meeting summaries

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

Krishna Prasad Vadrevu, University of Maryland, College Park, krisvkp@umd.edu
Chris Justice, University of Maryland, College Park, cjustice@umd.edu
Garik Gutman, NASA Headquarters, ggutman@nasa.gov

Introduction

South/Southeast Asia is experiencing a population boom accompanied by rapid economic development that has had significant impacts on ecosystems in the region. A growing population requires more places to live and work, so existing agricultural areas are rapidly being converted to residential and urban areas. Said population must also be fed, which means that even more forests are being cleared and converted to agricultural fields. Dramatic increases in land-cover and land-use change (LCLUC) inevitably impact virtually all aspects of the regional ecosystem—e.g., forest resources, biodiversity, regional climate phenomena, biogeochemical cycles, and water resources. Developing appropriate and effective land-use policies is essential to sustainable development of the countries in the region.

To address these issues, the International LCLUC Regional Science Team Meeting (STM) was held January 12–18, 2016, in Yangon, Myanmar (previously known as Rangoon, Burma). This international meeting provided a forum to discuss LCLUC and its impacts with a regional focus, in the context of the emerging South and Southeast Asia Regional Initiative (SARI). The goal of SARI is to develop an innovative research, education, and capacity-building program involving state-of-the-art remote sensing, natural sciences, engineering, and social sciences, which will enrich LCLUC science in South/Southeast Asia. More details about the SARI can be found at *www.sari.umd.edu*.

NASA's LCLUC Program organized the meeting, in collaboration with the University of Maryland, College Park (UMCP), the global change SysTem for Analysis, Research and Training (START), and the international Global Observation for Forest and Land Cover Dynamics (GOFC–GOLD) Program. The president of Myanmar endorsed the meeting, with guidance from the Ministry of Environment, Conservation and Forests (MOECAF) and the Department of Geography at the University of Yangon, Myanmar, which hosted the meeting. The LCLUC STM itinerary included an optional field trip on January 12, 2016, to visit Bago, a small city located 50 miles northeast of Yangon and its environs, which is in the southwestern part of the country. During the field trip the guides and local participants discussed local LCLUC issues relating to forestry, agriculture, and urban areas—including the cultural aspects of Myanmar. To learn more, see *Field Trip to Bago—An Ancient Capital and Modern Example of LCLUC Issues in Myanmar* on the next page.

More than 150 participants from 12 different countries attended the meeting. The nations represented included India, Sri Lanka, Nepal, Thailand, Indonesia, Vietnam, Singapore, the U.S., Japan, Myanmar, Germany, and Switzerland. The meeting included scientific sessions that addressed regional and international programs in South/Southeast Asia; agriculture and water resources; forest cover mapping and monitoring; urbanization; and land-atmosphere interactions, including fires. Discussion

NASA LCLUC Myanmar meeting participants. **Photo credit:** Yangon University staff

Field Trip to Bago—An Ancient Capital and Modern Example of LCLUC Issues in Myanmar

(As told by Krishna Vadrevu)

The LCLUC STM included an optional "field trip," to Bago, the fourth largest city in the Irrawady region of Myanmar, located about 50 mi (~80 km) outside Yangon. I was among those who participated. Travelling there, I noticed how my surroundings transitioned from the dense urban center of Yangon, with its traffic congestion and pollution, to the suburban and rural landscapes outside of town, with a marked decrease in atmospheric pollution.

Bago is a region of climatological contrast. The northern region merges into a dry delta, whereas the southern region is a mixed evergreen forest, averaging more than 80 in (~203 cm) of rainfall a year. Our tour guide mentioned that most of the northern Bago hills were earlier dominated by teak and other deciduous species, whereas ironwood trees (*Xylia xylocarpa*) are common on the southern slopes. Due to the rapid deforestation and commercial exploitation of timber in the area, the forests of Bago are now highly degraded. Local residents encountered on our sojourn told us about the negative impacts of illegal logging of forests, which has been on the rise since the country opened its doors to the outside world in 1988.

The field trip to Bago was an opportunity for participants to witness firsthand some of the LCLUC issues being discussed at the meeting, such as how the landscape has been impacted by agricultural abandonment. **Photo credit:** Krishna Vadrevu

We traversed a landscape completely transformed from its native state by agriculture, with paddy rice and pulse crops dominating. We learned that most of the agricultural land is leased to farmers by the government. We were also told that, as in other parts of the world, owing to both the increasing cost and hard work required, younger residents are abandoning the farm life to pursue education and other activities in the "big city."

The environment of Bago is at risk due to the ever-increasing urban sprawl of Yangon. Poor agricultural practices have led to widespread land abandonment (see photo above for example), further exacerbating the degradation of the land surface. We noticed, for example, river banks in Bago were covered with trash.

Bago is also a major historical site, having once been the capital city of the second Myanmar Empire*. Our group visited the famous Shwemawdaw Pagoda in Bago, which, at 375 ft (114 m), is the tallest in the country. We not only got a feel for some of Bago's history, we also discovered a connection to the land, in that Buddhism is the dominant religion in the country and that Buddhist monks play a significant role in promoting environmental conservation and cultural values.

The historical sites have made tourism a significant industry for the region, but as always there is a struggle to balance economic growth and environmental degradation. Tourism in Bago has had an adverse impact on the local environment around Shwemawdaw Pagoda and the nearby Shwethalyaung reclining Buddha site—a huge statue [55-m (80-ft) long and 16-m (52-ft) tall] constructed in 994 AD. In addition, the locals spoke about a new disruption to the environment caused by ongoing construction of the new Hanthawaddy International Airport in Bago. It is due for completion by 2022, and will become Myanmar's largest and most modern airport, replacing the current Yangon International Airport. Even more urbanization can be expected once the airport is complete and operational.

Overall, the trip was highly informative. The Bago region is distinct with rich cultural history, diverse land-use types, and archaeological structures. The field trip helped us understand the local drivers of land-use change. Most importantly, we saw firsthand how urbanization, tourism, and industrial development are acting together and changing the prime agriculture and forest dominated countryside. The resulting impacts of land-use change on ecosystem functions need to be thoroughly investigated. Bago can serve as a classic example for LCLUC studies in Myanmar.

* The Taungoo Dynasty, which reigned from the mid-16th century to 1752, made Bago its capital from 1539–1599 and again in 1613–1635.

sessions followed, which addressed the needs, priorities, and challenges of land-use research in Myanmar, and regional priorities for LCLUC in South/Southeast Asia, generally. Keynote presentations, invited contributions, and a poster session were all meeting components. The meeting presentations can be downloaded from *lcluc.umd.edu/meetings/international-lcluc-regional-science-team-meeting-south-and-southeast-asia*.

The program also included two days of training for 60 national and regional scientists on the use of remote sensing and geospatial technologies at the Department of Geography, Yangon University. Specifically, the hands-on training and presentations included such topics as suitability and vulnerability analysis for urban development, long-term data processing using Landsat data, mapping regional plantation extent and dynamics using multiscale imagery, rice mapping using LIDAR data, time series analysis and forest cover change detection, and remote sensing of fires and air pollution, including atmospheric products. All participants were given certificates at the end of the training.

Opening Presentations

Pho Kaung [University of Yangon—*Rector*] welcomed participants to the meeting, followed by **Garik Gutman** [NASA Headquarters (HQ)—*LCLUC Program Manager*], who presented the SARI LCLUC science focus. He reported that deforestation in the region has been increasing, as has rapid urban expansion into rural and agricultural lands. Due to increased planting of commodity crops such as rubber and oil palm, food production has been decreasing, and with attendant cost increases. Further, conversion of land to agriculture has impacts on the carbon cycle and air-quality issues. Specific to Myanmar, forests account for 40% of the total area, but that the country is undergoing rapid deforestation due to economic development. Gutman showcased LCLUC in the Inle Lake region, and mentioned that ongoing agricultural practices are causing sedimentation, eutrophication, and loss of water in the area. He mentioned that over 200 projects on different topics have been funded since the program's inception, including LCLUC monitoring and impacts assessment, carbon-water-ecosystems, drivers, climate interactions, modeling, vulnerability, and adaptation and synthesis. Gutman stated that NASA-SARI science efforts would be based on the recent NASA Research Opportunities in Space and Earth Sciences (ROSES) LCLUC 2015 solicitation, complemented by future selections on Southeast Asia (ROSES LCLUC 2016 solicitation). Gutman closed by encouraging strengthening the SARI-SERVIR[1] relationship to achieve maximum benefit with respect to training and capacity building.

[1] SERVIR is a major NASA initiative. It means "to serve" in Spanish. See the next section for more details.

Rubber plantations along the road travelling toward the city of, Moulmein, Myanmar. **Photo credit:** Krishna Vadrevu

Degraded secondary forest near Pyin Oo Lwin, a hill town in Mandalay Division, Myanmar. **Photo credit:** Krishna Vadrevu

Chris Justice [UMCP] presented the objectives of the meeting and described why the LCLUC topic is important for the region. He stated that proper land-use management is integral to sustainable development and livelihood issues, and noted that LCLUC studies help inform land-use policy and promote better understanding of the impacts of land-use change on climate. The main objectives of the meeting, therefore, were to promote increased participation of scientists from Myanmar in the SARI initiative, understand the regional priorities for land-use science, seek out opportunities for research collaboration, understand which Earth-observation data are freely available and how to access them, share knowledge and experience on the use of Earth-observation data to study LCLUC, share experiences on effective land management practices within the region, and strengthen international scientific cooperation on land-use issues regionally and globally.

Regional and International Programs in South/Southeast Asia

Background on SARI placed the initiative in the context of previous NASA regional science initiatives focused on ecosystems and LCLUC including Boreal Ecosystem and Atmosphere Study (BOREAS), Large Scale Biosphere-Atmosphere-Experiment in Amazonia (LBA), Arctic Boreal Vulnerability Experiment (ABOVE), Southern Africa Fire and Atmospheric Research Initiative (SAFARI), Northern Eurasia Earth Science Partnership Initiative (NEESPI), and Monsoon Asia Integrated Regional Study (MAIRS). Similar to

these other initiatives, SARI will aid in developing and strengthening bilateral science collaborations between the U.S. and countries in Asia and Europe, with research interests in the SARI region, enabling data collection and sharing mechanisms, and assisting in capacity building activities to utilize Earth-observation data.

Another important NASA initiative pertinent to the region is SERVIR, a program conducted jointly with the U.S. Agency for International Development (USAID), working in partnership with leading regional organizations. SERVIR brings space-based data collection to the *village level*[2] by making geospatial data useful to developing countries. The program works at the intersection of science, technology, and innovation to address the challenges of climate variability and change. The SERVIR global partners include hubs in Eastern and Southern Africa, Mesoamerica, the Himalayas, and the Mekong Basin. Each of these hubs serves countries in that region with data, analytics, training, and best practices for improved decision-making (*www.servirglobal.net/#aboutservir*). The program's focus areas include food security, weather and climate, water resources and disasters, land cover/land use, and ecosystems.

A national map system project, "OneMap Myanmar" (led by the Center for Development and Environment at the University of Bern in Switzerland), is creating an online open-access spatial data platform on land-use resources in Myanmar. Very few datasets are available for the entirety of Myanmar; thus, OneMap Myanmar is developing a one-stop portal on land use, land tenure, land use and land cover, base maps, land concessions and leases, and socioeconomic data.

The GOFC-GOLD international land-cover project office presented information on their latest project using a novel data-fusion approach to integrate two existing large-scale biomass maps into an improved pantropical, mean aboveground biomass map of woody vegetation over the period 2000 to 2013. (Additional information can be found at *www.wageningenur.nl/grsbiomass*.)

The International Center for Integrated Mountain Development (ICIMOD) has been conducting vegetation and land-use dynamics research over the Hindu Kush Himalayan region by integrating data from a number of sources including Landsat, the Japanese Advanced Land Observing Satellite (ALOS) Phased Array type L-band Synthetic Aperture Radar (PALSAR[3]), and high-resolution Google Earth images.

[2] *Village level* is considered 30-m (~98-ft) resolution—i.e., comparable to the area of a Landsat image.

[3] ALOS was launched in January 2006 into a sun-synchronous polar orbit with a 46-day repeat sycle. For more information on the ALOS PALSAR, see *www.eorc.jaxa.jp/ALOS/en/about/palsar.htm.*

Additional projects include development of harmonized land-cover maps for change analysis, mapping of LCLUC drivers, forest-species mapping, time-series analysis of aboveground carbon stocks, and development of operational ground data collection frameworks to improve validation of satellite-based methodologies.

Agriculture and LCLUC

Chris Justice discussed the Group on Earth Observations, Global Agricultural Monitoring (GEOGLAM), which was endorsed by the Group of Twenty (G20) Agriculture Ministers in June 2011 in Paris, France. GEOGLAM supports reliable, accurate, timely, and sustained crop-monitoring information and yield forecasts. One of the best examples of regional coordination in Asia is the GEOGLAM Asia-Rice project (*www.asia-rice.org*). The target agricultural products include rice crop area estimates and maps, crop calendars, crop damage assessment, agrometeorological information products, production estimates, and forecasting. (Various other GEOGLAM activities can be found at *www.earthobservations.org/geoglam.php*.)

There was also a discussion of the Global Food Security Support Analysis Support Data project at 30-m resolution (GFSAD30), which is developing unbiased estimates of global agricultural cropland areas, crop types, crop watering method, and cropping intensities, using multisensor, multidate remote sensing and mature cropland mapping algorithms on data from 1990 to the present. (More details about the project, relevant datasets, and publications can be found at *geography.wr.usgs.gov/science/croplands/index.html*.) Mapping and monitoring rice ecosystems to drive decision support in the Asian region points to the potential benefits of synergistic use of data from several other orbiting platforms including Landsat, PALSAR, and the European Space Agency's Sentinel-2 mission.

This session also included an overview of the agriculture sector in Myanmar. Agriculture is the backbone of Myanmar's economy, contributing some one-fifth of its gross domestic product and total export earnings, and employing almost two-thirds of the labor force. More than 75% of the total irrigated area is used for agriculture—and this area is increasing almost yearly. Rice is the main food staple in the country, and production has been increasing; rice is also a significant export product. Although slash-and-burn agriculture is still practiced in several hilly regions of the country, several projects support land reclamation through terrace farming. Fertilizers are mostly imported from China, although use of fertilizer is relatively low compared to the other Southeast Asian countries and the world. The combination of improved seed stocks, fertilizer use, and adoption of modern technologies should allow Myanmar to continue to raise its agricultural productivity.

Region-specific analysis leads to better understanding of the drivers of climate change in South Asia and thus makes the area less vulnerable to its impacts. In the specific case of India, for example, agricultural intensification has largely occurred through increasing the winter crop production. SARI research should focus on understanding the connections between changing economics, labor markets, and climate. Furthermore, increasing urbanization in the Asian region places agricultural areas at constant risk. For example, in Vietnam agricultural lands in and around Hanoi are increasingly fragmented, threatening the local food production capacity of *periurban*[4] areas.

LCLUC and Urban Areas

A recent study quantified LCLUC drivers in India at 30-m (~98-ft) resolution—i.e., at the village level—using Landsat imagery at decadal intervals (i.e., in 10-year windows, beginning in 1985, 1995, and 2005, respectively). The results suggest illegal forest encroachment, domestic use and subsistence activities, human pressure (e.g., roads, settlements, overgrazing, fodder extraction), and high income-generating dependence on forests as major causes of deforestation and forest degradation in the region.

In the specific case of Myanmar, the government is promoting effective land-use planning and refining land-use zoning in support of its National Land Use Policy (NLUP) formulation. During 2013, with the assistance from USAID, a roadmap for development of NLUP has been developed. The main objectives are to promote sustainable land-use management; strengthen land-tenure security; protect customary land-tenure rights of the ethnic minorities; develop transparent dispute-resolution mechanisms; encourage participatory decision making; and develop a national land law to implement NLUP. The initial phase of the NLUP lasts until early 2018. Very-high-resolution remote-sensing data are being used for NLUP decisions.

Big Data, Forests, and LCLUC

The NASA Earth Exchange (NEX[5]) provides significant utility in using *big data*[6] to explore forest characteristics and LCLUC. Global forest-cover change products with information on tree cover, forest loss, and forest gain from 2000 to 2014 at 30-m Landsat resolution are readily available. (The dataset can be downloaded from *earthenginepartners.appspot.com/google.com/science-2013-global-forest*.) Using NEX, data analysis suggests global net loss of 1.5 million km^2 (~579,000 mi^2) of forest between 2000 and 2012.

Remote sensing of wetlands—and mangroves in particular—in the Asian region is important due to their ecological, biogeochemical, and hydrological functions. About one-third of the world's mangroves are found in Asia. To learn more about this ecotype, India has attempted comprehensive mapping of its wetlands. They used data from the Indian Remote Sensing satellites for 1998, 2005, and 2012; the resulting digital atlas is available from Indian Space Research Organization (ISRO). Specific to Southeast Asia, PALSAR data have been used to map mangroves with assessments (conducted in 1990, 2000, and 2010, respectively) showing several areas of high mangrove biomass.

In Myanmar, six different institutions working under MOECAF are responsible for forestry and environmental work. The National Forest Master Plan (NFMP) covers the period from 2001 to 2031 and guides the development and implementation of forest management programs. The use of aerial photos for mapping the Irrawaddy (or Ayeyarwady) Delta mangroves goes back to the 1920s. The first recent appraisal of Myanmar's forest cover was done in 1980 under a project organized by the United Nations (UN) Food and Agriculture Organization (FAO) and the UN Environment Programme (UNEP). The challenges of forest-cover mapping in Myanmar include difficulties in procuring cloud-free images, application of automated methods to large areas, forest definition challenges, technical expertise, and funding constraints. Political activities apparently affect forest fragmentation, so the challenge for the new government lies in designing win-win policies that encourage economic and social development and ensures environmental protection.

Land-Atmosphere Interactions, Including Fires

Southeast Asia represents one of the most complex observing environments in the world due to high smoke pollution from large-scale biomass burning to clear land in the area. NASA's Seven Southeast Asian Studies (7-SEAS) mission focuses on using the synergy between satellite, aircraft, and ground-based network measurements, together with physics-based modeling, to understand interactions between aerosols, clouds, and the water cycle in Southeast Asia. Several NASA and Centre Nationale d'Études Spatiale (CNES) [the French space agency] assets are being pressed into service for this activity. These data show that Southeast Asia is among the highest contributors in the world to LCLUC-related carbon dioxide (CO_2) emissions. In addition, the Department of Meteorology and Hydrology in Myanmar collects data from meteorological, hydrological, and seismological stations spread all over the country and is responsible for processing the data and disseminating disaster-related information to the public.

[4] Periurban refers to the transition zone between urban and rural areas, where there is often conflict over how the land should be used.
[5] More details about the NEX can be found at *nex.nasa.gov/nex*.
[6] *Big data* refers to high-volume, high-velocity, and/or high-variety information assets that require new forms of processing to enable enhanced decision making, insight discovery, and process optimization. The vast information content returned from Earth-observing satellites falls into this category.

Discussion Sessions

There were two discussion sessions during the meeting. The first focused on the needs, priorities, and challenges of environmental issues specific to Myanmar; the second focused on the needs and priorities of LCLUC in the SARI region.

Needs, Priorities, and Challenges of Environmental Issues Specific to Myanmar

The first discussion session began with panelists from 10 nongovernmental organizations (NGOs) working in Myanmar. The NGOs in Myanmar are using Earth-observation data for (among other applications) natural resource assessment, land-use/land-change research, land-use planning, land tenure and rights, land-use policy, science-based conservation issues, evidence-based policy making, and sustainable management of peatlands.

After the panel exchanges, the floor was opened for discussion. All participants highlighted the need for open access to high-resolution imagery. Cloud-based internet platforms, such as Google Earth Engine, were suggested as Earth-observation data resources, and for their processing capability. Key to such efforts is the Myanmar Information Management Unit (MIMU; *www.themimu.info*), which maintains a common data repository from various sources on all sectors, countrywide, at the lowest administrative unit. In addition, OneMap Myanmar and the Mekong SERVIR projects can serve as platforms for data access and information sharing in Myanmar. Several participants from Myanmar mentioned that slow internet connectivity seriously hinders downloads.

With respect to data quality, often multiple, seemingly similar products are produced by different groups. For example, there are several products for forest cover and deforestation, and the decision on which product to use can be challenging. Stringent validation and accuracy assessments, peer review, and local expert judgment are needed to identify the highest-quality products. Cross-database standards—for definitions and classification systems—are also needed. The presentations also stressed the importance of effective communication for knowledge dissemination.

In this context, translating scientific outputs to issues that people care about (e.g., land-use change impacts on food, water, livelihoods, human well-being, and the environment) can help convey the message effectively. Panelists also encouraged the use of social media for information sharing and knowledge dissemination. Participants felt strongly about the need to collaborate more through geospatial dialogue forums and regular meetings to address environmental issues in Myanmar.

Needs and Priorities of LCLUC in the SARI Region

The second panel discussion welcomed active international participation to advance LCLUC science in the region. Of the various regional research priority areas for SARI, the emphasis has been placed on generating relevant scientific information in support of policy making in several areas. These include forest cover and change, agricultural land use and change, urban cover and change, water resources and quality, land-atmosphere interactions, land-use impacts on ecosystem services, and land-use and disaster management.

The ensuing discussion highlighted the need to move towards big-data processing to understand fine-scale changes, improve access to high-resolution Earth-observation data, involve social scientists, and develop and foster participatory approaches to address societal problems. Also, there is need for collaborative research among different government and university institutions, and an urgent need for capacity-building and training activities in the countries of the region.

Summary

The meeting served as a forum for the exchange of ideas and information from a diverse range of disciplines and interest groups. The presentations and discussions covered significant issues on the drivers and impacts of LCLUC including biophysical, social, legal, economic, political, as well as policy aspects. The training sessions were well received, and several participants expressed the need to include more such training activities in the coming years.The workshop participants acknowledged that understanding the impacts of LCLUC on the environment requires integrating both biophysical and socioeconomic datasets. They also emphasized the need to provide LCLUC related scientific information to policy makers in a timely manner to aid policy-based solutions. In addition, the workshop participants recommended increased capacity-building and training activities to advance LCLUC science in the South/Southeast Asian region.

Request for Papers on LCLUC Issues in South/Southeast Asia

As a part of meeting outputs, papers are being solicited on LCLUC issues in South/Southeast Asia, to be part of a special issue of the journal *Remote Sensing*. All researchers working on LCLUC issues in South/Southeast Asia are invited to submit articles at *www.mdpi.com/journal/remotesensing/special_issues/LCLUCAsia*. Email **Krishna Vadrevu** (*krisvkp@umd.edu*) for more details. ■