

# Summary of the Spring 2017 NASA Land-Cover and Land-Use Change Science Team Meeting

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## Introduction

The Spring 2017 NASA Land-Cover and Land-Use Change (LCLUC) Science Team Meeting was held on April 12-13, 2017, at the Hilton Washington, DC/Rockville Hotel & Executive Meeting Center in Rockville, MD. The meeting focused on LCLUC on mountainous regions, and a variety of synthesis studies and Multi-source Land Imaging (MuSLI) projects. The two-day event was organized into eight sessions, with four sessions each day. More than 100 participants, including scientists, post-doctoral scientists, graduate students, and researchers from academia and government agencies attended the meeting. The meeting presentations can be accessed at <http://lcluc.umd.edu/meetings/2017-lcluc-spring-science-team-meeting-apr-12th-13th-and-musli-meeting-april-14th>.

## Day 1: Opening Remarks, Invited Talks, Discussion of LCLUC in Mountainous Regions, Poster Session

**Garik Gutman** [NASA Headquarters (HQ)—*LCLUC Program Manager*] opened the meeting by sharing the importance of the date in space science history: April 12 was the International Day of Human Space Flight, the night of which is popularly known as *Yuri's Night*. He explained that it was on this day in 1961 that Yuri Gagarin took the first human space flight, marking the beginning of future space exploration for the benefit of humankind. He followed by paying tribute to **Piers Sellers**, a former colleague, astronaut, scientist, deputy director of the Sciences and Exploration Directorate at NASA Headquarters, and director of the Earth Sciences Division at NASA's Goddard Space Flight Center, who passed away in December 2016 of pancreatic cancer.<sup>1</sup> Gutman then gave updates on recent LCLUC activities, project updates, and developments.

**Chris Justice** [University of Maryland, College Park (UMD)—*Program Scientist*] followed with program updates and discussed the meeting agenda. He noted that some projects in recent NASA LCLUC solicitations [e.g., Research Opportunities in Space and Earth Sciences (ROSES) calls] are being led by social scientists, implying the increasing maturity of social science aspects of LCLUC. He also invited suggestions for potential areas for future directions of the LCLUC

<sup>1</sup> Read the "In Memoriam" for Piers Sellers in the January–February 2017 issue of *The Earth Observer* [Volume 29, Issue 1, pp. 4–5—<https://go.nasa.gov/2gaUrR5>]. Also see <https://go.nasa.gov/2gbBIVo> to read his memoriam by Chris Scolese, NASA's Goddard Space Flight Center's Center Director.



Participants at the NASA LCLUC Spring 2017 Science Team Meeting. Photo credit: Kristofer Lasko

program. Justice offered three recommendations for future research, which were to: focus on South America as the next regional initiative [i.e., after the South Asia Research Initiative (SARI)<sup>2</sup> is complete]; explore the link between globalization and land-use change (e.g., markets and soybean expansions); and focus on LCLUC in Africa, exploring the integration of *small-holders*—tenants of small farms that rely on mainly family labor—into market economies and food security and the linkage to the Sustainable Development Goals (SDG). Justice emphasized strengthening the relationships with partner programs with respect to common issues such as forecasting in the land sector, managing land-use interactions and tradeoffs, and land conflicts.

Two invited talks took place on the first day. **Jack Kaye** [NASA HQ—*Associate Director of Research for the Earth Science Division*] presented the broader current and future NASA interests and activities. He explained that with a fleet of Earth-observing missions currently in orbit, it is an exciting time for Earth-observation science and applications. He added that the variety of sensors enables multiple datasets at multiple scales across all geographic regions. To facilitate processing the large

<sup>2</sup> Read about a recent SARI Agricultural Workshop on page 44 of this issue. A number of the presenters at the LCLUC meeting also gave similar presentations at the SARI workshop.

volume of input data, he advocated the use of NASA Earth Exchange (NEX).<sup>3</sup> In addition to NASA's satellites, similar moderate-resolution sensors operated by other countries—like Japan, India, South Korea, and various countries in Europe—provide improved opportunities for land cover mapping applications and land-use science.

**Allison Thomson** [Field to Market—*Science and Research Director*] provided an introduction and update on the Global Land Programme (GLP)—<https://glp.earth>—which was established in 2005 as a cosponsored project of the International Human Dimensions Programme on Global Environmental Change (IHDP)/International Geosphere-Biosphere Programme (IGBP). She explained that the central task of GLP is the identification of scientific priorities and agenda settings through synthesis of existing knowledge, meta-analysis of land-based research, and targeted workshops. Thomson concluded that GLP provides a platform for the land system science community through networking activities. The GLP is interested in Earth Observations and welcomes increased cooperation with NASA's LCLUC program.

After the invited talks came several presentations focusing on LCLUC studies in mountainous regions gleaned from projects selected from LCLUC ROSES 2013. The projects addressed a range of factors that impact LCLUC in those mountainous regions, including environmental, social, economic, and political drivers.

**Volker Radeloff** [University of Wisconsin, Madison] spoke about the impact of wars on land use in the Caucasus region, which is situated at the border of Eastern Europe and Western Asia, between the Black Sea and the Caspian Sea. He showed the case studies of two mountainous areas, Nagorno-Karabakh (internationally recognized as part of Azerbaijan) and Chechnya. In each case, wars resulted in extensive agricultural abandonment near conflict areas, destroying settlements, and the growth of new agriculture in nearby Azerbaijan for Nagorno-Karabakh. Radeloff noted that, while war in these regions has had a significant impact of urban and agricultural areas in both these regions, the impact on existing forest cover, in his opinion, was less than might have been expected. He stated that his research found that wars had a stronger effect on land-use change in the Caucasus than did the collapse of the Union of Soviet Socialist Republics (USSR).

<sup>3</sup> NEX is a virtual collaborative computing environment that brings scientists together in a knowledge-based social network that provides the necessary tools, computing power, and access to big data to accelerate research, and innovation and to provide transparency. The goal of NEX is to improve efficiency and expand the scope of NASA's Earth science technology, research, and applications programs. Learn more at <https://nex.nasa.gov/nex>.

**Dan Slayback** [NASA's Goddard Space Flight Center (GSFC)] discussed the impact of climatic and socioeconomic drivers on high-altitude, tropical Andean alpine wetlands, called *bofedals*—peat bogs with rich dark soils that act like enormous sponges, capturing water from rain and snowmelt. He explained that the bofedals in the region consist of a dense carpet of cushion plants<sup>4</sup> and provide critical year-round nutritious forage for populations of llama and alpaca, which play an important economic role in the highland system of pastoral agriculture. He described how his group's project integrates climate models, hydrology, and biology to better understand the relevant physical processes, and as aids to local adaptation.

**Jefferson Fox** [East-West Center—*Director of the Research Program*] showed how he and others at the East-West Center<sup>5</sup> in Hawaii are mapping forest dynamics in the middle hills of Nepal. The mapping approach they use includes a rigorous evaluation of terrain correction methods and a Landsat-based disturbance detection algorithm in a cloud-computing framework. He showed the spatial distribution of hotspots of forest cover growth and loss across Nepal, and discussed his results with respect to the spread of Nepal's *community forests*<sup>6</sup> and remittance income arising from foreign labor migration.

**Giorgos Mountrakis** [State University of New York, Syracuse] discussed the impact of sociopolitical and environmental factors on grazing in the Altai Mountains in Russia, Kazakhstan, China, and Mongolia. His initial results show that after the fall of the USSR in 1991, China's grazing system remained the same (i.e., carefully planned, heavily subsidized, and intensive), while those in Russia and Kazakhstan dwindled, and those in Mongolia expanded with changes in herd composition.

**Andrew Hansen** [Montana State University—*Director of the Landscape Biodiversity Lab*] presented his results on LCLUC under different Intergovernmental Panel on Climate Change (IPCC) scenarios across northwestern U.S. mountain landscapes using the Spatially Explicit Regional Growth Model (SERGoM Model). He described how his group applied the results to address vulnerability assessments of biodiversity in response to

<sup>4</sup> A cushion plant is a low-growing plant, characterized by a tightly knit structure, that has a mat- or cushion-like appearance. They are commonly found in the Alpine Tundra and high-altitude areas. They help other plants to adapt to harsh conditions.

<sup>5</sup> Established by the U.S. Congress in 1960, the East-West Center serves as a resource for information and analysis on critical issues of common concern, and bringing people together to exchange views, build expertise, and develop policy options.

<sup>6</sup> Community forestry is a successful participatory approach for forest protection and management in Nepal. It is estimated that 850,000 ha of forests in Nepal have been handed over to 11,000 forest user groups.

future global change. His presentation examined rates of change of spatial patterns and change in exurban development, and tested hypotheses on the relative and context-dependent influence of proximity to cities and markets, natural resources, natural amenities, and climate change.

**Geoff Henebry** [South Dakota State University—*Codirector of the Geospatial Sciences Center of Excellence*] gave a presentation titled *How Environmental Change in Central Asian Highlands Impacts High Elevation Communities*. His team's research focuses on documenting environmental change at four different human settlements (and associated pasturelands) in the Kyrgyz Republic: At-Bashy and Naryn in Naryn oblast,<sup>7</sup> and Alay and Chong-Alay in Osh oblast. At each location the following four attributes are monitored: *changes in the thermal regime*—e.g., growing season timing and extremes; *changes in the moisture regime*—e.g., peak precipitation timing and onset and duration of snow cover; *changes in socio-economic conditions*—e.g., impacts of globalization through labor migration and remittance income; and *changes in land cover, land use, and land condition*—e.g., alterations in terrain. His results discussed the influences of snow-cover melt date and snow-cover duration on land-surface phenology as modulated by terrain.

A poster session closed out the first day of the meeting. It was preceded by a *rapid poster introduction*, where participants had the opportunity to give two-minute summaries to introduce themselves and their research to the meeting participants. The purpose of this session was to help to connect individuals working on closely related topics. To see a list of the posters presented, visit <http://lcluc.umd.edu/documents/lcluc-2017-poster-presentations>.

## Day 2: Opening Keynote, Synthesis Studies, MuSLI Projects

**Volker Radeloff** began the second day of the meeting with a keynote address on *Structural transformation, increasing returns to scale and land use change—or a proposal for a unified land use theory*. He proposed a conceptual model and outlined the contribution of three economic theories: land rent theory, new growth theory, and new trade theory<sup>8</sup> to his proposed model. The land rent theory proposes that the most valuable crop is grown in the most fertile soil implying comparative advantage in specialization and trade. He also noted that transportation costs impact land rent, and that this results in land use ring formation around cities where the outermost circle is comprised of wasteland while the innermost circle comprises of residential areas. The

new growth theory proposes that accumulated knowledge leads to new technology which in turn leads to economic growth. The new trade theory proposed the existence of agglomeration patterns resulting in core and periphery formations connected by trade. However, each of these theories on its own has deficiencies and is unable to explain current global land use patterns on its own. Radeloff proposed a conceptual model and used his proposed model to explain real-world land-use trends like urban teleconnections, forest transition trends in the U.S. and urban sprawl in maturing economies.

### *Synthesis Studies*

After the keynote presentation there was a series of presentations that covered a variety of synthesis projects funded under LCLUC ROSES 2013 selections, as outlined below.

**Karen Seto** [Yale University] presented a synthesis of LCLUC studies on urbanization, exploring the contribution of urban remote sensing studies to urban LCLUC science, sustainability, and the functioning of Earth's systems. She explained that, while globally land agricultural land lost due to urban expansion is relatively small, regional losses will be acute in the future, which is expected to lead to significant loss of staple crops in Asia and Africa.

**Dan Brown** [University of Michigan—*Director of the Environmental Spatial Analysis Laboratory*] discussed large-scale land transactions as drivers of land-cover change in Sub-Saharan Africa. Brown stated that according to the *land matrix*—an online public database on land deals (<http://www.landmatrix.org/en>)—the global extent of land transactions extends to 40.6 M ha, about 100 times the size of the state of Rhode Island. He added that most of these transactions are clustered in South-East Asia, Africa, South America, and Eastern Europe. Brown concluded that the projects he and others are carrying out are designed to study land transactions in three countries in Africa in a quasi-experimental framework. The projects also seek to identify and examine the link between LCLUC and land tenure.

**Peilei Fan** [Michigan State University] presented information on urbanization and sustainability under conditions of global change and in transitional economies—a synthesis from Southeast, East, and North Asia (SENA). Fan identified diverging patterns of urban LCLUC at different spatial and temporal scales, and successfully applied Bayesian sequential learning for global urban land mapping, hybrid mapping, informal settlement mapping, and multidisciplinary methods for mapping historical land-use changes. The major drivers and spatial determinants were economic developments (e.g., globalization, industrialization), institutions (role of government policies), urban land use, and environmental quality.

<sup>7</sup> An oblast is an administrative region that is considered autonomous.

<sup>8</sup> These theories address various how supply and demand of several parameters vary as a function of several aspects of human behavior.

*Multi-Source Land Imaging (MuSLI) Projects*

The Multi-source Land Imaging (MuSLI) projects session consisted of seven project updates. The objective of this session was to report on the current status of progress in these areas and to discuss issues that the community may have with respect to data processing and use of Landsat and Sentinel<sup>9</sup> images.

**Nathan Torbick** [Applied GeoSolutions] reported that for rice mapping applications, blending moderate-resolution radar data with optical data obtained from the Sentinel-1, Phased Array type L-band Synthetic Aperture Radar (PALSAR-2),<sup>10</sup> and Landsat-8 platforms generated the best overall classified Land Use/Land Cover maps. Torbick stated that Sentinel-1 data are particularly useful for use in assessing and monitoring rice at moderate scales over large cloud-prone regions using a phenology-based approach. He added that PALSAR-2 data show promise in research activities but are not ideal for operational monitoring due to insufficient image availability.

**Chengquan Huang** [UMD] showed the feasibility of using MuSLI Harmonized Landsat and Sentinel (HLS) products to monitor terrestrial surface inundation (e.g., wetlands, ponds). He explained how his group developed automated surface-water mapping algorithms and that they are now testing the algorithms over various test sites (e.g., Saskatchewan Prairie Pothole, Delmarva Peninsula, Florida Everglades). He stated that validation remains a challenge due to the high spatial and temporal resolution of the developed products and the absence of suitable validation datasets.

**David Roy** [South Dakota State University] reported on developing a prototype of a Landsat-8/Sentinel-2 global burned-area product for Southern Africa. The work builds on his experience with the Landsat WELD project and MODIS burned area mapping and validation. He pointed out issues in preprocessing Sentinel-2 data and the need for a continued dialogue between NASA representatives and their European Space Agency (ESA) counterparts on instrument performance and data processing.

<sup>9</sup> The first five Sentinel missions were discussed in “An Overview of Europe’s Expanding Earth-Observation Capabilities” in the July–August 2013 issue of *The Earth Observer* [Volume 25, Issue 4, pp. 4–15—<https://go.nasa.gov/2xt90Gu>]. For more information about Sentinel—including Sentinel 1–6—see [http://www.esa.int/Our\\_Activities/Observing\\_the\\_Earth/Copernicus/Overview4](http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Overview4).

<sup>10</sup> PALSAR-2 flies on the Japan Aerospace Exploration Agency’s (JAXA) Advanced Land Observing Satellite-2 (ALOS-2).

**Joe Sexton** [UMD] discussed a project that involves multisource imaging of a time-series of tree and surface-water coverage at continental-to-global scales. He and his colleagues determined that fusion of multisensor optical estimates of tree-canopy and surface-water cover was possible, but that C-band measurements alone are not useful for estimating tree cover. However, by combining C-band data with data at optical or other synthetic aperture radar wavelengths, the tree-cover estimates improve significantly. His group also found L-band polarimetry data useful for estimating tree cover and discriminating natural from plantation forests.

**Chris Small** [Columbia University] reported on the multisource imaging of infrastructure and urban growth using data from Landsat, Sentinel, and the Shuttle Radar Topography Mission (SRTM). He explained how he developed a continuous index to map the continuum of human settlements worldwide using optical and microwave datasets, and discussed the challenges of using his results to perform urban mapping.

**Marc Friedl** [Boston University] presented information on multisource imaging of seasonal dynamics in land-surface phenology; in particular, he shared his experiences using a fusion approach that employs data from Landsat and Sentinel-2. He and his colleagues used the MUultivariate Imputation by Chained Equations (MICE) method to fill in data gaps. Time series analysis of *image stacks*<sup>11</sup> showed sensitivity to subtle landscape patterns. This means that small changes in land cover characteristics over time influence the algorithm output.

**Matt Hansen** [UMD] spoke on integrating data from Landsat 7 and 8 as well as Sentinel 2 to improve crop-type identification and area estimation in the U.S. and Argentina. He demonstrated his approach applying large volume data processing to crop-area estimation methods and discussed the challenges associated with such an approach, such as the impact on estimates based land fragmentation and small field size.

There was also a session on International Programs and Capacity Building that focused on South/Southeast Asia. Three relevant programs support or are closely linked to some LCLUC projects in this region: SARI, SERVIR,<sup>12</sup> and the Monsoon Asia Integrated Research on Sustainability–Future Earth (MAIRS-FE). Because the focus of these discussions was more programmatic than data related, these are discussed in *LCLUC Programs and Capacity Building in South/Southeast Asia* on page 43.

<sup>11</sup> An image stack is a series of two-dimensional images “stacked” to produce a set of volume (i.e., three-dimensional) data.

<sup>12</sup> SERVIR is not an acronym. It means “to serve” in Spanish and French.

## LCLUC Programs and Capacity Building in South/Southeast Asia

**Krishna Vadrevu** [NASA's Marshall Space Flight Center] presented information on the South Asia Research Initiative (SARI—<http://www.sari.umd.edu>), which was formed in response to international LCLUC meetings in the region, highlighting the need for land-cover science products to meet regional science priorities. Projects focusing on regional science priorities were selected during the ROSES 2015 NASA solicitation that cover forests, agriculture and food security, urban development, and human health. SARI has a strong emphasis on applied research with regional and national societal applications and benefits and strengthening regional and national projects through experimental codesign and collaboration in implementation and data analysis.\*

**Nancy Searby** [NASA HQ] discussed SERVIR, which is a joint NASA/USAID program focused on the use of earth observations for societal benefit. The NASA-SERVIR Program ([https://www.nasa.gov/mission\\_pages/servir/index.html](https://www.nasa.gov/mission_pages/servir/index.html))—through the SERVIR-Mekong hub—supports SARI and helps in capacity building and training to meet regional needs by strengthening the relationships between research institutions and product end-users, with support from local governments.

**Jiaquo Qi** [Michigan State University] gave a presentation on the the Monsoon Asia Integrated Research on Sustainability and its connection to Future Earth (MAIRS-FE). MAIRS-FE (<http://www.futureearth.org/projects/mairs-fe>) is another regional consortium that operates in South and Southeast Asia. It was formerly supported by NASA's LCLUC program but now operates under Future Earth.\*\* The MAIRS region is characterized by monsoon climate, topography, and rapid economic growth. The projects that MAIRS supports focus on issues of regional priority such as sustainable food, water and energy systems, vulnerability to natural disasters, and rapid urbanization.

\*Learn more about a recent SARI Agricultural Workshop on page 44 of this issue.

\*\*Future Earth is a major international research platform providing the knowledge and support to accelerate transformations to a sustainable world (<http://www.futureearth.org>).

### Closing Activities

**Chris Justice** closed with summaries of the several discussions. Various issues raised during different sessions during the meeting were discussed, including retaining synthesis as an element of future LCLUC calls, further integration of LCLUC and social science, and the need for proposers to LCLUC to familiarize themselves with the program website and the research that has been funded to-date. Suggestions on synthesis projects leading to workshops, books, and directions for the future research agenda were welcomed. Participants expressed the need for further integration of LCLUC with social science, especially economics, by including economists in the projects without sacrificing the remote-sensing science involved. Opportunities between NASA and ESA for joint calls and solicitations were suggested for MuSLI projects so that scientists funded by both agencies can work to prevent duplication of efforts. The

potential role of commercial data providers in enabling LCLUC science was also discussed.

**Garik Gutman** closed the meeting with a meeting summary and notifications. He proposed to retain the social science component as an integral part of the LCLUC proposals except for special thematic calls, such as MUSLI, which are remote-sensing oriented. He encouraged continuing efforts with multisource land-imaging applications and proposed to continue support for SARI and the Northern Eurasia Future Initiative (NEFI)<sup>13</sup> through future solicitations and meetings. Participants were encouraged to contribute to the program through webinars, on Facebook, and by sharing their publications, news, and datasets at the LCLUC website. ■

<sup>13</sup> The NEFI, formerly called the Northern Eurasian Earth Science Partnership Initiative (NEESPI), was earlier supported by LCLUC but now has moved to Future Earth. LCLUC is helping with the transition phase.