The NASA Land-Cover/Land-Use Change (LCLUC) Program, NASA Headquarters
This synopsis is for the Land-Cover and Land-Use Change (LCLUC) part of the NASA Research Announcement (NRA) ROSES-2016 NNH16ZDA001N-LCLUC. This NRA offered opportunities for research to develop and use NASA remote sensing technologies to improve understanding of human interaction with the environment, and thus provide a scientific foundation for understanding the sustainability, vulnerability and resilience of land-cover and land-use systems. NASA LCLUC research contributes toward the goals of the U.S. Global Climate Research Program (USGCRP) by providing critical scientific information about LCLUC-climate interactions and the consequences of land-cover and land-use change on environmental goods and services, the carbon and water cycles and the management of natural resources. NASA received 25 Step-2 proposals and selected 9 proposals for a total funding of $6.1M for three years. More details are available at: http://nspires.nasaprs.com.

Varaprasad Bandaru/University of Maryland, College Park
Agricultural Land Use Change in Central and Northeast Thailand: Effects on Biomass Emissions, Soil Quality, and Rural Livelihoods
16-LCLUC16-2-0033

In South-Southeast Asia, the majority of the population is involved in agriculture. Land use change within agricultural landscapes, such as cropping system conversions or management adjustments, has been given little attention within land cover and land use change research. Yet such research is essential amidst policies to increase agricultural intensification, particularly in developing countries, and global efforts to develop sustainable agricultural production systems that improve food security and maintain the provision of ecosystem services (e.g. United Nations Sustainable Development). The recent South-Southeast Asia Research Initiative (SARI) workshop, Delhi highlighted the need for more attention towards land use change monitoring within agricultural landscapes and understanding the socio-economic and environmental impacts of these changes.

Recent changes in policy and market conditions have triggered rapid shifts in agricultural land use practices in Central and Northeast Thailand. Reductions in domestic rice prices and increased demand for bioenergy have led to declining rice and expanding sugarcane cultivation. This trend is expected to continue with support from the Thailand Government’s 5-year Agriculture Restructure Program (2015-2019). In addition to economic implications, this shift is expected to impact ecosystem services (e.g. soil and air quality), driven largely by the common practice of rice and sugarcane residue burning. Hence, it is essential to understand the implications of current and alternative residue management practices on economic, societal and environmental well-being of Central
and Northeast Thailand. Given market forces, similar policies could be adopted in South-Southeast Asia. The overarching questions of the proposed research are:
1) How do recent agricultural land use changes impact ecosystem services and economic well-being in rural communities?
2) How do current and alternative management strategies affect soil quality?
3) What are the socio-economic impacts of change in crops and management?

To address these questions, a US-based team of remote sensing scientists, crop modelers and social scientists together with scientists from the Joint Graduate School of Energy and Environment (JGSEE) in Thailand will conduct interdisciplinary land use research integrating remote sensing, field-scale research, agroecosystem modeling, and socioeconomic analysis.

The goal is to understand the impacts of land use changes in Central and Northeast Thailand on biomass emissions, soil quality, and rural well-being. Our objectives are to:
1) map major cropping system conversions (e.g. rice to sugarcane) from 2010-2014 and 2014-2018 at 30-m resolution using a combination of satellite datasets, 2) implement remote sensing Environmental Policy Integrated Climate (RS-EPIC) modeling framework to quantify the impacts of residue burning and alternative residue management strategies under rice and sugarcane production on crop productivity, erosion and carbon cycling at 1-km resolution, 3) quantify spatially-explicit biomass emissions using an improved bottom-up approach, 4) implement a mathematical programming input-output modeling to quantify socio-economic impacts, and 5) understand farmers’ willingness to adopt sustainable practices and barriers and incentives to adaptation of these practices.

Products developed here will inform regional land use and management planning and policy aimed at reducing emissions, meeting agricultural production demands, and ensuring rural well-being. Improved methodologies will be developed for monitoring land use change within agricultural landscapes, estimating biomass emissions and soil quality impacts, and understanding socio-economic impacts. These methodologies could be extended to other developing South Asian nations. Project analyses and methodologies will be shared broadly through targeted capacity building and training programs of SARI and through SERVIR hubs.

Kirsten de Beurs/University of Oklahoma
Land Use Patterns and Political Instability as Predictors for the Re-Emergence of Malaria in the Caucasus
16-LCLUC16-2-0017

We propose to investigate trends in land use in the Caucasus between 1984 and 2019 and focus specifically on the change in agriculture from rain-fed to irrigation, forest fragmentation because of overharvesting and natural causes, and changes in open surface water. We will examine the implications of these changes in terms of their impact on the vulnerability of the population (social system) to re-emergence of vector-borne diseases
such as P. vivax Malaria. We will apply quantitative and qualitative analysis to investigate political instability as a predictor for the re-emergence of Malaria. Our research area will cover and focus specifically on Armenia, Azerbaijan, and Georgia. We are collaborating with Dr. Ani Melkonyan who is a native Armenian. Dr. Melkonyan is an environmental (agricultural) economist currently working at the University of Duisburg-Essen, Germany. She has committed to act as the liaison between the research team and other collaborators (stakeholders from science and politics) in Armenia and Georgia.

This project proposes an innovative new method that combines spatial and temporal analysis to improve predictive modeling in disease ecology and international health. The three countries of the Caucasus are very relevant for this study because their stark socio-economic and political differences provide excellent comparison opportunities. All three regions have experienced cycles of instability and conflict since 1990. The overall objective is to apply remotely sensed data for the development of suitability maps for malaria in the Caucasus. Once these maps are created, the goal is to distinguish and isolate the effects of political instability, which include the cessation of malaria prevention, from the land use and land cover impact on malaria transmission by creating precise timelines of each country’s post-Soviet historical trajectory. Institutional failures under unstable governments during periods of conflict could undermine or interrupt public health work so that disease vectors proliferate. This research is based on a solid set of remote sensing methods, which will be expanded by the incorporation of SAR imagery. The development of error surfaces by comparing multiple data streams will present a significant new development.

Research questions:
1) How have the cropland areas and cropland intensity (irrigation and crop rotations) changed since the late 1980s to create expanded niches for malarial mosquitoes?
2) How did the collapse of the USSR and the regeneration of unstable successor states in the 1990s differentially affect forest fragmentation and P. vivax niche expansion across the region?
3) Can future malaria risk in the Caucasus and other politically or environmentally unstable regions be predicted by combining remotely sensed imagery with social/historical analysis of political corruption, agricultural development, and resource extraction?

Jefferson Fox/ Center For Cultural And Technical Interchange Between East and West
The Agrarian Transition in Mainland Southeast Asia: Changes in Rice Farming - 1995 to 2018
16-LCLUC16-2-0012

This project responds directly to the solicitation for LCLUC studies in Southeast Asia by examining how the region is responding to simultaneous loss of agricultural labor and intensification of rice production. Major project objectives include: 1) Build a
comprehensive multi-resolution, satellite image-derived database to characterize variability across and long-term changes within regional rice production systems; 2) Model current and past rice production under changing socio-economic and environmental conditions; 3) Use national population and agricultural censuses and other spatially-explicit secondary datasets compiled for sub-district units to quantify how changing conditions are correlated with changes in rice production systems through time; and 4) Conduct field interviews at selected sites to develop a place-based understanding of how rice farming is being revolutionized by changing demographics, economic opportunities, and technological innovations. We will explore these objectives for the major rice producing areas of four Mainland Southeast Asia (MSEA) countries (a total of six rice producing regions) between 1995 and 2018. The four countries and six regions include: 1) Vietnam (Red River and Mekong River Deltas), 2) Thailand (Northeast and Central Regions), 3) Laos (Savannakhet Province), and 4) Cambodia (Battambang Province). We will quantify changes in rice production systems between 1995 and 2018. As a means of quantifying long-term landscape dynamics in the persistently clouded study area, we will use an assemblage of complementary, cloud-resilient remote sensing analytical methods. First, we will classify Sentinel 2 SAR time series data (2014-2018) through an unsupervised rule-based clustering algorithm to differentiate stable standing water from flooded rice paddies to map locations and timing of rice production. Second, we will apply the Noise Insensitive Trajectory Algorithm (NITA) on Landsat (1995-2018) and Sentinel 2 (2015-2018) time series data to quantify and map sub-annual changes in timing and pattern of rice production across our six study regions. NITA models land cover dynamics for every satellite image pixel across all available image dates and is the first all-available-images time series algorithm specifically designed to process data suffering from signal degeneration due to atmospheric effects. We will then input satellite-derived measures of area under rice production to the CSM-CERES-Rice model to estimate plot-level as well as regional annual rice yields. We will examine quantitative relationships between rice production, physiographic variables, and socioeconomic data gathered from agricultural and national censuses. A regression forest relating socioeconomic and physiographic variables to change in rice production systems will be used to identify the most significant predictors of change in each study region and across the study area. Finally, to understand how changes in labor dynamics and increasing demands for off-farm employment alter processes associated with rice production in land preparation, planting, weeding, harvesting, and the number of crops grown per year, we will conduct semi-informal interviews with key informants and survey 100 households in each rice growing region (total of 600 households). The project’s significance to NASA lies in its improved, multi-sensor approach for mapping changes in rice production systems—a change in land use rather than land cover, its use of novel cloud-resilient LCLUC monitoring approaches, and its integration of regional and local-scale perspectives of conditions that underlie observed changes to rice production systems (e.g., urbanization or industrialization). The knowledge generated by the proposed research will improve understanding of the social and ecological transformations affecting MSEA rice production and broadly advance globally-relevant theory on agriculture adaptation and change.
Matthew Hansen/ University of Maryland, College Park
A Cobra in the Forest? Quantifying the Impact of Perverse Incentives from Indonesia's Deforestation Moratorium, 2011 to 2016
16-LCLUC16-2-0024

While initially heralded as a win for conservation and sustainable forest management, the Indonesian government’s moratorium halting the issuance of new licenses for logging, palm oil, and wood-fiber plantations in primary natural forests and peatlands has not substantially slowed deforestation. In fact the highest area of primary forest clearing since 2000 occurred in 2012, the first year of the moratorium’s implementation. Compared to Brazil, whose forest policy and associated enforcement has reduced deforestation by over 70%, Indonesia has made little or no progress in slowing primary forest loss. The acceleration of forest conversion in Indonesia suggests the government’s moratorium resulted in a Cobra Effect, whereby the policy created perverse incentives for local actors and industries to acquire permits prior to the freeze and intensify forest land conversion in the aftermath. The proposed study integrates remote sensing, socio-economic analysis, and spatially explicit modeling to address the following research questions: 1) To what extent can accelerated forest clearing be attributed to perverse incentives driven by Indonesia’s moratorium, 2) What political mechanisms enabled this policy to produce these unintended effects, and 3) How do socio-economic livelihoods and well-being vary across areas with different post-moratorium outcomes?

Jessica McCarty/Michigan Technological University
Land-Cover/Land-Use Change in Southern Vietnam Through the Lenses of Conflict, Religion, and Politics, 1980s to Present
16-LCLUC16-2-0008

Decades of conflict, colonialism, growing population, and global agriculture commercialization have resulted in land-cover/land-use change (LCLUC) on multiples spatial scales throughout Southeast Asia. These changes have had a profound impact on the ethnic minorities, particularly in southern Vietnam. Vietnam has experienced significant political, economic, and environmental change since the 1950s and the end of colonialism and French Indochina. All LCLUC in Vietnam must consider the impacts of the Vietnam War and subsequent regional and internal conflicts, the establishment of the one party government under the Communist Party of Vietnam, recent market and trade liberalization, and a complex religious and sociocultural tapestry. This project focuses on the Dong Thap and An Giang Provinces of the Mekong Delta region, which are home to some of Vietnam's largest ethnic minorities, including Khmers and Cham people. They are also home to a uniquely Vietnamese form of Buddhism, Hoa Hao, which figures importantly in the modern history and landscape of the region. Hoa Hao emphasizes the connection of an individual to the land in a relationship that is intimately ethical, spiritual, and national. The advent of the satellite era enables studies of the physical changes on the environment but to fully understand the trajectory of landscape change it is necessary to incorporate the social and religious factors endemic to the region. We propose to map the changes and model the future trajectory of LCLUC by incorporating a
sociocultural framework in a spatial modeling environment for the Mekong Delta region of southern Vietnam, with humanistic and sociological studies combined with very high resolution LCLUC in the Dong Thap and An Giang provinces. This project will map all agricultural, forest, and urban LCLUC around the Tram Chim National Park in Dong Thap Province, agricultural areas in both provinces, and the two cities of Cao Lanh, Dong Thap Province and Long Xuyen, An Giang Province using Landsat and very high resolution (VHR) Digital Globe data from NASA Commercial Archive Data for years 1985 to 2018. In year 3, the VHR LCLUC mapping will extend to the entire Mekong Delta region. This project will utilize decision tree algorithms within a data science approach to mine the Landsat archive and WorldView-1, -2, and -3 data on the large computing capacity of the Advanced Data Analytics Platform (ADAPT) at NASA GSFC’s NCCS (http://www.nccs.nasa.gov/services/adapt). Using a mixed methods approach of historical documentation, in-country interviews, qualitative method of cultural vignettes, and quantitative methods of socioeconomic development pathways, we will extract historical, current, and future land cover/land use change trajectories and theories of change. Historical documents will be retrieved in-country and from the U.S. Library of Congress. In addition to socioeconomic data, this project will focus on the impact of conflict, religion, and political changes on LCLUC. These sociocultural and socioeconomic variables are important given the complex religious, ethnic, and economic tapestry of the region. These theories of change will be used to create scenarios of future LCLUC mapped to Boolean grids (Swetnam et al., 2010) and tested against a Markov chain approach. GIS models of future LCLUC will combine the remote sensing-derived products with the spatially explicit theories of change and other suitability variables within geostatistical weighted models and tested against the large region. Working with our in-country collaborator, open source web visualization and Atlas.ti KML linked file will be created to display historical, current, and predicted spatially-explicit 10-30 m resolution LCLUC of these two provinces. All data products created in the project will be shared in collaboration with the NASA SERVIR-Mekong project led by Collaborator Potapov.

Son Nghiem/Jet Propulsion Laboratory  
Land Use Status, Change and Impacts in Vietnam, Cambodia and Laos  
16-LCLUC16-2-0005

The overall science objective of this research is to quantitatively document the current status and rate of change of how land cover and land use and how trajectories of these changes are linked to population and demographic transitions for the Southeast (SE) Asian countries of Vietnam (VN), Cambodia (CB), and Laos (LS). This is directly and closely relevant to the A.02 element on Land Cover and Land Use Change (LCLUC) in SE Asia. In the scope of this proposal, given the finite resources and schedule, we will focus the research on three interconnected science questions, each with specific aspects:

Q1: It is known that rapid LCLUC has occurred over VN, CB, and LS, especially the loss of important forest regions since the turn of the 21st century, considered as ecocide [Cdr. Jah, ISBN 978-93-82652-77-9, 2014]. Now a key question is what has happened over
those deforested land as well as non-deforested land in terms of the current land use status, specifically: (1) Whether the deforested areas are still denuded and/or deforestation has expanded to other areas; (2) whether the deforested land has converted to a more natural state (e.g., grass land) or is being used for agriculture (e.g., rice fields); and (3) where reforestation exists, whether it is on previously denuded land, or the natural forests are replaced by commercial tree plantations (e.g., rubber trees).

Q2: From the quantitative delineation of the above current land cover and land use status (denoted as LCLUS henceforth), the next connected component is quantifying spatial patterns and temporal trends of LCLUC, specifically: (1) How does multi-scale spatial fragmentation in rural and natural landscapes vary within a country and across borders of different countries; (2) with recent shifts in LCLUC, what type of seasonal vegetation change has emerged over rural and natural land in a country and in different countries? And (3) what is the quantitative characterization of the recent rate of LCLUC since year 2000.

Q3: The above observations of LCLUS together with the LCLUC patterns, trends, and rate of change are coupled/integrated with population and demographic data for each country, specifically to address: (1) How population distribution (e.g., rural versus urban) is associated with LCLUS for built, agricultural, and forested lands and how the population change trajectories in relation to the observed LCLUC patterns occur differently in the tri-nations; (2) how subnational demographic changes in working-age versus dependent populations may affect or be impacted by LCLUC; and (3) how policies in different regions and in different countries may be driving or impacted by LCLUC. Here, we consider specific case studies of factors that may drive the differences in LCLUC and force different impacts within and across borders of the different countries (e.g., plantation development in VN, Economic Land Concessions policy in CB, and population resettlement policy in LS).

We expect an array of new products that accurately and quantitatively document the LCLUS and LCLUC to answer Q1, Q2, and Q3 in the interconnected physical and socioeconomic dimensions in the tri-nations. Answering Q1/Q2/Q3 involves three tasks. Task 1: Massive SAR data products for LCLUS and derivative products from fusions of multi-sourced datasets. Task 2: Products for LCLUC obtained from multiple SAR data, decadal scatterometer data, and ancillary datasets. Task 3: Products for high-resolution population distribution also broken down by age group and gender, subnational dependency ratios for each year since 2000, which significantly advance the understanding of relationship between population dynamics and LCLUC to study policy effects in VN/CB/LS. Remote sensing results will be verified with ground truth data, and population results will be verified with census data and with independent satellite-observed patterns. Deliverables will include reports, presentations, and publications.
Georgia, a former Soviet Union Republic, has experienced more political, economic and social change in the last 30 years than most countries. But the environmental implications of these extreme events remain largely unknown - the region is understudied, no national forest inventory has been completed in 15 years, and previous research in the area conducted by the proposal team is now outdated. In this proposal, we outline a plan for a comprehensive analysis of Georgia’s land change patterns and terrestrial carbon dynamics during its dramatic modern history. We will analyze the impacts of shifting policies, globalization, and economic and political turmoil by mining the rich archives of satellite observations from NASA and other space agencies, as well as national census data and local inventories. The research will be implemented in close collaboration with local collaborators. An investigation based on time series analysis of satellite observations of surface reflectance that allows us to track the pixel-level land dynamics over the last 30 years will provide a comprehensive understanding of how Georgia’s dramatic modern history has impacted land use. Based on the history of land use, we will model the associated carbon dynamics using a spatiotemporal carbon bookkeeping model. Panel regression models will explore how local and global socioeconomic change has influenced land change. These analyses, together with estimates of potentially available cropland, will inform projections of future forest and cropland dynamics under different socioeconomic and climate scenarios. Using these data, local collaboration and implementation will aim at informing policy for more sustainable land use.

We expect the proposed research to provide much needed environmental and societal information about Georgia that currently does not exist. It will result in a marked increase of Georgia’s UNFCCC reporting capabilities and for the first time, fully explore the post-Soviet land change patterns and their implications. At the heart of the proposed investigation are time series of all surface reflectance observations collected over Georgia by the Landsat and Sentinel-2 satellites at spatial resolutions of 10 to 30 meters. By continuously monitor the land surface using these observations, we can readily capture and identify the gradual processes driven by small scale activities that are so characteristic of the post-Soviet Georgian landscape. Processes that are difficult or impossible to identify using more traditional change detection approaches focused on mapping categorical losses and gains of land cover.

Governments in Southeast Asia face the formidable challenge of rising economic aspirations of their growing populations in the context of climate change in a region
where landscapes are still mainly agricultural. One potential solution involves the operation of dams built to produce electricity to also support agricultural intensification, minimize negative environmental impacts, and mitigate the effects of extreme weather events. Identifying such scenarios requires a robust understanding of past land change trajectories, accounting for physical and socioeconomic factors, within a framework that can project the potential consequences of future policy choices. The proposed project brings together state-of-the-art remote sensing techniques with appropriate approaches from climatological, hydrological, and social sciences to inform policies in the Lower Mekong River Basin (LMRB). The proposed research will be implemented in tandem with a funded NASA IDS project that will undertake hydrological modeling across the LMRB focusing on the nexus of dams, water, wetlands and society.

The overall goal of this project is to use advanced remotely sensed information to improve our understanding of the dynamic interactions among hydropower dams, distant ecosystem services, and livelihoods in rural communities with an emphasis on economic, ecological, and social tradeoffs under a range of dam operation scenarios in the LMRB. The objectives of the proposed research are:

Objective 1: Building upon existing land use/cover information, along with location, capacity, and flow regulation of hydroelectric dams in the LMRB, our team will identify detailed land use attributes critical to household land use decision making in three selected watersheds. Specific land attributes include detailed hydroperiods and thermal dynamics of lakes and wetlands and wetland structure and composition, which will serve as inputs to Objective 2.

Objective 2: Building on existing hydrological models, our team will quantify ecosystem functions and services crucial to households. These include hydroperiod and cropping feasibility/potential of distant wetlands, thermal dynamics and linkages of affected lakes with river flows, and water resources for rural communities. This information, along with field surveys and historical land uses, will be used as inputs for analysis of societal effects and responses in Objective 3.

Objective 3: Using innovative social science approaches our team will model social motivations, consequences, and adaptation strategies that result from land use changes, accounting for dynamic interactions among dams, ecosystem services, and livelihoods.

Methods. Objective 1 will be accomplished using a combination of optical and radar imagery acquired by the Landsat and Sentinel platforms in combination with in-situ data from field surveys and ancillary information from local partners. Objective 2 will employ the dense temporal- and high spatial-resolution information from optical, thermal, and SAR sensors to develop n-dimensional “feature” signatures of land attributes, using the processed data and information from Objective 1 in combination with in-situ observations. Objective 3 will rely on a variety of quantitative and qualitative social science methodologies, including household surveys, ethnographic observation, in-depth and key informant interviews, participatory mapping, and scenario evaluation.

Significance. The proposed project directly addresses the scope of the solicitation by quantifying land change trajectories in an important region in Southeast Asia, understanding the physical and social causes and impacts of these dynamics, thereby advancing land change science while providing policy relevant information on
governance options. The project will further strengthen long term collaboration with a wide range of regional partners.

Volker Radeloff/University of Wisconsin-Madison
Long-Term Land Degradation in the Caucasus
16-LCLUC16-2-0013

Land degradation, both of forest and in grasslands, is widespread in the Caucasus, and a major environmental challenge. However, land degradation is more difficult to monitor with satellite imagery than, for example, outright land use conversion or forest disturbance. One reason is that understanding land use change and land degradation trends greatly benefits from long-term land use data, but assessing land use prior to the Landsat record is challenging. However, once those technical obstacles are overcome, studying land degradation can greatly advance land use science. The reason is that land degradation patterns in peripheral areas can be greatly affected by demand for resources from the cores of economic activity, especially in countries where ample oil and gas reserves foster rapid growth of their cores, and studying degradation patterns thus allows to investigate core-periphery relationships. This is why we propose here to:

a) develop new remote sensing approaches to monitor degradation that are based on a) the integration of multiple years of Landsat data while accounting for phenology, and b) changes in endmember mixtures, phenology metrics, and the classification likelihood of a given land cover class, in order to map forest and grassland degradation across Armenia, Azerbaijan, and Georgia;

b) apply new methods to rectify 1960s and ‘70s Corona data semi-automatically with structure-from-motion software, and develop new methods to classify Corona data with image segmentation; and

c) examine the effects of economic cores, especially those related to oil and gas development, on land use in the peripheries in Armenia, Azerbaijan, and Georgia.

This proposal builds upon a LCLUC project by PI Radeloff on land use change and the effect of wars in the Caucasus that will end in February of 2018, i.e., right when the work proposed here would start. The current project, now in its third year, has been highly successful, and highlighted that while land use conversions are uncommon, land degradation is widespread. The new work proposed here will build upon our findings, and extend them further.

We will create wall-to-wall maps of land degradation, examine long-term LCLUC via the analysis of Corona imagery, and advance the understanding of core-periphery relationships and the effects of oil and gas development as drivers of land use patterns. Our project will make extensive use of NASA remote sensing assets, develop new remote sensing methods, and advance land use science via the collaboration of remote sensing specialists, economists, and experts from the Caucasus region.