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-2011 NNH11ZDA001N-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. This particular solicitation was directed at early career scientists, with their Ph.D. degree not earlier than 2005 and aimed to stimulate more interdisciplinary research proposals that are commonly funded by the NASA New Investigator Program (NIP). All the topics on LCLUC were welcome. However, of special interest for this solicitation was the topic of differences in land cover and land use across political borders, explaining and attributing these differences to their primary causes. Social science component in proposals was considered a requirement for a proposal to be selected. NASA received 26 Step-2 proposals and selected 10 proposals for funding with the total $3M for three years. More details are available at: http://nspires.nasaprs.com.

Inbal Becker-Reshef/University of Maryland
Food, Price and Conflict: Earth Observations-Based Agricultural Production Forecasting to Assess Potential Impacts on Grain Markets and Civil Unrest

A primary focus of agricultural land use is on crop production for trading on commodity markets. Croplands account for approximately 11 percent of global land cover, the majority used for cereal production, with wheat as a primary crop. Satellite observations have long been proposed as an effective means to monitor agricultural lands and their production. Yet despite several national and international agricultural monitoring systems, there is still a lack of reliable and timely information on grain commodities. The need for such information is internationally recognized and is highlighted in several recent reports, in particular in the June 2011 G20 Action Plan on Food Price Volatility and Agriculture. The recent volatility in global grain markets has brought the issue of food security to the forefront of government agendas. Between 2006 and 2011 grain prices soared twice leading to civil unrest with food riots in over 40 countries, and according to FAO estimates, pushing an additional 140 people million below the poverty line. Clearly improving our monitoring of fluctuations in crop production and their implications in a socio-economic context is fundamental for governing and managing world food supplies and could potentially play a critical role in stabilizing grain markets, developing effective agricultural policies, mobilizing aid in response to impending regional food shortages, and contribute to averting social instability.
Recent improvements in remotely-sensed datasets provide an opportunity to enhance methods for global agriculture monitoring. We propose an exploratory project to examine the feasibility of generating timely and reliable satellite-based information on wheat production at national scales for the primary wheat export countries; assess the potential value of such information for reducing grain market volatility and thereby potentially reducing the associated food riots and civil unrest in vulnerable nations. We will focus specifically on wheat production estimation at national scales for a small number of countries that are responsible for the majority of global wheat exports.

This project has assembled an integrated team of remote sensing and social scientists with national and international operationally oriented partners focused on agricultural monitoring. We will build on approaches from the fields of agricultural remote sensing, agricultural economics, data mining and decision science, and public policy and conflict studies.

The project will be comprised of three elements: i) development of a robust earth observations (EO) based approach to timely wheat production forecasting at the national scale; ii) a simulation and empirically based assessment of potential price sensitivity to forecast errors and their impacts on market stability; iii) examination of the relationship between the availability and quality of agricultural production information, price fluctuations and civil unrest.

This study will utilize a range of earth observations data at multiple resolutions; time series of wheat production forecasts and end of season statistics on yield, area, consumption, imports, exports and grain stocks; data on grain price, and grain trade flows; and civil unrest data from zones of instability, historic violence trends, and primary socioeconomic and political violence indicators.

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**Kelly Cobourn/Boise State University**

**Water Institutions and Agricultural Land-Use Change Across the Western U.S.**

Ongoing climate change is expected to alter agricultural productivity, water demand, and water available for irrigation worldwide, with serious consequences for semi-arid producing regions. In general, these areas are expected to become hotter and drier, with more variable rainfall and reduced rates of surface water runoff and groundwater recharge. Under these circumstances, institutions governing the allocation of water across users will become increasingly important. It is critical to develop a better understanding of how water allocation institutions facilitate or impede climate change adaptation by agricultural producers. Doing so will aid in developing effective and efficient regional, national, and international policies that address the multifaceted impacts of changing climatic conditions.

The key contribution of the proposed research is to examine how water rights institutions in the U.S. Intermountain West influence agricultural decision-making. The supply of water in the region, which is driven by uncertain weather and climate factors, drives agricultural productivity, the value of agricultural land, and producers’ land-use decisions. Understanding of the economic impacts of climate change on irrigated agriculture has proven elusive to date because water allocation institutions complicate the
relationship between climate-driven changes in water availability and producer decision-making. Specifically, climate and weather govern the amount and timing of water inflows into a region, but the amount of water available to a producer also depends on the presence of water storage infrastructure and the structure of water rights institutions. Water rights, which govern how water is distributed across users, are complex and exhibit substantial spatiotemporal heterogeneity, making it difficult to evaluate how institutions affect producer behavior.

This project proposes to examine the impacts of variation in water availability and the structure of water allocation institutions on agricultural land-use decisions in the Snake River Basin. Our empirical analysis exploits heterogeneity in water rights institutions across state borders within the study region to identify the impact of institutional characteristics on agricultural land-use decisions. To conduct the analysis, we will use remote sensing data to identify irrigated and rainfed agricultural lands, integrating that data into an econometric model explaining producer behavior. We will use an established method of combining complementary Landsat and MODIS datasets to generate a panel of land-use observations long enough to capture changes in climate and at a spatial resolution consistent with the individual decision-maker. When combined with existing data on physical and economic variables that influence land-use decisions, the empirical dataset will constitute a unique and powerful combination of socioeconomic and remote sensing data.

The proposed project contributes significantly to the body of knowledge concerning the processes driving land-use change. In light of the increasing amount of attention devoted to the effects of climate change, and to the potential negative outcomes associated with land-use change, the results of the proposed study will be highly relevant to policymakers. Broadly, the research has implications for food security, economic livelihoods, and the environment, all of which are concerns of increasing importance given ongoing population growth and pressure on Earth’s natural resources. The proposed project thus supports NASA’s Strategic Goals by [advancing] Earth system science to meet the challenges of climate and environmental change and underscores the value of NASA products for use in social science research and as a tool to support informed policy decisions.

Gillian Galford/Woods Hole Research Center
Environmental and Socioeconomic Outcomes of the New African Green Revolution

This project combines data and techniques from social and natural sciences to study land-cover and land-use change. Malawi is one of the poorest countries in the world but has rapidly increased food security through implementation of the Farm Inputs Subsidy Program (FISP) starting in 2005/06. To date, very little research has analyzed variability of land cover and land use change (LCLUC) with changes in yields within the country. Lead by two New Investigators, Galford and Michelson, this project will analyze LCLUC, crop yields and their underlying drivers and correlates since FISP’s implementation. Some of these correlates may have fixed effects, such as the role of
slope in determining crop yields. Others may vary over time, including population density, soil fertility levels, area devoted to crops or proxy indicators such as distance to roads. Malawi, with the support of the World Bank and technical assistance of the IFPRI, conducted national household surveys in 1998/99, 2004/05 and 2010/11 a time period that aligns coincidentally and conveniently with the implementation of FISP as well as MODIS observations from 2000-present. This work pushes MODIS to the edge, demonstrating how a coarse sensor can be used to study small-scale farm production and LCLUC with validation using high-resolution imagery. Smallholder farms supply roughly 80% of Malawi’s staple food crop, maize, over a relatively short growing season (~5 months). Here, we combine remotely sensed data, GIS data and household survey data to determine the contributions of these correlates and FISP to LCLUC, crop yields and poverty outcomes. This is a novel approach that will advance the fields of remote sensing, LCLUC and economic analysis of food security and poverty.

Kathryn Grace/University of Utah

Examining the Links Between Agriculture and Human Health in a Context of Climate Change: A Case Study of Three West African Countries - Niger, Burkina Faso and Mali (University of Utah)

Central Objectives
As the global climate changes and the populations of Niger, Mali and Burkina-Faso (abbreviated to NMB-F) grow, these countries face daunting challenges to ensuring adequate local food availability. Landlocked, and with a large portion of their total land area located securely within the boundaries of the Sahara desert, this cluster of countries already has limited arable land and faces losing farmland as the climate changes. In this research we quantify the relationships between food availability and food insecurity through the use of several NASA products -- the Moderate Resolution Imaging Spectroradiometer (MODIS) landcover product, Normalized Difference Vegetation Index (NDVI), the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) and a measure of soil moisture from an existing Land Data Assimilation System (LDAS) project - and population/health survey data with a particular focus on household food insecurity. Similarities in climatic and topographic gradients in this tri-country region indicate the land cover land use change (LCLUC) differences reflect social and political forces. These differences lead to variations in human health outcomes reflected at the household level. We propose a three-stage analysis plan, building on the natural experiment setting provided by these countries that share many climate and population characteristics but differ on agricultural production or land use strategies. The three stages are as follows:
1) community-level estimates, based on MODIS data, of locally available food
2) country-specific models examining the relationship between food insecurity and locally available food, and 3) country-specific human-health impacts of climate change as outcomes of changes in expected agricultural output.

Methods
To accomplish our research objectives we have developed a series of methods. In Stage 1 we rely on NASA’s MODIS landcover product to identify broad areas with agricultural potential. We will then construct a 250 meter grid to identify the cultivated areas at a fine scale. The fine scaled interpretations allow for the estimation of cultivated area at the community-level. We will then build a cultivated area prediction model for locations not covered by the very high resolution data using -- rainfall, slope and elevation (DEM). We will also include both NDVI and a measure of soil moisture from an ongoing NASA-funded LDAS project. Both NDVI and the LDAS-based measure of soil moisture provide information at a fine scale supporting our goal of producing local estimates of cropping as a direct measure of the amount of locally available food. This strategy will be applied separately to each of the three countries to produce country-specific estimates of community-level local food availability.

In Stage 2 we incorporate results from Stage 1 into regression models to examine food availability and the relationship between several health outcomes related to food insecurity. The regression models are constructed around the hierarchy of the data - households are nested within communities. In this way we can examine the impact of community-level food availability on household malnutrition. In Stage 3 we incorporate climate data into the models created in the previous stage and estimate small-scale food availability given different climate scenarios.

Significance
One of the primary drivers of individual-level malnutrition and household-level food insecurity is food availability. In this project we will construct estimates of local food availability using remotely sensed imagery. We will then examine the relationship between micro-level malnutrition outcomes and food availability, ultimately expanding scientific understanding of household food insecurity. The research results will be relevant to the scientific community interested in micro-level food insecurity in a context of climate change.

Jason Julian/University of Oklahoma

Land Management Impacts on Water Quality in New Zealand Across Political Boundaries

The most immediate and widespread driver of land cover change is land management, such as forest clearing for livestock farming or grassland conversion to plantation forests for timber production. These land management decisions are heavily influenced by regional policies, and thus analyses of the socioeconomic drivers for land cover change need to occur at these regional levels. Evaluation of environmental impacts of land management is difficult because regional political boundaries rarely coincide with environmental boundaries such as catchments (aka watersheds). One nation has recognized this disconnect between political boundaries and environmental sustainability. In 1991, New Zealand (NZ) adopted the Resource Management Act, which among other policies related to sustainable development, redefined the political boundaries of the nation to coincide with catchment boundaries so that each Regional Council would be solely responsible for the health of their ecosystems, particularly water quality of their rivers, lakes, and coastal environments. The goal of this proposal is to use NZ as a case
study where land use change analyses at fine spatial and temporal resolutions are used to understand how Regional land management impacts water quality.

In order to assess the effectiveness of regional policies in improving or preserving water quality, we will create high-resolution (8-day, 30 meter) land use and water quality time series and then overlay them onto socioeconomic timelines for the period 1990 - 2014. The key products of this research will be: (1) a fused 30m land use time series for all of NZ and one of the most comprehensive spatiotemporal analyses of strip grazing and plantation forestry land uses; (2) empirical models, based on hundreds of catchments with 24 years of monthly data, that quantify relationships between land use, weather, and water quality (turbidity, dissolved organic matter, total and dissolved forms of nitrogen and phosphorous, and E. coli); and (3) an assessment of the effectiveness of catchment-scale land management in terms of water quality. Because NZ is the first nation to redefine its political boundaries to coincide with environmental boundaries (i.e. catchments), this project will set a precedent for future considerations of catchment-based governance.

The objectives and expected products of this proposal contribute to the mission of the NASA LCLUC Program by using interdisciplinary science (Remote Sensing, Geomorphology, Hydrology, Socioeconomics) to address the management of a natural resource (water quality) with multidimensional societal relevance (water treatment, recreation, safety, tourism, ecosystem health), starting with agricultural land use change. The proposed research will investigate Vulnerability of agricultural land uses to climate changes, particularly the Impact of severe droughts in NZ from intensifying ENSO phenomena (e.g. 1998 and 2008) on livestock grazing pressures; and how Regional governments are Adapting to these interdependent climate and land use changes. Indeed, NZ Regional Council policy statements are currently being modified to address predicted regional climate changes. The other agricultural land use that will be assessed with fine spatial and temporal resolution – plantation forestry – will also be of broad interest to NASA’s Carbon Cycle and Ecosystems focus research area, as well as GOFC-GOLD and GLP. The project’s focus on differences in land use across political Regions within NZ, along with the goal of explaining these differences using socio-political-economic factors and feedbacks, is directly related to this ROSES solicitation. An essential element of this international project is collaboration with regional scientists from NIWA, LCR, and the Regional Councils; and the use of local socioeconomic and geophysical data, some of which is proprietary to these institutions. Remote sensing and data fusion are essential components of this proposal.

Stephen Leisz/Colorado State University
Increased Accessibility, Landscape Changes, Rural Transformations, and Urbanization: Impacts of the East-West Economic Corridor from Da Nang, Vietnam, to Khon Kaen, Thailand

The proposed project will investigate the impact that the East-West Economic Corridor from Da Nang, Vietnam, to Khon Kaen, Thailand, is having on land-use and land-cover,
and urban growth patterns in three different, yet contiguous, countries with different political histories and current policies. In order to do this the project will work at the intersection of physical and social science and make use of a cross-section of remotely sensed data and social science data. Remote sensing data for three time periods will be collected. In order to create a baseline of land-cover for the EWEC and to understand the land-use associated with this baseline land-cover, Landsat and SPOT data from 1982 through 1990 (the first time period) and 1990 to 2000 (the second time period) will be collected and analyzed. For the third time period, from 2000 to 2011, 16 day 250 m MODIS VI products over yearly time steps will be acquired and hypertemporal analysis of the EWEC corridor will be done. This analysis will use hypertemporal characteristics as identifiers of where change is taking. Post-2000 Landsat and SPOT data will be used to investigate identified trends on a year-to-year basis. High resolution data (air photos and high resolution satellite imagery) will be used for ground truthing of hard to get to areas. Field-work will be done to ground truth satellite imagery collected. Recall data will be used to validate the baseline land-cover and land-use classifications done for the first two time periods. Time series population census data and agricultural census data for the EWEC area that correspond to the remote sensing data will be obtained. This data will be integrated with other available data (economic data, data regarding country specific and regional policies, institutional data, cultural data, livelihood systems data, etc.) within a geographic information system (GIS). As part of the ground-truthing, interviews will be carried out in the EWEC in each country to investigate the role that the EWEC is playing in the population’s livelihood systems and movements within the corridor. Data available from censuses and surveys will be used to score communities on characteristics such as population of smallholder cultivators, increase in non-agricultural activities, population mobility, mixture of land-uses, and female labor participation. The LCLUC, rural, urban, and peri-urban nature of the EWEC within each of the countries will be investigated by analyzing in tandem the remote sensing and social science data collected. The census and LCLUC data will be integrated to develop an index of urbanicity of the transportation corridor and to understand how the urbanicity of the corridor has changed from the baseline period to the present day and what roles the differing government policies have on these changes and on land cover/land use changes. Connections between LCLUC rural-urban transitions, and urban growth will be investigated using GIS and spatial statistics tools and agent-based modeling.

Tatiana Loboda/University of Maryland
Social Drivers of Land Cover Change Around African Transboundary Peace Parks

Africa’s transboundary Peace Parks aim to restore ecosystem connectivity and promote economic development of local host communities. However, more than 10 years since the establishment of the first Peace Park it remains unclear if they are successful in achieving either conservation or development goals. Despite the predictions arising from the economic theory, previous research suggests there is substantial conflict between rural residents and the agendas of governments and/or international conservation organizations associated with the environmental conservation. The proposed study takes a mixed method approach to study the linkages between land cover and land use (LCLU)
change and perceptions of socio-economic wellbeing and attitudes towards conservation areas. We leverage existing data on the Mozambican portion of the Great Limpopo Transfrontier Park (GLTP), building upon previous NSF-funded research project of Co-I Silva (an early-career social scientist) where she conducted a socio-economic survey and in-depth interviews with 375 households located in or near the southwestern boundary of the GLTP, in order to develop coupled socio-economic and remote sensing techniques that can be applied to assess human wellbeing, develop understanding of causal drivers of land use and management, and enhance predictions of human land use behaviors in conservation areas of Africa and potentially around the world.

While satellite imagery has been extensively used in support of monitoring protected areas worldwide, the traditional satellite-based observations of land cover from moderate (10 - 100 m) and coarse (≤ 100 m) resolution sensors are sub-optimal for monitoring and assessment of low-density rural development in Africa. These communities are mostly small settlements characterized by low contrast between natural soil and vegetation background and low-density rural dwellings (mainly made from local natural materials). This study will capitalize on the broader availability of multi-temporal Very High Resolution (VHR) (< 5m) satellite imagery to monitor fine-scale LCLU change processes that occur at the household and village levels which can be directly linked to household socio-economic surveys. The project will thus considerably enhance our understanding of the dynamics driving land use decisions of people living in or near protected, high-biodiversity environments and will provide documented approaches for enhancing the social value of NASA technology projects for rural people living near parks and protected areas.

The proposed project explicitly addresses all major priorities identified by the LCLUC program. It investigates the direct forcing of socio-economic parameters on land cover dynamics in Sub-Saharan Africa. This study (1) investigates how well information from self-reported natural resource use compares with satellite observations; (2) assesses the effects of global governance on land use decisions by comparing land use patterns of communities located within and outside of Peace Park management jurisdiction; (3) explicitly investigates how land use patterns are influenced by the perceptions and experiences of local residents; and (4) uses an iterative, mixed methodology to explore the impacts of Peace Parks at the regional and local scales. We will combine use of remote sensing from VHR and Landsat TM satellite instruments and socio-economic surveys to examine the impact of individual, household, community-level perceptions and experiences with conservation in conjunction with state- and international-level conservation policies on the resultant pattern of LCLU dynamics and their implications for biodiversity in the GLTP. Finally, the proposed work will contribute to the development of methods for quantifying LCLU change in low-density rural dwellings from VHR image analysis and will explore scaling the relevant metrics to applications for moderate resolution imagery.
This project will focus on quantifying the relationship of land-cover/land-use (LCLU) change in the former Soviet Union, specifically Belarus, European Russia, and Lithuania, from agricultural abandonment and afforestation and the relationship of this LCLU change to anthropogenic fires. This region of Eastern Europe is a well-documented area of LCLU change and also of consistent prescribed burning and recent extreme fire events. By focusing on this study area, this project aims to answer the NASA LCLUC program's goal of completing an interdisciplinary study of LCLU change and its relation to fire activity as a potential driver. This project will quantify changes in agricultural land use change in a large area of Eastern Europe as well as analyze the drivers of anthropogenic fire in an area where climatic changes and human-environmental impacts are important contributors to extreme fire events that have caused significant loss of life, property, and ecosystem functioning.

In this NASA Land-Cover/Land-Use Change Early Career Scientist Project, we will leverage ongoing NASA projects to: 1) map land-cover/land-use (LCLU) change from agricultural land abandonment, reestablishment of croplands, and afforestation in Belarus, European Russia, and Lithuania from 1990 to 2010 using moderate to high resolution satellite data; 2) analyze the relationship of observed LCLU change with socioeconomic conditions, land management practices, policy, proximity to infrastructure, and agricultural management across time and space; 3) using the results of the LCLU change analysis, analyze potential origins and spread of fire while also comparing extreme fire year of 2010 to fires mapped from 2011 to 2013. Additionally, this project includes the participation of three early career scientists: Drs. McCarty (Ph.D. awarded 2009, University of Maryland), Prischepov (Ph.D. awarded 2010, UW-Madison), and Dubinin (Ph.D. awarded 2010, UW-Madison).

The expected results from a 3-year project will be a Landsat-based LCLU change map for two decades, 1990 - 2000 and 2000 - 2010, of the study area where LCLU change will be mapped across vegetation and/or land use type, including dominant tree group and peatland classes. A statistical model of LULC changes will also be developed, providing further insight into the drivers of LULC change across these three former Soviet countries. Finally, the results of these first two analyses will allow for further investigation into the drivers of anthropogenic fire observed in Eastern Europe, an important consideration for the impacts of extreme fires on the local human populations and ecosystems as well as a documented source of short-lived climate forcers in the Arctic system.
Our overarching goal is to study the impact of land tenure form and security on land cover and land use change (LCLUC) and thus ecosystem services across political borders within the Mesoamerican Biological Corridor (MBC) in Central America. The MBC is a Central American-wide initiative that began in 1990 to develop migratory corridors to conserve biodiversity and foster sustainable development. The success of the MBC in protecting biodiversity and maintaining ecosystem services varies considerably across countries. While deforestation has slowed in some protected areas, major threats to the corridor system include the expansion of agricultural areas outside of parks and migration into parks. Land tenure and land tenure conflicts are often cited as a major driver of observed land use changes in the MBC, but little empirical evidence exists. This is true throughout the world: causal evidence on the direction of relationships among land tenure and LCLUC is limited by (1) conceptual confusion about how to define and measure tenure, (2) a lack of comparative assessments across countries, and (3) the empirical challenges of separating out the effects of land tenure from other drivers of LCLUC. The proposed research will address these gaps by integrating remote sensing science with an econometric analysis of the impact of land tenure form and security on LCLUC from the late 1980s to 2013 across five political borders in the MBC. We will use novel fusions of satellite imagery and socioeconomic data measured at fine- (< 5 m) and medium-resolution (30 m) scales. By focusing on transboundary sites, we can hold constant many of the biophysical and socioeconomic factors that can drive LCLUC, and focus on differences across borders in allocation and enforcement of property rights. Our integrated remote sensing-econometric analysis will include: (1) quantification of LCLUC and characterization of biodiversity habitat and carbon storage using remotely sensed data of differing spatial and temporal resolutions, including Landsat imagery and higher resolution data, and (2) estimation of econometric models to assess how changes in land tenure form and security across borders and time impacted observed LCLUC. In addition, the proposed research will evaluate how fine- versus medium-scale satellite and socioeconomic data impact the (1) quantification of ecosystem services, (2) mapping of land tenure, and (3) estimation of land use change models. This will allow tradeoffs across collecting fine- versus medium-scale data to be assessed, informing decision-makers interested in accurately, but cost-effectively, mapping and monitoring land use changes. Our study is noteworthy for its explicit integration of remote sensing science and econometric analysis and the novel combination of fine- and medium-scale datasets. The key contribution of our proposed research will be the generation of new knowledge about the primary drivers of LCLUC. Thus, it pertains directly to this NRA’s goals of focusing on land cover and land use across political borders, explaining and attributing these differences to their primary causes, inclusion of a social science component, and fusion from various sources of Landsat-type data with coarser and/or higher resolution data. The proposed research substantially contributes to: (1) NASA’s LCLUC science goals and themes Drivers of Change, Ecosystems and Biodiversity Impacts and Detection and Monitoring of LCLUC; (2) international global programs such as NASA’s
Yuyu Zhou/Joint Global Change Research Institute
Understanding and Simulating Global Urban Expansion in the Context of Climate Change

This project is to contribute to the NASA ROSES LCLUC program by generating a consistent global urban map series and developing an integrated modeling framework to project future urban expansion. Our goal is to improve the understanding of global historical urban expansion, its socioeconomic drivers, and potential future urban expansion. We propose an interdisciplinary research program to achieve our research goal through four objectives:

Objective 1: Building a consistent global urban map series. We will develop an algorithm to build a series of consistent maps of urban extent from 1992 to 2010 using NASA products and DMSP/OLS Nighttime Lights (NTL) data. The algorithm will include several key steps that address challenges in extracting urban areas from NTL data such as gas flare and overestimation. The global urban maps will be validated using finer spatial resolution satellite data in areas where urbanization is important and these high-resolution data are available.

Objective 2: Analyzing global urbanization and its driving forces and developing a region-specific macro-scale statistical model. Using the global urban maps, we will analyze the amount, rate, and patterns of urbanization and the temporal and spatial differences across national and sub-national boundaries, and explore socioeconomic and demographic forces driving these differences, such as population change and GDP growth. We will then develop a region-specific macro-scale statistical model for urbanization projection at the regional level. Special attention will be paid to the analysis in developing and underdeveloped countries, where methodological challenges exist and improvements are more needed.

Objective 3: Developing an integrated framework to project future urban expansion. We will combine the top-down macro-scale statistical model developed in Objective 2 with a bottom-up Cellular Automata (CA) based Urban Growth Model (UGM), and develop an integrated modeling framework to project urban expansion. The interaction between urbanization and its socioeconomic drivers will be considered in the projection through an embedded Global Change Assessment Model (GCAM) and the statistical model by using a set of consistent exogenous and GCAM projected variables.

Objective 4: Exploring scenarios of urbanization projection and its implications. We will construct alternative climate and socioeconomic scenarios to explore the robustness of the urbanization projection and improve our understanding of potential trajectories of future urbanization in the challenge of climate mitigation. Moreover, we will investigate
the implication of spatially explicit urban projection by taking building energy use as an example.

The outcome of this research will represent a unique contribution to a comprehensive understanding of historical urban growth and future spatially explicit projection from a global perspective. Understanding historical global urban dynamics and future urban expansion, especially its spatial dynamic, will enable land managers and decision makers to explore future urban dynamics under certain scenarios, and therefore direct urban development under the framework of global climate change mitigation. By combining unique remote sensing data and socioeconomic modeling capabilities from NASA, NOAA, and DOE, our proposed research falls under the priorities of NASA’s LCLUC Program: forcing factors, responses and consequences, and modeling and implications. Particularly, the proposed work aligns uniquely with special interest of this solicitation: differences in land cover and land use across political borders and their primary causes. This research aims to answer several key science questions identified in the LCLUC research program, including: Where is urban growth, what is the extent and over what time scale and how do the changes vary from year to year, and what are the causes? What are the projected urbanization and its potential impacts?