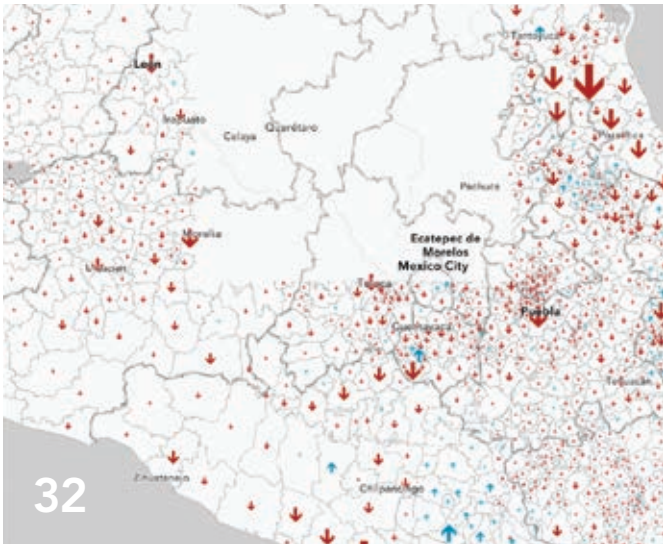
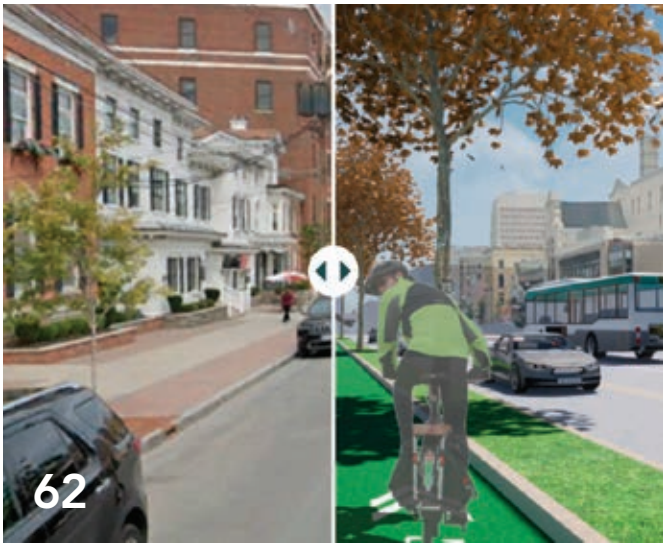
Departments





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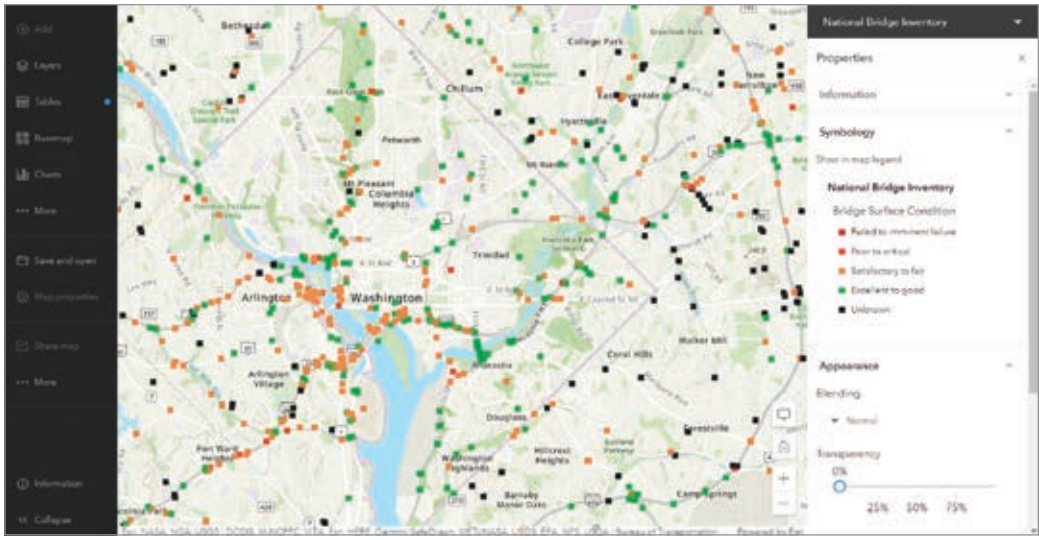
Briefly Noted

→ High-Demand US Datasets Are Widely Available Online

A collection of valuable, authoritative datasets, referred to by government users as National Geospatial Data Assets (NGDA), will now be available to government and private organizations.

This collection includes more than 75 national geospatial datasets on dams, bridges, federal public lands, runways, rail nodes, and more, which are regularly updated from federal sources. Making this data available to a wider audience will aid governments in addressing challenges such as climate change, disaster relief, broadband access, and racial equity.



↑ This feature layer uses National Geospatial Data Asset (NGDA) data from the Bureau of Transportation Statistics (BTS) to display National Bridge Inventory (NBI) information on bridges in the United States and Puerto Rico. The data provides the location, description, classification, and general condition of each bridge.

Wider availability of NGDA datasets benefits the commercial sector. Large companies with assets and interests spread throughout the United States, from national retailers and insurance companies to railroads and utilities, need data that cuts across cities, states, and regions. Having high-quality national datasets on hand will save organizations the time and money required to gather and process them.

An ArcGIS user license is not required to access this data. It is available under the Creative Commons Attribution 4.0 International (CC BY 4.0) license, so anyone can use, share, and adapt the data with proper attribution. For interoperable access, these datasets will also be available as both Esri REST services and Open Geospatial Consortium, Inc. (OGC), API Features. Esri will also be releasing the NGDA datasets through a custom explorer app.

Esri supports the broader vision of the Geospatial Data Act of 2018 (GDA), which seeks to empower more people to use geospatial data and break down barriers to interoperability. The NGDA dataset is the second dataset Esri released to the public in 2021 that does not require an ArcGIS license to access. In June, Esri released the first-ever high-resolution (10-meter), 2020 global land-cover map. These open data services are provided through ArcGIS Living Atlas of the World, the foremost collection of geographic information from around the globe, including maps, apps, and data layers.

To learn more and explore the new NGDA datasets, visit livingatlas.arcgis.com/esri_ngda_datasets/.

→ ArcGIS Users in the US Can Access More Current and Precise Address Data

Esri is collaborating with Infutor Data Solutions to improve the geocoding and address matching capability of the ArcGIS World Geocoding Service in the United States. Users in any industry—especially insurance, telecom, health care, utilities, real estate, and retail—will benefit from the increased precision of geocoding that comes from rooftop locations for addresses and subaddress information for places with multiple units.

Infutor specializes in consumer identity management and identity resolution, and its comprehensive spatial data includes validated, multisourced addresses and hyperprecise geographic coordinates (latitude-longitude), allowing for deep location-based analysis and decision-making.

New rooftop locations for the US became available for users of ArcGIS World Geocoding Service, which benefits users of ArcGIS Pro, ArcGIS Enterprise, and ArcGIS Online and developers using ArcGIS Platform. Improved geocoding is also available in ArcGIS StreetMap Premium.

→ New Legal Requirements Enable Collaboration among EU GIS Community

Esri commended the European Union (EU) for its leadership in implementing Directive (EU) 2019/1024 (Open Data Directive), which aims to encourage cross-border use of reusable data in Europe. Committing to a standardized open data policy framework will make it easier for EU member states to access high-value datasets, such as geospatial, earth observation, environmental, meteorological, statistical, mobility, and company ownership data, in a trusted manner.

With open data, EU members can use application programming interface (API) web services for access. At the unprecedented pace in which data is growing everywhere, the new model enables a European single market for open data that will benefit all members. As EU members finalize implementation of the Open Data Directive, geospatial tools must support data catalog interoperability requirements for open data portals across Europe.

To broaden its support for the directive, Esri is expanding the capabilities of interoperable web service APIs, metadata, and ArcGIS Hub catalogs. Using international open standards such as Data Catalog Vocabulary Application profile (DCAT-AP), European customers can share data that conforms to the new Open Data Directive and more easily expose their open data catalog and web services for reuse.

The inclusion of DCAT-AP 2.0.1, along with an extendable architecture on ArcGIS Hub, will serve as a road map to support and guide geospatial technology users as they adopt the legal requirements of the Open Data Directive. Geospatial data is transformative, and the EU's Open Data Directive has paved the way for greater accessibility and transparency. The changes will inspire exciting opportunities for member state collaboration and innovation across Europe.

Why You Should SHARE YOUR DATA

By Brent Jones

Data is expensive to create and maintain, so why should I share *my* data?

This often-asked question is discussed by government at all levels: local, state and federal. This discussion about sharing covers all kinds of data that includes lidar, imagery, topography, land cover, land use, geology, hydrography, biodiversity, soils, survey control, place-names, address, parcel, property characteristics, utilities, and school district boundaries.

Why don't we want to share the data we create and maintain? There are many reasons we're hesitant.

We're proud of our data, and we want recognition for our work. We don't want our data misused. Maybe there are errors in the data that we don't want to be made public. We've been working on collecting and improving our data for years. We pay for staff time, and it costs money to maintain servers, networks, and desktops. Some of us sell data to help recoup costs and use those funds for our departments.

It All Started with Data Sharing

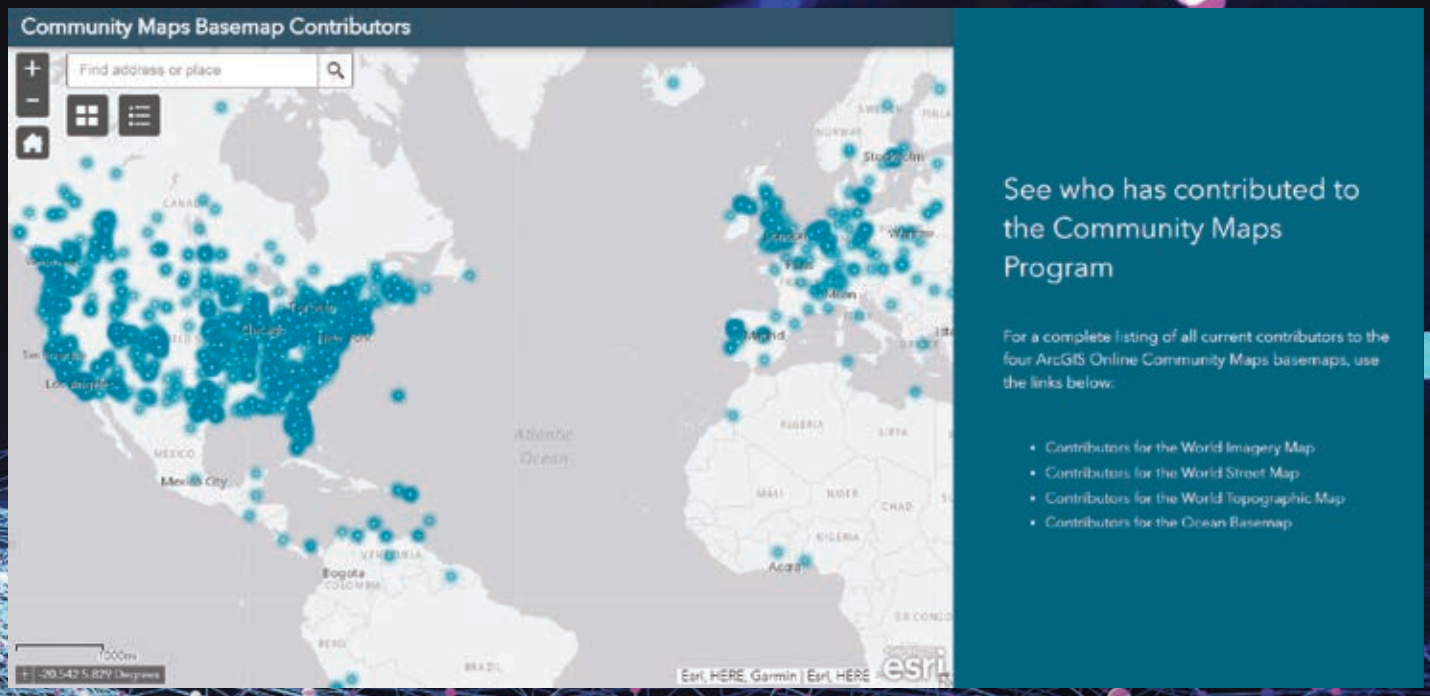
If you're like me, the last time you took a trip, you used Waze so that you would be alerted to road hazards, traffic, and speed traps. This information is the product of data about traffic conditions shared by other drivers with Waze. This sharing enables greater efficiency for you and others when traffic conditions change.

What you might not know is that the ease of navigation afforded by Waze and other systems that we enjoy and rely on started with the sharing of government data. It's a long story that began when the US Census Bureau wanted to make census data collection and management more efficient.

The bureau developed Dual Independent Map Encoding (DIME), an encoding system for efficiently storing geographic data. DIME became a key component in the development of the Topologically Integrated Geographic Encoding and Referencing (TIGER) system created for the 1990 census. It is a digital database of geographic features such as railroads, rivers, lakes, street centerlines, and political and census boundaries.

TIGER data was shared with the public. Several companies used this data to create commercial products for addressing, mapping, routing, geocoding, and many other uses. The street data we use today is developed from many sources, using many collection techniques, but it all started when the US Census Bureau shared its street centerline data. As the bureau noted in 2014 on the 25th anniversary of the development of the TIGER system, "The convenience of getting directions today on smartphones and tablets can trace its roots to the digital geographic database created 25 years ago by the US Census Bureau."

There's more to the story of data sharing. The Global Positioning System (GPS) was started by the US Department of Defense in the early 1970s and overcame the limitations of earlier navigation systems. In May of 2000, GPS became more valuable to the private sector and the general public



↑ Esri software users from around the world contribute to the Community Maps program.

when selective availability—the intentional degradation of location precision for nonmilitary users—was turned off. This changed everything by enabling everyone to acquire highly precise locations. Combining much more accurate GPS with the commercialized street centerline data eventually made possible maps and navigation on smartphones. Few of the multitude of uses of GPS and street centerline data were considered or even conceived of when these services and data were opened to the public.

Today we share our address datasets with emergency response systems, and everyone benefits. When errors are detected and corrected, the master address database is updated. As data becomes standardized and used by more organizations, it becomes more valuable. Duplicate datasets are eliminated, and reliable authoritative data is established.

Often data becomes more valuable to others than to the original owner and maintainer of the data. To a 9-1-1 caller, the accuracy of address data can be a matter of life or death.

A Better Way to Share Data

But what about that other data we have? Street data, digital elevation models, building footprints, and especially parcel data are extremely valuable for many government departments, local businesses, volunteer groups, individuals, conservation organizations, and others. Just about everyone can use good data.

But unfortunately, not all data is collected at the same scale, level of detail, and degree of accuracy, which makes combining data and sharing data in a consistent manner costly and difficult. The challenge is to combine shared data with other data and deliver consistent data and mapping across jurisdictions.

There is a solution. Esri helps you share your authoritative data and services with the wider GIS community through the Community Maps program, which contributes data to the ArcGIS Living Atlas of the World. Once vetted and incorporated, your data becomes part of a seamless map of authoritative data that is consistent, up-to-date, and accurate and displayed using sophisticated cartography.

While your data and maps have been created for specific reasons, your work can benefit others by sharing it through the Community Maps program. Your data improves the ArcGIS Living Atlas and makes it more complete. The utility of your data can be extended by adding curated data and services that help users solve problems and make better decisions.

In the tradition of government sharing data and services that laid the foundation for GIS, your data can become part of solutions to today's issues. Data sharing matters. Your contributions matter. Better maps and data help us make better decisions. Contribute to the Community Maps program. Learn how you can contribute at https://bit.ly/3cxDIY7.

Your data improves ArcGIS Living Atlas and makes it more complete.

Increase the Value of Imagery in Your Organization

With the release of ArcGIS Image for ArcGIS Online, organizations have a quicker and easier way to integrate imagery into workflows. With this newest addition to the ArcGIS Image suite of products, users can host, visualize, analyze, share, and collaborate imagery content from within ArcGIS Online, Esri's software as a service (SaaS) product.

An extension to ArcGIS Online, ArcGIS Image for ArcGIS Online makes imagery more accessible and more easily managed while eliminating the need for an organization to maintain infrastructure for imagery. Uploaded imagery and the results of analysis are saved as image services so that they can be shared and used in ArcGIS throughout an organization.

Imagery uploaded to ArcGIS Image for ArcGIS Online can be saved as a tiled imagery layer or as a dynamic imagery layer. Layers of either type can be used as input for raster analysis. Both layer types retain pixel information, pixel values for any location, and image metadata.

Static tiled imagery layers are more efficient for viewing and support client-side processing and rendering. Dynamic imagery layers support on-demand server-side processing, dynamic mosaicking, and image collection management. By returning only what is needed to display the current extent, dynamic imagery layers can deliver good performance over low-bandwidth networks.

Layers of either type can be built from a variety of raster formats sourced from many providers. ArcGIS Image for ArcGIS Online can handle overlapping, temporal, and multiresolution imagery. Different enhancements and renderings can be set for layers.

Opening Up the Use of Imagery

ArcGIS Image for ArcGIS Online liberates imagery that organizations may have locked away in hard drives or stored in disparate locations. Making imagery readily accessible increases its value by making it usable to many more people in an organization. Imagery—hosted, managed, and streamed from ArcGIS Image for ArcGIS Online as tiled and dynamic imagery layers—are ready for immediate visualization and analysis.

Eliminating the infrastructure—both staff and hardware—needed to manage imagery and replacing it with a secure, scalable, and performant cloud environment managed by Esri lets staff focus on finding solutions instead of maintaining processes.

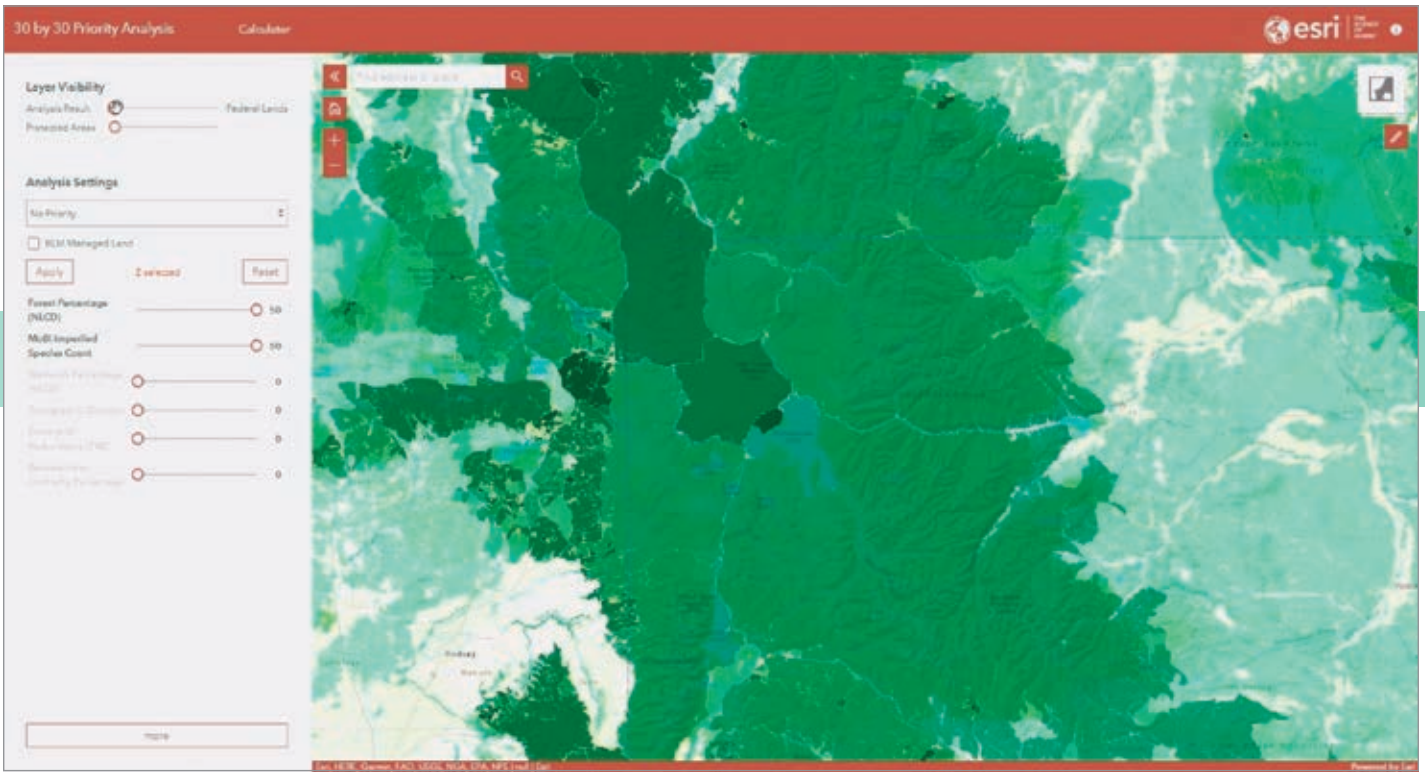
Making Imagery More Available

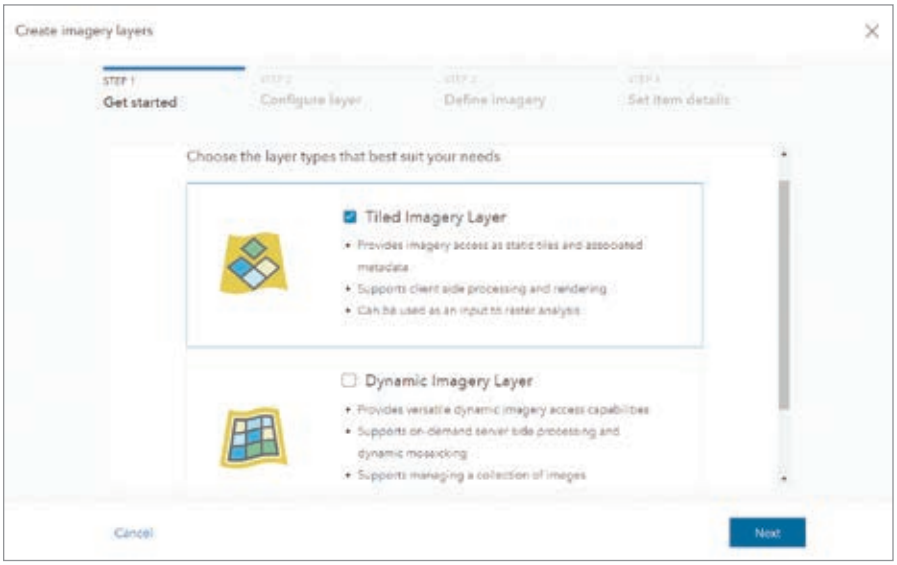
Because it frees organizations from acquiring and maintaining the infrastructure needed to process imagery, ArcGIS Image for ArcGIS Online makes the power of imagery in GIS workflows available to many more organizations and many more people in those organizations.

Object detection is just one of the raster analysis tools that comes with ArcGIS Image for ArcGIS Online. Using this tool, feature extraction from imagery hosted using ArcGIS Image for ArcGIS Online can take advantage of deep learning capabilities to automate the process and seamlessly use the library of deep learning models already available from ArcGIS Living Atlas of the World. This capability makes change detection analysis of the built and natural environments accessible to governments as well as private and nongovernmental organizations.

Access to current imagery provides critical information during disasters and emergencies. Imagery can be applied to asset and infrastructure inventory as well as to monitoring and evaluating the condition of vegetation, whether cropland or natural landscapes. Analyzing imagery can identify optimal paths and connections between areas, whether they are road networks or wildlife corridors. Imagery contributes to analysis workflows that forecast available water supply, evaluate the environmental impacts of planned projects, and design roads and storm drains.

These are just a few ways imagery can contribute to achieving an organization's goals when both tools and imagery are accessible. ArcGIS Image for ArcGIS Online can be scaled for specific types of users in an organization. The level of complexity for users can range from providing an intuitive web experience viewing and managing imagery to producing a processing workflow using the Raster Function Editor in ArcGIS Online to chain one or more raster functions together. Custom raster functions can also be created using the ArcGIS API for Python.





↑ Imagery hosted in ArcGIS Image for ArcGIS Online was used to create an app for a suitability analysis that lets stakeholders set criteria using sliders.

← Creating an image layer is a simple, guided process of choosing the layer type, configuring it, defining the imagery, and setting item details.

Access to current imagery provides critical information during disasters and emergencies.

Part of a Robust Strategy for Managing and Using Imagery

ArcGIS Image for ArcGIS Online joins ArcGIS Image Analyst for ArcGIS Pro, ArcGIS Image Server for ArcGIS Enterprise, and ArcGIS Image Dedicated. These products provide tools and services for comprehensive imagery data management, visualization, and analysis of imagery on the desktop, in ArcGIS Online, in an enterprise, or, with ArcGIS Image Dedicated.

ArcGIS Image Dedicated brings processing, analytics, and streaming capabilities directly to existing imagery collections that an organization already has stored in Amazon Web Services (AWS) or Microsoft Azure cloud, making these collections easier to manage and use. ArcGIS Image Dedicated is a SaaS offering managed by Esri.

ArcGIS Image for ArcGIS Online is available as an extension for the Creator or GIS Professional user type for an existing ArcGIS Online organizational account. User types allow organizations to control the type and extent of privileges assigned to members through roles. Once a license has been purchased, ArcGIS Image for ArcGIS Online can be managed from the Licenses section of the Organization tab. Purchase this license at https://bit.ly/3ry11C1.

AI Enables Rapid Creation of Global Land Cover Map

In June 2021, Esri released a new high-resolution 2020 global land cover map and made it available to everyone on the ArcGIS Living Atlas of the World. The *Esri 2020 Land Cover* map is the first map to possess this level of comprehensiveness, currency, and detail, and it is a vital resource for better understanding and preserving the world.

With its 10-meter resolution, this map can be used to help determine the characteristics of a particular place and answer questions such as these:

- Is an area bare ground or is it covered by trees or water?
- Does it contain buildings or other infrastructure?
- How has it changed over time?

To support answering these and other questions, high-resolution, open, accurate, comparable, and current land cover maps are critical for decision-makers in many industry sectors and nations with low- and middle-income economies. This will enable the surface of the earth to be characterized and classified into a manageable number of categories to identify and better manage resources.

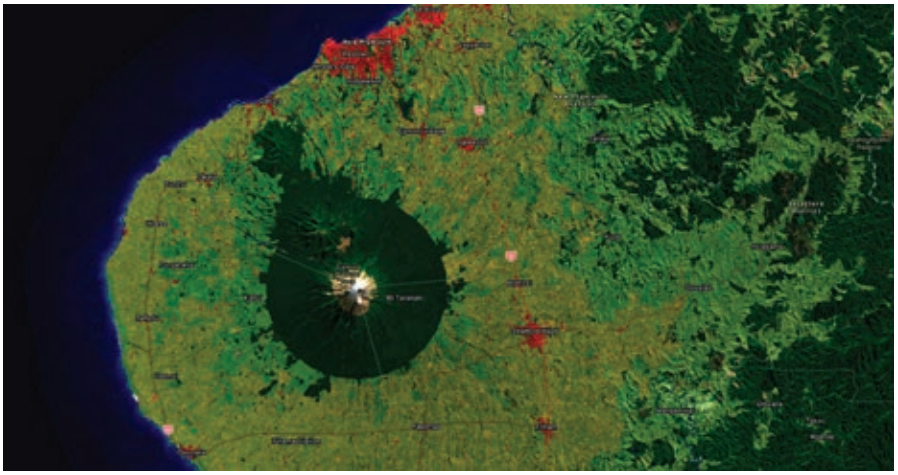
Mapping the Earth's surface will assist with land-use planning, hydrologic modeling, and resource management planning. National government resource agencies can use land cover as a basis for understanding trends in natural capital and help define land planning priorities such as food production or conservation.

A New Methodology

Typically, the value of land cover maps is diminished because the time between data acquisition and map availability can span several years. However, the use of artificial intelligence (AI) allowed this global land cover map to be produced in less than a week.

The *Esri 2020 Global Land Cover* map was built using European Space Agency (ESA) Sentinel-2 satellite imagery. It was created using a deep learning AI land classification model developed by Impact Observatory, on a massive training dataset of more than five billion labeled image pixels developed by the National Geographic Society. The global map was produced by applying this model to the Sentinel-2 2020 scene collection, processing more than 400,000 Earth observations of Land Use/Land Cover (LULC)—approximately 500 terabytes of imagery—hosted in the Microsoft Planetary Computer.

↓ Land cover classification shows how cropland extends up to to the circular boundary of the forested Egmont National Park in New Zealand.



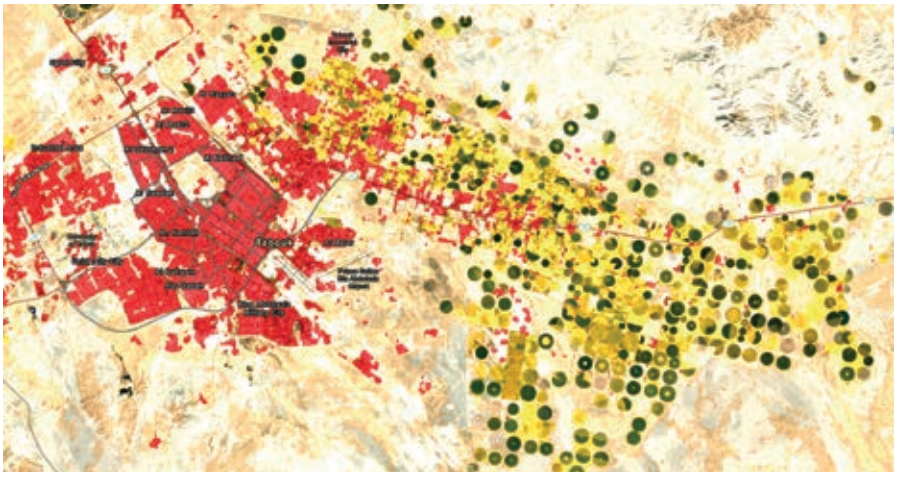
The dataset included more than 24,000 five kilometer by five kilometer areas from all the world's major biomes. The model was run on six bands of Sentinel-2 surface reflectance data: one band each of visible blue, green, red, near-infrared, and two shortwave infrared bands. The 10 classes generated are water, trees, grass, flooded vegetation, crops, scrub/shrub, built area, bare ground, snow/ice, and clouds (unclassified).

To create the final map, the model was run on multiple dates of imagery throughout the year, and the outputs were composited into a final representative map of 2020. The complete global run was approximately 1.2 million core hours of compute time. To complete the task in approximately a week, Microsoft Azure Batch was used to run up to 6,400 cores simultaneously.

The new map will be updated annually, supporting change detection and highlighting planetary land changes, especially related to the effects of human activity. Later in 2021, Esri and Impact Observatory will make this new land cover model available to support on-demand land cover classification, allowing the GIS community to create new land cover maps for project areas as often as every week. This model will empower land managers and disaster response organizations that need to monitor change in a specific area of interest, provide near real-time environmental situational awareness, or look at long-term change and seasonal differences in land cover.

Benefits and Uses

Publishing the *Esri 2020 Land Cover* map as a tile imagery layer on ArcGIS Living Atlas of the World makes it available for visualization and analysis in ArcGIS Online, ArcGIS Pro, and other client applications. GeoTIFF tiles of the layer can also be downloaded individually for areas of interest, or the entire 60 GB collection can be downloaded with a single click. Esri released this valuable resource under a Creative Commons license so that it can be downloaded by anyone.



↑↑ This section of the global land cover map shows an unprecedented level of detail, differentiating built areas, crops, water, and flooded vegetation for the area surrounding Kolkata (Calcutta), India.

↑ Center-pivot irrigation systems in western Saudi Arabia turn the desert into a polka-dot pattern of farmland.

"This is a critical year for climate action," said Jack Dangermond, Esri founder and president. "With the UN Climate Change Conference of the Parties *[COP26]* bringing international parties together to address a set of common goals, we are happy to do our part in making this map available to users who are working toward the health of our planet."

This data is globally consistent, which allows for comparisons across country boundaries, and it is complementary to existing national data, filling data gaps in remote and less-developed areas where detailed recent data may not be available. Using this 2020 land cover data can help countries identify national priorities and support national and subnational level reporting.

Users can visualize and analyze the land cover data in association with population, hazard, terrain, hydrology, weather, and other GIS layers, available in ArcGIS Living Atlas of the World or from their own organization. A consistent map of land cover for the entire world can be combined with other data layers for green infrastructure, sustainability projects, and other conservation efforts that require a holistic picture of both the human and natural footprint on the planet. Examples of these types of projects could include the following:

- Computing the percentage of land in a watershed categorized as built area, which will contribute to faster rainfall runoff and increased flood risk.
- Identifying coastal areas of built area and crops less than three meters in elevation that may be susceptible to storm surge.
- Intersecting land cover and species richness layers to determine conservation priority areas

Planners worldwide will be able to better understand site geography and make more informed decisions. Getting this data into people's hands is a key component of this mapping initiative. More than 10 million GIS users have direct access to it via web services in ArcGIS Living Atlas of the World.

Although the global land cover map has only been available since June 2021, organizations are already benefiting from it. Rafael Monge Vargas, director of Centro Nacional de Información Geoambiental, noted that, "Understanding the most up-to-date land-use and land cover information of Costa Rica at 10-meter resolution is a groundbreaking input for our national planning processes, including for the development of 'maps of hope' that identify Costa Rica's essential life support areas—where the implementation of nature-based solutions can lead to greater environmental, economic, and social benefits."

Access the Esri 2020 Land Cover layer at https://bit.ly/3rpuXjr or learn more about it at https://livingatlas.arcgis.com/landcover/.

TO BETTER *Understand* THE EARTH

By Monica Pratt

With the release of ecological coastal units (ECUs), another tool for understanding the Earth is available. Created for mapping and analyzing the world's coastal regions, ECUs are the most recent development in an ongoing effort to create a global framework for understanding ecosystems on land, ocean, and shoreline that provide the services that support life on earth. GIS plays a vital role in building, visualizing, and using this framework for better understanding ecosystems and preserving them.

Completely mapping the Earth in a standardized and rigorous manner is essential for tackling global challenges, such as climate change and the preservation of biodiversity, which are becoming more pressing concerns. Accurate geospatial information will make it possible for scientists, land managers, conservationists, developers, and the public to understand the current state of ecosystems and contribute to a more profound understanding of how they are changing. This data is vital to identify areas that must be protected and others that need to be managed in a more sustainable fashion.

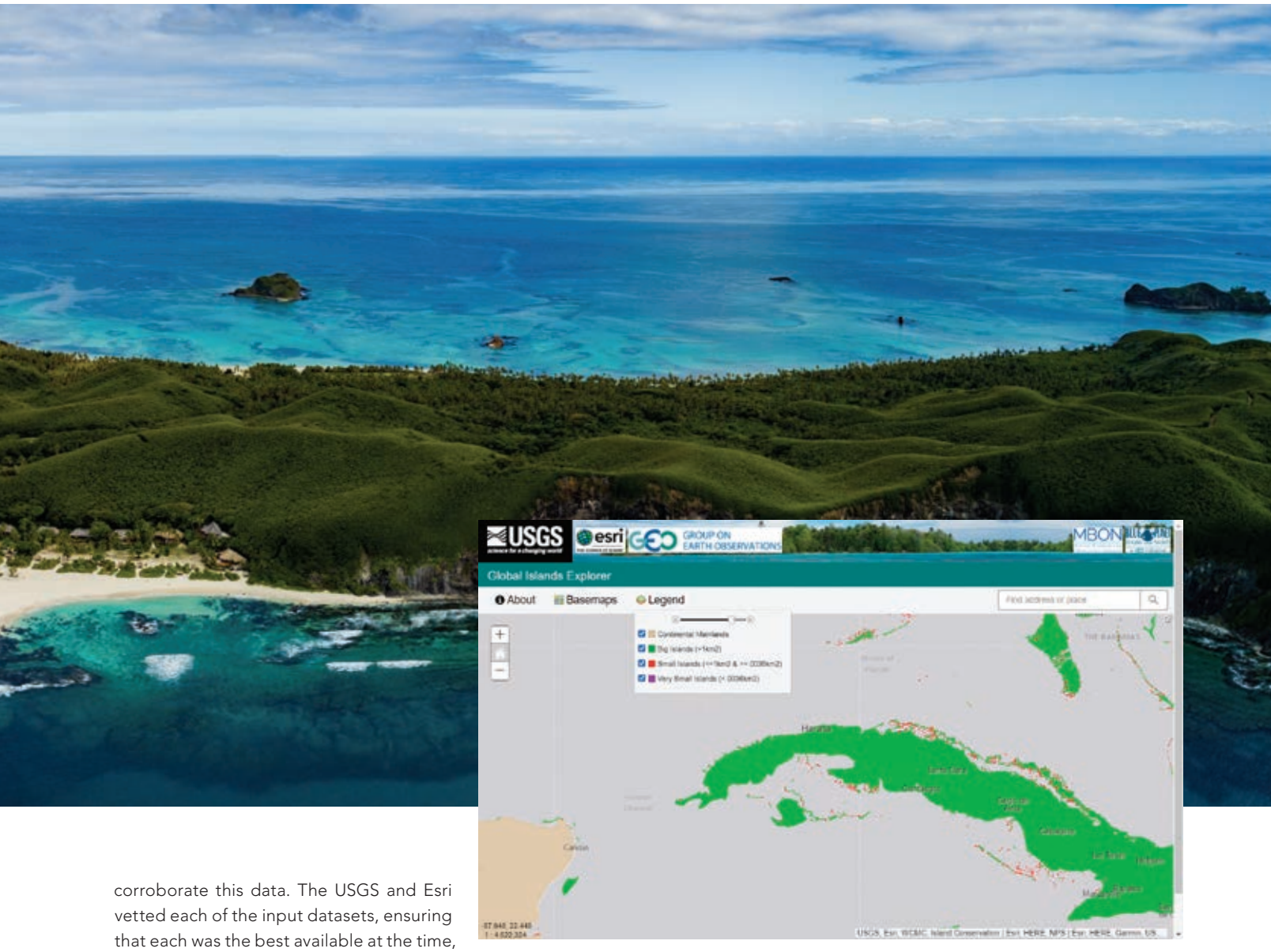
While an abundance of ecosystem data has been gathered, it has not been available at a global extent that was created with standardized scale and quality. Previously, no organization had undertaken ecological base mapping on a global scale using standardized units and terminology. Without a shared language for reference, it can be difficult or impossible to develop understanding.

The need for the first comprehensive maps that define all of Earth's ecosystems was recognized and supported by the Group on Earth Observations (GEO), a partnership of more than 100 national governments and more than 100 participating organizations that work to create innovative solutions to global challenges that transcend national boundaries.

GEO BON is GEO's Biodiversity Observation Network, and GEO Global Ecosystem Initiative (GEO ECO) is an initiative to map and monitor global ecosystems. A high-resolution, standardized, and practical map of global ecosystems for terrestrial, marine, and freshwater environments is an initiative of GEO ECO. Roger Sayre, senior scientist for ecosystems at the US Geological Survey (USGS), was asked to lead the US portion of this initiative and a team that was composed of scientists from USGS and various academic institutions as well as geographers, analysts, cartographers, and software developers from Esri.

Beginning on Land

In 2013, USGS and Esri began this formidable undertaking by mapping ecological land units (ELUs). They built a GIS of world landforms using a 250-by-250-meter grid that contained 3.5 billion cells. A collection of historical maps was used to validate and

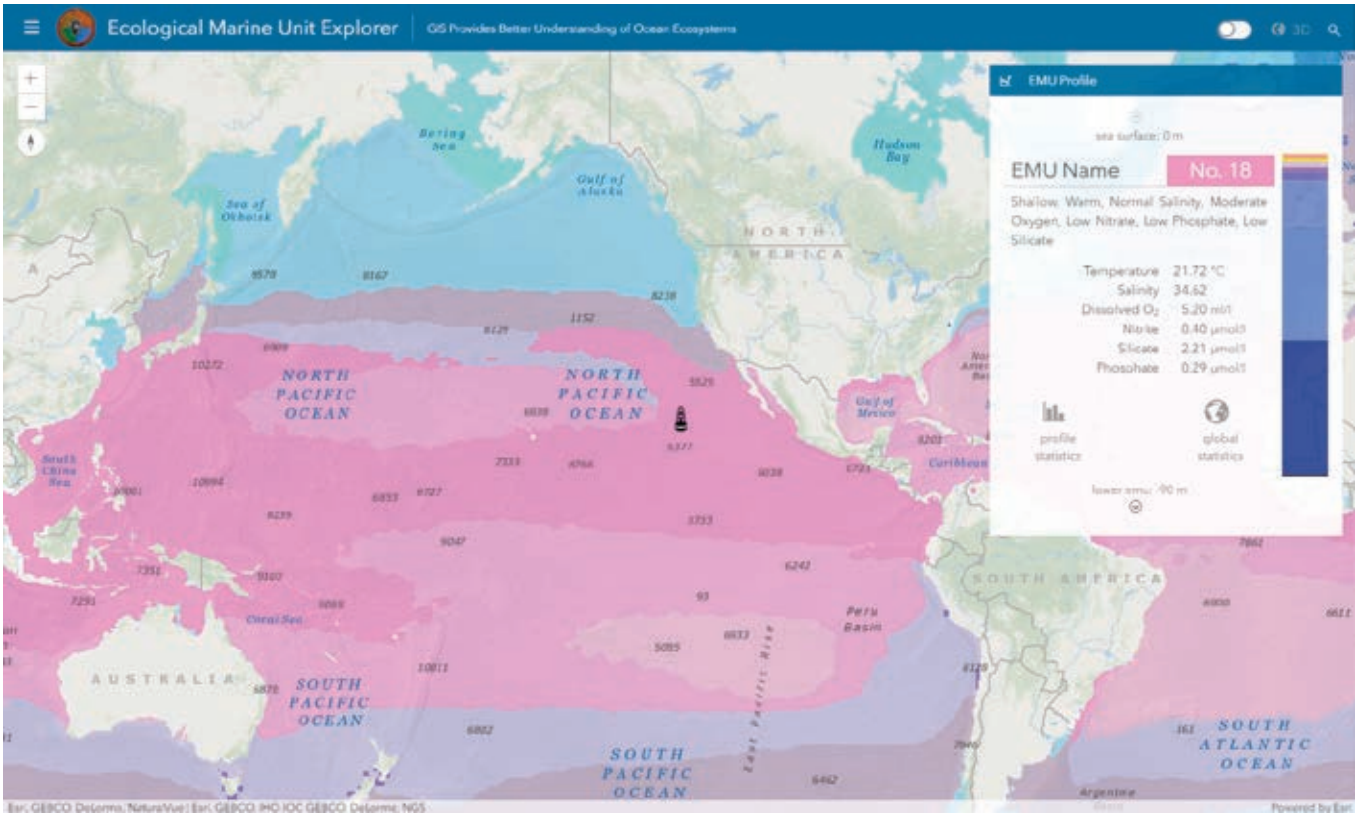


corroborate this data. The USGS and Esri vetted each of the input datasets, ensuring that each was the best available at the time, and evaluating each for data quality.

More than 105,000 ecological facets describing those cells were identified. These facets represent unique combinations of land cover, lithology, landform type, and climate. The facets were integrated based on different aspects of a terrestrial ecosystems—climate regime, soil moisture, geology, landform, and the organisms present—and aggregated into 4,000 ELUs, using GIS to create a geographic set of ecosystem areas that can be visualized and analyzed. ELUs were first made publicly available in 2015.

ELUs were the beginning of a global framework. They fill the gap between micro and macro views with medium-scale data that is useful for studying ecological diversity, rarity, and evolutionary isolation. Data at this scale is especially valuable

↑ Ecological coastal units (ECUs) cover the unique and extensive coastal region, which differs greatly from terrestrial and open ocean environments. ECUs data is available from the Global Islands Explorer.



↑ Released in 2016, ecological marine units (EMUs) delineate physically and chemically distinct regions of the open ocean and note variations in temperature, salinity, oxygen, and nutrients.

for conservation and preservation planning. By establishing common units and shared terminology, ELUs enable greater collaboration.

Mapping of the ELUs was based on structural elements, rather than biological assemblages. Once species distribution data has been incorporated, researchers will be able to explore questions about the carrying capacity of areas. This Esri Story Maps Journal (https://arcg.is/1SLKai) provides more information on the creation and use of ELUs.

A Framework for Understanding Oceans

The work of the initiative moved from Earth's landmass to its oceans with the development of the ecological marine units (EMUs). As the repository of almost all water on the planet, oceans are critical to the well-being of the planet and its inhabitants because of their impact on climate and weather and their role as a major source of food. Yet, despite this undeniable importance, it is estimated that only 10 percent of oceans have been explored.

To ameliorate this situation, a public-private partnership built the EMUs. The partnership was led by Esri and USGS in collaboration with NatureServe, the Marine Conservation Institute, the University of Auckland (New Zealand), GRID-Arendal (Norway), Duke University, the Woods Hole Oceanographic Institution, the National Institute of Water and Atmospheric Research (NIWA), the United States National Oceanic and Atmospheric Administration (NOAA), and the United States National Aeronautics and Space Administration (NASA).

The project establishes a 3D point mesh framework spanning 52 million points and amassed global measurements of six key variables of the ocean's water column over a 50-year period. The creation of EMUs was a big data project. EMUs represent data aggregation and computation on an unprecedented scale. Climatology data was extracted at one-quarter degree by one-quarter degree intervals (or approximately 27 kilometers by 27 kilometers as measured at the equator) at variable depths before being spatially analyzed and clustered using a multivariate statistical method and then verified by leading oceanographers.

Released in 2016, EMUs delineate physically and chemically distinct regions of the open ocean and note variations in temperature, salinity, oxygen, and nutrients. They are a standardized, rigorous, and ecologically meaningful set of ocean ecosystem units that may be used as a basemap for climate change impact studies, biodiversity priority setting, economic and social valuation studies, research, and marine spatial planning.

In describing the unique value of EMUs, Esri chief scientist Dawn Wright, who led Esri's efforts on the project, said, "The strength of EMUs is that they differ from existing maps of marine ecoregions or biogeographic realms by being globally comprehensive, quantitatively data driven, and truly 3D."

This is data that can help inform the actions of conservation-minded organizations, academic institutions, and scientists, who are working to preserve marine environments. NOAA's *World Ocean Atlas* is the primary data source for EMUs. They are easily accessed from Ecological Marine

Unit Explorer apps via the web browser and mobile devices and can be downloaded by joining the ArcGIS Online Ecological Marine Units group. This Esri Story Maps Journal (https://arcg.is/0GTzSH) provides more information on EMUs.

Between Land and Sea

While the 27 kilometer by 27 kilometer resolution of EMUs is relatively fine for open ocean data, the much higher 1 kilometer resolution was needed for coastal areas. The team that produced the EMUs developed a separate and independent effort to delineate global ECUs in 2018.

This new map covers the unique and extensive coastal region, which differs greatly from terrestrial and open ocean environments. In addition to the coastline itself, the global coastal zone includes the terrestrial ecosystems and marine ecosystems on either side of the coastline.

Understanding coastal zone ecosystems is critical to sustainability efforts and can help mitigate the environmental, economic, and social effects of climate change. Understanding coastal ecosystems is essential for meeting the United Nations (UN) 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs), Specifically, ECUs support SDG 14, Life Below Water goal, which calls for the sustainable management and protection of marine and coastal ecosystems and the conservation of at least 10 percent of coastal and marine areas. Achieving this goal requires a comprehensive inventory of coastal ecosystems and a strategy for determining the 10 percent of ecosystems to be preserved.

According to estimates by the United Nations, nearly 2.4 billion people or about 40 percent of the world's population currently lives within 100 kilometers of the coast, where they are at risk from flooding caused by sea level rise. Understanding coastal regions will be necessary to limit the social, economic, and environmental costs of sea level rise that analysis has shown will likely to increase within the next decade.

Creating ECUs

To build ECUs, the team took a coastline segmentation approach in analyzing the differences in coastline properties. The initial step in this process was the development of a brand-new 30-meter resolution image-derived map of Earth's coastlines. This effort was necessary because the coastline characterization then available was inadequate in terms of accuracy, spatial resolution, comprehensiveness, and the visual fit of the coastline vectors to the shore of existing noncommercial global shoreline datasets.

In a 2019 interview, Sayre said, "We needed a coastline vector as the spatial backbone for this project, so we went into the cloud and extracted a brand-new global shoreline from 2014 Landsat imagery. Looking at this new global shoreline, it occurred to us that since every landmass on the planet is an island, no matter how big it is, we were sitting on a new global islands database." The 2014 annual composite Landsat imagery was used because it dilutes the effect of clouds in imagery.

The result was the global shoreline vector (GSV) and the global island dataset derived from GSV through the application of polygon topology. GSV was developed using

↓ Ecological land units (ELUs) were the beginning of a global framework. They fill the gap between micro and macro views with medium- scale data that is useful for studying ecological diversity, rarity, and evolutionary isolation.

↑ ECUs join ELUs and EMUs in supporting the creation of a set of standardized, rigorous, and ecologically meaningful maps.

a semiautomated supervised classification approach using big data techniques. Because Landsat imagery was already available in the cloud, the need to house and manage vast amounts of imagery was eliminated.

This process captured data for hundreds of thousands of islands that were missing from previously created datasets. By developing the Global Islands Explorer (GIE) (https://rmgsc.cr.usgs.gov/gie), USGS and Esri made this new global data on islands accessible. Using this tool, 340,691 islands can be visualized and queried.

From GSV, four million, 1-kilometer segments were generated. These segments served as the basis for subsequent analysis. Each segment was attributed with 10 variables that described the ecological settings for that segment. Those segments were classified into 81,000 unique coastal segment units (CSUs) based on the Coastal and Marine Ecological Classification Standard (CMECS), a framework for organizing information about coasts and oceans and their associated living systems, which is endorsed by the Federal Geographic Data Committee (FGDC).

CSUs were statistically clustered into 16 groups that are globally similar as described by the 10 variables. This process yielded ECUs, standardized data that facilitates comparison on an apples-to-apples basis and collaboration between organizations.

A Valuable Resource

Although created as inputs for generating ECUs, CSUs are valuable in efforts to understand coastal ecosystems. CSUs provide a descriptive global inventory of coastal ecological settings that have management utility at local scales because they use data at the highest available spatial resolution. ECUs are exploratory and preliminary units that have utility for global assessments, especially for the 30 x 30 goal to preserve 30 percent of land and 30 percent of the oceans as well as the UN SDGs.

ECUs join ELUs and EMUs in supporting the creation of a set of standardized, rigorous, and ecologically meaningful maps. All have been produced using an approach that is objective and repeatable, and uses big data techniques to synthesize and classify ecologically important data layers into distinctive and meaningful georeferenced units.

The next steps in creating this framework for understanding Earth will be the creation of global ecological freshwater units (EFUs) and, possibly, ecological benthic units (EBUs).

These global ecological units are powerful and valuable to a much broader universe. They help promote a more profound understanding of the Earth that has potential for informing more sustainable decisions by governments, the private sector, and nongovernmental organizations.

About the Author

Monica Pratt is the founding and current editor of *ArcUser* magazine, the executive editor of *ArcNews* magazine, the editor of *Esri Globe,* and head of the publications team at Esri. She has been writing on technology topics, specializing in GIS, for more than 30 years. Before joining Esri in 1997, she worked for newspapers and in the financial industry.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South Korean City Uses a Digital Twin to Meet Challenges

By Greg Milner

A South Korean city is using a digital twin to become a truly smart city by using its geospatial infrastructure to engage its agencies and the public to help meet challenges, both present and future.

Incheon Metropolitan City, one of the largest cities in the Republic of Korea, is home to three million people and a sizeable population of mosquitoes. Exactly how many of the latter is difficult to say, but it is a question that interests the country's public health officials.

Located on the northwest coast of South Korea, near Seoul, the nation's capital, Incheon is a major industrial center. Incheon anchors the western side of the Seoul Capital Area, the world's second-largest megaregion. As the world continues to urbanize, the region will get more crowded.

In this age of global pandemics, Incheon is also the gateway city to South Korea, with one of the world's busiest international airports. "Due to the growth of overseas travel and global logistics, Incheon needs to be very careful about infectious diseases," said Jo Giwoong, a GIS expert who oversees Incheon's smart city initiatives.

In recent years, South Korea has experienced an uptick in dengue fever, which is carried by mosquitoes. Warming in the region caused by climate change intensifies the threat of other foreign mosquito-borne diseases, including malaria, yellow fever, West Nile fever, and Japanese encephalitis.

Downtown Incheon was the representative urban area in a recent study that examined how climate change is affecting the mosquito population on the Korean peninsula, and whether there was a correlating effect on disease spread. For three years, a monitoring system logged mosquito captures, transmitting the real-time data over a Long-Term Evolution (LTE) network to ArcGIS GeoEvent Server. *[LTE is a 4G wireless broadband standard that is used by mobile devices to connect to the internet from cellular towers.]* System data can be cross-referenced with other geographic data, such as real-time feeds from the national weather service.

"We're using an ArcGIS dashboard to monitor all this data together," Jo said. "We share the information with related agencies to quickly identify vulnerable areas, so that the problem can be intensively and preemptively controlled."

On the question of whether climate change was creating more mosquito-borne illnesses, the study was inconclusive. But the monitoring system itself was an example of an extraordinarily forward-thinking smart-city experiment unfolding in Incheon. Under Jo's leadership, the city has built a digital twin, which was introduced in early 2021.

Digital twins are virtual representations of the processes, relationships, and behaviors of real-world systems. The concept began as a way for manufacturers to record and log the intricate functioning of factories. Industrial designers began to use digital twins to visualize the effect of proposed changes to an object or process.

More recently, the digital twin concept has been applied to urban planning. Virtual 3D models of cities, augmented by local information, provide a means of proposing, understanding, and analyzing development projects and other changes to the urban landscape.

Incheon's digital twin attempts to mirror many of the city's functions in real time. The real-world system it duplicates is nothing less than Incheon itself. In this context, mosquitoes are not just pests and disease vectors; they represent one more dynamic system in a city that contains many, ranging from power grids to weather activity. To varying degrees, these systems all affect—and are affected by—the others. The digital twin is an ongoing record of the processes and interactions of these systems.

The use of GIS for government functions in South Korea dates back to the 1990s, when several high-profile gas explosions revealed the need for greater understanding of underground critical infrastructure. "These disasters were caused by negligence in safety management and a lack of proper guidance," Jo explained.

Municipalities across the country invested in GIS tools for surveying and mapping infrastructure, but not for gathering, sorting, and sharing data. For city managers, the costs of managing data were prohibitive.

Jo's expertise combines land management, which he studied in the 1980s, and computer engineering, which he later pursued. The development of Internet of Things (IoT) sensors and strong mobile networks made gathering large amounts of location data a more realistic proposition.

In 2013, some civic offices in Incheon began to use web-based GIS. Eventually, 250 departments across the city were using some form of it. In 2016, Jo began doing GIS work for the city of Incheon. By 2018, a "data-based administration," as Jo called it, was essential policy in Incheon. The next step, as Jo saw it, was to put all these departments on the same page using a digital twin.

As a first step toward that goal, Incheon's smart city department oversaw the construction of a 3D basemap as the foundation for the city's digital twin. "It's all about the data, and we decided that for a digital twin, we needed very elaborate data to understand and capture a high-density city," Jo explained. After considering several options, Jo's team decided to capture precise point cloud data by using lidar to scan the entire city. That would produce data at a scale of 150 points or more per square meter.

Throughout the process of creating the digital twin, Jo and his team concentrated more on data creation and management, and less on developing a system architecture that was unique to the Incheon project.

"Some organizations, when building a digital twin, spend more on system development and the integration side than on the data," he said. "But we decided to use web scenes. It's not perfect for Korean conditions, but I think it's the best solution, because the 3D basemap and data built by our city can be infinitely expanded."

By the end of 2020, the virtual city was nearing completion, ready to become a true digital twin. Waterworks Headquarters Incheon Metropolitan City was the first local office to import its data into the digital twin. Using Portal for ArcGIS, a component of ArcGIS Enterprise, the department deployed a water utility

↖ Incheon Metropolitan City is one of the largest cities in the Republic of Korea.

→ Incheon is located on the northwest coast of South Korea, near the nation's capital of Seoul.

network model and enabled web-service based architecture for the city's water supply management system.

"The mobile era is overflowing with location information," he said. "There is a convergence of data relating to temporal and spatial information, and the scope of use is expanding into all areas of local administration. There is so much data out there, from text data to large-capacity imagery data, but data that contains temporal and spatial information is like 100 percent pure gold."

Since the beginning of the year, the Incheon digital twin has grown to include six project areas: fire response management, traffic, urban sanitation, facilities management, urban development, and city revitalization.

Activities for improvements include a method for routing and tracking the location of street cleaning vehicles, so that managers have a better understanding of progress at any given moment. By creating maps of garbage and food waste disposal throughout Incheon and monitoring its status through an app, the department can understand how to effectively allocate cleaning vehicles.

The Incheon Fire Department has used the digital twin to launch an experimental program for allocating resources. By outfitting 35 fire trucks with receivers that use an IoT network and GPS for precise real-time positioning, the department has the real-time location for each truck. "When the department is able to determine instantly where its resources are, it will definitely speed up response times," Jo explained.

Incheon's digital twin will soon be used to manage underground assets, such as sewer systems, power grids, telecommunications, and subways. Even natural gas lines—the impetus for introducing GIS into the urban management process in the 1990s—will be monitored and controlled with the digital twin.

Jo is particularly pleased that Incheon's digital twin is now being used to operate a flood prediction monitoring system. This is an important development because the digital twin doesn't just mirror the city as it is in the moment; it can be used to predict events caused by changes in conditions in the city.

"The ultimate model of a digital twin city," he explained, "is a simulation based on the real world."

Altogether, 500 staff members from 30 different departments currently use the digital twin in some capacity. Jo expects those numbers to grow as the complexity of the digital twin increases. "We are constantly collecting data, and we try to keep it as current as possible," Jo said. He estimates that the digital twin has increased efficiency among Incheon city government offices by 10 percent. The next step in its evolution will be to begin making data from the digital twin more accessible to the public.

"We've realized that the more we engage constituents and connect data, the more we can reduce costs and make Incheon a more sustainable and prosperous city," he said. "What really makes Incheon a smart city is that we're creating a barrier-free zone with geospatial infrastructure. No matter what department, other agencies, as well as the private sector, can engage with us to help solve Incheon's problems."

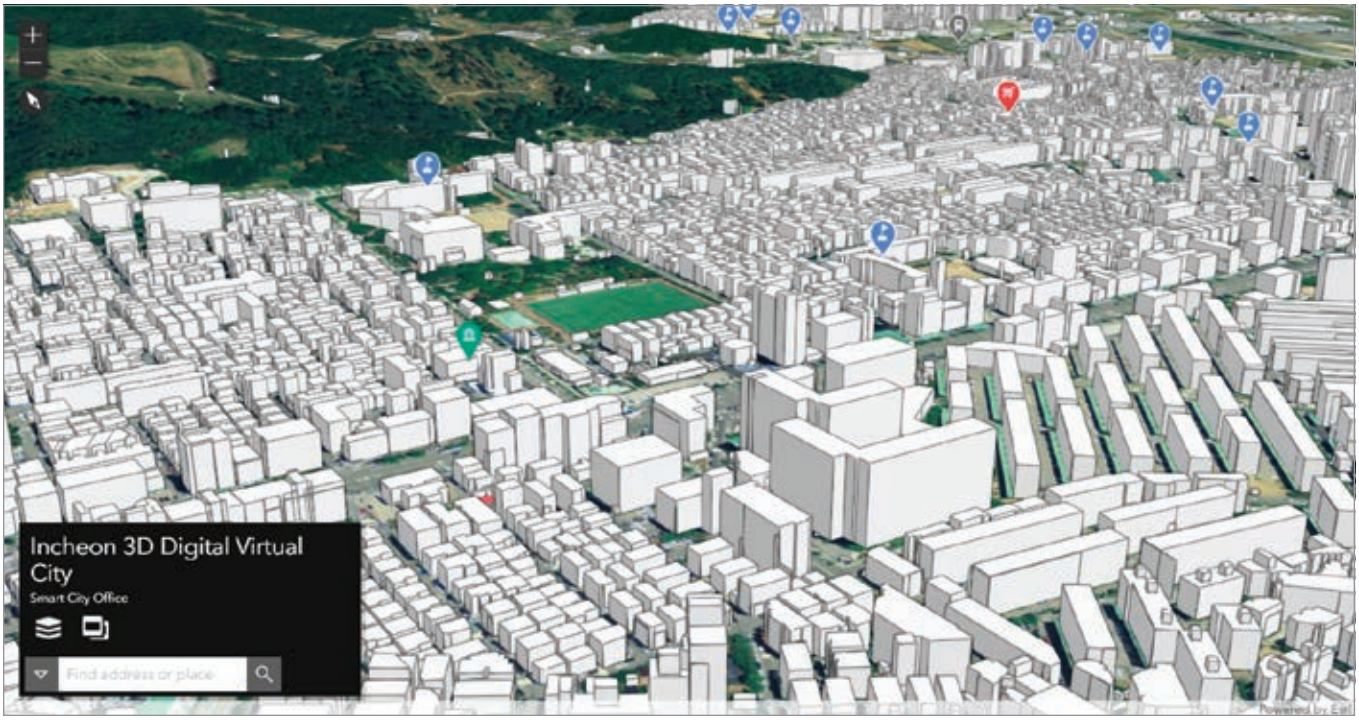
As more of the digital twin becomes public facing, the mapping aspect and its GIS foundation will come to the forefront. Jo's team is currently working on using the digital twin as the basis for mobile mapping apps.

The first of these apps is designed to support the local economy by focusing on Incheon's 12 shopping areas in the older section of the city. The oldest of these markets is more than a century old. "There isn't enough information about these old markets," Jo said. "The lack of information about the types of stores, opening hours, and contact info has been a barrier, making it difficult for them to attract new customers."

Incheon has worked with several

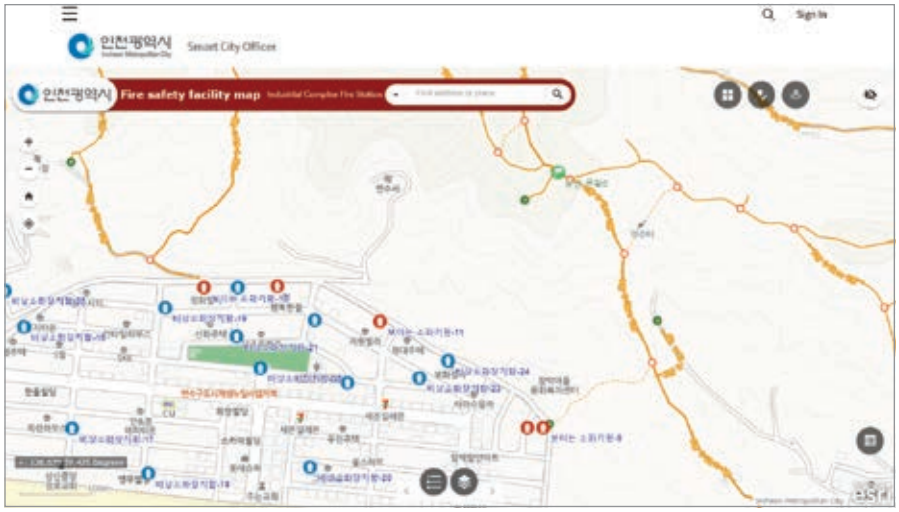
↖ The city's team is currently working on using the digital twin as the basis for mobile mapping apps.

↙ In recent years, South Korea has experienced an uptick in mosquito-borne diseases. Dashboards are used to monitor and share data on mosquitoes to quickly identify vulnerable areas, so that problems can be intensively and preemptively controlled.



↑ Incheon decided to build a 3D basemap for its digital twin.

→ The Incheon Fire Department has used the digital twin to launch an experimental program for allocating resources.



prominent Korean companies to create maps of these markets. "As a result, people can now search for information about the stores, and even use GPS to find the exact store location," Jo explained.

Generally, Incheon is not a city of young people. Nearly 30 percent of the population has limited mobility due to age or physical condition. To improve the city's walkability and create a more pedestrian-friendly environment, Jo's team is working on maps that are more than simple two-dimensional documents that flatten the city, both literally and figuratively.

"Maps help us find our way, but they don't typically provide details about things that might be difficult for people, like a pedestrian overpass, elevated roads, or crosswalks that have a short signal duration," he said. "Through data collection, we'll publish maps that let people walk freely while avoiding obstacles like steep slopes and stairs."

In a subtle way, these maps build on the premise that animates much of Jo's work—that the gold standard for data merges a 3D spatial perspective that includes slopes, stairs, and overpasses with temporal information, such as intersections with lights that may change too quickly for slow walkers.

A city's most dynamic system is always its people. In Jo's formulation of the digital twin, people will have a place in the digital twin's data. His dreams for its evolution, therefore, focus not merely on data, but on harnessing the power of the city's residents to make the twin even more powerful.

For the moment, Jo's smart city office has primary control over the digital twin, but in the coming years the digital twin will become a collaborative entity for all stakeholders. As he puts it, "all citizens will be part of this in the long run."

About the Author

Greg Milner is a writer in the strategic content group at Esri, where he tells stories about how location intelligence is transforming our world and how we perceive it. A former magazine editor and political speechwriter, he is the author of the books *Perfecting Sound Forever: An Aural History of Recorded Music*, which was a finalist for the National Book Critics Circle Award, and *Pinpoint: How GPS Is Changing Technology, Culture, and Our Minds*.

Mapping Pikas' Habitat to Help Save Them

By Thomas Dilts, Jane Van Gunst, and Jessica Castillo Vardaro

A team drawn from the Nevada Department of Wildlife (NDOW); University of Nevada, Reno; and San José State University used high-resolution imagery, ArcGIS, and R to identify the habitat necessary for the survival of a species of small mammal that is sensitive to increasing temperatures caused by climate change.

American pikas (*Ochotona princeps*) are small mammals that inhabit fractured rock habitats, such as boulder fields and talus patches, at high elevations in western North America. Although pikas already tend to inhabit high-elevation areas above the tree line, these thermally sensitive creatures have been affected by warming global temperatures, which has led to local extinctions and population declines over large parts of their range, particularly within the Great Basin ecoregion. *[The Great Basin is the largest endorheic watershed in North America. It spans portions of Nevada, Oregon, Utah, California, Idaho, Wyoming, and Baja California in Mexico.]* In 2007, a petition was made to list pikas under the Endangered Species Act.

↓ The American pika inhabits talus fields usually at high elevations and is sensitive to changing temperatures.

Recently, several populations of pika have been discovered at altitudes of between 5,800 and 7,000 feet, relatively low elevations for the Great Basin desert in northwest Nevada. These pikas inhabit climatic conditions that are much hotter and drier than those of their Alpine relatives in other parts of the western United States.

These areas are large basaltic talus fields that are located across northwest Nevada as well as neighboring California, Oregon, and Idaho. The term *talus* describes rock fragments, usually coarse and irregular, that accumulate at the base of a cliff, chute, or slope. Talus environments allow pika to experience more moderate temperatures that are cooler in summer and warmer in winter. Despite the existence of other similar talus areas throughout much of the landscape of northwest Nevada, many of these sites are not currently occupied by pika. Known occurrences of pika are scattered, and many recently discovered populations appear to have been wiped out.

To understand and catalog the occurrence of pika, the NDOW; University of Nevada, Reno; and San José State University teamed up to create the *Northwest Nevada Talus Atlas,* the first talus atlas for the region.

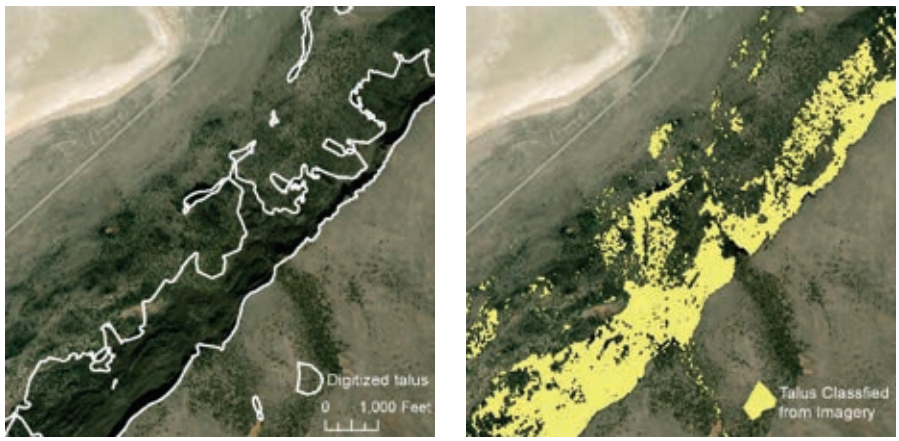
Although not all talus patches are occupied by pika, talus is necessary for pika to persist. Having a good map of talus can help biologists plan field surveys in a systematic manner to ensure that no locations are left out. Mapping talus locations can also be used to understand how pika populations might be connected and how dispersal and gene flow might have occurred in the past and be occuring now.

The research team used maps of talus that were hand digitized from the Sheldon National Wildlife Refuge in Winnemucca, Nevada, along with imagery from the National Agriculture Imagery Program (NAIP). NAIP imagery is produced by the United States Department of Agriculture Farm Service Agency. The team used imagery from 2017 that included red, green, blue, and near-infrared spectral bands that was resampled from 1-meter resolution to 5-meter resolution to speed processing. Using the polygons from the Sheldon National Wildlife Refuge study, the team generated 2,000 random points within talus areas and 2,000 random points outside of digitized talus areas and extracted blue, green, red, and near-infrared reflectance from the NAIP imagery.

With this point data, the team calculated the Normalized Difference Vegetation Index (NDVI), Green-Red Vegetation Index (GRVI), and a pseudo albedo from the spectral bands. Using the Marine Geospatial Ecology Tools for ArcGIS, the team could access advanced machine learning classification tools through the R statistical computing language.

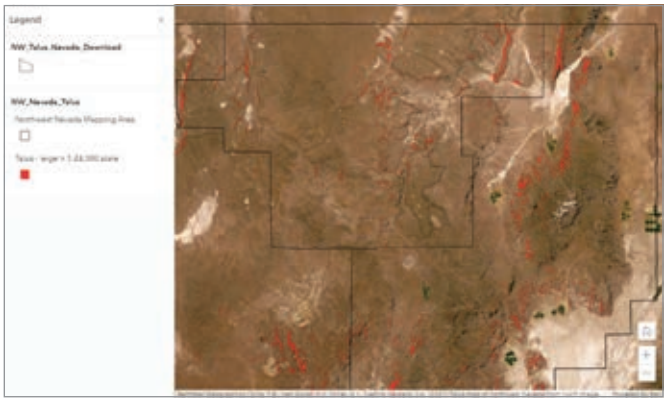
The Marine Geospatial Ecology Tools, a free open-source geoprocessing toolbox that plugs into ArcGIS, was developed by Duke University to integrate ArcMap and R using Python and C++. It provides a user-friendly graphic user interface (GUI) that eliminates the need for its user to know any R code.

The team used the randomForest package for R, which implements a machine learning method for classification and regression known for its high accuracy, ease of use, and advanced graphing capabilities. The use of this package resulted in a classified map that had an accuracy rate of greater than 71 percent.



↑ Maps show the digitized polygons (left) used to train the random forest classification model (right).

→ The *Northwest Nevada Talus Atlas* shows the location of talus fields within northwest Nevada. Data from the atlas is freely available on ArcGIS Online at https://bit.ly/3uTsNc6.



The extreme northwest portion of Nevada was not being classified as accurately in areas where talus fields were intermingled with juniper woodlands. For this area, the team developed a separate classification by hand digitizing 1,172 talus points and matching them with an equal number of digitized nontalus points. The two classified maps were combined, so the separately classified woodland map was used for the woodland portions, and the regular classification map was used in all other portions of the study area.

The research team made the *Northwest Nevada Talus Atlas* available through ArcGIS Online (https://bit.ly/3uTsNc6) so that the data would be accessible to biologists in all parts of Nevada and the neighboring states in an easy-to-use format. The University of Nevada has a partnership with Esri that provides a certain number of credits to faculty, staff, and students for hosting their projects on ArcGIS Online. To ensure that maps display rapidly and smoothly, these maps were generalized at three different spatial scales as tile services on ArcGIS Online. The underlying spatial data was made available as shapefiles for four different subsets of the study area.

The research team plans to use the *Northwest Nevada Talus Atlas* to identify new field sites for future visits and understand how proximity to other talus patches and patch size influence the probability of pika persistence. The team is using climatic variables, vegetation indexes, and connectivity to determine whether sites where pika populations have recently ceased to be viable are located in hotter and drier conditions or are more distant from neighboring talus.

To promote the viability of pika populations, biologists are also collecting genetic samples to identify which pika populations are most closely related, which are most isolated, and which are most at risk of population decline. In addition, biologists are using radiocarbon dating to estimate the time frames and patterns of the demise of pika populations across the region. Finally, NDOW works with the Bureau of Land Management (BLM), the regional land management agency, to identify threats to pikas, such as those from wildfire and livestock grazing, that may affect their food sources.

About the Authors

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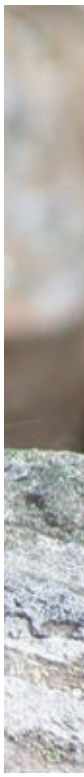
Jessica Castillo Vardaro is an assistant professor of biology at San José State University in California who focuses her research on population genetics and conservation genetics of North American wildlife. She has been studying the American pika since 2010 and has done extensive field work on pikas, including in the Sheldon National Wildlife Refuge. She can be reached at Jessica.Castillo-Vardaro@sjsu.edu.



How to Review a Geospatial Strategy

By Matthew Lewin

Over the last decade or so, I've been fortunate to work with a variety of organizations on their geospatial strategies. In some cases, my team and I developed the strategy. Other times, a customer asked us to review an internally produced document or analyze another consultant's work.

Regardless of the source, I've learned that you can usually tell a good strategy from a not-so-good one based on a handful of factors. These days when reviewing strategies, I regularly consult a checklist to help me evaluate a strategy.

There are 13 factors, and here they are:

- Is it aspirational?
- Is it business driven?
- Is it inclusive?
- Is it geospatial?
- Is it modern?
- Is it aligned with the IT strategy?
- Is it holistic?
- Does it commit to tough decisions?
- Is it traceable?
- Does it adopt best practices?
- Is it practical?
- Is leadership on board?
- Does it tell a good story?

In this article, I walk through each of the factors and a set of probing questions. You can use this checklist as a guide when developing your geospatial strategy or as a final checklist to see if you hit the mark.

Is It Aspirational?

A strategy—first and foremost—needs a vision. It needs a compelling articulation of a desirable future.

Most strategies I encounter have some form of a vision that is typically written as a statement, often in combination with a mission statement. It is typically supported by a set of guiding principles and high-level goals. This is all good stuff!

My interest is in seeing whether the combined statements are aspirational or not. Do they describe an ambitious future that's desirable or do they leave me searching for more?

First, the vision should be desirable. It should depict a future that creates value for the organization and its customers. It should motivate and unite people around a common purpose. At the same time, the vision should be ambitious. It should strive to create change.

Unfortunately, I frequently see geospatial vision statements that are middling in their ambitions. Often, they describe a future that looks a lot like the present, prompting me to ask, Why bother with a strategy at all? A vision must aspire to something that transcends the status quo. Without it, people will view your strategy as weak, uninspired shelfware.

Here's an example of a vision statement from a city government:

To provide the organization with a geospatial platform for mapping and spatial data analysis.

That's pretty ordinary. This is more of a service offering statement than a vision. It's not particularly ambitious and certainly not inspiring. And it seems to focus on internal operations while ignoring the community at large.

Here's a stronger, more aspirational version:

Our geospatial capabilities will be recognized as a core enabler of the city's strategic vision, where innovation and insights derived from geospatial information empower a prosperous, inclusive, and safe community.

This version is much more inspiring and more inclusive. It strives for a lofty goal (being recognized as a core enabler) and at the same time includes the ultimate beneficiary of the strategy, the community.

Is It Business Driven?

The main goal of a geospatial strategy is to create a capability that delivers value to the business through better location intelligence. The needs of the business determine the strategy.

When I review a strategy, I look to see that the business needs are front and center and concisely documented. Specifically, I'm looking to see that the needs are understood and at multiple levels across relevant stakeholder groups. The needs should be clearly defined and framed within a geospatial context (this is a geospatial strategy, after all).

At the corporate level, are the organization's goals, objectives, and priorities summarized? Are key initiatives highlighted, particularly those of high importance to senior management? Is a connection made between the corporate strategy and the role of geospatial technology?

At the department level, are specific business unit goals identified? Are critical business capabilities documented? Are key geospatial use cases described along with current challenges? How about new opportunities to leverage geospatial technology?

What about outside the organization? Are the needs of customers considered? Does the strategy articulate these stakeholders' requirements and how geospatial technology currently does or doesn't support them? Are there other groups external to the organization to consider?

Remember, a geospatial strategy serves the business, not the other way around. It will only be successful if it delivers material value and tangible outcomes to your business and your customers.

Is It Inclusive?

Ideally, a geospatial strategy considers the full span of the business—or at least a broad cross section of relevant stakeholders.

Few things can set a strategy back quicker than an influential group crying foul because it wasn't included in the strategy, not to mention the potential for missed opportunities when you focus only on the usual geospatial user groups and fail to include nontraditional or overlooked areas.

If there's a legitimate reason to limit stakeholder engagement, then I'd want to understand how the strategy could adapt to include other interests in the future. Sometimes geospatial strategies are developed in stages, with early stages focused on shoring up a core community. That's perfectly fine. But effective strategies are scalable strategies, and scaling across to include different types of stakeholders is as important as scaling up to allow for greater numbers of stakeholders.

Is It Geospatial?

It might sound obvious, but a geospatial strategy should focus on solutions that are, by and large, geospatial. I mean this in two ways.

First, proposed solutions should clearly show how insights derived from geospatial information help address an identified business need. If the solution descriptions are vague in terms of how they contribute to generating location intelligence, one might assume some other nonspatial solution could address the business need. You might even hear the dreaded words, "we could probably do that in a spreadsheet." Make sure you leave no doubt about the geospatial value proposition.

Second, the proposed solutions should be broadly geospatial. Often, I see recommendations that focus on one aspect of a geospatial workflow, such as map production, and fail to consider the upstream data acquisition requirements or downstream analysis needs.

Since location is information, I like to see solutions that address business needs across the entirety of the information life cycle. This life cycle includes collection and acquisition, validation and management, discovery and access, mapping and visualization, analysis and interpretation, and sharing and collaboration.

Is It Modern?

As in all digital industries, change in the geospatial industry is rapid and relentless. Not only are new versions of enterprise software released frequently, but also advances that were cutting edge just a few years ago can quickly become standard features.

The last thing you want is a geospatial strategy that's outdated from the start. This can lead to investment decisions that poorly reflect the current and future business environment. It can also exacerbate technical debt. A hallmark of an effective geospatial strategy is that the strategy helps to future proof the business from unforeseen disruption, not contribute to it.

When I'm reviewing a strategy, I look to see if it's centered on today and tomorrow, not yesterday. Does it embrace modern solutions and implementation patterns? Does it address pressing and future business concerns? Does it consider emerging technological advances such as geospatial artificial intelligence (GeoAI) or blockchain integration? Does it reflect changing workforce dynamics such as the shift to working from home and office staff decentralization? A good strategy positions the organization for a successful future.

Is It Aligned with the IT Strategy?

Geospatial technology refers to the range of technology that deals specifically with geographic information. As an information-centric technology, it's imperative that a geospatial strategy reflect and respect the direction, principles, and standards established through the IT strategy.

Why is this? In most organizations, the geospatial portfolio is one of many portfolios of solutions. To manage an ecosystem of solutions that can often number in the thousands, most IT organizations develop strategies to deal with the complexities. That means developing strategies

for mobile devices, storage, integration, and the cloud, in addition to implementing standards for security, privacy, and architecture.

Deviating significantly from the IT strategy can mean adding a considerable support burden to the IT organization and can make integration with other systems more difficult. In fact, I've seen IT organizations stop a geospatial strategy in its tracks for this reason. In other cases, IT organizations draw a strong, almost adversarial line between what they support and what the geospatial team is responsible for, which is usually everything above the operating system tier.

When reviewing a geospatial strategy, I determine whether the IT strategy's key principles have been acknowledged and factored into decisions about solutions, data practices, infrastructure, and the support model. I also like to know if the IT team was included in the strategy formulation process and validated any deviations from the IT strategy.

Is It Holistic?

I think of a geospatial strategy not as one strategy but as a set of interrelated substrategies. I refer to these as the seven building blocks of a geospatial strategy, which fall into three categories; people (workforce and culture), processes (governance and operations), and technology (applications, data, and infrastructure). An effective geospatial strategy gives due consideration to all seven building blocks.

Without a holistic perspective, your strategy is unbalanced. A strategy that makes strong technology recommendations but overlooks the new skills or workflows required to leverage these solutions will fail in technology adoption. Likewise, strategies that recommend centralizing staff and systems but ignore the organization's entrepreneurial, autonomy-centric culture will be perceived as poorly aligned and out of touch with business norms.

A strong geospatial strategy is holistic and self-reinforcing. It addresses the full span of people, processes, and technology decisions, and it supports and reinforces each building block.

Does It Commit to Tough Decisions?

Decision-making is the essence of strategy formulation. As Harvard Business School professor Michael Porter put it, "Strategy is about making choices, trade-offs." Often these are tough choices.

You might have to decide between shoring up your internal geomatics team or outsourcing to a partner. You might have to decide between shifting to a software as a service (SaaS)-only application strategy or having a balanced mix of on-premises and off-premises solutions. Perhaps there's a choice between acquiring a fleet of unmanned aerial vehicles (UAVs) and building an internal drone mapping program or partnering with a vendor.

The decisions are endless, but the point is that you need to commit to clear choices about the impactful or risky aspects of your geospatial strategy. When reviewing a strategy, I look for these commitments. They're the difference between a strong, clear strategy and a vague, noncommittal opinion piece.

Is It Traceable?

A good strategy traces a clear line to the issues it addresses and the business outcomes it creates.

No one wants a strategy that promises big things but, upon further inspection, fails to address the organization's critical issues or desired outcomes. Traceability ensures that strategy is fit for purpose.

When reviewing a strategy, I look for both backward and forward traceability. For backward traceability, there should be a clear connection between the strategic actions and the critical issues identified during the initial analysis. Are the business needs addressed? How? To what degree?

For forward traceability, I look for a link between the long-term goals and objectives and the strategic actions defined by the strategy. Years from now, will this strategy achieve or come close to achieving the stated goals?

Does It Adopt Best Practices?

An important test of the strategy is whether it adopts best practices for execution. While there are infinite decisions you can make in terms of people, processes, and technology, once you commit to your approach, adopting best practices is essential to effective implementation.

Your geospatial strategy isn't defined by best practices—that's the domain of your vision and your strategic choices. Best practices are the well-known methods that yield good outcomes under certain circumstances. Best practices can encompass those related to architecture, data management, professional development, and governance. The more you ingrain best practices into your road map, the greater certainty you'll enjoy through the execution phase.

Is It Practical?

I started this article by saying it's important to have an ambitious strategy but we live in a world of finite resources. A strategy

must reflect reality on some level. There's little point in committing time and energy to analyzing business needs, developing a collaborative vision, committing to tough decisions, and formulating a road map only to realize that there's no practical path forward. Likewise, if the change impact is so great that chances of adoption are minimal, then your strategy has missed the mark.

A practical geospatial strategy

- Prioritizes investments based on value, cost, and feasibility.
- Defines an appropriately paced road map that reflects available resources and funding.
- Identifies necessary governance to monitor and track the progress of the strategy.
- Identifies and manages the change impact on staff responsibilities, internal and external workflows, system interfaces, and customer interactions.

Is Leadership on Board?

Research by International Data Corporation (IDC) Canada, a global provider of market intelligence, noted in 2018 that leadership engagement is one of the most important factors for a geospatial strategy's success. This is especially true for new or transformational strategies where funding and approvals are strongly concentrated in the leadership ranks. But even when decisions are decentralized, a disgruntled or disinterested influential leader can railroad a strategy quickly if they're not engaged from the beginning.

A strong strategy involves senior leadership from inception and throughout its formulation. I'm specifically drawn to strategies that have a vocal champion at the sponsor level, who shows commitment to the strategy's success and provide the political will necessary to drive its execution.

Does It Tell a Good Story?

Even if your strategy has top-notch analysis and a thorough plan of action, if it's poorly written, sloppily organized, or if it fails to communicate a compelling message to decision-makers, it's DOA.

Once I've made it through the weeds of a strategy, I like to step back and ask these final questions:

- Is the strategy coherently structured and does it follow a logical flow? Can I easily decipher the current state of affairs, the vision and strategic decisions, and the plan of action?
- Is it easy to read? Does it use plain language and avoid jargon-heavy phrasing?
- Do the recommendations indicate who benefits and who is impacted?
- Are major risks and concerns called out and addressed?

You want people to believe in the strategy. Craft a simple, straightforward message that gets people excited about the journey ahead and motivated to prevent missed opportunities.

About the Author

Matthew Lewin is the director of management consulting for Esri Canada. His efforts are focused on helping management teams optimize and transform their businesses through GIS and location-based strategies. As a seasoned consultant, Lewin has provided organizations in the public and private sectors with practical strategies that enable GIS as an enterprise business capability. His interests lie at the intersection of business and technology, and he thrives on helping organizations bridge the gap between the two to achieve their most challenging GIS ambitions.

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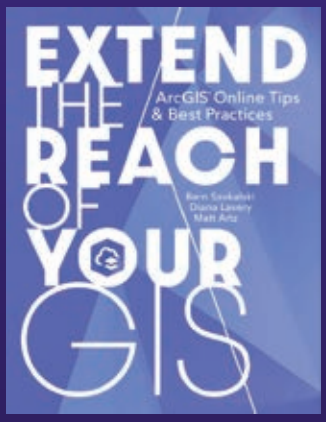

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Extend the Reach of Your GIS: ArcGIS Online Tips & Best Practices, a free PDF, is a collection of best practices for ArcGIS Online that will help you optimize the organization, administration, and quality of knowledge products you produce. As your cloud GIS, ArcGIS Online enables more effective use of GIS tools and geospatial data and insight across your organization. *Extend the Reach of Your GIS: ArcGIS Online Tips & Best Practices*, by Bern Szukalski, Diana Lavery, and Matt Artz, contains information that will benefit you, the ArcGIS Online administrator, whether you have been using itfor years or are just getting started with it.

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↑ Learn about the importance of branding your site so it is immediately recognizable as a credible source of quality information.

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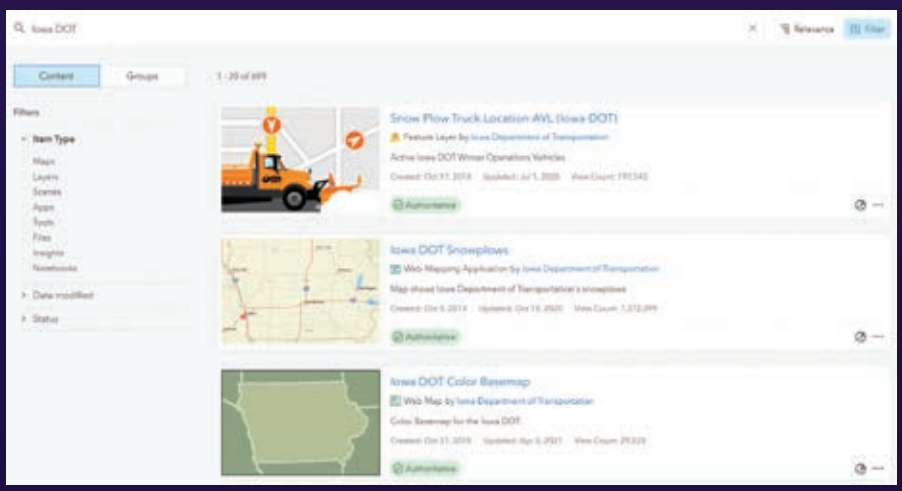
Because *Extend the Reach of Your GIS* is provided as a PDF, it can contain links to other free Esri resources and outstanding examples of ArcGIS Online sites. The most current version of the book can be downloaded at https://go.esri.com/extend.

↓ Marking content with authoritative badges gives users confidence in your data.



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Six Ways to Visualize Change Over Time in Web Maps

By Kristian Ekenes

Data visualization is an attempt to answer questions about raw data. These questions typically start with words like *what*; *how much*; *when*; and of course, *where*. In addition to these, people frequently ask questions about how a data variable changes over time. These could be questions such as the following:

- How did population change from 2010 to 2020?
- Over the last 30 years, has the climate been warmer or cooler?
- Where has voter turnout increased or decreased since the last election?

In this article, I demonstrate six ways to visualize change over time using the ArcGIS API for JavaScript with the following approaches:

1. Toggle layer visibility
2. Swipe widget
3. Side-by-side views
4. Stacked rings
5. Above-and-below theme
6. Animations

This article focuses on comparing how data changes over time in layers and does not discuss the use of time-enabled data containing features that have date/time attributes that are filtered with TimeSlider.

↓ Listing 1: Toggle Layer Visibility

```
const layer = new GroupLayer({
  title: "Educational attainment 2010 vs. 2020",
  visibilityMode: "exclusive",
  layers: [
    new FeatureLayer({
      ...layerProperties,
      title: "2010"
    }),
    new FeatureLayer({
      ...layerProperties,
      title: "2020"
    })
  ],
});

view.ui.add(new LayerList({
  view
}), "top-right");
```

1 Toggle Layer Visibility

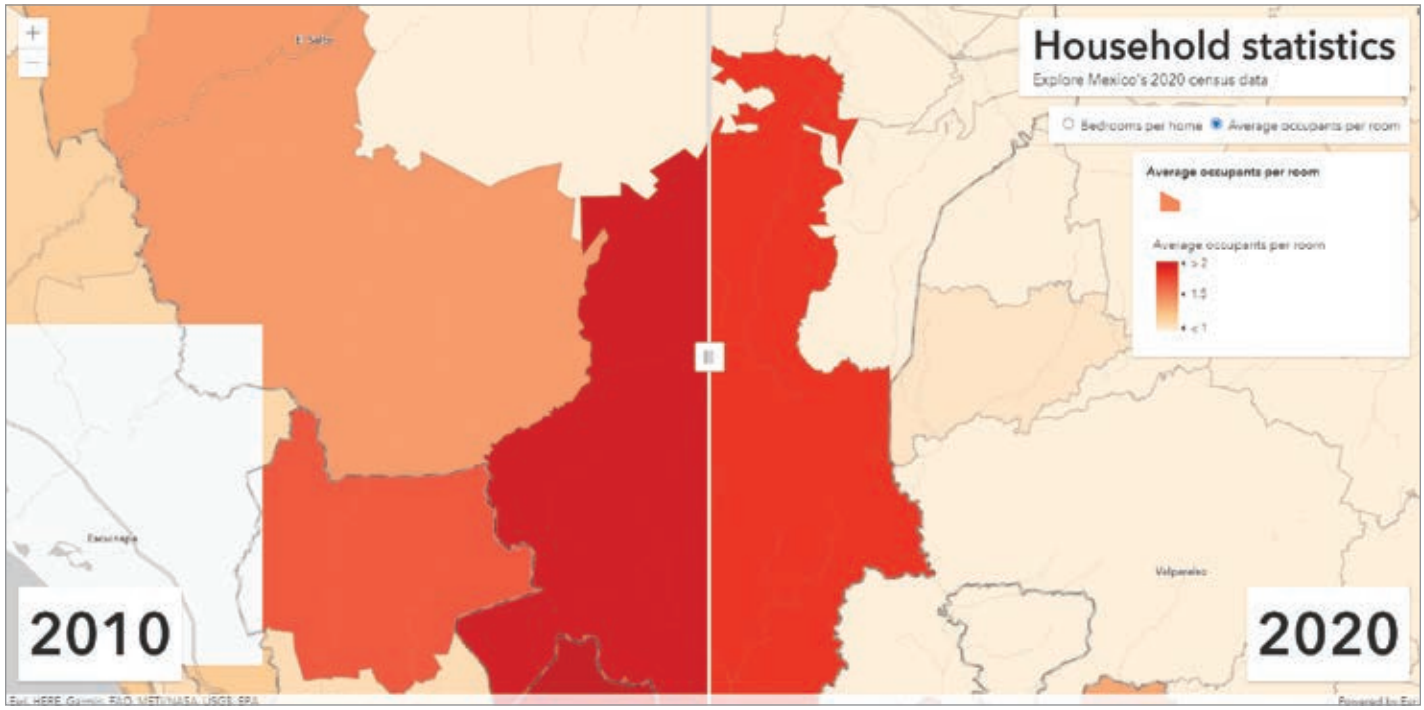
The classic way to compare change is to display the data in separate layers and toggle each layer's visibility on and off. I created an app (https://bit.ly/2RYeQwc) that visualizes average educational attainment for Mexico in 2010 and 2020 by adding both layers to a GroupLayer with an exclusive visibility mode property. That makes it easy for the user to toggle layers off and on using the LayerList widget as shown in Listing 1.

This approach works well when two layers differ greatly, and those differences can easily be spotted when layer visibility changes. This is generally true of choropleth maps (maps that use polygons with a fill color). This approach is not as effective when the layers use graduated symbols.

↓ Toggle layer visibility in this app to explore the average educational attainment in 2010 compared to 2020.

↓↓ Pink areas show where women outperform men in school. Yellow areas show where men outperform women. The 2020 numbers show an overall increase in women outperforming men in school from 2010 compared to 2020.

What?
How much?
When?
Where?



2 Swipe Widget

Using the Swipe widget is another way to compare how data changes over time. It is very similar to toggling layer visibility, but instead the Swipe handle is dragged to view the change, like turning the page of a book. View this app (https://bit.ly/34LSJvm), which visualizes household statistics for Mexico, to see how the Swipe widget works.

To create this experience, construct a Swipe widget instance as shown in Listing 2. Then reference layers under leadingLayers and the other layer under trailingLayers. Since the color ramps in each layer should match to make a fair comparison, only the style information for one of the layers is displayed in the legend.

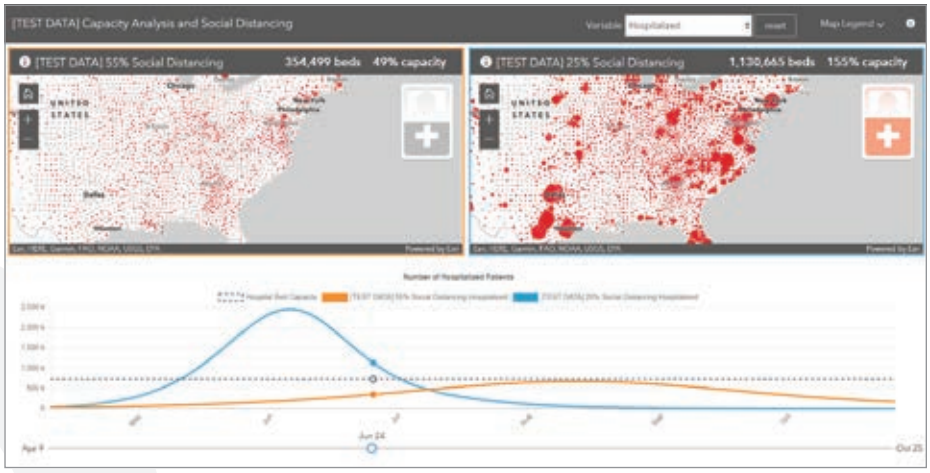
Like toggling layer visibility, this technique works well when layers differ significantly, but with the Swipe widget, data from the same feature for both time periods can be compared by straddling the feature with the Swipe handle. The swipe experience can be easily added to ArcGIS StoryMaps apps.

```
const legend = new Legend({
  view,
  // only display legend for one layer
  // and give it a generic title not
  // associated with a year
  layerInfos: [{
    layer: ppl2010,
    title: "Average occupants per room"
  }]
});
view.ui.add(legend, "top-right");

const swipe = new Swipe({
  leadingLayers: [ ppl2010 ],
  trailingLayers: [ ppl2020 ],
  position: 85,
  view
});
view.ui.add(swipe);

// indicate which year is displayed
// on each side of the swipe
view.ui.add("view2010Title", "bottom-left");
view.ui.add("view2020Title", "bottom-right");
```

↑↑ The Swipe widget splits the view of a feature, so that values at two times can be viewed simultaneously.

↑ Listing 2: Swipe Widget

3 Side-by-Side Views



Sometimes viewing data in side-by-side views can be the most effective technique for comparing change over time because it doesn't require any user interaction. The user can see all the data in one glance and determine which scenario is better or worse over time.

Because this approach requires a lot of visual scanning between two views, it does not work well when the differences between two visualizations are subtle. The side-by-side views approach works best with small-scale phenomena that change significantly over time. In most cases, the toggle or swipe approaches are more effective. Displaying two layers in side-by-side views can be effective for showing the difference between two layers at a single glance.

This example, Capacity Analysis (https://bit.ly/3ihUGb1), is an ArcGIS Online configurable app template that uses side-by-side views to compare the output of two models predicting the demand for hospital beds as a result of the COVID-19 pandemic.

You can also use the side-by-side view technique to show data for more than two time intervals. However, since most browsers support no more than 16 WebGL rendering contexts (one context is required per view), a single app is limited to no more than 16 views. The app, U.S. High Tide Flooding Probability Scenarios through 2100 (https://bit.ly/3vLxB4v), uses six views to compare data representing the probability of high-tide flooding for the next 100 years.

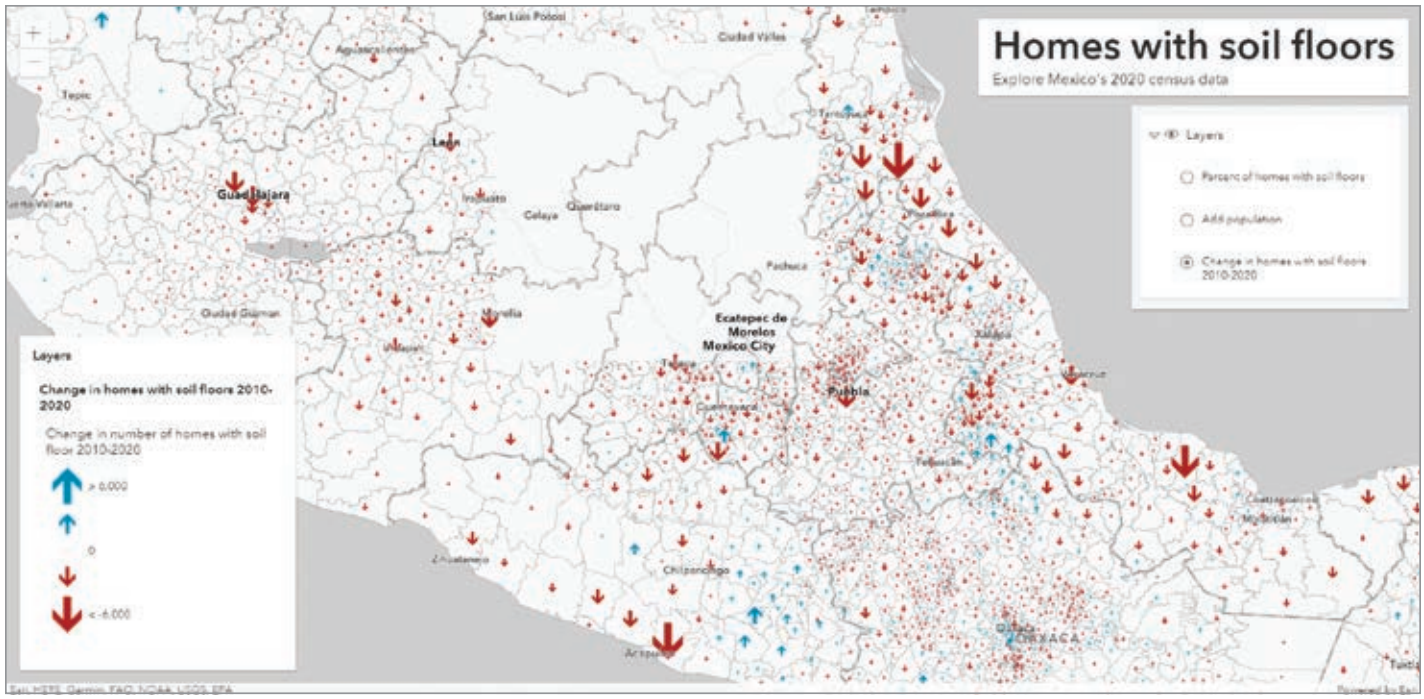
↑↑ The Capacity Analysis ArcGIS Online configurable app template uses side-by-side views to compare the output of two models predicting the demand for hospital beds as a result of the COVID-19 pandemic.

↑ Side-by-side view can show data for more than two time interval views, but owing to browser limitations, a single app is limited to no more than 16 views. The U.S. High Tide Flooding Probability Scenarios through 2100 app uses six views to compare data representing the probability of high-tide flooding for the next 100 years.

↓ Stacked rings can compare a variable for two time periods. This map shows the change in the number of people born outside their resident city. Orange rings represent 2010 numbers. Blue rings represent 2020 numbers.

4 Stacked Rings

Stacked rings can be used to show a variable's value in one year compared to that in another year. Rings of the same size indicate the variable experienced little or no change from the previous year. To implement this technique, set the style for the marker symbol to none and represent each year with different colors. The size variable configuration (i.e., stops) must be identical between the two layers. This technique can be difficult for users to understand, so use it with caution. It works best with small, dispersed datasets and will not be as successful in layers that have dense, overlapping icons.



↑ This map compares the number of homes with soil floors in 2010 and 2020. Rather than display two layers, it uses an ArcGIS Arcade expression to calculate the change, and the result is used by the renderer for a single layer.

↗ Listing 3: Using above-and-below theme

→ Listing 4: Using ClassBreaksRenderer

↘ Listing 5: Using univariate color and size smart mapping module

```
renderer.visualVariables = [{
  type: "color",
  valueExpression: "$feature.SoilHomes2020 - $feature.SoilHomes2010",
  valueExpressionTitle: "Change in homes with soil floors 2010-2020",
  stops: [
    { value: -6000, color: "red" },
    { value: 0, color: "white" },
    { value: 6000, color: "blue" },
  ]
}];
```

```
const renderer = new ClassBreaksRenderer({
  valueExpression: "$feature.SoilHomes2020 - $feature.SoilHomes2010",
  valueExpressionTitle: "Change in homes with soil floors 2010-2020",
  classBreakInfos: [{
    minValue: -6000,
    maxValue: 0,
    symbol: belowArrowSymbol
  }, {
    minValue: 0,
    maxValue: 6000,
    symbol: aboveArrowSymbol
  }]
});
```

```
const params = {
  layer,
  view,
  theme: "above-and-below",
  valueExpression: "$feature.F2020 - $feature.F2010",
  symbolOptions: {
    symbolStyle: "arrow"
  }
};

const { renderer } = await univariateRendererCreator
    .createContinuousRenderer(params);

layer.renderer = renderer;
```

5 Above-and-Below Theme

To view growth or decline over time at one glance, use the above-and-below theme for color and/or size. This approach involves calculating the change between the two variables (either as total change or as percent change), and visually indicating that difference with a single renderer.

It requires writing an ArcGIS Arcade expression to calculate the difference between two fields in the same layer. Set a midpoint of zero in the renderer break points using a color visual variable (shown in Listing 3) or by using a ClassBreaksRenderer (shown in Listing 4) to give the renderer distinct above-and-below symbols.

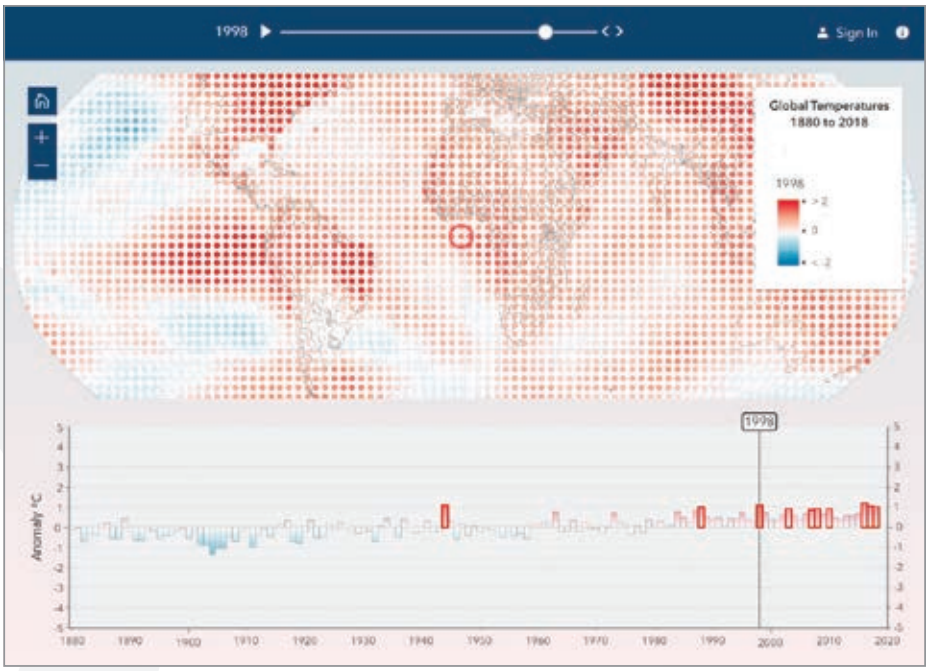
Alternatively, use the above-and-below theme in the univariate color and size smart mapping module and let the ArcGIS API for JavaScript pick the color scheme, symbols, and break points as shown in Listing 5. This approach only shows the delta between the two data values, not the totals for each year. If viewing the value of the variable for each year is important, then add an option that allows the user to toggle between both values for the change between years and the totals for each year.

See an example using the above-and-below theme at https://bit.ly/2URmOsf.

6 Animations

Another way to view change over time is to create a data animation. This is effective for showing subtle, compounding changes over long periods of time. As opposed to the other approaches, which only compare change between two dates, this technique allows the user to view change for many—even hundreds—of time periods.

This example, Global Temperature Anomaly to 1880–2020 (https://bit.ly/3iaw2ZN) doesn't use TimeSlider for filtering features with a date field. As shown in Listing 6, TimeSlider is used as a tool for updating the layer's renderer to point to a new attribute field (or Arcade expression) at each slider move. Updating the field name in the renderer to the column containing data for the selected year is the only change—no other renderer changes should be made.




```
slider.on(["thumb-change", "thumb-drag"], (event) => {
  const renderer = layer.renderer.clone();
  const colorVariable = renderer.visualVariables
    .filter( vv => vv.type === "color")[0];

  // update renderer to reference field
  // representing selected year on the slider
  const year = event.value;
  colorVariable.field = `$feature.F${year}`;

  renderer.visualVariables = [ colorVariable ];
  layer.renderer = renderer;
});
```

↑↑ This visualization combines an above-and-below theme showing global temperture anomalies between 1880 and 2020 with a timeline animation.

↑ Listing 6: Animation

← This visualization combines an above-and-below theme with an animation to show the number of visitors for specific time periods.

Combinations

The approaches listed in this article can be combined. For example, a layer that already visualizes change in a smaller time interval using the above-and-below theme can be animated, showing change over time. The *National Park* map (https://bit.ly/3yZlWRp) illustrates the use of the above-and-below theme with animation to visualize changes in year to year visits to US national parks.

A Word of Caution

When comparing data that changes over time in two separate layers, the same renderer and visual variable configurations must be used for both layers to ensure that the comparisons make sense. The same stops and break points must be assigned to the same colors and sizes.

Conclusion

The ArcGIS API for JavaScript provides many ways to visualize change over time. All of them are valid. The approach you choose depends on the final user experience you want. The next time you need to map a variable as it changes over time, try several of the approaches listed in this article because the best option may not be the first one you consider.

About the Author

Kristian Ekenes is a product engineer on the ArcGIS API for JavaScript team at Esri. His work focuses on mapping, visualization, and Arcade integration. Prior to joining Esri, he worked as a GIS specialist for an environmental consulting company. He enjoys cartography, GIS analysis, and building GIS applications for genealogy.

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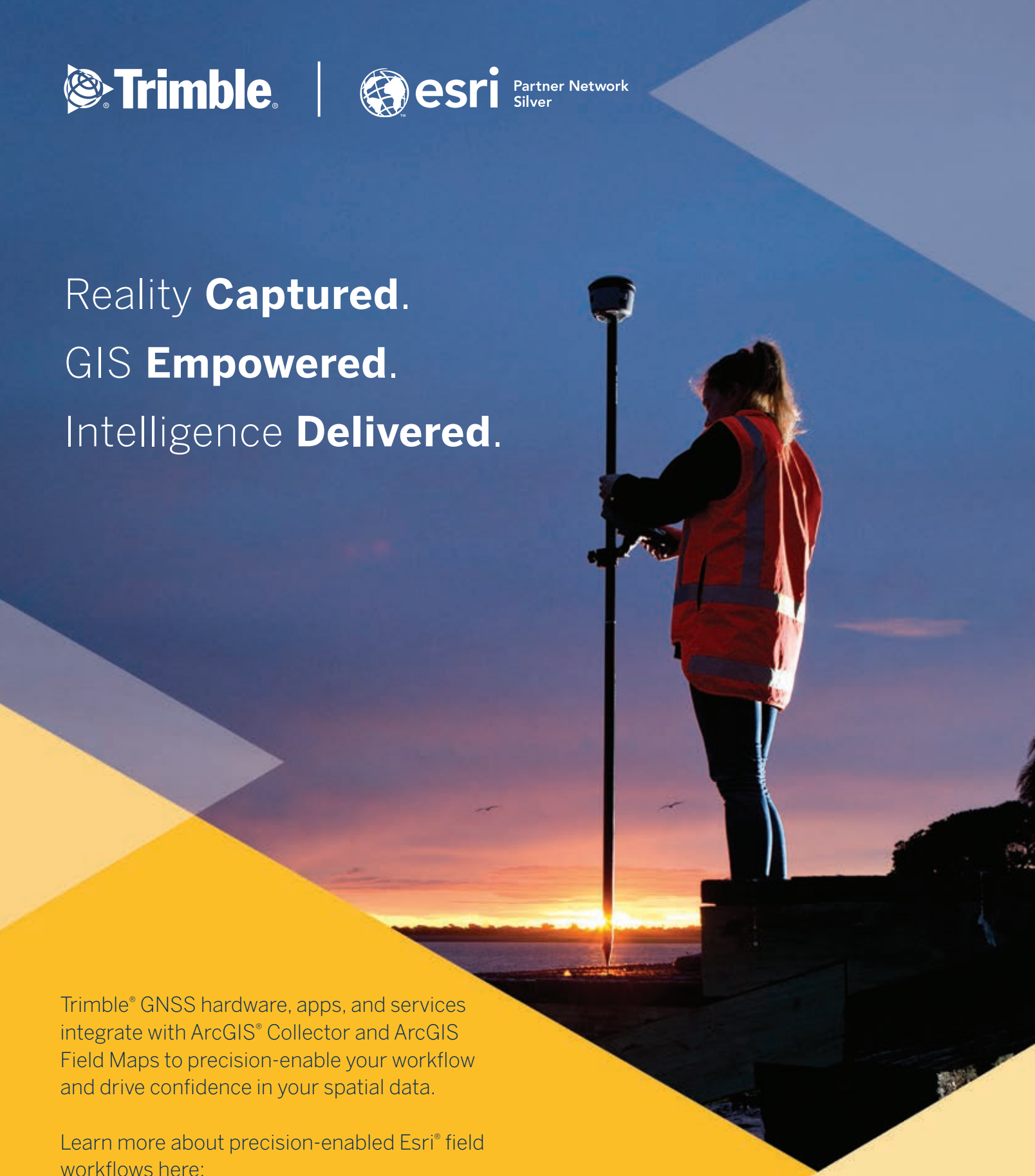

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Once again, the registered online attendance dwarfed any previous in-person attendance. Although attendees and Esri staff missed face-to-face encounters, the virtual format allowed tens of thousands to share the work of users. They could attend 153 tech workshops, interact with 181 exhibitors, and participate in 57 special interest groups (SIGs).

Toward a Sustainable Future

After welcoming attendees, Esri president and founder Jack Dangermond explained the conference theme, GIS—Creating a Sustainable Future. To build that future in the face of the many challenges the world currently faces will require balancing environmental, economic, and societal needs. When economic and social elements are considered together, endurability is ensured. When social and environmental elements are combined, equitability is produced. The intersection of all three elements—environmental, economic, and societal—creates sustainability.

Balancing these needs requires holistic thinking on both micro and macro scales. That thinking is engendered by the geographic approach and enabled by GIS technology. As GIS becomes more interconnected, it forms a geospatial infrastructure, which supports collaboration and helps transform workflows and decision-making at many scales. "This infrastructure is creating a nervous system for sustainability," Dangermond said.

Integration of ArcGIS with developments in mainstream IT will make previously unimaginable things possible, Dangermond noted. The ability to access massive data collections from transactional systems and imagery and link them to GIS tools will create new forms of understanding. "Big data integration is going to open our eyes; it's going to let us see new things—relationships we never understood before."

Highlighting Good Work

During the Plenary Session, three major awards were presented to organizations for exceptional and highly impactful work. The President's Award went to the University of Michigan for becoming a true geospatial university through its implementation of a large-scale, campus-wide GIS that is available to faculty, staff, and students in all disciplines as a tool for research, learning, and administration.

The Louisville/Jefferson County Information Consortium (LOJIC) received the Enterprise GIS Award for identifying GIS as critical infrastructure for its organization, enabling understanding of the region and sharing data and applications across 1,300 spatial databases.

Nespresso's dedication to ensuring quality, productivity, and social and environmental sustainability in coffee sourcing earned it the Making a Difference Award. Using GIS to bring information about farmers, landscapes, communities, and climate together has helped Nespresso create a positive impact across all aspects of its business.

Esri honored 242 individuals, groups, and institutions from across the globe with a Special Achievement in GIS (SAG) Award. Information about the work of these organizations is available at events.esri.com/conference/sagList/.

The innovative efforts of several organizations were showcased during the Plenary Session. A group from the US Department of Agriculture (USDA) Forest Service, led by Vicki Christiansen, chief of the USDA Forest Service, shared how the Forest Service uses advanced remote sensing technologies to fulfill its mission of monitoring all of America's forests to facilitate landscape-scale stewardship.

It is working in partnership with Esri to create the next generation of information products to improve decisions today and tomorrow. Its BIGMAP uses cloud computing to accomplish raster processing and analysis of tens of trillions of pixels to produce results in just days. Its maps combine many factors and sophisticated analysis to characterize forest inventories, particularly those susceptible to western forest fires. Its datasets and services are shared via ArcGIS Online and through the FIA Geospatial Showcase (https://fia-usfs.hub.arcgis.com/), a hub site designed to empower others to create a more sustainable future.

Contributing to the presentation were Charles "Hobie" Perry, PhD, program manager for the USDA Forest Service Northern Research Station, Forest Inventory and Analysis (FIA), Barry "Ty" Wilson, PhD, research forester for the USDA Forest Service Northern Research Station FIA; and Christopher Oswalt, PhD, research forester and National Digital Portfolio lead for the USDA Forest Service Southern Research Station FIA.

Another user presentation demonstrated the many ways Telluride Ski & Golf in southwestern Colorado uses a digital twin of the mountain to manage more than 2,500 acres for both winter and summer activities on private and forest service lands. Brandon Green, director of Snowmaking Operations and Capital, and Matt Tarkington, GIS analyst and drone operator, described how the resort uses its cloud-based geospatial infrastructure to make real-time information accessible to staff on the slopes and in the office so that quick and informed decisions can be made.

Dr. Fred J. Calef III, a Mars 2020 mapping specialist and science systems engineer from the NASA Jet Propulsion Laboratory, told how mapping was central to the success of the *Perseverance* rover in landing on Jezero Crater on Mars. During landing, the spacecraft used maps in real time for situational awareness and precise adjustment of its trajectory. This mission is also using maps to better understand the geology of Mars.

In addition to presentations by award winners, Esri also invited visionaries from diverse backgrounds to share their perspectives in keynote speeches. Paul Salopek, La June Montgomery Tabron, Dr. Enric Sala, and Wade Crowfoot provided keynote speeches during the Plenary Session.

A Walk through the Anthropocene

Salopek delivered his keynote address from Shanghai, China. He is in the eighth year of the Out of Eden Walk, a 24,000-mile journey that follows the migration route of humankind's early ancestors from Africa to the tip of South America. He invited his audience to share what he has been seeing along the way, as "we are all walking—collectively—into a challenging 21st century."

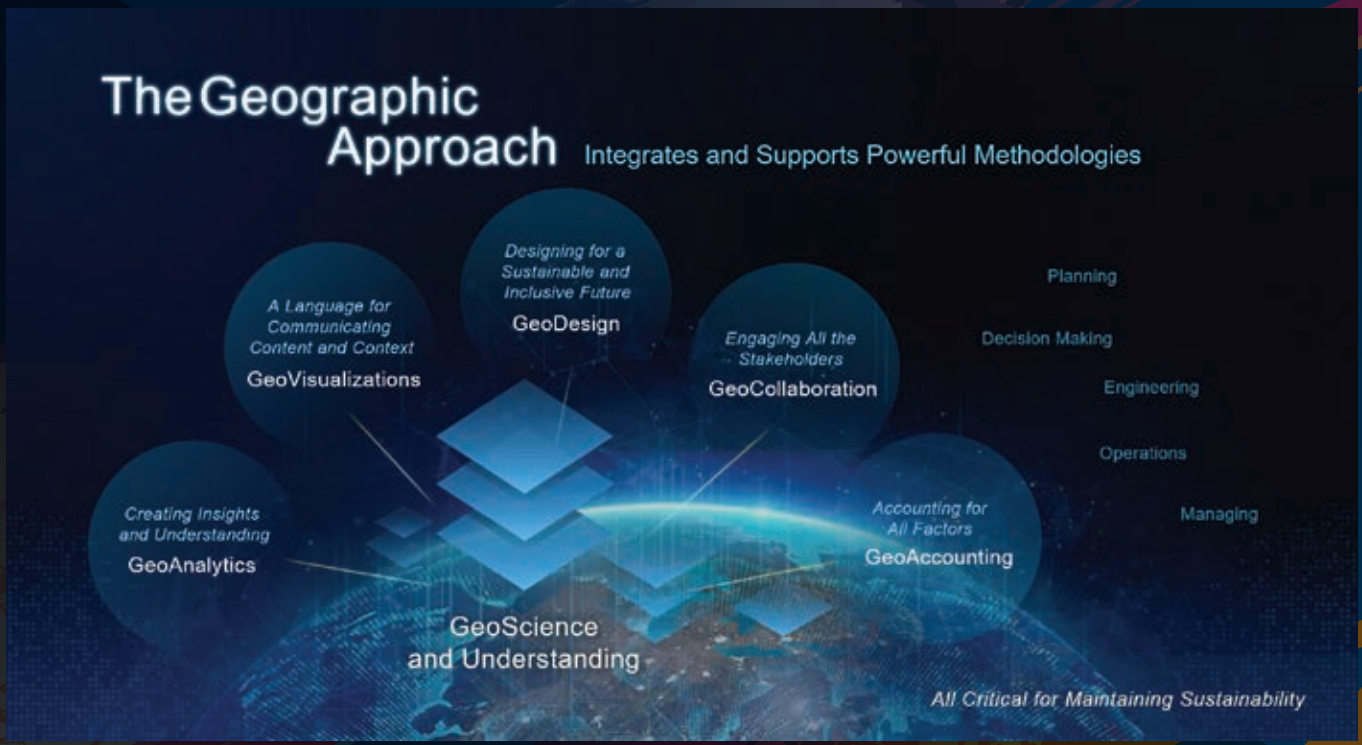
A writer and National Geographic Fellow, Salopek has gained a cumulatively sweeping view of this landscape from a perspective unique in the modern age—step-by-step. The idea of the walk was not just an experiment in "slow journalism," but a strategy for seeing just how interconnected issues, events, and people are at all levels and learning valuable lessons about sustainability from the average people who are dealing with the stresses brought on by climate change and other challenges. In closing, Salopek said, "We are an amazing problem-solving species. We've got lots of problems—most of them created by ourselves—and we have to resolve them." Learn more about Salopek's odyssey through his ArcGIS StoryMaps story, *My Walk through the Anthropocene* (https://bit.ly/3j0QyuN), and watch a video of his presentation at https://bit.ly/3l8H1o2.

Expanding Racial Equity through Community Action

As Dangermond introduced Tabron, president and CEO of the W.K. Kellogg Foundation (WKKF), one of the largest private foundations in the United States, he noted that societal sustainability is one of the three pillars of a sustainable future.

Tabron leads the WKKF in its global mission to foster the health, welfare, and education of children; support working families; and

↓ The geographic approach and GIS are key to a sustainable future.



To learn about all the improvements in ArcGIS announced at Esri UC, view videos from the Plenary Session at https://bit.ly/3BT5HqE.

build equitable communities. Much of the work WKKF does rests on promoting racial equity. As Tabron explained, "Racial equity is about believing that we are all human beings, we all have value, and we all deserve opportunities to thrive."

William Keith Kellogg, who founded the Kellogg Company, started WKKF with a mission to create a place where all children can thrive. "To make sure that children thrive, you must look at issues of racial equity, community engagement, and leadership. We call those three elements our DNA. These are at the root of creating thriving communities where all children can have an opportunity," Tabron said.

WKKF has been applying GIS to better understand systems and structures that create racial inequity, especially as those inequities have been highlighted during the COVID-19 pandemic. She noted that mapping data on COVID-19 revealed that people of color were more adversely affected and led to the exploration of the systems that produce those outcomes. "I would say the tools that you provide us through the GIS applications actually allow us to illuminate the current impact of the system and to determine what path forward might change the outcome," said Tabron.

Internationally, WKKF; its grantee, the PVBLIC Foundation; Esri; and the United Nations have created a partnership called the SDG Data Alliance in support of the United Nations Sustainable Development Goals (SDGs), specifically SDG 10: Reduced Inequalities. This partnership will promote SDGs in 20 countries in Africa, Latin America, and the Caribbean.

In the US, WKKF is working on the Southern Communities Initiative in creating a plan to address issues related to equity in Atlanta, Georgia; Birmingham, Alabama; Memphis, Tennessee; Houston, Texas; New Orleans, Louisiana; and Charlotte, North Carolina. As part of this work, Community Action Hubs will be created to make data and maps on wealth creation, jobs, education, health, and housing available to enable better-informed decision-making.

"We hope the GIS community will help us realize this vision," Tabron said. "We have the tools. We want the GIS community to stand up these Community Action Hubs all over the nation." Watch Tabron's presentation at https://bit.ly/3ihx6dX.

2021–2030: Our Last Best Chance to Protect the Ocean for the Benefit of Humanity

The presentation by Sala, Pristine Seas, was subtitled "Protecting the Global Ocean for Biodiversity, Food, and Climate," which neatly summarizes the goal of his work.

Sala, a former university professor, quit academia to become a full-time conservationist as a National Geographic Explorer in Residence. He founded the National Geographic Pristine Seas team, which partners with organizations and agencies around the world to explore oceans, promote marine reserves, and conduct scientific research with the goal of protecting 30 percent of the oceans by 2030.

Although Pristine Seas has helped to create 23 of the largest marine reserves on the planet, covering an area of 6.5 million square kilometers, only 3 percent of the ocean is fully protected. To discover which areas were the most in need of protection, Sala's team built a global database with pixels 50 kilometers by 50 kilometers that identified where species lived and their risk of extinction.

Working with Esri, the team built a tool for determining where it will be most beneficial to locate marine preserves so biodiversity can be preserved, fish populations rebuilt, and limit carbon emissions (caused by seabed disturbance) reduced. Sala emphasized the importance of this tool. "So, we can prevent the extinction of many species, the collapse of our life supersystem, and also we can help achieve the goals of the Paris climate agreement." Watch his Esri UC presentations at https://bit.ly/3zSayX9 and view his ArcGIS StoryMaps story *Protecting Our Pristine Seas* (https://bit.ly/2V0J2rT).

Nature-Based Solutions in California: Combating Climate Change and Achieving 30x30

Crowfoot, secretary of the California Natural Resources Agency (CNRA), was joined by Jennifer Norris, deputy secretary for biodiversity and habitat at CNRA, in his presentation. They described how CNRA is using Esri technology to consider the state's entire ecosystem and understand how the people, economy, and environment are interconnected. This effort will fulfill an ambitious state program to save 30 percent of the state's lands and coastal waters by 2030 through conserving and restoring natural areas.

CNRA is working with Esri to develop an integrated suite of mapping and visualization tools that use authoritative data to display, prioritize, and track the state's biodiversity, climate, and accessibility efforts toward achieving 30x30.

Enacting policies and action at this scale requires data-driven science and the mobilization of all stakeholders. Crowfoot noted that success will require leadership at the executive and grassroots levels. The CA Nature website (californianature.ca.gov), an open geospatial portal, helps advance community engagement goals by providing common language and understanding for conservation. View the video of Crowfoot's address at https://bit.ly/3zMkrG0.

Extending the Reach of GIS to Solve the World's Challenges

In addition to the presentations of keynote speakers and award winners, Esri staff demonstrated the many improvements and

↑ National Geographic Pristine Seas has helped to create 23 of the largest marine reserves on the planet and is working to protect 30 percent of oceans by 2030 to preserve biodiversity, rebuild fish populations, and limit carbon emissions.

innovations made across ArcGIS since the Esri UC last year. ArcGIS brings many components together to work as a single system. It serves not only the GIS community, but also the mapping community, the geoanalytics community, and communities of knowledge workers outside the geospatial field. This last group uses GIS that has been embedded into widely used software, such as Microsoft Office, SAP, and Salesforce, enhancing existing specialized workflows.

The many performance enhancements and new capabilities across the ArcGIS system were discussed throughout the Plenary Session. Of note, were the substantial increase in high-quality ready-to-use content available from the ArcGIS Living Atlas of the World; image hosting and analytics in the cloud; increasing use of machine learning, deep learning, and artificial intelligence (AI) across the ArcGIS system; and the introduction of ArcGIS GeoBIM.

The new 10-meter-resolution Esri 2020 Global Land Cover layer, added just before Esri UC, exemplifies the authoritative layers and services, such as biodiversity, air quality, global river flow, and wildfire risk, which are available and let users concentrate on finding answers rather than searching for and processing data. (See "AI Enables Rapid Creation of Global Land Cover Map" in this issue.)

Imagery and remote sensing are supported by an integrated system of map and data production, visualization, exploitation, analysis, management, and dissemination. ArcGIS Image for ArcGIS Online augments these capabilities with a software as a service (SaaS) offering for hosting imagery and performing analytics in the cloud. (See "Increase the Value of Imagery in Your Organization" in this issue.)

Improvements in the application of machine learning, deep learning, and AI intelligence include ArcGIS feature extraction from imagery, new pre-training models, and better integration with the open science ecosystem.

With ArcGIS GeoBIM, GIS and BIM work side by side to coordinate critical system details to build sustainable infrastructure. ArcGIS GeoBIM unlocks knowledge in both BIM and GIS across projects and aids project coordination.

The Time Is Now

The geographic approach reveals the interconnectedness of all life on Earth and leads to the realization that people can no longer live apart from nature but must live as part of it. Dangermond emphasized that while the geographic approach is going to provide us with the science and practical means to move toward a future that is sustainable on all levels, it is not enough. It will require the commitment of GIS professionals.

"You and your work are going to be essential in providing leadership in your own organization, carrying out problem solving. These are the kinds of things you already do, but think larger—think holistically," he said, exhorting Esri UC attendees to action.

"Personally, I feel like I'm all in. I'm going all in, and I really want to encourage you to act with urgency. These are the times where we really have to get it together and move at many different scales."

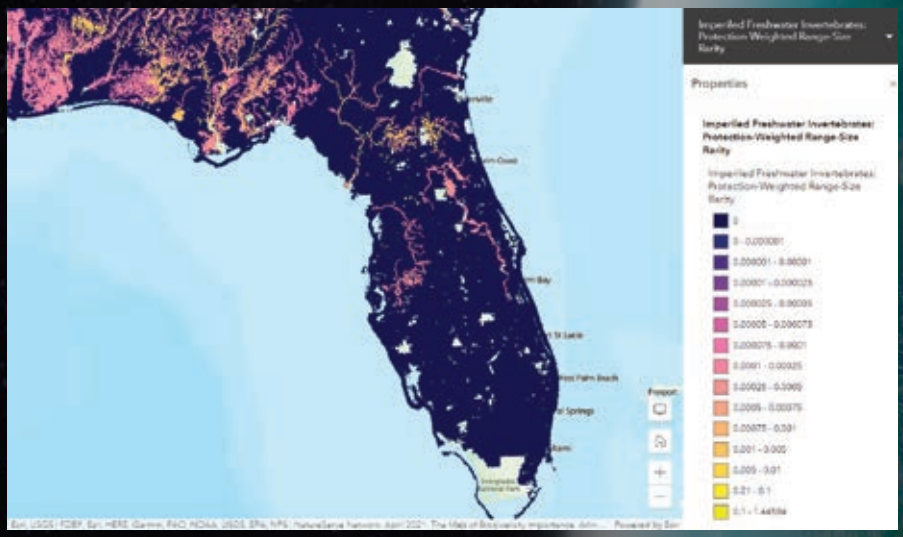
"Applying our best science, our best technology, and our best creative thinking will clearly be necessary," Dangermond said. "And I can't help but know that geographic thinking is going to be essential in this. Sustainability requires that we see the world as one single ecosystem. Geography provides the science and language to do this."

Science Symposium
Focuses on Biodiversity

By Monica Pratt

In her opening remarks to the sixth annual (and second virtual) Esri Science Symposium, Esri chief scientist Dawn Wright emphasized Esri's strong connections with the scientific community. Held on July 15 in connection with the 2021 Esri User Conference, this exclusively virtual event with 3,039 attendees was more inclusive than the most recent in-person Science Symposium in 2019, which was attended by approximately 700 people.

In addition to the scientific foundation of its software and tools, Esri is active in the international scientific community on various boards, councils, and research projects. It works collaboratively with some of the world's largest earth science organizations, focusing on six areas: open science, weather and climate science, ocean science, solid earth science, geographic information science, and social science. Soon Esri will add qualitative social science as a seventh area of emphasis.



↑ A map of protection-weighted range-size rarity of freshwater invertebrates, is part of the Map of Biodiversity Importance (MoBI) data collection created by NatureServe and available on the ArcGIS Living Atlas of the World.

Biodiversity Feeds, Shapes, and Saves the World

In keeping with the Esri User Conference theme, GIS—Creating a Sustainable Future, Healy Hamilton, PhD, and chief scientist for NatureServe, delivered her symposium keynote speech, "Biodiversity and Global Change: The Spatial Nature of Conservation."

Hamilton is a biodiversity scientist by training with graduate degrees from Yale and the University of California, Berkeley. She leads a staff at NatureServe who have expertise in ecology, zoology, botany, conservation, data science, and information management. Together they produce foundational information on the distribution and conservation status of species and species habitat. NatureServe, Inc., is a nonprofit that provides biodiversity network information, data, and tools that support conservation practices based on science.

Hamilton noted that the well-being of individuals and communities is utterly dependent on the natural world, so conserving the diversity of life is essential to our survival. Hamilton began by describing the vital role biodiversity plays in feeding the world. "Every single calorie ever consumed by all of mankind in all of human history comes from biodiversity. Supplying enough safe and nutritious food for a rapidly growing world really requires we increase food production globally without undermining planet capacity, to meet the needs of future generations and deliver other essential ecosystem services," she said.

The mission of balancing biodiversity preservation with feeding a population of billions is hampered by the current food production system, which relies on just 15 crop plants for 90 percent of food energy intake and ignores some 200,000 plant species with edible parts. As climate patterns change, the yield of this limited number of crops declines and food sources become less secure.

She pointed to the Dongria Kondh, a tribe that lives in southwest Odisha, India, as an example of people who appreciate and protect biodiversity. The government had introduced high-yielding rice varieties and encouraged the tribe to abandon the assortment of resilient heirloom rice varieties they were growing. When it became clear that the monoculture advocated by the government jeopardized the agricultural self-sufficiency of the Dongria Kondh, the tribe recognized that diversity equals security and returned to its previous practices and prosperity.

Biodiversity also ensures that the food supply by supporting pollinators—from bees to bats—provide ecosystem services valued at between $200 to $400 billion each year. Human well-being also depends on biodiversity in other ways. More than half the drugs approved in the last 30 years have been directly or indirectly derived

from natural products. The study of nature has also been beneficial in devising more effective treatments for chronic conditions. For example, the nerve regeneration of sea cucumbers is being studied and could lead to a cure for Parkinson's disease.

Hamilton highlighted the potential of biomimicry, a relatively new science that uses inspiration from the many ways that nature has evolved systems and strategies that can be applied to solve existing engineering problems. She used the nearly unsquishable diabolical ironclad beetle (*Phloeodes diabolicus*) as an example. It can withstand pressure that is 39,000 times its body weight, so it is being studied by materials scientists for developing armor, building, and packaging applications.

The value of biodiversity goes beyond direct benefits to our food, medicine, or materials. Many species are ecosystem engineers that directly or indirectly change their environment, making resources available to other species. She used sea grass beds as an example. They buffer coastlines from storm surges, provide habitat for commercially important marine species, and remove carbon from the atmosphere more rapidly than tropical rain forests. Although sea grass beds cover less than one-fifth of 1 percent of the seafloor, they are responsible for about 10 percent of the carbon uptake from the oceans. In summary, Hamilton affirmed, "We rely on biodiversity every day."

Despite the undeniable value of biodiversity, the number of species is declining precipitously, as demonstrated by the fate of beetles, a group with the greatest species diversity. Sixty percent of beetle species with an International Union for Conservation of Nature (IUCN) conservation status have been identified as threatened.

"How we manage the natural world will determine the future quality of life on earth."

Manage, Protect, and Restore

"How we manage the natural world will determine the future quality of life on Earth," Hamilton declared. Managing the natural world is an intrinsically spatial problem that requires identifying the location of areas of intact ecosystems that need protection and degraded areas that need restoration.

Essential to these management processes, GIS can assess the spatial distribution and intensity of human influence, monitor existing protected areas, and guide the establishment of new protected areas. Protected areas are fundamental in efforts to protect biodiversity. The great strides made by the conservation community in adopting standardized approaches to identifying and delineating key biodiversity areas complements the mapping of these areas.

Hamilton traced the development of the conservation movement from its genesis in 1968 and early work by The Nature Conservancy (TNC), which began creating the first biodiversity information network in 1974. TNC established nature heritage programs in every US state and expanded throughout the western hemisphere.

This network of heritage programs was spun off from TNC to become NatureServe in 2000. This network systematically inventories species and ecosystems and their locations and status. NatureServe has amassed over a million mapped locations of species populations over the past 50 years. However, while this data is valuable, it is incomplete. This means that NatureServe had to find a more comprehensive method for answering one of the most fundamental of all conservation questions: Where do imperiled species live?

Spatial Advances in Species Protection

NatureServe has fully embraced the integration of its 50 years of high-quality species data with spatial data on the environment, modern ecological modeling approaches, and cloud computing. NatureServe partnered with Esri, TNC, Microsoft, and experts across its network to produce a suite of national analyses called the Map of Biodiversity Importance (MoBI).

A series of 15 maps, with three different spatial analyses and five different taxonomic groups, MoBI can help set conservation priorities for 2,216 imperiled species. Data was aggregated and analyzed to reveal spatial patterns at unparalleled detail. These maps are freely available from the ArcGIS Living Atlas of the World. They are being used by many organizations, such as electric power companies, to guide land management.

Not just a set of static maps, MoBI is a dynamic habitat modeling system that lives in the Microsoft Azure cloud. It incorporates decades of natural heritage data, machine learning, and local knowledge to constantly refine and improve MoBI. A geospatial tool allows species experts and managers to improve model results in a transparent and collaborative process. Hamilton described the change in the capabilities provided by MoBI as transformational in its level of precision.

In closing, Hamilton emphasized that human actions have made everyone ecosystem managers, "so we need to be better ones. We need to protect what is left and restore what is degraded. That is a spatially explicit set of directions. The Science of Where and the science of conservation are absolutely intertwined." She urged the audience to join one of the many nature networks to work to protect and preserve the world's biodiversity.

Customize Legends in ArcGIS Pro

By Aileen Buckley

The tools in ArcGIS Pro give you great flexibility in presenting the information in your map. To more effectively communicate your message, you may want to modify the text for titles or labels, rearrange graphic elements, or add a caption that identifies the data source.

Map marginalia, such as legends, scale bars, and north arrows, help explain or support your map's message. Effective legends make the symbology used in the map clear and eliminate confusion. This tutorial shows how to make a customized legend in ArcGIS Pro for a map that uses bivariate colors symbology to represent a layer containing data about the prevalence of obesity and diabetes. This data was obtained from the County Health Rankings, 2020 layer, available from the ArcGIS Living Atlas of the World.

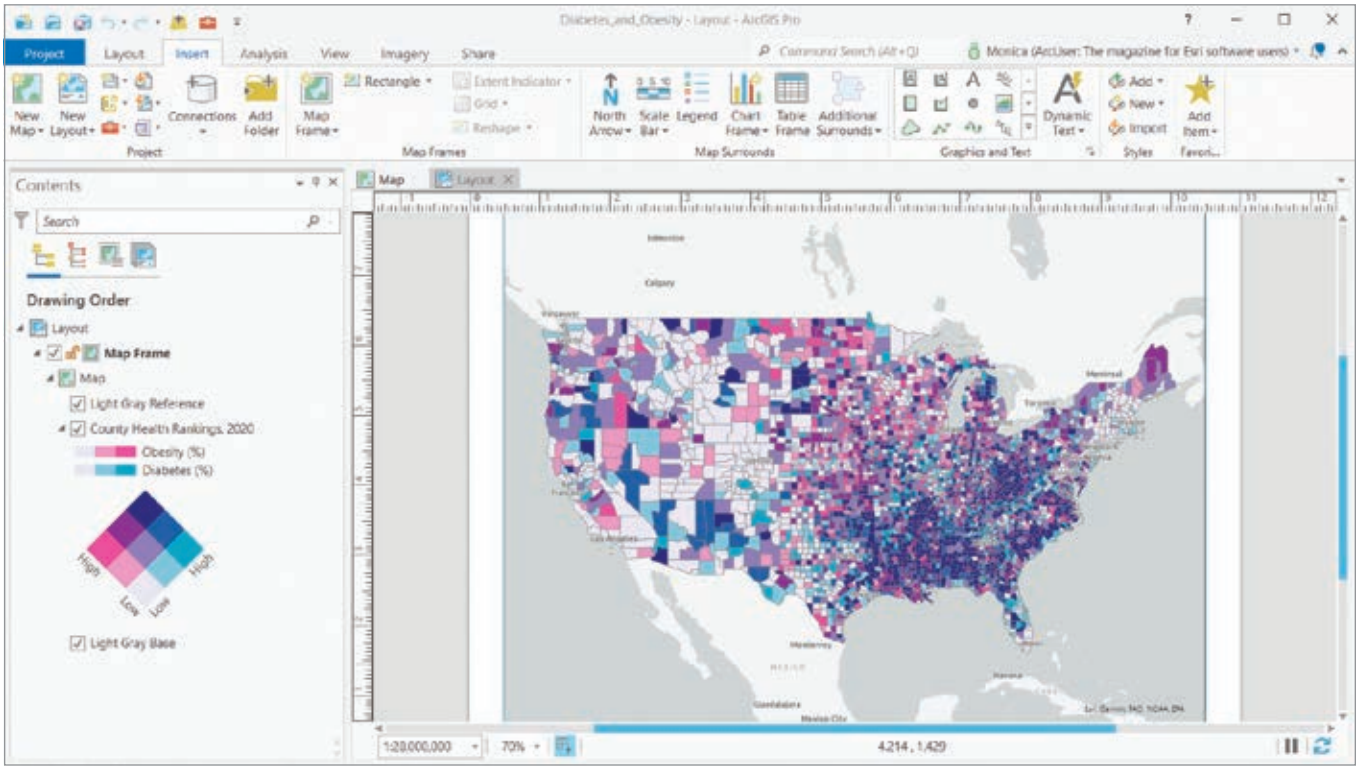
Bivariate colors symbology is used to show the quantitative relationship between two variables in a feature layer to compare, emphasize, or delineate values in a map. Each variable is classified and assigned a color. The bivariate color scheme is the product of those two variables and three classes for each variable, which creates a square grid of nine unique colors. This type of visualization emphasizes the high and low values or the correlations in a dataset.

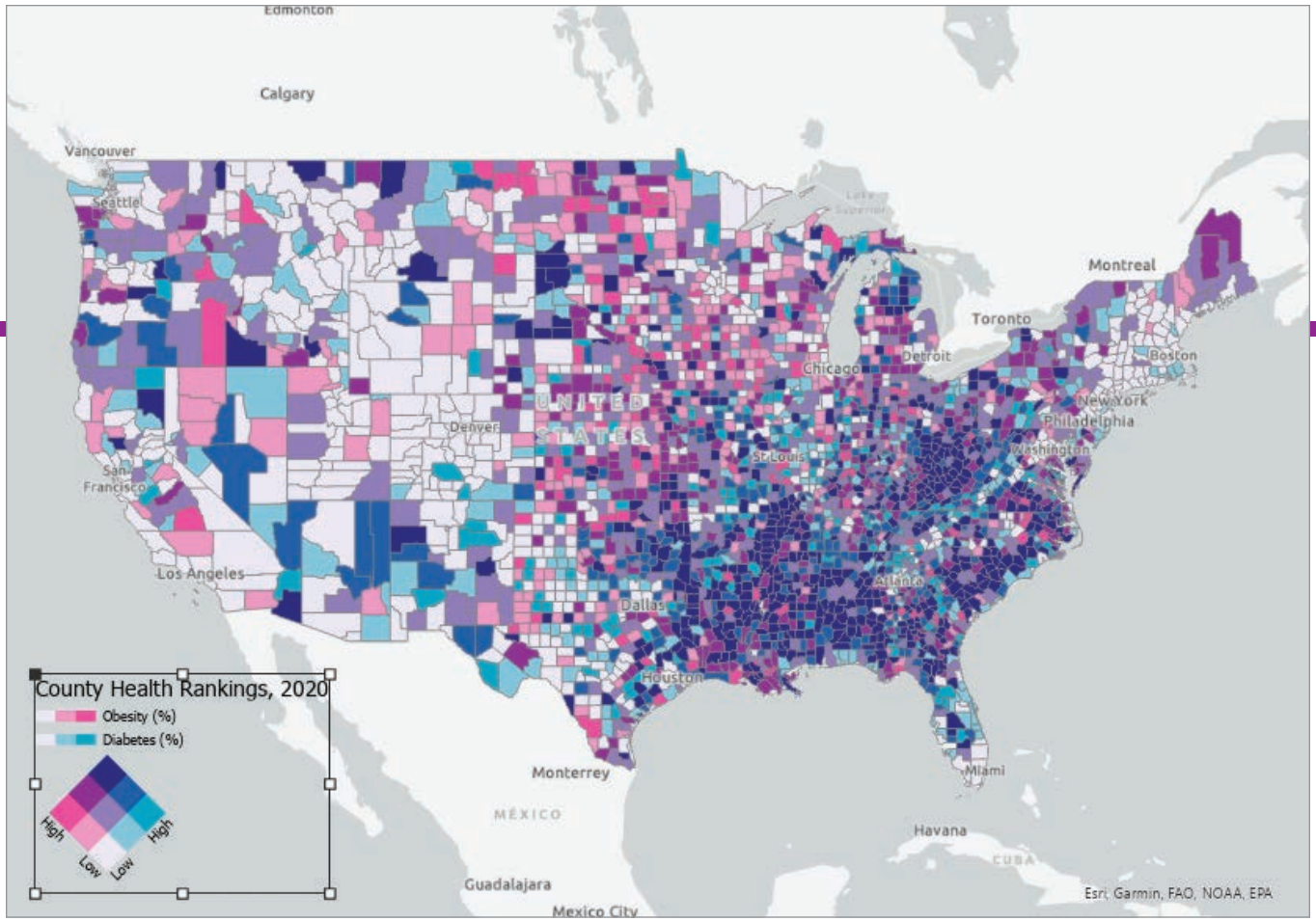
Add a Legend to the Map

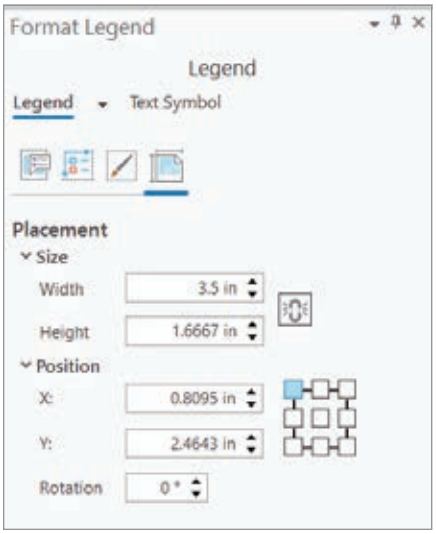
This tutorial requires ArcGIS Pro at any license level and access to an ArcGIS Online organizational account.

1. Open a web browser and go to the ArcGIS Online item (https://bit.ly/3fYZ1OM) on diabetes and obesity. Click Open in ArcGIS Pro.
2. It is a bivariate colors map showing the relationship between adult diabetes (percentage of adults aged 20 years

↓ Expand the County Health Rankings, 2020 layer to see the symbology used to display this layer and click the Layout tab to see the layout for this map.







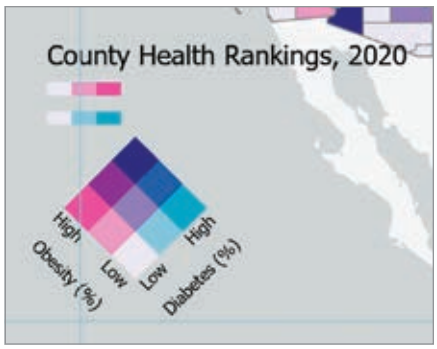
↑ In the empty space at the lower left of the layout, use your cursor to define the extent of the legend.

← In the Format Legend pane, click the Placement tab and change Width to 3.5 in to ensure that the legend will be scaled to fit the extent you drew when inserting the legend.

↘ After converting the legend to graphic elements, select the text for Obesity (%), rotate it, and place it on the lower-left side of the legend. Select the text for Diabetes (%), rotate it 45°, and place it along the right side of the legend.

and above with diagnosed diabetes) and adult obesity (percentage of adults aged 20 years and above with a body mass index of 30 or more), based on County Health Rankings data for 2020 (https://bit.ly/3x38GJL), available in ArcGIS Living Atlas of the World.

3. In the Contents pane, expand the County Health Rankings, 2020 layer to see the symbology used to display this layer. Click the Layout tab to see the layout that has been created for this map.
4. On the Insert tab, in the Map Surrounds group, click Legend. In the empty space at the lower left of the layout, place your cursor where you want to define the upper-left extent of the legend, then click and move the cursor to the location you would like to use to define the lower-right extent and release the mouse button.
5. Right-click the legend and then, in the context menu, click Properties. In the Format Legend pane, click the Placement tab and change Width to 3.5 in. This will ensure that it will be scaled to fit the extent you drew in the previous step.



Manipulate Legend Elements as Graphics

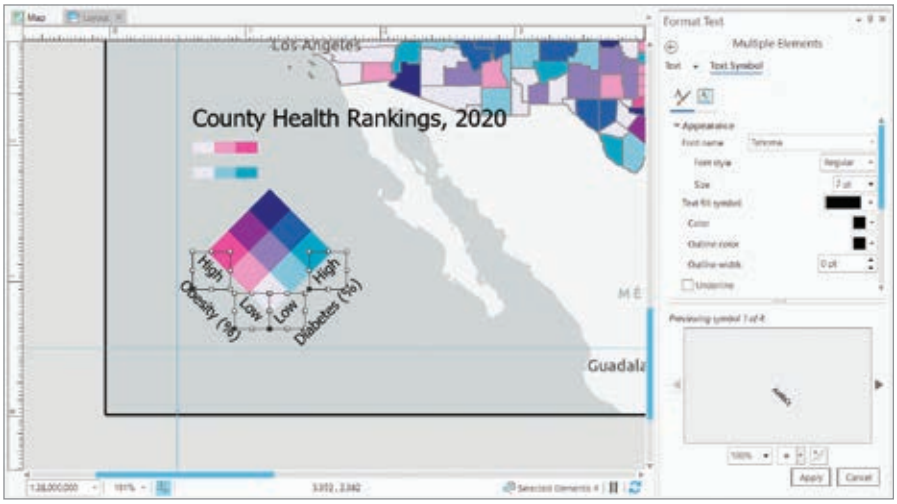
1. On the Layout tab, in the Navigate group, click the Navigate tool.
2. Click near the legend while holding the Shift key to create a rectangle around the legend to zoom in to that area.
3. The handles on the rectangle surrounding the legend are visible, showing that it is already selected. Right-click within the rectangle surrounding the legend and, in the context menu, click Convert to Graphics. The legend is no longer linked to the map, and you can modify the individual elements that make up the legend.
4. With the rectangle surrounding the legend still selected, right-click inside it again and, in the context menu, click Ungroup. Note that these elements are also displayed in the Contents pane. If layout elements are snapping to guides or existing page elements, you can temporarily disable snapping by pressing the spacebar while you are moving elements.

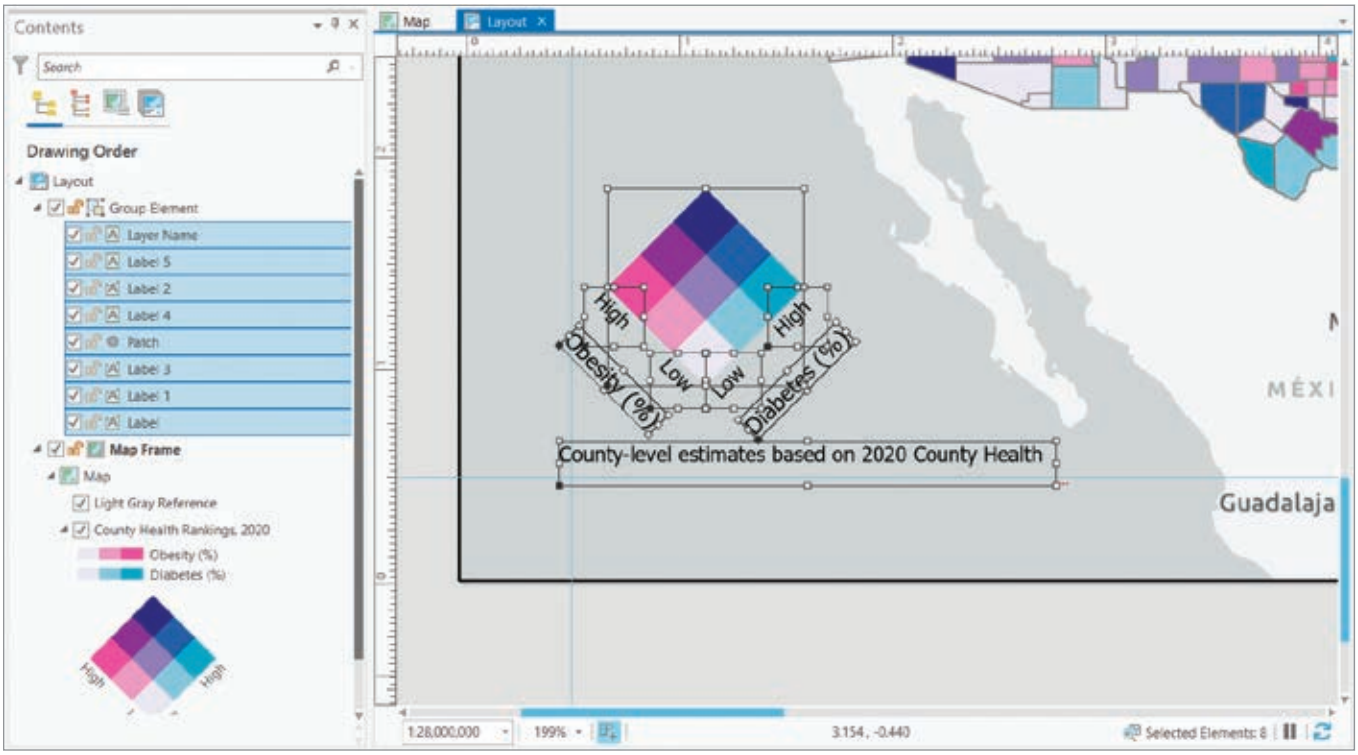
→ Select all four pieces of text for High and Low and use the Format Text pane to change the text size to 7 pt.

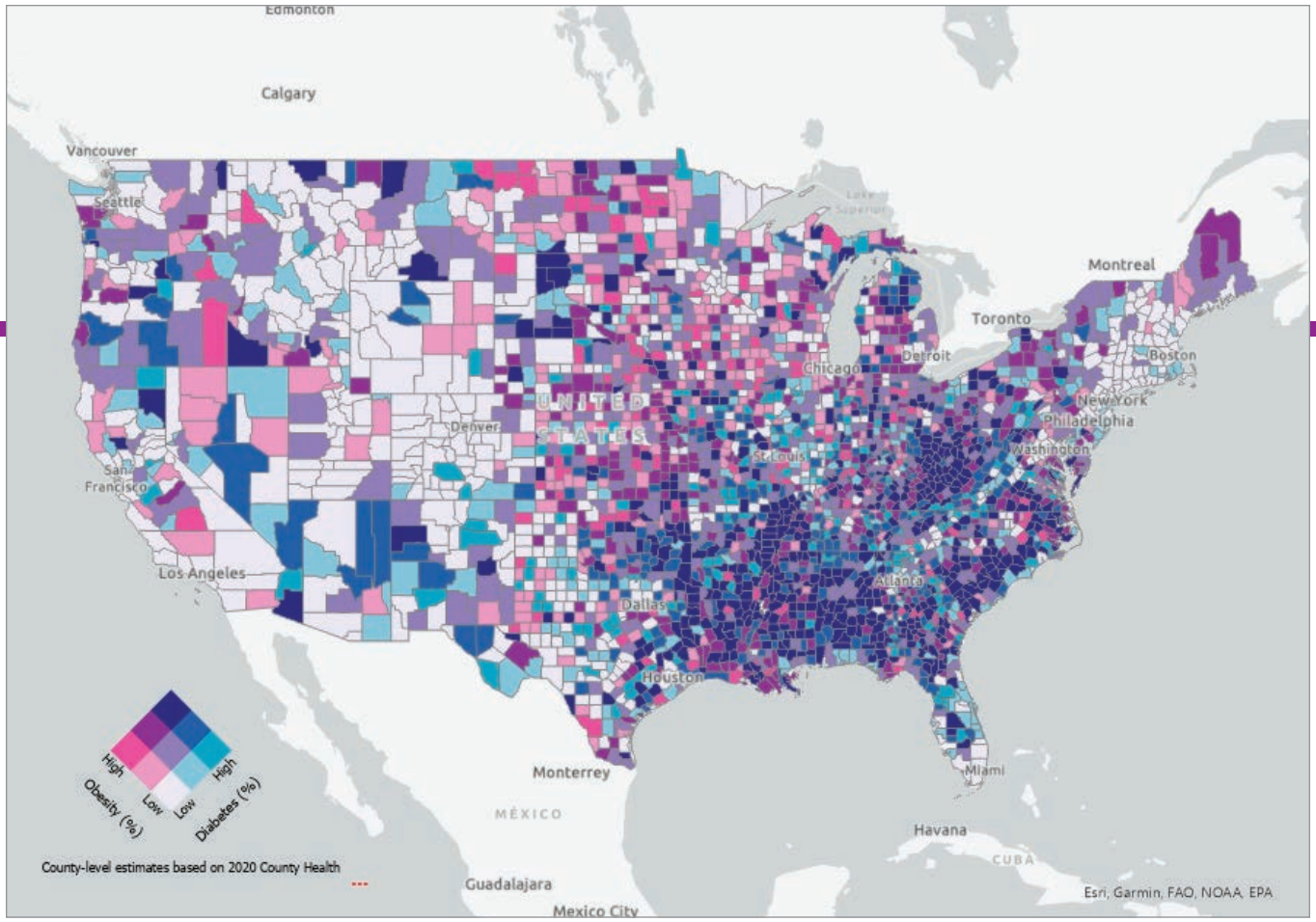
↓ After changing the legend title, move it under the legend. Select all the elements in the legend and group them. Now the grouped legend elements can be moved as a single page element.

Modify Text Placement and Size

1. On the Layout tab, in the Elements group, click Clear Selection. To select an individual element, click the Select tool in the Elements group of the Layout tab.
2. Select the text for Obesity (%). Point near the upper-right handle to see the rotate control, then use the number indicator to rotate the text 315°.
3. Perform the same process on the text for Diabetes (%), rotating it 45°.
4. Move the Obesity (%) text to the left side of the legend and the Diabetes (%) text to the right side of the legend.
5. Hold down the Shift key and select all four pieces of text for High and Low, then right-click and, in the context menu, click Properties. The Format Text pane will open, allowing you to modify the text and its appearance.
6. Click the Text Symbol tab, expand the Appearance section, change Size to 7 pt, and click Apply.
7. Deselect all text elements and reselect them individually to fine-tune the position of each.







↑ The layout now contains a custom legend for the bivariate colors map with text in different sizes and a descriptive caption.

8. Select the legend title. In the Format Text pane, on the Text tab, change the text to County-level estimates based on 2020 County Health Rankings data. The full title does not appear because the text is too large to fit into the extent shown by the box around the text. You will take care of this problem in the next step.
9. Repeat steps 6 and 7 to change the legend title text size to 7 pt and position the text under the legend.
10. Select the pink and blue color ramps and delete them.
11. In the Contents pane, hold the Ctrl key and select all the legend elements. Do not select the Map Frame element. If you inadvertently select it while the other elements are selected, hold the Shift key and click the Map Frame element to unselect it.
12. In the Layout View, hover over the rectangle for any selected element; right-click; and in the context menu, click Group.

The grouped legend elements can be moved as a single page element. The layout now contains a custom legend for the bivariate colors map with text in different sizes and a descriptive caption.

Try These Techniques and Improve Your Maps

With the tools used in this tutorial as well as additional tools on the Format tab that were not discussed in this article, you have many options for modifying legends and other map elements. Try modifying your maps using all of these options to take your map layouts to an even higher level.

About the Author

Aileen Buckley is a cartographic researcher on the ArcGIS Living Atlas of the World team and a member of the Esri science virtual team. She holds a doctorate in geography from Oregon State University.

Update Your Basemaps from Raster to Vector

If you have not already done so, make sure you update your ArcGIS maps and apps from raster to vector basemaps to avoid any disruptions. Esri vector basemaps have become the primary basemaps used by ArcGIS.

Esri vector basemaps are optimized to quickly generate and update maps and apps. With compact sizes and more efficient draw times, vector basemaps provide enhanced performance. In addition, the improved personalization options available with vector basemaps let you customize a basemap's appearance and styles.

↑ Esri vector basemaps have become the primary basemaps used by ArcGIS. They are optimized to provide enhanced performance.

Raster Basemaps That Should Be Migrated

Beginning in July 2021, most Esri raster basemaps entered the mature support phase, which means that these basemaps will remain available, but they will no longer be updated. To ensure that your maps and apps use the most current and best quality data, it is important to update the basemaps you use from raster to vector as soon as possible.

Mature Raster Basemap		Replacement Vector Basemap
World Dark Gray Canvas Base	→	**Dark Gray Canvas Base**
World Dark Gray Canvas Reference	→	**Dark Gray Canvas Reference**
World Light Gray Canvas Base	→	**Light Gray Canvas Base**
World Light Gray Canvas Reference	→	**Light Gray Canvas Reference**
World Boundaries and Places	→	**Hybrid Reference Layer**
World Hybrid Overlay	→	**Hybrid Reference Layer**
World Transportation	→	**Hybrid Reference Layer**
National Geographic World Map	→	**National Geographic Style Map**
World Street Map	→	**World Street Map***
World Topo Map	→	**World Topographic Map**

↑ This table lists the raster basemaps that need to be migrated and their vector replacements.

Raster Basemaps That Don't Require Migration

These foundational raster basemaps will continue to be updated. There are no vector equivalents for these basemap services, which include imagery, elevation, and polar services.

- World Imagery (including Clarity, Firefly, WGS84, and Wayback)
- World Hillshade
- World Dark Hillshade
- Antarctic Imagery
- Arctic Imagery
- Arctic Ocean Base
- World Ocean Base

Send any questions or concerns about mature basemaps to online_content@esri.com.

*Alternates to the World Street Map vector basemap include: Streets (Night), Streets (with Relief), World Navigation Map, and Navigation (Dark Mode)

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The Importance of Margins of Error and Mapping

By Lisa Berry and Diana Lavery

Almost all quantifications in your life are estimates: the speed on your speedometer, the weight on your bathroom scale, and the temperature on the thermometer in your oven.

Unless you've had these instruments calibrated recently, they are off by a bit. But you can still drive, track your weight, and cook dinner without fearing the effects of these small errors.

The same concept applies to the data we map. We can still understand which communities have higher or lower overall population even though the data contains some level of error.

Many fields of science rely on samples for their studies. Physical scientists work with water and soil samples to learn about the larger ecosystems. Doctors and medical scientists work with biometric lab samples to learn about the whole body. Social scientists often work with data that is a sample of a total population.

This is particularly true of the US Census Bureau's various surveys, which give us a representation of the population, without surveying every single person in the United States. Sampling is a cost-effective way to provide insight about a population and is a common practice when creating demographic datasets of all types.

When we create maps of sampled data—commonly using demographic and socioeconomic data—it is critical to understand the reliability of our data. It is also important to effectively communicate to our map readers the built-in error that comes with sampled data in a way that avoids causing them to mistrust the data. To understand how to do this, let's explore margins of error and what they mean to our mapping projects.

What Are Margins of Error?

Margins of error, or MOEs, are an artifact of sampled data. For example, the American Community Survey (ACS) from the US Census Bureau offers a margin of error for the data estimates it provides. A MOE tells people using the data that the estimate is not an exact figure, but rather a range of possible values. A MOE helps us figure out that range.

↓ Figure 1: Calculating MOE for a sample of 361 people.

Coefficient of Variation

Margins of error, or MOEs, are an artifact of sampled data. The American Community Survey (ACS) from the US Census Bureau provides MOEs for its data estimates that tell people using the data that the estimate is not an exact figure, but a range of possible values.

$$\left(\frac{\left(\frac{\text{MOE}}{1.645}\right)}{\text{Estimate}}\right) \times 100$$

Estimate: 361
Margin of Error: 158

$$\left(\frac{\left(\frac{158}{1.645}\right)}{361}\right) \times 100 = 26.6\%$$

↑↑ Figure 2: The ACS layers in ArcGIS Living Atlas of the World are free to use and do not require credits or a subscription.

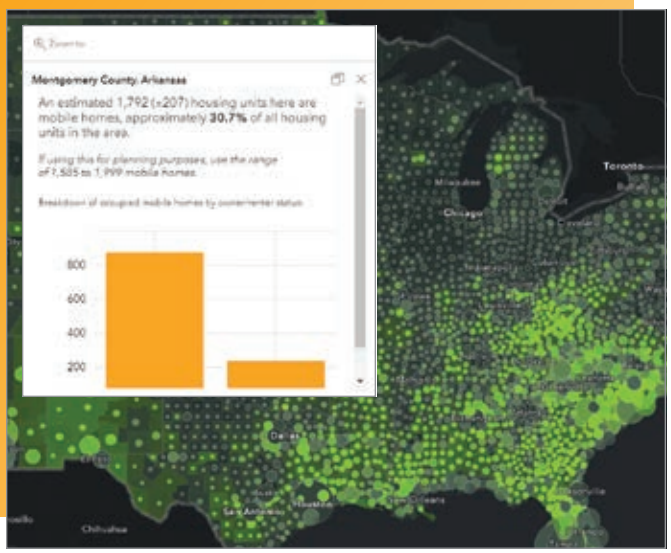
↑ Figure 3: Symbology can show MOE. An ArcGIS Arcade expression was used to calculate the coefficient of variation to extract the areas where there is lower reliability of the data.

As shown in the example in Figure 1, if the estimate for the number of people of a certain group in an area is 361, there will be an associated margin of error for that estimate. If the MOE is 158, the actual number of people in that group there falls somewhere between 203 and 519.

This range of values is known as the confidence interval, and it tells us that the Census Bureau is 90 percent confident that the count of population is between those upper and lower values.

Why Use MOEs in Your Maps?

As stated in *Understanding and Using American Community Survey Data*, a handbook on using ACS data published by the US Census Bureau, "Estimates with smaller MOEs—relative to the value of the estimate—will have narrower confidence intervals indicating that the estimate is more precise and has less sampling error



↑ Figure 4: Communicate MOEs in a pop-up as in this map of mobile homes.

associated with it." This tells us that not all MOEs and confidence intervals are equal.

In general, the larger the population, the smaller the MOE, and conversely, the smaller the population, the larger the MOE. Geographically, this means that states and counties typically have smaller MOEs than tracts and block groups because there are fewer respondents at smaller geography levels. Demographically, this means that estimates of a variable—as home ownership, education, health insurance status, or internet availability—has been disaggregated by age, sex, race/ethnicity, veteran status, or another characteristic, will have higher MOEs the more it is disaggregated, because the population being sampled as well as the sample is getting smaller and smaller.

Also, some population groups, such as those in low-income areas, are harder to survey due to lower response rates. For those areas, MOEs tend to be higher. When using the five-year estimates from ACS, the sample size is increased since there are 60 months of sample data pooled together, but even then, MOEs are often large.

There are two main types of survey errors: sampling and nonsampling.

- Sampling errors are caused solely by the fact that the entire population was not surveyed. Because a survey is only a sample, or subset, of the population, sampling errors are unavoidable. That is why—in part—figures that come from a sample are known as estimates. ACS MOEs only reflect sampling error.
- Any errors that are not caused by general sampling errors are nonsampling errors. An example of a systematic nonsampling error that is cited by the US Census Bureau could occur if no one from a sampled housing unit is available during the data collection time frame. This error is known as unit nonresponse. It increases the chances that bias appears in the final survey.

These are just a few of the many factors that can impact the reliability of our data. Because these errors exist and can come from so many sources, it is important to effectively communicate the associated margins of error to our map audience. Your map reader could see a map and assume that the numbers are exact, when, in fact, they contain sampling errors. Being transparent about margins of error creates accountability for both the map's creator and those making decisions from the data.

Evaluating Margins of Error

One way to evaluate the reliability of an estimate is to understand the relationship between the estimate and its associated margin of error. One measure of reliability uses the coefficient of variation, which is a fancy way of describing the error as a percent of the estimate. In the previous example, which had a MOE of 158, the percent coefficient of variation would be 26.6. If an error is large in relation to the estimate, this coefficient will be large, which indicates a lower reliability. The higher the coefficient, the lower the reliability.

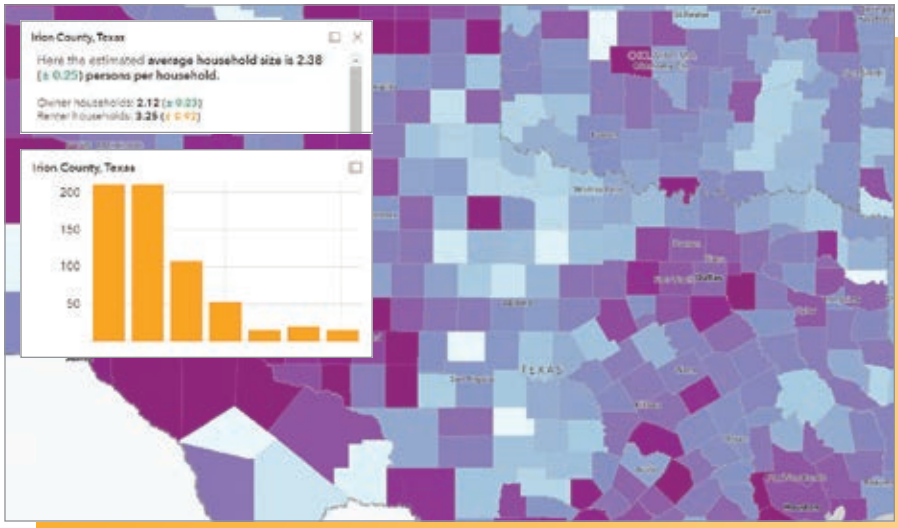
Note that 1.645 is used, since the ACS estimates are provided by Census Bureau at a 90 percent confidence level, and under a standard normal bell curve, 90 percent of the area beneath the curve is between 1.645 and -1.645. To convert to a different confidence level, use a different constant here, such as 1.96 for a 95 percent confidence level. If the MOE is 0, the estimate is likely controlled to be equal to a fixed value and has no sampling error.

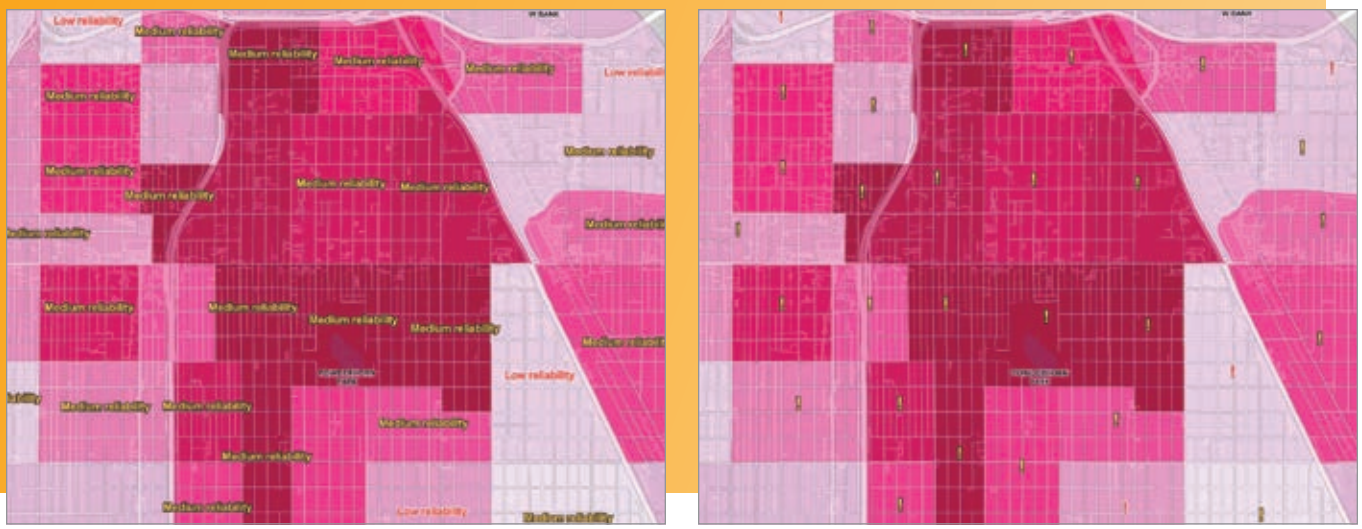
Ways to Use MOEs and Reliability in Mapping

ACS data is available through various GIS workflows in ArcGIS. This article provides a few examples of how to locate ACS data and map MOEs so that they can be better understood.

With ready-to-use Census ACS layers from ArcGIS Living Atlas of the World (https://bit.ly/3q5sjPm), you can access thousands of ACS variables and their MOEs. They are free to use and do not

↓ Figure 5: This example utilizes an ArcGIS Arcade expression to create custom colors that indicate the reliability of the estimates.





↑ Figure 6: These scale dependent labels indicate data reliability only when zoomed in (left) and are not visible when the map is zoomed out.

require any credits or a subscription to use. These layers are organized by various topics. One or many ACS tables are included in each layer. Each ACS estimate or precalculated percentage comes with its associated MOE.

To see the list of fields for a layer, go to the ArcGIS Online item details page, click the Data tab, and click Fields. These layers can be easily customized in ArcGIS Online, ArcGIS Pro, or ArcGIS Enterprise. They provide data at state, county, and census tract levels of geography.

You can include MOEs in maps you make with these layers using symbology, pop-ups, custom ArcGIS Arcade expressions, and labels. Although the maps accompanying this article were created in ArcGIS Online using ArcGIS Living Atlas layers and Arcade expressions, these maps can be replicated in ArcGIS Pro using the same data and expressions.

Symbology

Symbology is one method for showing MOE. In the example in Figure 3, an Arcade expression was used to calculate the coefficient of variation to extract the areas where data is less reliable. These areas of low reliability are overlaid on top of the map pattern to show areas with higher MOEs. This example highlights any area with a coefficient variance of more than 40 percent.

Pop-Ups

Figure 4 shows how MOEs could be communicated in a pop-up. Although this method is less alarming to the map reader than symbology, it still effectively warns the map reader that the data being mapped is an approximation. Note the use of words such as *estimated*, *approximately*, and *range*. Pop-ups subtly highlight that the estimates contain some amount of error without scaring users and eliminating all trust in the data.

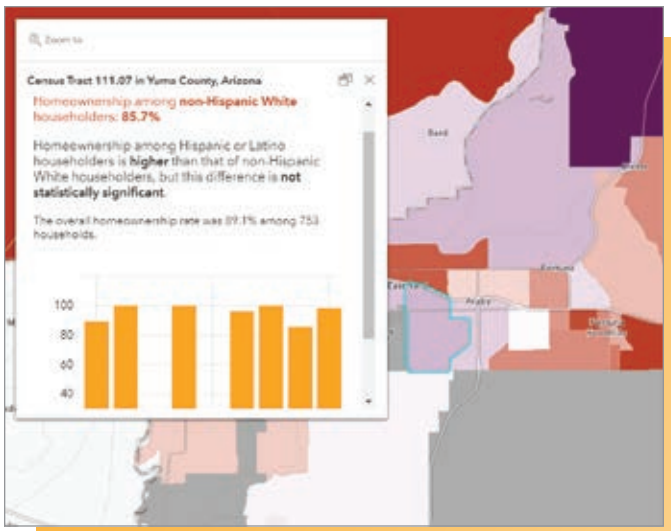
Custom Colors Using Arcade Expressions

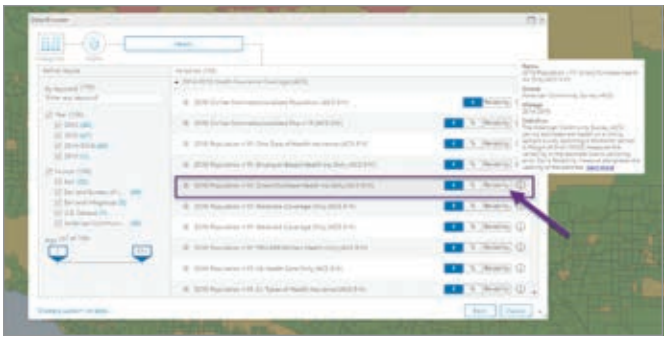
The example in Figure 5 uses some of the same techniques as the example in Figure 4 but utilizes an Arcade expression to create custom colors that show the reliability of the estimate. The color is based on the MOE as a percent of the estimate (the coefficient of variation). Arcade helps categorize this percentage into high, medium, or low reliability. (For an explanation of high, medium, and low category thresholds, see the section Using Esri Demographics and ArcGIS Business Analyst.) Note that a disclaimer is included in the pop-up for those unfamiliar with ACS data, and a link to learn more about it.

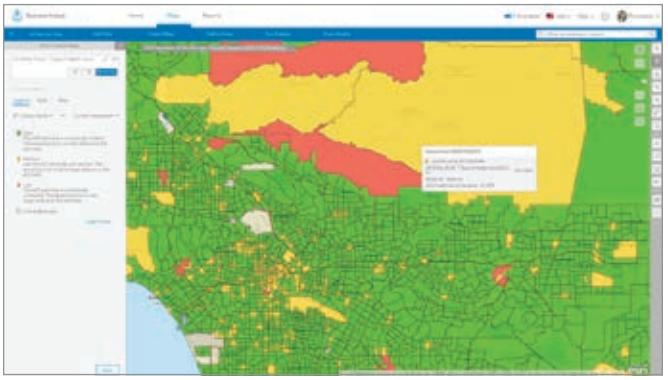
Labels

Figure 6 shows various ways labeling can communicate MOEs. These labels are scale dependent, so when the map is zoomed out, the map pattern is not obstructed. When the map is zoomed in to the neighborhood level, the labels become visible and display categorical estimates of the data's reliability. This map uses the same Arcade statement used as the map in Figure 5 and the label classes that are available in the new Map Viewer.

↓ Figure 7: Data reliability is conveyed statistically and visually in this map, which uses an Arcade expression to perform the statistical test on the fly and converts the results into an easy-to-read statement in the pop-up in combination with the Compare A to B mapping style.







↖ Figure 8: When choosing an ACS attribute in ArcGIS Business Analyst, the MOE is offered as a reliability estimate (REL).

↙ Figure 9: In Business Analyst, the reliability estimate is categorized as high, medium, or low.

Testing for Statistical Significance

MOEs also help calculate if two things are significantly different. By using the Statistical Testing Tool available from the US Census Bureau (https://bit.ly/2TvmZZg), two attributes can be compared while taking into account the MOE associated with survey estimates. The map in Figure 7 uses this z-score method to compare home ownership rates of White non-Hispanic homeowners and Hispanic or Latino homeowners. The pop-up uses an Arcade expression to perform the statistical test on the fly and convert the results into an easy-to-read statement in combination with the Compare A to B mapping style, which maps the ratio between two numbers, expressing that relationship as percentages, simple ratios, or an overall percentage and comparing two patterns both visually and statistically.

Using Esri Demographics and ArcGIS Business Analyst

Esri Demographics can be accessed in many ways (https://bit.ly/3gBbHuq) from ArcGIS products, such as ArcGIS Business Analyst, and via Esri's ArcGIS GeoEnrichment Service, as well as from ArcGIS Living Atlas. There are thousands of ACS variables available at geographies for states, congressional districts, ZIP codes, census tracts, block groups, and other levels. Custom polygons can also be enriched with the attributes of your choice.

When choosing an ACS attribute in Business Analyst, MOE is offered as a reliability estimate (REL) as shown in Figure 9. The REL attribute is a reliability estimate, which categorizes the MOE by the coefficient of variation. This reliability estimate is broken into three categories: high, medium, or low reliability. If the MOE is less than 12 percent of the estimate, its reliability is considered high (REL = 1). Between 12 and 40 percent, reliability is considered medium (REL = 2). If MOE is more than 40 percent, reliability is considered low (REL = 3).

Special thanks to Esri staff members Helen Thompson, Jim Herries, and Steven Aviles for the map examples included in this article. Also thanks to Kevin Krivacsy; Kevin Butler; and Kyle R. Cassal, chief demographer at Esri, for providing valuable insight about margins of error and mapping.

About the Authors

Lisa Berry is a senior product engineer at Esri on the ArcGIS Living Atlas of the World team. She works to create clear and concise stories about demographic, socioeconomic, and policy topics using cartography. Berry builds data layers and tutorials to help others create their own map masterpieces.

Diana Lavery loves working with data. She is a senior product engineer on ArcGIS Living Atlas of the World's policy maps team and has more than a decade of experience as a practitioner of demography, sociology, economics, policy analysis, and GIS. Lavery holds a bachelor's degree in quantitative economics and a master's degree in applied demography. She enjoys strong coffee and clean datasets, usually simultaneously.

Ten Tips FOR TABLES IN LAYOUTS

By Aubri Kinghorn

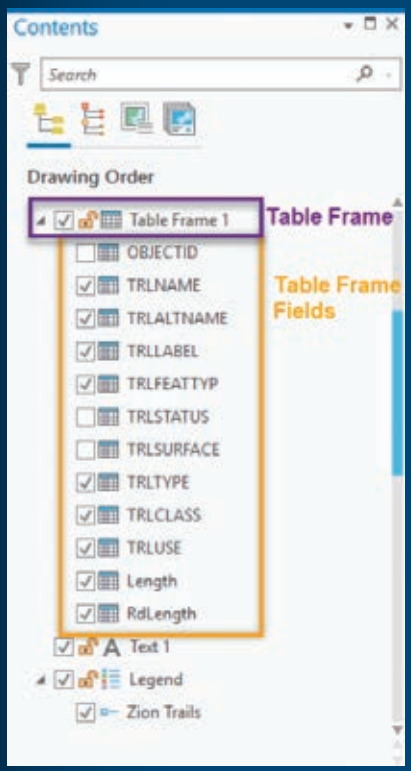
Tables are a powerful way to share information in an ArcGIS Pro layout. Table frames in a layout support a lot of formatting options—so many that it can be hard to remember them all. Here are my 10 tricks for tables in layouts. (Just try saying that fast 10 times.)

1 FRAMES VERSUS FIELDS

First, it is important to understand the difference between a table frame and table frame fields. The table frame is the layout container for the table data, just as the map frame is the layout container for a map. Table frame fields are individual fields in the table that are displayed as columns.

Some properties belong to the table. For example, controlling whether all the data is displayed or just data visible in the map frame is a property of the table frame. To access the properties for the table frame, select it in the Contents pane, right-click, and choose Properties.

Other properties, such as using word wrapping to determine field width, are set at the field level. By default, all fields in the table frame have the same properties, but you can edit properties for individual fields. For example, you can make the background of the first field blue and make the background for other fields gray. To access the properties for table frame fields, select one or more in the Contents pane, right-click, and choose Properties.



← Access the table frame properties from the Contents pane.

2 ADD, REMOVE, AND REORDER FIELDS

You can add, remove, and reorder fields in the table frame directly from the Contents pane. By default, only the first 10 fields are added to a table frame, so knowing how to add and remove fields is incredibly helpful. Simply right-click the table frame in the Contents pane and choose Add field. To remove a field, expand the table, right-click on the desired field, and choose Remove.

3 TABLE STRIPING

Changing the background for alternating rows can help your table data pop. In the table properties, you can set one or two different row backgrounds and choose how many consecutive rows that background appears on. There are a lot of possible combinations.

4 NUMBER FORMATTING

The appearance of numbers in your table reflects the number formatting settings in the table fields view. You can adjust these settings to show numbers as currency, percentages, and other formats. You can also control the number of decimal places displayed and whether a thousands separator is shown.

5 SORTING

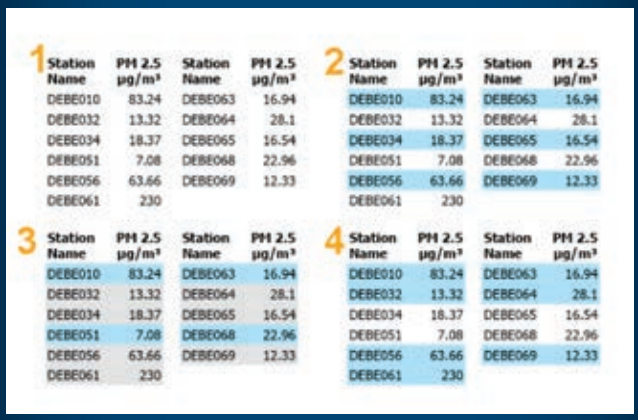
You can sort the table based on any field included in the table frame by modifying the table frame formatting. Text fields are sorted alphabetically, and numeric fields are sorted numerically. Date fields are sorted by date. With Custom Sort, multiple fields can be used for sorting.

6 ALIGNMENT

You can set the alignment for individual table frame fields. Sometimes I like to have my text fields aligned to the left and my numeric fields aligned to the right. That can be done by selecting the field you want to align, changing the drop-down to Data text (so that only the field text is modified, not the heading), and setting the alignment.

7 GAPS

Tables will automatically wrap to new columns if the data is too long. You can use other table frame fitting strategies to modify this behavior. You can change the gap between columns. If you want to make your table more compact, try decreasing the gap sizes of other table elements by adjusting the table frame spacing properties.



1

Station Name	PM 2.5 µg/m³	Station Name	PM 2.5 µg/m³
DEBE010	83.24	DEBE063	16.94
DEBE032	13.32	DEBE064	28.1
DEBE034	18.37	DEBE065	16.54
DEBE051	7.08	DEBE068	22.96
DEBE056	63.66	DEBE069	12.33
DEBE061	230		

2

Station Name	PM 2.5 µg/m³	Station Name	PM 2.5 µg/m³
DEBE010	83.24	DEBE063	16.94
DEBE032	13.32	DEBE064	28.1
DEBE034	18.37	DEBE065	16.54
DEBE051	7.08	DEBE068	22.96
DEBE056	63.66	DEBE069	12.33
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3

Station Name	PM 2.5 µg/m³	Station Name	PM 2.5 µg/m³
DEBE010	83.24	DEBE063	16.94
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4

Station Name	PM 2.5 µg/m³	Station Name	PM 2.5 µg/m³
DEBE010	83.24	DEBE063	16.94
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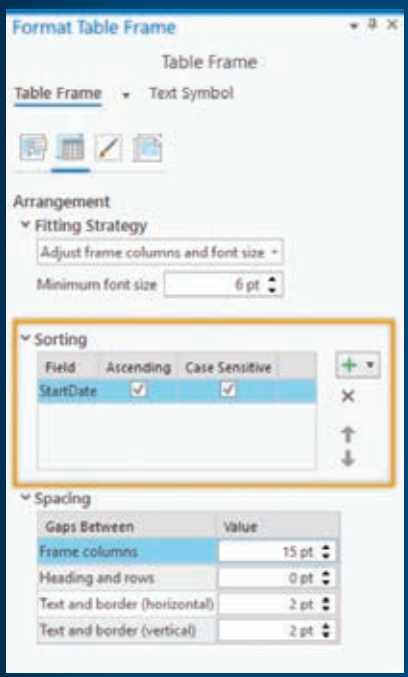
DEBE034	18.37	DEBE065	16.54
DEBE051	7.08	DEBE068	22.96
DEBE056	63.66	DEBE069	12.33
DEBE061	230		

↑ You have lots of flexibility in how you use table striping. Table 1 uses the same formatting for all row backgrounds. Table 2 uses one row background on every other row. Table 3 uses two row backgrounds, with a one row then two rows pattern. Table 4 uses one row background on every two rows.

County Name	Total Population	Total Households	Average Household Size	Median Household Income	Median Home Value	Unemployment Rate
Campbell County	50,562	18,637	2.69	$78,215.00	$223,549.00	5%
Fremont County	40,429	15,386	2.57	$50,799.00	$199,952.00	9.3%
Laramie County	100,887	40,602	2.44	$57,846.00	$216,158.00	2.3%
Natrona County	83,019	33,289	2.44	$59,026.00	$216,336.00	4.8%
Sweetwater County	45,694	16,957	2.65	$69,437.00	$196,435.00	4.9%

↑ Each numeric field in this table has a different number format. Total Population and Total Households fields use thousands separators. The Average Household Size field is limited to two decimal places and padded with zeros. Median Household Income and Median Home field values are displayed as currency, and values in the Unemployment Rate field are shown as percentages.



← Specify how individual fields are sorted from the Format Table Frame pane in the table frame properties.

8 USE DEFINITION QUERIES

Displaying all the spatial features in a table can take up a lot of space. Consider creating a duplicate invisible layer or a stand-alone table and adding a definition query to display only the most important features in that table.

9 QUICKLY UPDATE FONTS

There are a lot of ways to set text properties for tables. You can have different text properties for each field if you'd like or just set different properties for headings and text. Or set properties just for one field. You decide. I often find that I just need to quickly update the font or text color for all text in my table, so instead of poking through the pane, I just use the Format tab on the ribbon. Font settings that are updated there will be applied to all the text in the table.

10 TABLE FRAME OR TABLE DYNAMIC TEXT

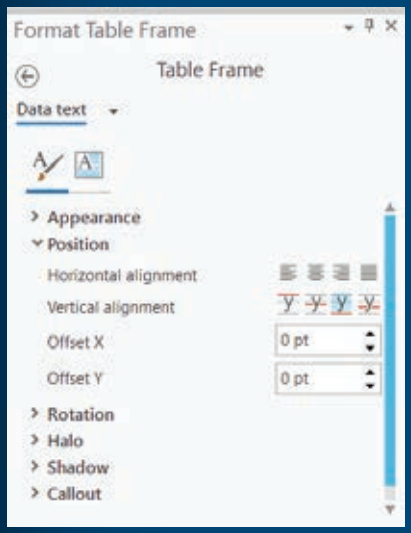
Sometimes, you can't get a table to look the way you want, or you don't want to display headings. Consider using table dynamic text instead of a table. Table dynamic text reads values from a table in your map and displays them as text. If those values are updated, the text is automatically updated (that's why it's called dynamic). Table dynamic text supports custom queries to determine what data is shown, and it uses ArcGIS Arcade expressions to format the displayed text. If a table just isn't working, dynamic table text might do the trick. Watch this video (https://youtu.be/HoUSchKbF_g) to find out more about using table dynamic text.

THAT'S IT

Here you have it: 10 tricks for tables in layouts. Have fun formatting table frames for your next layout. For detailed information on using tables, read the Tables topic in the ArcGIS Pro help documentation at https://bit.ly/3iVlI8F.

ABOUT THE AUTHOR

Aubri Kinghorn loves good cartography, good burritos, and helping people figure out effective ways to share their data with others. Luckily, her work as a product engineer on the ArcGIS Pro layout team lets her do that every day.



← Select Data text from the drop-down on the Format Table Frame pane to adjust text alignment and other text characteristics.

City	Population	Page Number
Nickerson	289	42
Waterbury	505	30
Lodgepole	369	46
Elwood	1473	49
Cortland	55	53
Axtell	1011	61
Crab Orchard	1429	64

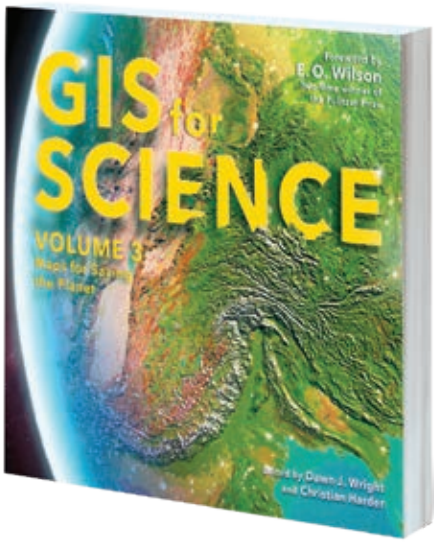
Nickerson, 289 . . . . . D-9
Waterbury, 505 . . . . . C-8
Lodgepole, 369 . . . . . E-2
Elwood, 1473 . . . . . E-5
Cortland, 55 . . . . . E-9
Axtell, 1011 . . . . . F-6
Crab Orchard, 1429 . . . . F-9

← In the top table, three fields are displayed in a table frame. In the bottom table, the same data is displayed using table dynamic text. An advanced Arcade expression was using to add the dots.

GIS Bookshelf

GIS for Science, Volume 3: Maps for Saving the Planet

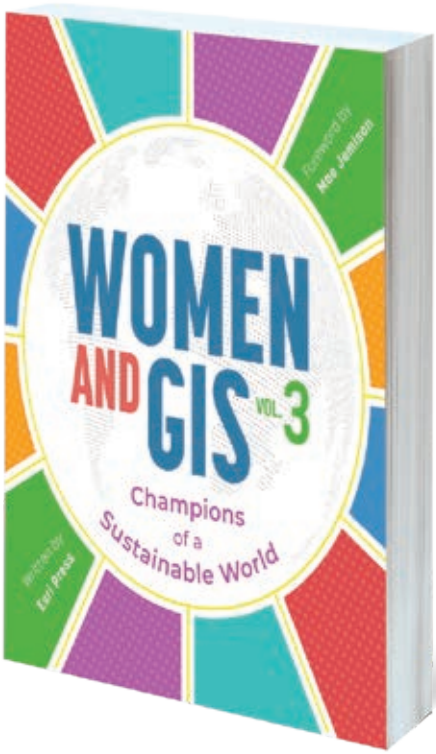
Edited by Dawn J. Wright and Christian Harder



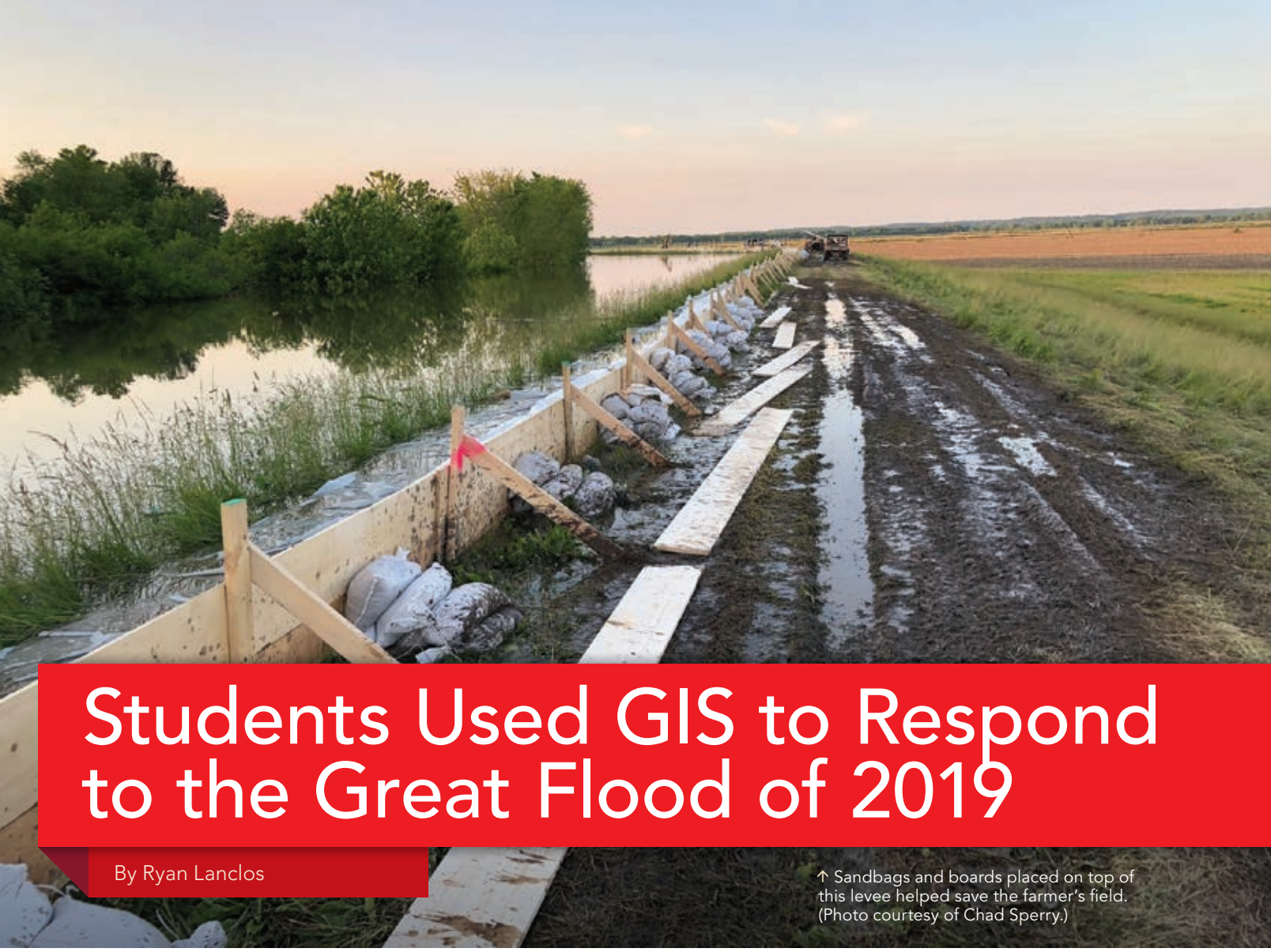
The natural world is on the line. The need has never been greater for a GIS to support scientifically informed decisions to meet the pressing challenges to life on Earth. With a foreword by two-time Pulitzer Prize winner E. O. Wilson, *GIS for Science*, Volume 3: *Maps for Saving the Planet* highlights real-world examples of how scientists are performing the analysis and creating the maps that are saving the planet. This collection of stories centers on biodiversity and is written for professional scientists and anyone interested in learning about the intersection of conservation and technology. Contributors represent a cross section of scientists who use ArcGIS to understand geographic data gathered with remote-sensing and on-site technologies. The ideas presented in *GIS for Science* and its companion website—including collaboration, spatial analysis, and science communication—can be applied across many disciplines and can inspire readers to join efforts to save the planet. Esri Press, 2021, 206 pp., Ebook ISBN: 9781589486720 and paperback ISBN: 9781589486713.

Women and GIS, Volume 3: Champions of a Sustainable World

By Esri Press



The stories in this collection tell how 30 women in various science, technology, engineering, the arts, and mathematics (STEAM) disciplines are using geospatial technology to find solutions to the world's problems. Each woman charts the course her life took from childhood through a career in some aspect of conservation, sharing what has often been a circuitous route and the insight she has gained along the way. These persevering women are tackling problems that range from the local to the global and span not only science, but also business, education, arts, conservation, humanitarianism, and social justice. The third in a series of collections about the work of women in GIS, this volume has a foreword by renowned ethologist and conservationist Jane Goodall, PhD, DBE. Esri Press, 2021, 320 pp., Ebook ASIN: B093SDS426 and paperback ISBN: 97815899486379.



Students Used GIS to Respond to the Great Flood of 2019

By Ryan Lanclos

↑ Sandbags and boards placed on top of this levee helped save the farmer's field. (Photo courtesy of Chad Sperry.)

It was called the Great Flood of 2019 for good reason. During the wettest spring on record in the United States, multiple storms hit. Rivers overflowed, flooding the Midwest, the High Plains, and the South from January through June and impacting 14 million people. This flood was one for the record books across many areas of science. New records for high-water marks were set in 42 different locations along the Mississippi River.

Students at Western Illinois University (WIU) at the Macomb campus had a front-row seat. Macomb is located between the Mississippi and Illinois Rivers, north of where they meet.

"The Mississippi River was having extreme flooding, and the Illinois River just couldn't drain," said Chad Sperry, director of the GIS Center at WIU and a member of the state incident management team. Sperry was dispatched by the Illinois Emergency Management Agency (IEMA) to the State Unified Area Command (SUAC) in Winchester. He brought a team of GIS students to create maps that could help first responders from IEMA, the National Guard, Illinois Department of Transportation, Illinois State Police, US Army Corps of Engineers, and other agencies.

"There were a lot of road closures, so the students were involved in making detour route maps and other mapping products," Sperry said. "We used drones to provide a real-time situational awareness capability. We were working 14-hour days for 16 days straight. The duration and the intense months of coping with flood response were exhausting."

While flooding is a regular occurrence in many of the small communities along these rivers, it doesn't occur to the extent and duration of these flooding events. Beardstown, Illinois, experienced 176 days of minor and moderate flooding. In nearby Havana, major flooding stretched for 37 days.

Providing a View of an Important Levee

In the unincorporated community of Nutwood, Illinois, Sperry and his team monitored the main stem levee system a few miles away from town.

"Nutwood isn't significant in terms of population, but *[it's]* very significant in terms of impact," Sperry said. "It sits right at the bluff, so it's almost out of the floodplain, but not quite." Predictive modeling done by the US Army Corps of Engineers and the National Weather Service using

GIS indicated this levee was going to fail.

The townspeople had built their own backup levee using bulldozers to push dirt from the farm fields around town. Unfortunately, the main levee failed, and then the town levee failed. When the Nutwood Levee was overtopped, it forced the closure of Illinois State Route 16 at the Joe Page Bridge near Hardin. It took weeks for the waters to recede.

Sperry and his team were there over the course of the levee failure, mapping Nutwood using drones and ArcGIS Drone2Map before, during, and after the levee breach. Detailed drone mapping and elevation models were used by IEMA to inform evacuation plans.

The team also used ArcGIS Survey123 and ArcGIS Collector for postflood damage assessments. Instead of using the paper-based system, the team photographed everything and collected data on Apple iPads. Sperry helped train everyone and kept them on task, even when that required guiding people through the uncomfortable process of adopting new workflows.

Keeping Rural Communities Mobile

Mapping transportation routes was one of the more critical elements of the students' work. Floods closed many roads and bridges, and people needed to evacuate.

"The Department of Transportation had an expert traffic flow modeler that was optimizing evacuation routes," Sperry said. "We imported that information into geodatabases to take it to the next step, creating map products to provide the context of where all the people would ultimately end up."

Because many rivers lack bridges, ferries are used to cross the rivers. Road and bridge closures from the flooding made mobility even worse. Commuters to Saint Louis used their own boats to cross the river, choosing to park their cars across the river to avoid a three-hour detour around the flooding.

As the high water moved downriver, the team did some inundation modeling to help understand impacts as flooding neared Saint Louis. The team asked what would happen if a particular levee broke. They created flood extent maps to understand the effects. Incident commanders and planning section chiefs studied the flood extent maps to create contingency plans. By looking at potential outcomes, they could determine which homes and roads would be impacted and prioritize evacuation areas should the levees fail.

"We used something like one million sandbags during the event," Sperry said. "Levees are typically built with an earthen core with sand over the top of them. Over time, the sand and core get saturated, and that puts pressure and stress on the surrounding soils. We had boils popping up a half mile inside the levee where the river found a path, and the team would put sandbags around those to equalize them with the height of the river." *[Sand boils occur when water under pressure wells up through a sand bed, contributing to liquefaction and levee failure.]*

The US Army Corps of Engineers used ArcGIS Collector to mark and monitor the boils, any depressions in the levee, and anything out of the ordinary. That data about weak spots will be used to inform future levee improvements.

One View for the Team of Teams

The real-time data collected by different agencies and GIS students was fed into ArcGIS Dashboards and shared across the state.

"We built a dashboard with the National Guard to show where sandbag troops were being deployed," Sperry said. After the first briefing during which the dashboard was used, the team moved into the main building, and the dashboard stayed up on the main screen.

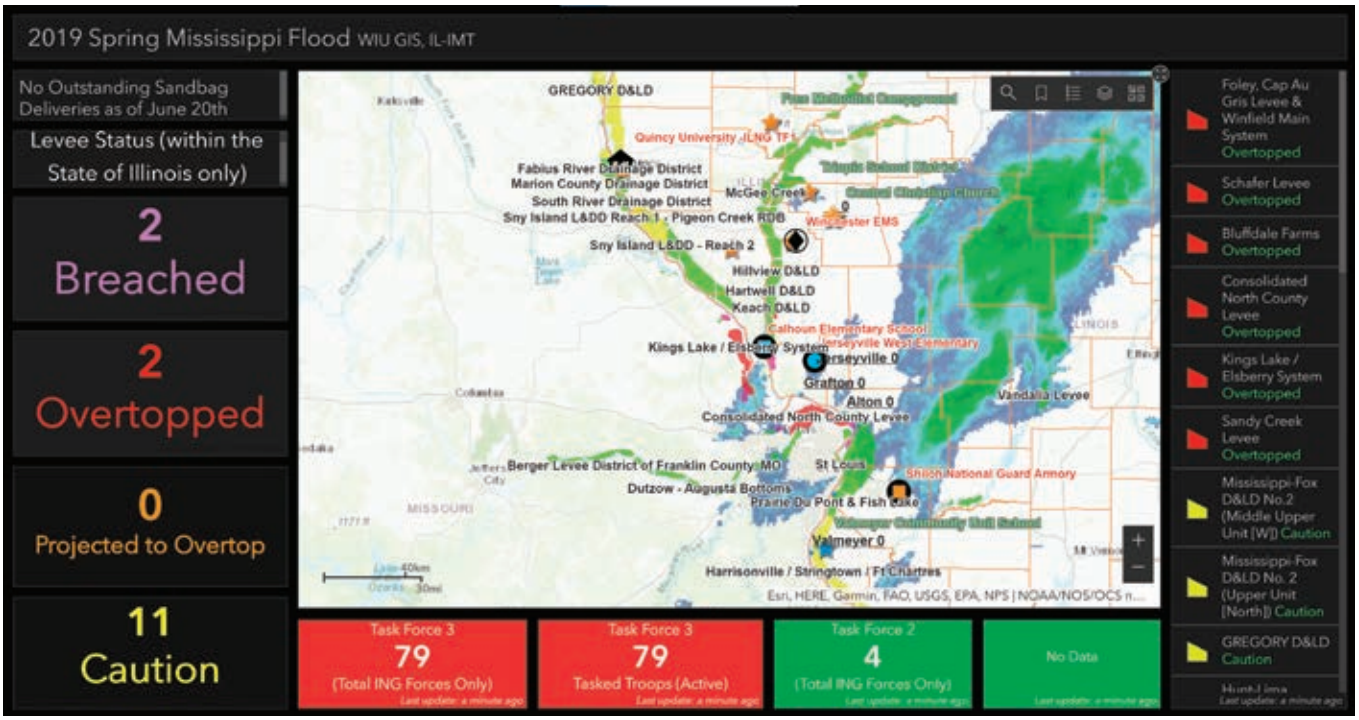
Soon the dashboard was shared with the Emergency Operations Center in Springfield, and the National Weather Service in Chicago used it to see what was really going on from a levee status standpoint. It was used to brief the governor, department heads, state senators, and US senators.

Eventually, the dashboard aggregated and consolidated data from 10 to 15 GIS analysts working for various agencies. WIU students worked alongside experts. Pam Brooks, GIS specialist at IEMA, had already fostered relationships with GIS people from other agencies and was able to help coordinate the collaboration.

At daily morning briefings, the teams discussed any status changes on the dashboard. For instance, the representatives from the US Army Corps of Engineers would inform the group of any levee breaching or overtopping, or levees in a state of caution.

The students kept track of details such as shelter locations because sometimes shelters would have to move if a levee failed.

↑ The drone was a helpful tool to keep an eye on Nutwood, Illinois. (Photo courtesy of Chad Sperry.)



↑ The dashboard built by the National Guard and students aggregated and consolidated data from 10 to 15 GIS analysts working for various agencies.

Keeping that information up-to-date was crucial to making sure evacuees had somewhere to go.

"We would get requests to add something, such as weather overlays for radar, and the students would research and find the best live data to add to the dashboard," Sperry said. "There were many hands-on opportunities."

Lifelong Lessons Learned

The students gained a tremendous learning experience from these events, with immersion in the use of a wide variety of GIS tools and the need to deliver answers quickly during a crisis.

"We got a call one night, just as we were getting ready to go home for the evening, that a levee had just overtopped," Sperry said. "So everybody just set their bags down and dug back in again. We were there for a couple more hours that evening."

The flood events gave students crucial practice in the fast-paced, high-stakes world of emergency response using GIS—a common and important application of the technology.

"It was definitely the most stressful work environment I've ever had to work in," said Ian Stearns, a WIU student majoring in meteorology who helped out. "Being able to learn how to control the stress of all the things going on, all the decisions you have to make, has been really helpful for me."

When he joined the student team, Stearns had taken one GIS class and had worked at the GIS Center for three months in a paid position that gives students real-world experience.

"When we flew over the temporary levee in Nutwood to identify places it might fail, that was really fascinating," Stearns said. "The way we were able to create a detailed digital elevation model from the

↑ Rivers overflowed, flooding the Midwest, the High Plains, and the South from January through June 2019 and impacting 14 million people. (Photo courtesy of Chad Sperry.)

imagery—and Chad Sperry was able to model water height in relation to it and other buildings—was awesome. I had never even thought of that kind of application of GIS."

In between events, the students talked about GIS jobs and got to know emergency personnel. The students' real-time skills made an impression on the GIS professional working on the efforts.

"One of our grad students had two different job offers from the US Army Corps of Engineers before he even got home," Sperry said.

Although the Great Flood of 2019 set many new records—it was longer in duration and had higher floodwaters—Sperry said the damages were less than had been anticipated.

"We had eyes in the sky and the ability to predict and not just react. Instead of waking up to find that a levee broke in the night, we deployed sandbagging efforts to where GIS predicted it would break. We knew what was coming with the rainfall models and the gauge models. And so technology was really given a lot of credit for minimizing the impacts."

About the Author

Ryan Lanclos is the director of public safety solutions at Esri where he is responsible for strategic initiatives across public safety and national security. He serves as Esri's subject matter expert on GIS for emergency management and humanitarian response, and he leads Esri's Disaster Response Program (DRP), which provides 24/7 GIS support to organizations during disasters. Previously, Lanclos served as Missouri's first state geographic information officer (GIO) and GIS adviser for the governor's Homeland Security Advisory Council, and participated as an innovation team and expert group member for the United Nations on various initiatives. He most recently served as the director of state and local government at the nonprofit National Alliance for Public Safety GIS (NAPSG) Foundation.

Understanding Water Behavior

The science and engineering of water behavior are built into Arc Hydro, which consists of a data model, toolset, and workflows developed for use for extrapolating runoff amounts based on rainfall amounts (hydrology) and hydraulics (the movement of liquids).

Hydrologic modeling in GIS provides information on what is flooded or where it's flooded. This knowledge can be streamed to dashboards, be applied in models for impact assessments, and fed into routing tools that automatically dispatch and route emergency vehicles around areas that are likely inundated.

There are more than 300 tools in Arc Hydro along with workflows for integrated analysis. The webinar series, Arc Hydro in Action (https://bit.ly/3wjB1ev), shows how to use GIS to understand and proactively respond to the movement of water.

Penn State's Geodesign Students See Opportunities for Community Growth

By Cassandra Wagner

In fall 2020, students from the Penn State University geodesign program participated in a studio project that focused on revitalizing the city of Utica, New York. During the project, they used ArcGIS technology to develop and present recommendations for the city to implement after the completion of its new hospital.

Penn State University offers geodesign graduate degree and certificate programs that empower the next generation of environmental and urban design experts around the world. It is offered entirely online and designed for working professionals.

Geodesign is a process that leverages the analytical power of GIS technology for a dynamic approach to designing and planning land-based projects that are environmentally, economically, and socially sustainable. Students in the program hail from a variety of academic disciplines and levels of GIS understanding. The goal of the three-year program is to develop students into creative problem solvers who understand and can orchestrate the process of geodesign.

Each year, the program offers students the opportunity to gain hands-on experience at studios in two different settings: urban and rural. The urban design studio presents challenges and complexities that are common to revitalizing a city. In fall 2020, a blended cohort of graduate and undergraduate students collaborated over 14 weeks on a citywide revitalization project for the City of Utica, engendered by the city's plans to build a new hospital.

"We knew where the hospital location was, and we wanted to know what kind of effects *[that it would]* have throughout the community. How can we look at the broader picture and opportunities for community growth that this might bring?" said James Sipes, lecturer in geodesign, Penn State Department of Landscape Architecture.

Sipes and his colleague Dan Meehan, Penn State geodesign program manager, believe that it is vital that students not only interact with innovative technology but also think about urban design and planning differently so that they can better use it.

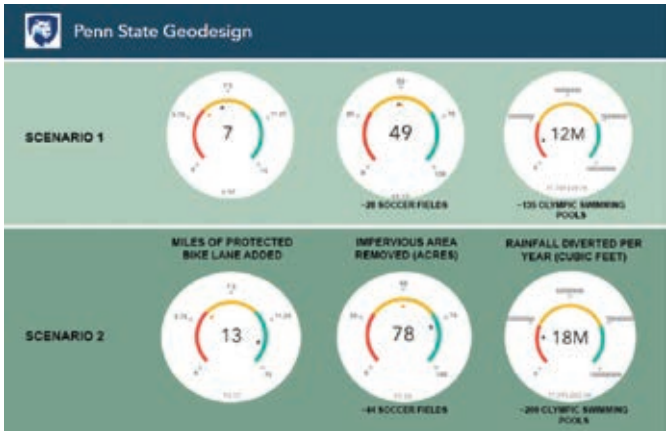
Sipes and Meehan format class projects around the International Geodesign Collaboration (IGC) framework. Using this format allowed students to study three design scenarios for the City of Utica: early adopter, late adopter, and current business-as-usual trajectory.

When these scenarios were visualized, the cumulative impact of implementing planning strategies sooner rather than later was highlighted. To frame the problems or challenges they chose to study, students were asked to estimate the impact of their strategies on the United Nations (UN) Sustainable Development Goals. By using the IGC format, students could evaluate scenarios to see whether they positively or negatively affected sustainability goals. "The key point wasn't to have students reach every goal but to see how the changes they were proposing would impact different levels of sustainability," said Meehan.

↓ The visualization on the left shows existing conditions, while the right shows modifications that would produce a safe, accessible city center that encourages walkability and bikeability. These changes would align improvements in Utica's downtown core with Utica's downtown revitalization initiative. (From an ArcGIS StoryMaps story by Sara Schwartz.)

GIS—specifically, ArcGIS Urban—helped students visualize these interconnected challenges and methods for resolving them. "ArcGIS Urban was at the core of what we were doing primarily because it's one of the few tools we know of that *[would allow]* us to put in so many different variables, assumptions, and different complexities at that scale and allow us to visualize the impacts," Sipes said. During the project, students used ArcGIS CityEngine, ArcGIS GeoPlanner, ArcGIS Online, and ArcGIS StoryMaps in addition to ArcGIS Urban.

Some students needed help learning these tools, but Esri staff provided multiple training sessions as well as tech support. Graham Mills, who is pursuing a bachelor's degree in landscape architecture at Penn



↑ Esri's tools enable the future of urban design by dynamically tying key metrics to design proposals and gauge, in real time, how design scenarios measure up. (From an ArcGIS StoryMaps story by Leslie Hendricks.)

State, said support from Esri staff helped him learn the workflows and gain the skills and expertise he needed for his career.

The first half of the project focused on where the hospital would be located—the city's U-District, an area of downtown for small businesses and entertainment. This portion of the project helped students become familiar with course concepts and tools on a small scale. The students' analysis included existing and potential business options, ideas to revitalize the historical character of downtown Utica, and opportunities to attract new residents.

"We went from this smaller-sized project to *[saying]*, 'OK, now that you have reimagined what would happen there, now apply that to an entire city.' So they had to stop and think about the things they had learned in that first project and apply it on a larger scale," Sipes said. "We wanted them to think big about how to change the entire city but think in a methodical way on how we can get there."

A central tenant of the geodesign approach is understanding key stakeholders. As a class, the geodesign students came up with five groups of stakeholders: government, residents, business owners, hospital affiliates, and developers. Acting as stakeholder group representatives, the students researched the needs and goals of each specific group.

They outlined a series of key topics including improving health and wellness with community gardens and agricultural farms, upgrading streets to be more pedestrian friendly, and working with new zoning plans and parcels. One project featured a tree-planting initiative that would focus on vacant land and parking lots to add greenery, enhance air quality, and improve wellness across the city.

"One of the things students did well was that they stopped thinking about singular issues and began to think about multiple issues and overlapping benefits or impacts," according to Sipes.

At the end of the course, students used ArcGIS Urban to present 3D visualizations and massing models of all the buildings in Utica. They were able to model zoning changes, propose transportation networks and bike lanes, and map areas for parks and gardens. Students presented their findings to geodesign experts and Utica city staff, using ArcGIS StoryMaps to deliver information in a graphical and easy-to-understand format. Student work is also viewable for further learning purposes via the Penn State studio design hub (https://bit.ly/3vj9Z6g). Through their efforts, students gained significant technical skills and a new way of understanding and applying geodesign.

"As a student who is used to small-scale, site-specific designs, moving toward a city-scale project was a huge challenge," said Sara Schwartz, who is pursuing a master's degree in landscape architecture and a geodesign certificate at Penn State. "Overall, these digital tools and their features and storytelling capabilities enhanced my work and experience."

Looking to the future, Meehan and Sipes hope the geodesign framework becomes more widely used. Geodesign empowers analysis for data-driven decision-making and inspires people to change the way they think about addressing ever-changing, complex issues in the world.

About the Author

Cassandra Wagner is a passionate storyteller who loves to leverage the written word to share the unique stories in the world. With a bachelor's degree in creative writing from the University of California, Riverside, and experience in journalism and public relations, Wagner joined Esri's content writing team in 2020, where she crafts compelling customer success stories. On a good day, she is a connoisseur of iced coffee and writing powerful stories.

↓ Analysis revealed lack of connectivity between multiple city master plans. (From an ArcGIS StoryMaps story by Leslie Hendricks.)

Textbooks and Resources for Educators

Esri Press publishes textbooks for teachers of spatial analysis, cartographic design, crime analysis, human geography, and other GIS-related subjects that are written for a variety of learning levels. Desktop copies are available for these ebook titles. The following recent Esri titles are recommended for use in the classroom:

Understanding Crime: Analyzing the Geography of Crime

By Spencer Chainey

This is the first book to fully explain how to effectively analyze the geography of crime. With comprehensive content that includes both new and old techniques, the book shows readers how to examine the spatial and temporal patterns of crime, analyze crime with other spatial data, and evaluate the impact of geographically targeted interventions. Whether readers are new to analyzing the geographic patterns of crime or are experienced analysts, they will benefit from learning the techniques presented in *Understanding Crime*. Esri Press, 2021, 304 pp., Ebook ISBN: 1589485853 and paperback ISBN: 1589485846.

The Esri Guide to GIS Analysis, Volume 2: Spatial Measurements and Statistics, Second Edition

By Andy Mitchell

This book teaches how to get better answers from map analysis using spatial measurements and statistics to get meaningful results. It provides a powerful method for analyzing geospatial data that does not require an understanding of the complex mathematical theories underpinning statistical tools. *The Esri Guide to GIS Analysis,* Volume 2*: Spatial Measurements and Statistics*, second edition, introduces readers to basic statistical concepts and some of the most common spatial statistics tasks: measuring distributions, identifying patterns and clusters, and analyzing relationships. This edition has been updated with the latest and most useful software tools and revised explanations to move from mapping to more quantitative statistical assessment. Esri Press, 2020, 288 pp., Ebook ISBN: 1589486080 and paperback ISBN: 9781589486089.

Resilient Communities across Geographies

By Sheila Lakshmi Steinberg (editor), Steven J. Steinberg (editor), Este Geraghty (foreword)

The ability to adapt to changing physical environments is essential in a world of unexpected changes. Resilience is more than an ideal—it can be achieved through intelligent planning and assessment. *Resilient Communities across Geographies* is a collection of case studies that examine the application of GIS to the analysis, planning, and creation of more resilient communities. *Resilient Communities across Geographies* helps readers develop an expanded sense of the power of spatial thinking and GIS to address the difficult social and economic problems. This book is edited by the authors of *GIS Research Methods* with a foreword by Este Geraghty, Esri chief medical officer. Esri Press, 2020, 320 pp., Ebook ISBN: 1589484819 and paperback ISBN: 9781589484818.

Introduction to Human Geography Using ArcGIS Online

By J. Chris Carter

This text combines a comprehensive examination of human geography with engaging activities using the ArcGIS Online service to explore questions such as, Why are birthrates higher in one country than another and are there patterns or correlations in these rates? *Introduction to Human Geography Using ArcGIS Online* gets students actively involved in using geography through the ArcGIS Online exercises in each chapter. Esri Press, 2019, 440 pp., Ebook ASIN: B07N8LJVMZ and paperback ISBN: 1589485181.

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Upon approval, an instructor can sample any ebook by locating it, completing a form about the course for which it will be used, and clicking the Complete Your Request button. After receiving an email from VitalSource, clicking Add to Library makes the book accessible from My Bookshelf.

The VitalSource interface for international educators may vary. Desk copies for a specific book can also be requested from an Esri distributor or by sending an email with the name of the book, the instructor's institution, and a contact email to esripress@esri.com.

Educators of K–12 students or those at nontraditional institutions, such as consultants or professional services agencies, can obtain e-desk copies by sending an email to esripress@esri.com.

ArcGIS Learning Available through Your LMS

Developing and maintaining a skilled workforce is essential for long-term success, given the rapid changes in both technology and the workplace.

While most organizations recognize the need for continual learning, every organization has a unique learning culture and workforce training needs, and many use enterprise learning management systems (LMS) for delivering professional development and training courses.

A new subscription-based product from Esri combines the convenience of a single LMS with the company's high-quality e-Learning resources created by experts in Esri technology and adult learning. Esri Academy LMS Integration makes Esri's large collection of e-Learning resources available to help organizations build workforce expertise with ArcGIS software. An LMS Integration subscription includes web courses, training seminars, and videos.

Web courses, which range in length from one to four hours, are interactive, self-paced courses that include conceptual information, activities, hands-on exercises, and quizzes. To complete course exercises, students must have their own access to Esri software.

Training seminars are one-hour recorded technical presentations and demonstrations by Esri experts and may include question and answer sessions from live seminars.

Videos show Esri experts demonstrating product capabilities and applications. They range in length from 5 to 90 minutes. A curated selection of recorded technical workshops from Esri conferences is included.

Esri Academy LMS Integration subscriptions are available at levels that support organizations of varying sizes. Subscription levels range from 50 to 100,000 users. To purchase a subscription, organizations must have an active Esri maintenance subscription, a high-speed internet connection, a Sharable Content Object Reference Model (SCORM)-compliant LMS, and an LMS administrator familiar with procedures for ingesting SCORM files into an LMS.

↑ Once the LMS administrator uploads SCORM files into the organization's LMS, learners can connect to live e-Learning resources on Esri Academy.

SCORM is a common e-Learning format supported by LMS. Esri Academy LMS Integration supports SCORM 2004, third edition, and SCORM 1.2. Ingesting SCORM files is a common workflow, and many administrators are familiar with it.

After the purchase of an LMS Integration subscription, Esri provides the organization's LMS administrator with a link to download SCORM files and metadata files for all resources. The metadata, in comma-separated value (CSV) format, includes the resource format, title, content description, and file name for each resource.

Once an administrator uploads SCORM files into the organization's LMS, learner access can be enabled so that individuals can seamlessly use Esri e-Learning resources at any time to build and reinforce ArcGIS skills. Although resources are accessed from an organization's LMS, Esri resources are hosted on Esri Academy. Learners can access live versions of all Esri Academy e-Learning resources and automatically see resource updates. New resources are regularly added to Esri Academy, and the related SCORM files are provided each quarter.

With an Esri Academy LMS Integration subscription, managers use one system to assign learning tasks and track the progress of team members. Learn more about Esri Academy LMS Integration and get started using it at go.esri.com/esri-academy-lms.

↓ Gachina Landscape Management provides a full range of landscape services to about 1,000 clients in the San Francisco Bay Area. These beds of colorful annuals at the Del Monte Shopping Center in Monterey, California, are managed by Gachina. (Photo courtesy of Gachina Landscape Management.)

Saving Water, Money, and Time with GIS

By Carla Wheeler

Before embarking on a digital transformation using ArcGIS, Gachina Landscape Management staff members used different colored pencils to draw the irrigation zones for a client's property on 8.5- by 11-inch college ruled paper. They tacked up sticky notes that described plant materials and hardware such as controllers and valves.

Gachina Landscape Management, headquartered in Menlo Park, California, provides a full range of landscape services to about 1,000 clients in the San Francisco Bay Area and Monterey Bay—large corporate campuses; homeowner associations; country clubs (excluding golf courses); school districts; and several federal, state, and local government organizations including cities and towns. The company, which employs 400 people, ranked number 55 on *Landscape Management* magazine's top 150 revenue-generating companies in 2020, with close to $40 million in revenue.

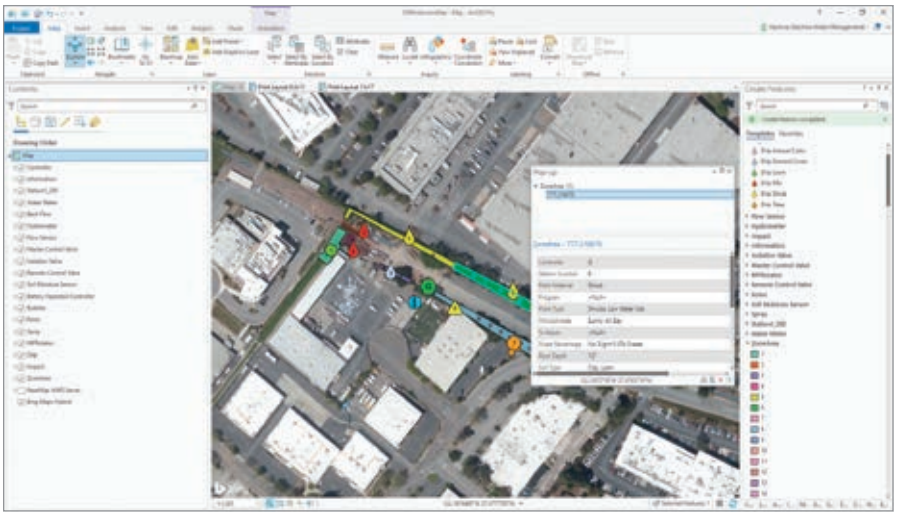
The average size of a client's landscape is about 2.5 acres, so Gachina landscapers care for approximately 2,500 acres. They install and operate irrigation systems, create drought-resistant landscapes, and provide landscape maintenance services.

Finding a Better Way

While many other landscape companies were using hand-drawn irrigation maps—and continue to do so—Chad Sutton, water resource manager for Gachina, decided change was in order. "I said, 'We are going to find a better way.' So that is exactly when the digital transformation started," said Sutton.

The year was 2014, and Sutton, an irrigation expert and lifelong landscaper who had just been hired by Gachina, happened to see maps created by the City of Fremont that used Esri software. The maps defined the areas where Gachina was contracted to spray herbicides and pesticides and delineated where spraying had already been performed. Sutton saw immediately that the same technique could be used for irrigation mapping. He thought that if the City of Fremont could do it, Gachina could probably do it too.

Today most of Gachina's irrigation maps are maintained in a GIS and can



← The Gachina project template and workflow in ArcGIS Pro. (Photo courtesy of Gachina Landscape Management.)

be accessed by irrigation technicians on their phones. Using Esri products such as ArcGIS Pro on the desktop, ArcGIS Online in the cloud, and the mobile app ArcGIS Collector (iOS), Gachina collects and edits irrigation-related data for each client's property, creating and managing a geodatabase that contains the information. It shares pertinent irrigation information through custom PDF maps or web maps for clients.

Irrigation technicians in the field use the ArcGIS Explorer mobile app on Apple iPhones to view the maps hosted in ArcGIS Online. If edits to data are needed, they can be made in the field by Sutton and other staff members using ArcGIS Collector on their iPhones, and the geodatabase will be updated in real time.

With irrigation data digitally mapped with GIS, Gachina can make well-informed irrigation system-related decisions and accomplish the following:

- Irrigate clients' properties more efficiently, saving water and money.
- Create optimal water budgets that establish the expected amount of water that a site will need in any given time period by taking into account historical weather data, the size of the property, and other factors.
- Respond in a faster, more informed manner when issues arise.
- Provide clients with irrigation maps of their properties in PDF format. Clients with Gachina's premium GIS irrigation mapping service receive access to a much more detailed web map.
- Share information with property owners, managers, and outside contractors who need to know exactly where the irrigation system equipment is located.

Managing Almost a Billion Gallons of Landscape Water per Year

Sutton, who leads GIS projects at Gachina; Salvador Gutiérrez, GIS developer in the IT Department at Gachina; and their teams manage close to one billion gallons of landscape water annually.

With the San Francisco Bay Area in extreme drought, according to the *U.S. Drought Monitor* map, water conservation is a high priority for the company. "We are really trying to *[encourage]* our clients to put in low water use, attractive, drought-resistant, and resilient landscaping," Sutton said.

To help manage irrigation water usage and get the details needed to program each irrigation controller to be water wise, in late 2014 and early 2015, Sutton and Gutiérrez began to use ArcGIS Pro 1.0 beta to start the process of creating a geodatabase schema for the data that the company collects for each zone of its clients' sites.

They customized that schema with features, layers, symbology, and attribute values. Some attributes in the geodatabase included plant types, root depth, and water use requirements based on those plant types; site characteristics such as microclimate; slope percentage; soil type; sun and shade exposure; and information on the irrigation system such as types of sprinklers or drip irrigation systems, the irrigation pipe manufacturer, and valves. More detailed information can be added in the notes field, such as the names of the plants

↓ Landscaped slopes at an award-winning homeowner association in Hayward, California. (Photo courtesy of Gachina Landscape Management.)

→ The standard PDF map layout that Gachina provides to its clients. (Photo courtesy of Gachina Landscape Management.)

or flowers in each zone. Gachina does not map the location of individual sprinklers unless a premium service client requests it.

The information in the geodatabase, created in ArcGIS Pro, is published as layers that are hosted in ArcGIS Online, where Gachina staff can call up a client's irrigation map, click on a zone, and view a pop-up containing pertinent information associated with each zone. That information helps staff determine the amount of water each zone in the site receives.

Landscaping today is a science. Overwatering is a big issue in the world of landscaping, according to Sutton, which is why adding information, such as root depth, in the geodatabase is critical.

"We were not getting anywhere near the level of detail and specificity that we needed in a consistent manner with those hand-drawn maps," Sutton said. "This GIS geodatabase is where we defined all the questions that needed to be answered to program a controller properly."

"We don't want to water deeper than the roots grow. We don't want to force water 24 inches down if there are no roots down there to suck up the water," Sutton said. "Overwatering is a silent killer of plant material and also budgets. We show our clients that not only are we going to save them water and save them money, but their plant material is going to look better and live longer."

If new drought-tolerant plants are added to a landscape, for example, that information will be collected in the field using ArcGIS Collector and automatically updated in ArcGIS Online. That new information will be factored into adjusting the irrigation scheduling.

"We need to build on that GIS database to help us understand how to program the irrigation controller properly for that zone," Sutton said. "We can edit that in the future quickly and easily as things change. That efficiency gain is what's going to make us

→ Detailed information, such as names of the plants or flowers in each zone, can be added in the notes field in the geodatabase. (Photo courtesy of Gachina Landscape Management.)

← Gachina encourages its clients to put in attractive, drought-resistant landscaping such as these succulent beds at Del Monte Shopping Center in Monterey, California. (Photo courtesy of Gachina Landscape Management.)

better water managers and help us conserve more water and help our clients save more money and make the *[property]* look better." He estimates that using GIS for irrigation mapping and providing those maps to clients leads to significant savings in both water and money.

Sutton also utilizes the information in the geodatabase—along with maps created in ArcGIS Pro that bring in US Geological Survey (USGS) soil maps and the satellite imagery in Microsoft's Bing Maps—to help create water budgets for each client's site. Gutiérrez also uses high-resolution aerial imagery from Nearmap, an Esri partner.

"We need to have super high-quality, very detailed basemap satellite images to work off of—that's been really important to us," said Sutton. "We *[don't need the]* big 50,000-foot view. We're down in the dirt, you know?"

Sutton takes topography, plant material, soil type, and other factors into account when devising a water budget formula. "I am kind of using the database as a way to help me quickly get to a water budget for the site," Sutton said.

The Value of Communication

The maps also are a great resource for knowing what types of hardware are installed in each zone on a client's site, which is critical when repairs need to be made by field crews. Having irrigation assets digitally mapped lets Gachina staff and clients share information more easily via Gachina's GIS mapping service.

With Gachina's premium mapping service, assets such as spray and rotor sprinklers, drip systems, controllers, isolation valves, and water meters are mapped. This is valuable information when construction work needs to be done, or a water leak occurs, or when landscaping isn't receiving adequate water.

The ArcGIS Explorer app also helps crew members locate assets. It gives them a standard knowledge base when they are out in the field, which can save valuable time. Turnover can be high in the landscaping business: people transfer within Gachina, find new jobs and leave, or retire. Now crew members can call irrigation maps up on their iPhones so that even employees new to the job instantly get a good picture of where everything is located.

"They need to be able to hit the ground running as fast as possible," Sutton said. "They need to learn that site as quickly as possible and not take the three to five years it took for that last person without a map to figure it all out themselves."

"Giving our whole team the ability to carry more than 1,000 irrigation maps on a mobile app on a phone that's in their pocket is incredible," said Gutiérrez.

Providing GIS Maps to Clients

The maps that Gachina provides to clients are created using ArcGIS Pro. The PDF fulfills most clients' needs, according to Sutton. "They just think it's beautiful and amazing and light-years beyond what they used to get," he said.

Other customers—including some school districts and some high-tech corporate campuses—want a more detailed map, which Gachina provides through its premium mapping services. Those web maps, which are made using ArcGIS Pro and hosted in ArcGIS Online, can be highly detailed so these clients can use them when doing financial budgeting and construction planning, according to Sutton. These clients realize the tremendous value in having that level of documentation on the map.

Gachina has also used AEC Project Delivery, a subscription service from Esri

> "Giving our whole team the ability to carry more than 1,000 irrigation maps on a mobile app on a phone that's in their pocket is incredible."
>
> Salvador Gutiérrez
> GIS Developer at Gachina

↑ Plantings like this stunning spring color bed at a San Francisco hotel get just the right amount of water based on plant, location, and irrigation system characteristics maintained in Gachina's geodatabase. (Photo courtesy of Gachina Landscape Management.)

that gives the landscaping firm the ability to share its internal GIS content and other information with clients and other stakeholders outside its organization.

Sutton said that using AEC Project Delivery has been important for sharing GIS maps and other information with clients and their contractors who are having excavation work done such as the installation of fiber-optic cable. Seeing where the irrigation assets are located on a digital map helps prevent costly damage.

A Vision Fulfilled

Gutiérrez is proud to be part of such a groundbreaking green project at Gachina and is amazed at what has been accomplished in a relatively short amount of time. He said he came on board at Gachina in late 2014 as a gardener but had an information technology degree and was quickly recruited by Sutton for an IT position.

"A couple of weeks later, Chad *[Sutton]* and I were walking together at a property while he was explaining to me his vision and how cool it would be to carry irrigation maps on phones and give the irrigation technicians the ability to create and edit those maps through their phones," Gutiérrez said. "He also talked about how cool it would be to help our team and also make some profit by eventually selling that project as a service. I thought, 'How in the world are we going to do such a thing?' But I guess the rest is history—because we did it!"

ArcGIS played a major role in the project's success, according to Gutiérrez. "We were able to plant the seed and then let this project grow organically within Gachina Landscape Management," he said. "Small steps led us to big accomplishments, and with feedback from our irrigation technicians, we were able to advance the process. What had been carried out manually could now move into the digital world, which is saving paper; money; and, most importantly, time."

About the Author

Carla Wheeler is a technology writer and editor at Esri and a former journalist. She graduated from the University of Minnesota with a bachelor's degree in journalism and political science. She currently edits *ArcWatch* and works with Esri Story Maps apps. Follow her on Twitter @gisjourno.

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