

ArcUser

The Magazine for Esri Software Users

**Conserving a Network of
Climate-Resilient Lands 26**

A Growing Hunger 22

**Helping Safeguard Threatened
Raptors Worldwide 66**



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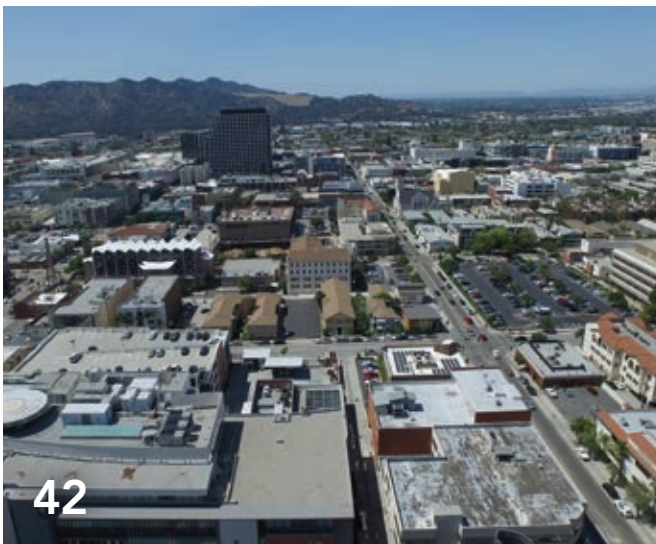
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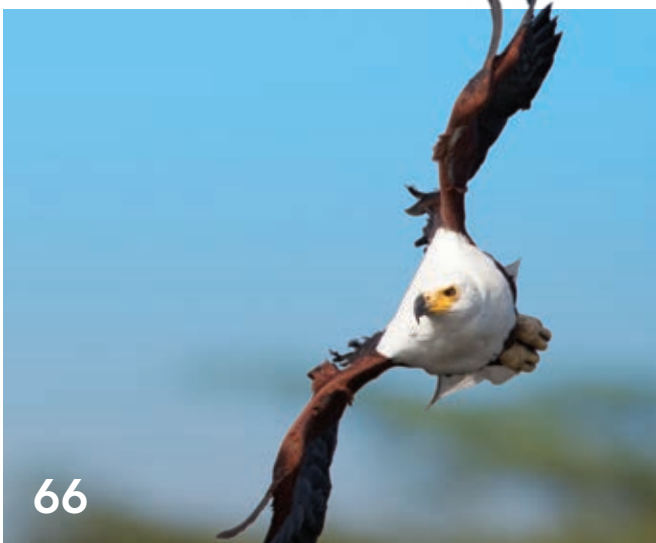
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On the Cover

The Resilient and Connected Network, a GIS mapping tool developed by The Nature Conservancy (TNC), gives conservationists a way to save biodiversity for the future. As the climate warms, species are moving to find more hospitable places to live. This map shows the movement of mammals in pink, birds in blue, and amphibians in yellow. (© Dan Majka and Nicholas Rapp/TNC)

Proving Tobler's Law

In the last year, the world has run up against a hard truth that geographers have known all along—the world is a very interconnected place. As Waldo Tobler's First Law of Geography states: "Everything is related to everything else. But near things are more related than distant things." This has been demonstrated vividly as disruptions, decisions, and events in one location have caused repercussions that are perhaps most acutely felt locally but are often palpable regionally and sometimes internationally. The effects of individual decisions can extend far beyond our immediate circle and can ripple across our communities and nation.

GIS is a particularly adept tool for letting us visualize and measure just how much our fates are tied to each other and the natural world. Researchers for The Nature Conservancy developed a GIS tool for examining biodiversity, the movement of species, and the health of landscapes. They found that areas resilient to climate change formed an interconnected web. This finding is leading to a shift in the paradigm of large landscape conservation.

Similarly, mobile GIS apps supported on the cloud are tracking raptor populations. These birds are valuable indicators of environmental health that warn when vital earth support systems are threatened. The African Raptor Databank (ARDB) was developed to track the well-being of eagles, hawks, vultures, and other birds of prey.

GIS lets us also see where change is needed by identifying threats to societal well-being. The pandemic and accompanying social unrest of the last year has highlighted threats to basic needs such as food and shelter and obstacles that limit opportunities for education and employment. Through viewing these challenges in all their complexity using GIS, we can better understand how to work together to improve these situations, whether it is delivering food to neighbors more efficiently or providing more equitable access to broadband internet to make sure students don't fall behind in their schoolwork.



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ArcUser Editor

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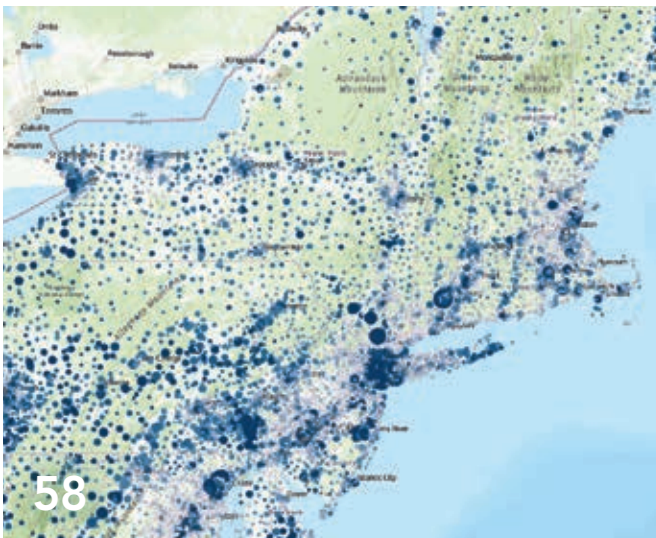
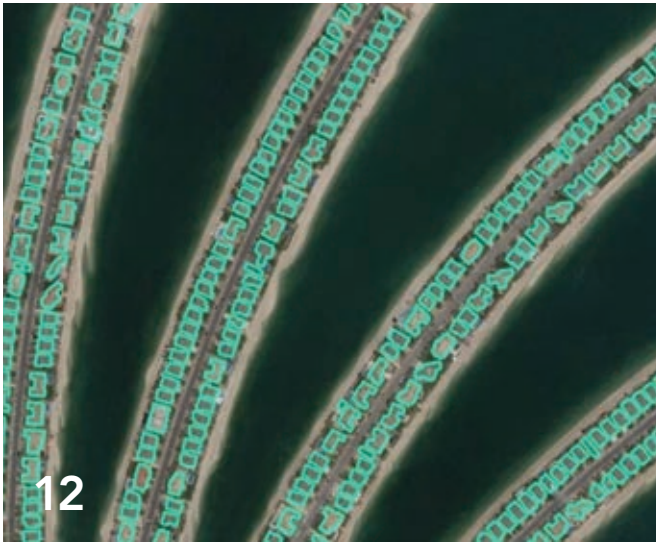
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Briefly Noted

→ Esri Acquisition Will Enhance 3D Visualization Capabilities

Esri acquired Zibumi Yazılım Biliim Tasarım Arge Sanayi Ticaret S.A. (Zibumi), a software development company headquartered in Turkey and known as a developer of innovative visualization, analysis, and simulation capabilities for leveraging game engines. Zibumi will help advance 3D visualization and simulation in Esri software and expand the ongoing integration of game engine technologies into ArcGIS. Esri also announced the creation of the Ankara R&D Center.

→ New American Community Survey Data in ArcGIS Living Atlas of the World

ArcGIS software users have easy access to the newest values for five-year estimates of current data on demographic, housing, and workforce characteristics of the US population. Through ArcGIS Living Atlas of the World, users have access to 1,700 annually updated attributes of American Community Survey (ACS) tables from the US Census Bureau.

→ Tool Will Provide Data to Help Improve Ocean Quality

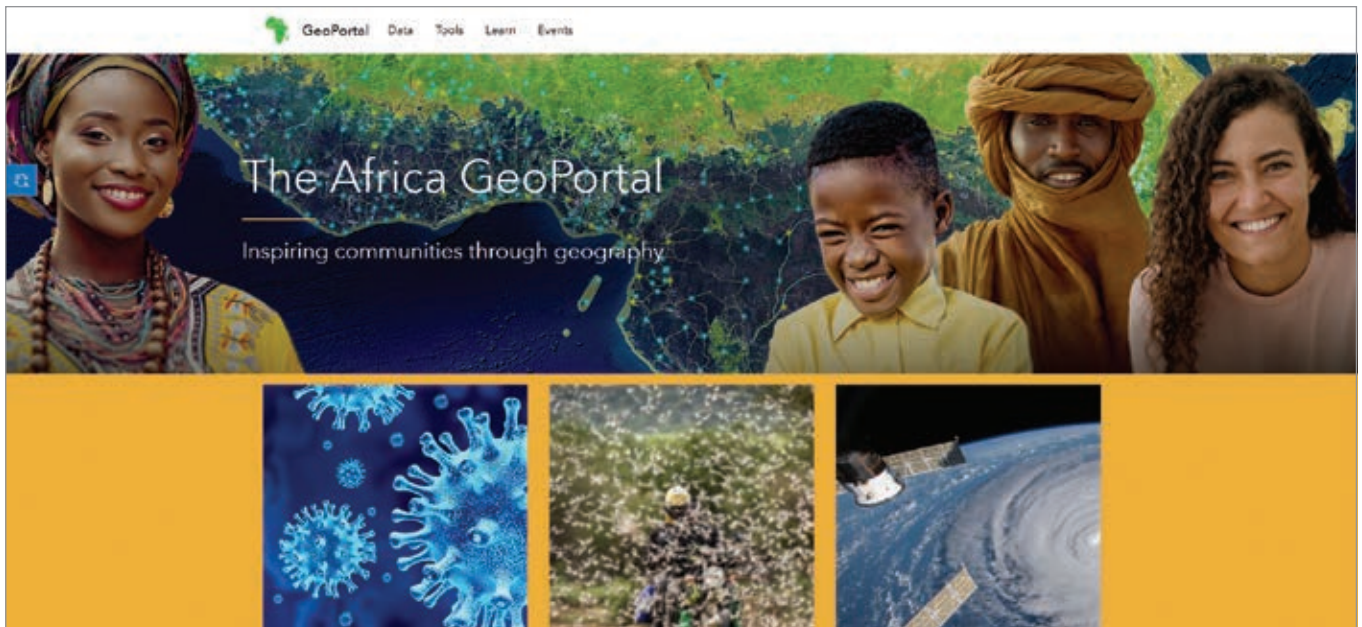
A team composed of staff from Esri, the United Nations Environment Programme, and GEO Blue Planet released the Water Health Tool, a new free tool that uses real-time analysis enabling countries to monitor coastal water quality and gather information to guide policy and reduce pollution from land sources. This new statistical approach uses satellite data and geospatial technology supports one of the United Nations Sustainable Development Goals (SDG) to prevent and significantly reduce marine pollution of all kinds by 2025. The team was recognized with the SDG Award for the Special Category, Collaboration for developing this tool.

→ Esri Recognized for Its Work in Mapping COVID-19

Inc. magazine's inaugural Best in Business list has awarded Esri the gold medal in the Government Services category. These awards were created to honor companies that have gone above and beyond to make a positive difference, tackling today's problems to lead to a better future. "This year, more than ever, our mission of helping our customers make an impact through the use of GIS is critical," said Jack Dangermond, Esri founder and president.



↑ The Water Health Tool uses real-time analysis and enables countries to monitor coastal water quality.



→ Pan-African Nonprofit and Esri Encourage Geospatial Technology Use

Esri and AfroChampions, a Pan-African nonprofit that promotes policies that foster private-public collaboration for Africa's economic transformation. This new partnership with AfroChampions will contribute to sustainable economic development in Africa and promote the benefits of a shared geospatial infrastructure throughout the continent. GIS technology will be used to create new opportunities for growth, especially in critical fields such as health and telemedicine, land management, agriculture, and mobility. Africa GeoPortal, the continent's existing geospatial community platform built by Esri, will support the AfroChampions' virtual festival Boma of Africa as well as other ongoing community outreach activities. To learn more, visit esri.com/en-us/about/about-esri/mea.

→ AAG Diversity and Inclusion Awards Announced

The American Association of Geographers honored Raynah Kamau, Whitney Kotlewski, and Dr. Jovan Lewis with its 2021 AAG Diversity and Inclusion Awards. Kamau and Kotlewski created Black Girls M.A.P.P. and the People for the People (P4TP) initiative. Both are employees at Esri and grassroots activists whose collaborative work has increased visibility for community-engaged geography and promoted greater inclusion within GIS professional culture. Lewis is an economic geographer at the University of California, Berkeley.



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ArcGIS Pro 2.7 Enhances Data Capture, Use, Analysis, and Management

ArcGIS Pro 2.7 introduces a new data type and new type of geodatabase as well as more extensive analysis tools and capabilities for integrating workflows across ArcGIS applications from field to enterprise to the cloud. New with ArcGIS Pro 2.7 is support for Global Navigation Satellite System (GNSS) device location, mobile geodatabases, layer and feature blending, Movement Analysis tools, linear reference editing, and 3D object

feature layers. This release also provides additional Spatial Statistics tools and an expanded and enhanced SDK.

GNSS Device Location Support

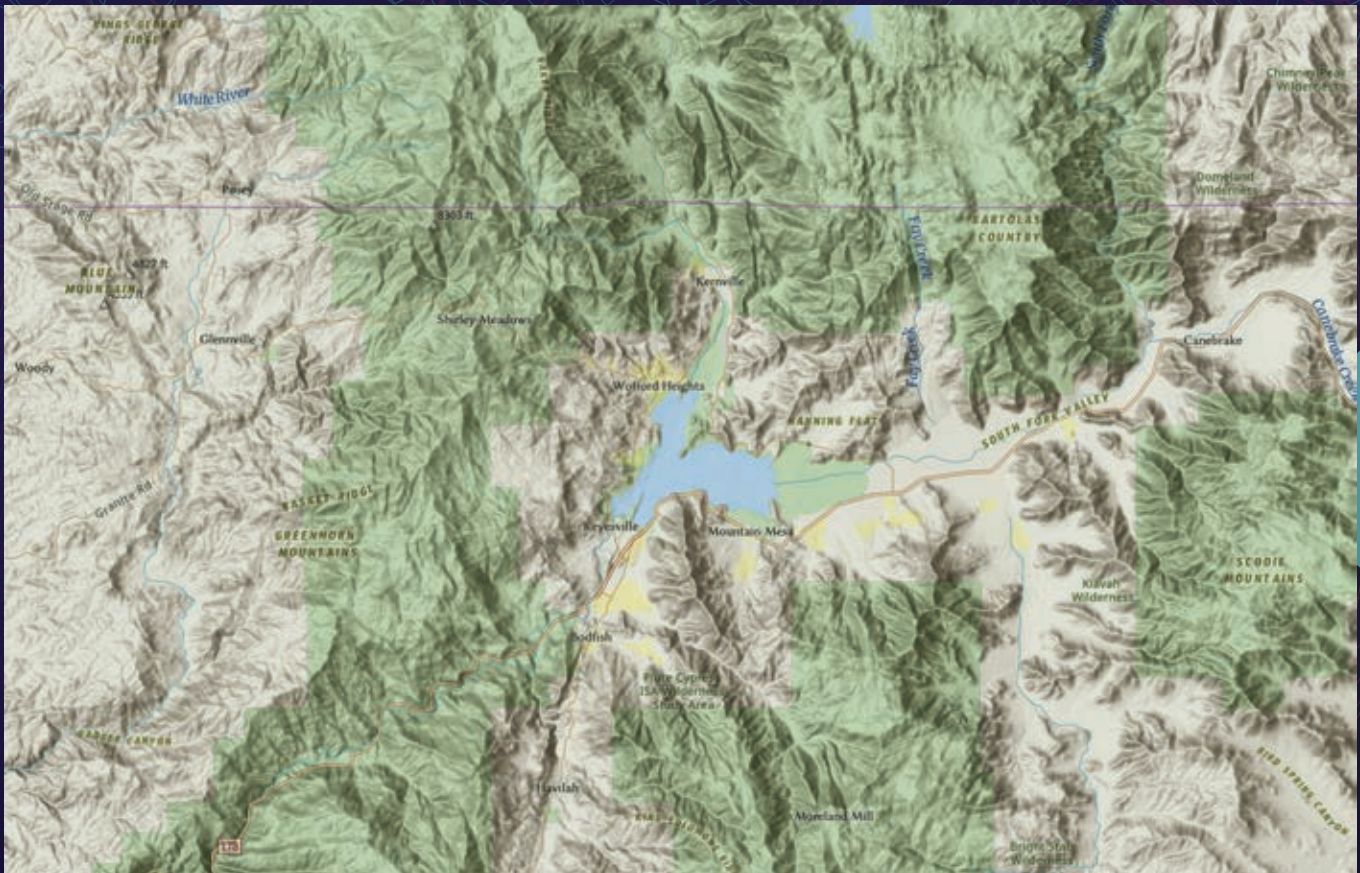
ArcGIS Pro supports the collection of high-accuracy data in the field using any GNSS device. When connected to a GNSS device, ArcGIS Pro will show the location of the device on a map or in a scene. As the device travels, its location automatically updates in the view. A point feature class can be set up that will automatically log

data from the device as its position is updated. Features can be created based on the current geographic location of a GNSS device. Detailed information about a device's position can be recorded to a log file.

Mobile Geodatabases

ArcGIS Pro 2.7 introduces a new type of geodatabase, the mobile geodatabase. As with other geodatabases, a mobile geodatabase can store geographic datasets, perform data modeling tasks, and be used as inputs to geoprocessing tools and

↓ Layer blending can now be used in ArcGIS Pro as an alternative to transparency when combining layers or features.



scripts. A mobile geodatabase is stored in an SQLite database, which is a widely available, stable, and trusted database. As a full-featured relational database, it allows querying and reporting workflows through SQL. It is open source and in the public domain, so no licensing is required and it has cross-platform support. SQLite databases are stored in a single file on disk, making them portable. They provide an efficient data exchange format.

The mobile geodatabase is the foundation for fully interoperable workflows between ArcGIS Pro and ArcGIS Runtime that will enhance workflows between ArcGIS Runtime applications and the Esri suite of mobile apps.

Layer and Feature Blending

Layer blending, which has been available in the ArcGIS API for JavaScript and the ArcGIS Online Map Viewer beta, can now be used in ArcGIS Pro as an alternative to transparency when combining layers or features. Use blending to brighten or darken a layer to bring attention to the highs or lows of map color ranges. When a blending mode is applied to a layer, the layers below it in the map's drawing order are visually altered. Most blending modes are applied to each color channel independently. For further control, blending modes can be applied to features within a single feature layer. In this case, symbolized features are blended with each other within the layer. Blending modes enhance the visualization of features and can change how maps are designed for publication.

Movement Analysis Tools

Movement Analysis tools use point track data to analyze and visualize the movement of objects in space and time. Point track data consists of time-sequenced

→ 3D objects can display characteristics such as reflection, shadowing, and roughness, adding detail and realism to ArcGIS Pro scenes.

point locations grouped by unique devices, such as GPS or other mobile devices. The Movement Analysis toolset contains tools that analyze point track data, allowing the comparison of tracks over different areas, the extraction of unique identifiers from a point track dataset, and the identification of the locations where tracks meet. The movement tools are Find Cotravelers; Find Meeting Locations; Compare Areas; and Classify Movement Events, the newest tool.

Classify Movement Events attributes point track data with turn information (including U-turns), stops, and information about acceleration and deceleration. This simplifies the time-consuming process of reviewing track points to figure out how an entity was moving at a location. This is useful for analysts working with shipping telemetry, monitoring feeds from traffic, or reviewing GPS device metrics.

Linear Reference Editing

New linear referencing editing capabilities are now part of the core ArcGIS Pro application and are designed for users who have basic linear referencing needs such as maintaining measures on features and linear referencing routes. Used by linear referencing systems (LRS), routes model linear distances and related events. Routes are created as m-aware polyline centerline features with measure values (m-values) at each vertex that are stored independently of the line geometry. With ArcGIS Pro 2.7, users can create a route from selected line features; calibrate a selected route using two or more specified calibration points; and define a portion of a linear route by tracing and clicking two points along the route.

Note that these new tools are intended for use only when a single LRS is required. The Roads and Highways and Pipeline



↑ The new linear referencing editing capabilities are part of the core ArcGIS Pro application.

Referencing extensions, available with ArcGIS Pro, support a more comprehensive solution for linear referencing system workflows and provide an advanced set of linear referencing editing and management tools in addition to the new capabilities available in core ArcGIS Pro.

3D Object Feature Class Layers

The 3D object feature class is a new data type that has evolved from the multipatch feature class. Objects in this class are stored in file, enterprise, or mobile geodatabases. Like multipatches, 3D objects combine geometry and textures for models of features that occupy 3D space and have additional properties. 3D object features can display characteristics such as reflection, shadowing, and roughness, adding detail and realism to ArcGIS Pro scenes.

The same editing and analysis tools that work on multipatches can be used on a 3D object feature layer in a scene in ArcGIS Pro. Geoprocessing tools are available to convert multipatch feature classes to and from 3D object feature classes. File

geodatabase 3D object features can be opened and edited in third-party modeling applications such as Maya and Blender.

Spatial Statistics

The release of ArcGIS Pro 2.7 includes many improvements to the Spatial Statistics tools, that range from out-of-the-box data engineering tools to sophisticated statistical methods for analysis. Data engineering is an integral part of an analysis, and it is often the most time-consuming. The new Dimension Reduction, Transform Field, Standardize Field, Encode Field, and Reclassify Field tools aid in more quickly preparing data for subsequent analysis.

The new tools in the Spatial Statistics toolbox, which include the Spatial Outlier Detection, Spatial Association Between Zones, and Neighborhood Summary Statistics tools, can give you a better understanding of your data. Three new parameters for detecting and identifying outliers at each location—Curve Fit Forecast, Exponential Smoothing Forecast, and Forest-based Forecast—are

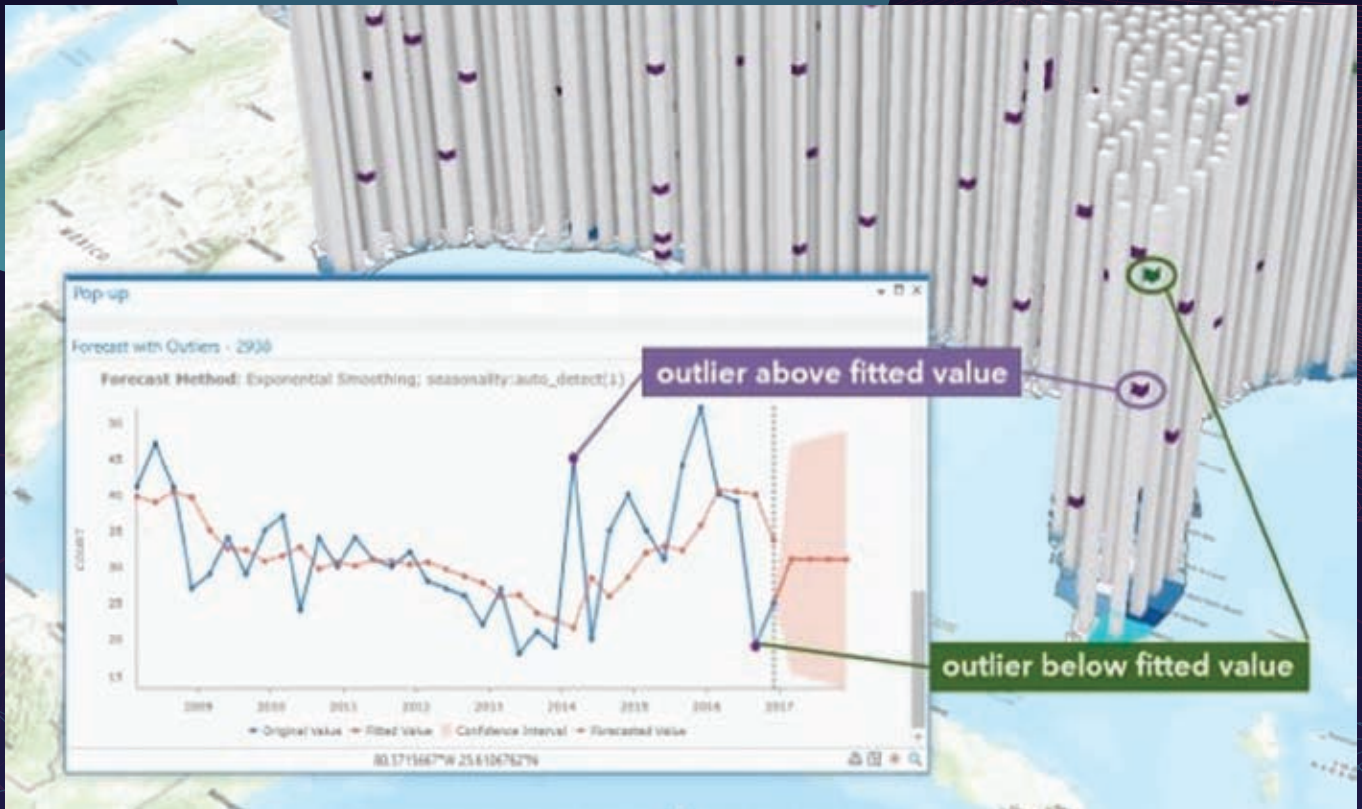
introduced with the new Space Time Pattern Mining tools. The Visualize Space Time Cube in 3D and Visualize Space Time Cube in 2D tools help explore the time series outliers of a space-time cube.

ArcGIS Pro SDK for the Microsoft .NET Framework

This is an extensive and important release of the ArcGIS Pro SDK that complements new capabilities in the core product. It includes new APIs for Device Location, Parcel Fabric, and Voxel Layers. Existing APIs for Geodatabase, Layouts, and Reports APIs were also improved.

New Start Page

The new start page features a Resources section that provides centralized access to information about ArcGIS Pro and helps users migrating from ArcMap to ArcGIS Pro. Links tutorials, web courses, and documentation about ArcGIS Pro will build essential skills and helps users keep up with new developments in the software.



↑ Time Series Outlier Visualization in 3D with above fitted values show in purple and below fitted values shown in green.

Pantone Colors

ArcGIS Pro includes eight styles of the Pantone® spot color books that will ensure the consistent appearance of output in printing workflows. These colors are part of a proprietary and widely used system for standardized color reproduction. They are organized into books categorized by type and output medium.

In ArcGIS Pro 2.7, each of these books is presented as a separate system style of predefined and named colors. Pantone colors are denoted by a white corner on the color chip. Although these styles are read-only, they can be copied to a Favorites style and modified to limit the number of colors to just the ones needed for specific projects.

ArcGIS Workflow Manager

ArcGIS Pro 2.7 is the first release of ArcGIS Workflow Manager's new service-driven architecture in ArcGIS Pro. This release primarily improves the productivity of organizations and industries that perform mapping functions using the Utility Network,

Roads and Highways, and ArcGIS Parcel Fabric. ArcGIS Pro 2.7 can connect to the new service-driven architecture to run steps. With traditional geodatabase-driven architecture deployment, ArcGIS Pro has achieved feature parity with ArcMap.

ArcGIS Data Reviewer

The ArcGIS Pro 2.7 release includes new methods for automated validation, and enhancements to error management tools. Automated validation methods evaluate a feature's quality without human intervention, saving time and resources while ensuring data is accurate and trustworthy.

ArcGIS Pro 2.7 includes many more improvements including enhancements and new capabilities in the areas of application sharing, mapping and visualization, labeling and annotation, editing, analysis, data management, and the use of multidimensional and lidar data. More than 50 changes were made in response to user requests.

For a complete description of changes in this release, see "What's New in ArcGIS Pro" at <https://bit.ly/3hO8xDC>

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Ready-to-Use Geospatial Deep Learning Models

By Vinay Viswambharan and Rohit Singh

With the fire hose of imagery that's streaming daily from a variety of sensors, the need for using artificial intelligence (AI) to automate feature extraction is only increasing.

The ability to train more than a dozen deep learning models on geospatial datasets and derive information products has been available using the ArcGIS API for Python or ArcGIS Pro, and users can scale up processing using ArcGIS Image Server.

Esri is taking AI to the next level with ready-to-use geospatial AI models in the ArcGIS Living Atlas of the World (<https://bit.ly/2VGRh9m>). Initially, three models have been made available. Two of the models use satellite imagery. One model extracts building footprints and the other performs land-cover classification. A third model classifies points representing trees in point cloud datasets.

These newly released models have been pretrained by Esri on huge volumes of data and can be readily used—with no training required—to automate the tedious task of digitizing and extracting geographic features from satellite imagery and point cloud datasets. Not only do these models bring the power of AI and deep learning to the Esri user community, but they are also accessible to anyone with an ArcGIS Online subscription at no additional cost.

Using the Models

Using these models is simple. You can use geoprocessing tools, such as the Detect Objects Using Deep Learning tool in ArcGIS

Pro, with the imagery models. Just point the tool to the imagery and the downloaded model. That's it. Deep learning has never been this easy. Though it's not necessary, a graphics processing unit (GPU) can help speed things up. With ArcGIS Enterprise, you can scale up inferencing using ArcGIS Image Server.

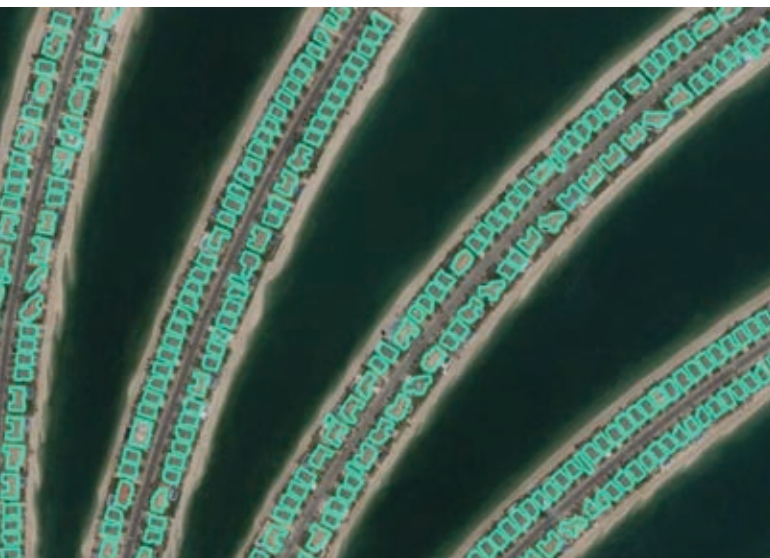
In the future, you'll be able to consume the model directly with ArcGIS Online Imagery and run it against your own uploaded imagery without an ArcGIS Enterprise deployment. The 3D Basemaps solution is also being enhanced to use the tree point classification model and create realistic 3D tree models from raw point clouds.

How to Benefit from Deep Learning Models

It probably goes without saying that manually extracting features from imagery—like digitizing footprints or generating land cover maps—is time-consuming. Deep learning automates this process and significantly minimizes the manual interaction needed. However, training your own deep learning model can be complicated. It requires a lot of data and extensive computing resources as well as the knowledge of how deep learning works.

With ready-to-use models, you no longer have to invest time and energy either manually extracting features or training your own deep learning models. These ready-to-use models have been trained on data from a variety of geographies and work well. As you receive new imagery, you can extract features at the click of a button and produce GIS layers for mapping, visualization, and analysis.

↓ Building footprints extracted from imagery of Palm Islands, Dubai.



Ready-to-Use Models

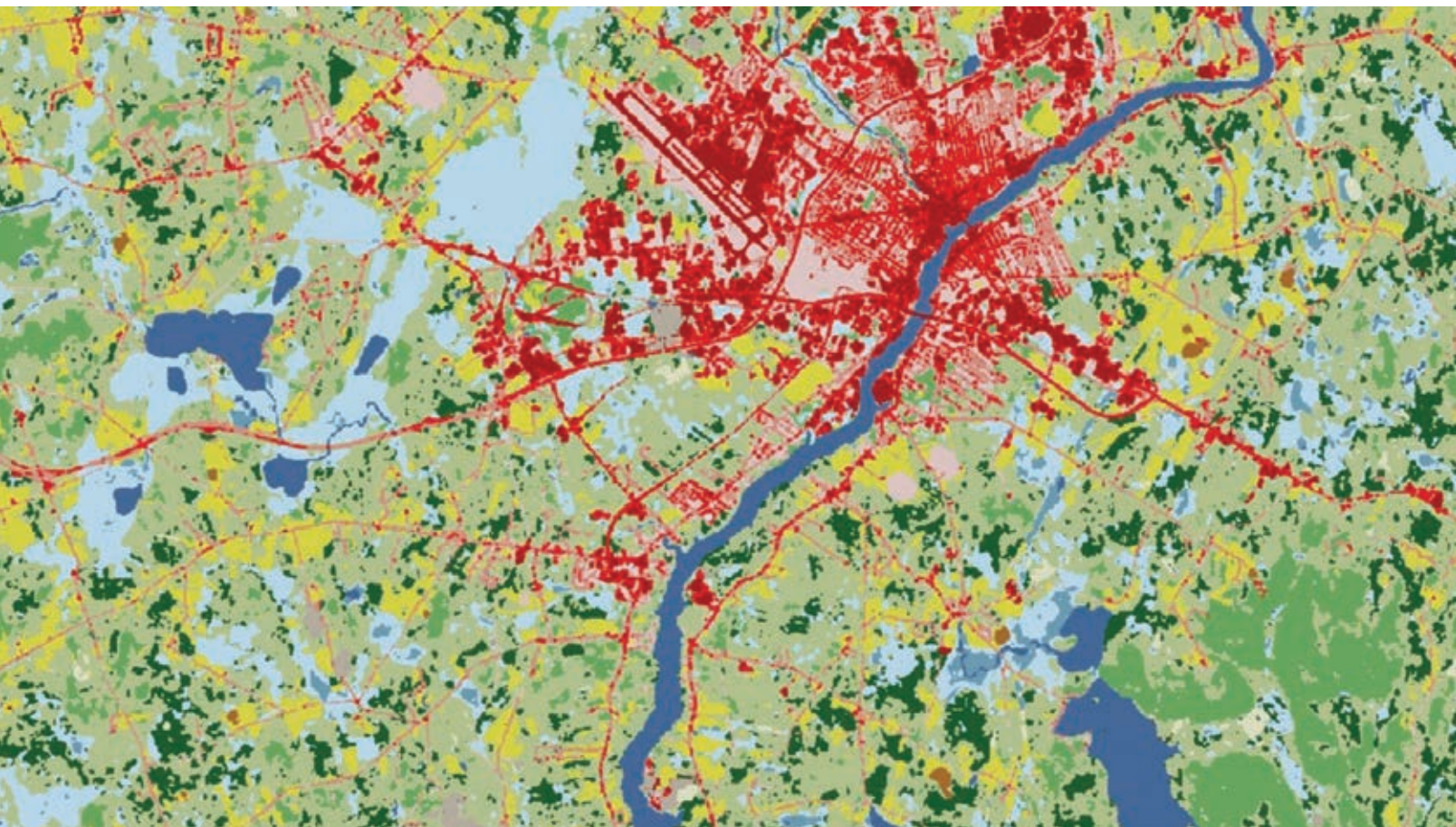
The three deep learning models available from ArcGIS Online as deep learning packages (DLPKs) can be used with ArcGIS Pro, ArcGIS Image Server, and ArcGIS API for Python.

The Building Footprint Extraction—USA model is used to extract building footprints from high-resolution satellite imagery. While it is designed for the contiguous United States, it performs fairly well in other parts of the globe. Building footprint layers are useful for creating basemaps. They are also used in analysis workflows for urban planning and development, insurance, taxation, change detection, and infrastructure planning. Learn more about the Building Footprint Extraction—USA model from this story map at <https://arcg.is/1GXrvu>.

The Land Cover Classification (Landsat 8) model uses Landsat 8 imagery to create land-cover products that have the same classes as the National Land Cover Database (NLCD). The resultant land-cover maps are useful for urban planning, resource management, change detection, and agriculture.

This generic model has been trained on NLCD 2016 with the





↑ The Landcover Classification (Landsat 8) model has been trained on NLCD 2016 with the same Landsat 8 scenes that were used to produce the database.

same Landsat 8 scenes that were used to produce the database. Because land-cover classification is complex, it is hard to capture using traditional means. Deep learning models can learn these complex semantics and give superior results.

The Tree Point Classification model can be used to classify points representing trees in point cloud datasets. Classifying tree points is useful for creating high-quality 3D basemaps, urban plans, and forestry workflows.

Try These Models for Yourself

The deep learning tools in ArcGIS have dependencies that require downloading and installing Python site packages. Get the installer to add these packages from the Esri GitHub repo at <https://bit.ly/2LluzvR>. Download the DLPKs from the ArcGIS Living Atlas of the World. Learn more about using these models from the Imagery and Remote Sensing community page on GeoNet (<https://bit.ly/3oxnv36>).

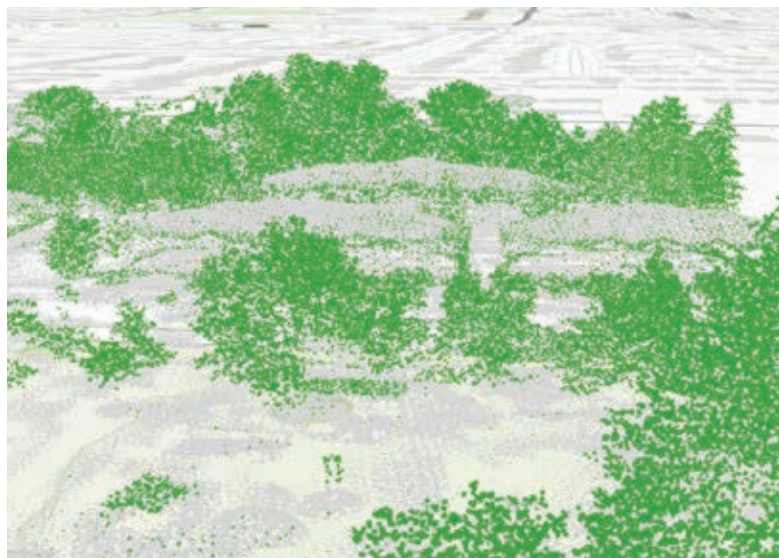
About the Authors

Vinay Viswambharan is a product manager on the Imagery team at Esri. He is passionately interested in remote sensing and imagery.

Rohit Singh is the managing director of the Esri R&D Center in New Delhi and leads the development of data science, deep learning,

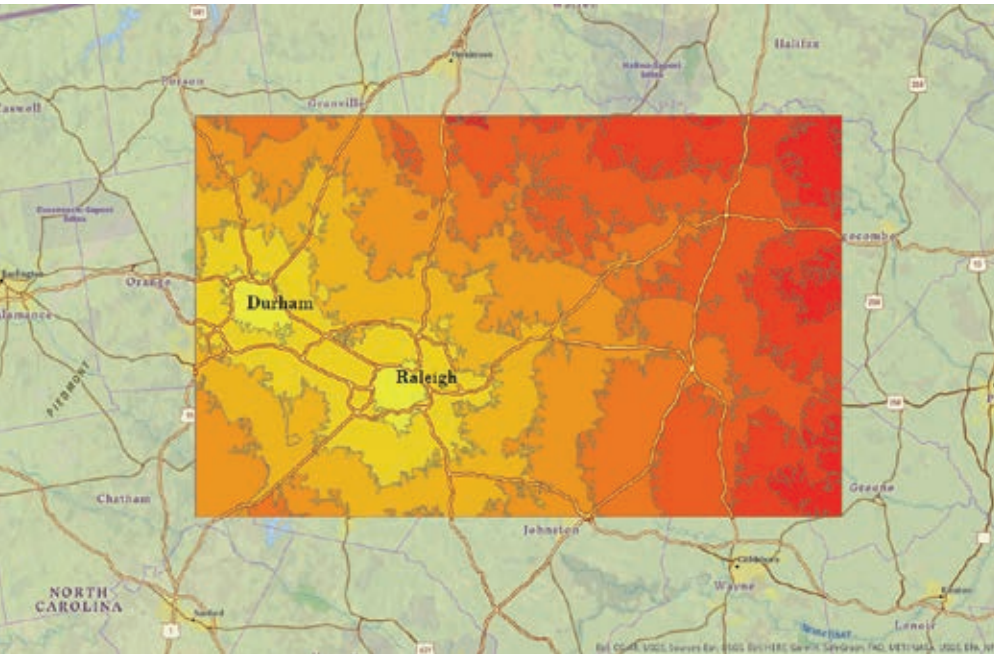
and geospatial AI solutions in ArcGIS. He is passionate about deep learning, its intersection with geospatial data and satellite imagery, and the application of deep learning to the Science of Where.

↓ 3D scene created by employing Tree Point Classification model.



A Happy Collaboration between ArcGIS Pro and R

By Witold Fraczek, Jian Lange, and Carsten Lange



← This map shows the location and relative size of the study area in North Carolina and includes one of the explanatory variables: the driving time between the cities of Durham and Raleigh. Driving time was classified into 10-minute intervals beginning with bright yellow, indicating less than 10 minutes and progressing to 90 minutes. Thick yellow lines indicate freeways.

looking for opportunities to invest in real estate and commercial infrastructure can use the model to locate suitable areas.

The availability of large datasets, advanced spatial analysis, and machine learning tools allow data analysts to combine technologies to take predictive analytics to the next level. Existing research about predicting urban development often requires working with more than one type of software. The exchange of large datasets between different software applications complicates the data infrastructure and data exchange between collaborators.

The project was initiated by Fraczek. He selected and preprocessed raster data from the National Land Cover Database (NLCD) for 2001 and 2016. The data was processed with ArcGIS Pro and stored in a geodatabase.

ArcGIS Pro and various R packages were used in creating the predictive analysis model, which assessed the effects of factors such as terrain characteristics; projected population growth; and proximity to roads, urban centers, an environmental areas that are protected.

In the early stages of the project, data

A good urban growth prediction model empowers city planners to make informed urban policy decisions and assists investors in making profitable choices. Although the resultant monetary and social benefits can be large, it is difficult to quantify them.

The authors—Witold Fraczek, Jian Lange, and Carsten Lange—worked together on a project to develop a workflow and build a machine learning model for identifying locations with a higher probability of urban development.

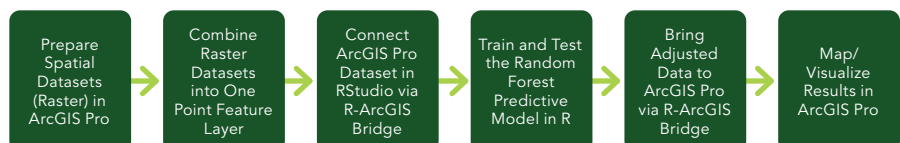
Fraczek and Jian Lange are trained GIS professionals who work for Esri, use ArcGIS products daily, and are proficient with geospatial technology. Both prefer to work with ArcGIS Pro. Carsten Lange is a professor of economics who specializes in data science and machine learning. He uses the R programming language for statistical computing with RStudio to solve data science problems.

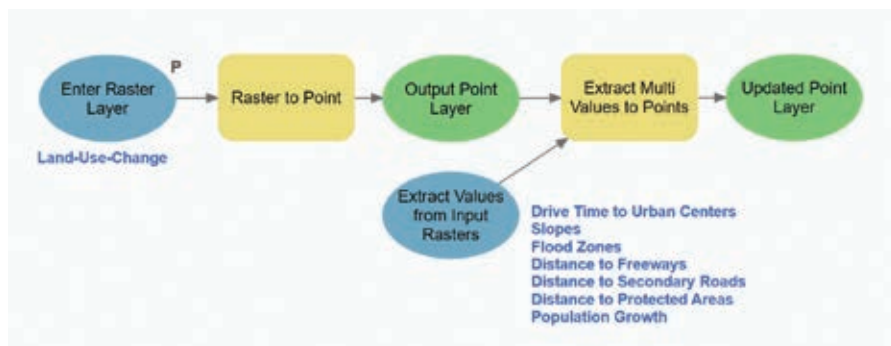
Which areas would be most suitable for urbanization?

How probable is urban development in a specific area?

Answers to these questions can benefit government agencies, such as planning departments, that need a deeper understanding of urban growth to make better policies. Using predictions from the model, areas not currently zoned for development but likely to be urbanized might be good candidates for development, although other factors, such as environmental impacts, must be considered. Private investors

↓ Project workflow





← ModelBuilder model for creating the point feature class containing response and explanatory variables

The original NLCD dataset has a resolution of 30 meters. The subset used for the study area consists of 10.6 million cells, which is an area of 4,143 cells by 2,570 cells. From that study area, 1.7 million cells that were already urbanized in 2001 were not considered. The remaining 8.9 million cells either stayed nonurban or changed to urban between 2001 and 2016.

To prepare the explanatory factors for the predictive model, ArcGIS Pro was used to create seven new raster layers for the study area:

- Drive time to the nearest urban center
- Proximity to the nearest freeway
- Proximity to the nearest secondary road
- Proximity to the nearest environmentally protected area
- Location in a flood zone
- Predicted population growth for the raster cell area as a percentage
- Terrain slope in degrees

Predictive Model

Random Forest, a supervised machine learning algorithm based on multiple decision trees, was chosen to predict urban development. [For more information about Random Forest, see the accompanying article "Seeing the Random Forest in the Decision Trees."] The model was trained in R because

was exchanged between ArcGIS Pro and R using comma-separated value (CSV) files as an intermediate step. This hindered project development and collaboration because whenever a change in the underlying GIS raster data was needed, several intermediate datasets had to be recreated, stored, and exchanged.

Introducing R-ArcGIS Bridge automated many processes and changes to the underlying GIS infrastructure. This dramatically helped the collaborators develop the project. R-ArcGIS Bridge is an Esri R package that allows data to seamlessly pass between ArcGIS Pro and R. The powerful spatial data processing and advanced mapping capabilities in ArcGIS Pro could easily be combined with statistical computing in R.

Project Scope

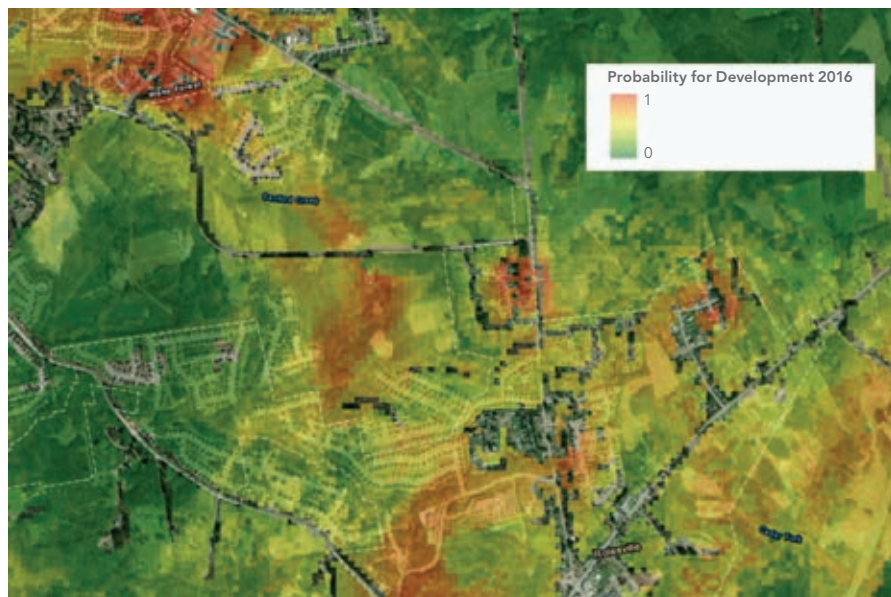
The study area for this prototype project is the Research Triangle (The Triangle) in North Carolina. This region of approximately 3,744 square miles encompasses North Carolina State University, Duke University, and the University of North Carolina at Chapel Hill. This region was chosen based on its relatively limited size, which would cut down computer processing time for spatial operations. The land-use patterns in The Triangle are geographically typical for the United States.

Project Data

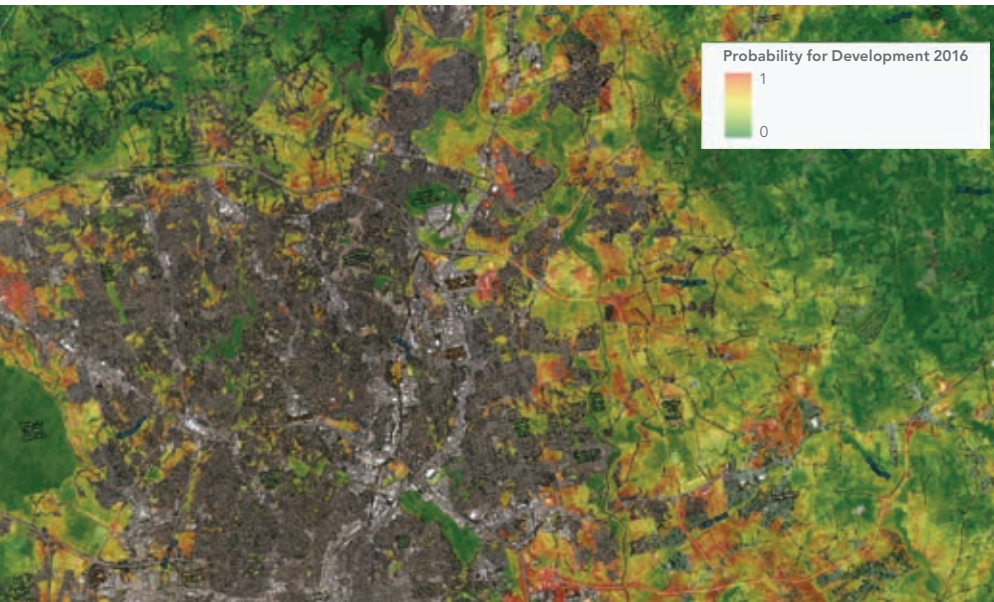
Like most statistical procedures, machine learning is based on analyzing past

patterns to uncover future patterns. This study obtained land-cover raster data from NLCD and compared land cover for 2001 to land cover for 2016 with the goal of revealing patterns that could be used to forecast urban development.

As population grows, new areas must be converted to urban land use. To identify areas of urban growth, ArcGIS Pro was used to recategorize raster datasets for 2001 and 2016 into urban and non-urban land-use types. Next a new raster dataset (ChangedToUrban) was added to the geodatabase. Cells categorized as nonurban in both 2001 and 2016 were categorized as ChangedToUrban=NO. Cells categorized nonurban in 2001 that changed to urban in 2016 were categorized as ChangedToUrban=YES. Cells categorized as already being urban in 2001 were not considered because the project's focus was on urban growth.



→ A large-scale view of the predicted probability of urban growth is displayed over a satellite imagery basemap. Red and orange denote areas of high suitability and therefore high probability of urban growth, whereas green indicates areas that have a low probability of urban growth.



← A large-scale view of the predicted probability of urban growth over the study area is displayed over a satellite imagery basemap.

was run with the name of the feature class and its full path to connect the feature class to an R variable. Then, `arc.select()` was used to pass the feature class attributes to the R data frame `DataAllFromPro`.

Training and Testing in R

With the established connection between the ArcGIS feature class and the R data frame, R can dynamically access the spatial data and train a Random Forest model to predict urban development based on the explanatory variables. Not all data was used to train the Random Forest model. The dataset was split into training and test data. The training data consists of 85 percent randomly chosen records. The remaining 15 percent of the data is held back as testing data to validate the model's performance.

Before applying the Random Forest model, one problem needed to be addressed: the dataset was unbalanced. Most areas (99.9 percent) that were undeveloped in 2001 remained undeveloped in 2016. Only 0.01 percent of the records changed from undeveloped in 2001 to developed in 2016.

Because machine learning models tend to choose the easiest solution, the model would predict no change to urban for all cells, given that this was a highly unbalanced dataset. This would lead to an absurd accuracy rate of 99.9 percent.

To solve the problem, the Synthetic Minority Oversampling Technique (SMOTE), from the `DMwR`-package in R was used to generate a more balanced dataset. SMOTE randomly deletes records from the majority class, which was `ChangedToUrban=NO`, and then uses a `k-Nearest-Neighbors` algorithm to artificially create new records for the minority class, which was `ChangedToUrban=YES`.

In the original training dataset, the majority class consisted of 7,427,248 records, while the minority class consisted of only 9,038 records. After SMOTE was applied, the majority class was reduced to 36,152 records, while the minority class was increased threefold to 27,114 records. The balanced training dataset was then used to train the Random Forest model.

the Random Forest-based Classification and Regression tool in ArcGIS Pro 2.6 does not output probabilities. Random Forest model training was based on the explanatory factors stored in the seven explanatory raster datasets plus the `ChangedToUrban` dataset as the response variable.

Workflow

The eight spatial datasets (i.e., the `ChangedToUrban` dataset plus seven explanatory datasets) were prepared and processed in ArcGIS Pro. The raster datasets were converted into a single point feature layer, which was passed via R-ArcGIS Bridge to R as an R data frame. R was used to train and test the Random Forest model and create predictions. Finally, the predictions were passed back to ArcGIS Pro via the R-ArcGIS Bridge to visualize the results.

Preparing Spatial Data in ArcGIS Pro

To pass the eight spatial datasets into one R data frame, all variables needed to be in one attribute table. This was done by creating a point feature layer in ArcGIS Pro with `ModelBuilder`, which automated the process and documented the steps. The `Raster to Point` conversion tool was applied to the `ChangedToUrban` raster to save a point feature class in the file geodatabase. The output feature class contained an attribute—also named `ChangedToUrban`—with a value of `NO`

for cells that stayed non-urban cells and `YES` for changed-to-urban cells. The `ChangedToUrban` attribute was used later in the predictive model as the variable to be predicted.

The `Extract Multi Values to Points` tool in the ArcGIS Spatial Analyst extension was used to add the explanatory variables to the point feature class. It extracted values from the seven explanatory raster layers at the location of each point and stored them as attributes in the point feature class table.

The resultant point feature class had 8.9 million records with attributes that included `Point ID`, the response variable `ChangedToUrban`, and the seven explanatory variables.

Connect Spatial Data from ArcGIS Pro to RStudio

Passing the point feature class to R using R-ArcGIS Bridge required setting up R-ArcGIS Bridge on a computer on which R, RStudio, and ArcGIS Pro were already installed. (R-ArcGIS Bridge can be set up using the R-ArcGIS Support option on the `Geoprocessing` tab.)

Once the R-ArcGIS Bridge was set up, RStudio was started and the ArcGIS binding package loaded along with other packages. The data transfer process started with the function `arc.check_product()`, which binds the RStudio session to the ArcGIS installation. To pass the feature class attributes to an R data frame, the function `arc.open()`

The trained model was used on the test dataset to predict if each record changed from non-urban to urban. Since the true values were already contained in the test dataset, they could be compared with the predicted values to gauge the accuracy of the model for the complete test dataset. From the 1,310,690 records in the test dataset that did not change to urban, 1,245,362 records were predicted correctly (95 percent). From the 1,594 records in the test dataset that did change to urban, 1,421 records were predicted correctly (89 percent).

To visualize the predictions in ArcGIS Pro for the study area, the trained model was used to predict the entire study area of 8.9 million records. The resulting data frame, which includes the predicted values and related probabilities, needed to be transferred back to ArcGIS Pro.

Bringing Data Back into ArcGIS Pro

In RStudio, `arc.write()` was used to write the data frame from R to the original geodatabase in ArcGIS. The resulting table in ArcGIS included columns containing the prediction results from the Random Forest model and included the predicted probability for each record to change from non-urban to urban.

The ArcGIS Pro table imported from R was joined to the original point feature class based on the common Point ID, using the Add Join tool in ArcGIS Pro, then a

raster layer was created based on the joined point feature using the Point to Raster tool in ArcGIS Pro.

Visualizing Prediction Results

The advanced cartographic capabilities in ArcGIS Pro makes it ideal for mapping and visually evaluating the prediction results. The predicted patterns were as expected. Predicted urbanization areas were located close to existing developed areas and roads. What was interesting was that some of the areas that were predicted to have a high probability for urban growth—based on 2016 NLCD data—were confirmed by the 2020 satellite imagery in the basemap used for mapping.

Summary

This project with ArcGIS Pro and R achieved its objective: predicting urban growth in the study area. The team integrated knowledge and skills from GIS and data science to make this project successful. R-ArcGIS Bridge was a key component in creating a smooth workflow. It allowed R to dynamically access ArcGIS Pro data and save R results back to an ArcGIS dataset.

This prototype showed promising prediction results. However, there is room for further research. For example, in this project, the predicted urban growth included residential and commercial urban developments. Since some explanatory variables, such as distance

to freeways or airports, may have opposite effects on residential and commercial development, it might be better to perform separate predictions for these urban types, although this would also reduce the records for each analysis. A follow-up project might shed more light on these issues.

About the Authors

Witold Fraczek is a longtime employee of Esri who currently works in the Geo Experience Center. He received his doctorate in the application of GIS in forestry from Agricultural University; a master's degree in hydrology from the University of Warsaw, Poland; and a master's degree in remote sensing from the University of Wisconsin, Madison.

Jian Lange is a principal product manager at Esri, focusing on spatial analysis. She is responsible for business planning, product road maps, overall product direction, and the requirements and product management of ArcGIS spatial analysis products including the ArcGIS Spatial Analyst and ArcGIS Geostatistical Analyst extensions.

Carsten Lange is a professor in the Department of Economics at California State Polytechnic University, Pomona. He specializes in monetary economics, economic impact analysis, machine learning, artificial intelligence, and GIS. He is a featured data science expert at Cal Poly Pomona.

Seeing the Random Forest in Decision Trees

A Random Forest classifier is the mean of the predictions of many Decision Tree classifiers. To understand Random Forest models, an explanation of a Decision Tree classifier is a good starting point.

A Decision Tree classifier guides each record through a treelike structure consisting of nodes where decisions are made that determine if it proceeds toward the left or the right tree branch. Decisions at each node are based on benchmark values for a specific explanatory variable. The respective variables and the benchmarks for the decision criteria are chosen by an optimization procedure. All records from the training dataset are guided through the tree and end up in one of the bins on the bottom of the tree.

Decision trees, although intuitive, are called weak predictors because they respond sensitively to small changes in the data or

parameters. This problem can be mitigated by combining many different decision trees—ones that are different at each node in terms of benchmarks and chosen variables.

The idea that a combination of weak predictors can lead to a strong prediction can be compared to a competition sometimes held at county fairs. Visitors to the fair, who likely have limited agricultural knowledge, try to estimate the weight of a pig. Although most predictions will be off, the mean of all predictions (surprisingly) will be very close to the real weight of the pig. This is the basic concept of Random Forest.

Online Schooling Prompts Municipalities to Map Digital Inequities

By Patricia Cummins

The challenges caused by unequal access to broadband internet are not new. However, the COVID-19 pandemic exacerbated their effects on some populations as the internet has become a lifeline for students and employees who are studying and working remotely. Those without broadband access have fallen behind academically and economically. The “homework gap,” which occurs where students lack the connectivity and access to computers needed to complete schoolwork at home, is more pronounced for Black, Hispanic, and lower-income households. Two large school districts are using GIS to identify these students and deliver solutions to their problems.

Two of the country’s largest school districts in Philadelphia, Pennsylvania, and Palm Beach, Florida, examined the digital divide to provide resources to low-income students when they were forced to study from home.

As the coronavirus pandemic endangers and upends the lives of millions, it perhaps affects no group more universally than children. Adults fortunate enough to retain jobs they can do from home are at least familiar with the concept of remote work. For kids, live video classwork reflects an alien pedagogy, and the lack of in-person peer interaction hinders the development of social skills.

Pivoting to computer-based remote learning has also deepened existing fault lines in American education. With broadband integral to schoolwork, researchers at the Pew Research Center documented a widening homework gap.

Teens in households with annual incomes of less than \$30,000 are nearly three times as likely to report having trouble completing homework assignments, due to lack of access to a computer or a reliable broadband connection, compared to households with annual incomes above \$75,000. Nearly half of teens in low-income families say they sometimes do their homework on a cell phone.

Pew also found that the homework gap involves racial disparities. More than one in five Black teens are forced to search out public Wi-Fi sources for connectivity.

Hispanic teens are twice as likely as White teens to report that they lack access to a home computer.

The pandemic made the problem impossible to ignore. “The digital divide was suddenly starkly apparent,” said Mark Wheeler, chief information officer for the City of Philadelphia’s Office of Innovation and Technology (OIT). “There were families who couldn’t afford reliable internet. They were using whatever they could to get by—public computing centers, free Wi-Fi through businesses, libraries—and with those shuttered, we had a sizable population that couldn’t participate in daily life.”

The school closures that roiled American life last spring underscored a crisis within a crisis. Almost overnight, school districts—especially those with large populations of students from low-income families—had to devise ways to keep the gap from swallowing students whole.

A Common Goal

At first glance, the City and County of Philadelphia in Pennsylvania would seem to have little in common with Palm Beach County, located in southeastern Florida. Each has a population of around 1.5 million, but Philadelphia’s is squeezed into an area one-sixteenth the size of its distant neighbor on the tropical end of the Eastern Seaboard. Philadelphia has twice the poverty, two-thirds the median income, and significantly less sunshine.

Scratch the surface, however, and

Philadelphia and Palm Beach look more alike. Although Philadelphia is one of America's poorest large cities, it contains pockets of high affluence. Although Palm Beach County's considerable wealth is mostly concentrated on the Atlantic coast, in cities like Palm Beach and Boca Raton, poverty persists in several communities sandwiched between the ocean and the I-95 freeway. The poverty rate in the Glades—the inland area near Lake Okeechobee that includes the cities of Belle Glade, Pahokee, and South Bay—is higher than Philadelphia's, and the median income is much lower.

Philadelphia and Palm Beach also share a civic quirk. Each county has consolidated its schools into a single school district. Each district serves about 200,000 students. One

out of every 130 public school pupils in the country lives in one of these two districts.

Palm Beach Rises to the Challenge

Each district acquired 80,000 Chromebook computers, using a combination of philanthropic and public funds. To better understand which students most needed computers and ensure those students and others had broadband access, the two districts adopted similar data-driven approaches.

To assess needs, the Division of Performance Accountability for Palm Beach County schools sought the advice of Donna Goldstein, an IT manager with the district. Goldstein's area of expertise is GIS, software that analyzes people and places

based on location-specific data.

Goldstein began her analysis by using geocoded student data to see where students lived. The data contained demographic information relating to each student, which could be displayed as layers on a map showing where incomes were lowest. She could also see who had already accessed the online student portal.

Goldstein's team was especially interested in students coded as eligible for subsidized school lunches, thinking these students might be from families with limited access to technology. Using GIS, she performed a point density analysis that displayed geographic clusters of families, which Goldstein then color-coded into three levels of concentration.

These clusters helped the county devise

↓ Students who can no longer attend school in person, may not have access to a computer and the broadband connectivity needed for remote learning at home.



where to place Wi-Fi hotspots. These pole-mounted transmitters broadcast Wi-Fi signals that nearby students can access with a special receiver.

To refine the analysis, Goldstein added more data layers, including municipalities, census tract data, and the location of neighborhoods already earmarked for community revitalization funds. She also mapped housing subdivisions, since the county would need to request easements to install the receivers on private property.

The map also helped the county plan where to lay fiber to bring the signals to the Glades. To reach far-flung homes, officials used the map to pick buildings onto which pole-mounted transmitters would be placed. These buildings include schools, a church, a library, and an animal care and control office.

"We combined all this data to give us a really well-rounded view of what's going on in the county, and where the greatest areas of need were," Goldstein said. "If the team wasn't able to work with the data

geographically and had to look through raw databases, I don't know how long it would've taken, but it would've been an extraordinarily long time."

Bridging the Digital Divide in the City of Brotherly Love

Meanwhile, a similar process was unfolding in Philadelphia. A program called PHLConnectED, a joint effort launched by the OIT and the Mayor's Office of Education, was helping families obtain computers and establish home Wi-Fi hotspots, while also making plans to establish community computing access centers. By late October 2020, more than 11,000 public school families were receiving free internet access thanks to the collaborative effort of city government, the school district, and business and philanthropic leaders.

As in Palm Beach, the initial difficulty PHLConnectED faced was how to identify the families that needed the program the most. Those experiencing housing insecurity were hard to contact. An even bigger

problem was finding families in relatively stable situations but with very limited incomes. "We have to make them realize what we offer them is free and that this isn't a rug that will be pulled out from under them after a few weeks," Wheeler said.

To help organize efforts, Wheeler's office tapped CityGeo, a dedicated team within OIT devoted to mapping and spatial analysis. CityGeo was already using GIS to maintain a city stress index. This index compiles geographic data on crime, homelessness, drug abuse, and other issues that would suggest the existence of students in need. The data helped PHLConnectED prioritize the distribution of wireless routers to create mobile hot spots for students.

"A lot of our work is focused not only on mapping but on keeping data dynamically up to date through the dashboard," said Hank Garie, CityGeo's geographic information officer. "So whether it's meal sites or access centers, it's all fed into the GIS, which gives us a great way to visualize and analyze where we might want to target outreach programs based on need or affordability."

Closing the Larger Gap Post-COVID-19

The progress made around bridging the homework gap in Philadelphia and Palm Beach County has implications for broader social equity issues. "As spin-offs from this initiative, we've been able to do parallel work with our Commerce Department," Garie said. "A lot of these same datasets are applicable, and we can even use them to view the city's budget through an equity lens."

Wheeler noted frequent references to the stress index in city meetings "really brings into stark relief that so much of this is about where people live."

"The work the CityGeo team has done has really laid the groundwork for me, as a CIO, to have conversations at the mayor's level about where populations we're trying to reach live, and how they're aligned with so many other critical problems we're trying to solve in the pandemic," Wheeler said.

Goldstein agreed. "For me, it goes

↓ Schools, like this one in the Hunting Park neighborhood of Philadelphia, have been closed in response to the COVID-19 pandemic. Credit: Wikimedia Commons





beyond kids," she said. "That's our primary focus, but now you've got parents and other adults in the home who have broadband access, which opens up whole new worlds of possibilities for them economically."

She sees the effort as providing a small silver lining during the crisis. "From my perspective, this is one of the only good things to come out of the pandemic," she added. "As educators, we've been fighting the digital divide for eons. So, this is really exciting."

Visit Esri's Racial Equity GIS Hub at <https://bit.ly/34Ylwdd> to view resources that help organizations address racial inequalities.

About the Author

Patricia Cummins is the director of government strategy and policy solutions at Esri. She provides guidance on state and national government initiatives and emerging policy issues. The digital divide is an aspect of social inequity that Cummins

has focused on for some time. She works with executives including state governors' offices, the White House, and US Congress. She uses her skills to bridge the gap between policy and technology and helps governments understand the value of geospatial data and GIS technology in promoting efficient, smart government. In 2018, she was named a Top Woman in Tech by the public sector media company *StateScoop*. She serves on the National Geospatial Advisory Committee, the National Governors' Association Smart States Advisory Board and has served as chair of both the National Association of State Chief Information Officers (NASCIO) and the National States Geographic Information Council (NSGIC) corporate advisory councils. Prior to coming to Esri, she was the GIS director for the New Jersey Department of Environmental Protection and served in a variety of roles for the State of Minnesota.

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A Growing Hunger

By Rebecca Lehman

GIS technology can help Feeding America food banks across the United States by enabling these organizations to understand their constituents, manage volunteers, and efficiently deliver services.

Feeding America operates a national network of food banks that provide meals to 46 million people each year. Each local chapter sources food and then stores and distributes food to a network of local partner food pantries and soup kitchens.

The COVID-19 pandemic has added to the challenges faced by Feeding America food banks. The staggering increase in food insecurity across the United States is being met by thousands of Feeding America's food banks. While the pandemic remains a threat to safety and health, hunger is creeping into many homes. For the first time, many families are facing insecurity not only in food but also in jobs and housing.

Food insecurity has a slew of deleterious effects. It means that families can afford fewer options at the grocery store, and many of those options are less healthy. Feeding America estimates that overall one in nine people may face hunger.

The organization has been dealing with a shifting landscape: food suppliers in limbo, volunteer support scaled back, and a massive increase in food support needs. Workflows are continually evolving due to COVID-19, and it is often challenging for food banks to identify new solutions. Working with limited in-person staff, as well as a huge increase in food needs, has shifted organizational priorities and limited resources.

A local organization, Feeding America Riverside San Bernardino (FARSB), was hit particularly hard by growing food insecurity. FARSB serves people in two large counties in Southern California, Riverside and San Bernardino. In 2019, FARSB served 18 million meals. Since the pandemic, it has seen a 60 percent increase in food needs across the community.

Pandemic Brings New Challenges

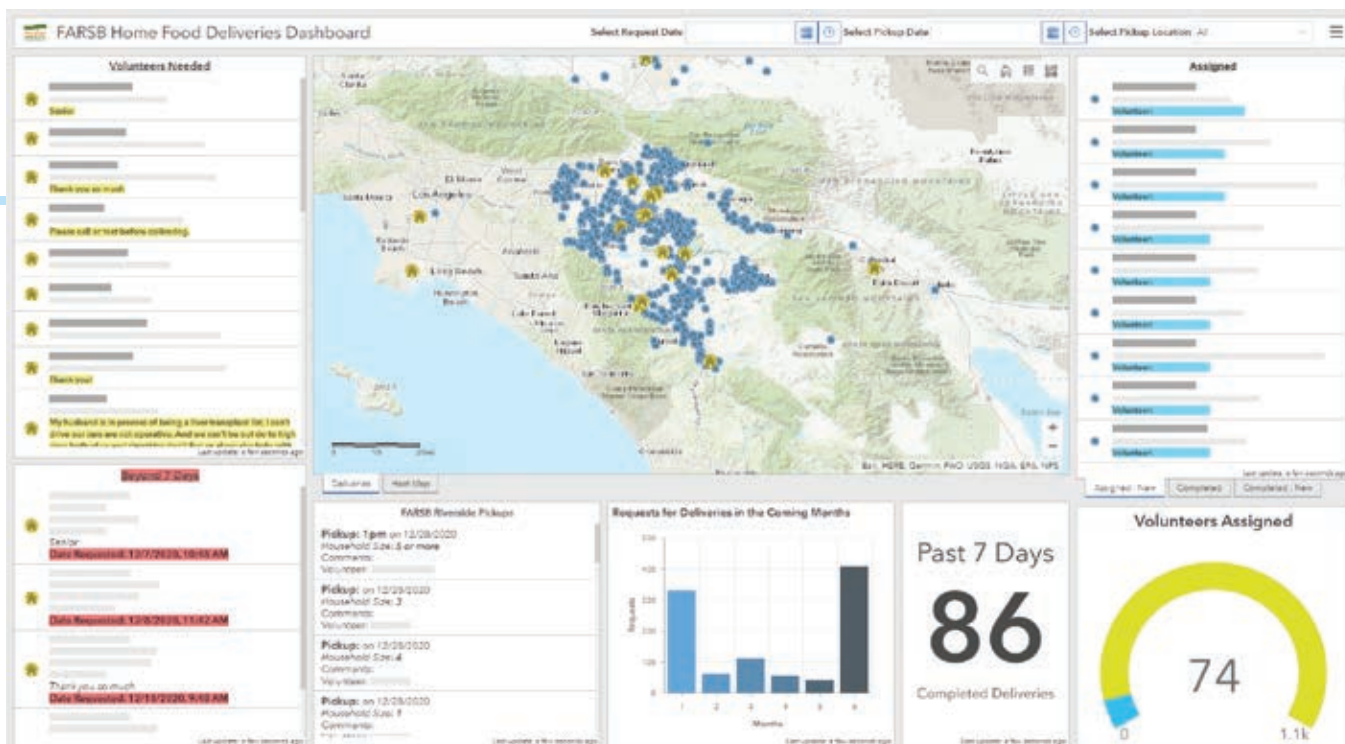
Since the pandemic, driving to food pantries has not an option for families without a car, some elderly persons, or those who are immunocompromised. FARSB needed to rapidly scale its home delivery program to reach these vulnerable community members. The requests for home delivery had

increased from one or two per week to 50 or 60 per week.

That's when Vanesa Mercado, operations manager for FARSB, mobilized the Homebound Emergency Relief Outreach (HERO) program. The program operationalized the food banks' large network of volunteers to find and deliver food to

↓ The HERO program taps into the food banks' large network of volunteers to deliver food to people who couldn't drive to food pantries during the COVID-19 pandemic.





↑ The Volunteer Delivery Dashboard lets volunteers easily see if there is a home delivery near their location, assign themselves to make it, and get on the road.

their neighbors.

Volunteers who signed up through the FARSB website were placed on an email list. Mercado manually created spreadsheets containing new delivery requests and sent them each day to volunteers, who assigned themselves deliveries, completed them, and updated the spreadsheets.

With this method, Mercado had no clear way to track progress and it was a huge

logistical challenge. “It was very administrative intensive,” Mercado said. Volunteers were struggling with a system of lots of spreadsheets. Staff paired volunteers with those in need and gave instructions for food pickup and delivery in addition to other responsibilities related to the COVID-19 pandemic.

A Solution Designed

Amanda Stanko, who works at Esri as a solution engineer, wanted to get involved. She put GIS as a special skill on her volunteer form for FARSB two years ago. She’s been working with Mercado’s team ever since.

“We all started brainstorming,” said Stanko. They wanted to put a system together that would take the stress off the administrative side and use maps and location intelligence to streamline the food delivery process. Stanko worked with Mercado to develop a new home delivery system using the Esri mapping platform.

Volunteers and those requesting assistance now fill out forms online that feed into the Volunteer Delivery Dashboard. This web-based dashboard lets volunteers easily see if there is a home delivery near their location, assign themselves to make it,

and get on the road.

Mercado likes the system. “Overall it’s been very efficient. It’s very friendly for new users and easy to maneuver. It’s been a great platform for us to use.” She can also share program insights from the app with a much broader audience. “The information from these dashboards is shared with the community, it is shared with funders, and it’s shared with our board.” It has helped in showing the impact of the HERO program.

FARSB is planning to support the HERO program indefinitely, allowing Mercado to expand the program to meet additional needs. “I absolutely see this tool being useful long-term as this program grows.”

To learn more about how you can volunteer or receive food assistance, go to feedingamerica.org.

About the Author

Rebecca Lehman, a nonprofit program lead at Esri, finds innovative ways to leverage technology in addressing social and environmental problems and creating sustainable solutions. She has a master’s degree in environmental management from the Yale school of Forestry and Environmental Studies.

↓ Amanda Stanko, Esri





Taking a DATA-DRIVEN APPROACH to Affordable Housing

By Keith Cook

Any conversation that planners and administrators have today about community resilience has to include a sustainable housing policy. A key component of that policy must be access to affordable housing.

According to *The 2019 State of the Nation's Housing*, a report released by Harvard University's Joint Center for Housing Studies, 15.2 percent of households were spending more than 50 percent of their incomes for housing in 2017. The study was sponsored by Habitat for Humanity.

According to Robert Hickey, Habitat's director of housing policy, the core of the housing affordability crisis is that fewer new homes are being built, particularly starter homes. This circumstance increases rents and home prices at a rate faster than incomes grow.

The role of the planning professional in developing a housing policy that is sustainable, affordable, and equitable is more

critical than ever. When people can't afford to live in the community in which they work, the result can be undesirable sprawl in surrounding communities. Even with an excellent transit system, this will increase traffic on roadways.

Implementing policies that support a sufficient inventory of affordable housing can provide many benefits to communities. These benefits include increased spending power, more educational opportunities, job creation and economic mobility, growing municipal revenue, lower stress on transportation networks, and reduction of poverty by ending the cycle of homelessness.

GIS plays a crucial role in implementing these policies by empowering planners in three main areas: taking a location- and data-driven approach to developing a sustainable policy for housing; creating equitable and attainable affordable housing; and designing a path for economic mobility for economically disadvantaged residents.

Housing Policy Development

In assigning areas for affordable housing, planners and policy makers must be able to define the need, benefits, and challenges. Locating affordable housing directly impacts other policies for mitigating homelessness and improving overall quality of life.

By taking a data-driven approach, planners can develop multiple housing scenarios in neighborhoods and measure their potential effectiveness using apps such as ArcGIS Urban and the Policy Validation App. Policy makers can then evaluate and visualize these scenarios, collaborate with community leaders, and engage the public to meet expectations of transparency and accountability. Specifically, GIS empowers planners to:

- Identify and analyze demographic and socio-economic variables for neighborhoods to assess needs.
- Allocate percentages of development to affordable housing as part of a comprehensive plan



- Evaluate accessibility to essential services, such as transit, education, health care.
- Understand the impact of homelessness in the area.
- Communicate policy to stakeholders and monitor feedback.

Designing Affordable Housing

Effective affordable housing relies on sustainable design that is centered around location. The design needs to incorporate transit-oriented design (TOD) in more dense urban neighborhoods to increase accessibility to services, education, training, and jobs and create a more walkable and desirable neighborhood.

In addition, affordable housing developments need to blend seamlessly with existing developments. This will generate a more cohesive and inclusive neighborhood that meets the needs of all its residents. Creating even one successful affordable housing development helps justify policies

to create additional affordable housing developments in other neighborhoods, expanding these benefits throughout the city.

Many municipalities developed zoning ordinances years—if not decades—earlier and didn't anticipate the demand for specific types of growth, such as mixed use, that have become widely accepted in the planning community. Previously, many municipalities had to outsource proposed changes to a consulting firm.

GIS benefits the development of affordable housing by empowering planning professionals to design sustainable and affordable housing developments. It aids the modernization of zoning ordinances. ArcGIS Urban allows planners to test different growth capacity and build-out scenarios with modified existing zoning parameters, such as maximum building heights, changes in permitted uses or the creation of new zoning. ArcGIS Hub provides a platform for citizens and stakeholders to learn about development scenarios and provide feedback.

Economic Mobility

Affordable housing and economic mobility are inherently linked. Economic mobility provides a path for residents—particularly low-income residents—to elevate themselves from stagnant economic conditions. Planners, economic developers, and community leaders have the obligation and the ability to design neighborhoods that provide economic opportunities for residents.

These opportunities can be enhanced if employers are incentivized to make long-term investments in personnel. This can create jobs and break cycles of poverty and homelessness.

This also grows municipal revenue, which provides more resources for services. When combined with affordable housing, an economic mobility strategy provides pathways for residents who are disadvantaged and disenfranchised to capitalize on opportunities and make a tighter connection with their neighborhood.

Planners need GIS to develop an economic mobility strategy to analyze and understand community demographics and socioeconomic characteristics and assess community needs for employment,

training, education, and services. monitor and quantify status of economic mobility in neighborhoods.

GIS can also be used to coordinate with economic development office (EDO) officials to recruit sustainable new investments and expand existing ones and report to policy makers and the public the impact of mobility in neighborhoods.

The City of Seattle, Washington, has been using GIS for years and recently used some advanced web-based tools to manage its dramatic growth. Seattle has had the fastest growth rate among the 50 largest US cities since 2010. By using GIS to inventory housing and employment capacity, city policy makers gain a growing understanding of its changing demographics so they could design affordable housing that would be evenly distributed among its many neighborhoods.

The city used the site suitability tools now found in the Policy Validation app and then the design tools in ArcGIS Urban to plan for new and affordable housing in the Eastlake neighborhood.

The City of Charlotte, North Carolina, has taken a repeatable approach to affordable housing. The city used GIS to create site scoring for proposed locations based on proximity to transit assets and amenities, income diversity, reasonable access to jobs, and level of neighborhood change. The city's housing operations manager and data analytics team did all analysis using web-based tools in ArcGIS.

From increased municipal revenue to decreased auto traffic and poverty to more diverse and cohesive neighborhoods, an effective strategy for encouraging affordable housing and economic mobility benefits all residents.

About the Author

Keith Cooke is the global industry manager for planning and community development at Esri. A graduate of Auburn University, he has been a GIS professional since 1994 and has worked for planning and community development agencies. Prior to his current role, he was an account executive at Esri for 15 years, working with more than 100 local governments.

Conserving a Network of Climate-Resilient Lands

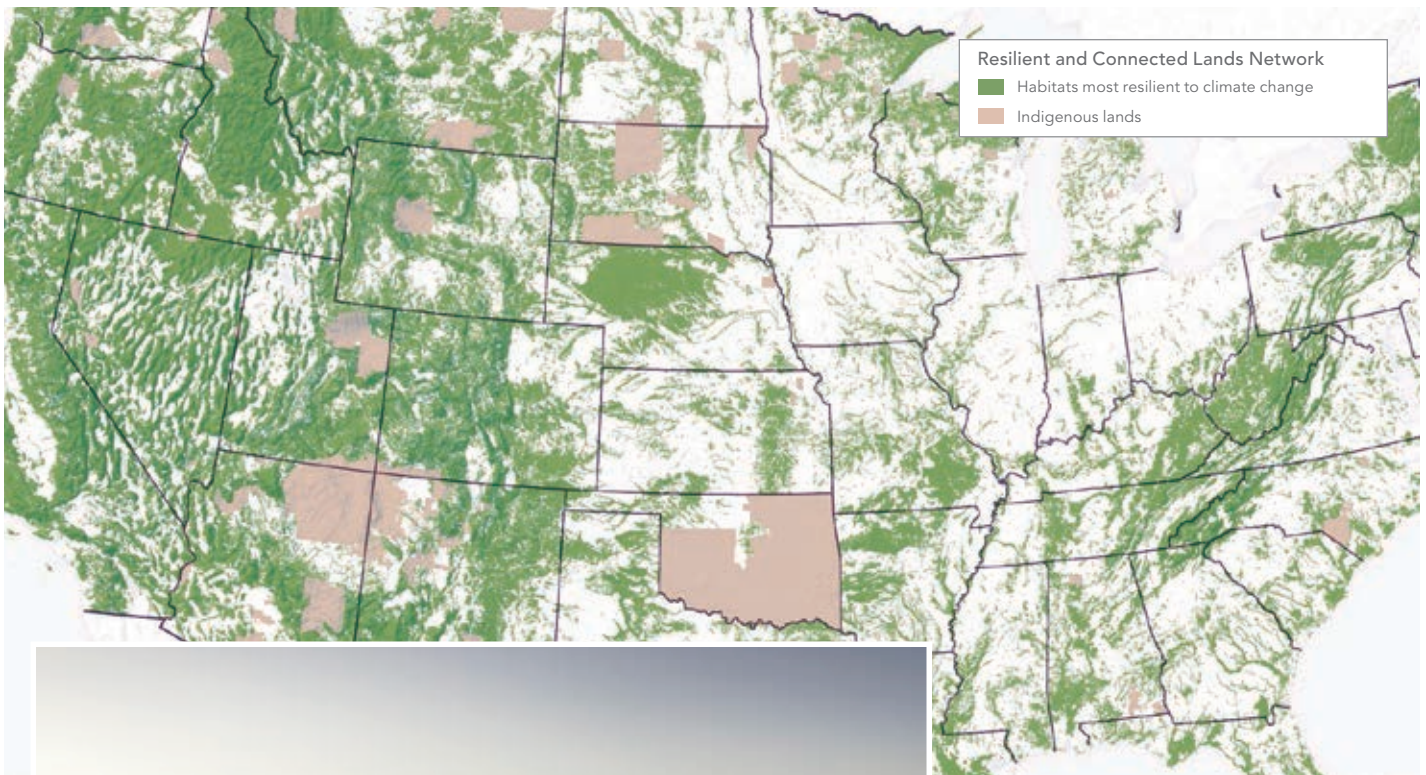
By Eric Aldrich

The Resilient and Connected Network, an ambitious GIS mapping tool developed over the past 10 years by more than 270 scientists led by The Nature Conservancy (TNC), gives conservationists a way to save biodiversity for the future. It is now available for land trusts, government agencies, and scientists for conservation planning throughout the contiguous lower 48 US states.

→ The Loess Hills of western Iowa, with its peak and saddle topography, is one of the places in the region that is most resilient to climate change. (© Mark Godfrey/TNC)

↓ As the climate warms, species are moving to find more hospitable places to live. On average, each decade, species travel to areas that are 11 miles north and at an elevation that is 36 feet higher. On this map, the movement of mammals is shown in pink, birds in blue, and amphibians in yellow. (© Dan Majka and Nicholas Rapp/TNC)





↑ Over the past 10 years, TNC scientists have mapped a network of landscapes across the United States with unique topographies, geologies, and other characteristics that can help withstand climate impacts.

← Western Iowa's Loess Hills harbor a tremendous diversity of plants and animals. This area holds more than half of Iowa's remaining tallgrass prairie habitat. (© Chris Helzer/TNC)

GIS has long been one of conservationists' main go-to tools to identify and protect land, water, plants, fish, wildlife, and habitat across the globe. Using GIS to identify places with high levels of biodiversity has often played a leading role in those efforts.

Now, climate change is altering biodiversity and habitats. As warmer temperatures, increased flooding, and other climate impacts alter and destroy habitat, species are being forced to find new places to live. Diverse plants and animals that thrive in one landscape today may end up living in a very different landscape in the future.

Scientists have found that globally, species are moving an average of 11 miles north and 36 feet higher in elevation each decade to find more hospitable places to live.

How can conservationists continue to protect biodiversity if the cast of plant and animal species keeps moving to escape growing climate impacts?

Natural Neighborhoods and Highways

The answer, according to Dr. Mark Anderson, is to focus on the future. Anderson is director of science for TNC's Eastern US Division and, for many years, has been studying the connections between climate change and shifting biodiversity. Anderson is also a GIS junkie who knows well the crucial role that GIS plays for land trusts, state agencies, and other entities planning conservation projects. Conservationists have limited funding and face huge challenges in their

work preserving biodiversity and clean water and protecting the health of landscapes. They need GIS to help identify and focus on high-priority projects.

Rich data from scientists, universities, and state and federal agencies provides great insight into current biodiversity, habitat, and other natural features. But Anderson sought to see how GIS could identify places that would have long-term resilience as the climate changes.

Anderson and his team found that landscapes with diverse physical characteristics—such as steep slopes, tall mountains, deep ravines, and diverse soil types—create numerous microclimates that offer plants and animals the opportunity to move around their local neighborhood to find suitable



↑ Among the things that make places resilient to climate change are diverse physical characteristics—such as steep slopes, tall mountains, deep ravines, diverse soil types that create numerous microclimates and allow plants and animals to move to suitable habitat. The landscapes also have good connectivity, allowing movement across local microclimates and between climate resilient landscapes.

→ In the area near Oklahoma’s Canadian River, prairies and contrasting wooded canyons provide climate-resilient habitat for plants and wildlife. (© Jay Pruett/TNC)



habitat where they can escape rising temperatures, increased floods, or drought.

Anderson and his colleague Melissa Clark also mapped natural highways across the country—connecting corridors that allow species to move safely within and between these climate-resilient neighborhoods.

While studies show that species are moving to cooler places, nearly 60 percent of US lands and waters are fragmented by human development, blocking species’ movement and preventing them from finding new homes.

“Nature is on the move,” Anderson said. “It’s not enough to have isolated and disconnected landscapes that are resilient to climate impacts. Species also need a way to reach these resilient sites. While some

species will be able to relocate to new homes within their local resilient neighborhoods, others will need to move great distances to entirely new landscapes. If these pathways are destroyed, many species could disappear forever.”

A Ton of Data and Essential Esri Tools

To create the Resilient and Connected Network mapping tool, Anderson and his team had to “compress 200 gigabytes of data into a useful tool and make it look and work seamlessly,” said Erik Martin, a TNC spatial ecologist who helped lead the GIS work. “The map reflects a ton of data, pulling from hundreds of datasets from all around the country.”

Using Esri’s advanced spatial analysis and modeling tools and working many long nights over the past 10 years, TNC scientists Clark, Arlene Olivero Sheldon, and Analie Barnett developed, tested, and retested methods to map and measure characteristics of resilient lands. Their analytical and problem-solving skills, coupled with their determination and passion for conservation, took the idea of a network of resilient lands from concept to reality.

One of the big challenges, according to Anderson, was persisting over the 10-year life-span of the project. During that time, the project grew organically region by region, starting with the Northeast. To ensure accuracy as the map was being built, the team had reviews by some 270 scientists, who

were looking at localized geography or geography at a nationwide scale, depending on their expertise. Aiding in that process was the ability to share regional versions via ArcGIS StoryMaps.

Many other Esri products and apps were essential for the job. These included ArcGIS Pro, ArcGIS Online for hosting tiled map services, ArcGIS Server for hosting dynamic map services and geoprocessing services that run custom ArcPy-based scripts, and the ArcGIS API for JavaScript to develop the front end of the tool. All those components came together, making the map fast and responsive for users.

The team relied heavily on ArcMap and ArcGIS Pro, using 30-meter scale raster data of the entire country for analysis and mapping. The ArcGIS Spatial Analyst toolsets contained the team's go-to tools. Python and ModelBuilder were used to test analysis and iterate steps in each region. Getting feedback from regional scientists helped shape the final product. The team used the quick publishing capabilities of ArcGIS Online. ArcGIS StoryMaps stories were key in explaining analysis results and showcasing resilient places across the US.

"Each of these components is like a building block of a house. We used the ArcGIS API for JavaScript to build the frame of the house—the structure of the app. Then [we] connected together all of the electrical and plumbing—the map and geoprocessing services that feed into the app," Martin said. "The Esri tools integrate all of the parts of this data into one useful app."

A Paradigm Shift for Large Landscape Conservation

When the nationwide map was completed, one of the big surprises for Anderson was the large number of areas around the country that are resilient to climate change. "When I first envisioned this, I thought there would be a bunch of big, broad areas. It's really like a web, or a network of connected places."

Among the many large and small resilient and connected lands in the map are:

- **Nevada's Monsoon Passage**, a natural highway of mountain ranges and wet valley bottoms that extends up from Lake Mead through the Great Basin National Park to the Idaho border.

- **The Cumberland Forests area**, which spans 253,000 acres across Tennessee, Kentucky, and Virginia, that not only safeguards wildlife habitat but also stores millions of tons of carbon.

- **Wisconsin's Kettle Moraine region**, which was shaped by glaciers during the last ice age and contains diverse features such as large kettle lakes and 300-foot-high ridges.

- **Bobcat Alley**, a 32,000-acre forested corridor in northwestern New Jersey that provides habitat to state-endangered bobcats.

Along with providing safe places where species can thrive, the network of resilient lands also brings benefits to people. The lands mapped in the eastern US, for example, contain 75 percent of the region's sources of drinking water, generate billions of dollars in outdoor recreation, store 3.9 billion tons of carbon, and mitigate 1.3 million tons of pollution. Taken together, this results in an estimated \$913 million in avoided health-care costs.

"To achieve conservation at the scale needed, we must collaborate with people and organizations across both the public and private sectors," Anderson said. "Keeping these resilient areas safe and healthy will require a wide range of conservation practices including such things as sustainable management, public and private land acquisition, and easements."

Numerous state and federal agencies and land trusts have already incorporated the map's data into their conservation planning. Among the growing number of state agencies incorporating the map into their state Wildlife Action Plans are Connecticut, Massachusetts, New Hampshire, New York, and South Carolina.

The urgency of protecting lands and biodiversity given the challenges of climate change is clear and pressing, according to Andrew Bowman, president of the Land Trust Alliance. At Rally 2019: The National Land Conservation Conference, the country's largest gathering of land trusts, Bowman made a passionate plea for safeguarding biodiversity for the future. The Resilient and Connected Network is an important tool for that urgent task.

"This map provides a new way to look at

the landscape for purposes of prioritizing lands for the conservation of biodiversity," Bowman said. "I've watched this work take shape over the last decade, and I truly believe it marks a paradigm shift in how we think about large landscape conservation."

See the mapping tool at <http://maps.tnc.org/resilientland/>. For more information, contact Eric Aldrich at ealdrich@tnc.org.

More Resources

For information and data on resilient and connected landscapes, visit nature.org/climateresilience.

For information on the TNC's work, visit nature.org/naturallhighways.

View the ArcGIS StoryMaps stories on resilient and connected landscapes at <https://bit.ly/34HyqA7>.

About the Author

Eric Aldrich is the marketing manager for TNC's North American conservation strategies. Based in New Hampshire, Aldrich has written on renewable energy, climate change, ecological fire, wildlife, fisheries, rivers, and other conservation topics for more than 30 years.

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Interactive Map Depicts Global Submarine Cable Networks

By Jim Baumann

The internet is not up in the clouds but under the oceans.

Ninety-eight percent of the internet runs on cables that stretch across the world's seabeds.

Submarine Telecoms Forum, Inc. (STF) is the news and research analysis outlet for the submarine fiber communications industry. It publishes magazines, almanacs, and reports about the industry and provides an interactive map of undersea cables. STF has more than 130,000 users in 115 countries.

Until STF began publishing its ArcGIS-based Submarine Cables of the World Interactive Map (subtelforum.com/cablemap/) as a companion to the *STF Submarine Cable Almanac*, the industry did not have access to a comprehensive map depicting important information about submarine cable networks.

This regularly updated interactive map shows submarine fiber-optic cable systems around the world, both current and planned. It also provides details associated with these networks including landing

points, data centers, offshore oil and gas systems, and the global cable ship fleet.

"We track the laying of new submarine telecommunications cable and analyze its impact on the industry in general. We are not affiliated with any suppliers, installers, or vendors. We are a neutral third party that provides an unbiased overview of the industry," said Kieran Clark, lead analyst for STF.

Because the map is interactive, it not only displays an overview of cable networks, but a map user can also drill into a specific area to find information about an individual network on a granular level. For existing networks, that information can include network name, owners, capacity, cable characteristics, and estimated cost. For planned networks, the status of individual networks can be tracked to determine if key milestones have been completed.

STF originally used ArcMap to create the maps that appear in its printed publications but has switched to ArcGIS Pro. Now STF's publications are delivered digitally and ArcGIS Pro is used for mapping and analysis.

"I am not a GIS analyst by trade, and ArcMap was always a daunting piece of software for me to use," said Clark. "However, ArcGIS Pro has made the capabilities of GIS much more accessible. We can do more data analysis, and we are making use of web apps and the operational dashboards."

STF uses a managed crowdsourcing effort for collecting data used in the map. All information and update recommendations are derived from the public domain by a company analyst. Data tables in the Microsoft Azure-based SubTel Forum Cable Database are linked to layers in the interactive map.

"We draw new cables and their landing

points for the map in ArcGIS Pro and then connect it to our submarine cable database, which has details on all of the major submarine cables in the world," said Clark. "We currently have over 500 submarine cables that we track and have data on."

Lines representing the submarine cables displayed on the map are associated with attribute data about that cable such as the company that installed the cable, built it, how much it cost, its capacity, and many other details. These details are displayed in a pop-up when the line is selected.

Every six hours, STF pulls location data for all cable-laying ships around the world via the Automatic Identification System (AIS) ship tracking service, updating the locations of 46 cable ships. ArcPy scripts are used to automatically update the map. STF has developed an ArcGIS Dashboard around the map that lets users view and filter different datasets available from the map. Cable routes depicted on the STF map do not indicate the actual locations of these networks. Instead, the map lets its viewers easily identify individual cables and their landing points.

A fiber-optic cable is about the size of a garden hose and is placed directly on the ocean floor. Although these cables are strong and much care is taken in laying them, annually approximately 100 submarine cable network faults occur throughout the world. Because cable failures disrupt communications, redundancy is built into networks. The data being transmitted is spread over several cables. Cables laid in the same area take similar routes that are determined by marine surveys to avoid hazardous conditions that might damage cables.

The map also includes more than 1,700 data centers. These data centers aren't specific to the submarine fiber communications industry, but they are important, so

they are included on the map. Data center locations are plotted using addresses and linked to information about each data center. ArcGIS Pro is used to geocode and display all data center locations.

Previously, data centers and submarine cable networks were located somewhat independently. A cable would come ashore at a location that was distant from its data center so it would require hundreds of kilometers of fiber to access the nearest network data center.

Newer data centers are built closer to shore so that submarine cables can quickly connect to the onshore cables and access specified networks more easily. Mapping the proximity of data centers to submarine cable networks can be used to anticipate the need for network expansion. If data

centers are located where there aren't a lot of submarine cables coming on land, this indicates where the cable network could be expanded.

"The information that we disseminate is widely used. People in the submarine cable industry use it when they are looking for information on cables that are currently being laid, cables that are in service, or cables that are planned," said Clark.

Analysts may want to determine the current status of a specific cable system. The maps STF creates are used for educational purposes by teachers, students, and others to learn about the industry. Companies use the STF website when they want to put together reports about specific cables and make use of the information the company provides.

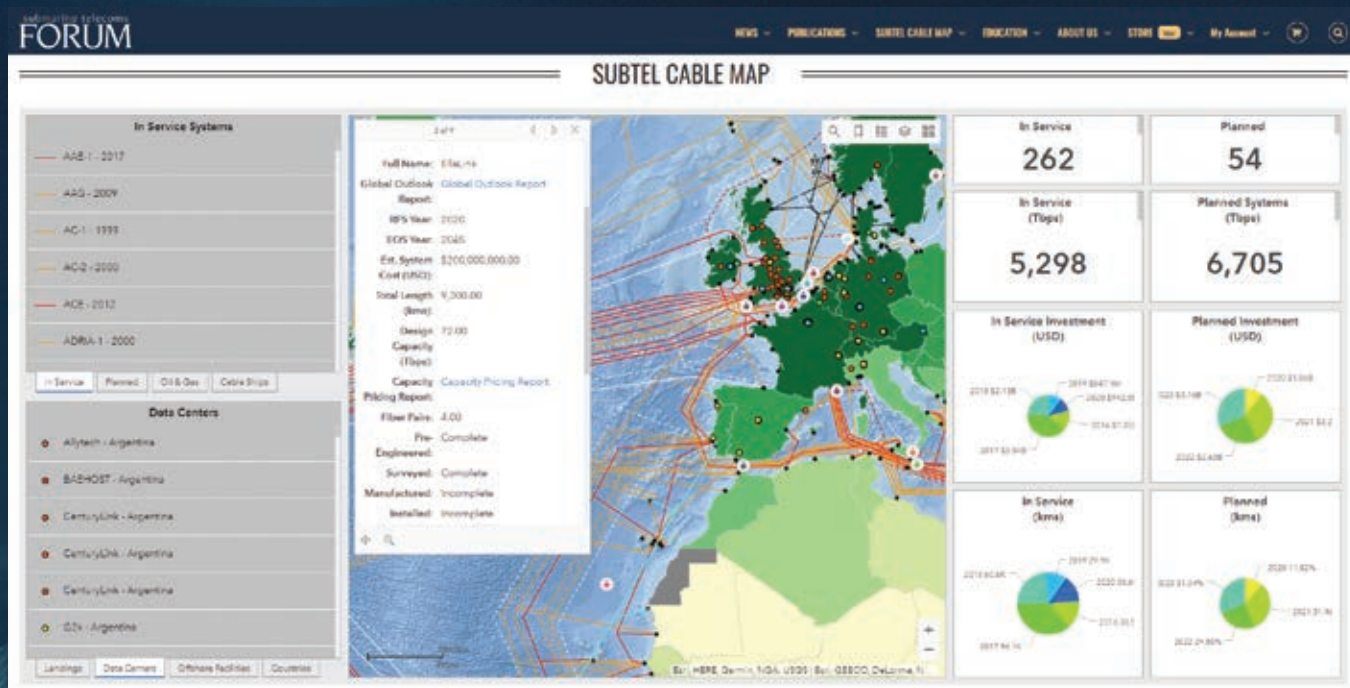
STF has begun using ArcGIS StoryMaps stories to publish its annual report on the state of the submarine cable industry, a document that is in demand by the industry.

"The report runs more than 100 pages. By including dashboards, we could add some interactive charts and regional overviews. This brings a whole new dimension to publishing," said Clark. "ArcGIS Pro gives us the tools and flexibility to prepare our technical information in a dynamic manner and present it in a way that is easily understood."

About the Author

Jim Baumann is a longtime employee at Esri. He has written articles on GIS technology and the computer graphics industry for more than 30 years.

↓ STF has developed an ArcGIS Dashboard around its interactive map that lets users view and filter different datasets available from the map.



A Better Way to Quickly Deploy ArcGIS Solutions

By Andy Shoemaker

With the June 2020 release of ArcGIS Online, Esri added a new way to quickly deploy ArcGIS Solutions to your organization—the ArcGIS Solutions app.

ArcGIS Solutions are a collection of focused maps and apps that help address challenges in your organization. Part of the Esri's cloud architecture, ArcGIS Solutions leverage your authoritative data and are designed to help you improve operations, gain new insight, and enhance services.

When you log in to your ArcGIS Online organization, you'll find the ArcGIS Solutions app in the app launcher. This

application helps you quickly discover and deploy ArcGIS Solutions in your organization. Designed to find the ArcGIS Solutions most useful to your organization, you can browse the collection of solutions in the app, search for a specific solution, or filter the gallery to quickly find a solution.

Once you discover the solution you are interested in, the information panel will provide an overview of the solution and

an option to deploy it. A link to additional documentation is also available if you want to learn more about the value the solution provides, the software it requires, and workflows it supports.

When you click Get Now, all ArcGIS items included in the solution are created in your ArcGIS Online Content and summarized in a new Solution item that helps you visualize related ArcGIS items, such as

hosted feature layers, hosted feature layer views, maps, apps, surveys, and groups, and understand where they are used.

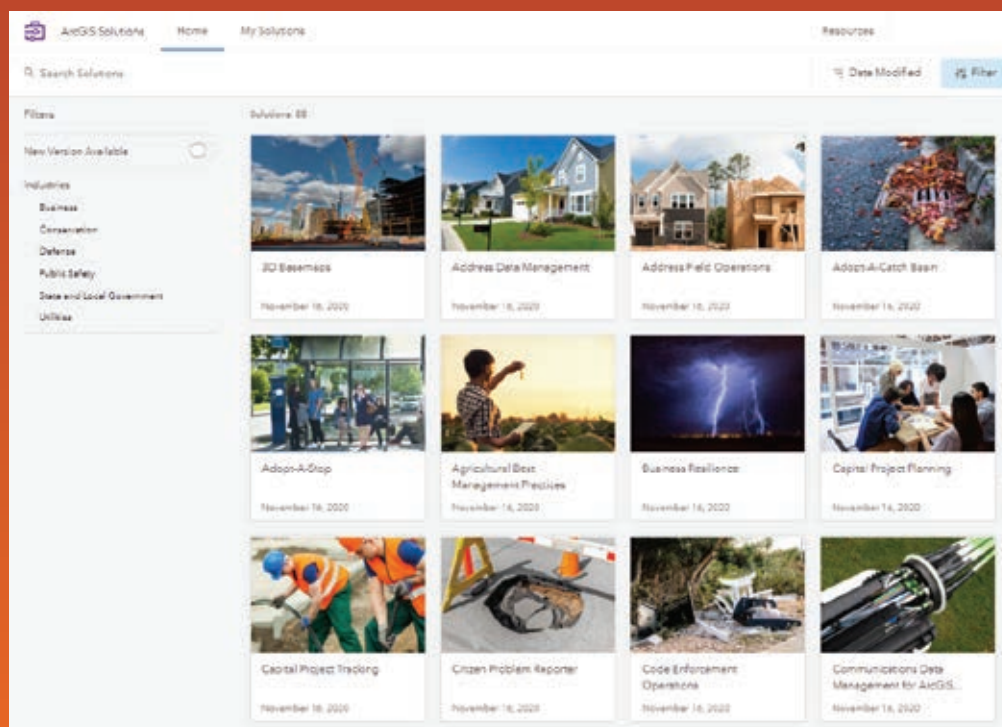
This information will help you quickly configure the solution to fit your organization's needs. Once configured, share the application, map, and layers with end users.

A collection that includes the most popular solutions and several new solutions is available in the first release of the ArcGIS Solutions app. Solutions are added to the ArcGIS Solutions app as part of new releases of ArcGIS Online and will be added to a future release of ArcGIS Enterprise.

If you are looking to reduce the time it takes to deploy geoenabled solutions in your organization, increase the business impact they make, and leverage fully supported ArcGIS configurations, use the ArcGIS Solutions app available in ArcGIS Online and deploy one of the many ArcGIS Solutions.

About the Author

Andy Shoemaker is a product engineer on the ArcGIS Solutions team and has been with Esri since 2014. In his free time, he enjoys hiking, camping, and hanging out with his dog, Cosmo.



Management Improved by Understanding

By Brent Jones

Many people consider Peter Drucker the founder of modern management. “What gets measured, gets improved,” is one of his many famous quotes. However, many organizations that focus on measuring specific performance factors that are thought to support desired outcomes often overlook the holistic view. GIS delivers that holistic view.

Cartographers have been using maps and other visualization techniques to convey complex information for centuries. GIS, the technology behind modern mapping, takes advantage of cartographic techniques. Nearly every digital map you see today is powered by GIS and can incorporate advanced cartographic capabilities, such as smart mapping. These capabilities democratize mapping. You can make meaningful maps and apps that help you discover patterns and hidden information in your data and easily communicate these insights to others.

Perhaps the most viewed GIS application in world history is the COVID-19 Dashboard by the Center for Systems Science and Engineering at Johns Hopkins University. What makes this dashboard so powerful? It changes how we see the pandemic. It gives us a new understanding of COVID-19—not just the what, but the where, how much, and how fast.

Dashboards, a key component of GIS, improve decision-making by visualizing and analyzing data to support less biased and more science-based action. Another special thing about dashboards is that they are interactive. If information about an exact measurement is not provided, you can use the dashboard to explore views of the data and perform analyses to uncover it.

Data from outside the organization can be incorporated. With data enrichment—or when using map-based data, geoenrichment—allows the near limitless use of data from an organization or real-time feeds for traffic or weather. Dashboards can be used to explore, augment, and analyze data and utilize sophisticated models.

Not long ago, designing and publishing maps, deploying apps on mobile devices, or building dashboards meant custom development—a time-consuming and costly undertaking. Now maps, apps, and dashboards, which are all GIS components, can be configured. This means existing solutions and workflows can be modified to meet an organization’s unique needs without coding.

Geospatial infrastructure is data and services delivered

via modern architected technology. An organization’s geospatial infrastructure enables it to take full advantage of all the capabilities of GIS. These capabilities not only include maps, apps, and dashboards, but also a platform for sharing and collaborating that keeps everyone connected and informed and delivers a holistic view to the entire organization.

Setting up a geospatial infrastructure for your organization allows you to quickly deploy new maps, apps and dashboards and configure them for your specific needs. Using additional analytical components, such as ArcGIS Insights, provides deeper analysis and improved visualization. ArcGIS Hub enhances sharing and collaboration outside your organization. Properly architected geospatial infrastructure eliminates multiple point solutions and delivers nearly limitless new capabilities for you that improve your organization’s understanding.

Measuring performance is important but doesn’t deliver understanding. Understanding is what organizations need and GIS can improve it.

About the Author

Brent Jones oversees Esri’s worldwide strategic planning, business development, and marketing activities for land records, cadastre, surveying, and land administration. As a recognized innovator, Jones specializes in modernizing existing land administration systems and designing new GIS-based cadastral management systems for small and large governments globally. He is president-elect of URISA; past president of the Geospatial Information and Technology Association; and a current member of the United Nations Committee of Experts on Global Geospatial Information Management, sitting on the Expert Group on Land Administration and Management. Esri creates systems that drive all components of land and cadastral administration.

Bridging the World of 3D GIS and Game Engines

By Rex Hansen

In October 2020, Esri announced a beta program for developers who want to use ArcGIS with game engines. This program hosts ArcGIS Maps SDK for Unity and ArcGIS Maps SDK for Unreal Engine. These products enable direct access to ArcGIS data and operations within a game engine.

Over the past few years, many industries and organizations have pursued next generation 3D GIS solutions. These solutions, which include client applications that target specific workflows, require a photo-realistic experience driven by real-world data.

These applications need to take advantage of high-end graphics capabilities on modern devices and utilize hardware designed specifically to support extended reality (XR) experiences. They also need to be highly interactive, visually compelling, and deeply immersive to increase engagement, improve understanding, and optimize the decision-making experience. Operationally, they need to support modeling and simulation scenarios and quickly render real-time geospatial information.

Many of these industries and organizations—most notably in the AEC, defense, natural resources, and transportation sectors—are using game engines to power photorealistic, interactive, and immersive 3D GIS applications. Game engines deliver high-performance, premium rendering experiences, and engaging special effects. The highly competitive nature of the gaming industry pushes the limits of game technology as well as its associated content and hardware.

Successful game engine vendors have spent years developing premium, high-definition rendering pipelines that deliver simulated world experiences, optimized for multiple platforms and form factors. The introduction of high-fidelity assets, physics engines, animation properties, and

atmospheric, water, and other special effects has enabled game engines to deliver beautiful, photorealistic visuals that look and act like the real world.

Game engines also support a wide variety of desktop and mobile platforms and dedicated, specialized hardware. Part of the next generation of 3D GIS solutions will include the use of headsets, such as HoloLens, Oculus Quest, and HTC Vive, providing XR workflows in business settings. Game engines are built to support the responsiveness, frame rates, and fidelity needed to power these experiences.

To this end, the first beta release of the ArcGIS Maps SDKs integrate with the two market-leading game engines, Unity and Epic's Unreal Engine. The ArcGIS Maps SDK for Unity and ArcGIS Maps SDK for Unreal Engine are available as plug-ins that provide direct access to ArcGIS services and data. Although the functionality delivered in both SDKs is equal, the capabilities of the editors and engines may differ.

To deliver the best experience possible, Esri is working with Unity's geospatial team and Epic's Unreal Engine development team to enable and optimize access to the Esri geospatial platform.

"As gaming technology is increasingly adopted in many industrial sectors including AEC, government, energy, and transportation, we are excited to partner with Esri to bridge the world of GIS and real-time 3D," said Julien Faure of Unity Technologies. "The addition of Esri's best-in-class real-world geospatial data into Unity's real-time 3D development platform

will help create real-time digital twins of an unprecedented scale, to better operate and manage massive infrastructure and entire cities in immersive environments."

For software solution providers, Sébastien Lozé of Epic Games noted that "As the needs of the geo-intelligence community continue to grow, training, simulation, architecture, and urban planning projects are creating new challenges. Esri's new plug-in for Unreal Engine will allow ArcGIS users to experience virtual environments in entirely new ways and will equip them to meet the ever-rising demand for innovation."

Development in either editor is supported on Windows and macOS. Although both engines support developing apps for a variety of platforms, this first beta release only targets apps for Windows, macOS, Android, and iOS. Note that support for Windows includes 64-bit apps on desktops and 32- and 64-bit Universal Windows Platform (UWP) apps, which means Esri supports the use of apps with first- and second-generation HoloLens devices.

Both local and global experiences are available. Local scenes support display of geographic data on a planar surface and can work with different projected coordinate systems, which are usually appropriate for smaller, local areas. Global scenes support the display of geographic data on a sphere or globe, which is usually appropriate for large areas or regions. Other content, such as game objects and actors, can appear in these scenes, but this content must appear within the geographic coordinate space and the camera control established by the ArcGIS Maps SDK plug-in.

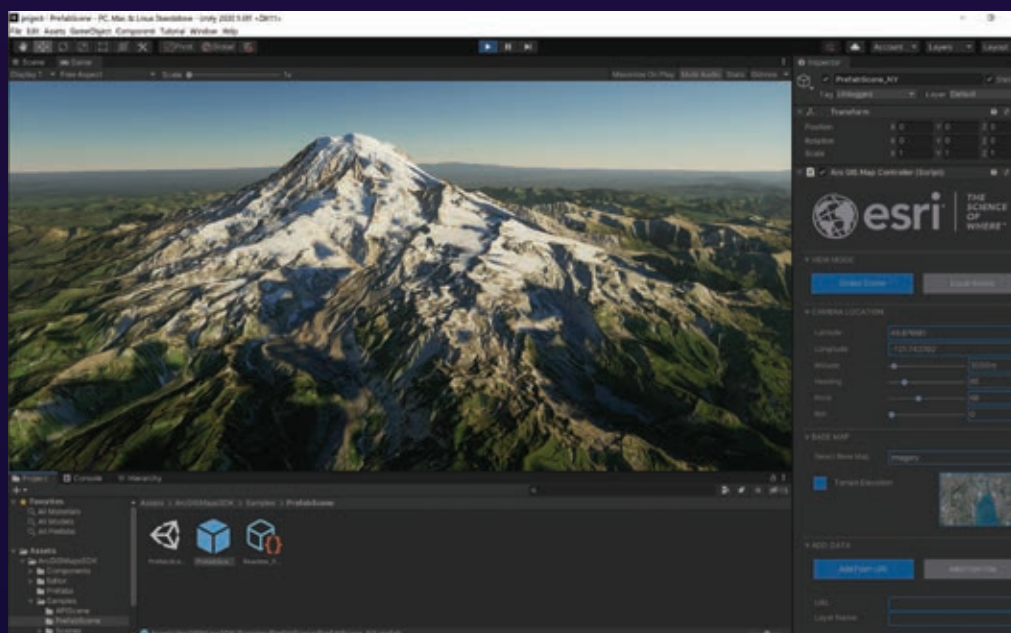
The ArcGIS data sources that are accessible by the plug-ins include single elevation service for terrain, multiple raster tile layers, and multiple 3D objects or integrated mesh scene layers.

➤ This high-resolution depiction of Mount Rainier, Washington, uses global imagery and elevation services hosted by ArcGIS Online with the ArcGIS Maps SDK for Unity.

➤ This global scene, created with the ArcGIS Maps SDK for Unreal Engine, shows the City of New York. It uses aerial imagery, elevation data, and operational data to show transit frequency and 3D structures.

Single Elevation Service for Terrain

This data source is an image service hosting Limited Error Raster Compression (LERC) encoded tiles with elevation values, which includes ArcGIS Online World Elevation services for terrain and bathymetry. [LERC is a highly effective raster data compression technology invented by Esri.]



Multiple Raster Tile Layers

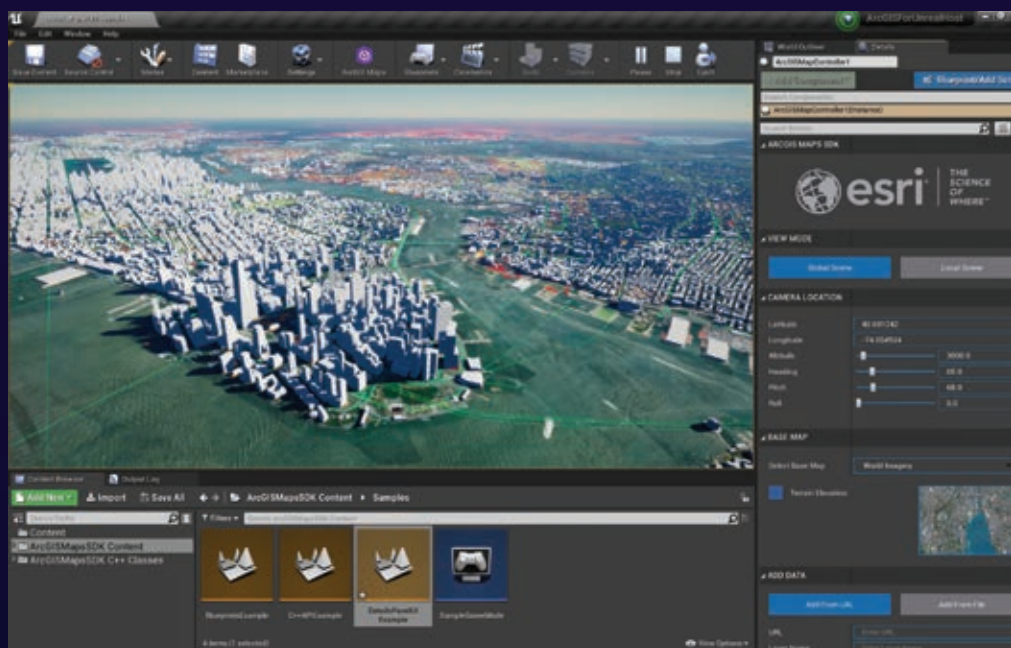
This data source includes cached map or image data for display from an ArcGIS map service or a local tile package (.tpk file). Sources include ArcGIS Online basemaps with imagery, topography, or street data.

Multiple 3D Object or Integrated Mesh Scene Layers

These data layers are founded on i3S, an open specification optimized for the delivery and use of 3D data. 3D objects can include textured buildings and structures. Integrated mesh scene layers use a triangulated irregular network (TIN) to represent a continuous 3D surface that is usually acquired from satellite or aerial imagery. These layers can be delivered as scene services or local scene layer packages (.slpk files). Scene layers should be published with version 1.7, the latest version of i3S, because that version includes significant improvements to performance and memory usage.

Note that this first beta release will only support access to public ArcGIS services, not secured services. Esri plans to add support that will enable access to secured services in the next beta release.

In addition, built-in access to feature sources, such as ArcGIS feature services or mobile geodatabases, is not supported in the first beta. Esri will target support for these feature sources in a future release. However, a location component is



provided for integrating custom content, such as game objects and actors, within the scene established by the ArcGIS Maps SDK plug-in. A developer can use this location component to craft a solution that retrieves feature geometry and attributes to display and use in a scene. The location component can be used to bring in a wide variety of content to participate within the scene.

To join the ArcGIS Maps SDK for game engines beta program, visit <http://esriurl.com/a4ge>. The beta program includes

product downloads, links to product documentation, and access to forums.

About the Author

Rex Hansen is a product manager for the ArcGIS Runtime and Maps SDKs. He has more than 25 years of experience in GIS, spatial analytics, and computer mapping. Currently, he guides the development of native GIS technologies that use authoritative geospatial content and analysis in offline workflows, photorealistic experiences, and immersive, extended reality solutions.

Simplify Integrating Frameworks and Build Tools with the ArcGIS API for JavaScript

By Andy Gup and Julie Powell

If you use the ArcGIS API for JavaScript with a third-party framework such as Angular or React or create custom builds of the API, this process just got easier. The release of version 4.18 in December introduced a new option for consuming the ES modules, which work natively in the browser, are built to the latest ECMA standards, and allow seamless integration with modern frameworks and build tools.

How Was the API Consumed Before ES Modules Were Available?

The API has always been available as Asynchronous Module Definition (AMD) modules, and it continues to be available as AMD modules for developers who prefer this format. If your app references Esri's content delivery network (CDN) to access the API via `https://js.ArcGIS.com/<API version number>`, you are using the AMD version.

Understanding AMD and ES Modules

With both AMD and ES modules, API functionality is divided into logical subsets and packaged as modules. AMD modules use a `require()` method and a third-party script loader to load modules and their dependencies.

ES modules are an official, standardized module system that works natively with all modern browsers through `import` statements. ES modules do not require a separate script loader. An example showing the differences between the two coding patterns is shown in Listing 1.

```
import MapView from '@arcgis/core/views/MapView';

require(["esri/views/MapView", function (MapView) { ... }]);
```

↑ Listing 1

Should You Migrate to ES Modules?

If you aren't integrating with a framework or creating custom builds of the API, there is no need to migrate to the new ES modules. The AMD modules will continue to be available alongside the ES modules for the foreseeable future. Both formats have the same capabilities because they are built from the same code base.

AMD modules are hosted on the CDN and therefore offer these benefits when accessing the API in this manner, as opposed to creating custom builds:

- Fast download and highly optimized caching for API modules
- No installation or configuration required
- It is easy to update applications to the next API version

If you are integrating with a framework or creating local builds, you should consider using ES modules. This will simplify your implementation as ES modules do not require a separate script loader or additional configuration. When using AMD, you typically either use a webpack plugin to integrate the API into your webpack build or use `esri-loader` with framework tools or other bundlers.

Note that you will still want to use AMD modules when creating local builds if your app uses Dojo1 or RequireJS.

Get Started Using ES Modules

Whether you are creating a new application or integrating the API in an existing application, the first step is to install the API using npm with the following command:

```
npm install @arcgis/core
```

Then use import statements to load individual modules. Note that the ES modules package naming convention uses /core rather than /esri, which is used by the AMD CDN modules, as shown in Listing 2.

```
import WebMap from '@arcgis/core/WebMap';
import MapView from '@arcgis/core/views/MapView';
```

↑ Listing 2

Copy Assets

You will need to copy the API assets (which includes styles, images, fonts, pre-built API web worker JS files, and localization files) from the @arcgis/core/assets folder to your build folder. A simple way to accomplish this is to configure a Node Package Manager (NPM) script that runs during your build process. For example, use npm to install ncp and configure a script in package.json to copy the folder. See the React example in Listing 3.

```
// package.json
{
  "script": {
    "start": "npm run copy && react-scripts start",
    "build": "npm run copy && react-scripts build",
    "copy": "ncp ./node_modules/@arcgis/core/assets ./public/assets"
  }
}
```

↑ Listing 3

Configure CSS

The final step is to set up the CSS. Choose a theme and then configure your code to copy the theme files from @arcgis/core/assets/esri/themes/ into your project. Listing 4 provides a React example. Now you can run your build and the API's ES modules will be bundled along with all your other imports.

```
// React - Index.js
import '@arcgis/core/assets/esri/themes/dark/main.css';
```

↑ Listing 4

Refactor Code, If Necessary

If you previously used AMD with esri-loader or arcgis-webpack-plugin and want to migrate to ES modules, review the "Build with ES modules" help topic in the JavaScript API Guide for the code changes required.

Documentation and Examples

For an introduction on developer tooling and your choices when it comes to consuming the API, please visit the JavaScript API Guide and see the Developer Tooling pages. You can find examples that integrate ES modules with frameworks and build tools in the jsapi-resources GitHub repository (<https://bit.ly/2VNpmEO>). This includes integration with Angular, React, Ember, Node, Vue, Rollup, and Webpack.

Road Map for ES Module Migration

At version 4.18, ES modules were released as beta. The production release is planned for early 2021. If you try the modules while they are in beta and they meet your app's requirements, you can use them in your app. The modules have been broadly tested but they are still considered provisional as they could change based on feedback or an improved design.

ES modules are covered by Esri Technical Support while they are in beta so you can obtain support as needed. If you have feedback on the modules, associated documentation, or sample code, you can submit your comments or questions to the early access repository at <https://github.com/Esri/feedback-js-api-next>.

Summary

If you are using a framework or creating custom builds, use ES modules to make your development work easier. If you are not using a framework or creating custom builds, you don't need to do anything.

About the Authors

Andy Gup is a senior product engineer on the ArcGIS API for JavaScript team, who works on third party JavaScript frameworks and mobile apps. He has been with Esri for more than 15 years.

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Features and Capabilities in the New ArcGIS API for Python

By Atma Mani

The 1.8.3 release of the ArcGIS API for Python adds a slew of new features and capabilities. Over the last few years, it has expanded and now includes several different modules and more than 2,300 methods and functions.

The ArcGIS API for Python is designed to serve a wide spectrum of users, including GIS administrators, Python developers, and data scientists. The API can be used for tasks like administering web GIS; publishing, updating, and cloning a wide variety of GIS data; building sophisticated analytical models; and automating mission critical workflows.

Framework Improvements

One of the biggest improvements performed behind the scenes was migrating the HTTP communication modules to use Requests (a popular third-party module) from a built-in urllib module. There is no change to your scripts, except that Esri can now better support some custom and complex authentication systems. For JSON parsing, Esri switched to UltraJSON, a faster JSON decoder and encoder. These changes improve support for fundamental features, such as multipart uploads, while extracting performance improvements. In addition, support for Python 3.8, JupyterLab 1x and 2x, and Pandas v1.0 was added.

GIS Administration

ArcGIS Notebooks and the Notebook Server play a key role in enabling the spatial data science capabilities of ArcGIS. The ArcGIS.gis.nb module has been enhanced, allowing you to manage instances of Notebook Server that are running and inspect their properties. This module also enables powerful workflows such as executing notebooks on demand and scheduling notebooks. Plans include support for managing different versions of these items.

There are numerous small updates and fixes to other parts of the GIS administration API. When creating users, administrators can now use smart defaults they have defined for their organizations. The new ArcGIS Online Usage Reports class allows better compilation of usage reports in ArcGIS Online, something users have been asking for.

On the security front, the API now supports authentication using API keys. This new login mechanism targets GIS developers; more information will be released in the coming months.

Content Management

The new ArcGIS.apps.dashboard module lets users create ArcGIS Dashboards apps using Python. Many data scientists want a medium that is simpler than notebooks to communicate results. This module can help them quickly compose such apps.

Content migration and cloning are important workflows for users. The new GroupMigrationManager workflow allows group administrators to migrate content from one group to another across organizations.

Long-term users of the API who are familiar with the clone_items function that is native to the Python API will find that it has been enhanced to support additional app types along with various bug fixes.

This release also adds new publishing workflows such as publishing directly from content deposited into a data store and the ability to set desired item IDs for certain workflows and environments.

On the Open Geospatial Consortium (OGC), Inc. and Free and Open Source Software for Geospatial (FOSS4G) fronts, Esri has added the ArcGIS.mapping.ogc sub-module to work with OGC layers. Another exciting development is the ability to directly read in-memory GeoPandas GeoDataFrame objects into ArcGIS. The API now supports reading GeoPackage files and newer columnar file formats such as feather. Esri is researching new patterns to increase the performance of Spatially Enabled DataFrame (SeDF) objects.

Spatial Analysis

You can now pass SeDF objects as inputs to spatial analysis tools, allowing you to easily enable

california_wildfires_2017_thomas_fire_analysis (unsaved changes)

Analysis Files Share Info Save

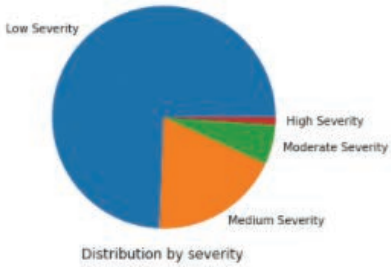
File Edit View Insert Cell Kernel Help Python 3

Out[40]: **Thomas fire has consumed 307,428 acres till 2017-12-25**

In [41]:

```
import matplotlib.pyplot as plt
%matplotlib inline

plt.title('Distribution by severity', y=-0.1)
plt.pie(histogram, labels=['Low Severity', 'Medium Severity', 'Moderate Severity', 'High Severity']);
plt.axis('equal');
```



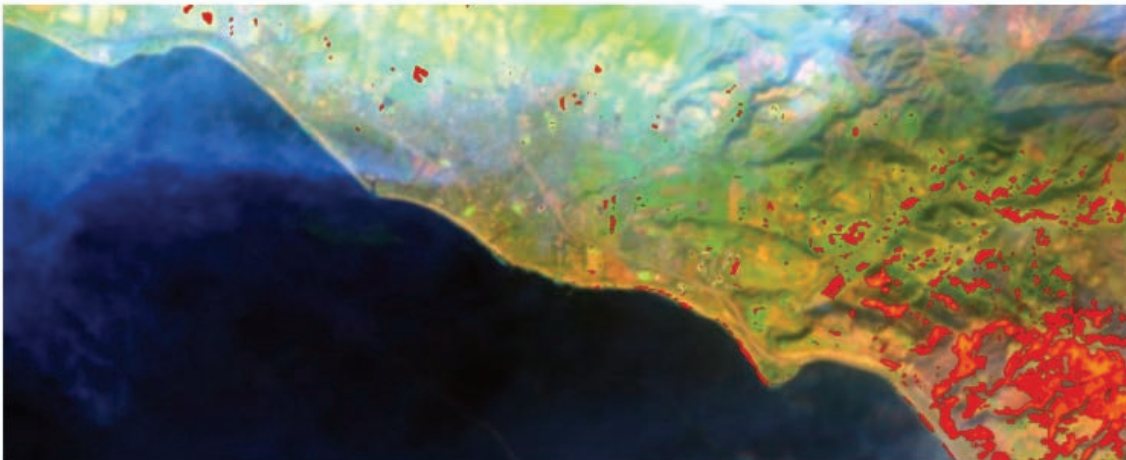
Low Severity High Severity Moderate Severity Medium Severity

Distribution by severity

Visualize burnt areas

In [88]:

```
m = gis.map('Carpinteria, CA')
m
```



In [43]:

```
m.add_layer([midfire, burnt_areas])
```

data engineering workflows that use the powerful ready-to-use tools for spatial analysis in your Web GIS. Another feature is the ability to sanitize column names (i.e., cleaning column names by converting them to strings, removing special characters, and renaming columns) before saving the DataFrame.

SeDF objects now support a new `renderer` property to store symbology or drawing information. When reading a feature layer, the renderer will pick up the symbology defined on that web layer and

utilize it to visualize the layer on a map. You can override it with custom symbols at any time.

Now almost all web tools in the Python API support asynchronous processing. Async processing allows you to submit big and long-running tasks to the server and get back a `GPJob` object. This essentially frees up the Python kernel so subsequent commands can run while the server keeps working on the submitted job. The job object can be polled anytime to know its status or cancel the job.

Raster Analysis

Esri added two new classes—Raster and RasterCollection—that allow you to work with a wide variety of imagery data in a seamless manner. You can read and work with local file-based raster data and publish it as imagery layers (services). When you read local raster data, the API chooses ArcPy as the processing engine. When you read an image service, it uses the ArcGIS Image Server as the back-end engine. This allows you to work with the same API, no matter where the data is stored and/or processed on the back end. New raster functions and distributed raster analytics tools for applications, such as trend analysis, multidimensional analysis, and change detection, have been added.

Deep Learning

The ability to train deep learning models for

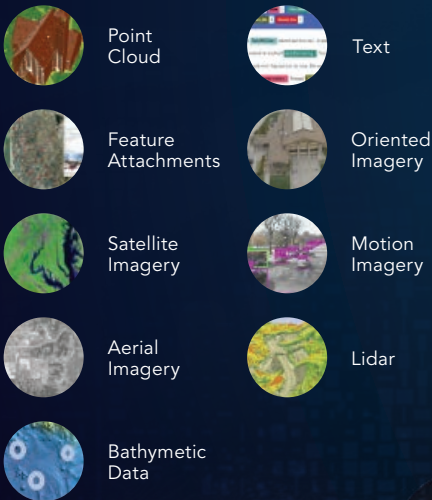
geospatial applications using the ArcGIS.learn module is a significant feature of the API. It supports more than 30 models for various advanced workflows. These models can work with a wide variety of data such as planimetric and oriented imagery, point cloud, feature, tabular, time-series data and unstructured text. This release adds models for key workflows such as edge detection, change detection, road extraction, and image translation.

A new computer-vision model allows users to go from scanned paper maps to georeferenced vector layers. This release challenges the common myth in the geospatial industry that deep learning is suitable only for imagery data by innovating with models that work on tabular and time-series data.

The FullyConnectedNetwork model allows

Deep Learning New model and tools

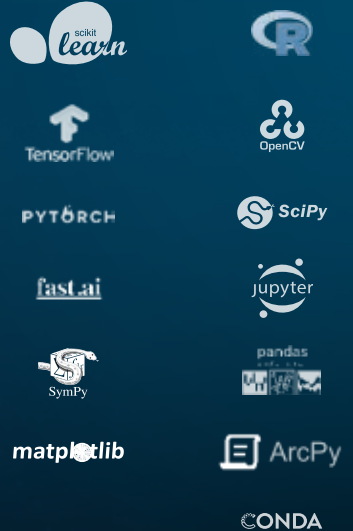
Data Types



Tasks



Integration



users to feed tabular and raster layers into a deep neural network, letting it learn and model even the most complex of patterns. The `TimeSeriesModel` allows you to perform time-series forecasting.

The new `MLModel` class allows you to integrate machine learning models from the popular `scikit-learn` library and the new `ArcGIS.learn.text` submodule, which has models for natural language processing (NLP).

What does NLP have to do with GIS? For starters, you can extract addresses and location information from unstructured text, predict missing parts of an incomplete address, and autocorrect errors in addresses, making them suitable for geocoding.

To simplify the installation of the libraries and frameworks needed for deep learning, Esri has added new deep learning installers for ArcGIS Pro and ArcGIS Enterprise and a new `conda` metapackage for independent installation.

A significant addition around this release is the availability of ready-to-use deep learning models in the ArcGIS Living Atlas of the World. [To learn more about these models, see “Ready-to-Use Geospatial Deep Learning Models,” also in this issue.] Since these models have been previously trained by Esri, they eliminate the tedious and data-intensive task of cleaning and preparing the large volumes of data necessary to train models or procuring the hardware necessary for such tasks. Instead, you can simply download the models and perform inference.

Mapping and Visualization

The map widget in Jupyter Notebook can now link with other map widgets in the same notebook. This allows you to synchronize navigation between two or more widgets to load and visualize different layers side by side for the same extent. Once linked, any interaction in one of the linked maps will cause other maps to update. The synced navigation works with 2D and 3D modes of widgets, so both perspective and planimetric rendering of the same study area can be viewed.

In addition to static map images, live, interactive versions of a map can be embedded in a notebook. When exporting a notebook as an HTML file, maps can be embedded as static images or dynamic web maps. If a map in a notebook is not big enough, use the export to HTML function to

generate a full-size web page of your map.

Local file-based raster files can be loaded on the map widget by adding the new `Raster` class as a layer to a map and easily visualize imagery and raster data.

JupyterLab IDE versions 1x and 2x are supported. Search for the ArcGIS extension within the JupyterLab IDE and easily install it.

Documentation

Older guides were replaced in 2020 with comprehensive, tutorial-style Notebook guides for network analysis, geoenrichment, orthomapping, and the geometry modules. These guides provide foundational information followed by a layout diagram that describes the parts of the module and how they work with the rest of the API. These guides are numbered to aid new users.

Esri has also embarked on a long-term project to improve the API reference by adding contextual snippets for parameters, cross-referencing keywords, schematic images for certain tools, and example Python scripts.

The Try-it-Live samples experience for the API has now been migrated to ArcGIS Online at <https://bit.ly/2Mgo9Eo>. These sample notebooks run in ArcGIS Online—simply log in and test-drive them.

Conclusion

The members of the Python API team are passionate about what they do and are determined to bring you a first-class Python API for geospatial analysis.

Ready to try out the new API? You can upgrade by typing “`conda upgrade-c esri ArcGIS`” into your `anaconda` prompt.

Thirsty for more details? Check out the release notes at <https://bit.ly/3pAn20J>.

About the Author

Atma Mani is a principal and lead product engineer for the ArcGIS API for Python at Esri. He has over 13 years of experience working for private, academic, and government research institutions, applying different facets of geospatial technology. He holds a bachelor's in engineering from the College of Engineering, Anna University, India and a master's degree from the University of Northern Iowa.

Ready to try out the new API? You can upgrade by typing “`conda upgrade-c esri ArcGIS`” into your `anaconda` prompt.



Regional Data Platform Strengthens Collaboration and Cooperation

By Stephen Goldsmith

Throughout his career, Rex Richardson has not only spoken about the public service ethic, he has embodied it. He began a fruitful and service-oriented career as student body president at California State University, Dominguez Hills and then continued as a Service Employees International Union (SEIU) leader. He currently spends his days advocating for more equitable public policies as a Long Beach city council member.

Richardson also serves as president of the Southern California Association of Governments (SCAG), the largest—and arguably most successful—council of governments in the country. It serves six counties, 191 cities, and 19 million residents.

SCAG is undertaking one of the most significant and ambitious cross-jurisdictional mapping initiatives in the country, the SCAG Regional Data Platform (RDP). When asked to highlight his primary goals for RDP, Richardson focused not on the technical details, but instead referenced how it will further his commitment to equity, inclusion, and transparency.

Richardson explained that “lots of times positive outcomes seem elusive, and a major reason for that is because policy makers fail to collect and visualize all the relevant data, particularly demographics. Data platforms should be a tool, a solution to help local and regional governments chart a course forward and track progress as well.”

The geographers whose technical abilities facilitate major policy

breakthroughs should be able more often to hear the language of the “electeds” who apply the insights in words similar to those used by Richardson. More often, senior officials should be shown the potential of ArcGIS applications. With the RDP, SCAG will enable both to occur.

SCAG’s Future Communities Initiative, a plan to deploy smart-tech and use data analytics to reduce traffic and improve air quality, led to a commitment to build RDP, which will bring together information from members on demographic, economic, land-use, and transportation data. RDP will provide technical resources for in-depth analysis locally and regionally.

Two factors drive SCAG’s ambitious mapping goals. The first is a recognition that technology was driving major changes in the region. The second is that the data captured using new technologies is growing rapidly and exponentially. The organization’s local government members needed assistance harnessing the constantly changing technologies and data to help cities prepare for the future.



↑ The Southern California Association of Governments (SCAG) is the largest council of governments in the country, which serves six counties, 191 cities, and 19 million residents. (Photo of the City of Long Beach provided courtesy of SCAG)

Darin Chidsey, SCAG's chief operating officer (COO), helps both the organization, which also serves as the region's metropolitan planning organization (MPO), and its members conduct more strategic planning activities. He points with pride to the fact we "have approached our role as a regional policy center where we can be a resource to help cities plan for a long-term sustainable future. And so the regional data platform initiative is a revolutionary system for collaborative data sharing and regional government. The well-being of the region is ultimately tied to the ability of local jurisdictions to plan for their own futures and share those plans in the form of land use."

In addition to its prime responsibility of enabling better planning at the local and regional level, the underlying Esri GIS-based RDP furthers multiple goals that include streamlining data sharing, improving transparency and collaboration, and creating equitable outcomes.

Streamline Data Sharing

RDP serves to streamline the data sharing process between member cities and SCAG. With this platform in place, both SCAG and local jurisdictions will have access to the same up-to-date, robust data for planning purposes. Chidsey underscored the importance of data standardization and usability of data when he emphasized that these features should be a "core function of the

platform," to support multi- or cross-jurisdictional transportation and city planning where plans and actions in one city can impact outcomes in another. Chidsey likens his team's potential to that of a good baseball team during spring training. His team has lots of potential but requires more practice and analytics. He said that the opportunity for participating cities to build on baseline data provided by RDP by continually incorporating other data elements over time will create value for all member cities.

Improve Transparency and Collaboration

The map-based planning platform will also provide opportunities for transparency and collaboration between member cities as well as with SCAG. Richardson painted the picture of why this is so important. He explained the current process for collaboration, and how the RDP will help to improve it.

Currently, every city in California is responsible for drafting its own general plan. General plans, according to Los Angeles City Planning, "serve as blueprints for the future, describing policy goals and objectives to shape and guide the physical development of the city." While each city has its own plan, general plans are the individual puzzle pieces that fit together to bring the region into focus.

For Chidsey, as SCAG's COO, a major benefit of the initiative is that it will increase the ease of data sharing and collaboration between municipalities as they develop their general plans, while



SCAG develops the coordinated Regional Transportation Plan/Sustainable Communities Strategy. He noted that the regional plan represents the “an aggregation of a lot of data sources—we know our cities have the best data on their area and so this will ease the process of sharing it and increase access to each other’s information.” Beyond improving ease of access, this platform will allow data sharing to flow more freely and continuously with minimal interruption to any city’s operations.

Collaboration built on spatially oriented data sharing also increases cooperation in day-to-day governance, not just within cities but between them. When the issue is high-quality transit or good jobs or sustainability policy agendas, politics can interfere in the policy making process. In those situations, SCAG’s joint planning efforts require parties to work with the same data to help overcome differences.

Using shared data enhances the chances the parties will use the same language, helping create a symbiotic relationship between regional planning and local planning as well as benefiting the individual jurisdictions that can more easily access data from neighboring communities as well as the entire region. Cities can plan within the context of a larger, more interconnected system.

Richardson and Chidsey both highlighted the ability of a common data platform to create shared narratives that help to build consensus and a sense of responsibility to work together to achieve mutual goals. With GIS and maps, they said “well-visualized spatial data can change the conversation and power collective actions.”

↓ SCAG Regional Data Platform (RDP) streamlines data sharing between member cities and SCAG and gives access to the same up-to-date, robust data for planning purposes.



“Data platforms should be a tool, a solution to help local and regional governments chart a course forward and track progress as well.”

Collaboration in government through platforms like RDP can occur at multiple levels in ways never possible before, but it’s not just about collaborating with government. For SCAG, collaboration between government and residents and community groups is equally, if not more important. Their voices should inform planning and governance.

By allowing direct engagement with planners, residents will benefit from the transparency and high-quality visualization provided by the platform. SCAG plans broad use of Esri tools including story maps, public survey applications, 3D visualization, and digital twin modeling. SCAG developed an effective story map (<https://bit.ly/3f8y1dH>) that describes RDP and explains its importance.

Richardson said SCAG is piloting an engagement program using these tools and he has already seen their value to create shared narratives. “This [platform] will allow us to all have one conversation about the most important issues that face our region from housing to transportation to jobs. We can focus on these issues from an equity standpoint and to collaborate and engage civically around this platform,” said Richardson.

“For example, we have an innovative collaboration program that we’re deploying this fall that challenges nontraditional partners and community-based organizations to apply for grant funds for housing production in partnership with jurisdictions or within communities. And I would imagine that as the data platform is launched, you will see more applications from community-based organizations speaking the same language that SCAG speaks so that we can track the impact of these innovative programs and how they impact our vision and core goals.”

Create Equitable Outcomes

Once the potential power of RDP is understood, its connection to addressing equity concerns becomes clear. Sharing data, being transparent, and using spatial visualizations to enhance a shared narrative will keep a community engaged and can help overcome the NIMBY (not in my backyard) effect that occurs in more balkanized and opaque approaches.

Richardson emphasized this valuable aspect. “Patterns of disparity result from aspects of a system that need to be changed, and the only way to shift that system is to present alternative systems based on data. Equitable outcomes are elusive, just like other policy goals because we often fail to account for data, demographics, and rates of disparity. And so once we have the same common denominator, we can begin to track our outcomes. A data platform and data in general is not the end, it’s the means to the end—the language that we’ll all need to use in order to actually chart and track a path to a more inclusive society.”

These GIS tools will provide context to difficult discussions that often involve social factors but after the platform becomes



↑ RDP promotes direct engagement with planners so that residents will benefit from the transparency and high-quality visualization provided by the platform. (Photo of the City of Glendale provided courtesy of SCAG)

operational SCAG realistically hopes it will “allow big data to be the lens or the backbone of the conversation from which we can extract real fact-based insights that further better decision-making amongst multiple stakeholders who need to make decisions based on what they feel is truly best for their own communities.”

Shared Service and Data Uptake

While it may seem less glamorous at face value, one of the most transformative features of SCAG’s approach is its work assisting member cities in better utilizing technology generally and ArcGIS specifically. Its Open Data/Big Data committee focused on how SCAG could provide resources and supporting data tools after it found that nearly 75 percent of members responding acknowledged that they lacked the financial and staff resources to support data and technology projects.

SCAG’s role now explicitly includes facilitating use of the regional data platform including helping members develop the data and analytic capacity necessary for insights. One benefit that Chidsey sees is that these services will help level the playing field for all member agencies, regardless of their current capacity.

An exciting aspect of the shared service work will be that as members use the tools, they will understand their power and increasingly apply them in more and deeper ways. This virtuous cycle of RDP and ArcGIS usage will drive substantial public value.

Increased value will come not only from access to the tools, but also from grants made to members as well as providing Esri licenses to assist local governments in planning that supports transit, housing, or economic opportunity.

Over the last decade, this large council of governments has developed a track record of providing technical services starting with GIS training, analyses, and hardware to cities that lack necessary capabilities. SCAG’s nationally significant work brings home the fact that government organized to serve its residents must plan and operate recognizing the importance of place.

About the Author

Stephen Goldsmith is the Derek Bok Professor of the Practice of Urban Policy and the Director of the Innovations in American Government Program at Harvard Kennedy School of Government. He previously served as Deputy Mayor of New York and Mayor of Indianapolis, where he earned a reputation as one of the country’s leaders in public-private partnerships, competition, and privatization. Goldsmith was also the chief domestic policy advisor to the George W. Bush campaign in 2000, the Chair of the Corporation for National and Community Service, and the district attorney for Marion County, Indiana from 1979 to 1990. His most recent book is *A New City O/S: The Power of Open, Collaborative, and Distributed Governance*.

Explore Your Data First

By Lisa Berry and Jim Herries

So many times, tutorials depict the mapmaking process as a guided and regimented step-by-step process, but this isn't what the process is like at all.

Every great map starts with a purpose. But how can you choose a purpose for your map if you don't understand the data? After spending an incredible amount of time finding, processing, and analyzing data, you can run out of energy by the time you need to use it to tell your story.

In most cases, you have no idea what to expect from the data. You might find this unsettling, but it can be an opportunity to create a map with a new perspective.

Anyone can drop some data onto a map and call it a day. The internet is full of maps like that. Don't do that. Ask more of the

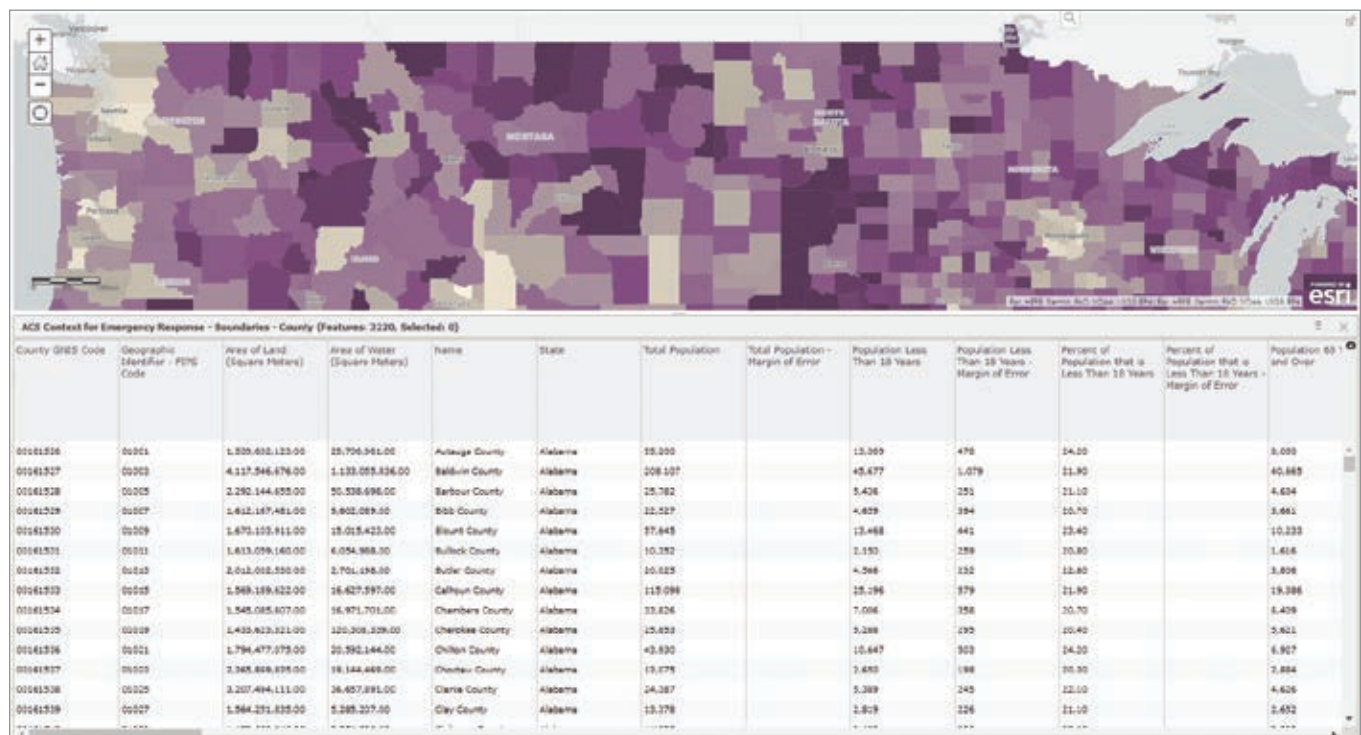
data and of yourself. Challenge yourself. Take an extra five minutes (or more) to explore your data in ArcGIS Online. This exploration can lead to better maps, more informed cartographic decisions, and more meaningful narratives about the data you spend so much time preparing.

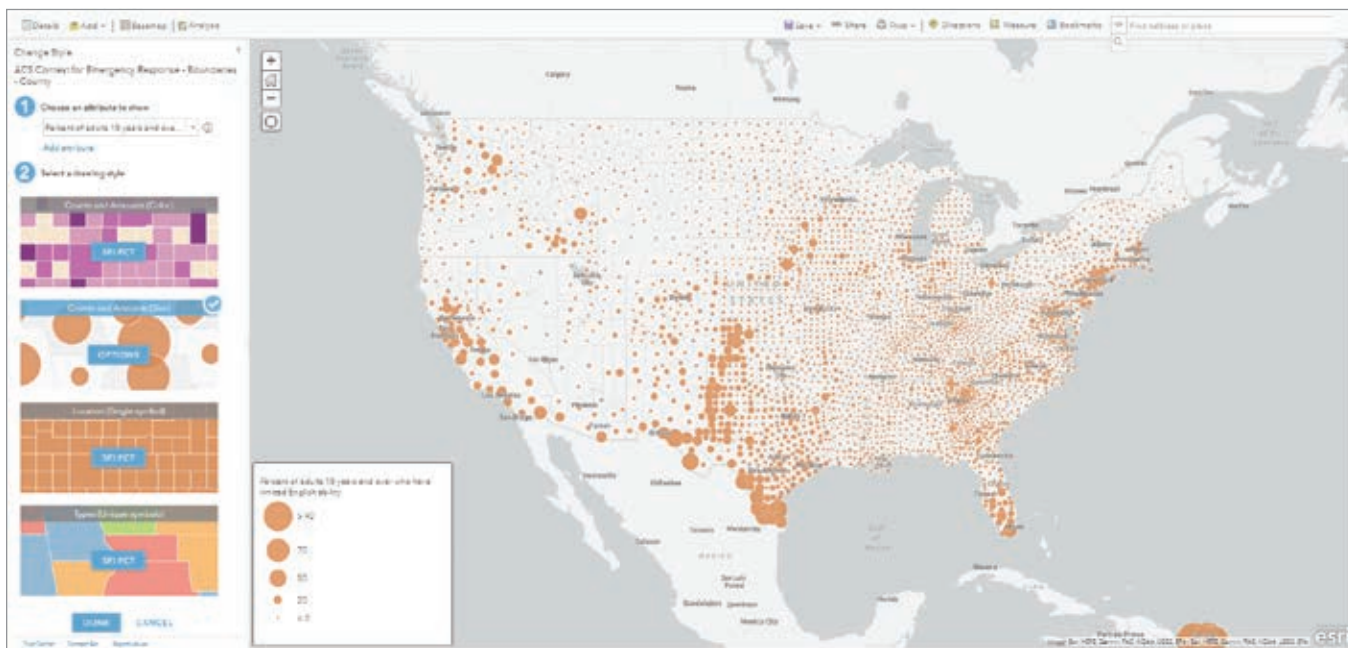
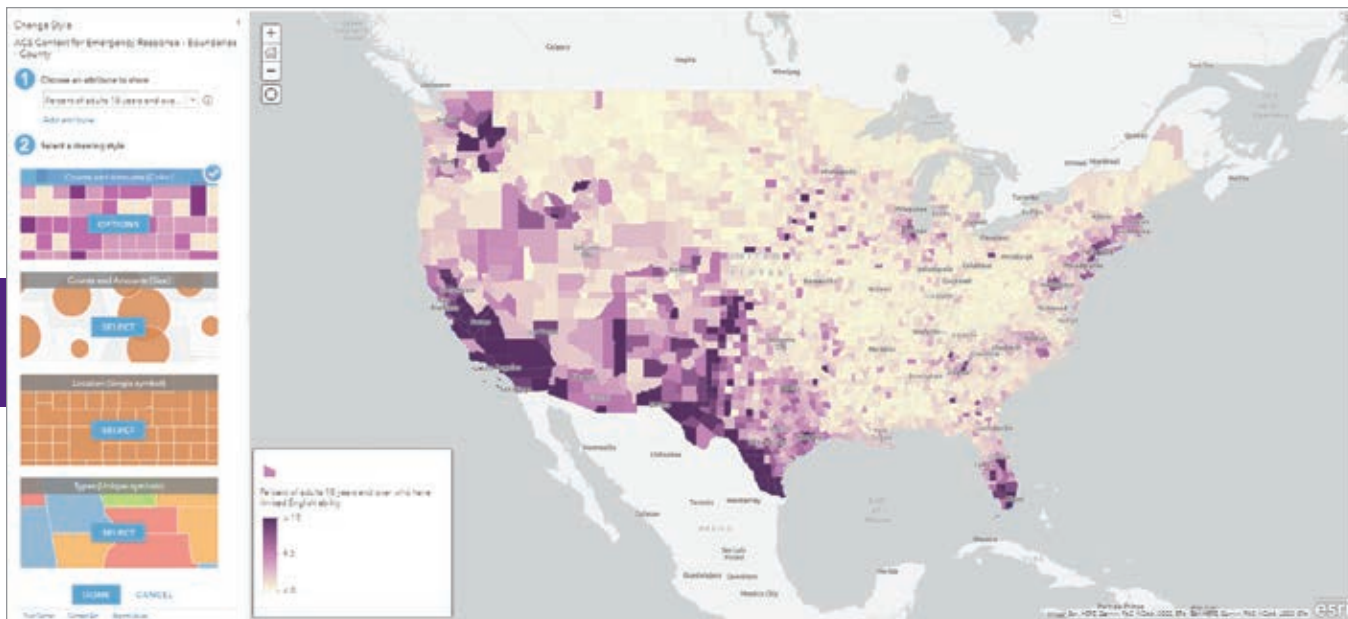
For example, you may want to better understand which parts of the country are at higher risk when evacuation orders are necessary in response to natural disasters such as hurricanes, fires, or floods. Or perhaps you are interested in visualizing patterns related to poverty, non-English-speaking

populations, and households without a vehicle because these are indicators of populations that are at risk during evacuations, when time is short and every minute counts.

Here are some easy ways to explore a spatial dataset you have never seen before. You can follow along by opening the ACS Context for Emergency Response—Boundaries web map (<https://bit.ly/3lqeZkF>) that is available from the ArcGIS Living Atlas of the World in ArcGIS Online. This layer contains demographic data from the most recent American Community Survey (ACS) that is provided by the US Census Bureau.

↓ Browsing attributes is the foundation of your understanding of a dataset.





↑↑ Start your exploration of the attribute “Percent of adults 18 years and over who have limited English ability” by using the default mapping style for a numeric attribute, Counts and Amounts (Color).

↑ After switching to the Counts and Amounts (Size) option, there is still a pattern, but it is a bit harder to differentiate areas with at-risk populations.

Browse the Attributes

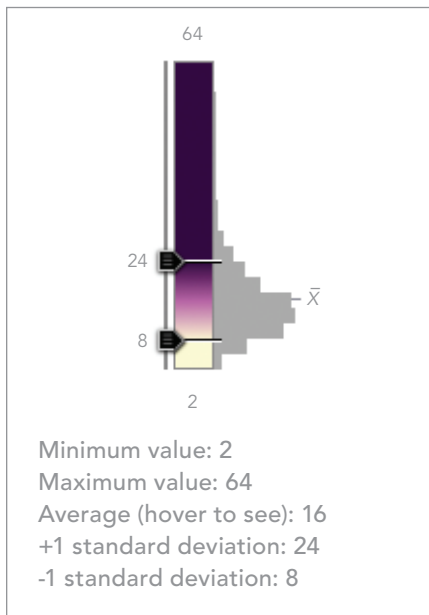
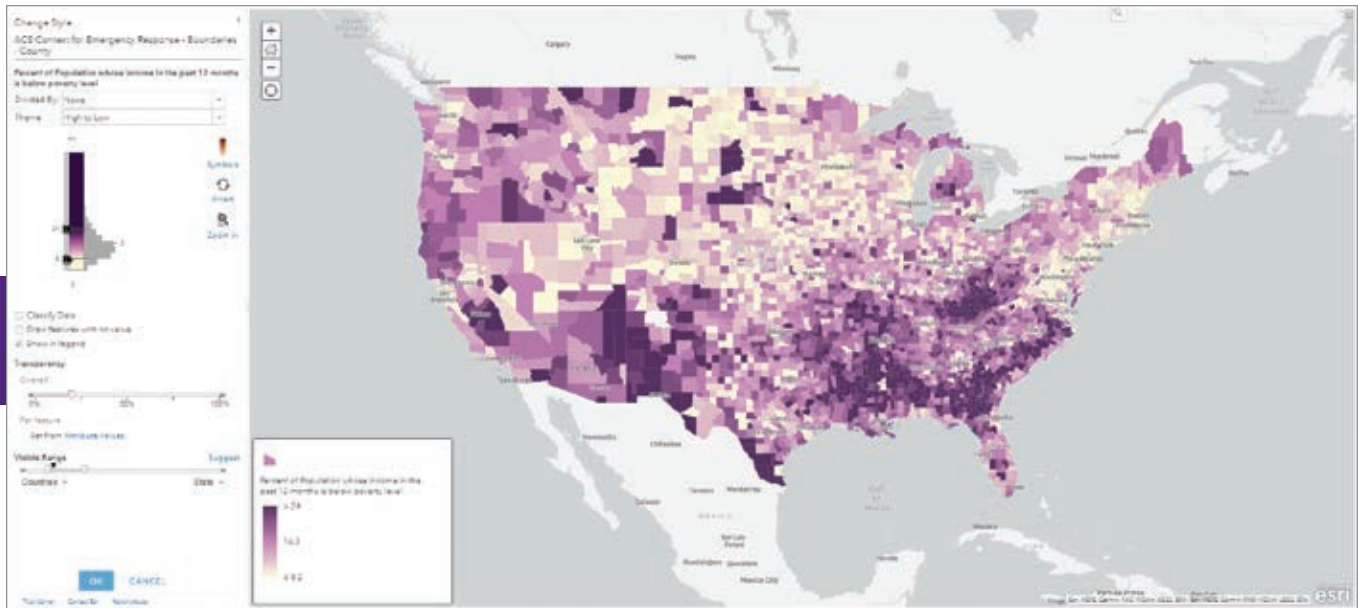
Open this layer and you will see three layers—state, county, and tract—in the table of contents. Start by viewing the counties to see what nationwide patterns emerge during data exploration. Change the basemap to Light Gray Canvas. When you explore the data on a neutral light gray basemap, the colors won’t compete with the basemap as you try new things.

Although this may sound obvious, browsing attributes is the foundation of your understanding of a dataset. Because this dataset was created by a government agency, it won’t be as familiar as a dataset you created yourself.

Start exploring the table to see the types of fields (numbers, dates, categorical) it contains. Get a sense of how many records

the database contains. This layer has data on 3,220 counties in the US, including Puerto Rico and Washington, DC. As you scroll through the table horizontally, you will see most attributes are numeric. They cover a wide range of demographic topics that are related to at-risk populations.

Another way to explore the data is to explore the item page for this web map



↑ Explore “Percent of Population whose income in the past 12 months is below the poverty level,” another at-risk group, by clicking the Options button to see the histogram for data on this attribute.

← The histogram helps you understand the statistics associated with an attribute.

attribute represents the population who sometimes or always speak a language other than English at home. They may be at higher risk during evacuation orders because they may not understand evacuation orders provided in English.

Use smart mapping to immediately see patterns in the map. It’s called “smart” because no matter what attribute you choose, the software recognizes the data type, such as numeric or date, and offers mapping options specific to the data type, making it easy to quickly choose different attributes and try mapping styles that are appropriate.

Although an attribute table helps you see the fields and the values in them, you can often get a better sense of these fields by mapping them. Click Change Style for the County layer and choose an attribute to show. Find the attribute “Percent of adults 18 years and over who have limited English ability.” Since this is a numeric attribute, Counts and Amounts (Color) is the default mapping style. The map shows the location of distinct areas that have at-risk populations.

Switch to the Counts and Amounts (Size) option. There is still a pattern, but it is a bit harder to differentiate areas with at-risk populations. Click the Options button

to see the distribution of data values. It shows an outlier is reducing the variation of symbol size in this map. To overcome this, drag down the upper handle and see how the symbol sizes change.

In general, percentages work well when mapping with color, but size is usually more appropriate to use when mapping a count such as the number of adults 18 years and over with limited English proficiency. Trying different styles helps you decide how to map this attribute.

Since it is easy to try different attributes and styles, spend a few minutes scrolling through the list of attributes and mapping different attributes that you find interesting. You may be surprised at what you find. You don’t need to have a plan, but this initial discovery should help inspire you to get started. You may even discover another attribute that helps support your map’s purpose.

Tip: If you don’t know what the attribute means, click the “i” icon next to the attribute to see the long descriptions that are included for each attribute in this layer.

Let Statistics Tell You Something

Smart mapping in ArcGIS Online not only recognizes the types of attributes and offers appropriate mapping suggestions, it

also shows you statistically significant patterns by default

If you choose a numeric attribute and choose map by color, the map will automatically highlight areas in your data that are plus or minus one standard or significant deviation, which makes it easy to quickly see patterns. Explore another at-risk group in this layer by finding the attribute “Percent of Population whose income in the past 12 months is below the poverty level.” Click the Options button to see the histogram for this data.

Simply by choosing an attribute of interest, you can learn which parts of the country have significantly high rates of poverty (i.e., a rate of more than 24 percent). These areas are shown in the darkest shade of purple.

You can also use these statistics by trying out different themes. Themes can help emphasize significant patterns by drawing focus to outlier values or values that make up the bulk of the data.

If you use the Above and Below theme on

your map, it will adjust the colors to show which parts of the country are either above or below the average value for poverty for counties, which is 16 percent. This emphasizes areas of need, shown in orange.

Don't Be Afraid to Try Things (and Sometimes Fail)

This may be the most important step in data exploration. If you limit yourself to the defaults that are given, you may never reveal the most interesting patterns hidden in your data. The Options button is your best friend and will open a world of possibilities and tools for exploring. You won't make the perfect map in your first few clicks and don't be afraid to make some ugly maps along the way.

Try different basemaps, color ramps, symbols, and themes and have some fun while you are doing it. Through this process, you can end up with multiple maps you like. Save each one and you might notice that the same attribute can be shown in very different ways.

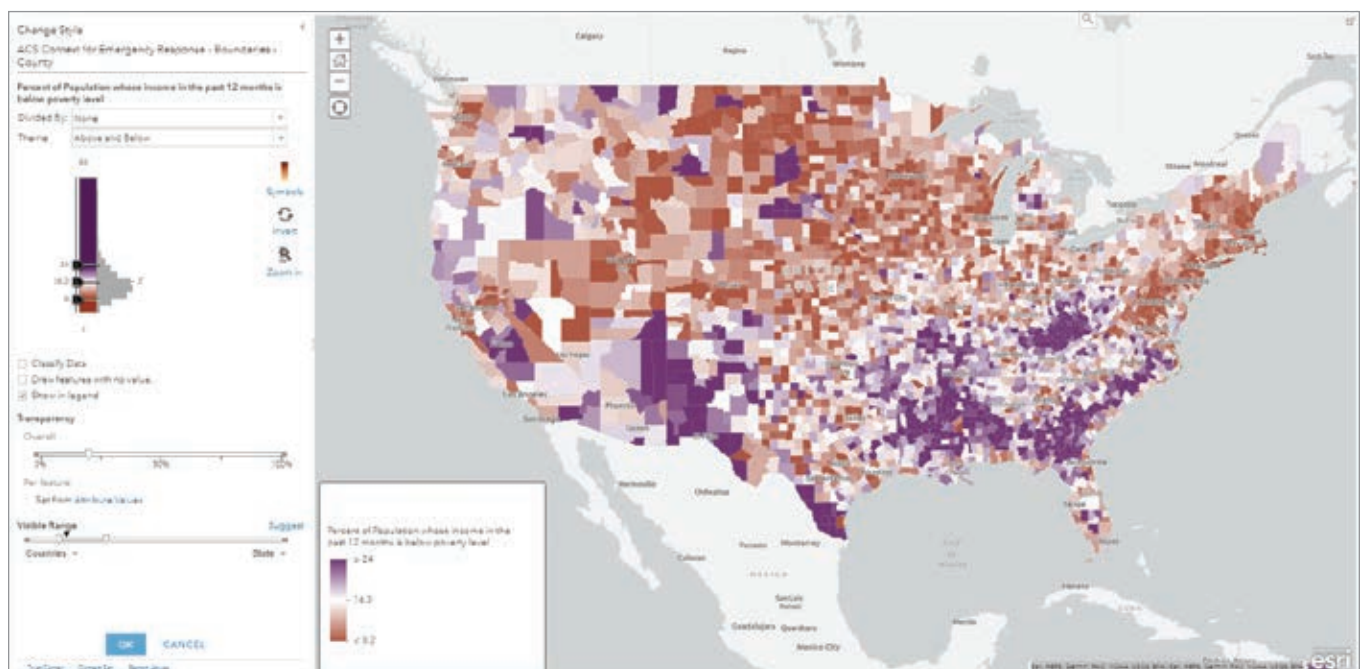
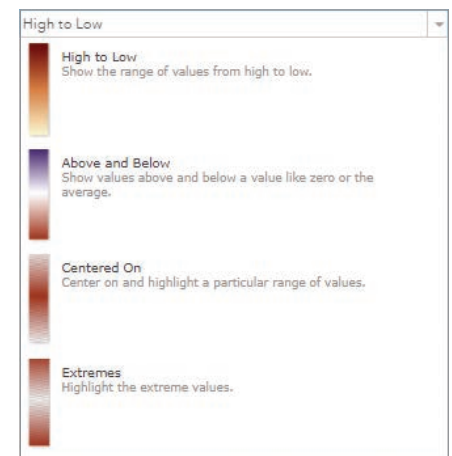
Try Mapping Multiple Attributes

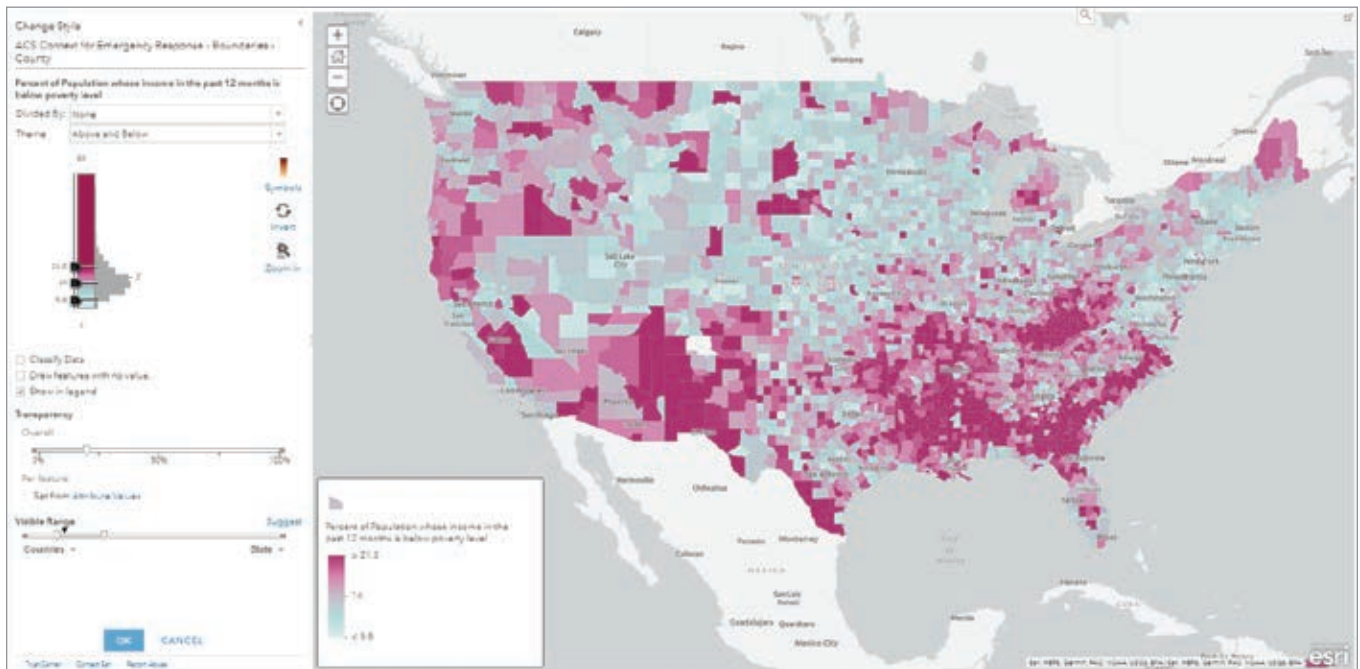
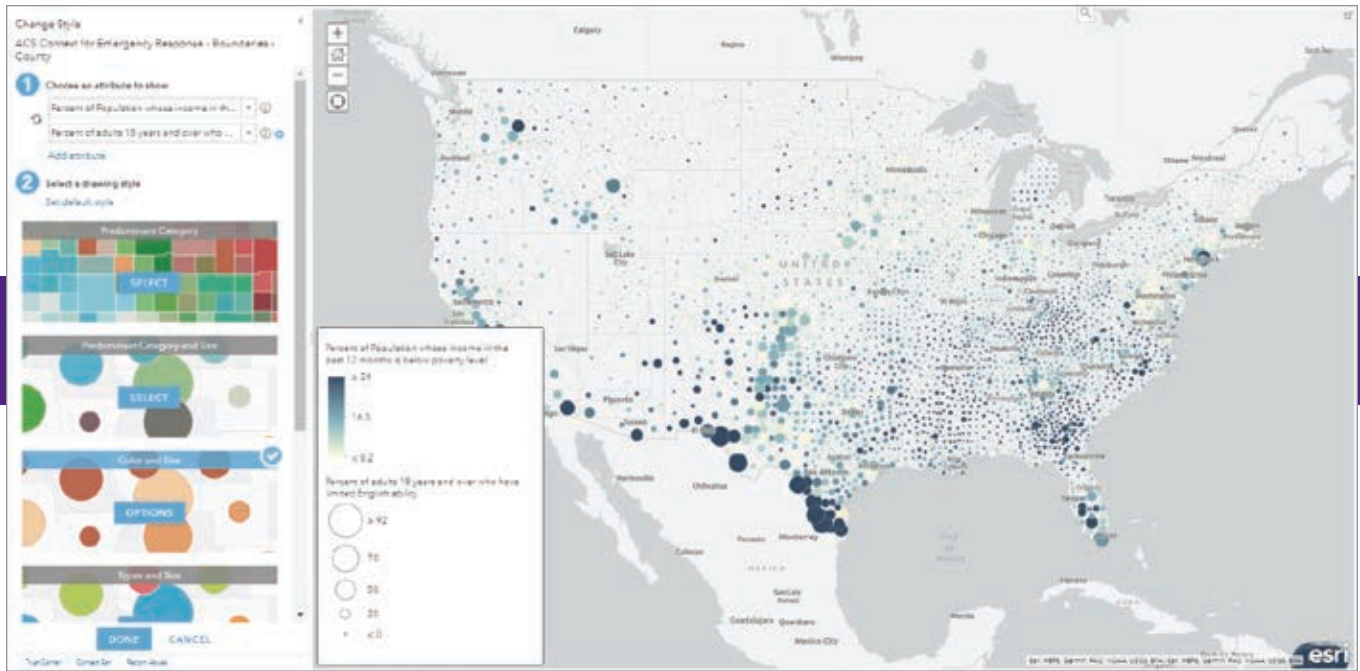
Once you're feeling comfortable with your data and the tools, start thinking about the connections between the different attributes in your data. The two attributes, Percent of households with no vehicle available and Percent of adults 18 years and over who have limited English ability, could be related because in an emergency these could be important attributes to map together since they both present at-risk populations.

Smart mapping also knows what to offer you when you choose two (or more) attributes. These are two numeric attributes, so smart mapping offers color and size,

→ Themes, such as Above and Below, can help emphasize significant patterns by drawing focus to outlier values or values that make up the bulk of the data.

↓ When you use the Above and Below theme on your map, it will adjust the colors to show which parts of the country are either above or below the average value for poverty for counties, which is 16 percent.





↑↑ Percent of households with no vehicle available and Percent of adults 18 years and over who have limited English ability could be related. Smart mapping also knows what to offer you when you choose two (or more) attributes.

↑ Use the Above and Below theme and center the map on the national average instead of the county average to provide more context for the map.

predominance, and relationship styles. Try each one and compare the patterns. See what relationships emerge. Not every option will provide a useful map, but you may see some interesting things along the way. It's all part of the data exploration process.

Here are some more data exploration tips:

- The Color & Size option is good for showing a count and a normalized version of that count. For example, the color can show the percent of poverty and size can show the number of people in poverty.
- Predominance works best when comparing multiple numeric attributes that are counts. For example, an election map compares the count of voters for each party.
- Relationships are a powerful way to compare the patterns of two different numeric attributes such as the counts or percentages for two attributes.

Use Your Knowledge

While technology can help you make better maps, nothing beats the power of the human mind. Smart mapping can get you most of the way there and help you learn new things, but your own knowledge of the world is your most powerful tool.

As you get closer to deciding your map's purpose, bring meaning to your map by establishing if there are values that anchor the map or provide context for it. For example, if you mapped the percent of households in poverty for an area and discover that the value is 16 percent, that is a good start.

However, if the map will be released with a report that references the national average, which according to the ACS is 14 percent, you need to add context and create consistency with the report. Use the Above and Below theme and to center the map around the national average instead of the county average. This gives the map a solid anchor point. Areas below the national average are one color and areas above the national average are in another color, clearly showing areas of deep poverty.

The national average is just one way to anchor the map. Using the same technique, you can set the center color around a threshold, goal, or other meaningful number to create deeper meaning for the colors in your map. If you were interested in showing areas in which more than 10 percent of people are in poverty, you could use the number 10 to anchor the map.

Always Search for Great Maps

Now, zoom in to a city where you see the census tracts, and use the techniques you just used to explore new patterns. Try using different attributes or use the same ones and see what the pattern reveals about a local area.

You should realize that turning data into a purposeful map is a journey, not an event. Making one good map should lead to better questions, which leads to other good maps. It's a virtuous cycle you use to improve your mapmaking.

Putting data on a map is only the beginning because your map has no purpose, only data. A map gains purpose as the mapmaker begins to understand the data, explores it, asks questions of it, and

modifies the map based on answers to those questions.

To learn more about how to add purpose to your map, see the accompanying article, "Mapping with Purpose" in this issue.

About the Authors

Lisa Berry is a cartographic product engineer on the ArcGIS Living Atlas of the World team at Esri. She creates clear and concise stories about demographic data using cartography. Berry also builds data layers and tutorials to help others create

their own map masterpieces.

Jim Herries is a geographer with Esri in Redlands, California. He serves as a principal product engineer on the team responsible for ArcGIS Living Atlas of the World. Herries is particularly engaged in thematic mapping and map visualizations and wants to help GIS users bring their data to life on the map and stimulate insights. He constantly looks for ways to create clear, focused map information products that incorporate meaningful spatial analysis and evocative visualizations.

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Mapping with Purpose

By Heather Smith

You have data, but that's not enough to make a map. You also need a purpose.

There's no point in making a map unless you have something to say. Making a map means making many decisions. Making decisions without guidance is hard. Making decisions toward a goal is easier.

Consider these questions, ones that commonly come up when making a map:

- What should I title this map?
- Which color scheme should I use?
- Should I include this layer on the map?
- Do I need a legend?
- Should I include a chart in the pop-ups?
- What should be the extent of this map?
- What medium should I use to share this map?

Until you've decided on your map's purpose, answering these questions will remain difficult.

A Map without Intent

I made the map in Figure 1 without knowing

what I wanted to say. My lack of intent resulted in an uninteresting map. That's okay!

Experimenting with symbology, making charts, and exploring the attribute table are all important methods you should use to become familiar with your data. Never assume that you already know what your data says, or what you want to say with it. Making different maps is one method for arriving at your intention. *[An accompanying article in this issue, "Explore Your Data First," shares techniques and tips for using ArcGIS Online for exploring your data and gaining a better understanding of it so that you can make maps that have purpose.]*

But it's important to distinguish between the maps you make for yourself—the maps you make to help you explore your data—and the maps you make to share with others. The maps you make to share should be purposeful.

If I stopped my experimenting here and called the map in Figure 1 complete, what messages would be communicated to the reader?

- Blueberries are not grown in the middle of Canada.
- Cumberland County, Nova Scotia, grows a lot of blueberries, considering its size.

Your map will always convey some message. It's important to assess if it's the message you intended.

A Map That Communicates Intent

You can communicate your intended message more clearly if you design the map with that message in mind. If the messages listed above were intentional, rather than accidental, I might arrive at the map in Figure 2. Because I made that map knowing what I wanted to say, I made decisions

↓ Figure 1: This map was made without any intention, which resulted in an uninteresting map.



➤ Figure 2: This map compares Cumberland County to its closest rival, Greater Vancouver, in terms of blueberry production.

➤ Figure 3: This map was designed to show which region grows more blueberries, Quebec or the Maritime provinces.

that led to the following actions.

I added text to emphasize Cumberland County and compare it to its closest rival, Greater Vancouver.

To make it easier to compare the relative colors, I zoomed in on the blueberry-growing regions and cut out the middle portion of the map that was empty.

Removing the middle of the map also helped emphasize the lack of blueberry crops in central Canada.

With its middle missing, the map was a bit disorienting. To compensate, I added a locator map, which also emphasizes the empty center of the map.

Changing the Map's Intent

Consider a different map intention—one that determines which region grows more blueberries, Quebec or the Maritime provinces. This intention is narrower and more focused and it results in a more effective and interesting map.

Except for the basemap and projection, every other decision I made for this map differs from the previous two maps because I was guided by a different goal.

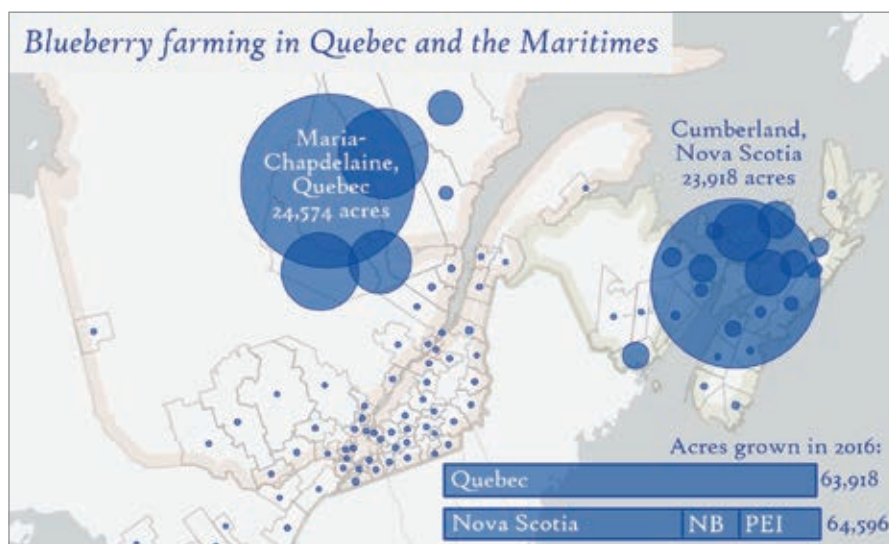
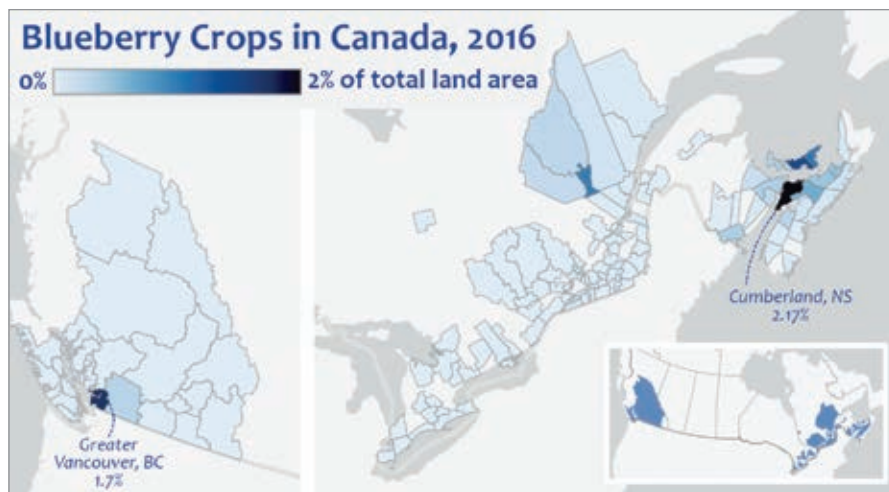
Quebec is large, so showing blueberry crops as a percentage of total land area won't do it justice. By switching to proportional symbols, I can show Quebec as a major player in the blueberry industry.

In 2016, Quebec and the Maritimes were almost perfectly tied for dominance in blueberry farming, so I added a chart to illustrate this.

British Columbia and Ontario also grow blueberries, but they are not relevant to this map's goal, so I didn't show them.

The title is about the intent of the map, not the contents of the data.

I outlined the regions that are being



compared. The colors are faint, so they don't compete with the primary data.

I chose a font that softens the tone of the map to avoid the appearance of competition between the two regions.

Showing a Different Intent

Consider making a map to show that blueberries are the dominant berry crop grown in Canada. For the map shown in Figure 4, comparing blueberries to other berry crops was important. Symbolizing by charts allowed me to do that. Should I even make a map?

If you find that you're fighting with your map to make it say what you want it to say, consider other methods of presenting your data. In the example in Figure 4, do I need to show the geography? Could a single stacked bar chart (shown in Figure 5) convey

my message more clearly? Sometimes the best map isn't a map.

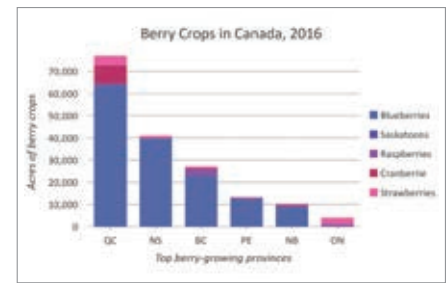
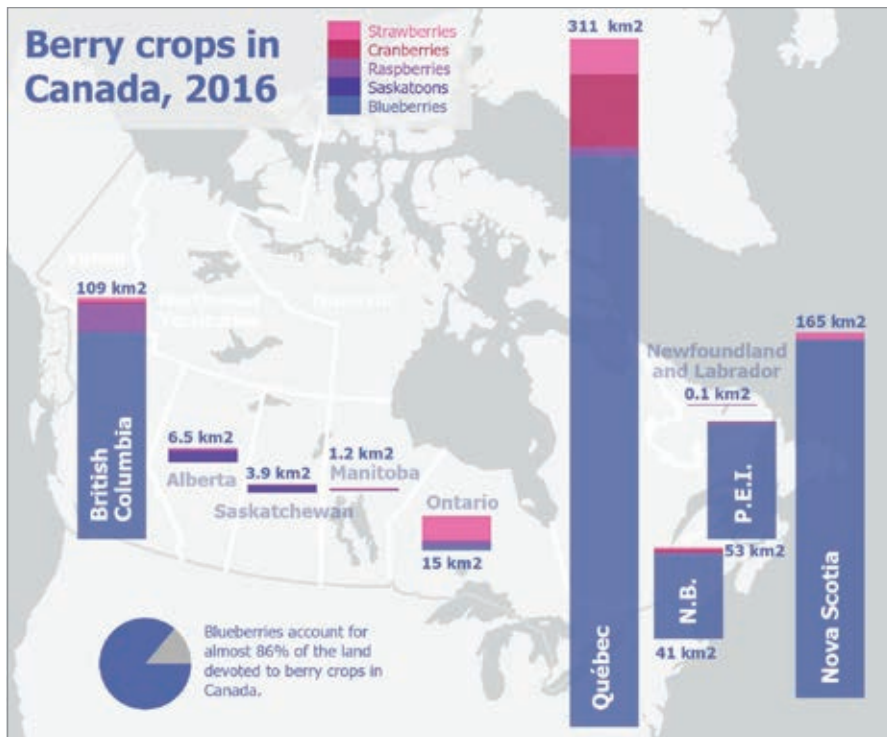
Having an Intention Makes the Difference

In all these examples, shifting the intention resulted in different choices and different maps. What is the intention of your map? Why are you making it? What do you want it to say?

You can phrase a map's intention as a goal.

These are examples of goals that clarify a map's intention.

- Help campers find their campsite and the nearest bathroom.
- Convince councillors that a new commercial development in your town will be beneficial.
- Educate children about the history of colonialism.



↑ Figure 5: If you find that you're fighting with your map to make it say what you want it to say, consider other methods of presenting your data, such as this single stacked bar chart.

← Figure 4: This map shows that blueberries are the dominant berry crop grown in Canada, as compared with other berry crops.

About the Author

Heather Smith is a cartographer and artist who mixes both practices to express and understand landscapes. She works as a product engineer at Esri, where she writes and edits lessons for the Learn ArcGIS website. View more of her work at www.heathergabrielsmith.ca.

You can phrase the map's intention as a **statement**. These are examples of statements that clarify a map's intention:

- Our company offers better shipping services than our competitors.
- This is a remote region with great natural beauty and few services.
- This lake has been shrinking since 1965.

You can phrase the map's intention as a **question**. These are examples of questions that clarify a map's intention:

- Where are sensitive ecosystems most at risk in this country?
- Where should you locate a new health clinic?
- Which intersections have the most traffic accidents?

A Good Map Has Something to Say

Make sure that your map doesn't just ask the question—it should also answer it.

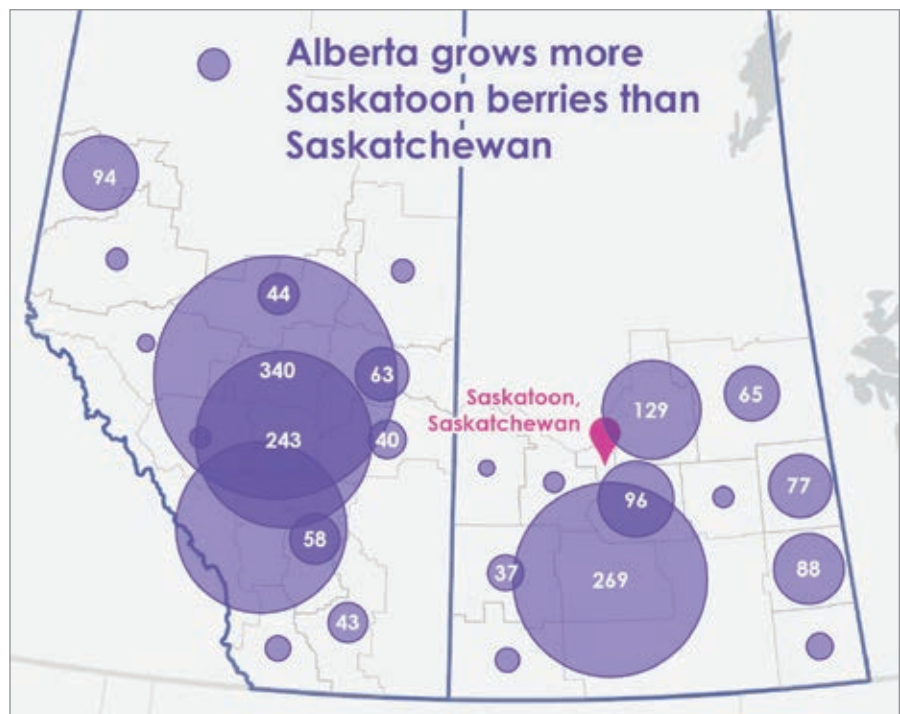
Don't be afraid to state your intention outright. Consider making it the title.

Gone are the days when maps merely stored information. We have computers for that now. A good map has something to say.

Download MappingWithPurpose from <https://bit.ly/2Jp1qon> to view all the maps shown in this article and see how they were constructed in ArcGIS Pro. The primary

dataset used in these maps is the Census of Agriculture 2016—Crops layer from ArcGIS Living Atlas of the World, sourced from the Government of Canada 2016 Census of Agriculture.

↓ Figure 6: Make sure your map answers the question it asks. This map answers the question of which province grows more Saskatoon berries, Alberta or Saskatchewan.





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PROTECT YOUR EDITABLE FEATURE DATA FROM THE PUBLIC

By Kelly Gerrow-Wilcox

ArcGIS Online has a lot of great features that help engage audiences with data. Although the interactive tools shape the experience, your data is what draws an audience to your application. People come to your application to discover facts and insights in your data.

Effectively managing feature layer capabilities is an easy way to ensure that your public applications securely show up-to-date information. Hosted feature layer views let you create layers (views of the same data) that have different editing capabilities and sharing levels, so the editors and viewers of a layer can interact with the same dataset in different ways.

For example, you can have a hosted feature layer view that is shared with the public in an application but cannot be edited by the public. Another hosted feature layer view can have editing capabilities that are limited only to specific users that it was shared with in your organization.

When publishing hosted feature layers to ArcGIS Online and ArcGIS Enterprise, editing is primarily controlled by two mechanisms: the layer editing setting and the sharing level. To modify the editing settings, go to the Settings tab in the Editing section for a hosted feature layer or feature layer view item page. After editing is enabled on the layer, any user who has access to the layer can edit it. For example, if a road construction editing app that contains an editable construction status layer is shared with a road maintenance group, then only members of that group can access, add, or update features in the layer.

It is essential to understand how to secure public datasets to ensure that only known and approved data is shared with the public by you and your organization's members. Follow the four simple tips outlined in this article for using hosted feature layer views to protect your data.

Note: Administrators and members of update capability groups within the organization have some additional editing capabilities in some circumstances.

TIP 1

Only share editable hosted feature layer views with a group that contains approved members of your organization.

In most public applications, the featured data is updated over time, such as when showing election results, wildfire evacuation zones, or construction project status. With the example of a wildfire evacuation zone app, the wildfire boundary and status of evacuations will change over the duration of the event. This data is used to inform the public whether it is safe to be in their homes or it is time to leave. Ensuring that this data is only modified by an approved group of people is critical to providing accurate information to the public, especially those members of the public who may need to evacuate.

TIP 2

Use read-only hosted feature layer views in your public applications.

When sharing data to inform the public, it is important that layers that are used to edit and update the data are not shared with everyone. Editable layers that are shared with everyone can also be edited by anyone, including those who shouldn't be editing the data and may have malicious intent.

When you are sharing an application with the public, it is important to use a hosted feature layer view with the public that does not allow editing. Use a hosted feature layer view with editing capabilities that is shared with a group of trusted editors. As hosted feature layer views created from the same source layer point to the same dataset, the view of the data that is not editable will immediately have access to updated data from the private editable view.

TIP 3

Do not share editable hosted feature layers with the public unless these layers are specifically for public data collection for use with ArcGIS Survey123 and an ArcGIS StoryMaps crowdsourcing app.

In some instances, such as crowdsourcing apps or public surveys, sharing editable layers with everyone is needed to collect data. To ensure that editable layers are intentionally shared with the public, a new setting called Public Data Collection was added to hosted feature layers with the September 2020 update of ArcGIS Online.

By enabling this setting, you are approving the layer to be shared publicly with editing capabilities turned on. When this setting is not turned on and the layer is not shared publicly, you cannot change the layer's sharing level to Everyone (public). This new setting is an extra safeguard to verify that publicly editable data is being shared intentionally for the purpose of data collection.

TIP 4

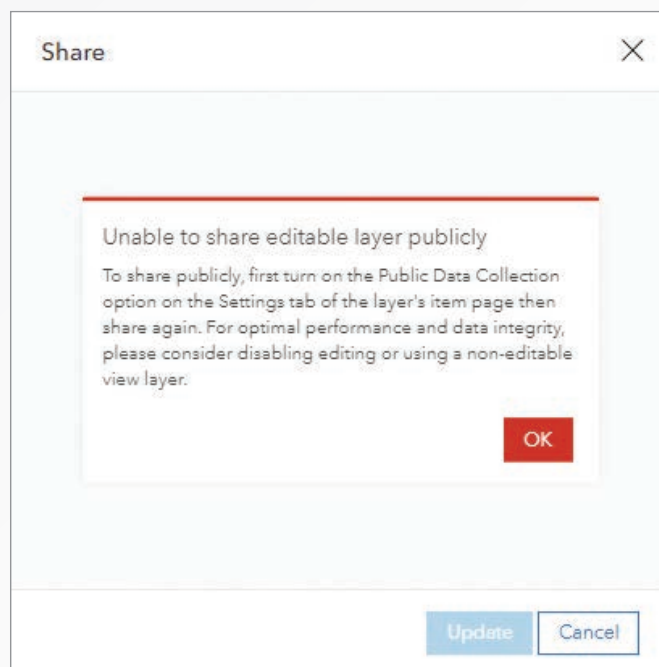
Make sure you follow best practices for data collection when using hosted feature layers for Public Data Collection.

Because Public Data Collection is a new setting for feature layers, any editable layers that you own that are shared with the public will display a banner warning you. This warning will also appear on publicly shared, editable layers published from ArcGIS Pro or programmatically.

Maintaining data integrity is critical at all times. The ArcGIS Security Advisor is an unsupported tool created by the Esri software security and privacy team to help advise on your ArcGIS security settings and review your logs. Use it if you want to double-check which publicly shared items are editable in your organization and designate the appropriate layers as Public Data Collections.

About the Author

Kelly Gerrow-Wilcox is a product manager on the ArcGIS Online team. She has been with Esri since 2012 and enjoys blogging, web app building, and outdoor adventures.



Ready-to-Use US Census Data Layers

By Lisa Berry and Diana Lavery

Traditionally, using American Community Survey (ACS) data required processing the newest estimates from the US Census Bureau each year, which could take days or weeks.

Since 2018, ArcGIS Living Atlas of the World has made many ACS tables readily available for use with your GIS workflows. These layers are updated automatically each year when the US Census Bureau releases its annual estimates.

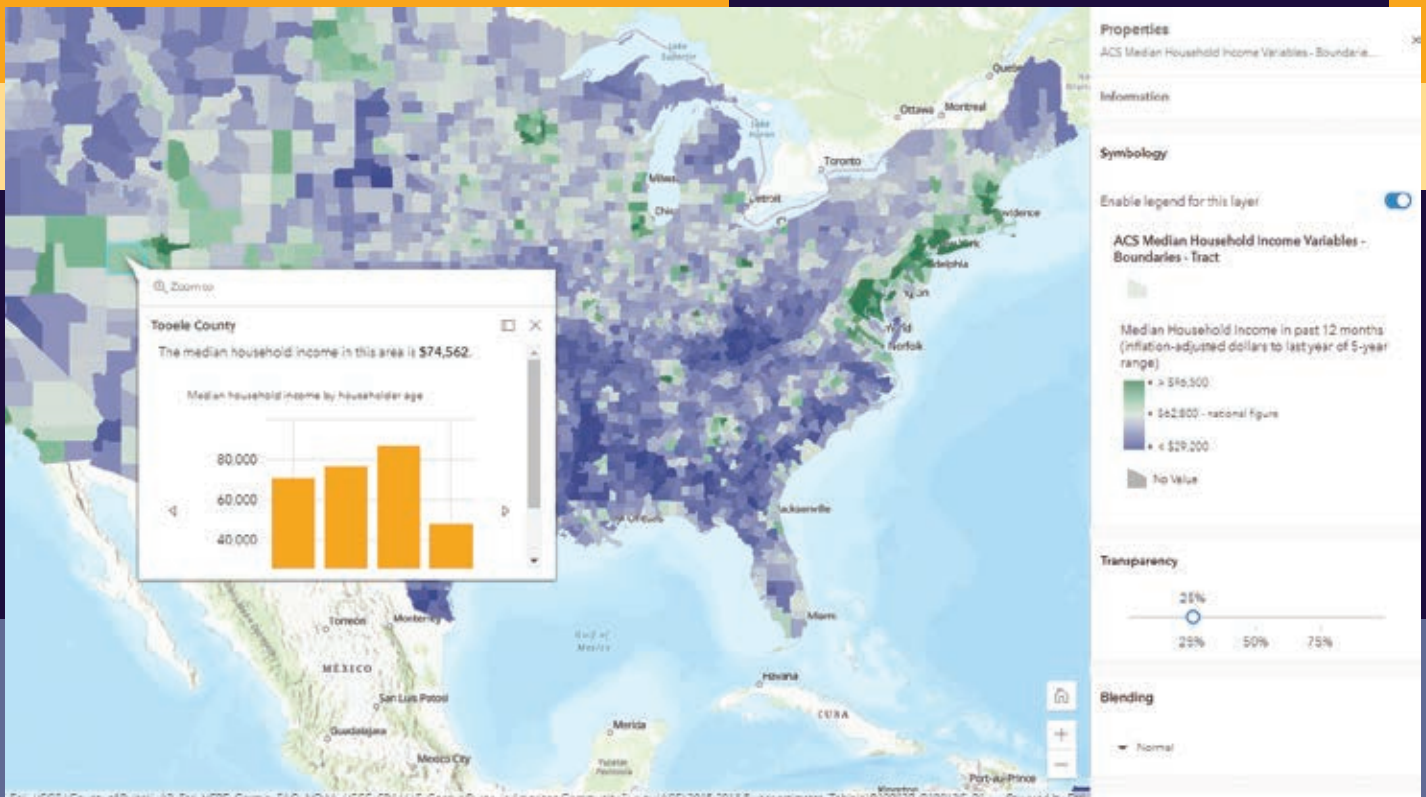
You can quickly map more than 1,700 ACS attributes covering a wide range of demographic topics such as income, housing, age, race, and education. Each layer maps an interesting subject with informative pop-ups. You can immediately see important patterns anywhere in the United States or Puerto Rico. You can also use the

layers to create your own customized web maps and applications to tell an endless number of stories about the population or housing in an area.

These layers are accessible in ArcGIS software, are free to use,

Household Income Variables

ArcGIS Living Atlas of the World makes 1,700 attributes from the American Community Survey (ACS) accessible, covering a wide range of demographic topics such as income, housing, age, race, and education.



sourced directly from the US Census Bureau API and require no login or credits. To make using these layers even easier, percentages and related margins of error have already been calculated. These layers are provided as both boundaries and centroids layers.

New Enhancements with this Release

As of December 11, 2020, these layers contain the newest 5-year estimates for 2015-2019. Boundaries layers always reflect TIGER (Topologically Integrated Geographic Encoding and Referencing) boundaries that are appropriate for the newest ACS figures. In this update, many layers have adjusted cartography that highlights the national rate of the attribute being mapped and legends that clearly state the national figure, which helps create a reference point for map readers.

The alias names have been updated to describe race and ethnicity attributes to be consistent with the ACS race and ethnicity categories as published by the US Census Bureau.

Some attributes with precalculated percentages now have revised calculations based on feedback from the US Census Bureau. These attributes help you map a normalized attribute quickly without needing to research what the denominator should be.

New Attributes Allow for More Mapping Possibilities

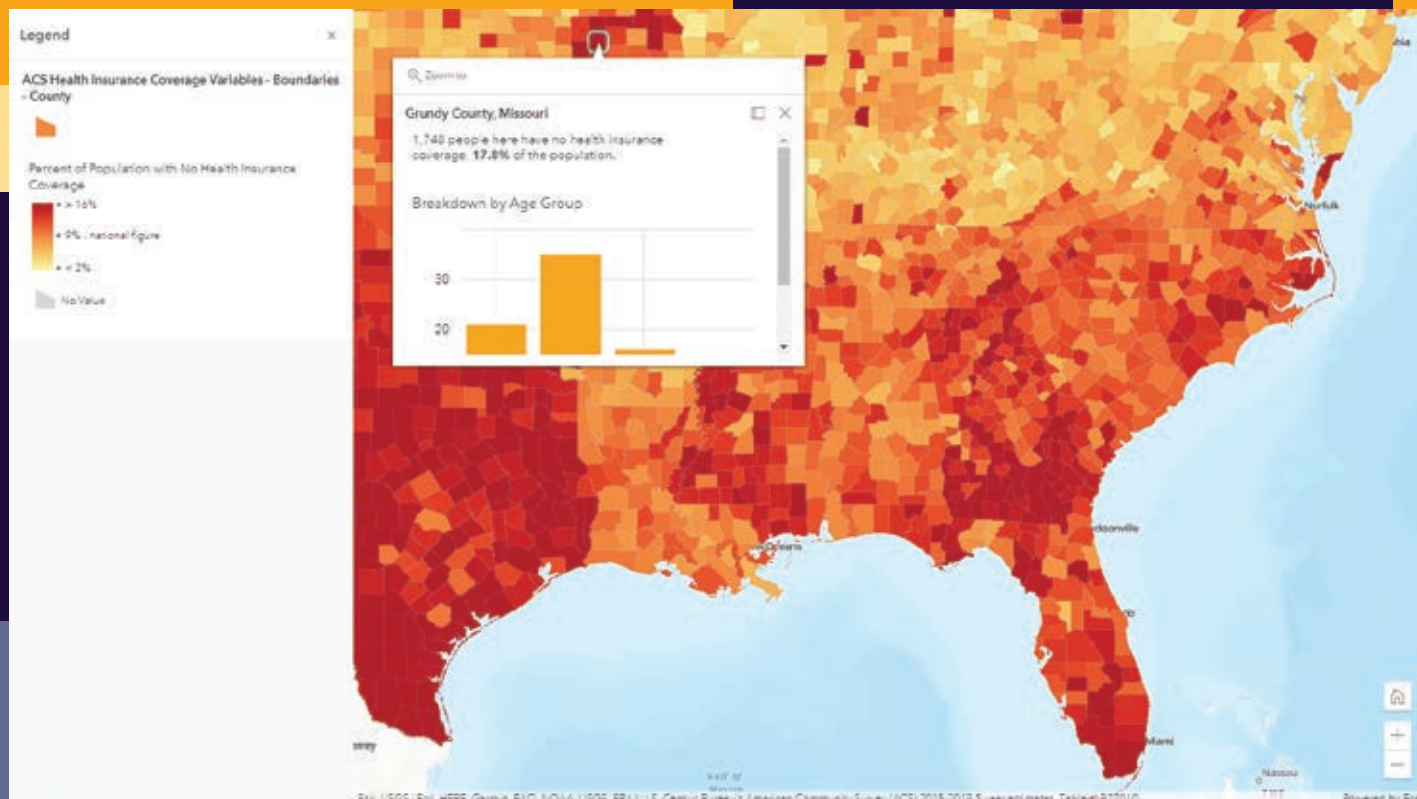
ACS layers in the ArcGIS Living Atlas of the World cover a host of topics around housing, income, internet access, education, disability, and other characteristics, created in response to user requests.

New attributes include:

- **Disability by Type**—This attribute shows types of disability and persons who have difficulty living independently.
- **Health Insurance by Race and Age**—This attribute lets you see where there are disparities in the rates of uninsured persons.
- **Household Size**—This attribute identifies communities with many one-person and two-person households. See how household size differs between owners and renters and map the average household size anywhere in the country.
- **Housing Units Vacancy Status**—This attribute shows areas with many seasonal or recreational homes. You can explore the rental and homeownership vacancy rates to see where these markets have been tight.
- **Housing Units in Structure**—This housing attribute provides data on single-family detached, small multifamily units, high-rise apartments, and mobile homes, and the type of occupancy.
- **Housing Units by Year Built**—The attribute provides the location of newer and older housing units and the type of occupancy.
- **Internet Access by Income**—Assess the state of the digital divide in a community using this attribute.

Insurance by Race and Age

ACS data about health insurance coverage by type and by age group that is symbolized to show the percent uninsured.



New 2010–2014 layers allow for comparisons over time. Many users have requested historical ACS data so that they can compare how patterns have changed over time. Because the 2010–2014 layers and the most recent 2015–2019 data match and are symbolized in the same way and none of the survey years overlap, they can be used to compare changes in patterns of distribution in a map.

There are several tools for comparing layers. The Compare App (<https://bit.ly/3asMtgv>), a free configurable app template, supports side-by-side or stacked comparison of two maps or scenes. Swipe comparisons in an ArcGIS StoryMaps story, classic Esri Story Maps app, or ArcGIS Web AppBuilder app are also supported by this data. Also bring layers into ArcGIS Pro to join, analyze, and map change over time.

Get Started Today with These Resources

- Learn where to find these census ACS layers and how to start using them in your mapping and analysis workflows from this story map, “Easily Access and Use American Community Survey Data,” (<https://bit.ly/3ahB9Ui>).
- Look at the American Community Survey (ACS) Current 5-Year Estimates group (<https://bit.ly/38bRnvt>).
- Read “Make a Map About Your Community in 4 Easy Steps” (<https://bit.ly/3oTjvdq>) for a quick introduction to using ACS data.
- Get answers to any of your questions from the “FAQs for ACS Hosted Feature Layer” page (<https://bit.ly/3gTAt8Y>) or by posing them to the Living Atlas community on GeoNet. You can

also learn more about the layers from the blog post “Mapping American Community Survey (ACS) Data Just Got Easier.”

If you already use ACS data in your maps, make sure you update them with this new data. When updating data, check class breakpoints to ensure that the map symbology still makes sense.

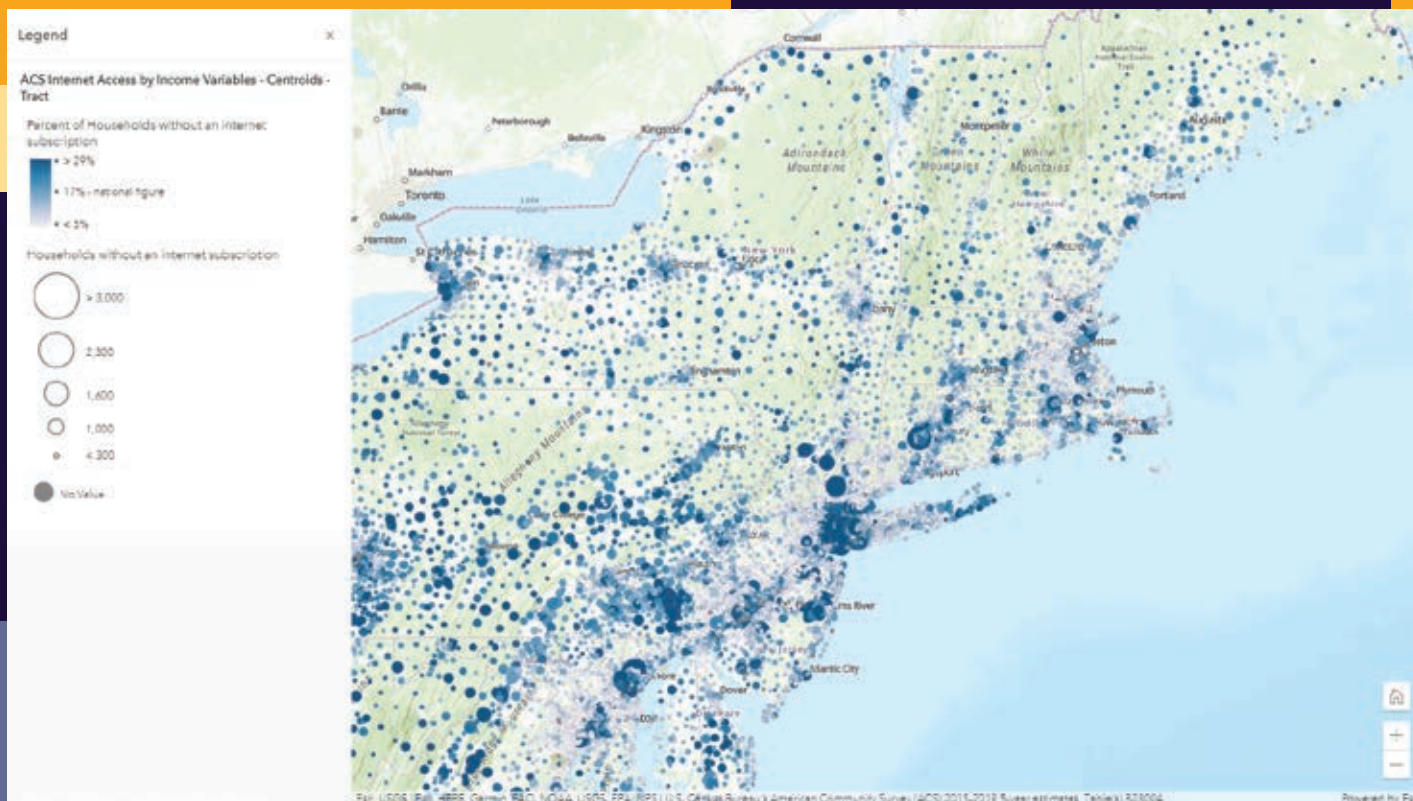
About the Authors

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

Diana Lavery loves working with data. She has more than a decade of experience as a practitioner of demography, sociology, economics, policy analysis, and GIS—making her a true social science quantoid. Lavery holds a bachelor’s degree in quantitative economics and a master’s degree in applied demography. She has been with Esri as a product engineer on the ArcGIS Living Atlas of the World and policy maps teams since 2017. She enjoys strong coffee and clean datasets, usually simultaneously.

Computer Ownership and Internet Access

ACS data is provided as boundaries and centroids. This centroid layer shows computer ownership and internet access by income group.



GIS Bookshelf

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

By Andy Mitchell and Lauren Scott Griffin

Esri Guide to GIS Analysis, Volume 2: *Spatial Measurements and Statistics* builds on the foundation provided by volume 1 of the series by taking users beyond visualizing patterns in maps and teaching them how to quantify patterns in a significant way, providing a deeper understanding of spatial statistics. It guides readers through some of the most common spatial statistics tasks, including measuring distributions, identifying patterns and clusters, and analyzing relationships. While explaining how to apply these techniques, the book focuses on using spatial statistics to answer important questions. This book also explains how spatial statistical tools can be applied in a range of disciplines, from public health to habitat conservation.

This book's authors have decades of experience in GIS and spatial analysis. Andy Mitchell,

who has been writing about GIS for more than 30 years, has authored or coauthored several books, including *The Esri Guide to GIS Analysis series* and *Zeroing In: Geographic Information Systems at Work in the Community*. Dr. Lauren Scott Griffin has more than 33 years of experience in software development and GIS at Esri. She has delivered presentations, workshops, and short courses at the National Institute of Justice, Centers for Disease Control and Prevention, New York City Department of Health, University College London (UCL) Jill Dando Institute of Security and Crime Science, London Health Protection Agency, Sault Ste. Marie Innovation Centre, World Vision, and the University of Copenhagen Institute of Geography. Esri Press, 2020, 320 pp. ISBN: 9781589486096 (digital) ; ISBN: 9781589486089 (paperback).

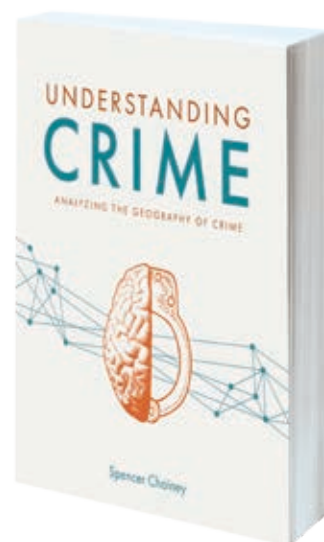


Understanding Crime: Analyzing the Geography of Crime

By Spencer Chainey

By addressing both the theory and application of the geographic analysis of crime, *Understanding Crime: Analyzing the Geography of Crime* is intended as a comprehensive resource and a textbook. This book makes crime analysis more accessible for readers through detailed descriptions, explanations, and illustrations of geographic analysis techniques. It explores spatial and temporal patterns of crime, the use of spatial data in crime analysis, and methods for evaluating the impact of geographically targeted interventions. Every

chapter begins with key learning points and ends with a summary and references. The author, Dr. Spencer Chainey, is the director of continuing professional development and director of the Latin America and Caribbean unit at University College London's Jill Dando Institute of Security and Crime Science. He draws on 25 years of experience, which includes working in Europe, North America, Latin America, the Caribbean, Australasia, the Middle East, and China. Esri Press, 500 pp. ISBN: 9781589485853 (digital); ISBN: 9781589485846 (paperback).



VIRTUAL GIS DAY EVENTS ARE A HIT

In spite of all the changes the world has experienced over the past year, one thing has remained steady: GIS is making a difference in so many of the things we do. Some might even argue that GIS is more important now than ever before, given how COVID-19 has raised awareness around the globe of how important geospatial technology is for problem-solving and decision-making.

GIS Day was officially commemorated on November 18, 2020. Celebrations were not only extra cautious, they were also extra special. Most events were held online, which allowed people from all over the world to attend presentations, workshops, interactive meetups, and other virtual functions hosted by government agencies, libraries, schools, universities, nonprofit organizations, and private companies. The hosts of each registered event used ArcGIS Hub to organize and present their GIS Day content and engage, serve, and collaborate with their communities.

“You just can’t stop the enthusiasm and quest to share GIS knowledge, even during a pandemic,” said Maria Jordan, Esri’s product marketer for ArcGIS Hub. “Whether celebrating as part of a city, county, university, or private business, GIS Day hosts stepped their creativity up a notch this year to plan virtual events, record YouTube videos, and broadcast radio show programs to

reach their audiences.”

More than 1,200 GIS Day events were registered at gisday.com, putting them on the GIS Day map. And most of these activities were open to the public. Just a few of the events that were held in 2020 are included here.

At the University of Salzburg in Austria, the geoinformatics program held a GIS Day event to teach people what the technology is and why it matters. Part of the fun for attendees was exploring the nine most beautiful hidden places in Austria, using maps and map narratives built with ArcGIS StoryMaps stories.

Government agency Land Information New Zealand sponsored a virtual, three-day field trip for schools that showed students how to use maps to safely hike the outdoors. Nepal’s Federation of Community Forestry Users led attendees through a demonstration and discussion of its critical forest work.

GIS practitioners from a range of professions presented their work to attendees at an event hosted by Central Connecticut State University and the Connecticut GIS Network. Other participants submitted map posters, ArcGIS StoryMaps stories, and other geospatial apps to a gallery. The university also held a rousing game of GeoJeopardy.

↓ GIS enthusiasts registered more than 1,200 events on the GIS Day website, officially putting their functions on the map.





↑ The geoinformatics program at the University of Salzburg had attendees use maps and map narratives to explore the nine most beautiful hidden places in Austria.

The National Geospatial Technology Center of Excellence (GeoTech Center) organized six hours of events—in both English and Spanish—that included talks, geogames, mapping activities, and a map contest and gallery. GeoTech Center promotes the use and teaching of GIS in community and technical colleges.

The Udzungwa Ecological Monitoring Centre in Tanzania taught other GIS Day participants about tropical biodiversity through its GIS Day event.

Geospatial Libya Consulting in Misratah, Libya, held a discussion on spatial data infrastructure. The School of Geography at the University of Costa Rica demonstrated what faculty and students are doing with GIS in their instruction and research.

In addition to these events hosted around the world, the GIS Day website served up some new, on-demand content to help everyone celebrate the technology, from the comfort of their own homes. Videos, articles, and podcasts posted on the website spotlighted GIS influencers who are using the technology to do important work such as building inclusive workforces, designing landscapes with

climate change in mind, and responding to devastating wildfires.

Esri also released a new GIS Day mobile app, available for download from the Google Play and Apple app stores, that was designed to help GIS professionals share the technology with their colleagues, students, and community members through games and map exploration activities. The idea was to let people experience GIS firsthand on their own devices.

Each host who registered an event on the GIS Day website received five ArcGIS for Personal Use licenses. The hosts had full discretion over how to distribute the licenses. Some held contests and lotteries, others gave them out at networking activities, and still others doled them out as gifts to presenters or donations to nonprofits. The point was to help hosts further the use of GIS within their communities beyond GIS Day.

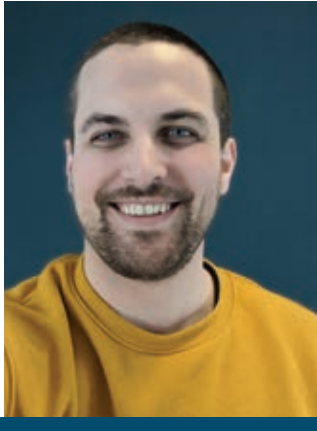
Around the world, people use GIS Day as a way to help others discover GIS, share their accomplishments, and inspire their peers with the infinite ways that geospatial technology can be used. The next GIS Day will be November 17, 2021, so plan to join in.

↓ GIS Day, on November 18, 2020, was the first mostly virtual celebration.



A Foundation for Problem Solving

By Charlie Fitzpatrick and Carla Wheeler



Did what you studied in seventh grade have an impact on what you do today?

For Nate Ebel that question is a no-brainer. His first experience using GIS technology 18 years ago started him on a path that led to his current career as a software developer.

During the 2001 school year, Ebel was enrolled in a GIS class for gifted students at Jenifer Junior High School in Lewiston, Idaho, taught by Steven Branting. Students in the class used Esri technology to study Lewiston, including a project investigating the relocation of a cemetery in the city. They used GIS, GPS, and satellite imagery to study the sequence of reburials from an 1860s era cemetery to a cemetery that opened in about 1889.

The class won an Esri competition for schools to map and analyze their community, which earned Branting and two students a trip to San Diego, California, to speak to thousands of GIS professionals during the Esri User Conference Plenary Session. A 13-year-old Ebel, his classmate Ian Coleman, and their teacher Branting gave a presentation about the community atlas they created and the graveyard relocation project.

Branting's class covered topics such as celestial navigation and position fixing, GPS fundamentals and applications, digital photography, introduction to image analysis, and data analysis, and visualization with Esri software.

His seventh-grade project opened Ebel up to a new world of location technology.

"We had a computer at home, but I had never used the computer for anything more than typing up a research report and playing some games," Ebel said in a recent interview. "This was my first exposure to doing cool things, including GIS, on the computer," he said. "That sent me down the technologist path. I remember thinking I would be some kind of engineer but didn't know what kind."

Until his senior year of college, Ebel was planning on pursuing a career in GIS. "I figured I would probably be a GIS analyst, and honestly, I was already in that role at that time too," he said. "In the summer, before my junior year of college, I got a job as a GIS intern with Lewiston Public Works," he said.

The job went well, so Ebel worked there for

four years part-time during the school year and full-time during the summers. Ebel attended the University of Idaho, majoring in geography with an emphasis in GIS.

He had tried but didn't like a general computer science and programming class. Instead, Ebel enrolled in a GIS programming class and realized, "Here's how we can write code to make these GIS projects at work easier to solve. Solving real-world problems clicked in a way the general computer science instruction didn't. It was just like back in our original work with Steve [Branting]."

Those problem-solving skills helped him as a GIS technician for Lewiston. He was working on a project that involved multiple parcel datasets that needed to be validated, cleaned up, and combined into a single dataset. Using Python and the Python site package ArcPy, he automated the process. By letting the computer do the work, he saved a huge amount of time and money. Two weeks into the project, which was expected to take two full-time staff members six to nine months to complete, Ebel had pretty much finished it.

That's when Ebel realized that was what he wanted to do, he wanted to be a software developer. "I was in school for two more years to get a master of science degree in computer science, and then got a software developer internship at Esri in 2013. I spent the summer at Esri, finished up one last year of school, and worked for Esri again for two years on the Android development team."

Because he had started using GIS in seventh grade, when Ebel began work at Esri, he had already had 10 years of GIS experience. "That really gave me a leg up. I had domain knowledge and could contribute to discussions and decisions," he said, adding that he worked on apps such as ArcGIS Explorer, ArcGIS Navigator, and ArcGIS Collector.

Ebel left Esri in 2016 to focus on education technology. For the last four years, he has developed consumer-facing apps for startups and has been active in developer communities, writing, and doing public speaking. He also has done some teaching. He recently taught an Android

development course at a community college in the Seattle area.

"I'm an engineer first but went out of my way to host meetups and help people learn to write Android apps," Ebel said. "I really enjoy meeting people, sharing information, and creating tutorials. Through all of this was the thread of GIS and computers."

Ebel credits that first GIS class and the guidance Branting gave him for helping to think through problems to find solutions.

"Anyone can dabble with the GIS architecture," Branting said when contacted at his home in Lewiston, Idaho. "As Alexander Pope wrote, 'A little learning is a dangerous thing.' Looking for mastery, my focus with him and his classmates was to help them internalize how to know—diversely and authoritatively—in a loop commonly called O-O-D-A, [which is] an acronym for observe, orient, decide, act. Pose a good question, invent chaos, and search for patterns and order."

Ebel also said he is thankful for the public

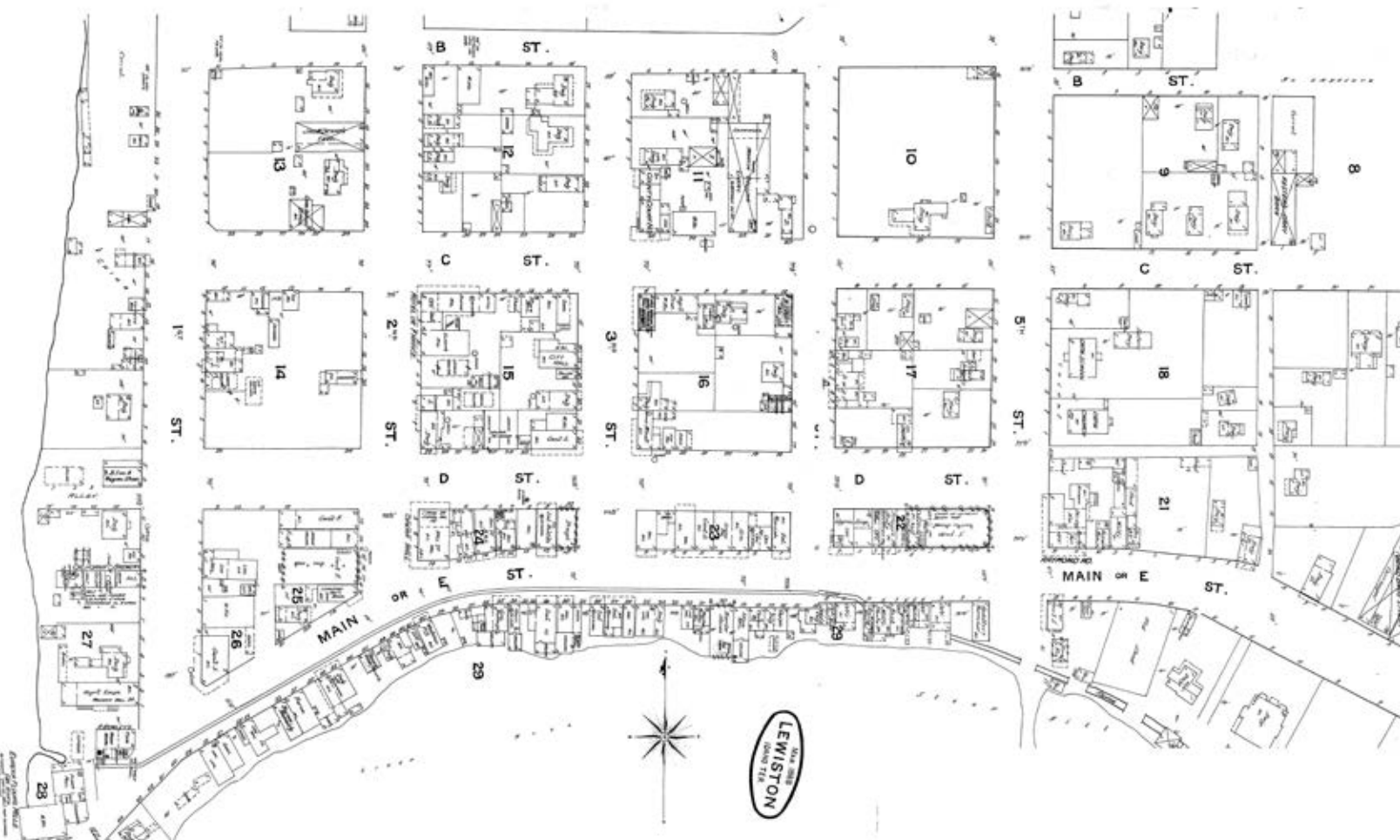
speaking and technical writing skills that he cultivated and honed during his junior and senior high school years.

"That seventh-grade class was not a GIS class per se, but something like, 'Learn to solve problems.' Steve got us to look at a problem from different perspectives. He trained us to look at things from all these different angles, to make inferences, and to use data. The whole first part of the course was training us to think about solving problems," Ebel said.

"When I talk with people today, one piece of advice I give is that tools and frameworks are not as important as they seem. There's all this attention to inputs and outputs, but I try to teach people that how you think about the problem is much more relevant and more challenging than being able to sit down and write the actual code. That's what Steve [taught] us."

For more information on using GIS to teach K–12 students, for free (even remotely), see Esri's program for schools at <https://bit.ly/374H4t>.

Solving
real-world
problems
clicked in
a way the
general
computer
science
instruction
didn't.



HELPING SAFEGUARD THREATENED RAPTORS WORLDWIDE

By Rob Davies



↑ An African Fish Eagle attacking prey at Lake Naivasha, Kenya. Photo courtesy of Rob Davies

↓ Rob Davies

The author, Rob Davies, is the director of Habitat Info Ltd., a global technology company that specializes in the capture, management, analysis, and distribution of spatial data. In 2012, Habitat Info launched a charitable citizen science project to collect data on the conservation status of African raptors to determine how much habitat space was left for them.

Initially, the African Raptor Databank (ARDB) met with opposition from critics who said collecting the status of raptors across Africa could not be done because Africa was too big. They urged Habitat Info to limit efforts to a region of Africa at most, focusing on protected areas and countries. However, raptors range freely, and many make annual pilgrimages across and between continents to breed and winter. In addition, it is funny that people often believe a smaller study area is less work to map in GIS. It's not.

Starting with Africa

Two people and one organization stood out for their support of Habitat Info's holistic approach: Dr. Rick Watson and Dr. Munir Virani of The Peregrine Fund. *[The Peregrine Fund is a science-based, project-driven conservation organization based in Boise, Idaho.]* Watson and Virani, through their organization, have done much good work for raptors around the world. They supported ARDB from the start by generously sponsoring ARDB's Esri software. Esri provided ARDB with a nonprofit grant



scheme that helped launch the project.

With access to ArcGIS Server, Habitat Info could pull in data from mobile phones from pretty much anywhere across the continent because in Africa almost everyone carries a mobile phone. First Virani, then later Darcy Ogada, coordinated the database for East Africa. Database coordination was done by Andre Botha in southern Africa; by Clive Barlow, Dr. Joost Brouwer and Dr. Ralph Buij in Central and West Africa; and by Dr. Hichem Azafzaf in North Africa. With the right team in place, data flowed in from hundreds of keen-eyed raptor observers across Africa.

After five years, ARDB had more than

200,000 sightings of African raptors. At the end of this data collection period, the author travelled to Boise to show the results to members of The Peregrine Fund and thank them for believing in the project when others did not. Their response was, "Why stop at Africa? Let's go global!"

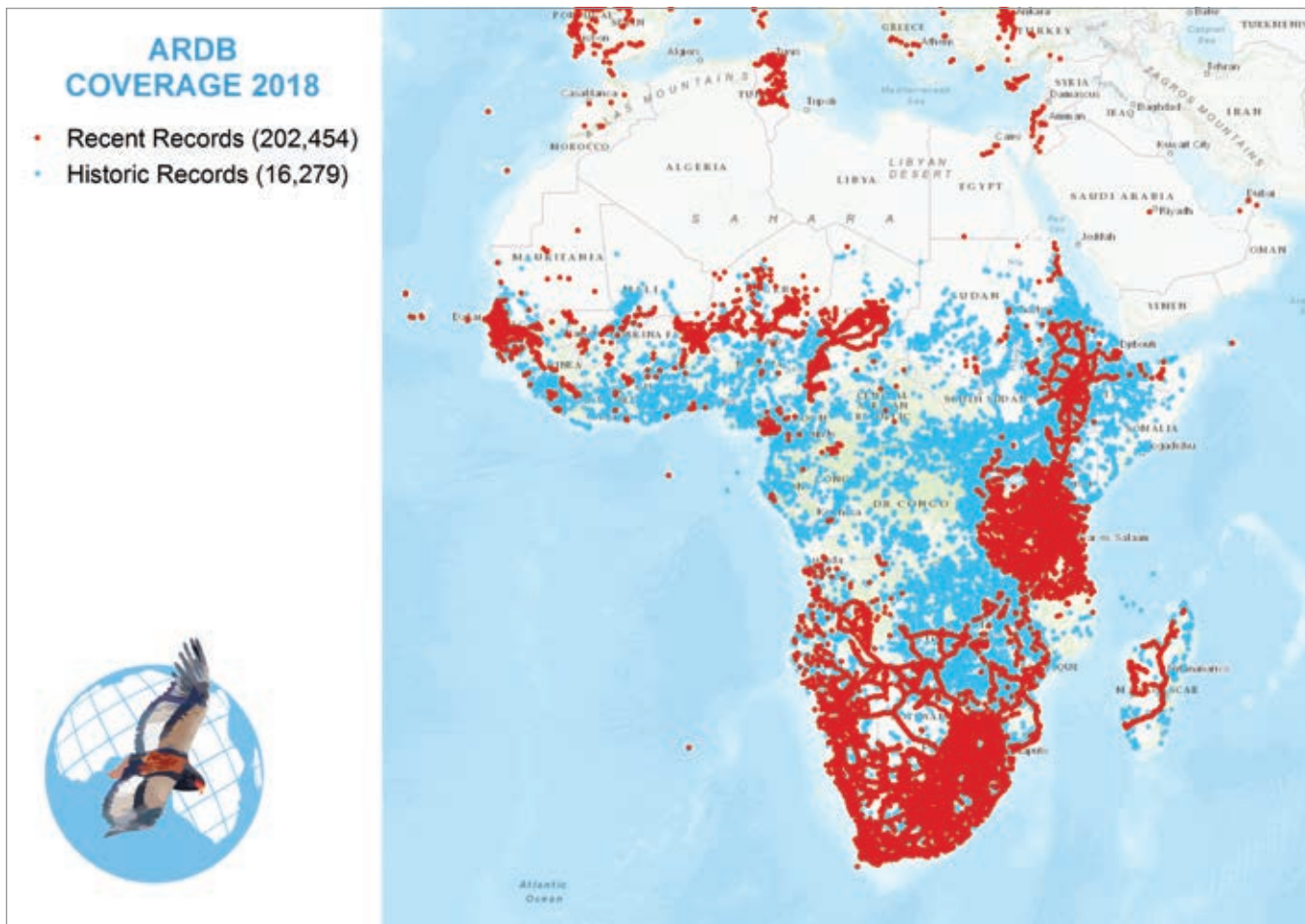
Going Global

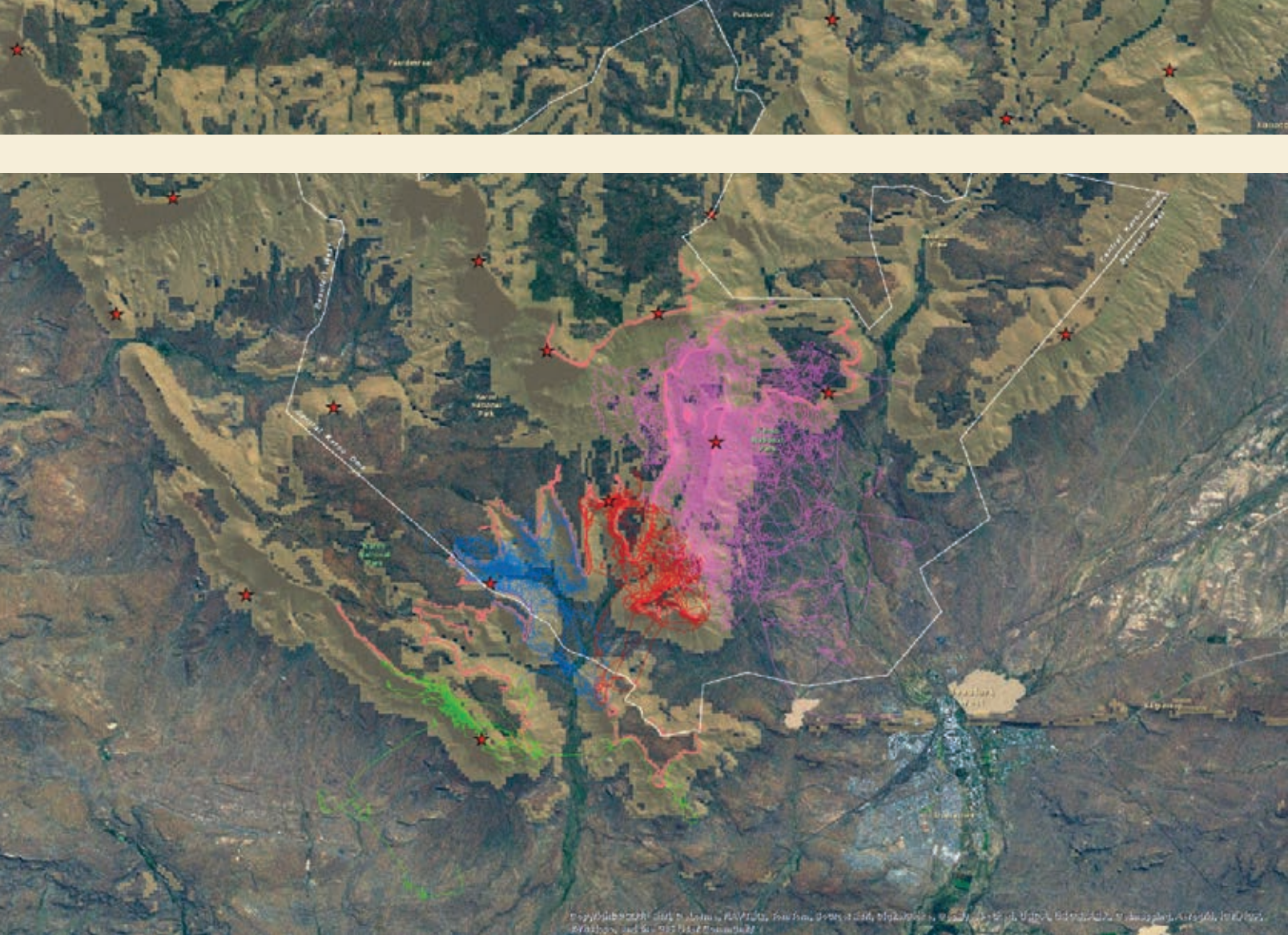
ARDB then entered a new phase. Thanks largely to Dr. Chris McClure, Leah Dunn, Paul Spurling, and Brett Sebring, ARDB has become fully integrated with The Peregrine Fund's existing Global Raptor Impact Network (GRIN) and is hosted by a large database on the Amazon cloud. The

Peregrine Fund's approach has facilitated the successful reinstatement of many locally extinct raptors around the world.

While overcoming the technological challenges of gathering and collating data on raptors, there was convergent evolution in the quality and resolution of global, and especially Africa-wide, environmental datasets. The digital elevation models (DEMs), which revealed mountainous Black Eagle habitat; the global forest cover datasets, which represented Crowned Eagle habitat; and landcover, climate, and human population impact datasets. All showed improvement by orders of magnitude. These datasets were available at resolutions of 1 kilometer

Map showing the coverage of the African Raptor Databank (ARDB) in 2018. Blue dots represent historic records (pre-1977) and red dots represent recent sightings.





↑ Visualization of the flightpaths recorded for four adjacent pairs of Black Eagles in the Karoo National Park.

or even 300 meters, which were scales ecologically meaningful to individual pairs of raptors finding territories across Africa.

Dr. Corinne Kendall joined the team of coordinators towards the end of data gathering and she added an entirely new type of data on African raptors—movement data. This data from satellites and GPS tags fitted to wild birds revealed extraordinary behaviours and filled many gaps in our knowledge about where these birds travel. This data created a much more complete picture of raptors, one that could only have been dreamed of a decade earlier.

The project initially started with an Enterprise Geodatabase hosted on a little server housed in Habitat Info's office. It benefited enormously from the enthusiasm of Habitat Info staff members Andrew Rayner, Tim Wroblewski, and Simon Trice,

who worked industriously with interns Sarah Wigley and Zoey Taylor to build the database.

Battling with the many different formats in which data was submitted made the team long for a method that would let observers add their own data. Rayner developed a pro forma spreadsheet for bulk loading existing data while ensuring data quality and verification, but the challenge of automating the addition of new data remained.

Early attempts to solve this problem with mobile technology made use of ArcPAD on an HP iPaq. Subsequently, Habitat Info staff member Rayner successfully applied his clear vision and programming skills to fulfill Habitat Info's elaborate requests to produce an intuitive, state-of-the-art mobile recording app for logging almost all aspects of raptors and their behaviour.

These efforts attracted a lot of interest, including development support from Kurt Eckerstrom, Nick Williams, and the Convention on Migratory Species. Habitat Info is most grateful for their help.

Ultimately, the Global Raptor Impact Network App was funded by The Peregrine Fund in conjunction with GRIN using Esri's ArcGIS Mobile SDK for Android and iOS. It is provided by The Peregrine Fund as a free tool for conducting raptor research that works happily offline—which is essential when working in remote parts of Africa—and seamlessly uploads to the enterprise database when the device becomes connected to the internet.

The app allows both professional and citizen scientists to conduct multiple survey types with just a single tap of the screen. Simple sightings can be entered, and a

wide array of morphological and behavior data appended. The app avoids tedious data entry by securely uploading data directly to the GRIN database.

With the GRIN app developed and available, Habitat Info is turning its attention back to Africa and intends to gather support to publish the ARDB and produce a hardcopy of the *Conservation Atlas for African Birds of Prey*.

The Value of Vultures

One group of raptors brought the need for the ARDB into acute relief—Africa's vultures. Vulture populations have been spiralling downward in the last couple of decades.

The decline is clearly caused by the illegal use of poison. Poachers in southern Africa lace elephant carcasses with poison to eliminate tell-tale soaring birds that give away the location of their crimes. A 40 percent decline in vulture populations has been attributed to poisoned carcasses. In Eastern Africa, a 60 percent decline in the vulture population was caused mainly by farmers who were trying to poison predators that were killing their livestock. A single carcass laced with poison can easily kill all the vultures in the surrounding area. This practice has been causing local extinctions.

In West Africa, a 90 percent decrease in vulture populations was linked to the illegal trade in vulture body parts. These parts are used in traditional medicine and play a part in superstitious practices used to predict soccer scores.

With such a precipitous decline, something needed to be done quickly. Buij, with support mainly from the Dutch government, stepped in and coordinated a project that pulled together everything then known about vultures and the threats to them. This project was the first significant use of ARDB and the clearest example of why these knowledge management systems are needed to enable more efficient conservation.

Sightings, habitat suitability models, and the movement patterns of vultures helped

identify the most important habitat strongholds for vultures across Africa. This knowledge has helped conservationists focus efforts on the most important places instead of spreading efforts too widely across the vast continent. The culmination of the project is a series of maps and an educational poster to promote awareness and understanding of the threats to vultures.

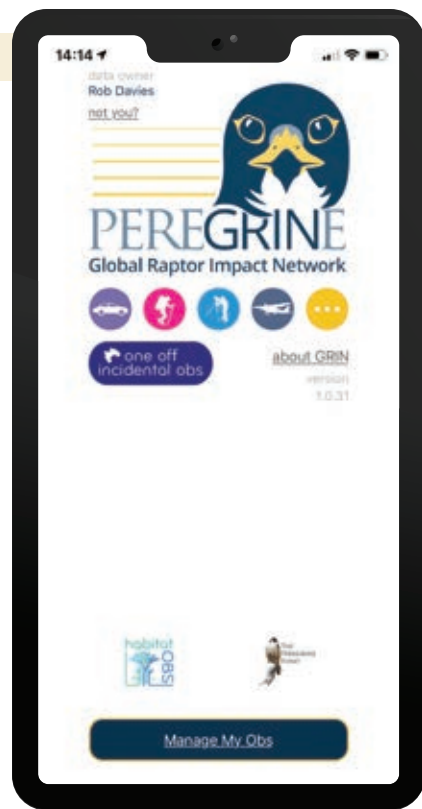
The decimation of the vulture populations from the Indian subcontinent has been attributed to the use of diclofenac,

an anti-inflammatory drug given to cattle beginning in the 1990s. The decrease in vultures led to an increase in feral dogs that has been associated with an increased incidence of rabies and other diseases, according to an article published in the scientific journal *Nature* in 2004.

Strongholds for vultures are also strongholds for most other wildlife, especially vulnerable large carnivore populations, such as lions and wild dogs, as well as a host of other species that are less visible than

↓ Andrew Rayner, a programmer with Habitat Info





↑ The Global Raptor Impact Network App is a free tool for conducting raptor research that works offline and uploads to an enterprise database when internet connectivity is available.

raptors and consequently, less capable of signalling that something is wrong in their habitats.

The Role of Raptors in Protecting Ecosystems

The loss of vultures and other raptors from Africa may be far more consequential than the loss of elephants, rhinos, and other higher-profile species that monopolize popular attention and funding. Raptors are indicators of environmental health. They are highly effective as “canaries in the coal mine” that provide early warning when vital earth support systems are threatened.

Learn more about the Global Raptor Impact Network (GRIN) App at <https://bit.ly/2KdfLop> and start collecting data.

As notable raptor researcher Professor Ian Newton put it, “An abundance and diversity of raptors invariably signals a largely undisturbed ecosystem supporting an abundance of other wildlife.”

For more information, contact Rob Davies at rob.davies@habitatinfo.com.

Acknowledgment

A word of thanks to Esri and its associates. Whenever I have approached Esri for help with my many and varied conservation projects around the world, it has always helped creatively. I guess the culture that has arisen from a company, originally called Environmental Systems Research Institute, and the people who built it have great empathy for the environment. Thank you to Esri for helping raptors and other wildlife. It is very much appreciated.

About the Author

Rob Davies moved from Wales to South Africa in 1982. His PhD on Black Eagles in the Karoo led him into GIS in 1986 with the mapping of flight paths and eagle territories. Throughout his career in conservation in Africa and in Wales 2001, Davies has endeavoured to harness GIS technologies for improved biodiversity conservation and human adaptation to climate change. He has directed two NGOs, worked with the Peace Parks Foundation, and set up a biodiversity information centre in Wales. He established the African Raptor Databank, which has now developed into the Global Raptor Impact Network. In addition to his mapping work, Davies illustrates wildlife and has recently published a field guide to African raptors. He now runs Habitat Info, a consultancy in West Wales.

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