meeting/workshop summaries

NASA Land-Cover/Land-Use Change Program 15th Anniversary Science Team Meeting

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The NASA Land-Cover/Land-Use Change (LCLUC) Program's Spring Science Team Meeting was held March 28–30 at the University of Maryland, College Park (UMCP). The meeting celebrated the 15th anniversary of the NASA LCLUC program and focused on historical, current, and emerging science in the field of LCLUC. One hundred thirty-five people attended the meeting, including the currently funded Science Team and a number of members from the first Science Team that was formed in 1996. **Garik Gutman** [NASA Headquarters—*LCLUC Program Manager*] and **Chris Justice** [UMCP—*LCLUC Program Scientist*] co-chaired the two-and-a-half day meeting. **Gutman** opened the meeting with an overview of the program's evolution, its context within the NASA Carbon Cycle and Ecosystems Focus Area, and remarks on the ongoing importance of LCLUC research for NASA in the national and international arena. He explained that the recent body of LCLUC research conducted in Northern Eurasia, Central Asia, and Southeast Asia is well developed and is expected to produce synthesis studies and products in the near future. The program is also planning to shift its attention to LCLUC in South Asia and South America. Land-use change is dynamic in these regions but up until now the program has given relatively little attention to these areas—the notable exception being the Amazon region, which was studied extensively under the Largescale Biosphere-Atmosphere (LBA) Program.

The LCLUC Spring Science Team Meeting was held at the University of Maryland Marriott Hotel, with more than 135 attendees.

Chris Justice summarized some of the program's major achievements. He described the shift in focus from the initial program emphasis on the impacts of LCLUC on ecosystem goods and services, through case studies on the process of change and regional and global forest monitoring studies, to studies on the impacts of land-use change on climate and the impacts of climate change on land use. Current funding includes a small number of exploratory studies on land-use adaptation. Justice outlined various partnerships the program has developed over the years, expressing the importance of continuing to strengthen relationships with international programs including Global Observation of Forest and Land Cover Dynamics (GOFC–GOLD), SysTem for Analysis, Research and Training (START), Global Earth Observation System of Systems (GEOSS), and the Global Land Project (GLP). He continued reinforcing the importance of the land-use component of regional international science initiatives. Justice suggested that possible future program emphases might include research on land-use scenarios and climate adaptation; land use, food, and water supply research; vulnerability and social impact studies; and an expanded product development initiative to include land use, targeted at supporting the new generation of integrated land models.

Dave Skole [Michigan State University] provided an overview of the roots of the NASA LCLUC program, which can be traced to the science agenda developed by the Land-Use and Land-Cover Change (LULCC) program of the International Geosphere-Biosphere Programme/International Human Dimensions Programme (IGBP/IHDP). Skole stated that the LULCC project was the first integrated IGBP/IHDP project, requiring a combination of physical and social science. He pointed out that there is a well-documented body of research from that program, and that the research agenda and approach outlined for the LULCC program remains relevant today. The integrated science model adopted by the LCLUC was subsequently taken up by the U.S. Global Change Research Program and U.S. federal agencies in the context of understanding coupled human-environment systems. Skole stressed the increasing importance of LCLUC research with respect to climate change mitigation and adaptation, vulnerability, and resilience. He also stated that strengthening the relationship between disciplines is essential for successful systems research under the LCLUC rubric.

Anette Reenberg [University of Copenhagen—*GLP Science Steering Committee Chair*] presented information on the status of the current IGBP/IHDP GLP and its move into a synthesis phase, fostering collaboration among scientists and supporting integrated research through various team meetings and workshops. Numerous publications, special issues, and book chapters have

resulted from GLP efforts to promote collaboration and synthesis among the program's scientists.

Some of the current and past program PIs provided a review of the state of LCLUC science. **Billie Turner** [Arizona State University] described the importance of land use and sustainability, and stressed the need to move beyond "traditional" driver research before land-change science is surpassed by other global environmental change initiatives. He also noted that the critical driver-oriented research remaining is either aggregate, comparative, or synthetic in nature. Even though land-change monitoring remains an important element, a more systematic and quantitative exploration is needed. **Ruth DeFries** [Columbia University] provided an overview of the complex relationships embedded in land-use change, describing that significant recent changes are driven by: *distal drivers*, such as demographics and markets and their gaining dominance; increases in competing objectives for land; and the fact that land-use decisions are being influenced by climate change phenomena.

Tony Janetos [Joint Global Change Research Institute] proposed that future priorities of the LCLUC program should involve increased interaction with the integrated modeling community. He suggested project topics for research including: further development of land-use models, to incorporate additional human factors involved in land-use change; assessment of relationships between models and observational data on land cover and land use; modeling interactions with the physical climate system, to illustrate potential future scenarios that meet societal demands; understanding sustained ecosystem services and interactions with a changing climate system; and understanding potential climate change consequences through the lens of adaptation and vulnerability.

Dan Brown [University of Michigan] described different techniques for modeling processes and projections of land-use change. His presentation continued with a description of issues surrounding the representation of human processes that include understanding decision-making strategies, heterogeneity, interactions and adaptability of populations, scales of actions in time and space, and the stochasticity of data and modeling. **George Hurtt** [University of Maryland] provided further description of integrated land-use change modeling. He showed the importance of using integrated models to understand Earth's systems and land-use effects in the past, present, and future. Hurtt also explained why studies are needed to further constrain land-use models with improved data on land-use and land-management practices, to prepare for the next generation of fully integrated models.

Alexander Shiklomanov [University of New Hampshire] reviewed the impacts of LCLUC on hydrological systems, with an emphasis on northern Eurasia. He showed that the water cycle in this region is intensifying and that changes in land cover in cold regions can significantly modify hydrological processes.

Dev Niyogi [Purdue University] reviewed the impact of LCLUC on weather, climate and energy balance. He suggested that the impact of LCLUC is likely equivalent to other major global forcing's, but unlike warming seen from GHG emissions, LCLUC forcing is multi-directional and can warm or cool and cause positive or negative feedbacks depending on the region and timing. He stated that without an understanding of the role of LCLUC, we will have an incomplete understanding of human impacts on the climate system.

LCLUC Spring Science Team meeting participants.

The first day concluded with a panel discussion on future directions for land-cover and land-use research, provided by senior members of the community: Ruth DeFries, **Emilio Moran** [Indiana University], Anette Reenberg, Dave Skole, **Robert Kaufman** [Boston University], and **Richard Moss** [Joint Global Change Research Institute]. **Moran** identified key issues associated with future LCLUC science, including food security, the effects of land grabs and rural-to-urban migration, the effect of LCLUC policy implementation, and the usefulness of multiresolution data and multiple methods for analysis. **Reenberg** emphasized that essential steps for the future involve strengthening the links between decision making, ecosystem services, and global environmental change, as well as defining the important feedbacks for human activities at the local, regional, and global scales. **Skole** specified that LCLUC monitoring needs should continue to be an important focus of the program, taking advantage of the unique role that NASA plays in satellite observations and science. **Defries** stressed the importance of understanding LCLUC as an integral component of the Earth systems. **Kaufmann** added that the social factors should be given equal attention, followed by **Moss's** confirmation that the feedbacks between the physical and the social systems require new methodologies for research and collaboration within geographic regions and among numerous related disciplines.

The second day started with short presentations from early-career LCLUC scientists in the NASA New Investigators Program (NIP) and doctoral students supported by the NASA Earth and Space Science Fellowship (NESSF). **David Lobell** [Lawrence Livermore National Laboratory—*NIP 2007*] presented research on agricultural applications of multiyear remote sensing to explore the relationship between weather and agricultural management and to explain drivers of crop growth, development, and yield. **Kimberly Carlson** [Yale University—*NESSF 2008 recipient*] presented her research on spatially explicit land-use change modeling and the impacts of oil palm expansion on carbon flux in the Ketapang District of Indonesian Borneo. Carlson showed that 87% of oil palm plantations are converted from forests and that only 5–10% of the forests will remain intact in the future.

In the next session, LCLUC Science Team Members presented second-year project results. **Jane Southworth** [University of Florida] presented research on understanding and predicting the impacts of climate variability and climate change on land-use and land-cover change via socioeconomic institutions in Southern Africa. Southworth is collecting field measurements of social and ecological components to understand how households cope with climate variability, and which factors lead to greater resilience in the face of current and anticipated variability. Preliminary results of the study show that alternatives to land-based livelihoods enhance resilience to climate variability and highlight the need to place the research in a landscape context in terms of spatial patterns to evaluate finer-scale socioeconomic analyses in a broader context.

Xiangming Xiao [University of Oklahoma] described research currently being conducted for developing land-cover classification products in Monsoon Asia over the period 2004–2007 through the integration of Landsat and Advanced Land Observation Satellite/Phased Array type L-band Synthetic Aperture Radar (ALOS/PALSAR) images. Different approaches have been used to combine the data for operational rice monitoring.

As part of the anniversary meeting celebration, some of the project investigators reviewed various aspects of LCLUC monitoring and their past and proposed future directions. **John Townshend** [University of Maryland] reviewed progress made since the 1980s in coarse- and moderate-resolution remote sensing, and discussed various challenges associated with acquiring and processing global datasets. Townshend expressed the need for multiple, moderate-resolution images per scene, continuous monitoring for areas of rapid land-cover change, and industrial-scale processing of land-cover-related products. He made the case for renewed international collaboration with respect to global-scale moderate-resolution products and the need to implement a virtual global-land-surface-imaging constellation.

Matt Hansen [South Dakota State University] presented results of monitoring land-cover change around the world using bulk processing of Landsat data. He pointed out that infrequent acquisition of Landsat data makes annual updates difficult for many parts of the world. Hansen's presentation concluded with a description of a new 30-m vegetation continuous-field product for the coterminous U.S. that used Web-Enabled Landsat Data (WELD).

David Roy [South Dakota State University] then presented information on the NASA Making Earth System Data Records for Use in Research Environments (MEaSUREs) WELD project, which provides a consistent 30-m record of the land surface of the conterminous United States (CONUS) and Alaska for eight years by applying MODIS data processing principles. He showed examples of the WELD products, described planned algorithm improvements to the product, and presented preliminary results for applying the Spectral Image Analysis Mapper (SIAM) software to develop automated continental scale land cover at 30-m spatial resolution. He concluded by showing the first WELD global composite for one month, made using 7,000 Landsat scenes, and discussed the possibility of using NASA Earth Exchange (NEX) supercomputers for generating global WELD products.

Chengquan Huang [University of Maryland] described a procedure—known as the Vegetation Change Tracker (VCT)—for extracting land-cover change history from dense time series stacks of Landsat data. Huang presented results on characterizing land-cover disturbance and recovery for North America. He made a strong case for global high-temporal-frequency acquisitions from Landsat-class sensors. The session included presentations from: **Shunlin Liang** [University of Maryland], on the Chinese Data Accessibility Project; **Jeff Masek** [GSFC], on the Global Land Survey (GLS); **Jim Irons** [GSFC], on the status of the Landsat Data Continuity Mission (LDCM); **Chandra Giri** [U.S. Geological Survey], on LDCM processing plans; and **Noel Gorelick** [Google], on the *Google Earth* Engine.

On the third day, investigators on projects that were at the end of their funding cycle provided a final report of the significant results from their work. **Hanqin Tian** [Auburn University] presented results from the Land Use-Ecosystem-Climate Interactions in Monsoon Asia Project. Tian concluded that in Monsoon Asia total carbon storage decreased over the years 1700–2005. However, net carbon exchange for the past 10 years has been increasing—particularly in East Asia—primarily due to increased forest plantation and elevated nitrogen inputs. He explained that climate extremes, especially drought, have significantly reduced carbon storage and productivity in cropland, grassland, and forest. The negative impacts of climate change or extreme events, however, could be mitigated through optimizing land management.

Sue Conard [U.S. Forest Service] summarized her long-term research on land cover and fire in Siberia, including results from a number of experimental burns and airborne campaigns. Conrad highlighted improvements to burned-area estimates, which showed significant interannual variability in extent and location. She showed a wide variability of fire intensity and severity within and between fires in larch and Scots pine, stressing that ground fires were more common than crown fires, with low tree mortality over much of the landscape, with landscape return intervals of around 50 years. Conrad also pointed out that emissions from Siberian fires can be highly variable.

Jeff Fox [East–West Center, Hawaii] provided results from his research titled *The Expansion of Rubber and Its Implications for Water and Carbon Dynamics in Montane Mainland Southeast Asia*. The research documented the expansion of rubber into nontraditional areas, and that monitoring at well-instrumented sites revealed that evapotranspiration from rubber may be higher than for forest, with significant differences in seasonal cycles. Fox described how the annual carbon-flux cycle is strongly influenced by the phenology of rubber production.

Garik Gutman wrapped up the meeting by summarizing future plans for the program. He emphasized the need to synthesize and integrate past case study results. Essential components of synthesis and integration of LCLUC research include: summarizing the state-of-the-art knowledge; compiling available relevant datasets and research studies; advancing our understanding of the processes, drivers and impacts of LCLUC; and developing new understandings and conceptual frameworks. He indicated that the future direction of the LCLUC program would continue existing international efforts and integration of the social sciences in LCLUC projects, balancing thematic and geographical research. The program will continue to advance the monitoring of land cover and land use and to foster generation of global products, taking advantage of the new NASA sensors coming online in the next few years [e.g., LDCM, Visible Infrared Imager Radiometer Suite (VIIRS)] and to promote the broad use of NASA data and products. ■

Attending the poster session on Monday night. [*Left to right*] **Kyle McDonald** [City University New York], **Kathleen Bergen** [University of Michigan], and **Susan Conard** [USDA Forest Service].