Esri News
for Agriculture

Summer 2012

GIS-Based Water Requirement Maps Help Produce More Crop per Drop

By Jim Baumann, Esri Writer

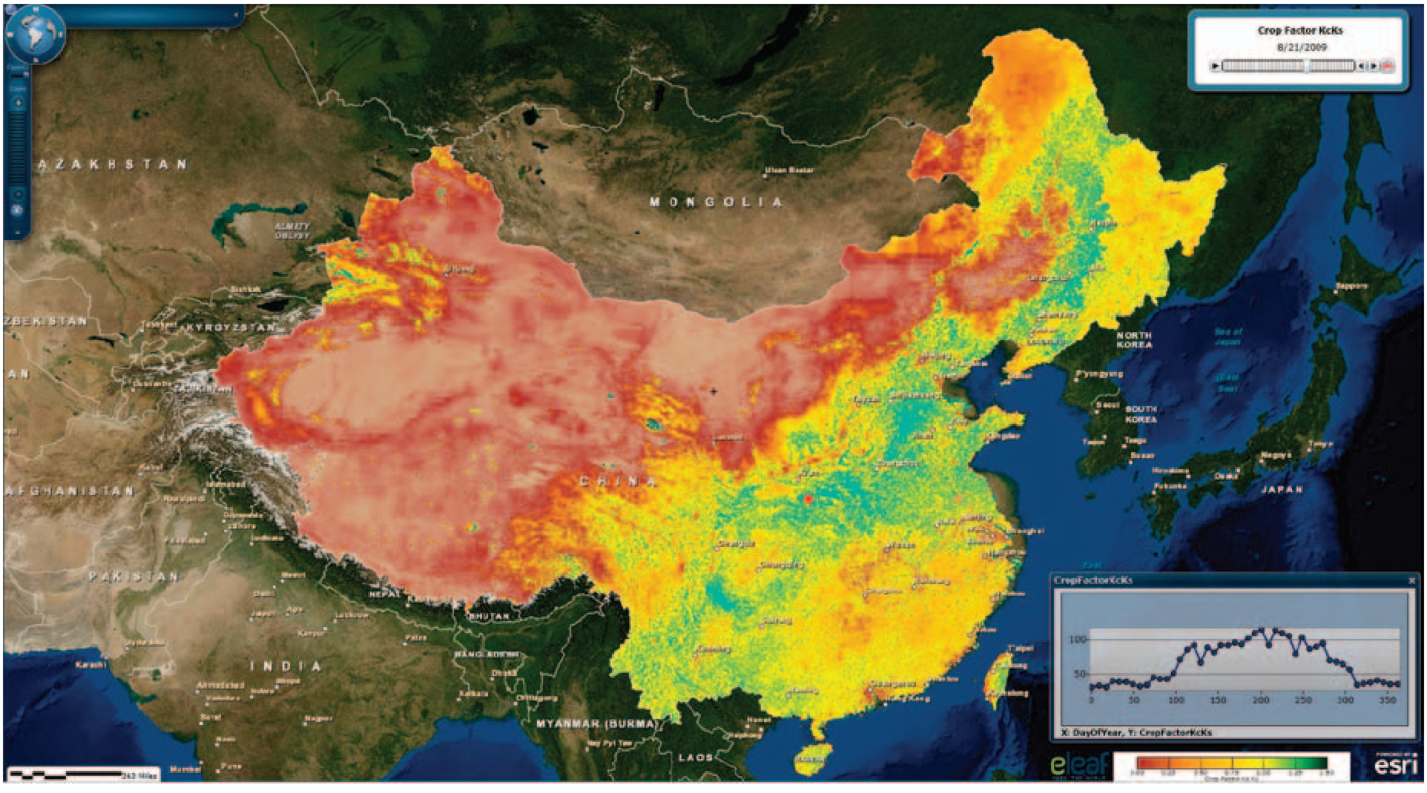
The impact of the accelerating change in climatic conditions around the world is well documented. It provides an ongoing point of discussion and debate in our national and international governing bodies and a regular talking point for the news media.

A primary effect of global warming is the decrease in freshwater resources, which is increasingly evident today, particularly in certain regions of Africa. There, the dwindling water supply has caused the mass die-off of livestock, the abandonment of subsistence farms, and the migration of entire villages in search of a sustainable water source.

In addition, a decrease in reliable sources of freshwater has an enormous negative impact on agricultural production at a time when there is a global need to increase yield. According to *How to Feed the World in 2050*, a strategic report issued by the Food and Agriculture Organization of the United Nations in 2009, world population will grow by another two billion to around nine billion people in the next 40 years, requiring a 70 percent increase in food production.

Measuring Water Use Instead of Land Use

Recently, two well-established companies in the Netherlands, WaterWatch and Basfood, formed eLEAF to support global solutions for agriculture and the environment with data they collect on vegetation, water, and →



↑ The required amount of water for a certain crop under irrigation is calculated by multiplying the reference evapotranspiration by a crop coefficient, KcK.

Contents

Summer 2012

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USDA's KYF2 Initiative Uses ArcGIS to Promote Local Food Systems throughout US

As part of the ongoing commitment of the US Department of Agriculture (USDA) to support local and regional food systems, USDA recently released the Know Your Farmer, Know Your Food (KYF2) Compass Map. The interactive, web-based map provides information about these food systems and is a component of the Know Your Farmer, Know Your Food Compass, which was recently announced by agriculture secretary Tom Vilsack and deputy secretary Kathleen Merrigan of USDA. The map uses Esri's ArcGIS technology and web map services designed and developed by VSolvit LLC.

> "USDA has shown how legacy GIS content can be rapidly organized to benefit broad groups of constituents."
>
> Jack Dangermond, Esri President

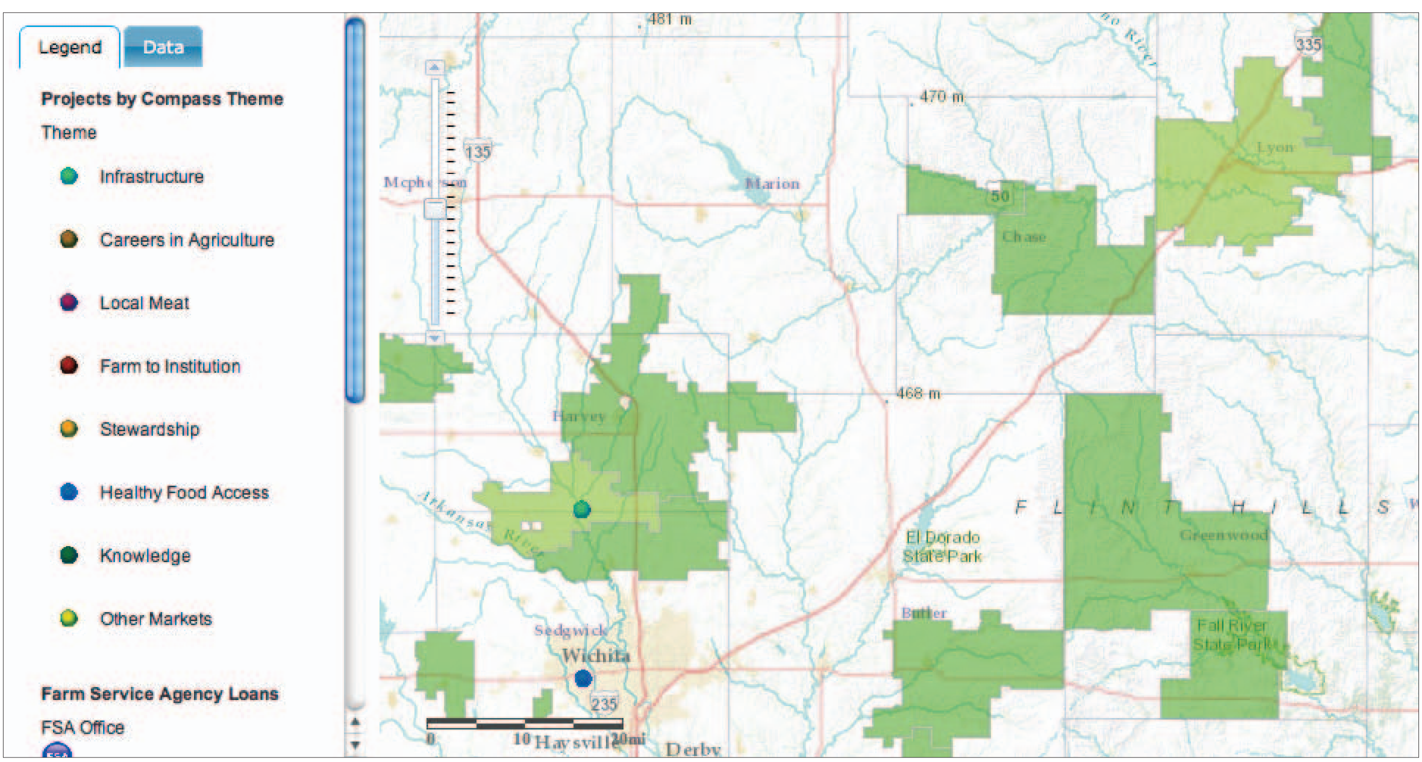
USDA originally launched the KYF2 initiative in 2009 to help revitalize rural communities by identifying the resources needed to grow, market, and distribute local food. The KYF2 Compass Map was created to carry that momentum forward by providing the public with a way to access information about where food is grown and the availability of local markets.

"USDA has shown how legacy GIS content can be rapidly organized to benefit broad groups of constituents," said Jack Dangermond, Esri president. "We are pleased that USDA has mapped local food systems and extended the use of government data to all stakeholders."

The KYF2 Compass Map is deployed using Esri Managed Services. Future plans include updating and adding new datasets and offering dynamic map views and map services. As the map evolves, it will ultimately benefit farmers, educators, businesses, and other organizations by aggregating many sources of data about local and regional food supply chains.

Part of the USDA mission is to help build a national dialog about local food systems. To promote this dialog, Esri supports the Twitter campaign around the compass and encourages those Twitter users involved with local food projects to include the hashtag #KYF2 when referring to the KYF2 initiative and talking about the KYF2 Compass Map.

Try the KYF2 Compass Map at esriurl.com/kyf.



↑ The USDA's interactive Know Your Farmer, Know Your Food Compass Map provides information about local food systems throughout the United States.

 continued from page 1

→ climate. WaterWatch previously developed PiMapping technology, a family of GIS-based tools that delivers more than 50 data components.

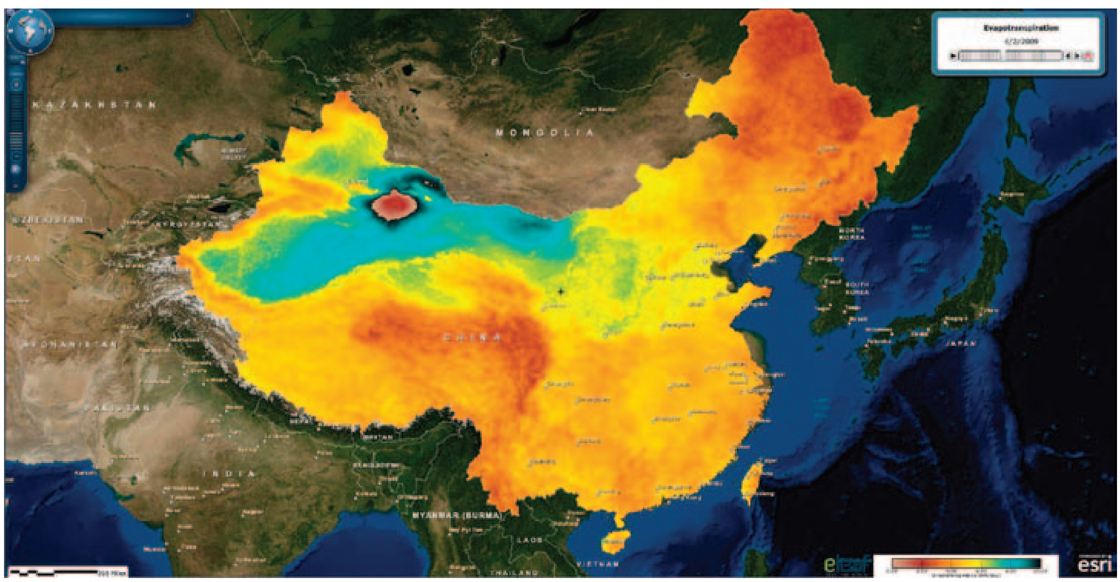
"In the past, the efforts to expand agricultural productivity have focused on the land, commonly measured as a yield per hectare," says Patrick Sheridan, chief marketing officer for eLEAF. "However, with the increasing global scarcity of water resources, the focus is shifting away from the land on which the crop is grown and to the productivity of the water applied to the crop, or a yield per cubic meter."

Optimizing crop water use efficiency requires quantitative measurements of crop water consumption. The physical process behind crop water consumption is called evapotranspiration. It is the combination of plant transpiration (the loss of water vapor from plants) and surface evaporation.

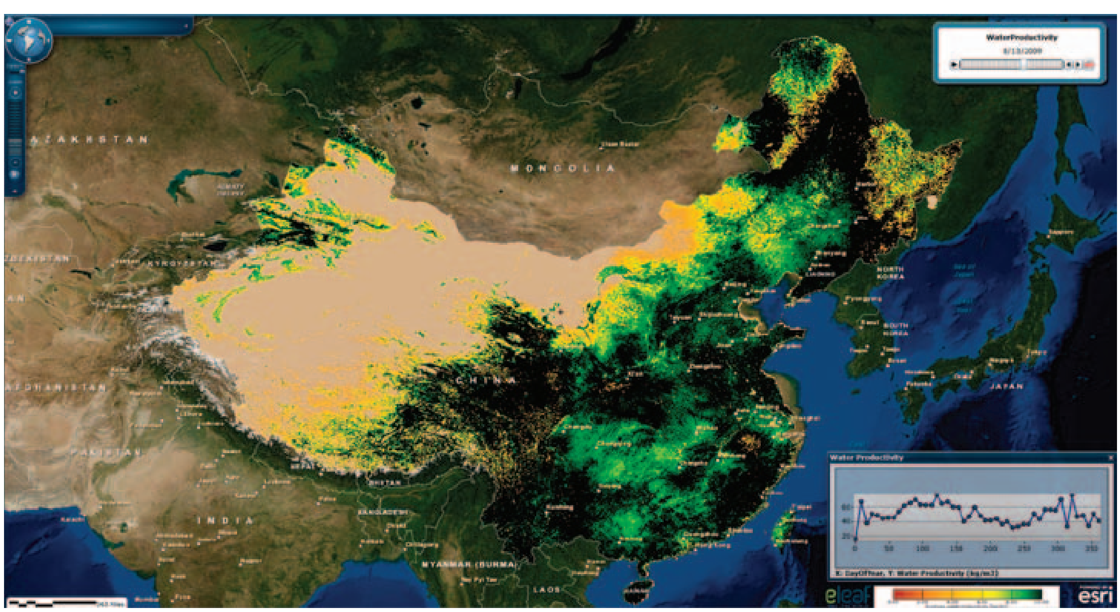
Utilizing Remote-Sensing Data

During the mid-1990s, professor Wim Bastiaanssen, a water resources modeling and remote-sensing specialist and founder of WaterWatch, developed the Surface Energy Balance Algorithm for Land (or SEBAL) model to calculate crop water consumption from remote-sensing data. The model measures the energy balance that specific plants in a defined area require to sustain the hydrologic cycle. Basically, the energy driving the hydrologic cycle is equal to the incoming energy from the sun minus the energy reflected back into space and the energy used to heat the surrounding soil and air.

The model uses satellite imagery (spatially distributed, visible, near-infrared, and thermal infrared data) that includes the albedo (solar



→ Evapotranspiration, the sum of evaporation and plant transpiration, is calculated using satellite images and meteorological observations to determine optimum water needs for plant health.



→ This standard international measurement for water productivity in agriculture indicates the performance and sufficiency of water use in a specified area.

reflection coefficient), leaf area index, vegetation index, and surface temperature. This complex algorithm calculates evapotranspiration on a pixel-by-pixel basis to determine the optimum amount of water needed to sustain healthy plant life in any part of the world. It can also calculate the biomass production (total plant life in a specified area) and soil moisture in the root zone.

Bastiaanssen established the think tank WaterWatch to pursue his research in water resource modeling and remote sensing. The framework WaterWatch developed for PiMapping is based on the SEBAL model. Along with supporting algorithms, PiMapping provides essential meteorologic input data, such as wind speed, humidity, solar radiation, and air temperature. Combining those inputs with remote-sensing data, PiMapping generates weekly updates on biomass production, water productivity, crop water requirements, root-zone soil moisture, and CO_2 intake.

PiMapping Moves to the Cloud with ArcGIS

With complex tools that have been developed for many years, eLEAF is working with Esri's Professional Services team to port PiMapping to a standardized ArcGIS platform. "The solution will leverage Esri's cloud infrastructure, opening many new exciting opportunities for data analysis and dissemination," says Bastiaanssen.

Time-series data collected from this framework is plotted in ArcGIS to create evapotranspiration and biomass production maps. Benefits are substantial and include the estimation of water requirements for different agro-ecosystems, drought monitoring, the identification of areas for possible water savings, and the potential volume of such savings. "Compelling visualizations of our results are essential to get the message across," Bastiaanssen explains. "In our day-to-day consulting work, we have seen substantial productivity increases thanks to the great mapmaking features of Esri's products."

Because they are GIS based, evapotranspiration maps can also be combined with land-use and biomass coverages. Combining these maps provides a great deal more information, such as the amount of water use by land-use class, the boundaries of areas where water consumption can and cannot be controlled, the impact of changes in land use on downstream water availability, crop water productivity, and the amount of water that can be saved while the same production levels are maintained.

"From our analyses, you can determine how much water is available in a specified area, what yield you can expect from the water that is available for your crops, and how efficiently water is used. This will enable farmers to produce more food in a sustainable way," says Sheridan.

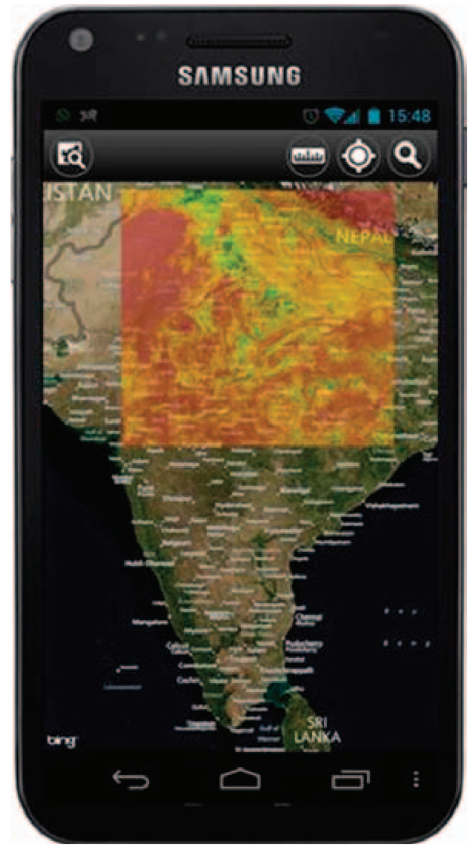
ArcGIS Delivers eLEAF's Database

eLEAF relies on ArcGIS hosted in the Amazon cloud to deliver data to clients. "We are in the process of creating a worldwide database from our analyses that anyone can access using very simple web services," says Sheridan. "ArcGIS has the features we need to integrate with our clients' systems."

Once data is processed and quality checked, it is posted in eLEAF's data warehouse. ArcGIS for Server exposes the data in multiple formats, such as Open Geospatial Consortium, Inc. (OGC), web services or through an image server. This way, eLEAF feeds websites, as well as smartphone applications, and can react flexibly to customer demands. To afford easy access to its global databases, eLEAF also provides its service via ArcGIS Online. "ArcGIS Online is a wonderful platform, as people can experience our products and easily integrate them in their maps," adds Sheridan.

eLEAF's rollout of its ArcGIS Online service has begun in South Africa; as new data is acquired, the service will expand to the entire African continent and then the Middle East. Updates are applied to the previously collected data weekly to assure users that the data they are basing their decisions on is up-to-date.

"Initial reports from South Africa indicate that the eLEAF service has been well received by agronomists, particularly because of its portability to the field," Sheridan concludes. "We are happy that our efforts will help local farmers increase their productivity."



↑ eLEAF's biomass production analysis for Northern India is mapped with ArcGIS and displayed on a smartphone.

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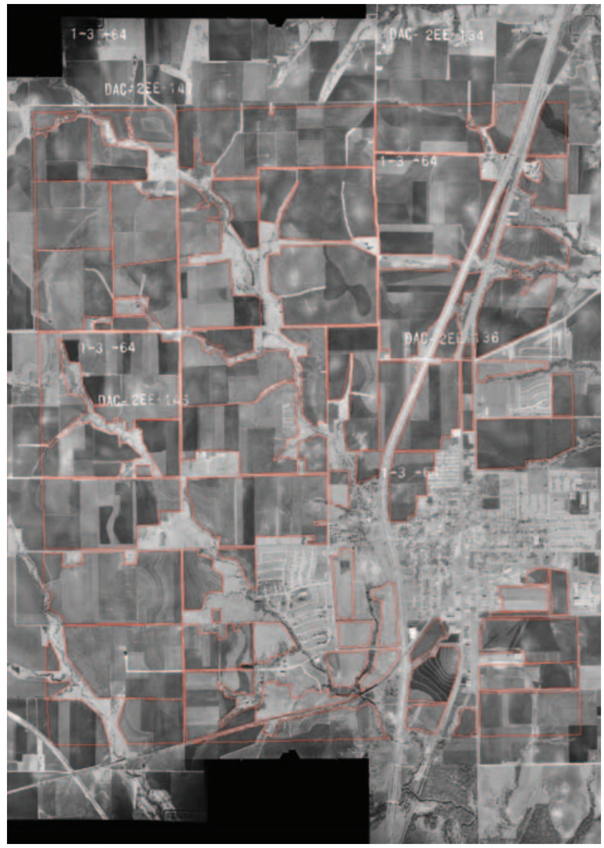
> Patrick Sheridan, Chief Marketing Officer for eLEAF

Featured Maps

Mapping the Nation: Government and Technology Making a Difference was published by Esri Press in 2012. The book includes more than 100 full-color maps produced by 40 US government agencies and illustrates how GIS technology can be used to evaluate and respond to social, economic, and environmental concerns.

Among those agencies featured in the book is the US Department of Agriculture (USDA), a longtime user of GIS. The technology is used by USDA to analyze high-risk landslide and flood areas, estimate global population numbers from crops, and provide the public with a better understanding of agricultural issues.

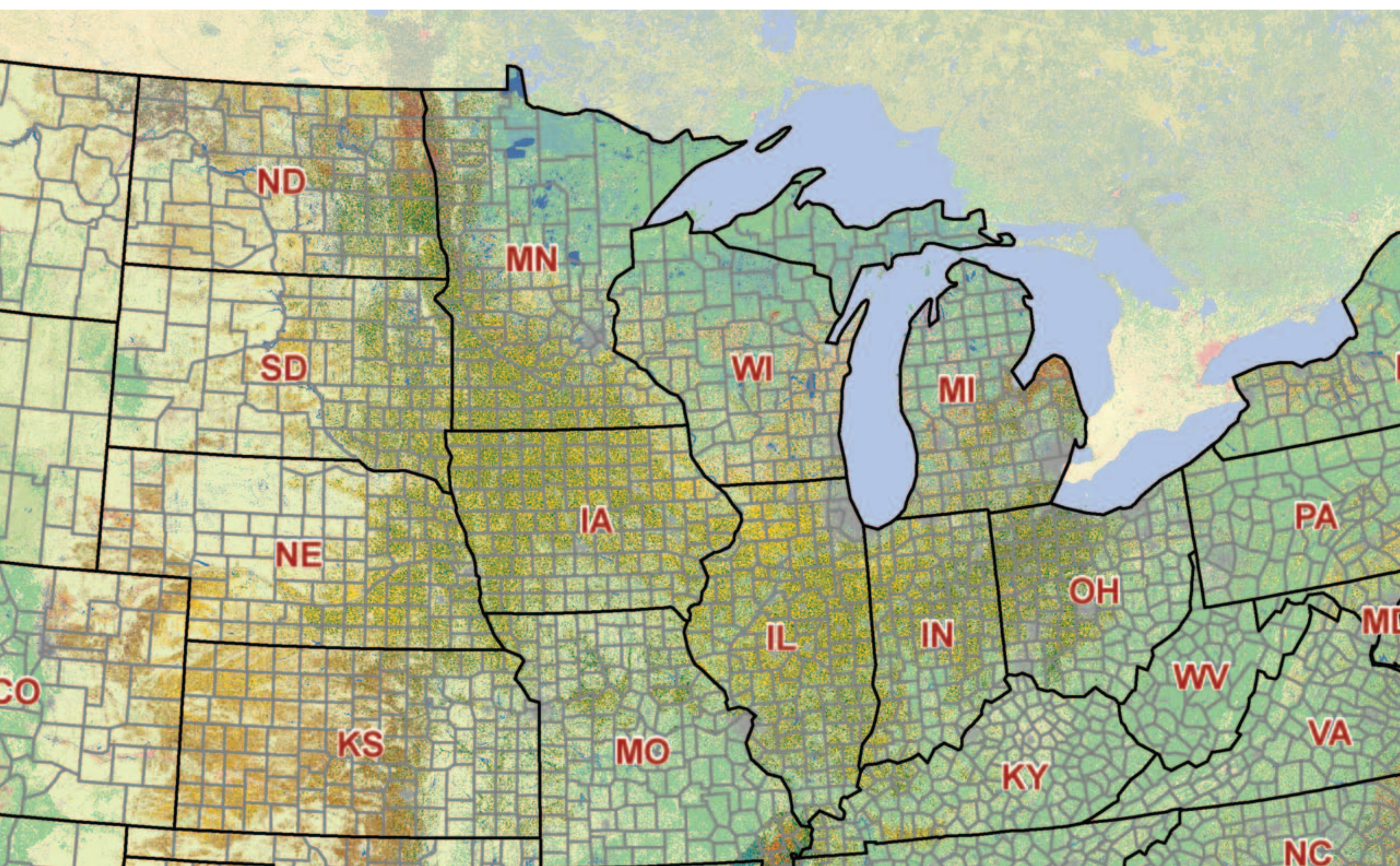
The maps included here in the Featured Maps section illustrate two of the many applications in which USDA is using GIS technology.



↑ 1964

↑ 1981

↓ USDA's National Agricultural Statistics Service utilizes GIS in CropScape, a web-based application that provides Internet users with the tools necessary to display, analyze, and download crop-specific categorized imagery. This detail from the US map highlights the primary crops of the Midwest including corn (yellow), wheat (gold), soybeans (green), and wild rice (blue).



Using GIS, staff from the Aerial Photography Field Office of USDA's Farm Service Agency analyzed urban expansion and its effect on agricultural land in Plano, Texas, during the past 44 years. By overlaying agricultural land polygons on selected images from a collection of historic aerial photography, it created a time series illustrating the loss of agricultural land acreage since 1964.

→ 2008

HarvestChoice Introduces Geospatial Tool for Evaluating Agricultural Service Locations

AgMarketFinder Helps Site Businesses and Services Supporting African Farmers

> "Initial user response has been extremely positive, and we're working to improve the quality and range of the underlying data as well as expand awareness of the tool among our target audiences."
>
> Stanley Wood, Senior Research Fellow at HarvestChoice

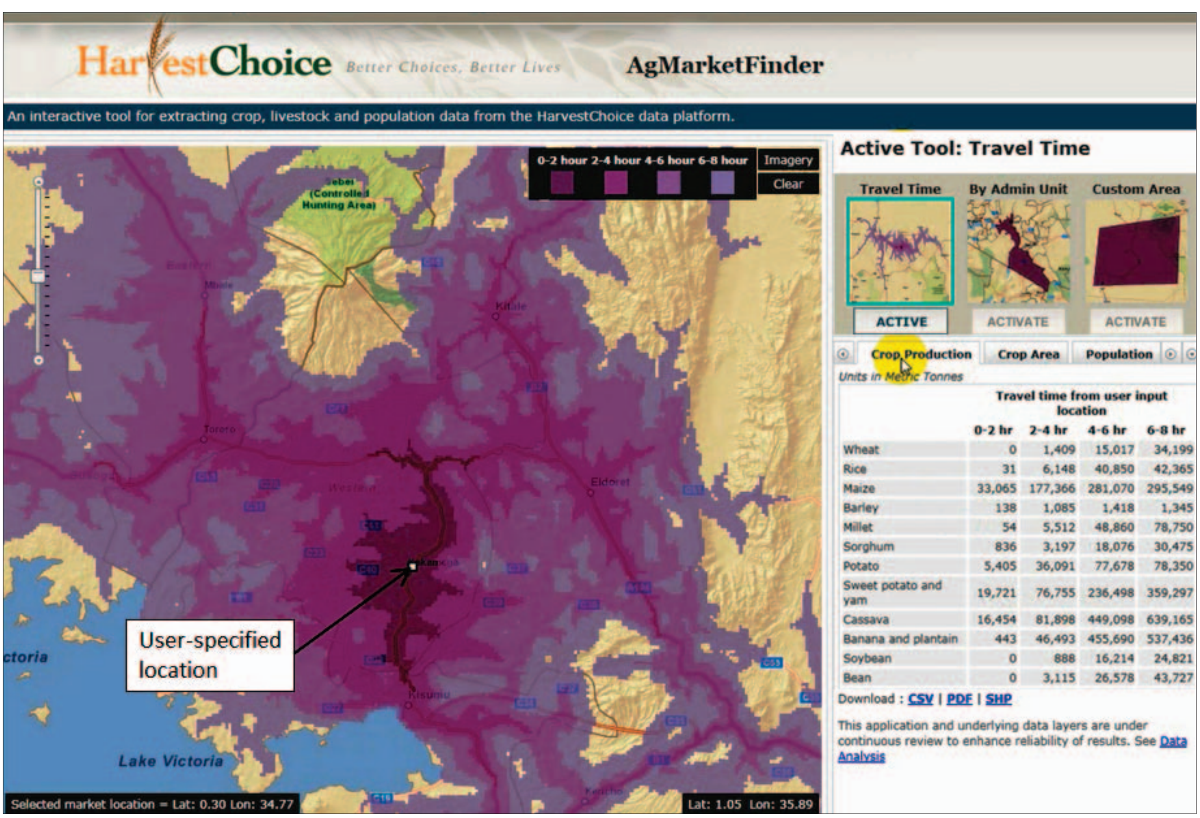
Subsistence agriculture, with its extreme drudgery and small, unpredictable rewards, remains the predominant livelihood of the vast majority of rural households in sub-Saharan Africa. Raising the productivity of subsistence agriculture in sustainable ways is increasingly seen as not only a way out of smallholder poverty and hunger but also a means of releasing household resources, particularly the time of women and children, who are disproportionately the farmers and agricultural laborers of Africa, to engage in more productive endeavors.

Achieving the broad-scale transformation of subsistence agriculture, however, requires significant growth in the provision and uptake of public and private services and products. Examples include improvements in land registration, credit, crop and livestock extension, and veterinary service provision, as well as greater access to input supplies such as improved seeds, fertilizers, and agricultural implements and machinery. Greater opportunities for smallholders to market their farm products are also needed through improved access to farm product collection and sales points, as well as storage, processing, and transit facilities.

Recognizing these specialized, location-based information needs and the opportunity to help address them, the HarvestChoice team at the International Food Policy Research Institute (IFPRI), headquartered in Washington, DC, developed AgMarketFinder. This ArcGIS software-based query tool is used to help pinpoint and evaluate locations across Africa in terms of their potential suitability as operational bases for supporting smallholder farming efforts.

To aid in the development of AgMarketFinder, HarvestChoice partnered with SpatialDev, a Seattle-based spatial software development

→ Travel-time-based query for a potential market location in Kakamega, Kenya. With the user-selected travel-time tool, AgMarketFinder generated estimates of crop production and human and livestock populations within different travel-time bands from Nairobi (0–2, 2–4, 4–6, and 6–8 hours).



↑ Photograph courtesy of Neil Palmer of the International Center for Tropical Agriculture

company, and Esri, which donated the specialized services of its Applications Prototype Lab to accelerate the effort. (You can watch Stanley Wood, senior research fellow at HarvestChoice, demonstrate the capabilities and potential of the AgMarketFinder on YouTube at tinyurl.com/767jjhn.)

Although public agencies and private entities, from local to international, are increasingly willing to invest in supporting smallholder transformation for a range of humanitarian, economic growth, and commercial reasons, many practical obstacles remain. One of those challenges is to identify the most appropriate locations to site relevant service and support facilities. For example, farm input and production service providers need to be assured of adequate demand as indicated by sufficient numbers of farm households, hectares of cropland, or livestock populations in viable proximity to their selected operational bases. Similarly, enterprises dealing in farm outputs need to assess the reliable scale of supply to sustain local aggregation, storage, and processing facilities or potential national, regional, and international marketing operations. In addition, both public and private enterprises are interested in the scale of human populations, both urban and rural, that may represent target clients or customers, welfare beneficiaries, or sources of labor within practical reach of planned service centers or business locations.

AgMarketFinder allows users to examine the service and market potential of any geographic location they identify in sub-Saharan Africa through its map-based user interface. Available information for any location includes production levels of the 20 principal crops grown in Africa; rural, urban, and total human population numbers; and the population of major livestock species. The most detailed results are provided by the travel-time-based query that generates estimates of crop production and human and livestock populations within different travel-time bands (0–2, 2–4, 4–6, and 6–8 hours) from a user-specified location. Other query options generate reports of those same indicators according to either a user-selected administrative unit or a user-drawn boundary circumscribing a customized geographic area of interest.

"Initial user response has been extremely positive," says Wood, "and we're working to improve the quality and range of the underlying data as well as expand awareness of the tool among our target audiences."

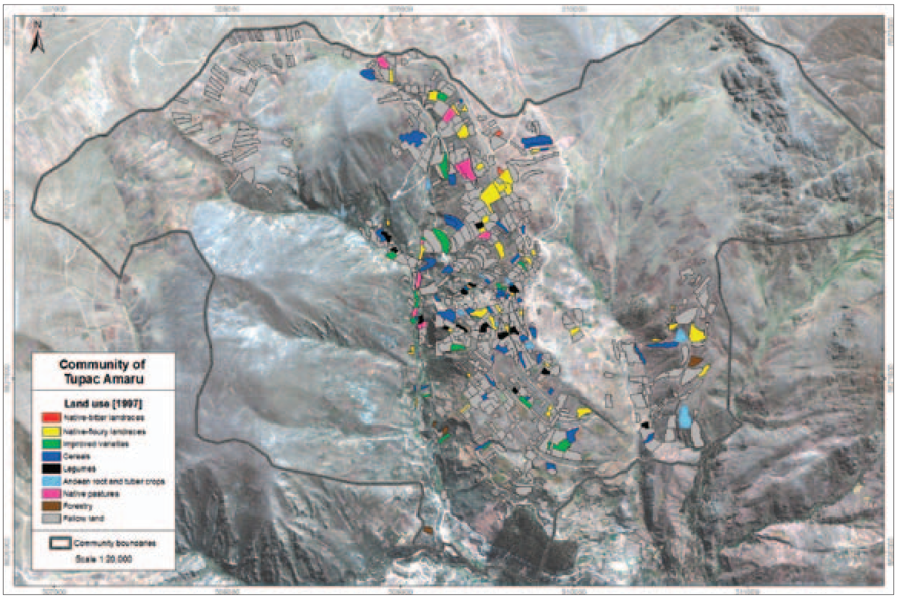
Launched in 2006, HarvestChoice is jointly implemented by IFPRI and the Center for International Science and Technology Practice and Policy (InSTePP) at the University of Minnesota. IFPRI is part of a network of international research institutes funded in part by the Consultative Group on International Agricultural Research (CGIAR), which in turn is funded by governments, private businesses and foundations, and the World Bank.

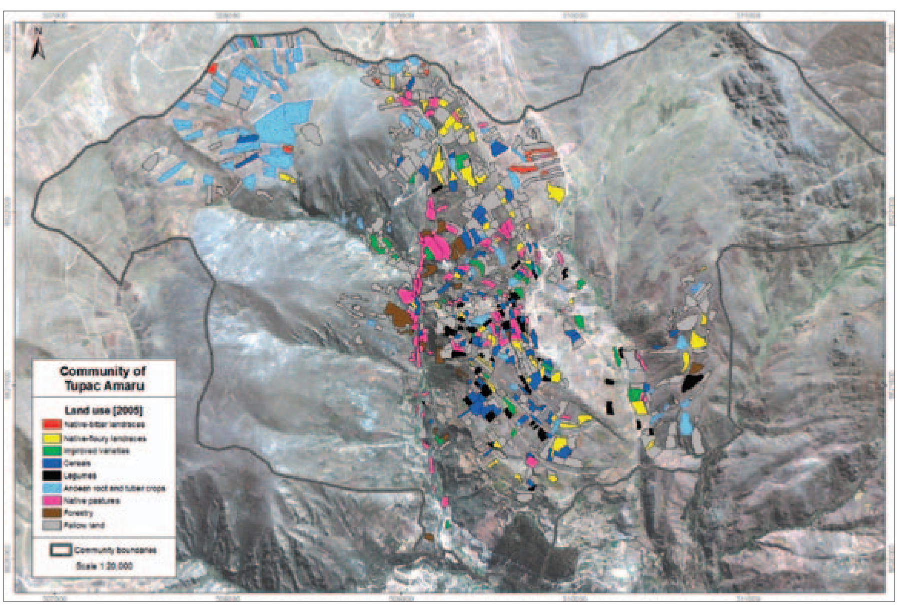
The overriding objective of HarvestChoice is to promote the more effective use of smallholder resources in enhancing the performance of the crops and livestock in their farming systems in ways most likely to deliver sustainable benefits to Africa's poor and undernourished. To accomplish its objectives, HarvestChoice builds and applies decision support databases, analytic tools, and knowledge delivery mechanisms to help guide evidence-based, strategic investments.

Explore the capabilities of AgMarketFinder at http://marketfinder.info.

Mapping the Dynamics of the Contemporary Genetic Diversity of Peruvian Potatoes

By Henry Juárez, Franklin Plasencia, and Stef de Haan, International Potato Center





↑ The change in land-use tendencies from 1997 to 2005 highlights potato cropping areas dedicated to native-bitter landraces (red), native-floury landraces (yellow), and improved varieties (green).

The potato is a traditional crop grown by smallholder farmers in the central Andes. A staple of the Peruvian diet, the potato was first domesticated about 8,000 years ago. The International Potato Center (CIP) in Peru conserves more than 3,800 native Andean cultivars in its collection. Genetic analysis involving both cultivars and wild potato species has determined that the cultivated potato was derived from a complex domestication process in southern Peru and northwestern Bolivia (Spooner et al. in *PNAS*, vol. 104, no. 49, 2007).

CIP is a research-for-development organization with a focus on potatoes, sweet potatoes, and Andean roots and tubers. During the past 40 years, its mission has evolved from increasing crop productivity to the more complex challenge of alleviating hunger and poverty through the implementation of farming system innovations that support sustainable development. CIP's research includes analyzing the effects of climate change on potato cultivation, conserving biodiversity, maximizing food security, and ultimately improving the quality of life of smallholder farmers.

The central and southern Peruvian Andes are the richest area of potato biodiversity in the world. CIP employs high-resolution satellite imagery for ArcGIS software-based geospatial research on potato cropping, biodiversity hot spots, pest and disease incidence, and priority setting for cultivation opportunities for local farmers. CIP has also implemented community mapping projects to gather grassroots information about biodiversity conservation and local farming practices. Participatory community mapping relies on in-depth field-level mapping; focus group meetings; and interviews with families from the highland community study areas of Cusco, Huancavelica, and Junín (Peru).

Detailed mapping was conducted for three cultivar categories: native-bitter, native-floury, and improved. Farmers were asked to identify their potato fields on high-resolution maps of the community area. Fields were assigned a numerical identifier so that data could be attached to them. The owners of each plot were asked a series of questions to reconstruct the recent history of field level management: cultivars grown, type of tillage, rotation design, and so on.

Results from these participatory mapping exercises indicate that between 1997 and 2005, the total cropping area dedicated to improved cultivars grew quickly, whereas those areas reserved for native-floury and native-bitter cultivars (with their broad genetic diversity) have remained stable. The sustained growth of potato farming in the Peruvian highlands can be attributed to the reduction in fallow periods for existing fields and the gradual incorporation of high-altitude virgin pasturelands for farming. Although areas of improved cultivars are proportionally growing fastest at extremely high altitudes (between 3,900 and 4,350 meters), overall cultivation intensity and fallowing periods are inversely related to altitude. No evidence of a straightforward replacement of one cultivar category by another was found. In addition, the data gathered by CIP indicates that the traditional practice of community-wide crop rotation, known as sectoral fallowing, has been lost in many areas. However, smallholder farmers continue to cultivate widely dispersed fields to minimize the risk of losing an entire crop to disease or other factors in the high-risk mountain environment.

Data from the participatory mapping exercise allows CIP scientists to develop an understanding of the patterns of cultivation and the differences between the distinct potato cultivars grown in the Andean highlands. It also provides material that allows researchers to draw conclusions about the effects of external phenomena, such as market forces and climate change, on cultivation methods. Conscious of the practical application of its work, CIP shares results and conclusions with the communities where the studies were originally conducted as well as with the scientific community. The data is useful not only to farmers as they plan their annual cultivation but also to scientists throughout the world who are studying the biodiversity and sustainability of this humble, yet precious, agricultural resource.

↑ Cultivation data is gathered through participatory mapping, in-depth interviews, and focus group meetings with community members.

Potato Guardian Helps Sustain Traditional Farming Methods

Lino Mamani is a Papa Arariwa, or Potato Guardian, in the Sacaca farming community near Pisac in the Peruvian Andes. He and others in five neighboring communities have established a 12,000-hectare potato park where they cultivate and conserve Andean potato cultivars.

Says Mamani, "In the old days, the rain came at the right time, the land was very fertile, and the sun used to shine in the right amount. Now we see that the sun is hotter, and the rains do not come at the right time. We have hailstorms, freezing temperatures, and droughts like we have never seen before. There is also an increase in insect pests and diseases. The potato cultivars that our grandfathers grew down by the river are now moving higher up the mountain slopes. In this land, we have our Apu [sacred mountains] around us, which help our potatoes and the other crops and animals grow. Once there was snow on those mountains; now they look sad, because the climate is getting warmer, and there is no more snow. Other species and animals are suffering, including the condor, foxes, deer, ducks, and fish that have always lived with us and are very dear to us. We know that Pacha Mama [Mother Earth] is not happy with all these changes, and we have to work together to make her happy again."

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