Summary of the 2018 NASA LCLUC–SARI International Regional Science Meeting

Krishna Prasad Vadrevu, NASA's Marshall Space Flight Center, USA; krisvkp@umd.edu
Mylene Cayetano, University of the Philippines Diliman, mcayetano@iesm.upd.edu.ph
Gay Jane Perez, University of the Philippines Diliman, gpperez1@up.edu.ph
Toshimasa Ohara, National Institute of Environmental Studies, tohara@nies.go.jp
Chris Justice, University of Maryland, College Park, cjustice@umd.edu
Garik Gutman, NASA Headquarters, ggutman@nasa.gov

meeting summaries

Introduction

South and Southeast Asian countries account for more than 25% of the global population. The annual population growth rate (averaged across all the countries in the area)[1] is ~1.25% per year. This rapid rate of growth is coincident with rapid economic development, which has led to substantial land-use change (e.g., the conversion of forested areas to agriculture and agricultural areas to residential and urban uses) in this area, which in turn has a significant impact on the environment. Further, increased land-cover and land-use changes (LCLUC) in the region are impacting forest resources, biodiversity, regional climate, biogeochemical cycles, and water resources. To address the LCLUC issues in the framework of NASA's South/Southeast Asia Research Initiative (SARI), an international science meeting was held in the Quezon City, Metro Manila, the Philippines, May 28-30, 2018.[2]

The organizers of this meeting included **Krishna Vadrevu** [NASA's Marshall Space Flight Center (MSFC), U.S.—*SARI Lead*], **Garik Gutman** [NASA Headquarters, U.S.—*LCLUC Program Manager*], **Chris Justice** [University of Maryland, College Park (UMCP), U.S.—*LCLUC Project Scientist*], **Toshimasa Ohara** [National Institute of Environmental Studies (NIES),

Japan], **Tsuneo Matsunaga** [NIES, Japan], and **Atul Jain** [University of Illinois, Urbana-Champaign, U.S.]. **Mylene Cayetano** [Institute of Environmental Science and Meteorology (IESM), University of Philippines (UP) Diliman] and **Gay Perez** [IESM, UP Diliman] served as local hosts. Eighteen other local and international organizations sponsored the event, which also served as a forum for the Global Observations of Forest and Land Cover Dynamics (GOFC–GOLD) Southeast Asia Regional Network to discuss important research needs and priorities.

In total, 202 participants from 21 different countries from Asia, Europe, and the U.S. attended the meeting—see the group photo below. Scientists from five different space agencies in the region were represented, including the Japan Aerospace Exploration Agency (JAXA), the Space Technology Institute of Vietnam and Vietnam National Space Center (VNSC), the Indian Space Research Organization (ISRO), the Geo-Informatics and Space Technology Development Agency of Thailand (GISTDA), and the Indonesian National Institute of Aeronautics and Space (LAPAN). Representatives from several international programs also participated, e.g., the Group on Earth Observations (GEO) Global Agricultural Monitoring [GEOGLAM], GOFC–GOLD, and NASA SERVIR.[3] In total, 103 organizations were represented at the meeting. Prior to the meeting, local hosts also organized a two-day field visit to Mount Pinatubo, a volcano that erupted in June 1991, to observe how the eruption impacted local land cover and land use—see *An Excursion to Mount Pinatubo 27 Years After Its Eruption* on page 36.

---

[1] The countries considered part of South/Southeast Asia for purposes of this calculation are Afghanistan, Pakistan, Nepal, India, Bhutan, Bangladesh, Sri Lanka, Timore-Leste, Brunei, Philippines, Cambodia, Laos, Malaysia, Myanmar, Vietnam, Indonesia, and Thailand. Note that in the Maldives, annual population growth is negative (-0.07).
[2] The 2017 LCLUC–SARI International Science Meeting was summarized in the November–December 2017 issue of *The Earth Observer* [**Volume 29**, **Issue 6**, pp. 40-47—*https://eospso.nasa.gov/sites/default/files/eo_pdfs/Nov_Dec_2017_color_508.pdf*].

[3] SERVIR is not an acronym; it is derived from a Spanish word meaning "to serve."

NASA LCLUC–SARI meeting participants in Quezon City, Philippines. **Photo credit:** University of Philippines, Diliman team

meeting summaries

An Excursion to Mount Pinatubo 27 Years After Its Eruption

Mount Pinatubo is an active volcano in the Philippines. The volcano erupted explosively in June 1991, filling the neighboring areas with volcanic deposits as much as 200 m (~656 ft) deep. The eruption removed so much magma and rock that the summit collapsed to form a caldera 2.5 km (~1.5 mi) across—see *Photo*. To further complicate matters, at the time of the eruption, tropical storm Yunya passed to the northeast of Mount Pinatubo, resulting in a torrential rainfall in the region. The ash that was ejected from the Pinatubo mixed with the water in the air and caused a rainfall of *tephra* (fragments of rock from the eruption) that covered almost the entire island of Luzon, the remnants of which were visible even today. Nearly 10 cm (~4 in) of ash covered a 2000 km² (~772 mi²) area.

There were other long-lasting effects caused by the eruption and consequent earthquakes, with significant physical and infrastructure effects. Even today—27 years later—travel is still problematical in some areas, and the rice yield in the region surrounding the volcano is still low.

Prior to the start of the meeting, some participants visited Mount Pinatubo and the surrounding area of Bacolor (a municipality in the Province of Pampanga) to understand the local land cover and land use issues, and the impact the 1991 eruption had on the landscape. They saw a half-buried church, and observed the vegetation changes on the lower slopes of the Luzon Mountains and lowland forests. The hill-top upper montane forests are covered with trees that are shorter in stature along with epiphytes, vines, and moss.

Lake Pinatubo formed due to the collapse of the summit of the mountain due to volcanic eruption. The lake is the deepest in the country with a depth of 600 m (2000 ft). **Photo credit:** Krishna Vadrevu [MSFC]

The first and third days of the meeting included plenary sessions on Agriculture, Atmosphere, Forests, Land, and Urban themes. The second day was devoted to in-depth parallel sessions on the Agriculture and Atmosphere themes, each having technical presentations followed by panel discussions, with time for formal discussions and ample opportunity for informal conversations. Sixty-four scientific presentations were given, along with 25 poster presentations.

The following summary presents highlights from each day of the meeting. The full agenda and all presentations are available from the LCLUC program website at *http://lcluc.umd.edu/meetings/land-coverland-use-changes-lcluc-and-impacts-environment-southsoutheast-asia-international*.

Day One

The meeting began with introductory welcome remarks followed by two thematic technical sessions with presentations on agricultural LCLUC, atmospheric correction, emission inventories, and land-atmospheric interactions.

Plenary Sessions

The meeting started with welcome remarks from the local hosts **Mylene Cayetano**, **Gay Perez**, and **Lemnuel Aragones** (all from IESM, UP Diliman). Aragones stated that IESM integrates environmental sciences and the meteorology and oceanography programs, and for

the past fourteen years has served as a center of excellence in the Asia Pacific. IESM addresses the science of human impact and responses to the changing weather systems and climate, including impacts on the environment in the Philippines. Aragones remarked that the current meeting is the first NASA science meeting held on the LCLUC topic in the Philippines, and noted that regional scientists are looking forward to strengthening international collaborations in the region.

Garik Gutman then welcomed the participants. Speaking on behalf of NASA, he said that addressing LCLUC issues is of high importance for the region, and that SARI is therefore facilitating such activities. Since its inception, NASA's LCLUC program has funded over 300 projects.[4] Gutman emphasized that integrating remote sensing, biophysical, and socioeconomic data to address LCLUC issues is one of the program's priorities. **Chris Justice** welcomed the participants and explained how SARI meetings are bringing the U.S. and international scientists together to discuss the latest science in the region. **Krishna Vadrevu** highlighted ongoing SARI

---

[4] The activities of NASA's LCLUC Science Team parallel, and sometimes overlap, with some of what is reported here. To read a summary of the most recent LCLUC Science Team Meeting, see the July–August 2018 issue of *The Earth Observer* [**Volume 30**, **Issue 4**, pp.14-18—*https://eospso.gsfc. nasa.gov/sites/default/files/eo_pdfs/July-August%202018% 20 Color%20508.pdf#page=14*].

projects, stressing strong research and capacity-building needs, and encouraged participants to join the SARI initiative. **Toshimasa Ohara** also welcomed the participants and remarked that most of the local air pollution concerns are closely tied to land management; thus, integrated research is necessary.

Agricultural LCLUC and Remote Sensing

The international GEOGLAM coordination initiative is the agricultural flagship of GEO. Its vision is to use coordinated, comprehensive, and sustained Earth observations to inform decisions and actions in agriculture through a system of agricultural monitoring systems, as has been described at a previous meeting. Recently, the Earth Observations for Food Security and Agriculture Consortium (EOFSAC—recently renamed "Harvest")—newly organized by NASA to focus on agriculture—was formed with 40 collaborating entities from academia, government, and nongovernmental organizations to advance agriculture and food security applications. UMCP coordinates the Consortium (*http://www.eofsac.org*).

In support of these and other activities, the European Space Agency's (ESA) Copernicus Sentinel-1[5] is a synthetic aperture radar (SAR) mission that provides an excellent opportunity for operational rice-monitoring applications, especially in cloud-hampered tropical regions. Systematic Earth observations (e.g., from the Landsat and Sentinel series) are useful for operational purposes. For example, **Thuy Le Toan** [Centre d'Études Spatiales de la BIOsphère (CESBIO), France] and her collaborators are working in Vietnam through a project titled Georice, providing operational rice monitoring, which include rice vs. non-rice maps in near-real time for three seasons per year, and providing annual crop intensities using Sentinel-1 data.

Local scientists discussed how, in the Philippines, agriculture and fisheries sectors are vital for employment, sustenance, and the economy generally. Agriculture in the Philippines is continuously challenged due to natural hazards such as recurrent typhoons. In addition, the agriculture sector is also sensitive to tariff rates, which are significantly higher than those in the industrial and mining sectors. Land degradation due to soil erosion is also quite common. In an effort to combat this, the Philippines government is working on land reclamation programs.

Similarly, India has seen 25 drought events between 1871 and 2017, with concomitant effects on its people.

To explore such effects, an operational National Agricultural Drought Assessment and Monitoring System (NADAMS) has been developed, which delivers monthly and fortnightly (two-week) district- and subdistrict-level-drought assessments for the 14 dominant agricultural states in India. The NADAMS system integrates AVHRR, MODIS, and AWiFS datasets for mapping droughts.[6]

The Asia-Rice Project is led by JAXA in collaboration with the Centre National d'Études Spatiales (CNES) and Asian space agencies and ministries of agriculture to enhance rice production estimates through the use of Earth-observing satellites. Asia-Rice is collaborating with the Association of Southeast Asian Nations (ASEAN) Food Security Information System (AFSIS) to provide rice-growth outlook maps to the GEOGLAM Crop Monitor database.

In Vietnam, the Ministry of Agriculture and Rural Development (MARD) is responsible for rural development and the governance, promotion, and nurturing of the agriculture sector. MARD generates monthly reports on crop production and conducts surveys in agriculture, forestry, and aquaculture, providing periodic summaries and updates in relevant matters. They are currently working with VNSC to utilize information derived from Earth observations. The Remote sensing-based Information and Insurance for Crops in Emerging Economies (RIICE) Project—not to be confused with RICE with one "I" mentioned earlier—is delivering rice maps, early yield forecast, production, and damage assessment for 10 provinces, including eight in the Red-River Delta and two in the Mekong Basin.

In Thailand, GISTDA has been applying geo-informatics and space technology for crop monitoring and yield estimation to support the government and local agricultural organizations. Critical agricultural outputs include crop area estimation, yield prediction, crop stress, and delivering weather and climate information.

Atmospheric Correction

Specific to the atmospheric correction of optical satellite data, the Landsat surface reflectance code (LaSRC) is mature, and a pathway toward validation, and automated quality assurance has been identified. The algorithm is generic and based on documented and validated radiative transfer code, so the accuracy can be traced, making it easier to construct error budgets.

---

[5] Each Sentinel mission is based on a constellation of two satellites to fulfill revisit and coverage requirements, providing robust datasets for Copernicus Services. Mentioned in this article are: Sentinel-1, a synthetic aperture radar (SAR) mission; Sentinel-2, a land-imaging mission similar in scope to U.S. Geological Survey–NASA Landsat missions; and Sentinel-3, which measures ocean surface topography, land- and sea-surface temperature, and ocean color. Learn more about the Sentinel missions at *http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Overview4*.

[6] NOAA-AVHRR stands for National Oceanic and Atmospheric Administration-Advanced Very High-Resolution Radiometer, which has flown/flies on a number of NOAA's Polar-Orbiting Operational (POES) satellites, the most recent being NOAA-15 launched in 1998. MODIS stands for Moderate Resolution Imaging Spectro-radiometer, which flies on NASA's Terra and Aqua platforms. AWiFS stands for Advanced Wide Field Sensor, which flies on ISRO's RESOURCESAT-1 and -2 satellites.

meeting summaries

The incorporation of bidirectional reflectance distribution function (BRDF) correction enables easy cross-comparison among different sensors (e.g., MODIS, VIIRS,[7] AVHRR, Landsat, Sentinel-2, and Sentinel-3).

Emission Inventories

The Japanese Greenhouse gases Observing Satellite (GOSAT) is dedicated to monitoring greenhouse gases (GHG) from space; it represents a joint effort among the Japanese Ministry of the Environment (MOE), JAXA, and NIES. GOSAT was launched in 2009 and has been monitoring atmospheric carbon dioxide (CO_2) for more than nine years. The successor, GOSAT-2, will be launched in FY2018 with enhanced Earth-observation capabilities over its predecessor. GOSAT data can be used to quantify CO_2 emissions from urban areas.

The Regional Emission inventory in ASia (REAS) version 3.0 is being updated and will include bottom-up emissions inventory from anthropogenic sources for different countries for 1950 through 2015. Results from the inventory suggest that emissions increased throughout the early 2000s and reached the highest value of the measurement series in 2015. REAS is being updated for NO_x emissions. Satellite-observed NO_2 over India and Southeast Asia suggest a recent increasing trend in NO_x emissions. Studies combining bottom-up emissions inventory and modeling are vital for accurate characterization of emissions.

Land Atmospheric Interactions

An important ongoing regional project is the Seven South East Asian Studies (7-SEAS) project. As a part of the project, biomass burning, aerosol, chemical, microphysical, and radiative properties over the Indochina region have been characterized. Transport patterns of biomass burning plumes from Indochina have been identified and verified by *in situ* measurements. In several southeast Asian countries, particulate pollution from black carbon (BC) is common due to incomplete combustion. BC is a major short-lived pollutant and can warm the atmosphere regionally. Specific to Manila, Philippines, old-technology vehicles are the primary cause of BC pollution. As a result, BC concentrations in some urban areas are higher than those for India or China. Furthermore, trends in surface temperature from 1880 to the present in Southeast Asia, including the Philippines, suggest a warming trend. Also, unusually high sea surface temperature is correlated with very strong typhoons in the region. A recent example was Typhoon Haiyan (2013), which resulted in extreme damage and changes in current land cover and land use in the region.

Day Two

Day-two included two different parallel sessions: remote sensing of agricultural land use and atmospheric science and land-use change. The presentations and the highlights of the panel discussion are summarized here.

Remote Sensing of Agricultural Land Use

The Agricultural Market Information System (AMIS)[8] is an interagency platform launched in 2011 by the G20, or Group of Twenty, ministers of agriculture following the global food price hikes in 2007-08 and 2010. GEOGLAM has been delivering a monthly bulletin since 2013 on current growing conditions for the four major crops (wheat, maize, soybean and rice) with operational crop assessments using Earth observations, which is published in the AMIS Market Monitor. Following the AMIS Crop Monitor example, researchers at UMCP have developed the Crop Monitor for Early Warning that provides crop conditions within countries at risk (*https://cropmonitor.org*).

In the Philippines, rice area detection and monitoring using multitemporal SAR images is being carried out as a part of the Philippines Rice Information System (PRISM) project (funded from 2014 to 2017) at the International Rice Research Institute (IRRI), in collaboration with the Philippines' Department of Agriculture and other partners. As a part of the project, data products that describe rice area, cropping intensities, flooded rice-area during floods, and droughts are being delivered. A drought index, *standardized vegetation-temperature ratio* (SVTR), derived from MODIS normalized difference vegetation index (NDVI) and land surface temperature (LST) data was used to detect and characterize agricultural drought in the Philippines with 73% accuracy. SVTR forecasts show good agreement with actual drought events.

The sugarcane industry is growing in the Philippines, and Sentinel-2 data are being used to estimate tons of sugarcane per hectare at the provincial level. For rice, SAR-based yield estimation combined with the Oryza crop-growth model (*https://sites.google.com/a/irri.org/oryza2000/about-oryza-version-3*) has an added benefit. Crop-suitability mapping using remotely sensed land cover and geographic information systems (GIS) is being carried out as a part of a nationwide project called Smarter Approaches to Reinvigorate Agriculture as an Industry (SARAI, *http://www.sarai.ph*).

In Vietnam, rice monitoring from space is led by Ho-Chi Minh City Space Technology and Application Center in collaboration with CESBIO in France and An Giang University in Vietnam as a part of the Asia-Rice

---

[7] VIIRS stands for Visible Infrared Imaging Radiometer Suite, which flies on both the Suomi National Polar-orbiting Platform (NPP) and the Joint Polar Satellite System-1 (JPSS-1, which is now known as NOAA-20) platforms.

[8] AMIS provides a synopsis of major developments in international commodity markets, focusing on wheat, maize, rice, and soybeans (*http://www.amis-outlook.org*).

project and a contribution towards GEOGLAM. Data on rice crop area, yield, and production, as well as crop calendars are generated using RADARSAT, Sentinel-1, and ALOS-2 [9] data from 2013 to the present.

LAPAN is developing algorithms to characterize rice paddies using multitemporal MODIS, Landsat 8, and Sentinel-1 data with 70–80% accuracy on the harvested area and 90% accuracy on paddy growth. LAPAN is also receiving land-imaging data from Himawari-8,[10] MODIS, Landsat, and SPOT,[11] as well as fine-resolution satellite data (from a variety of sources) and applying them to a variety of LCLUC applications.

AgriNet Solutions (www.agrinetsolution.com), India is using data at several spatial resolutions from AWiFS, LISS-III, and LISS-IV [12] to map basmati rice areas in Punjab, Haryana, Uttar Pradesh, Jammu, and Kashmir provinces in India with 91.8% accuracy.

The Environmental Policy Integrated Climate (EPIC) model is a semi-mechanistic terrestrial ecosystem model useful for simulating crop biomass, yields, water use, nutrient fluxes, and soil erosion under various land use management and climate change scenarios. UMCP researchers are integrating remote sensing inputs on crop cover, crop emergence, and leaf area index data into EPIC to improve crop characterization. A forecasting framework using EPIC to produce in-season crop condition and yield outlooks is also being developed. At the University of Arizona (U.S.), time-series NDVI integrating data mining is being used for crop type mapping with 90% accuracy.

Agricultural Applications of Remote Sensing Panel Discussion

The panel was comprised of agricultural experts from academia, government, and nongovernmental organizations. The panelists were asked to identify important agricultural research needs and priorities in South/Southeast Asia.

During the discussion session that followed, panelists strongly expressed a need to establish robust crop inventory and monitoring systems using remote sensing, reflecting immediate

national priorities. In support of this, documentation of best practices would be extremely useful. In several countries of South and Southeast Asia, optical remote sensing is being augmented by microwave data (e.g., Sentinel-1); thus, technical support on microwave data processing and robust algorithms are needed. At the national level, all panel members identified the need for accurate and up-to-date information on crop area, planting dates, crop condition, pest and disease occurrence, yield, production forecasting and estimation. National monitoring systems should also help individual farmers and subnational decision making. Emphasis should be on transitioning from research to applications; as the process is slow, early engagement of end users and co-development is recommended. For long-term sustainability, there is a need for a strong relationship between research and operational groups. Panelists articulated the need for highly accurate products from national monitoring systems. Research is needed on prioritizing data collection for both satellite and ground data to reduce uncertainties and also to improve yield forecasting. Collecting field validation data to support the intercomparison of different approaches is also important. All participants felt that data sharing among countries is important in order to generate consistent regional products with high accuracy, which would meet the needs of multiple agencies. Participants also identified a need for a separate workshop focusing on time-series analysis techniques and standardization of remote sensing data.

Atmospheric Science and Land Use Change

In India, there are significant uncertainties on methane (CH_4) emissions. (Methane is one of the most important GHGs as it has 28 times higher global warming potential than CO_2.) Results from integrating remote sensing data for wetlands mapping and ground-based emission measurements suggest CH_4 emissions are on the order of 3 Tg annually. In cloud-affected areas, Advanced Land Observing Satellite Phased Array type L-band Synthetic Aperture Radar (ALOS-PALSAR) data can be useful in mapping wetlands and paddy areas to estimate CH_4 emissions.

In Singapore, both urban pollution and biomass burning impact air quality. For example, black carbon (BC) accounts for about 21% of locally measured atmospheric particulates with diameter ≥ 2.5 μm ($PM_{2.5}$) concentrations in Singapore during episodes without haze. In the presence of haze, the BC contribution is only about 10%. This decrease implies that other chemical species contribute significantly to $PM_{2.5}$ levels during biomass burning episodes.

---

[9] These are SAR missions: RADARSAT is a Canadian Space Agency mission; Sentinel-1 was defined in footnote #3; and ALOS stands for Advanced Land Observing Satellite, also called "DAICHI" in Japanese, developed by JAXA.

[10] Himawari-8 is a geostationary satellite launched by the Japan Meteorological Agency (JMA).

[11] SPOT stands for Satellite Pour l'Observation de la Terre. It is French commercial high-resolution optical imaging Earth observation satellite system. Initially created by CNES, it is now run by Spot Image, a private company based in Toulouse, France.

[12] LISS stands for Linear Imaging Self Scanner, which, along with AWiFS (defined in footnote #3) flies on ISRO's RESOURCESAT-1 and -2 satellites.

In several cities in the Philippines, emissions from automobile exhaust contribute to largest emissions. Ground-based measurements suggest significant pollutant enhancement during the "work week"—coinciding with increased levels of vehicular traffic.

In Indonesia, there is an increase of GHG fluxes after deforestation and land use conversion to oil palm growth. Proper mitigation efforts are needed to reduce the impact of deforestation on emissions and the soil environment. Peat fires are an important source of emissions and are currently underestimated. Aerial photographs combined with field observations can help detect small-scale peat fires, including underground fires. Wireless sensor networks and the like can also help to better monitor fires. Specific to agricultural fires in India, VIIRS 350-m (~1148-ft) data can detect more fires than MODIS due to a higher spatial resolution. Thus, for emissions estimation, VIIRS products can provide improved results. Validation of VIIRS-retrieved aerosol optical depth (AOD) with data from NASA's Aerosol Robotic Network (AERONET)[13] suggests that VIIRS AOD products can capture pollution events more effectively than MODIS AOD products.

Aerosol optical thickness (AOT) data retrieved using the Advanced Himawari Imager (AHI) onboard the Himawari geostationary satellite and processed using the Non-hydrostatic ICosahedral Atmospheric Model (NICAM) developed by NIES, were quite useful in capturing AOT transport from Siberia to Japan. Multimodel intercomparison of surface ozone (O_3) and related species suggests large variation in the assimilated surface O_3 over East Asia. State-of-the-art models still overpredict summertime surface O_3 around Japan; more modeling efforts are needed. The NIES team has developed a new database of vegetation and biogenic volatile organic carbon emission factors for Japan.

The National Astronomical Research Institute of Thailand (NARIT) is involved in atmospheric measurements and research. Consistent and year-long mixing-layer-height measurements using airborne lidar in the mountain valley of Chiang Mai suggests significant enhancement of air pollution due to biomass burning aerosols. The NARIT team has also participated in the High Altitude and LOng Range (HALO) – Effect of Megacities on the Transport and Transformation of Pollutants on the Regional to Global Scales (EMeRGe) Asian Aircraft Measurement Campaign (conducted in March–April, 2018) and the data are being analyzed (*www.narit.or.th*).

Some important mitigation measures to reduce pollution in Asia include: end-of-pipe mitigation measures (e.g., desulfurization equipment), improvement in the quality of fuels from high-sulfur to low-sulfur content,

improvement in energy efficiency, and drastic energy-source shifting from coal to renewables or natural gas. Integrated assessment models can aid in identifying appropriate mitigation measures for pollution reduction.

Atmospheric Science and Land Use Change Panel Discussion

The discussion session began with reports from a panel comprised of atmospheric science and land use change scientists, representing different south/southeast Asian countries. They were each asked to identify important pressing issues on air pollution including research priorities in South/Southeast Asia.

All panel members and participants agreed that air pollution is a highly complex, multifaceted problem. Emissions from transportation, industries, and biomass burning are the most common sources in this region of the world. Operational monitoring of pollutants at a high spatial and temporal resolution—integrating ground and satellite measurements—is needed to understand the pollutant characteristics and impacts on the environment. Of the different pollutants, panel members felt that $PM_{2.5}$ needs immediate attention, as this can significantly impact human health. Not every city in Asia has implemented pollutant standards; there is an urgent need to find evidence-based standards and robustly implement them. Understanding chemical speciation of $PM_{2.5}$, source apportionment, and quantifying health risks to humans through measurement and modeling are all important and will require stronger linkages between the measurement and modeling communities. Participants also emphasized the need to educate the public on pollution impacts on health, and strong enforcement of the law to curb air pollution regionally and locally. Sustainable land-use planning along with efficient fuel technologies in the transportation sector can help to mitigate air pollution. Panel members felt a stronger need for capacity building and training relating to atmospheric science, remote sensing, and air pollution in the region.

Day Three

The day began with short-presentations on panel summaries from the previous days followed by technical presentations on LCLUC in the forestry sector and urban areas.

LCLUC Applications in the Forestry Sector and in Urban Areas

Forests can undergo degradation due to disturbance from fires, insect infestation, diseases, or extreme

---

meeting summaries

weather events. Thus, developing tools to detect forest disturbance from satellite-data is one of the important focus area in forestry research. For example, on a global scale, the time-series vegetation change tracker algorithm can be used effectively to detect forest disturbance using Landsat data. Annual forest disturbance records for the U.S. and Canada are available.[14] As a part of ESA's Fire Climate Change Initiative (Fire-CCI) project, burnt areas are being mapped during the period 2001-2017 on a global scale using MODIS 250-m (~820-ft) data.

In the Philippines, the National Mapping and Resource Information Authority (NAMRIA) is responsible for forest mapping and monitoring. NAMRIA initiated national land scale cover mapping using digital classification of Landsat data from 2003, 2010, and 2015; mapping efforts are ongoing for 2017–2020. For the 2017–2020 mapping, Sentinel data in addition to Landsat 7 and 8 data will be used. Forest cover classification using lidar data was also attempted for 2012-2017 as part of a national mapping program in the Philippines.

In India, major drivers of LCLUC include urbanization and population growth. Extreme climate events such as floods and droughts also impact LCLUC. Specific to Andhra Pradesh State, agricultural lands are being converted to Eucalyptus, Leucaena, and Casuarina plantations, as they need less human activity than other crops for their growth.

In Myanmar, forest-type mapping from 2016, including identifying drivers of deforestation, is being led by the Smithsonian Conservation Biology Institution, with the help of the Forestry Department, One-Map Myanmar Project Team, Yangon Institute of Technology, and local nongovernmental organizations. UMCP researchers are studying the role of LCLUC in malaria transmission under changing socioeconomic and climate conditions in Myanmar with fine-resolution Worldview[15] data for land-cover mapping.

In Nepal, the deforestation rate is decreasing due to community forestry programs and privately managed agroforestry. In Indonesia, digital classification methods using Landsat and lidar data including automated digital preprocessing, are being used for forest classification as a part of a collaborative project.

In the Mekong Delta, rice-paddy cultivation, shrimp farming, and urbanization are destroying the mangrove ecosystems. Researchers from Michigan State University are studying LCLUC-related *water-energy food (WEF) nexus*[16] and challenges in the upper Mekong Basin. Preliminary results suggest that construction of new dams can affect the mainstream flows in the Mekong.

In Vientiane, Laos, urbanization is occurring rapidly. An operational LCLUC mapping and monitoring program at the country level is a high priority. In Malaysia, greenspace in several cities is fast disappearing; whereas in Kaula Lumpur an increase in greenspace has been observed since 2010.

Conclusion

The SARI meeting in the Philippines served as a forum for the exchange of ideas and information across a diverse range of SARI researchers. Regional researchers emphasized the need to continue SARI meeting and training activities[17] for the benefit of the LCLUC community, not only to enhance regional science, but also to address policy-relevant LCLUC issues in the region.

Three publications are planned to record and describe discussions at the meeting. These include:

- *A special issue of Remote Sensing (https://www.mdpi.com/journal/remotesensing/special_issues/lclu_sasia);*

- *a special issue of Environmental Pollution(https://www.journals.elsevier.com/environmental-pollution/call-for-papers/call-for-papers-on-greenhouse-gases-shortlived-climate-poll); and*

- a two-volume book set focusing on biomass burning published by CRC Press, Taylor & Francis Group.

Interested authors should contact **Krishna Vadrevu** (Krishna.p.vadrevu@nasa.gov) for details on article submissions. ■

---

[14] See *https://daac.ornl.gov/NACP/guides/NAFD-NEX_Forest_Disturbance.html*.

[15] Worldview is a tool developed by the Earth Observing System Data and Information System (EOSDIS) that allows users to interactively browse global satellite imagery—within hours of it being acquired. Learn more at *https://worldview.earthdata.nasa.gov*. The complete record of MODIS imagery is now available in Worldview. To learn more see "NASA's Worldview Places Nearly 20 Years of Daily Global MODIS Imagery at Your Fingertips" in the July–August 2018 issue of *The Earth Observer* [**Volume 30**, **Issue 4**, pp 4-8—*https://eospso.gsfc.nasa.gov/sites/default/files/eo_pdfs/July-August%202018%20Color%20508.pdf#page=4*].

[16] *WEF nexus* refers to the places these three related sectors—water security, energy security, and food security—converge. The three are inextricably linked and the actions in one area more often than not have impacts on one or both of the other areas.

[17] After the meeting, 130 early-career scientists and students from the SARI countries participated in a three-day, hands-on training, focused on the use of remote sensing and geospatial technologies for LCLUC applications. Specific topics included, Introduction to Remote Sensing, Multi-Temporal Analysis of Satellite Images, Modeling of LCLUC, Forest Disturbance Mapping, SAR Remote Sensing Data and Applications, Machine Learning Tools, and Cloud Computing Using Google Earth Engine.