meeting summaries

Summary of the NASA LCLUC Spring 2014 Science Team Meeting

Catherine Nakalembe, University of Maryland, College Park, cnakalem@umd.edu
Garik Gutman, NASA Headquarters, ggutman@nasa.gov
Chris Justice, University of Maryland, College Park, cjustice@umd.edu

Introduction

The NASA Land-Cover/Land-Use Change (LCLUC) program held its annual spring Science Team Meeting April 23-25, 2014, in Rockville, MD. The objective of the meeting was for LCLUC principal investigators to present progress reports on various projects, including urban studies, synthesis studies, LCLUC-supported or -related program activities, and to discuss new and planned program developments.

The opening session served to put in context the importance of the urban component of the LCLUC program and—accordingly—in NASA's Earth Science Program, as the world faces challenges for sustainability. According to the United Nations, more people now live in cities than in rural areas, and even higher urban growth rates are expected in the developing world in next 30 years. There are now 21 *megacities*[1] compared to just two in 1950 (New York and Tokyo). Of these 21 megacities, 17 are located in developing countries. Though cities still represent a relatively small footprint globally (about 3% of total land area), the process of urbanization most often involves irreversible shifts from agriculture to built-up space and industry: infrastructure, technologies, and services that modify carbon, water, and energy cycles at various spatial scales. Remote sensing offers unique opportunities for understanding rates and trajectories of change in urban land use, and for modeling future changes and impacts on LCLUC.

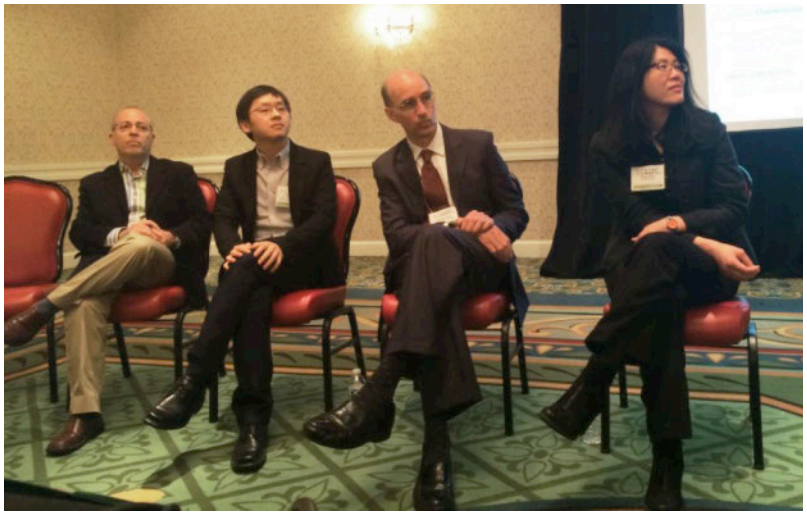
[1] *Megacity* is defined by the United Nations' Human Settlement Program (UN HABITAT) as a city with a population of more than 10 million.

After the welcome, **Garik Gutman** [NASA Headquarters (HQ)—*LCLUC Program Manager*] presented an overview of the LCLUC program. He remarked on how rapidly the LCLUC program has expanded through its international and regional networks, partners, and initiatives, and highlighted the recently published National Research Council (NRC) report, *Advancing Land Change Modeling: Opportunities and Research Requirements,* a distinguished outcome of the program's long-term partnership with the U.S. Geological Survey (USGS).

Jack Kaye [NASA HQ—*Associate Director for Research, Earth Science Division*] followed with a brief summary of NASA's *Earth Right Now* suite of activities (*www.nasa.gov/content/earth-right-now*), a NASA-wide endeavor that focuses, among other topics, on five NASA Earth Science missions—all scheduled for launch in 2014[2]. With more Earth-focused launches in a single year than took place in the entire last decade, NASA will significantly enhance its Earth-observing capabilities, allowing scientists to collect even more crucial data needed to better understand our changing planet.

Chris Justice [University of Maryland, College Park (UMD)—*LCLUC Program Scientist*] emphasized the importance of remote sensing for monitoring and characterizing urban and suburban area expansion.

[2] These include the Global Precipitation Measurement (GPM) Core Observatory (launched in February 2014); second Orbiting Carbon Observatory (OCO-2) (launched in July 2014); Soil Moisture Active Passive (SMAP); International Space Station Rapid Scatterometer (ISS-RapidScat); and Cloud-Aerosol Transport System (CATS).



[*Left to right*] **Francesco Tubiello** [UN FAO] and LCLUC Principal Investigators **Yuyu Zhou**, **Stephen Leisz**, and **Karen Seto** during a Q&A session. **Image credits:** All photos in this article were taken by the authors of this report, or other members of the LCLUC team.

Farm laborers in Hyderabad, India, use the hard surface of a *special economic zone* (SEZ) entrance road to separate wheat from chaff.

In addition to LCLUC monitoring with moderate-resolution products today, fine-resolution and lidar data are used to characterize urban areas. New datasets from Landsat and the National Geospatial-Intelligence Agency (NGA) offer a unique perspective, critical to understanding the consequences of today's changes in urban areas. The remainder of the meeting was organized under the following sessions:

- Urban LCLUC Studies;
- Invited Presentations on International Programmatic Activities;
- Programmatic Perspectives and Initiatives;
- LCLUC Synthesis Presentations; and
- Urban Interdisciplinary Studies (IDS) on Environmental Impacts.

The remainder of this report consists of summaries of each session. A list of speakers and affiliation is provided at the beginning of each section, followed by a narrative description of the most significant results. The individual presentations can be found at *lcluc.umd.edu/meetings.php?mid=52*.

Urban LCLUC Studies

This session included presentations from: **Karen Seto** [Yale University]; **Peilei Fan** [Michigan State University (MSU)]; **Cristina Milesi** [California State University, Monterey/NASA's Ames Research Center (ARC)]; **Eric Brown de Colstoun** [NASA's Goddard Space Flight Center (GSFC)]; **Yuyu Zhou** [Joint Global Change Research Institute]; **Stephen Leisz** [Colorado State University]; and **Charles Vörösmarty** [City College of New York].

Several reports in this session focused on urban development in specific regions. Just as natural land cover varies greatly over Earth's surface, the contours of the "concrete jungle" are anything but homogeneous, and vary considerably depending on one's location. Cities in India, for example, are primarily building out, with dense urban centers and little urban sprawl. Building regulations and land tenure issues are complex, and most buildings in urban centers do not rise above three or four stories. On the other hand, high-rise residences are common in peri-urban areas, where agricultural land use often conflicts with urban growth—see photo, above.

By comparison, Chinese cities are building both up and out, and urban expansion is associated with a decline in agricultural land use intensity. Development accelerated in coastal Chinese cities after government reforms, with high rates of expansion beginning in the late 1980s and early 1990s. Areas targeted for the earliest reforms, including the cities of Shenzhen and Ningbo, expanded rapidly before others. One of the presentations focused on the three major institutional forces underlying urban development in Hangzhou. These included administrative annexation and establishing development zones; increasing involvement of the market by facilitating relocation, satisfying housing demands of migrants, and investing foreign capital; and implementing the local *entrepreneur state*, which exploited land transactions to accumulate profit.

Other reports during this session highlighted the application of certain types of remotely sensed data and analytical techniques to study specific aspects of urban LCLUC. For example, by employing a *cluster-based standardized approach*, based on multisensor characterization of human settlements, it is possible to track urbanization consistently over large regions. A bonus of this approach is that it requires minimal

data training. Meanwhile, surface reflectance products from Landsat and the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard NASA's Terra and Aqua satellites are highly consistent and useful for mapping impervious cover to detect and map urbanization *hot-spots* at the global scale. Multiseason characterization of mean reflectance properties and low variability distinguishes built environments from adjacent agricultural or undeveloped areas in most situations. However, longer time series of Landsat-scale data [i.e., 30-m (~98-ft) spatial resolution] are needed to resolve reflectance ambiguity over desert cities. Multitemporal analysis shows strong indication of urban growth and rural urbanization in Vietnam, Laos, and Thailand. Connectivity between these countries has increased significantly due to development of the East-West Economic Corridor.

A global-scale assessment of threatened urbanized river delta systems shows that *delta hotspots* of incident hazards *versus* environmental stress are predominately heavily urbanized Asian deltas, including the Han, Pearl, Yangtze, Yellow, Godavri, Ganges, and Indus river deltas—see **Figure** below. Results from a study that used interferometric data collected between 2007 and 2011 show strong evidence of subsidence from groundwater extraction due to the presence of fish farms in the Yellow River Delta[3].

[3] These data were obtained by the Advanced Synthetic Aperture Radar (ASAR), onboard the European Space Agency's Environmental Satellite (Envisat), and the Phased Array type L-band Synthetic Aperture Radar (PALSAR), onboard the Japan Aerospace Exploration Agency's Advanced Land Observation Satellite (ALOS).

Invited Presentations on International Programmatic Activities

This session included presentations from: **Francesco N. Tubiello** [Food and Agriculture Organization (FAO) of the United Nations]; **Tony Janetos** [Boston University (BU)]; and **Karen Seto**.

The Intergovernmental Panel on Climate Change's (IPCC) Working Group III reported that greenhouse gas (GHG) emissions accelerated at an estimated +2.2% per year between 2000 and 2010, despite reduction efforts. Emissions are rising with the growth in gross domestic product (GDP) and population. The report warns that without more mitigation, global mean surface temperature might increase from 3.7 °C to 4.8 °C (~6.7 °F to 8.6 °F) by the end of the twenty-first century.

While the rapid rate of urban expansion is not without concerns in terms of environmental and climate impacts, over the short term it may also offer the best hope for mitigating the impacts of climate change. The next 20 years are predicted to see a rapid increase in urbanization. In many cases, the urban form and infrastructure of these areas are not locked in and there is an opportunity to design "greener" cityscapes that minimize emissions and other harmful impacts on the environment. One of the presentations noted that cities in non-Annex I[4] countries generally have higher levels of energy use compared to the national average, whereas cities in Annex I countries

[4] This refers to parties to the Kyoto Protocol not listed in Annex 1. For the most part, this includes developing countries and countries especially vulnerable to the adverse impacts of climate change.

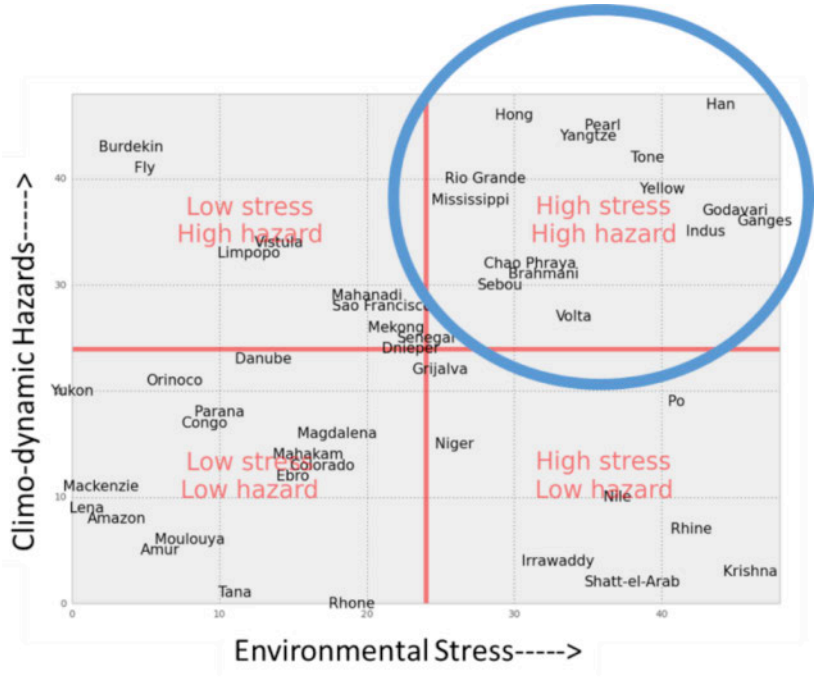


Figure. This plot of delta hotspots shows incident hazards versus environmental stress in urbanized river delta systems around the world. Most of the high-stress, high-hazard deltas are found in urbanized regions, particularly in Asia.

generally have lower energy use per capita than national averages. However, such urban design opportunities will be challenged by limited governance, technical, financial, and institutional capacities, all the while requiring closing some of the significant gaps in knowledge that still remain due to the lack of consistent and comparable emissions data at local scales. Also contributing to the problem is the lack of scientific understanding of the magnitude of the emissions reductions resulting from altering urban forms. There also remain large uncertainties as to how urban areas will develop in the future, as well as a general lack of scientific understanding of how cities can prioritize climate change mitigation strategies, local actions, investments, and policy responses that are locally relevant.

The presentations in this session highlighting two international programs that are working to help close the gaps in our knowledge. The first program discussed was the FAO of the United Nations GHG Emission Estimates Database, which is a global GHG emissions database designed to help member countries identify and report GHG emissions and mitigation actions in agriculture, forestry, and other land uses. The database provides a complete and coherent time series of emission statistics at the country level over a reference period from 1961 to 2010, based on FAO Statistical Databases (FAOSTAT) activity data and IPCC *Tier 1* methodology. The database site is found at *faostat3.fao.org/faostat-gateway/go/to/download/G1/*/E*.

The second program discussed was the Global Observations of Forest and Land Cover Dynamics (GOFC-GOLD), a nongovernmental international scientific program that plays an important ongoing role in enabling methods, validating data, and intercomparing data sources. The program has been instrumental in developing regional science networks addressing land-cover-related science questions and has focused on coordinating major space data sources from NASA, the USGS, and the European Space Agency (ESA), as well as coordination with data providers from Brazil, China, and the private sector. The site is accessible at *www.fao.org/gtos/gofc-gold*.

Programmatic Perspectives and Initiatives

Presenters during this session included: **Dan Brown** [University of Michigan]; **Jeff Masek** [GSFC]; **Jiaguo Qi** [MSU]; **Pasha Groisman** [National Oceanic and Atmospheric Administration (NOAA)/ University Center for Atmospheric Research]; **Brice Mora** [GOFC-GOLD/ Wageningen University, Netherlands]; **Krishna Vadrevu** [UMD]; **Jana Albrechtová** [Charles University, Czech Republic]; **Jiaguo Qi** [MSU]; **Rama Nemani,** [ARC]; and **Chris Justice** [UMD].

Brown briefly summarized the NRC's report on Land Change Modeling[5]. Most operational Land Change Models (LCMs) fall in between process identification challenged by *equifinality* (different processes produce similar patterns) and *multifinality* (same process produces multiple patterns), while their projections are challenged by nonstationarity, complexity, and path dependence in processes. Remote sensing observational advances in temporal, spatial, and spectral details, as well as the extensive Landsat archive, create opportunities in LCM research. These include advancement of process-based models, cross-scale integration of models, cross-scale integration of LCMs with Earth system models, and bridging LCM optimization with design-based approaches.

Masek gave an update on Landsat-8 and collaboration with ESA's Sentinel-2 Program. Landsat-8 currently acquires approximately 550 of a possible ~850 land scenes per day, and continues to perform well. The Operational Land Imager (OLI) onboard Landsat-8 is meeting or exceeding all radiometric and geometric performance requirements, while the Thermal Infrared Sensor (TIRS) is meeting most requirements. The planned MultiSpectral Instrument (MSI) onboard ESA's Sentinel-2 spacecraft (scheduled for launch in 2015) will have a Level-1C (L1C) data product that is analogous to Landsat's Level-1T (L1T) data. ESA will downlink and process between 800 and 900 GB of Sentinel-2 raw data per day. The USGS will pull L1C products from processing and archive centers for archive and distribution to ARC, Canada Center for Remote Sensing, and the general public. Sentinel data will be made available at no cost. NASA is investing in approaches to harness Sentinel-2 and Landsat data for land science to harmonize their surface reflectance products and develop products from the combined data. This will enable a frequency of moderate-resolution satellite coverage of between two and three days, as opposed to the 16-day coverage available today.

A series a presentations then followed on the activities of the LCLUC-related programmatic initiatives of the Monsoon Asia Integrated Regional Study (MAIRS), Central Asian Regional Information Network (CARIN), Northern Eurasia Earth Science Partnership Initiative (NEESPI), GOFC–GOLD, the South/Central East European Regional Information Network (SCERIN), and the South Asia Research Initiative (SARI).

- MAIRS focuses on cross-cutting global change issues for monsoon Asia, developing links between research groups across the region and disciplines. The program is currently involved in promoting a Future Earth (FE) research initiative across Asia.

[5] The full report can be accessed from the National Academies press at *www.nap.edu/catalog.php?record_id=18385*.

- CARIN is pushing for Central Asian agricultural communities to codesign and coproduce knowledge for sustainable land and water management in a changing climate in FE Asia through research engagement, joint regional capacity building, and program coordination.
- NEESPI is an umbrella organization for over 165 individual research projects, with a combined annual budget close to 15 million U.S. dollars. In 2013–14, Russia, the U.S., and China funded a new set of NEESPI projects
- GOFC-GOLD (discussed previously in the *Invited Presentations on International Programmatic Activities* section) is a panel of the Global Terrestrial Observing System (GTOS). It recently published the GOFC-GOLD Reducing Emissions from Deforestation and Forest Degradation Plus (REDD+) sourcebook (*www.un-redd.org/aboutredd/tabid/102614/default.aspx*), which discusses methods and procedures for monitoring and reporting anthropogenic GHG emissions and removals associated with deforestation, gains and losses of carbon stocks in remaining forests, and forestation.
- SCERIN members work with regional forest and land management agencies to ensure continuous, high-quality observations and information products for operational and management application. This is done to facilitate feasible and sustainable natural resources management practices in Romania, Hungary, Bulgaria, Turkey, Poland, Slovakia, Czech Republic, and Ukraine.
- SARI is still in its development stage, but several researchers and regional organizations in India have already indicated interest, including the Indian Council of Agricultural Research (ICAR), Indian Institute of Tropical Meteorology (IITM), Indian Institute of Science (IISc), and National Remote Sensing Center (NRSC), and is planning to engage regional partners outside of India. The main goal of this activity is to develop an innovative research, education, and capacity-building program involving state-of-the-art remote sensing, natural sciences, engineering, and social sciences to enrich LCLUC science in South Asia.

Justice concluded this session with a report on the first joint workshop on "Frontiers in Earth Observation for Land System Science," organized by the European Association of Remote Sensing Laboratories (EARSeL) Special Interest Group on Land Use and Land Cover and the NASA LCLUC program. Humboldt University in Berlin, Germany, hosted the meeting, at which 156 researchers from 32 countries discussed upcoming opportunities and challenges in remote sensing. Keynote addresses highlighted the fact that land use and land cover monitoring is entering a new era, with Landsat-8 and the upcoming Sentinels flying at the same time as the opening of the Landsat archives. With new sensor constellations, new technologies of automated algorithms and faster processing, longer time series, and open image archives, this is truly exciting time to be involved in remote sensing for land change science. Good collaboration between NASA and ESA was emphasized as paramount in order to optimize scientific outcomes of these new opportunities, e.g., through common standards in preprocessing and data policies and exchange through joint scientific workshops.

LCLUC Synthesis Presentations

The two presentations in this session were made by **Tatiana Laboda** [UMD]; and **Volker Radeloff** [University of Wisconsin, Madison].

Laboda described results from a project on forested LCLUC in the Russian Far East and Central Siberia under the combined drivers of climate and socio-economic transformation. She noted that fire disturbance in the Russian Far East and Central Siberia is better quantified with coarser wide-swath, high-temporal-resolution sensors, such as the Advanced Very High Resolution Radiometer (AVHRR) and MODIS instruments. At the regional scale, fire disturbance is higher in mountainous regions and further east (i.e., Russian Far East and Irkutsk) but lowest in Central Siberia, where the most logging occurs. She closed her presentation by reporting that—while insufficient for mapping selective logging at the landscape regional scale—Landsat data show that clear-cut logging has decreased over time in Central Siberia, with slight-to-large increases in deciduous forest regeneration. However, regeneration varies strongly, due to topology and climate in the Russian Far East.

Radeloff presented some findings from synthesis of studies on institutional change and LCLUC effects on carbon, biodiversity, and agriculture after the collapse of the Soviet Union. Synthesis studies such as these enhance the conceptual underpinnings of LCLUC science and summarize state-of-the-art knowledge to advance our understanding of the processes, drivers, and impacts of changes in LCLUC. He noted that in post-Soviet times, hardwood (deciduous) forests came to constitute a major part of Russia's exploitable forests because of over-harvesting of softwood and failure to renew forest resources under a centrally planned economy. The resulting mismatch between available technology suitable for softwood production and increasing availability of hardwood resources has become a hindrance to effective timber harvesting.

Urban Inter-Disciplinary Studies (IDS) on Environmental Impacts

Presenters during this session included: **Son Nghiem** [NASA/Jet Propulsion Laboratory]; **Soe Myint** [Arizona State University]; **Douglas Stow** [San Diego State University]; **Geoff Henebry** [South Dakota State University]; **Lucy Hutyra** [BU]; and **Lahouari Bounoua** [GSFC].

Soe described how spatial arrangements of paved surfaces have various impacts on *land surface temperature* (LST). For example, clustered configurations of grass can significantly lower summer daytime LST, while clustered configurations of paved surfaces significantly elevate nighttime LST.

Henbry showed that seasonal snowfall may affect the satellite retrieval of nitrogen dioxide (NO_2) column density in the winter over the midwestern U.S., as there were large discrepancies in winter NO_2 columns as determined by the Ozone Monitoring Instrument (OMI) product and the Berkeley High Resolution (BEHR) project. The group is investigating causes of these discrepancies, as this feature had not been noted previously.

Stow focused on urban expansion, and described how pattern-based characterization of urban areas enables expanding the classic rural/urban definition of *space*. In Ghana, for example, detailed classification schemes of place enables identifying subtle differences in fertility levels of women within and between urban areas, such as spatial variability of fertility within cities.

Hutyra stated that although urban areas have ~50% less biomass compared to forested areas, observations from modeling LCLUC carbon dynamics show ~50% increase in per-tree productivity, i.e., trees in low-density residential areas show higher biomass increment compared to preconversion from forest.

Bounoua showed that in the continental U.S., carbon lost to urbanization is estimated to be ~2%, whereas agriculture has increased carbon uptake by ~5%. While statistically distinct, these numbers are striking, considering that agriculture represents about 32% [2.75 petagrams of Carbon (PgC)] of the total land area, whereas urbanization represents only 1% (0.003 PgC).

LCLUC spring Science Team Meeting participants.

Summary and Conclusion

To recap, the meeting's discussions raised concerns that the remote sensing community is not asking the right questions to mitigate climate change as there is still a gap in determining to what extent urban areas are contributing to emissions. Participants expressed high interest in participating and kick-starting LCLUC webinars as a means to expand the community and to increase program visibility. There was also strong support of continuing and further expanding LCLUC international initiatives.

Garik Gutman closed the meeting, remarking that LCLUC will continue its international efforts under the Committee on Earth Observation Satellites (CEOS) on the land-surface imaging constellation, forming a Land Imaging Science Team, and developing preparatory studies using Sentinel-2 and Landsat-8 data in concert. Moving forward, the program will aim to continue balancing LCLUC project calls thematically and geographically in terms of the regional focus. ■