

Wind Farm GIS Optimization Model Improves Design Process

By Meagan Krawczyk, Contract Wind Energy Analyst, Shell Wind

Effective wind farm layout design is critical to the success of any wind project. Currently, the most common practice is to design a layout that achieves maximum energy production, quantified as a capacity factor (the ratio of actual output of energy over a period of time and its output if it had operated at full capacity). However, it is more efficient if the wind farm modeler also includes an analysis of the economic trade-offs between more efficient wind capture and increased project construction and operating costs. Geographic information system (GIS) technology can be used to meet

the complexities of including cost optimization in the wind farm design process.

The traditional design process is to study site and wind conditions, calculate energy optimization, and finally create the wind farm layout. This approach does not consider project costs related to roads, cables, construction, and other factors until after a layout has been created. Some wind farm engineers choose to perform optimization analysis separately. The wind farm design would be more efficient if engineers and modelers would employ the alternate model, cost of energy optimization. It includes

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project cost metrics in the layout design phase and uses this information, along with wind and site data, to guide turbine placement.

AWS Truepower, LLC, developed openWind, a software program for designing, optimizing, and assessing wind farm projects. By using it in tandem with ArcGIS, wind farm modelers can include optimizations of grid, energy, and cost for energy analysis to determine the cost of energy associated with a given wind farm layout.

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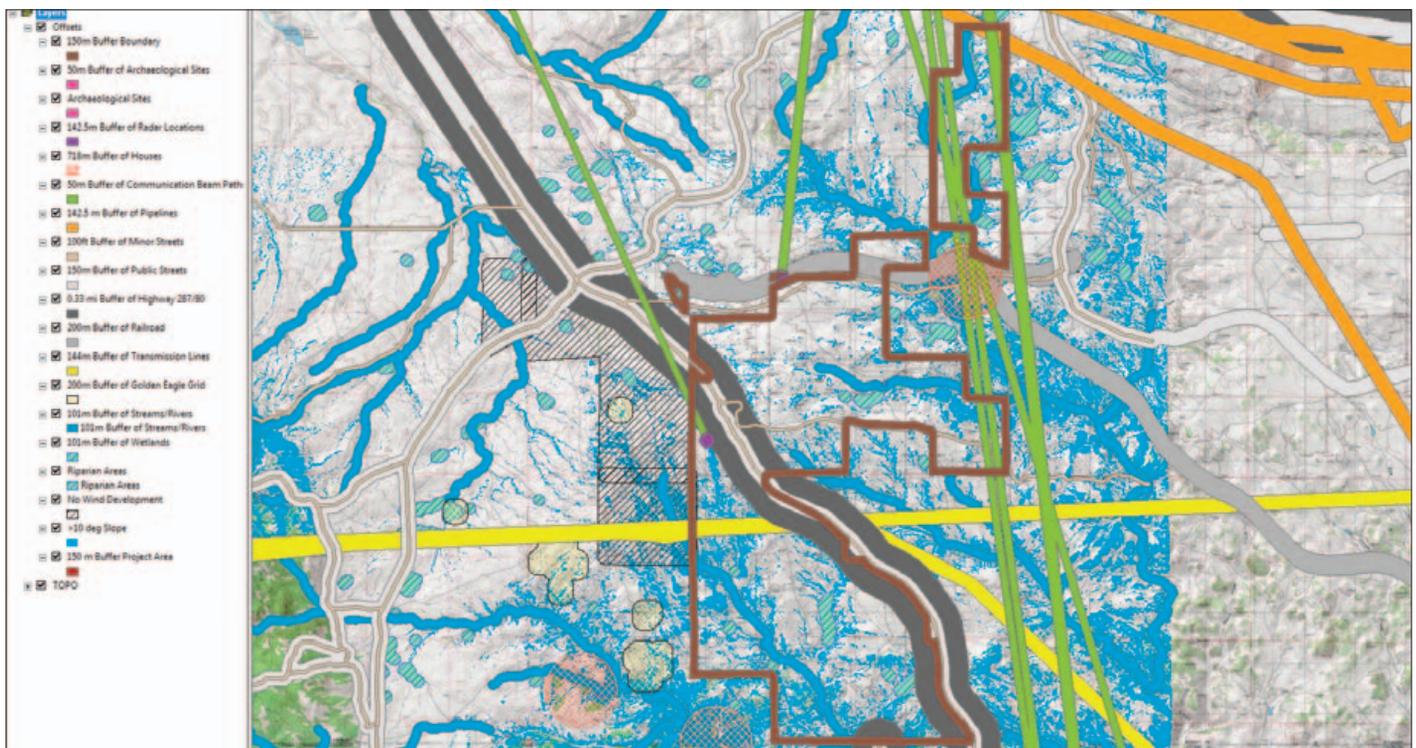


Figure 1—Wind farm site constraints, such as pipelines and transmission lines, are buffered.

Wind Farm GIS Optimization Model Improves Design Process

A wind resource grid, turbine specifications, site constraints, turbine spacing, and defined site-specific characteristics are needed to complete an optimization analysis.

Wind Resource Grid (WRG): This file defines the wind regime based on wind frequency and direction. Input a digital elevation model (DEM), a land-cover/roughness file, and meteorological data in the form of a .tab file to define wind frequency and direction.

Turbine Specifications: Input the attributes that define the height of the turbine, the turbine blade length, how much power the turbine will put out related to wind speed, and so forth.

Site Constraints: These are areas where turbines cannot be sited. Shell Wind's procedure is to input shapefiles representing various site characteristics, such as roads, water bodies, transmission lines, pipelines, and steep terrain, into the GIS and create buffers for them that meet site-specific setback requirements (figure 1). Shell Wind uses ArcGIS to merge, dissolve, and invert buffers to show a buildable area where turbines can be placed (figure 2).

Turbine Spacing: How far apart to space turbines is defined by the characteristics of the wind for the site. The modeler will define a minimum and maximum turbine spacing based on the wind rose in figure 3. Defining how far apart turbines are spaced is impor-

tant, because if turbines are placed too close together, they begin to affect each other with turbulence and a slowing and diversion of the wind—this is the wake effect.

Once all necessary files have been entered and characteristics defined, the layout is ready to be optimized. There are three options for designing a layout in openWind: gridded, optimized for energy, and optimized for cost of energy.

The gridded layout tool produces compact layouts that fit into a defined area. This tool is well suited to layouts for offshore wind farms where there is a fairly uniform wind resource and few natural obstacles.

The energy optimizer uses the WRG to design a layout that should, in theory, capture the most energy. This optimizer can create layouts that are widely distributed and not designed very well from a construction point of view.

The cost of energy (COE) optimizer integrates the cost of construction and operation and allows those costs to be offset by the turbine energy production. Part of this calculation includes looking for the best wind resource and lowest wake effects. To run this optimizer model, additional files must be input and cost characteristics defined, such as cable, road, and turbine costs, as well as financial assumptions.

Cable costs include cost/km of cable, running cables along roads, and substations. Road costs include cost/km of building new and using existing roads, steep terrain definitions, and cut-and-fill definitions. The turbine cost mostly includes the foundation, the turbine, and periodic turbine component costs, which can be defined as a function of the site suitability assessment. Financial assumptions include the total life of the wind farm, the debt ratio, and annual costs.

COE results also require shapefiles or rasters for roads, cables, and water bodies as well as information that should be considered as a cost-multiplier layer. For example, the costs for crossing rivers can be applied per geometry object. This methodology truly leverages the ability of ArcGIS to integrate site survey information into shapefiles. In a similar manner, the modeler can include cost savings such as existing roads, with each road segment having its own upgrade cost. The modeler defines a start node for the collection system (substation) and for the road network. All this information is used to assess the cost of energy associated with a given layout.

The output for all three of these optimizers is a turbine layout, which Shell Wind uses to produce energy estimates for a specific site and layout. In addition, the COE optimizer also produces a collection system and road network in the form of polylines and includes costs and lengths for roads and collection systems in the energy estimate.

When comparing the estimated energy of the energy optimized layout to the COE layout, the observation is that the layout plan that includes COE will generally have lower gross energy and capacity factors than the energy optimized layout. This seems logical, as the energy optimized layout focuses on producing the optimal layout for the wind resource on-site, and the COE optimizer focuses primarily on lowering the cost per megawatt-hour of the layout. This then leads to the COE

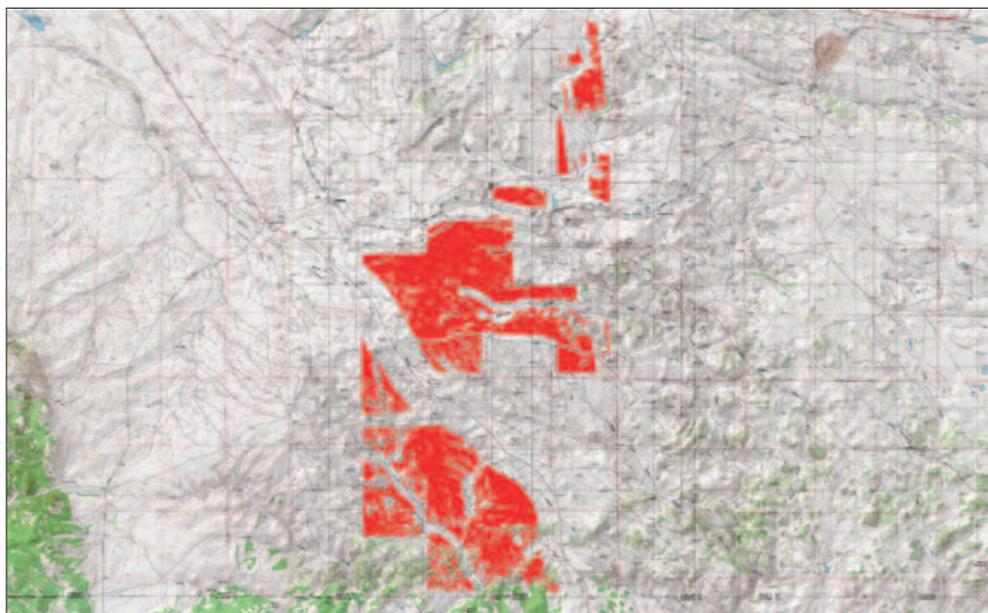


Figure 2—Buildable Areas Where Wind Turbines Can Be Placed

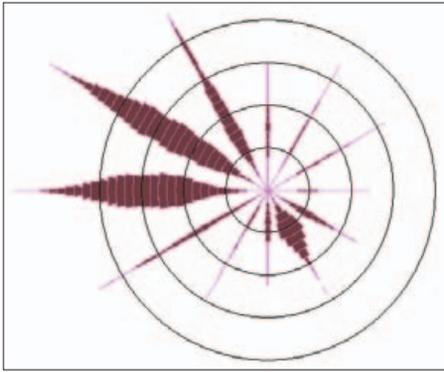


Figure 3—This wind rose indicates that wind is dominant in the west.

layout's estimated cost generally being lower than the energy optimized layout's cost. The map output displays the COE layout versus the energy optimized layout. The COE layout is condensed and linear compared to the more distributed energy optimized layout.

The COE layout appears to have greater impact for sites that have a low ratio of turbines to land. If the site is highly constrained (too little available land) and the turbines are packed in tightly, the COE layout will turn out to be very similar to the energy optimized layout.

Using the highest-resolution DEM available is important because it supports more accurate road and cable design when the program is calculating steep terrain and cut-and-fill costs, for example. Additionally, testing a few different locations for the road and cable nodes could be beneficial, as shifting these nodes can create varying layouts and, in turn, alter the estimated costs.

The openWind compatibility with ArcGIS allows users to take advantage of the advanced functionality and wealth of data associated with ArcGIS programs to collect and prepare input data for project design. Additionally, incorporating GIS resources into wind farm layout design has helped mature the layout optimization process. This enables Shell Wind's engineers and wind farm modelers to work together more dynamically on cable and road design and create a more efficient wind farm plan.

For more information about wind energy projects, visit the American Wind Energy Association website (www.awea.org). For more information on openWind and for a free download of the software, visit www.awsopenwind.org.

Attend the Esri International User Conference

The Esri International User Conference is an the essential event for people using GIS for weather analysis. Along with technical session offerings and expert consultants to help you with your projects, there will be climate-focused tracks such as climate change, conservation, and environmental management. See software demonstrations, talk with like-minded users, and get ideas. In addition, Esri is presenting the Environmental Showcase, where you will be able to

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- Raise awareness of your mission goals, concerns, and successes.
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ArcGIS Spatial Analyst

Solar Analysis

The solar radiation analysis tools in the ArcGIS Spatial Analyst extension enable you to map and analyze the effects of the sun over a geographic area for specific time periods. These tools account for how daily and seasonal shifts of the sun angle, along with variations in elevation, orientation (slope and aspect), and shadows cast by topographic features, affect the amount of incoming solar radiation. Microclimate factors, such as air and soil temperature regimes, evapotranspiration, snowmelt patterns, soil moisture, and light available for photosynthesis, can all be accurately analyzed. Outputs can then be easily integrated with other GIS data to model physical and biological processes affected by the sun.

ArcGIS Spatial Analyst is an extension for ArcGIS that helps users build complex models and perform advanced raster analysis quickly and easily.

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annual.ametsoc.org

Esri Federal GIS Conference

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Esri Developer Summit

March 26–29, 2012
Palm Springs, California, USA
esri.com/devsummit

The Environment, Energy & Sustainability Symposium

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California Sunshine Is an Energy Goldmine Solar Mapping Portal Calculates Energy Cost Savings

By Barbara Shields



A solar value analysis tool shows where solar panels are profitable.

California looks to an energy future that includes renewable resources. Los Angeles (LA) County has abundant sunshine and is encouraging people to capture its energy by installing solar-energy systems. A system's effectiveness to generate electric energy is dependent on the size and number of solar panels installed and how much sun reaches them. LA County Solar Map is an online map service that provides solar value analysis for every commercial and residential building in the county and helps property owners make informed solar installation decisions.

Launched on Earth Day in April 2011, LA County Solar Map (solarmap.lacounty.gov) generation 3 is a simple, elegant map that generates sophisticated solar calculations for any building in the county. The service provides a detailed model of solar photovoltaic potential and accesses existing aerial imagery and data from the Los Angeles Regional Imagery Acquisition Consortium. Via the online map interface, anyone can select a location, see aerial imagery of the rooftops and color-coded dots indicating the amount of direct sunlight hitting each portion of the selected roof, and perform analysis essential for making solar installation decisions. Available to everyone, the portal typically gets

between 50 and 100 hits per day but has capacity to serve many more people as solar demand grows.

The Benefits

LA County Solar Map benefits LA County because it

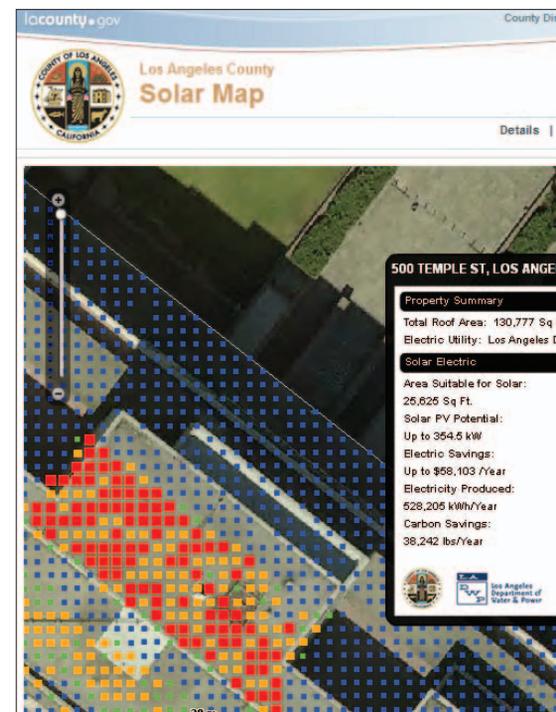
- Supports the county's clean energy goals
- Can be integrated into the county's Energy Upgrade California in LA County (energyupgradeca.org/county/los_angeles) home energy efficiency program
- Is a one-stop shop for
 - Solar rebate/incentive program links
 - Licensed solar contractors and installers information
 - Solar savings calculators
 - Solar news and resources
- Offers credible, impartial data that supports solar product marketing
- Adds scientific accuracy for policy making and grant applications
- Allows other county services to access data
- Opens geospatial data layers to multipurpose analysis
- Provides a tool for reducing building operating costs
- Drives economic development in clean energy

The Story

LA County geographic information officer Mark Greninger became interested in solar mapping because he wanted to put a solar panel on his own roof. He found he had to do a lot of research to understand his risks, rewards, and return on investment. Thinking that there must be an easier way, Greninger researched how other cities had approached the problem. He came across the San Francisco Solar Map model and looked into developing a similar application for LA County.

While looking at the feasibility of a solar map project, Greninger found that the LA County Internal Services Department (ISD) Office of Sustainability was already developing programs to support energy efficiency and solar installations. So he partnered with ISD to apply for a County Information Technology Fund grant to implement the project. The chief information officer provided the technology expertise, and the ISD Office of Sustainability coordinated county support and policy development.

Once the county had acquired a grant for



The SmartNet coverage area is approximately 730 square miles.

the project, Greninger contacted Critigen, the developer of San Francisco Solar Map, and began working with its geospatial technology consultants to develop a then state-of-the-art solar map service built on the Bing Maps platform. On Earth Day 2009, LA County launched the service on LAcounty.gov and on Critigen's SolarMap.org. In a simple, JavaScript-based interface, the solar map service showed parcel boundary information and solar potential by parcel. Although it was limited in its ability to show the specific locations suitable for solar, it was a major success, with over 5,000 hits on its first day.

Starting in late 2010, Greninger and Critigen began working on the next generation of the site, with advances in technology that would make the site cleaner and more robust. Greninger wanted the updated map to be simpler and more intuitive to use; faster; and able to handle high demand to show rooftop potential, pinpoint optimal panel placement, and quickly answer value questions. Critigen had already developed more than 15 solar maps for cities and counties. Bringing this new

knowledge and technology to the solar update project, Critigen created the first generation 3 solar map in the world.

LA County Solar Map covers more than 2,200 square miles and includes all 88 cities in the county and unincorporated areas. Detailed solar modeling of such a large area requires a massive database that, on the previous platform, was unwieldy and impossible to display.

The county deployed Esri's ArcGIS to drive the new site, enabling it to manage the enormous database and integrate multiple map services into the content provided by the site. All data was migrated into an ArcGIS geodatabase, thereby making it possible to use existing installations and solar-augmented parcels data countywide. By exploiting the caching capabilities of ArcGIS 10 for Server as well as limiting the size of the solar data to that of rooftop locations' solar potential, the model quickly accesses data and is highly responsive. The software's Flex API delivers a professional grade viewing experience.

A major step forward in solar mapping, LA County Solar Map offers more than 100 million points for solar potential on LA County rooftops and calculates solar radiation every 5 feet. The database contains 250 million individual measurements including shading from trees, roof features, roof pitch, nearby buildings, and mountains. Each cell grid has been converted to a dot that represents the amount of solar potential for 25 square feet.

The user types in an address and instantly sees the aerial image of the property, its roof, and the exact locations on the roof that receive the most sunlight. The model can be switched seamlessly between English and Spanish. The user can print out a report showing the details of the selected property. County-owned facilities are represented by six-inch resolution and can be viewed in highly detailed 3D solar models. The website also provides information about utility rebates and tax credits, comparative cost analysis for solar versus utility power, and other solar advantages.

The next iteration of the model includes sophisticated solar calculators. These will enable users to draw the location of a potential solar array on a roof and calculate the projected production and various financial benefit data using local incentive, utility rate, and insulation data.

Solar installers get the most direct value from the portal's ability to perform analysis. This reduces installation costs, making solar a more desirable investment. For a nominal cost, they can buy the entire database of assessor information and use it for marketing research. Seeing relationships of solar potential, demographics, years of ownership, savings to clients, and current solar installations data helps these entrepreneurs see the best areas to canvass. Also, solar manufacturers and companies that build and distribute solar cells and modules can use the model to anticipate demand. City governments refer to the model to locate solar energy opportunities in their area.

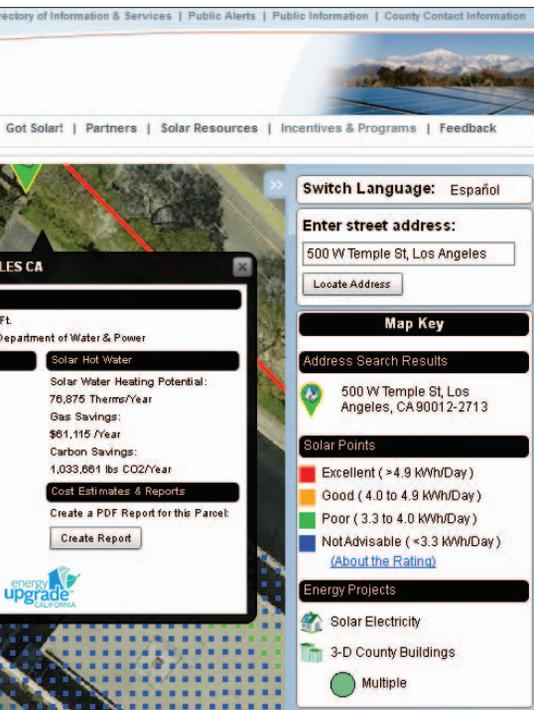
Additionally, plans are in development to add building energy efficiency calculator tools to the map so that property owners and managers may obtain complete building information on energy efficiency potential as well as solar energy potential.

The accuracy of LA County Solar Map was tested by the University of California, Los Angeles (UCLA), with findings that showed only a 4 percent level of inaccuracy. Analysis capabilities were independently verified as accurate by the US Department of Energy, which tested an array of monitoring production levels. These findings add credibility to Solar Map's authority, making it a valid reference for grant and loan applications, scientific analysis, and solar installation.

Contact Mark Greninger at MGreninger@cio.lacounty.gov.

Learn more about Critigen at critigen.com or contact Ty van den Akker, Ty.vandenAkker@critigen.com.

Learn more about ArcGIS for Server at esri.com/arcgisserver.



ArcGIS for Climate Cartography

By Hans Edwin Winzeler, Phillip R. Owens, and Zamir Libohova

Editor's note: A team of Purdue University researchers, headed by Hans Edwin Winzeler, worked on the project Climate of the United States for Continental and Multiscale Conservation Efforts. The resultant map won the Innovation Award in the 2011 Esri/Society for Conservation GIS (SCGIS) International Conservation Mapping Competition.

The purpose of this project is to provide a continuous classification of climate and a method for visualization of complex information using three color ramps combined in one red/green/blue visualization. It offers a method of visualizing climate that can be used in models of soil moisture, wetland preservation, species diversity efforts, and other natural resource management tasks. A continuous classification bypasses discrete boundaries, which often do not exist in nature.

The map displays temperature, rainfall, and seasonality (a Mediterranean index that measures the strength of annual precipitation imbalance) using red, green, and blue. These measurements have traditionally played an important role in the understanding and classification of climate.

First, a standard deviation histogram stretch ($n = 2$) was applied to allow greater visualization of contrasts between high and low ranges of values of the histogram. Second, red, green, and blue rasters were combined into a single climate raster for visualization.

The climate inputs will be applied to the Newhall Simulation Model, which is a detailed simulation of soil moisture, to estimate soil moisture for the conterminous United States at multiple scales. The understanding of soil moisture has important implications for wetland conservation, species diversity and management, and many other natural resource planning and management decisions. Winzeler and his team are developing visualizations and estimates of soil moisture that can be used by natural resource planners at multiple scales.

Using choropleth classifications of climate, such as those of Koppen, with discrete categories requires detailed documentation of those categories, as well as conceptual realization by map users. Continuous classifications can consist of measured values, such as 30-year climate inputs, on a pixel-by-pixel basis that can be more meaningful and, we believe, easier to interpret. Continuous classification also avoids implied abrupt boundaries between natural zones that may in reality have gradual boundaries.

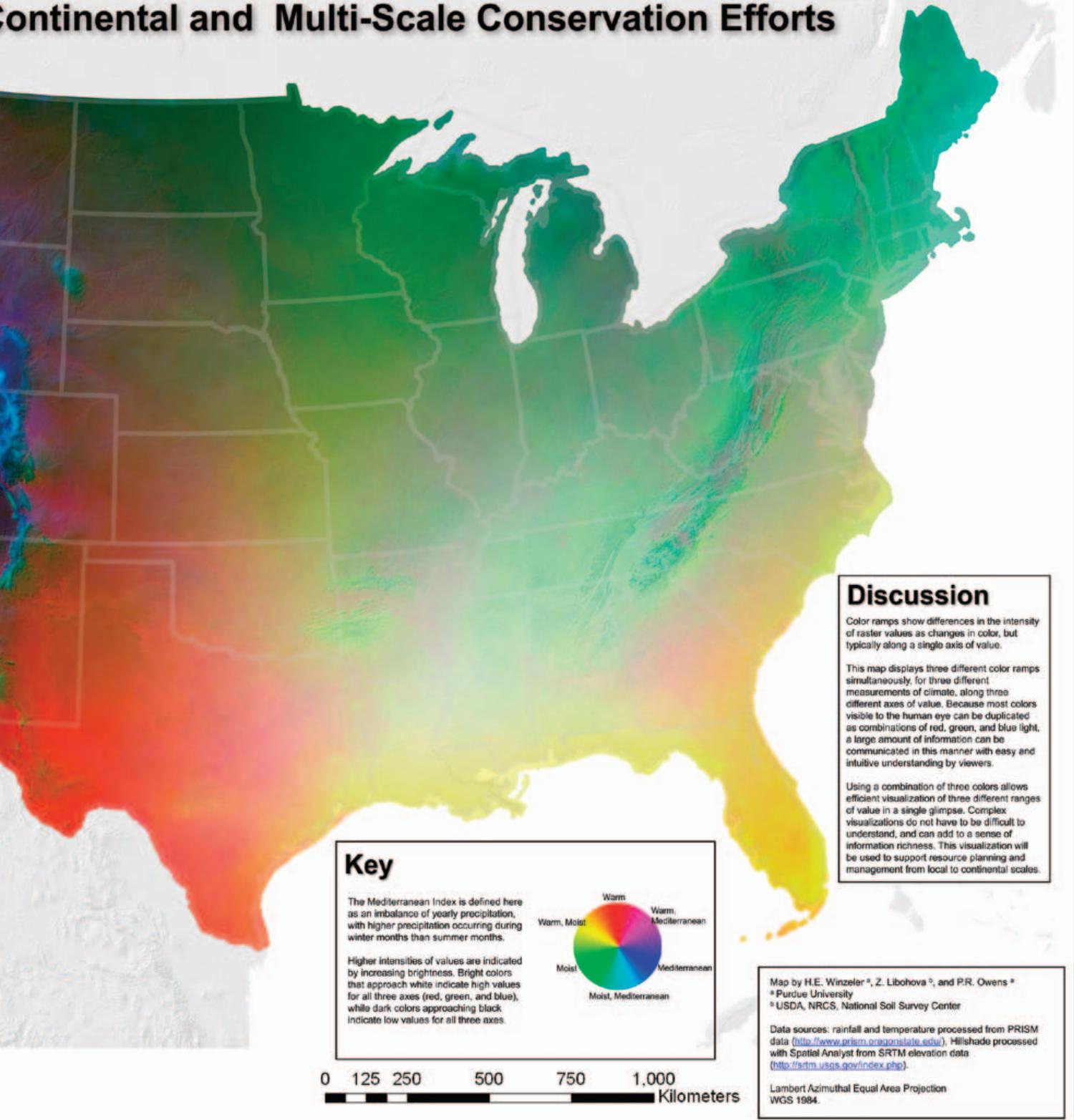
Data sources

PRISM Climate Group (Oregon State University); SRTM digital elevation model

Hans Edwin Winzeler and Phillip R. Owens, Purdue University, and Zamir Libohova, National Soil Survey Center



Visualization of the Climate of the Coterminous United States for Continental and Multi-Scale Conservation Efforts



Key

The Mediterranean Index is defined here as an imbalance of yearly precipitation, with higher precipitation occurring during winter months than summer months.

Higher intensities of values are indicated by increasing brightness. Bright colors that approach white indicate high values for all three axes (red, green, and blue), while dark colors approaching black indicate low values for all three axes.

Discussion

Color ramps show differences in the intensity of raster values as changes in color, but typically along a single axis of value.

This map displays three different color ramps simultaneously, for three different measurements of climate, along three different axes of value. Because most colors visible to the human eye can be duplicated as combinations of red, green, and blue light, a large amount of information can be communicated in this manner with easy and intuitive understanding by viewers.

Using a combination of three colors allows efficient visualization of three different ranges of value in a single glimpse. Complex visualizations do not have to be difficult to understand, and can add to a sense of information richness. This visualization will be used to support resource planning and management from local to continental scales.

Map by H.E. Winzeler^a, Z. Libohova^b, and P.R. Owens^a
^a Purdue University
^b USDA, NRCS, National Soil Survey Center

Data sources: rainfall and temperature processed from PRISM data (<http://www.prism.oregonstate.edu/>), Hillshade processed with Spatial Analyst from SRTM elevation data (<http://srtm.usgs.gov/index.php>).

Lambert Azimuthal Equal Area Projection
 WGS 1984.





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