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Summary of the Spring 2016 NASA Land-Cover Land-Use Change Science Team Meeting

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The Spring 2016 NASA Land-Cover Land-Use Change (LCLUC) Science Team Meeting was held on April 18-19, 2016, in North Bethesda, MD. This meeting marked the twentieth anniversary of NASA's LCLUC program. On this special occasion the meeting focused on accomplishments, current issues (with discussions on future directions to advance LCLUC research), and a special session on mapping industrial forests. The two-day meeting was organized into ten sessions, with five on each day. More than 100 participants, including U.S. and international researchers from academia, government, and the private sector, attended.

Participants at the NASA LCLUC Spring 2016 Science Team Meeting.
Photo credit: Kristofer Lasko

Day 1: Opening Session, Invited Talks, Panel Discussion, Regional Synthesis

After a welcome and formal opening of the meeting, **Garik Gutman** [NASA Headquarters (HQ)—*LCLUC Program Manager*] shared his experiences based on almost two decades with the LCLUC program and its partners. Since its inception in 1997 the program has supported over 250 projects focusing on one or more of the program's nine science themes to advance land cover and land use science, leading to many peer-reviewed publications, development of land cover products[1], regional collaborations[2], and outreach activities[3]. With a stable financial budget the program has successfully balanced funding research on "Processes of change" with "Regional land cover projects" and grown in the past 20 years by coalescing with other NASA programs.

There was an "In Memoriam" presentation to recognize the contributions to LCLUC Program of the late **Jack Estes** [University of California, Santa Barbara], **Don Deering** [NASA's Goddard Space Flight Center (GSFC)], and **Greg Leptoukh** [Goddard Earth Sciences' Data and Information Services Center (GES DISC)-Data Manager]—see *Remembering Those Who Contributed to the LCLUC Program* on page 27. Numerous studies conducted by these and other LCLUC alumni have been integral to the program's success. Over the years, the NASA LCLUC program has established itself as the leading program in land-cover and land-use science by addressing critical research areas and needs with its connections to various other land-cover programs both at the national[4] and international levels[5].

Chris Justice [University of Maryland, College Park (UMD)] went on to describe his own 20-year journey with the program, highlighting his perspective on its various accomplishments. He shared how the program had its roots in the IGBP's Land Use and Cover Change

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[1] Some noteworthy products include, the Global Forest Cover Change Product, 2013; Mangrove Forest Cover Change 1990-2005; and NASA-U.S. Geological Survey (USGS) global land surveys (GLS) datasets.
[2] Examples of regional collaborations include the Large-scale Biosphere-Atmosphere Experiment in Amazonia (LBA) and network development [e.g., the Northern Eurasian Earth Science Partnership Initiative (NEESPI), Monsoon Asia Integrated Regional Study (MAIRS), and the South/Southeast Asia Research Initiative (SARI)].
[3] Outreach activities include the NASA–Michigan State University International Association for Landscape Ecology (MSU IALE), Trans-Atlantic Training (TAT), LCLUC webinars, the LCLUC newsletter, and the LCLUC website and Facebook page.

[4] National programs include those from NASA, the U.S. Global Climate Research Program (USGCRP), U.S. Geological Survey (USGS), and the U.S. Agency for International Development (USAID).
[5] International programs include Global Observation for Forest Cover and Land Dynamics (GOFC-GOLD), Committee on Earth Observation Satellites Group on Observations (CEOS/GEO), International Geosphere-Biosphere Programme International Human Dimension Programme (IGBP-IHDP), European Association of Remote Sensing Laboratories (EARSel) Special Interest Group (SIG) on Land-Use and Land-Cover (LU/LC), the European Space Agency (ESA), and the French Centre National d'Études Spatiales/Centre d'Études Spatiales de la BIOsphère (CNES/CESBIO).

(LUCC) Program, chaired by **David Skole** [Michigan State University] in its early years, and which was strongly supported at NASA by **Tony Janetos** [NASA HQ—*First LCLUC Program Manager*] and **Bob Harriss** [NASA HQ—*Former Earth Science Division Director*], leading to the first LCLUC Science Team meeting at Airlie House, VA, in 1997. Justice sketched the evolution of the foci of the program from its early days exploring the impacts of LCLUC on ecosystem goods and services and the processes of change, to detection and monitoring change (initially by epochs) and climate-change interactions. The present thematic and regional focus of the program is on LCLUC processes pertinent to South and Southeast Asia. Compared to previous decades, the emphasis has moved from biogeochemical impacts (which are now addressed by the NASA Carbon Program) to characterization of land use (e.g., agricultural field size, plantations), urban expansion, adaptation, and other land-use processes. He suggested future directions in which the program could expand based on: new or improved Earth observations (EO) and data continuity activities and missions[6]; greater regional collaboration in South and Southeast Asia under the SARI network; opportunities for new collaborations in South America; thematic focus on agriculture, forests, and land use to support climate agreements (e.g., The Paris Agreement); food security; and land use climate adaptations. Justice ended his presentation with an acknowledgement of the invaluable, long-term contributions of **John Townshend** [University of Maryland, College Park] to the program in the area of global land cover mapping.

LCLUC Invited Talks

Eric Lambin [Stanford University and Université catholique de Louvain, Belgium] focused on the influence of *telecoupling*[7] and land-use governance on investments in land systems and specific land use. Investment decisions beyond national boundaries often impact the expansion of nonstaple crop coverage (e.g., soy) at the expense of forests in emerging economies with weak institutions, while staple crops are grown in intensive cycles in urban areas. He discussed forest transition, offshoring deforestation

trends, where sending manufacturing to other countries can have concomitant environmental impact in the country where the industry is relocated in the form of deforestation, and the role of private governance, where private companies and nongovernmental organizations (NGOs) effectively enforce forest conservation policies.

David Skole focused on the evolution of land-cover products. In the past two decades, global land-cover datasets have evolved from coarse-resolution products from the Advanced Very High Resolution Radiometer (AVHRR) to 30-m (~98-ft) Landsat products. The evolution is accompanied by a shift in focus from pattern- to process-oriented science and applications. In the post-Paris Climate Agreement environment, the importance of a closer link between science, regional culture, and development policies cannot be emphasized more highly. Suggested areas for future exploration include forest degradation, forest carbon-stock mapping, and monitoring trees outside of forests and woodlands.

Panel Discussion

Garik Gutman led a panel discussion on *Past Achievements and Future Directions of Land-Cover Land-Use Science*. Panelists included **Karen Seto** [Yale School of Forestry], **Dan Brown** [University of Michigan], **Stephen Walsh** [University of North Carolina at Chapel Hill], **Mutlu Ozdogan** [University of Wisconsin-Madison], and **Volker Radeloff** [University of Wisconsin-Madison], as shown in the photo below. The panelists agreed that technology and policy advancements have increased the availability of data sources and have enabled the community to look into land-use processes that drive land-cover patterns—something that could not be done 20 years ago. However, much more remains to be explored in terms of understanding how complex socioeconomic systems and telecoupled events impact land cover and land use at different scales in an increasingly globalized world. Addressing these questions requires availability of time-series of high-resolution remote sensing and social data

[6] The international Multi-Source Land Imaging science team's missions include the ESA Sentinels, China-Brazil Earth Resources Satellite (CBERS), NASA/Indian Space Research Organization (ISRO) Synthetic Aperture Radar (NISAR), ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS), Global Ecosystem Dynamic Investigation Lidar (GEDI), the Joint Polar Satellite System Visible Infrared Imaging Radiometer Suite (JPSS VIIRS; an instrument), and Biomass (ESA's seventh Earth Explorer mission).

[7] Telecoupling is a conceptual framework that encompasses both socioeconomic and environmental interactions among coupled human and natural systems over distances.

Participants in the panel on *Past Achievements and Future Directions of Land-Cover Land-Use Science*. **Photo credit**: Kristofer Lasko

with wider spatial coverage at affordable costs, and integration of the activities of social and remote sensing scientists into cohesive activities. The panel suggested that future directions to advance LCLUC research include improvements in methods, a need for validation and accuracy assessments of data products, and a deeper understanding of interconnections between climatic, socioeconomic, and land-cover systems.

LCLUC Regional Synthesis Presentations

Regional synthesis provides an opportunity for new conceptual development for land-use science, based on previous program investments in regional science.

LCLUC in Central Asia and Northern Eurasia

In Central Asia, mismanagement of water—combined with warmer and drier climate in recent times—has led to less irrigation, shrinking croplands, and decreasing vegetation. The most rapid rates of change have been observed in areas of moderate population that are undergoing development. In the Mongolian Plateau, the complex, coupled, nature-human system was found not to be driven by climate alone as most ecologists believed; however, the feedbacks between human and climate systems have yet to be studied in depth. Another study addressed the impact of different land-use scenarios on biogeochemical cycling in North Eurasia. Different land-use scenarios produce different predictions of the future of carbon in North Eurasia, ranging from an overall decrease in the terrestrial carbon sink by 74%, to net creation of a carbon source (~17 Pg of carbon) during the twenty-first century. There is large uncertainty in methane emissions due to uncertainties in the effects of complex hydrological dynamics upon permafrost thaw and net methane emissions over the region, which greatly affects total radiative forcing. Further, it was found that the dominant drivers of evapotranspiration (e.g., temperature, precipitation) are the same regardless of the input forcing datasets used (i.e., regardless of which model is used). Other work showed that during the growing season, precipitation is dominant in the regional south, while temperature is dominant in the north. In rapidly warming permafrost regions, ice-wedge degradation and the hydrological changes associated with the resulting differential ground subsidence (e.g., as exhibited in the Yamal Peninsula) are expected to expand and amplify. The highest rates of shrub expansion were found in northwestern Siberia, where active *frost boils*[8] are common.

A study in the Siberian Yamal-Nenets[9] Social-Ecological Systems showed that the combination of abundant availability of food, space for long-distance reindeer migration, and bureaucratic intervention sensitive to the needs of the herders have helped the native people adapt to a variety of pressures from oil and gas extraction in recent decades. The study also identified cultural aspects of resilience such as, intact nuclear families with high retention among youth, accepting attitudes toward climate change and industrial development, and consciousness of their role as responsible stewards of the territories. Russian institutions administering reindeer herding accommodate decision-making that is sensitive to herders' needs and timetables and smaller, privately managed herds that can better utilize available pastures have also helped them persist.

LCLUC in South and Southeast Asia

Synthesis studies in South and Southeast Asia highlighted the important role of policy in determining regional LCLUC trends. Capitalist economic policies were found to drive the transition from agrarian to industrialized systems in the less-developed nations and uplands of mainland Southeast Asia. A country-by-country analysis of the rate of LCLUC in whole of South and Southeast Asia highlighted Nepal's successful forest conservation efforts, involving community forestry programs. As mentioned earlier, more studies are expected in the program as it focuses on this region of the world.

Posters and Celebratory Reception

The first day ended with a poster session, which began with participants giving a two-minute description of their posters. That evening, Stinger Ghaffarian Technologies and Science Systems and Applications, Inc. sponsored a celebratory reception to show their appreciation for the former and current principal investigators (PIs), LCLUC alumni, and program staff.

Day 2: Presentations From LCLUC Program Partners, New Program Initiatives, Industrial Forest Mapping, and Wrap-up

GOFC-GOLD Program—Nineteen Years of Coordination Activities

GOFC-GOLD is an extragovernmental scientific organization that has been involved with the LCLUC program for 19 years. It continues to be closely associated with the program through the Land Cover and Fire Implementation Teams (IT) and the global change SysTem for Analysis, Research and Training (START) activities. To help developing countries understand and

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[8] *Frost boils* (also known as mud boils, frost scars and mud circles) are upwellings of mud that occur through frost heave and cryoturbation in permafrost areas, such as arctic and alpine regions. They are typically 1-3 m (~3-10 ft) in diameter with a bare soil surface, and predominantly circular, lacking "a border of stones."

[9] The Nenets are the indigenous people of Siberia that live on the Yamal peninsula, which extends from northern Siberia to the Kara Sea—far above the Arctic Circle.

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Remembering Those Who Contributed to the LCLUC Program

An "In Memoriam" presentation took place during the meeting to honor the contributions of several individuals that have played a key role in and/or made key contributions to the Land-Cover, Land-Use Change Program.

Jack Estes led the "Accuracy Assessments of the IGBP Fast-Track 1-km Land Cover Data Sets" project in the LCLUC Program. He was a pioneer of remote sensing and GIS applications in environmental sciences. He worked closely with federal agencies like NASA and USGS and was awarded the 1999 William T. Pecora Award and 2001 Distinguished Public Service Medal for his outstanding contribution to satellite based earth observations.

Don Deering founded the Northern Eurasia Earth Science Partnership Initiative (NEESPI) program. NEESPI is a regional program that LCLUC supports. A detailed description of Don Deering's role in formation of NEESPI (written by Garik Gutman) can be found at *http://neespi.org/news/Don-in_memorium.pdf*.

Gregory "Greg" Leptoukh was a member of LCLUC and supported NEESPI and the Monsoon Asia Integrated Regional Study (MAIRS) partnerships. He led the development of the Giovanni Data Portal and Giovanni NEESPI was the first application developed, which allowed analyses of more than 35 interdisciplinary parameters from multi-satellites observations and numerical models over the Northern Eurasia. The 2012 and 2014 Online Giovanni Workshops[1] were named in his honor.

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[1] These two workshops were reported on in the March–April 2013 [**Volume 25**, **Issue 2**, pp. 39-40] and May–June 2015 [**Volume 27**, **Issue 3**, pp. 14-18] issues of *The Earth Observer,* respectively.

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prepare their own REDD+ reports[10], the GOFC-GOLD Land Cover IT office has developed REDD+ training material. The material is posted at *http://www.gofcgold. wur.nl/redd/Training_materials.php*. They also developed Boston Education in Earth Observing Data Analysis (BEEODA), a suite of open-source software and educational materials for processing Earth-observation data. An update of the GOFC-GOLD Fire IT activities highlighted fire monitoring with the next-generation operational polar orbiters [e.g., VIIRS on the Suomi National Polar-orbiting Partnership (NPP) and JPSS-1, Sea and Land Surface Temperature Radiometer (SLSTR) on Sentinel 3, Geostationary Operational Environmental Satellite (GOES)-R]; Moderate Resolution Data Continuity [e.g., Landsat 8, Sentinel 2, ResourceSat, CBERS-4]; Regional/Global Burned Area Products from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) Collection 6 and ESA's Climate Change Initiative; Moderate-resolution (i.e., Landsat-class) derived and validated fire products; Multi-source fire data fusion and information integration [e.g., Advanced Fire Information System, MuSLI]; and Near Real-Time global daily active fire monitoring [e.g., VIIRS via NASA's Land, Atmosphere Near real-time Capability for the Earth Observing System (LANCE)]. The next GOFC Fire-IT meeting with GEO's Global Wildfire Information System (GWIS) will be held in November 2016 in Santiago, Chile.

START's work contributes to building and enhancing capacities for advancing knowledge on global environmental change in Africa and Asia-Pacific. Future directions for START include capacity building within GOFC-GOLD objectives, and more opportunities for cross-network knowledge exchange, through learning forums and collaborative research.

New Initiatives

Future Earth U.S. is an international global change research program launched in 2013. It addresses the second and fourth goals of the U.S. Global Change Research Program[11]—to inform decisions by providing the scientific basis for timely decisions on adaptation and mitigation, and to advance communication and education to broaden public understanding of global change and to develop a future scientific workforce—by being involved in building funding coalitions to support co-created science for sustainability [e.g., Ocean Knowledge-Action Network[12]], capacity building [e.g., International Institute for Applied Systems Analysis (IIASA), International Social Science Council (ISSC) in Africa], and spreading awareness about global change through the Future Earth media portal (*http:// medialab.futureearth.org*) and *Anthropocene Magazine*. Future Earth in Asia focuses on the regional priorities in the Asian region: the Water, Energy, and Food

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[10] REDD+ is an abbreviation meant to describe efforts to reduce deforestation and forest degradation and to support sustainability and mitigation in such areas. Additional information may be found at *https://www.forestcarbonpartnership.org*.

[11] For more on the USGCRP goals, see *http://www.global-change.gov/about/mission-vision-strategic-plan*.

[12] For more information, visit *http://futureearth.org/knowledge-action-networks*.

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(WEF) nexus. A group discussion focused on the role of the land system and the impact of land-cover and land-use changes in the WEF nexus. Population in the Asian region is expected to grow rapidly over the next few years and food, water, and energy consumption is expected to grow by 50%, 30%, and 50%, respectively. To meet the increased demands in a sustainable manner remains a regional challenge.

Regional needs of the South/Southeast Asia Research Initiative (SARI) region that were identified during the recent LCLUC meeting in Burma in January 2016[13]. The next SARI meeting is in October 2016 at Ho Chi Min City (Saigon), Vietnam. More information on SARI can be found at *http://www.sari.umd.edu*.

The final initiative discussed was the Northern Eurasia Future Initiative (NEFI), a successor of the Northern Eurasia Earth Science Partnership Initiative (NEESPI). NEFI expands on the NEESPI program to answer the question: *What will the changes in this ecosystems dynamics and interactions mean for the societal well-being, activities, health, and strategic planning?* The NEFI White Paper can be found at *http://neespi.org/NEFI-WhitePaperDraft.pdf*.

Mapping Industrial Forests

This session provided an opportunity to the PIs from NASA's Research Opportunities in Space and Earth Sciences (ROSES) 2014 call to share their results with the community. The two mapping-effort foci in this session were algorithm development and regional application. Landsat data, with its global spatial coverage and rich historic archive, was a popular choice for all of the PIs. Of the four mapping methods discussed, two focused specifically on Landsat spectral and temporal information to develop forest disturbance maps. One such effort is the North America Forest Disturbance Product (NAFD-NEX), distributed through the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL-DAAC) (*https://daac.ornl.gov*). In combination with ancillary datasets, these products can be used to develop higher-level products like a pre-Landsat-era forest-disturbance map, and species-specific plantation and harvest maps. Another effort used Landsat vegetation fractional cover to develop plantation type and rotation maps for Malaysia. A time-series analysis based on these products provided insight as to the dynamic teleconnections of economy and land-use relationships in that region. The fourth study proposed a three-step method to combine the information from Landsat and radar observations to map industrial plantations—a method that was able to successfully map rubber and oil-palm plantations in China.

International Partner Programs, Education, and Capacity Building

The last working session included presentations from representatives of the international partner programs. **Ioannis Manakos** [The Centre for Research and Technology, Hellas, Greece—*European Association of Remote Sensing Laboratories (EARSeL) Special Interest Group (SIG) Land Cover Chair*] discussed the opportunities and challenges in using EO data to monitor the condition of various ecosystems in Europe. To promote collaboration between NASA and European scientists on land-cover and land-use change research, the First Joint Workshop between the EARSeL SIG on Land Use and Land Cover (LU/LC) and the NASA LCLUC program was held in Berlin 2014. Following on its success, the second EARSeL SIG LU/LC and NASA LCLUC Joint Workshop was held in Prague, Czech Republic, on May 6-7, 2016, in conjunction with the ESA Living Planet Symposium held May 9-13, 2016.

Vladimir Gershenzon [ScanEx, Russia] discussed opportunities for future collaboration with ScanEx. The company provides a suite of near-real-time remote sensing applications and services for a variety of land-cover mapping applications, ranging from fire monitoring to industrial plantation mapping. It has been involved with the NASA-USGS International Mid-Decadal Global Land Survey (MDGLS) Project since 2006. For more information on ScanEx, visit *http://www.scanex.ru/en*.

SERVIR[14]—a joint venture between NASA and the U.S. Agency for International Development (USAID)—plays an important role in facilitating the use of EO, geographic information systems (GIS), and predictive models in regional decision-making. SERVIR is present in 4 global regions covering 37 nations. The SERVIR Hubs[15] work with regional governments to incorporate satellite-based information in end-user decision-making processes. SERVIR provides tools in key application areas like water, land cover and land use, natural disasters, agriculture, and biodiversity. This helps improve the lives and livelihoods of individuals, and ensures community safety.

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[14] SERVIR is an acronym standing for the Spanish words meaning Mesoamerican Regional Visualization and Monitoring System; it also means "to serve."
[15] The hubs include the International Center for Integrated Mountain Development (ICIMOD), the Himalayan hub that covers Kathmandu and Nepal; the Regional Center for Mapping of Resources for Development (RCMRD), the Eastern and Southern African Hub, covering Nairobi, Kenya, and the Asian Disaster Preparedness Center ADPC, the Mekong hub, which covers Lower Mekong countries and is located in in Bangkok, Thailand.

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[13] Please see "Summary of the 2016 Land-Cover Land-Use Change Regional Science Team Meeting" in the May-June 2016 issue of *The Earth Observer* [**Volume 28, Issue 3**, pp. 24-29].

The NASA-Michigan State University Professional Enhancement Awards Program started in 1998 and has been supported by the LCLUC program since its inception. The objective of this program is to provide outstanding students with support to attend the annual meetings of International Association for Landscape Ecology (IALE), thereby to establish and expand their professional networks, train future generations of scientists, and nurture future leaders in areas related to NASA's mission. Since its start, the very successful program has provided awards to 382 individuals from 140 institutions in 16 countries.

The Trans-Atlantic Training (TAT) and Capacity Building Activity is a joint venture of NASA and ESA to increase awareness among East European students about EO products available from NASA and ESA, expose them to scientific research while young, educate them about use of analytical tools, and motivate them to consider careers in Earth science. The activity is being coordinated by the LCLUC partner, Charles University, in Prague.

Meeting Wrap-Up

During the closing session, participants got a "tour" of the new LCLUC website from **Kristofer Lasko** [UMD]. **Garik Gutman** and **Chris Justice** then presided over a question-and-answer session on the LCLUC program, which, with further discussion, surfaced suggestions for future directions that included integration of land cover and land use change science across different regions, studying ecological and social connections through telecoupling frameworks, integration of land-cover products generated from the LCLUC program with datasets from other fields for use in land-use modeling, synthesis with other users with an increased social component, a need for cross-program research calls, and increased involvement of computer and social scientists in the program. The meeting successfully provided a platform for long-term and recently added LCLUC members to share their research ideas and experiences, discuss current LCLUC issues, and seek future directions for program advancement. ∎

Two NASA Earth Scientists Among the 2016 Class of AGU Fellows

Since the American Geophysical Union (AGU) established its Fellows Program in 1962, the organization has elected outstanding members as Union Fellows. This special honor recognizes scientific eminence in the Earth and space sciences. It acknowledges Fellows for their remarkable contributions to their research fields, exceptional knowledge, and visionary leadership. Only 0.1% of AGU membership receives this recognition in any given year.

This year, **Claire Parkinson** and **Brent Holben** [both at NASA's Goddard Space Flight Center] are among the 60 that have been chosen as AGU Fellows. The exceptional achievements, talents, and inspirations of these individuals will be recognized in a ceremony to be held December 14 at the 2016 AGU Fall Meeting in San Francisco, CA.

The Earth Observer staff extends congratulations to Claire and Brent, along with all this year's other AGU Fellows.

Claire Parkinson

Brent Holben