NASA Science Mission Directorate
Research Opportunities in Space and Earth Sciences -2019
NNH19ZDA001N
A.2 NASA Land-Cover/Land-Use Change, Step-2

This synopsis is for the Land-Cover and Land-Use Change (LCLUC) part of the NASA Research Announcement (NRA) ROSES-2019 NNH19ZDA001N-LCLUC. This NRA offered opportunities for research by early career scientists 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 proposals and selected 9 proposals for a total funding of $4 Million for three years. More details are available at: http://nspires.nasaprs.com.

Nicholas Cuba/Clark University
Evaluating the Drivers of International Migration from the Northern Triangle of Central America and Its Implications for Land Systems in the Region
19-LCLUC19_2-0009

Flows of population from the Northern Triangle (NT) countries of Central America (Guatemala, El Salvador, and Honduras) to the USA have increased substantially in the past decade, precipitating a humanitarian, social, economic and political crisis in the NT, Mexico, and USA. As in many parts of the world, traditional and widespread livelihood strategies based on agriculture have become less viable in NT countries. Threats to traditional livelihood strategies are many, including extreme weather events, or climate change, changes in access to land and water resources due to large-scale land purchases, pollution, upstream mining activities, or hydro-power projects. Information about land systems derived from remotely sensed data, considered in conjunction with administrative and survey information, can help to better understand the drivers of international immigration as well as the counter-impacts to land systems after outflows of population and in-flows of capital in the form of remittances.

This project will first investigate the policy, socioeconomic, and ecological drivers of migration from the NT to the USA, across time, space, and spatial scale using coarse resolution remotely sensed data (e.g. MODIS, SMOS, TRMM) alongside political, legal, and other data. It will then attempt to categorize the changes to land systems in locations that experienced significant out-migration, allowing for variation in space and time linked to different sets of drivers, using remotely sensed data from platforms such as Landsat and Sentinel alongside new collections of survey and interview data. The most significant product of this project will be sub-national scale data on sources of migration in NT. It will also provide more detailed understanding of the relative strength of various drivers in

explaining migration over time and space, as well as developing new methods to detect the signature and spatial footprint associated with the LCLUC induced by each.

Meha Jain/University of Michigan, Ann Arbor
Policy, Market, and Climate Change Impacts on Maize Production in Mexico
19-LCLUC19_2-0018

Climate change, including warming temperatures, changing rainfall patterns, and more extreme events, is threatening agricultural production across the globe. This is particularly true for grain crops across the tropics, which have been shown to be negatively impacted by changes in climate. While a significant body of research has focused on how farmers may adapt to climate change, less work has acknowledged that climate is only one factor that farmers respond to. Changing policies and market fluctuations, among other factors, likely also play a strong role in explaining agricultural transitions. Yet, it is unclear whether agricultural transitions in response to non-climatic factors lead to maladaptation to longer-term changes in climate. This proposal examines agricultural transitions, their drivers, and potential climate change impacts across Mexico for the nation's main grain crop, maize. We focus on maize because it is one of the crops projected to be most negatively impacted by climate change, and we focus on Mexico because it is one of the nations that will face some of the greatest negative impacts of climate change, it is the seventh largest producer of maize worldwide, and maize is critical for the nation's food security. Previous studies have suggested that maize production has greatly transitioned across the country over the last several decades, with abandonment of production in some parts of the country and concentration in others. Simultaneously, farmers who continue to grow maize have altered their cropping strategies by expanding irrigation, adjusting planting time, altering tillage practices, and/or changing crop variety. To date it remains unclear why such transitions have occurred, and how climate change will impact these new maize landscapes in the future.

In this proposed project, we will use a combination of remote sensing, census data, and household surveys to understand transitions in Mexican maize production over the last 20 years. Specifically, we will (1) quantify maize transitions by mapping crop and landcover type across our study region from 2000 to the present. We will also examine if farmers have altered their maize planting strategies, by mapping maize sowing date, crop duration (an indicator of maize variety), tillage practices, and evapotranspiration (an indicator of irrigation use). We will (2) link these data products with climate, policy, and price data and use econometric regression methods to assess the causes of maize transitions over the last 20 years. Finally, we will (3) use crop model simulations and climate projections to assess whether these transitions are adaptive to future changes in climate.

Zhenong Jin/University of Minnesota

Evaluating Land Use Change and Livelihood Responses to Large Investments for High-Value Agriculture: Managing Risks in the Era of the Green Morocco Plan
19-LCLUC19_2-0005

Morocco is a drought-prone, climate-constrained country that has made significant investments in agriculture with the goal of enhancing the adoption of higher-value cropping systems for economic development. The Moroccan government currently offers a multi-peril insurance program for cereal crops but has not yet developed a product that could help absorb the risks impeding the adoption of such higher value, but riskier, cropping systems. Within this context, two early-career scientists with specialties in spatial and economic analysis, respectively, will lead a project to evaluate the possibility of using remotely-sensed indicators to effectively shield farmers from risks of adopting higher value crops via their use in an indexed insurance and/or drought relief program.

Achieving this overarching objective will involve three main tasks:
1. Detecting the extent of olive cropping systems and evaluating the degree of conversion from cereal crops to olives.
2. Evaluating socioeconomic conditions and risk management strategies in two study areas of Morocco. This step will first involve expert elicitation to ground the analysis in the realities and perceived risks in the supply chain, and will be followed by a series of stratified surveys among agricultural producers in two olive producing regions of Morocco whose agro-climatic conditions vary.
3. Integrating data on socioeconomic conditions with remotely sensed environmental changes to evaluate the correspondence of a remotely-sensed trigger of farmer losses due to adverse conditions such as drought.

Perennial crops are emblematic of the possibility to adopt higher value cropping systems that are otherwise too risky for many farmers to take on without insurance. Even if they are drought-resistant, perennials are much more costly than many annual crops and involve a long period before they have economically-harvestable fruits. Even once producing, weather fluctuation remains a risk: recent reports suggest Moroccan olive farmers perceived yield declines on the order of 36-64% less than expected in recent dry years. Drought can therefore amplify risk exposure for farmers when the farmers face higher absolute losses relative to their potential. Despite the importance of perennials, most studies evaluating indexed products for agriculture focus on annual cropping systems or broad indicators of drought stress rather than the particulars of high value, long-term investments.

Three senior collaborators from UC Davis, UMN, and the National School of Agriculture in Meknes, Morocco, with significant on-the-ground experience and technical expertise in agricultural economics and agronomy will advise the project to ensure alignment with the realities of Morocco’s environment and policy context.

Our interdisciplinary approach to integrating social and environmental processes as well as disaggregating impacts across space aligns with the LCLUC research priorities to understand the sustainability, vulnerability, and resilience of human land use.

Furthermore, our results will be made public to help advance land change science as well as inform land use policy in Morocco, the Mediterranean Regional Information Network (MedRIN), more broadly -- areas that have been evaluated as highly vulnerable to future climate change.

Carlos Munoz Brenes/Conservation International Foundation
Impacts of Global Markets and National Policies on Forest Carbon Trajectories and Social Outcomes in the Guiana Shield Ecoregion
19-LCLUC19_2-0030

Forests in countries that have had historically high forest cover and low deforestation rates are now being lost due to globally traded commodities and related market forces. The deforestation of these old-growth forests contributes substantial carbon emissions to the atmosphere, and tropical deforestation is a key driver of climate change. In recognition of the need to balance deforestation-driven economic development and the future resilience of their nation-states from a changing climate, countries have begun to adopt Natural Climate Solutions (e.g., REDD+) to protect and enhance their forest carbon stocks. There is, however, uncertainty as to how these policies will impact land-cover/land-use change and deliver co-benefits to indigenous and local communities. One source of uncertainty is a limited ability to effectively measure forest carbon dynamics associated with forest degradation and regeneration in the tropics. An additional barrier to forecasting impacts of Natural Climate Solutions (NCS) is a lack of rigorous impact evaluation of how NCS will influence human behavior and forest use in both the target areas as well as other, distant locations (i.e., diffusion and spillover effects).

Our proposal aims to improve our understanding of how market forces and NCS interventions impact forest carbon dynamics in the Guiana Shield ecoregion. Specifically, we propose to (1) Advance methods to map forest degradation, and forest regrowth, and the carbon dynamics associated with these processes through data fusion of optical, radar and lidar satellite imagery; (2) Quantify the impact of NCS interventions on forest carbon trajectories and socioeconomic outcomes using counterfactual impact evaluation methods; and (3) Quantify the rate of diffusion of NCS interventions and their spillover impacts within and across countries. The geographical focus of this research are the countries that lie entirely within the Guiana Shield ecoregion, which includes Guyana, Suriname, and French Guiana. Together, all three countries boast more than 80% forest cover, storing large amounts of carbon stocks. Their continued intact state is considered vital for the resilience of the adjacent Amazonian forests and global climate mitigation.

Our proposed research will pioneer the development of state-space models that connects satellite time series data across different sensors to a network of forest inventory plots to quantify forest carbon dynamics across time and space. We will leverage these satellite-derived data products on forest carbon trajectories for our assessment of NCS interventions. We will then link these spatial forest carbon outcomes to the welfare of

local people to quantify their linkages and feedbacks in the context of a coupled human-natural system.

Our interdisciplinary research team that comprises three early-career scientists is well-positioned to accomplish these project goals based on our combined expertise in remote sensing, quantitative methods, and social sciences. We have all conducted research to assess forest cover change, carbon dynamics, and social outcomes within the Guiana Shield ecoregion and Latin America. Together we have demonstrated strong collaborative research skills, including working closely with regional collaborators across scientific disciplines. We will leverage our expertise and research network to catalyze a new body of cutting-edge interdisciplinary social science research to guide global investments in NCS. The knowledge we generate will be pivotal to guide policymakers and practitioners in designing effective and scalable NCS interventions.

Christoph Nolte/Boston University
Comparing the Effectiveness of Conservation Strategies in the Colombian Andes Biodiversity Hotspot
19-LCLUC19_2-0007

This project will combine remote sensing and social science methods to measure and predict the relative effectiveness of conservation instruments in protecting threatened forest habitat in the Colombian Andes. This ecoregion stands unequaled among global biodiversity hotspots in terms of species richness and endemism, but is also one of the most severely threatened by habitat loss, climate change, and post-conflict development. In response, Colombia has implemented a range of conservation policies, including protected areas (PAs), land acquisitions for conservation (LACs), and payments for environmental services (PES), and now faces critical policy decisions about the importance given to each in a future policy mix to conserve Andean forests. These choices are currently undermined by limited evidence on the effectiveness of each instrument in the Colombian Andes. Remote sensing-based impact assessments can help narrow this gap, but applications in the tropical Andes have long been inhibited by cloud cover and topography. We will address this problem by combining continuous change detection and classification and a fusion of Landsat and Sentinel 1/2 data to develop the first temporally consistent map of 25-year forest change in the Colombian Andes that discriminates between forest types of different habitat value: mature forest, disturbed forest, secondary forests, dry forests, and forest plantations. We will quantify the impacts and cost-effectiveness of PAs, LACs, and PES by combining the forest change layers with nationwide parcel data and a unique dataset of thousands of publicly-financed conservation instruments. Using counterfactual inferential methods, novel machine learning methods, and field research, we will examine and predict how causal effects of each instrument vary across landscapes as a function of ecological, demographic, and institutional variables. Collaboration with Colombia's leading research institutes in land cover change mapping (IDEAM) and biodiversity research (IAVH, Universidad Javeriana) will ensure responsiveness to national priorities, exchange of expertise, and timely dissemination of results. This research combines the expertise of three early-career

researchers to support Colombia's environmental institutions in the design of optimal and equitable policy strategies that conserve forest habitat under budget constraints. By producing the first evidence on conservation effects of LACs in the tropics, the project also makes a novel, unique contribution to the global evidence base on the effectiveness of conservation instruments.

Xiaopeng Song/Texas Tech University, Lubbock
Soybean Expansion in South America: Quantifying Historical Land-Use Change, Modeling Socioeconomic Drivers and Projecting Future Trajectories
19-LCLUC19_2-0029

Finding practical solutions to balance food production and environmental conservation is a grand challenge the world faces today. Extensive soybean expansion in South America, at the expense of natural vegetation, pasture and other cropland, is at the forefront of this challenge. We propose to integrate satellite observations, economic models and an agricultural ecosystem model to quantify historical patterns of soybean expansion across South America, analyze the underlying socioeconomic drivers and project future trends. We will use Landsat, MODIS and Sentinel 2 data to characterize soybean cover and map soybean expansion from 1985 to present with continentally distributed ground data for training and validation. To understand individual landowners' land-use decision-making, we will employ a spatially explicit econometric Land-Use Change (eLUC) model and use the satellite-derived soybean expansion maps and other remote sensing-based land-use data to empirically calibrate the model. We will extrapolate the resulting mechanistic understanding to project future change. In addition to the microeconomic factors captured by eLUC, projection of future trajectories must also factor in changes in macroeconomic conditions such as international trade. This requires establishing tele-connections between downstream soybean consumption and upstream soybean production. We will extend the Multi-Regional Input-Output (MRIO) analysis to track the land resources embodied in the international soybean supply chain. This land-use extended MRIO analysis can effectively translate the projected soybean consumption in one country (e.g. China) to demand for land resources in the production country (e.g. Brazil), and will subsequently be used by eLUC for spatial allocation. Projecting future trajectories must also take into account climate change and agrotechnological change, which can affect cropland suitability and yield potential, and consequently alter the costs and benefits of land-use conversion. We will assess these biophysical and technological impacts using the Agro-Ecological Zone (AEZ) model. Thus, the eLUC model, MRIO analysis and the AEZ model are synthesized in a coherent modeling framework for future scenario analysis. By integrating these different observations and models, the main goal of our proposal is to improve our scientific understanding of land-cover and land-use change in South America. The proposed 30 m resolution annual long-term soybean expansion map will serve as an important baseline for monitoring and verification of the effectiveness of deforestation-free supply chain initiatives. The spatially explicit projections of future soybean expansion will provide critical scientific insights to support various stakeholders,

including individual farmers, private companies, governments and non-governmental organizations.

Aaron Sparks/University of Idaho, Moscow
Understanding the Socioeconomic Drivers of Agricultural Land Abandonment and Associated Fire Risk in Greece
19-LCLUC19_2-0022

In recent decades, fire-prone areas in the Mediterranean region have experienced significant agricultural land abandonment, which can increase fire risk due to fuel accumulation and increased fuel continuity. In the case of Greece, which is increasingly affected by large fires, there is no quantitative assessment of the increased fire risk due to abandoned lands, and little understanding of the drivers of land abandonment. The overarching objective of the proposed research is to address these knowledge gaps and inform policy, land planning, and fire management efforts by integrating state-of-the-art remote sensing mapping methodology with socioeconomic empirical analyses for three regions in southern Greece from 1990 to 2019. Specifically, this project will: 1) map abandoned agricultural land across the study area using Landsat time series data, 2) quantify changes in fire risk as a function of time-since-abandonment, using field-derived vegetation cover and structure measurements as input for wildfire modeling, 3) develop spatially explicit multivariate statistical models using socioeconomic, sociocultural, and geophysical variables to identify drivers of agricultural land abandonment for several time periods corresponding to major agriculture policy changes and economic crises, and 4) identify policies and incentives most likely to encourage land management practices that reduce fire risk using a discrete choice experimental survey. This project will make extensive use of NASA remote sensing assets (Landsat Collection 1 data and high spatial resolution data available through National Geospatial Intelligence Agency Commercial Archive Data). Ultimately, this project will contribute new knowledge regarding underlying socioeconomic drivers of agricultural land abandonment and the resulting consequences of this land use change, such as changes in fire risk. The proposed research is directly responsive to the current solicitation goals and has high societal relevance given the project results will inform policy makers and land managers on agriculture and land management policy solutions that reduce fire risk. This proposed project also makes substantial contributions to: 1) NASA LCLUC program goals of understanding human dimensions of LCLUC and impacts of LCLUC on the management of natural resources, and 2) international programs, such as the GOFC-GOLD Mediterranean network (MedRIN), through the direct participation of several regional collaborators in the proposed research.

Xin Xi/Michigan Technological University
Mapping and Modeling Desertification and Its Impact on Aeolian Dust and Human Health in Central Asia

19-LCLUC19_2-0002

This proposal is aimed at a systematic assessment of desertification and its impact on aeolian dust, air quality, and human health in Central Asia during the past twenty years (2000-2019). By leveraging the PI's past and ongoing research on Asian drylands and dust, this proposal seeks to address several important knowledge gaps in the mechanism, relationship, and impact of desertification occurring in the dryland ecosystems of Central Asia. The motivation behind this study is that desertification poses an imminent threat to dryland ecosystems and human well-being, and combating desertification, which comes with climate mitigation co-benefits, depends on accurate knowledge of the spatial pattern, temporal trajectory, driving processes, and societal impacts of desertification. In Central Asia, human-driven desertification processes have led to severe loss of land productivity and degradation of air quality. So far, there has been limited knowledge of the health impact and associated external cost to society of desertification-induced air pollution, despite it being a long-standing problem in the area. To guide actions of combating desertification, this study is designed to address the following science questions: (1) What is the current extent of desertification and what are the major drivers? (2) To what extent does desertification contribute to the region's aeolian dust and air pollution? (3) How do climate variations and desertification affect the long-term dust activity? (4) What are the health and socioeconomic impacts of desertification-induced air pollution?

To answer these questions, an integrated desertification-pollution-impact pathway approach will be developed by combining remote sensing, statistical and physical modeling, environmental justice analysis, and economic valuation of air pollution. The specific objectives of this study are: (1) Map the spatiotemporal dynamics of desertification using multiple remote sensing-based indicators, and determine the roles of climate and socioeconomic drivers; (2) Quantify the contribution of desertification to aeolian dust and particulate matter pollution using a process-based model system; (3) Synthesize surface observations, remote sensing, and global model reanalysis to characterize the spatiotemporal variability of aeolian dust; and (4) Assess the environmental justice and health impact of human exposure to outdoor particulate matter pollution. The primary outcome of this project will consist of an updated assessment of desertification in Central Asia in accordance with the reporting guidelines of Sustainable Development Goals on Land Degradation Neutrality, process-level analysis of the relationship between desertification, aeolian dust, and air pollution, and assessment of the health and socioeconomic impact of air pollution in Central Asia. By integrating physical, social and economic sciences in the desertification assessment, this proposal responds to the LCLUC program goal of "applying NASA remote sensing assets, as part of an interdisciplinary approach, to improve understanding of human interactions with the environment and the interconnection between terrestrial ecosystems and sustainability, vulnerability and resilience of human land use and land cover change". This work also contributes to the NASA Earth Science Division program goals of "Advance the understanding of changes in the Earth's radiation balance, air quality, and the ozone layer that result from changes in atmospheric composition" and "Further the use of Earth system science research to inform decisions and provide benefits to society".