

Summary of the 2013 NASA Land Cover/Land Use Change Regional Science Meeting, South India

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Introduction

The 2013 NASA Land Cover/Land Use Change (LCLUC) Regional Science Meeting was held in South India and had three components:

- a focused workshop on water resources at the Centre for Water Resources Development and Management (CWRDM), held in Kozhikode, Kerala in India, from January 7-8, and a Land Use (LU) Transect Study from Kozhikode, Kerala, to Coimbatore, Tamil Nadu, in India¹, on January 9;
- a NASA international regional meeting, held January 10-13, at Karunya University in Coimbatore, Tamil Nadu; and
- a training workshop titled *Remote Sensing and Geospatial Technologies for Land Cover and Land Use Change Studies and Applications*, held January 14 at Karunya University.

The goal of the meeting was to discuss land cover/land use change (LCLUC) issues and impacts in the South Asia region. The meeting was organized around eight technical sessions:

1. Agricultural land-use change;
2. LCLUC-related Earth observations (missions, data, and products);
3. Atmosphere/land-use interactions (aerosols, greenhouse gases);

4. LCLUC and the carbon cycle;
5. Forests and LCLUC in mountainous areas;
6. Coastal zones and water resources;
7. Urban LCLUC; and
8. Working towards a Regional Global Observation for Forest and Land Cover Dynamics (GOFc-GOLD) South Asia Regional Information Network (SARIN) (including prospects, opportunities, and challenges).

The meeting was a joint effort of the NASA LCLUC Program; GOFc-GOLD Program; International System for Analysis Research and Training (START) Program; Monsoon Asia Integrated Regional Studies Program (MAIRS); University of Maryland College Park (UMD); Centre for Water Resources Development and Management (CWRDM) in Kozhikode, Kerala; and Karunya University, in Coimbatore, Tamil Nadu.

NASA LCLUC Workshop on Water Resources and Land Use Transect

Thirty top-level delegates from different institutes and universities in India attended the meeting in addition to twelve researchers from the U.S. **Narasimha Prasad** [CWRDM], welcomed the participants and highlighted the CWRDM water research activities.

After the welcome, **Garik Gutman** [NASA Headquarters] addressed the workshop's participants, presenting an overview of LCLUC issues in South Asia, with focus on agricultural land-cover conversion,

¹ Kerala and Tamil Nadu are two of the 28 states in India.



Water resource-focused workshop participants. **Images Credit:** All photos in this article were taken by author or other members of the LCLUC team.



Rhizophora mangle, known as the “red mangrove,” near Kadalundi bird sanctuary in Kerala.

forest-cover loss, increasing urbanization, and air pollution. **Chris Justice** [UMD] stressed that much needs to be done in terms of the underpinning science of LCLUC and the linkages with global climate change in South Asia.

Some highlights from the workshop are summarized here:

- The most important LCLUC issue impacting agriculture in south India is *paddy fields* (wetlands) being converted to urban areas and/or left abandoned, with the attendant deficit in rice production.
- This *paddy conversion* is complex, and crosses economic, ecological, sociocultural, structural, and class dimensions.
- Economic return from paddy cultivation does not tend to encourage conservation—due to labor costs.
- At present, land is seen only as real estate needed for residence status, and is the safest and best investment to maximize profits.
- Coconut farming is shrinking due to the unavailability of skilled labor.
- Pollution and sedimentation from *anthropogenic* activities seriously affects aquatic systems/wetlands in South India. This requires more-stringent regulations and greater wetland protection.
- The roles of coastal vegetation and mangroves in protecting lives and property require more research to address contamination—possibly due to saline water intrusion, likely from inadequate drainage systems and poor maintenance of the well surroundings.

The CWRDM arranged several field visits to highlight local LCLUC issues and responses, including urban green park and wetlands conservation, mangrove conservation, and coastal and riparian land use management.

On January 9, participants departed for a Land Use Transect Study from Kozhikode, Kerala, to Coimbatore, Tamil Nadu, involving local scientists. The processes of urban expansion and forest degradation were quite evident during the transect study. During the transect, the participants observed forest fires in the mountains, 50 km (~31 mi) away from Coimbatore.



Coconut, arecanut, banana, and yam plantations, Kozhikode, Kerala.



Smoke from forest fires, Palakkad, Western Ghats, Kerala.

NASA International Regional Meeting

Nearly 120 participants from India attended the meeting, held January 10-13 at Karunya University in Coimbatore, Tamil Nadu. In addition, there were 18 researchers from the U.S., 3 from Nepal, 2 from Sri Lanka, and 1 each from Myanmar, Afghanistan, and Bangladesh. On January 9 top-level personnel from the Karunya University—including **E. J. James** [Karunya University—*Vice Chancellor*], the dean, department heads, and students greeted the participants with a grand welcome and reception dinner.

Thursday, January 10, 2013

International LCLUC South Asia meeting participants convened in Coimbatore, Tamil Nadu.

E.J. James, **Chris Justice**, and **Garik Gutman** each discussed the role of LCLUC generally, and in South Asia specifically. **Narasimha Prasad** summarized CWRDM workshop findings. **R.D. Singh** [National Institute of Hydrology, Roorke, India], **Olga Krankina** [Oregon State University], and **Jianguo Qi** [Michigan State University] then followed with overview talks on water management, GOFC-GOLD regional networks, and the MAIRS network, respectively.

Chris Justice, **Prasad Thenkabail** [U.S. Geological Survey (USGS)], **Gumma Muralikrishna** [International Rice Research Institute, Philippines], **Wataru Takeuchi** [National Institute of Environmental Studies, Japan] and **Ruth DeFries** [Columbia University], all gave presentations during a technical session on agricultural land-use change. This material is summarized here:

- Agricultural lands are fast depleting due to urbanization in South Asia, with attendant changes in agricultural production and produce flows, leading to changes in regional dependencies.
- Cropland area, crop type, and rotations are changing across the planet, with poorly documented

extent and dynamics of irrigated lands. The Group on Earth Observations-Global Agricultural Monitoring (GEO-GLAM) initiative is coordinating satellite monitoring observation systems in different regions of the world to enhance crop forecasting. **Prasad Thenkabail** has received funding from NASA's MEaSURES² Program to create a new Earth Observation Global Cropland Area Database (GCAD). The project will contribute to GEO-GLAM efforts. Increased participation by South Asian scientists in the GEO-GLAM initiative was recommended.

- Spatial databases and decision support systems in South Asia in support of improved cropland inventory and monitoring using Earth-observation data are needed, as is active involvement of the Indian Space Research Organization (ISRO) and the Indian Ministry of Agriculture in the design and implementation of a GEO-GLAM data acquisition program coordinated with the Committee on Earth Observation Satellites (CEOS).
- Increasingly, extreme events are negatively affecting agricultural production in South Asia, resulting in increasing interannual production variability and the unsustainability of traditional land use practices. Mitigation and adaptation research is needed to address these issues.
- Land use studies in the region need to better integrate irrigation resources and agricultural land use.
- Several remote sensing methods are available for mapping cropping intensities for South Asian *smallholder* farming. The “best” method to map cropping intensity depends on the scale of results required.
- Drought areas are being monitored with Moderate Resolution Imaging Spectroradiometer (MODIS)-

² MEaSURES is an acronym for Making Earth System Data Records for Use in Research Environments.



International regional meeting participants.

based drought indices and the *Keetch–Byram Drought Index* (KBDI). In addition to these indices, coupled weather forecasting models and increased validation efforts are needed to improve drought forecasting, including crop yield estimation.

- Agricultural residue burning is one of the major issues affecting air pollution in South Asia. Better residue management practices are needed through education and extension activities in the region.
- Agricultural monitoring in India is well developed, using remote sensing technologies at a national scale. Systems continue to be enhanced for monitoring crop type, cropping intensity, etc. at finer spatial scales.

Dadhwal [National Remote Sensing Center, Hyderabad, India], **P. S. Acharya** [Department of Science and Technology, Natural Resource Data Management System, India], **Uttam Kumar** [Indian Institute of Science, India], and **Rama Nemani** [NASA's Ames Research Center] each gave presentations during a session titled *LCLUC-related Earth Observations: Missions, Data, and Products*. Conclusions from this session are summarized here:

- The lack of geospatial data sharing in South Asian countries is a major issue; coordinated policy efforts are needed to resolve this problem.
- International cooperation between NASA, ISRO, and other space agencies in the region is needed to secure satellite data continuity and to increase effective dissemination of data.
- Personnel capacity building is needed in geospatial and web-based technologies to address regional LCLUC issues.
- Development of spatial tools using free and open-source software for geospatial applications shows promise for addressing LCLUC issues.
- Data fusion methodologies are needed to address scaling issues relating to LCLUC problems.
- Department of Science and Technology/National Spatial Data Infrastructure in India is helping to build geoportals for web-based data dissemination. Interagency cooperation is needed to build decision support systems.
- NASA's Earth Exchange (NEX) provides an excellent framework for supercomputing involving large spatial datasets. Such frameworks are needed at a regional level in South Asia—otherwise, scientists need to collaborate with international partners to avail themselves of such capabilities.

Friday, January 11, 2013

Karen Seto [Yale University] presented an overview of urban LCLUC issues. **Brent Holben** [NASA's Goddard Space Flight Center (GSFC)], **Krishna Prasad Vadrevu** [UMD], and **M. M. Sarin** [Physical Research Laboratory, India] each gave presentations on aerosols and biomass burning impacts. The discussions are summarized here:

- There are many institutions, groups, and individual scientists making atmospheric, aerosol, and trace gas observations. There is a need for peer review of these datasets and for the community to collaborate on data analysis.
- There are “major issues” in reconciling *in situ* measurements of aerosols with remote-sensing-based estimates. Comparison/validation studies of satellite aerosol retrievals to surface-based measurements are needed. Local and regional studies should be encouraged to understand the uncertainty of the satellite products. Improved methodologies are needed to link remote sensing data with *in situ* measurements.
- Availability of *in situ* observations and surface-based aerosol and trace gas observations is often difficult, and assessment of uncertainty is an issue. Improved coordination is needed for temporal long-term continuity of *in situ* and ground-based aerosol and trace gas observations.
- Availability of reliable airborne observations is very limited in the South Asia region; airborne campaigns can help in understanding tropospheric chemistry.
- South Asian scientists are encouraged to establish international collaborations with well-established networks such as AERONET³. In that regard, AERONET would like to find an interested partner to establish a long-term observation site in southern India. Participants were encouraged to contact **Brent Holben** for details.
- Atmospherically corrected satellite data should be used when possible for LCLUC models and studies.
- Biomass burning is an important contributor of aerosols and greenhouse gas emissions in the region. Integrated campaigns are needed to address uncertainties in biomass data, combustion factors, emission factors, and aerosols.

Atul Jain [University of Illinois at Urbana Champaign], **Vinay Dadhwal** [National Remote Sensing Center, India], and **Prabir Patra** [Japan

³ AERONET is short for Aerosol Robotic Network, which is a worldwide network of ground-based sun-photometers measuring aerosol concentrations and related atmospheric properties.

Agency for Marine Earth Science and Technology, Japan] gave presentations during a technical session on the carbon cycle. Session highlights are summarized here:

- South Asia is highly diverse, consisting of many different ecosystems and land use systems. Understanding carbon cycling in the region requires integrated approaches.
- Regional LCLUC impacts on the carbon cycle include deforestation, forest fires, soil carbon emissions, and agricultural change. Satellite data provide important information that can be used to study the impacts of historical LCLUC on carbon. However, more ground-based measurements are needed to validate satellite data and to further improve carbon estimates.
- Carbon emissions are not only due to LCLUC, but are also due to several environmental factors and management practices. Biogeochemical models can help in understanding carbon-cycle processes and important factors governing source/sink relationships.
- *Eddy correlation* carbon-flux measurements are being developed and conducted in India in different forest sites. Such measurements are needed throughout South Asia to better understand carbon source/sink relationships.
- There is a need to integrate top-down and bottom-up approaches to address uncertainties in carbon fluxes in South Asia.

Saturday, January 12, 2013

The day's deliberations started with **Dan Brown** [University of Michigan] presenting an overview that stressed the need for integrated models involving socioeconomic variables. **Jagdish Krishnaswamy** [Ashoka Trust for Research in Ecology and the Environment, India], **Karunakaran** [Salim Ali Centre for Ornithology and Natural History, Coimbatore, India], **M.S.R. Murthy** [International Center for Integrated Mountain Development (ICIMOD), Nepal], and **Sanjay K Jain** [National Institute of Hydrology, Roorke, India] took part in a technical session that addressed forests and LCLUC in mountainous areas. Pertinent points are as follows:

- Glaciers in the Himalayan region are retreating due to climate warming combined with topographic and morphological factors. The impact of climate change on the snowmelt runoff and total stream flow of the large Himalayan rivers should be investigated, using coupled general circulation and calibrated hydrological models.

- Forest cover in India is regularly monitored using satellite remote sensing technology. Technological advances and methods have improved the product quality and reliability, but some scientists disagreed on pertinent statistics and noted that a clear definition of what constitutes a “forest” is needed.
- Greening and browning of vegetation in the mountain regions are tied to regional and global change climate drivers. Higher elevations tend to be greening, as compared to browning at mid-to-lower elevations.
- ICIMOD has been focusing various LCLUC activities in the Hindu-Kush Himalayan region and working closely with the NASA SERVIR-Himalaya⁴ science applications framework. ICIMOD provides a good opportunity to foster science collaboration within the region.

Chandra Giri [USGS], **J.K. Garg** [Guru Gobind Indraprasth University, India], and **G.M. Tarekul Islam** [Bangladesh University of Engineering and Technology, Bangladesh] gave presentations during a technical session focused on land use in coastal zones and water resources. Important issues identified from this session are highlighted here:

- Statewide area statistics of wetlands in India are available. There is a need to develop similar wetland inventories (i.e., not just for mangroves) for other regions in South Asia.
- In mangrove regions, anthropogenic changes are much more significant than natural changes; thus, more attention is needed to study LCLUC drivers. Urban development and shrimp farms have been replacing mangroves in several regions of the world—including South Asia.
- Large regions in Bangladesh are flood-prone. Wetlands associated with river/floodplain systems capture and retain water, and thereby reduce the duration and severity of floods. Wetlands are being converted into built-up areas at a rapid rate, affecting both groundwater and flooding.

Yogesh Kant [Indian Institute of Remote Sensing, Dehradun] closed out the technical sessions. Important points relating to the urban presentations are summarized here:

- Urban sprawl is a major LCLUC issue in South Asian countries.

⁴ Principally supported by NASA and the U.S. Agency of International Development, SERVIR is a global network of regional partners dedicated to environmental management through the integration of Earth observations and geospatial technologies.

- *Urban clusters* have become a key topic in economic, innovation, and globalization debates. The underlying socioeconomic drivers in urban clusters need more attention, as they represent agglomerate economies. Drivers and patterns of urban expansion in India are different from those in China. Urban development intensity and spatial extent can be assessed from satellite data through mapping the impervious surface distortions, which is being undertaken in a NASA LCLUC project at GSFC and UMD.
- Nighttime surface temperature can provide robust information to help understand urban heat island phenomena, whereby radiative cooling differences are maximized between urban and surrounding rural locations at night.
- In Kerala, traditional labor-intensive agriculture is becoming less economically viable; buying agricultural land and wasteland for real estate development is seen as a quick investment opportunity.

On the same day, the meeting participants took a half-day field-trip to the Attappady Valley in Palakkad district, and got first-hand experience with ecorestoration projects in the region.

Olga Krankina led a panel discussion, titled *Towards a regional GOF/GOLD South Asia Information Network (SARIN): Prospects, Opportunities, and Challenges*. Participants included representatives from India, Afghanistan, Nepal, Myanmar, and Bangladesh. Some of the important regional science priorities mentioned during the panel discussion are highlighted here:

India

- LCLUC and water resources are a high priority area in South India. Several irrigation projects focusing on LCLUC in the Western Ghats river basin provide a good opportunity to develop underpinning science.
- Research into the links between LCLUC and climate-change studies are needed, as are studies focusing on the impact of LCLUC on human livelihoods.
- A multiyear regional science initiative is needed, complementing initial national funding and international funding. Such an initiative should include data sharing and infrastructure, including data centers focused on implementation of the initiative.

Afghanistan

- Science programs need to be built from scratch; international help is much needed. A national research priority is on land use and water resources.

Research on agricultural drought and uncontrolled urban expansion is needed to help in developing of national policies.

- Extensive capacity building, education, training, and data access are needed on remote sensing and geospatial technologies.

Nepal

- There is a need to develop regionally consistent LCLUC datasets.
- Greater attention to agricultural and rangeland monitoring and management issues is needed in the mountain ecosystems that offer a number of methodological challenges to satellite-based monitoring.
- Biomass burning is a major transboundary air pollution problem; research is needed to inform both land management policy.
- Improved monitoring of forest and land cover change is needed to address threats to biodiversity in the Nepal Himalayas.

Myanmar

- Deforestation is accelerating in Myanmar; there is an urgent need for satellite-based forest monitoring at the national level.
- Similarly, the extent and impacts of biomass burning associated with slash-and-burn agriculture needs to be quantified and understood.

Bangladesh

- Training is urgently needed on remote sensing, e.g., workshops on how to access and use data. Advanced topical workshops are needed on recent science developments.
- Development of a regional science network is a priority, to include collaborative research projects; faculty, staff, student exchange programs; and data sharing.

Recommendations from the Panel on SARIN

- The panel was in full agreement that developing a major regional integrated science initiative—with a central theme of LCLUC aspects involving South Asia researchers—was a high priority; SARIN development would be an integral part of the initiative.
- International programs (e.g., GOF-GOLD, START, MAIRS, GEO-GLAM), should be engaged as a means to strengthen the SARIN network, through science-based contributory

projects. A series of SARIN planning workshops will be needed to identify, prioritize, and address local/regional scale research questions associated with such an initiative.

- Developing bilateral collaboration activities between SARIN countries and with the U.S. would strengthen regional LCLUC research and enable exchange of students and researchers.
- There is a need to strengthen capacity-building activities in SARIN countries on the use of satellite remote sensing datasets for LCLUC research.
- A regional integrated science initiative in South Asia would enable regional scientists to promote scientific data collection and dissemination activities. This would be facilitated by developing a dedicated data center.

Chris Justice ended the meeting with a summary of the most important LCLUC issues in South Asia, followed by closing remarks from **E.J. James** and **Garik Gutman**.

Sunday, January 13, 2013

On January 13 an optional field visit was organized to Ooty (Udhagamandalam), located in the Nilgiris district of Tamil Nadu, a hill station with a range of LCLUC, including forest and eucalyptus, pine, and tea plantations—see photo on right. Many portions of the hills are preserved as natural reserve forests.

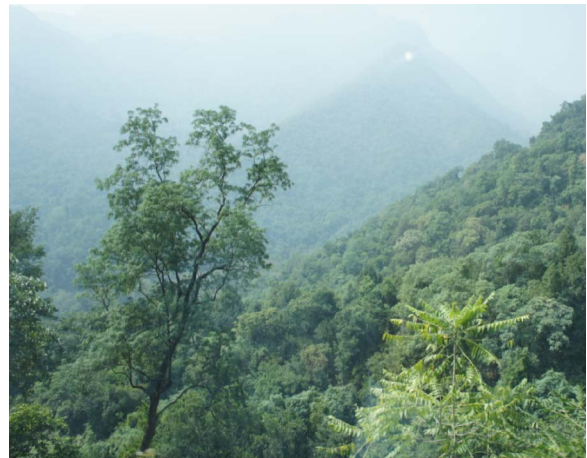
Training Workshop

The training workshop took place January 14 at Karunya University. The objective of the workshop was to introduce the latest methods, tools, and remote sensing data and products available for advanced studies of LCLUC dynamics in South Asia, with a focus on water resources, agriculture, and food security. Nearly 130 participants from different universities in India

attended the highly successful training program, which was conducted by **Jianguo Qi**, **Krishna Vadrevu**, **Atul Jain**, and **Prasad Thenkabail**.

The following topics were discussed: Fundamentals of remote sensing and geospatial technology; advanced tools, methods, and data products for land use and land cover, air pollution and applications; environmental modeling and land-use and land-cover change and its impact on biogeochemistry (carbon and nitrogen) and biogeophysics (water and thermal energy) in Asia; and data, methods, and tools for Earth observation for studies pertaining to global croplands, cropland water use, and food security.

START and UMD provided financial support for the workshop through NASA, CWRDM, Kozhikode, India, and Karunya University. The workshop agenda and presentations can be accessed at lcluc.umd.edu/meetings.php?mid=40. A training certificate was issued to participants who attended the training. ■



Fog enshrouds the forest-covered hills at Ooty (Udhagamandalam), located in the Nilgiris district of Tamil Nadu.