

Land-Cover/Land-Use Change Science Team Session at the 2011 NASA Carbon Cycle and Ecosystems Joint Science Workshop: Observations and Data for Land-Use Change with a Focus on Agriculture

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The 2011 Carbon Cycle and Ecosystems Joint Science Workshop, held from October 3-7, 2011, at the Hilton Alexandria Mark Center in Alexandria, VA, included a focus group meeting to discuss observations and data for land-use change. The one-day focus group meeting, organized by the NASA Land-Cover/Land-Use Change (LCLUC) program that took place on October 6, 2011, with over 60 participants. The meeting included presentations by LCLUC Science Team members and invited scientists, a breakout session organized for discussion of the future program focus and direction, and a poster session.

Garik Gutman [NASA Headquarters (HQ)—*LCLUC Program Manager*] opened the proceedings, presenting an overview of the LCLUC program status, discussing its current focus, and describing initiatives to shape the future of the program. Gutman highlighted the currently funded projects that address regional and global land use. He stated the necessity for *synthesis initiatives* to develop the conceptual underpinnings of LCLUC science based on funded studies during the last several years on land-cover and land-use processes, drivers, and impacts. He described particular developments related to the education and outreach initiatives of the program, including the recent research opportunity for early-career scientists to undertake LCLUC research. Gutman concluded with an overview of programmatic issues, including strengthening the social science component of LCLUC projects, the need to prioritize the science while maintaining some thematic and geographic programmatic balance, and the necessity for the program to foster the generation of global products, including a synthesis of global forest products from the Global Land Survey (GLS) projects and a new generation of global land-use products for use in integrated models.

Chris Justice [University of Maryland, College Park (UMCP)—*LCLUC Program Scientist*] followed with a review of LCLUC observations, data, and recent advances in moving from a land-cover to land-use focus. Justice noted that since its inception, 30% of the program funding has been allocated to observations, detection, monitoring, and data products. Emphasis to date has been primarily on land cover (e.g., forests and carbon), but the evolving science of global change, which addresses the impacts of climate change and adaptation,

requires a broader view to include land use. With increasing human pressure on Earth's systems, the linkages between land use and food, water, and energy must be better understood. Emerging policy-relevant, integrated land-use models will need a new suite of global and regional land-use change products. Justice finished with a restatement of the meeting's purpose: *to summarize recent advances and new opportunities in land-use observations and products, and to provide an opportunity for input in terms of the program's future direction.*

LCLUC Projects

The first session of the meeting included presentations of the ongoing LCLUC projects. **Matt Hansen** [UMCP—*LCLUC Principal Investigator*] provided an update on his project titled "Advancing Methods for Global Crop Area Estimation," which is directed at estimating global soybean area using Moderate Resolution Imaging Spectroradiometer (MODIS) data, and developing a turn-key model for sub-regional/national soybean cultivation, using subpixel percent-cover training data with Landsat and RapidEye samples. Global crop-type mapping is a context-critical input to agricultural monitoring.

David Roy [South Dakota State University] presented early results from his project titled "Changing Field Sizes of the Conterminous United States: A Decennial Landsat Assessment," describing the importance of field size as an indicator of agricultural management practices such as intensification, and as a lens on the drivers of rural land-use change. Roy's analysis included applying automated object-based crop identification using multiple vegetation indices, textural features, and crop phenology to his ~100 ft resolution Web Enabled Landsat Data (WELD) product. He showed his preliminary global multi-temporal WELD product, generated in collaboration with the NASA Earth Exchange (NEX) system at NASA's Ames Research Center (ARC).

Xiaoming Xiao [University of Oklahoma (OU)] presented results from his project titled "Quantifying Changes in Agricultural Intensification and Expansion in Monsoon Asia during 2000-2010," which involves modeling cropping intensity on a global scale using MODIS surface-reflectance composites. Temporal pro-

files for individual pixels are used to derive the crop calendar and cropping intensity for a particular area. Xiao summarized the challenges posed by the identification of land cover in monsoon regions, including savannas and summer drought-affected grassland vegetation.

Kirsten de Beurs [OU] concluded the session, discussing “Land Abandonment in Russia: Understanding Recent Trends and Assessing Future Vulnerability and Adaptation to Changing Climate and Population Dynamics.” De Beurs discussed the research methods and preliminary findings on land-use/land-cover change for four study regions in rural European Russia. A logistical model has been developed to link MODIS land-surface phenology estimates to Landsat-based, land-cover estimates to describe cropping intensity; individual land-owner production surveys from regional statistical offices are used to complement the model. De Beurs explained that there are several drivers with varying degrees of influence associated with agricultural abandonment and resurrection in the study region, including growth in the agricultural sector and improved productivity.

Abstracts for LCLUC projects, including those mentioned above, are available on the LCLUC Program webpage at lcluc.umd.edu/projects.php.

LCLUC Program

The second session included several invited presentations relevant to the LCLUC program. **David Skole** [Michigan State University] described his research on carbon, agroforestry, and trees on farms for the Carbon Benefits Project: Modeling, Measurements, and Monitoring. The project combines satellite and field observations in a Web-based geographic information system (GIS) framework for carbon monitoring, reporting, and verification (MRV) purposes. The project includes use of fine-resolution (<1-m) imagery for mapping tree occurrence and crown size; field sampling, to determine biomass growth

rates; and an online data management system to allow project participants to upload inventory data and perform carbon calculations to show carbon sequestration in each project area.

Steffen Fritz [International Institute for Applied Systems Analysis] stated the importance of improving the accuracy of current cropland datasets, and outlined a new Cropland Mapping Initiative in the framework

of the Group on Earth Observations (GEO) Agricultural Monitoring Task to generate the best available current global cropland map. He provided a comparison of existing global land-cover products, highlighting extensive disagreement between data from MODIS, GlobCover, and Global Land Cover (GLC)-2000 with respect to cropland distribution. He described a community-driven data sharing portal, GEO-Wiki, which provides an online arena to foster data sharing, validation, and product cross-comparison. Fritz

emphasized the need for a concerted international effort to provide accurate global cropland maps and change on a periodic (five-year) basis, with annual monitoring of areas undergoing rapid change.

George Hurtt [UMCP] gave a presentation on the requirements for land-use information to parameterize and calibrate global land-use models. The requirements included spatially explicit data on land-use distribution (with a spatial resolution of 0.5°), disturbance, and annual land-use transitions including wood harvest and regrowth. Hurtt explained that the next generation of terrestrial models will require improved land-use classification and subannual land-use transition data at one-hectare¹ resolution. He made several recommendations to the LCLUC community, including combining satellite-based and national inventories and separating land-use classes into multiple fractional categories; constraining model reconstructions of land use with data; and



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¹ 1 hectare is 2.47 acres

generating new products that address important land-management issues, including distribution and characterization of mechanization, irrigation, and fertilizer application, to prepare for the next generation of fully integrated Earth System Models (e.g., iESMs+).

Chris Neigh [NASA's Goddard Space Flight Center (GSFC)] gave a presentation describing the new National Geospatial Agencies (NGA) commercial archive, and the GSFC fine-resolution data initiative. This initiative provides high-resolution commercial data from U.S. vendors to the NASA project investigators (PIs) in National Imagery Transit Format (NITF). Conversion to other formats and software for conversion are available upon request. Neigh stressed limitations on data sharing, but indicated that imagery or derived products could be shared with local, state, and national government and nongovernmental organizations supporting U.S. government interests, and suggested that reduced-resolution, derived products could be posted on the Website as a community resource.

Luigi Boschetti [UMCP] gave a presentation on progress towards operational, fully automated, fine-resolution mapping using a two-stage, land-cover classification system that includes a fully implemented *a priori* knowledge decision-tree classifier—the Satellite Image Automatic Mapper (SIAM) technology—and traditional techniques, including image clustering, segmentation, and supervised classification algorithms. This would result in a purely spectral, discrete, and finite six-target category land-cover classification scheme. At fine resolutions, accurate land-cover mapping can provide an analyst with information on land-use and land-management practices. Boschetti noted that the SIAM technology is capable of processing data from all calibrated multispectral sensors that have spectral bands overlapping with those of Landsat's Thematic Mapper (TM), and the number of spectral categories detected depends on the bands and the sensor. Systematic evaluation is ongoing, and successful tests have been conducted for single-date (e.g., forest/nonforest) and multitemporal applications (e.g., burned-area mapping and detection of field boundaries). Development of a single-date classifier for Landsat data and object recognition for very-high-resolution data is underway.

Breakout Sessions

The breakout sessions that followed focused on how to expand the land-use aspect of LCLUC, with questions involving the speed, direction, and focus of the program over the next 10 years, and any additional recommendations for program management. Suggestions

included using ancillary data to supplement remote sensing studies including, but not limited to, models, census information, surveys, and the fusion of multi-sensor data at various temporal and spatial scales. Others recommended moving away from coarse-spatial-resolution sensors in favor of increasing sensor spatial and temporal capabilities, particularly for global analysis. Everyone acknowledged that description of land use, such as multicropping, seasonal variation, and land-cover change, requires time-series, coarse-resolution data. One suggestion included using the coarse spatial resolution that is presently available, and incorporating finer-resolution data into the analysis as such data become accessible. Some research could already benefit from recently released fine-resolution satellite data available to LCLUC Science Team members from NGA commercial archive found at cad4nasa.gsfc.nasa.gov.

Meeting attendees agreed that the land-use aspect of the LCLUC program should be strengthened; several priorities for such improvement were discussed. One predominant suggestion during the breakout session was to improve land-use definitions and methodological development. This may lead to the scientific community gaining a stronger understanding of the relationship between land cover and land use and the tools needed to identify associated phenomena. A clearer definition of what is really needed to conduct various LCLUC analyses could provide the framework for shaping future satellite and sensor missions and the role of the LCLUC community in land-use analysis.

Workshop Outcomes

A number of priorities for land-use science were identified, including climate impacts, vulnerability and adaptation to rapidly changing conditions, and the increasing stresses on agricultural production and water, while working towards sustainable resource use. It is also important to improve our understanding of land management to help identify issues surrounding sustainability. High-resolution data with higher temporal frequency are necessary for Integrated Assessment Models (IAM), and could be used to gain insight into patterns and processes. Continued outreach to the modeling community to obtain a more complete description of necessary inputs to drive IAMs seems warranted. The group recognized that the relevance of land-use science is increasing, and that NASA should consider increasing the LCLUC budget to enable additional or broader annual research solicitations to fulfill the needs of the growing LCLUC and modeling communities in the context of adaptation science. ■