Distant fields of grain

"When you are trying to get people to spend money or act, you need clear information."

Chris Funk
University of California
at Santa Barbara

by Jane Beitler

From his Santa Barbara office, geographer Chris Funk is trying to watch ears of maize in Zimbabwe fill with kernels. Funk knows that years of drought and turmoil in Zimbabwe make it urgent to know exactly how well crops are growing there. As of February 2009, an estimated seven million people in Zimbabwe faced serious food shortages, many surviving on just one meal per day. Zimbabwe's once-thriving agricultural production had fallen by more than half, and both political upheaval and drought contributed to the prospects of widespread hunger. The unraveling of the agricultural system also made it difficult to get good estimates of crop production. Funk said, "Governmental numbers don't really exist. As a result, there were different ideas about the level of crop production in Zimbabwe."

Zimbabwe farmers lay out maize to dry after harvesting it on their community-run farm. Drought and political turmoil have threatened food supplies in Zimbabwe in recent years. (Courtesy K. Holt, HelpAge International)

But organizations poised to send famine-mitigating aid need clear and early answers to questions about food security. Funk and his colleague, geographer Michael Budde, are helping provide that clarity, with a breakthrough in the accuracy of satellite data in estimating crop production. Funk said, "When you are trying to get people to spend money or act, you need clear information. Remote sensing is a visually compelling way of showing how crops are performing."

A hunger for knowledge

Zimbabwe depends on its own farms in ways that many nations have forgotten. In the United States, grocery stores are always well stocked; our supply chains stretch around the world, so affordable imports can replace local shortfalls. But in Zimbabwe, the food supply chain is not so resilient. Once one of Africa's breadbaskets, Zimbabwe now has many farms lying fallow after struggles over farm ownership. Other segments of the economy are in tatters as well, limiting the ability to shift to imported food supplies. A failure of Zimbabwean crops means that citizens will face severe food shortages and inflated prices. Add on Zimbabwe's inflation rate, exceeding 10,000 percent, and it becomes a recipe for hunger.

Funk and Budde are studying Zimbabwean food issues as part of an interagency effort on world food security. Funded by the United States Agency for International Development (USAID), the project includes several partners, including NASA and the United States Geological Survey (USGS), with which both Funk, at the University of California at Santa Barbara, and Budde, at the USGS Earth Resources Observation and Science (EROS) Center, are affiliated. Not so long ago, outsiders became aware of a nation's food crisis only when it had reached a dire stage: images of starving children flooded the news, as well as images of aid workers struggling to send relief in time. Satellites are among the technologies that now help people determine ways to intervene earlier, and in a more targeted manner. More than ten years ago, Funk worked on his first project to study crop production in southern Africa, using satellite data. Funk said, "I got hooked on the idea of using satellite information to help people in the developing world."

Funk knew how valuable data from the sky could be when the situation on the ground was tumultuous. He persisted in digging into the variables of climate, weather, plant growth, and time, sure that there must be a way to remotely estimate yields of staple crops like maize and wheat. Funk said, "We thought that the Moderate Resolution Imaging Spectroradiometer [MODIS] sensor with its high-resolution data was a great resource that had yet to be used routinely in Africa." In the end, Funk and Budde solved the complexities of satellite crop estimates by making the problem simpler.

A matter of rain and time

The climate and weather of Zimbabwe, in southeast Africa, lie under the influence of the Indian Ocean to the east. Most years, easterly trade winds bring heavy summer rains from October to April. Some years, winds flow more southward, drawing that moisture away from southern Africa.

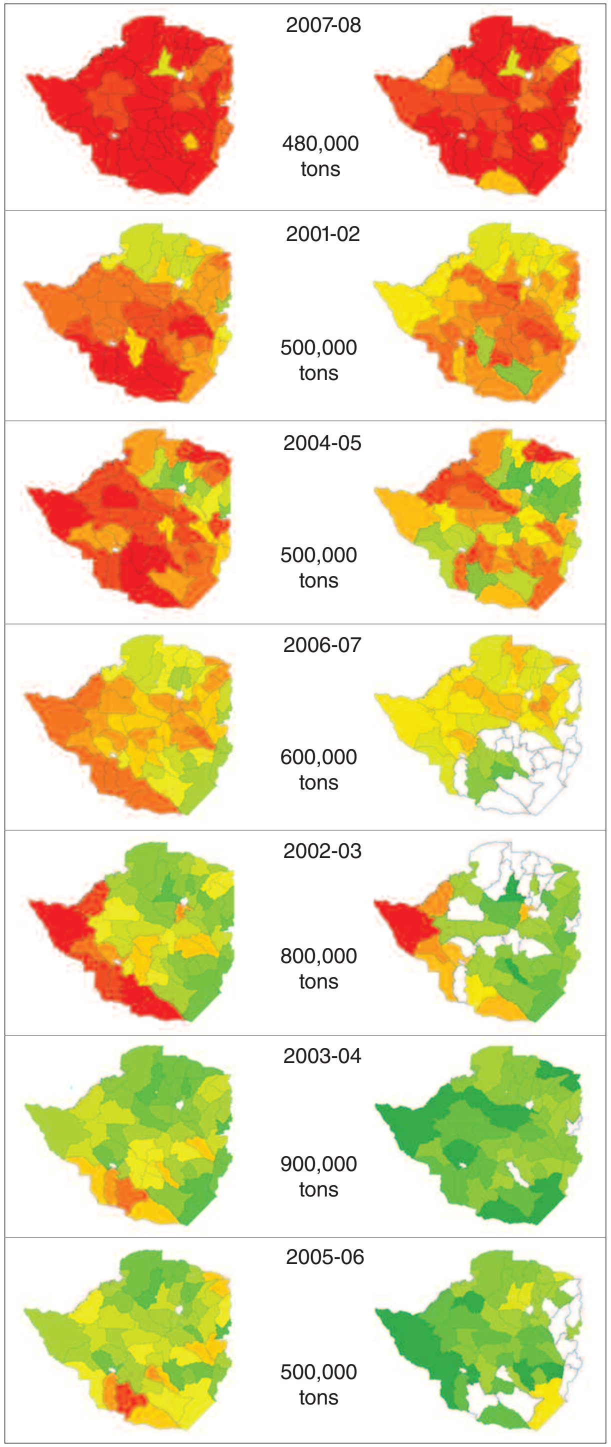
Previous work had compared rainfall and plant health. Satellites orbiting over Africa can measure energy reflected from vegetation, resul-ting in measures of plant health such as the Normalized Difference Vegetation Index (NDVI). Researchers worked for years to take the leap to

This maize in Zimbabwe appears to be thriving in its early stages, but its grain yield will depend on proper timing of rains. (Courtesy C. Reynolds, United States Department of Agriculture, Foreign Agricultural Service)

crop production estimates from rainfall and NDVI data. Satellite and ground data showed a tantalizing relationship, but remote sensing alone could not estimate crops.

Funk and Budde thought the answer would be not in season averages, but well-timed samples. Maize needs a certain amount of water at each phase of development, especially early season growth and grain filling. Funk said, "One of the reasons it's tricky is that there are two stages. First, in the vegetative stage, plants emerge and put out a lot of leaves. That 'greenness' is not really related to the amount of cereal they produce in the end."

Funk and Budde used the life cycle of maize to take a new look at rain and vegetation data. Farmers plant in hopes of rain, and the seed



waits. Rains come and swell the seed, and even more rains let the water-thirsty maize fill their ears with kernels. How would the researchers know, on the other side of Earth, when the growing season really started?

Satellite rainfall estimates helped them pinpoint early growth. These estimates, provided by the National Oceanic and Atmospheric Administration (NOAA) to USAID, use data from a complex ensemble of NASA, NOAA, and European satellites. Budde said, "We looked at each pixel of rainfall data, and when 25 millimeters [0.98 inch] of rain fell in a ten-day period, then we looked for a subsequent 20 millimeters [0.79 inch] in the next twenty days." This start-of-season approach helped them unlock the information in the NDVI data: the two scientists could then look ahead in the vegetation data for the next growth stage and get NDVI measures of how well the maize was faring. Funk said, "We use some pretty simple thinking about how plants grow to find the right time to look at the NDVI. We think the crop started growing here, then we jump forward a couple of months in time." By checking in at each critical stage of plant development, they had a much more accurate picture of the plants' success. They also worked hard to make the data as clean as possible.

These map pairs compare maize production estimates for Zimbabwe over seven growing seasons, sorted from lowest- to highest-production years. The maps illustrate the variability in production from year to year. The poor 2007 to 2008 season stands out as one of the worst years in the series. Maps on the left use greens and reds to indicate higher and lower estimates respectively, from the phenologically-sensitive Normalized Difference Vegetation Index (NDVI) sum analysis. Maps on the right show anomalies, with greens and reds indicating above and below average NDVI sums. Production numbers in tons are from ground-based estimates. (Courtesy C. Funk)

The researchers looked back at years of NDVI data, captured by MODIS and distributed through the NASA Land Processes Distributed Active Archive Center. Funk said, "First we created a time series for each district in Zimbabwe for the seven and a half years we had data, using satellite rain data to decide the start of season date for each year. Then we jumped forward in the future and looked at NDVI for a thirty-day period. It really does simplify the problem." Now rain and time and vegetation could be entered into an equation that would produce a crop estimate from remote sensing data.

Problem presents opportunity

Funk and Budde responded to United States government calls during the 2006 to 2007 season for inputs on Zimbabwean crop production. Drought was causing aid groups to pay closer attention to Zimbabwe's food supplies, already complicated by national unrest. Funk and Budde were ready to put their crop estimates on the table for comparison with other analyses. Funk said, "The NASA data providers completed special processing so we could get data in a timely fashion."

The results were as they had hoped. Their crop estimates were close to figures on the ground, and closer than the seasonally averaged NDVI that had until now been the best approximation for crop production. Budde said, "Our analysis contributed to a clear picture of the situation in Zimbabwe: a 55 percent shortfall in production. This information led to an appropriate and timely international request for aid in 2007."

The following season provided an even more challenging test of their approach. Again during the 2007 to 2008 season, Zimbabwe experienced drought. But this time, when seed distribution delays forced many farmers to plant late, Funk and Budde used ground information to help establish the start of the growing season for their analysis. The scientists were able to replicate the lower yields of the late-planting districts, which were off-timed with the rainy season. The season demonstrated the flexibility and accuracy of their method, which in turn increased confidence in the data for groups planning aid.

Information for action

Budde and Funk continue watching crops in Zimbabwe and other struggling nations around the world, recently completing a study of winter wheat production in Afghanistan. They make their results available through the Famine Early Warning System Network (FEWS NET), which collects data from many sources to construct the clearest picture of food security in nations at risk.

Budde said, "We're studying very large areas that lack good ground information. We throw our hat into this ring: here's our estimation, does that fit with others? If all the evidence points towards a certain situation, it is more likely to be true." Funk added, "You're making decisions. People might put food on a boat and ship it over. If you make the wrong call it can be devastating; unnecessary food aid can cause crop prices to drop, punishing farmers and creating a disincentive for development and investments in agriculture. You want to try to get the answer right."

To access this article online, please visit http://nasadaacs.eos.nasa.gov/articles/2009/2009_crops.html.

About the remote sensing data used

Satellite	Terra
Sensor	Moderate Resolution Imaging Spectroradiometer (MODIS)
Data set	MODIS Vegetation Indices 16-Day (MOD13A1)
Resolution	500 meter
Parameters	Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI)
Data center	NASA Land Processes Distributed Active Archive Center

About the scientists

Michael Budde is a geographer at the United States Geological Survey Earth Resources Observation and Science Center (USGS EROS). He specializes in satellite remote sensing applications for monitoring vegetation dynamics, surface energy balance, and other landscape processes to support early warnings of food insecurity in the developing world. USAID funded his Zimbabwe research. (Photograph courtesy M. Budde)

Chris Funk is a senior research geographer with the USGS EROS, and a collaborator with the Climate Hazard group within the University of California, Santa Barbara Geography Department. His research focuses on drought monitoring and food security analysis for Africa, including early warning applications using remote sensing, rainfall modeling and prediction, and climate change and agricultural development analyses. USAID funded his Zimbabwe research. (Photograph courtesy S. Barattucci)

References

Funk, Chris. 2009. New satellite observations and rainfall forecasts help provide earlier warning of African drought. *The Earth Observer* 21(1): 23–27.

Funk, Chris, and Michael E. Budde. 2009. Phenologically-tuned MODIS NDVI-based production anomaly estimates for Zimbabwe. *Remote Sensing of Environment* 113: 115–125.

British Broadcasting Corporation: Zimbabwe http://www.bbc.co.uk/topics/zimbabwe

British Broadcasting Corporation News: Zimbabwe in facts and figures http://news.bbc.co.uk/2/hi/africa/7304635.stm

For more information

NASA Land Processes Distributed Active Archive Center (LP DAAC) https://lpdaac.usgs.gov

Moderate Resolution Imaging Spectroradiometer (MODIS) http://modis.gsfc.nasa.gov

Famine Early Warning Systems Network (FEWS NET) Zimbabwe food security update, February 2009 http://www.fews.net/docs/Publications/Zimbabwe_2009_02%20final.pdf