This synopsis is for the Land-Cover and Land-Use Change (LCLUC) part of the NASA Research Announcement (NRA) ROSES-2010 NNH10ZDA001N-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 solicitation was focused on two major themes: 1) Synthesis of prior Land Use and Land Cover Change studies and 2) wetlands Vulnerability, Impacts, and Adaptation (VIA), as related to climate interactions with land-use changes around the world. Social science component in proposals was considered a requirement for a proposal to be selected. NASA received 25 Step-2 proposals and selected 7 proposals for funding. More details are available at: http://nspires.nasaprs.com.

Kathleen Bergen/University of Michigan
LCLUC Synthesis: Forested Land Cover and Land Use Change in the Far East of Northern Eurasia Under the Combined Drivers of Climate and Socio-Economic Transformation

PROPOSAL SUMMARY: In response to the SYNTHESIS component of the 2010 solicitation for the Land Cover Land Use Change (LCLUC) program, we will focus on better understanding forest-cover dynamics over a broad region of the Northern Eurasian Far East over the past 35 years by combining previously developed knowledge and methodologies. RATIONALE: The Russian and Chinese portions of the study region present contrasting political systems operating on similar landscapes over very different eras in their recent histories. The abrupt changes in the economies of Russia and China over the past 30 years, and the region's importance as a locus of forest resources, carbon and biodiversity make this area a particularly critical hot-spot of change and conflicting economic interests. Located in Earth's largest forest, the region is also predicted to show some of the greatest change in climate over the near future. The critical issue and our driving RESEARCH QUESTION for this synthesis project is the following: How have human-driven disturbances related to use of forest resources, combined with natural or interacting disturbances (e.g. fires), created the landscapes of the region over the past 35 years? How might they change in the future? To answer, we must integrate human and natural drivers and their consequences. Therefore the overarching GOAL of this synthesis is to quantify and attribute changes in land-use and land-cover due to climatic variability and due to changing socio-economic drivers in this large region. We will build our
specific OBJECTIVES AND APPROACH to synthesize research, previously funded by NASA LCLUC and other related programs, by (1) Synthesizing local and small-regional Landsat-based case studies previously funded by NASA, (2) Mapping change in the extent of the land cover and forest composition from the MODIS data applying the past disturbance reconstruction approach recently developed for the region, (3) Evaluating the impact of climatic change on forest composition and characteristics using the individual-based forest gap model (IBM) FAREAST to identify potential vegetation composition under different climate scenarios in combination with observed rates of natural and socio-economic disturbances, and (4) Attributing forest characteristics to changing forest policies and climate change in Russia and China over the past 35 years, using a systems dynamics model to integrate and illustrate the impact of these drivers. The RESULTS of these four objectives are three intermediate yet stand-alone synthesis outputs (Landsat case study sites and LCLUC records, region-wide MODIS-derived disturbance record, and multiple region-wide IBM-derived scenarios) and analyses derived from them; and one capstone modeling integration (systems dynamic model, scenarios and analyses). These will be interpreted and tested in order to answer our driving research question. The evolution of the institutional frameworks for the forest sectors in both countries provides an opportunity to evaluate, through multiple scenarios that are informed by modeling, remotely sensed data and available socio-economic statistics, the interactions between changing social and economic structures, climate change, and the state of the forests.

Laura Hess/University of California Santa Barbara

Land and Resource Use on the Amazon Floodplain Under Evolving Management Systems and Environmental Change: Fish, Forests, Cattle, and Settlements

The floodplain (varzea) of the main stem Amazon river extends over nearly 100,000 km², constituting the world's largest riverine wetland. The complex and dynamic landforms of the floodplain result in a mosaic of permanent and seasonal lakes and channels, levees, and flats supporting economic activity and biodiverse plant and animal communities with distributions largely determined by flood depth, flood duration, and successional stage. Over the last 40 years, two major economic drivers have been transforming the floodplain ecosystem: the growth of commercial fisheries, and the expansion of cattle and water buffalo ranching. The impacts of these activities are exacerbated by climate-induced changes to flooding regimes. The observed trends in land use and climate induced changes in flood regime raise key questions for the future of the varzea and entire Amazonia: 1) How are past and current land cover change impacting varzea communities and biodiversity? 2) How are varzea land use systems impacted by climate-induced variability in flood regimes? 3) How are these impacts predictive for the entire Amazon floodplain? 4) What policies and management strategies are most effective for managing changes and mitigating their impacts? To answer these questions, we propose to carry out integrated remote sensing and modeling studies in order to quantify key drivers of land cover and land use change on the lower Amazon floodplain. We will use archived remote sensing datasets (ALOS PALSAR, Landsat TM, historic aerial photography, videography), historic maps and charts, and socioeconomic datasets (fisheries, ranching, and household surveys) in analyses of the vulnerability of varzea
land-cover and land-use systems to multiple stressors. The proposed research is organized to test a set of hypotheses regarding the current state and historic trends of the varzea system and the feedbacks between them: 1. Observed reduction in forest area and degradation of grasslands is due to an increase in cattle densities on the floodplain and associated cattle management practices. 2. Reduction of forests and degradation of remaining forests and aquatic macrophyte communities, combined with an increased frequency of extreme flood events, could lead to reduction in the productivity of floodplain fisheries. 3. Household and rancher economic strategies and associated cattle management practices are the primary drivers of deforestation and habitat degradation on the Lower Amazon floodplain. 4. Effective co-management policies can influence household and rancher economic strategies to reduce pressure on forest and grassland habitat and floodplain fisheries and increase resilience to impacts of climate change.

Proposed remote sensing work will 1) map contemporary land cover of the lower Amazon floodplain and adjacent uplands at 30 m scale for input to analyses of fisheries productivity and flood pulse variability; 2) estimate what proportion of the currently non-forested floodplain was historically forested; 3) create spectral fraction images suitable for assessment of pasture degradation due to grazing; and 4) test an approach for generating a bare-earth floodplain DEM at 30 m scale. The project will take advantage of research, community development and policy analysis on varzea ecology and resource management conducted in the region since the early 1990s including a regional fisheries dataset collected since 1992 and extensive socioeconomic data collected since 1995. We will complement these data sets with research on the impacts of government management policies on rancher and smallholder economic strategies.

Volker Radeloff/University of Wisconsin-Madison

Synthesis of Studies on Institutional Change and LCLUC Effects on Carbon, Biodiversity, and Agriculture After the Collapse of the Soviet Union

Our proposal addresses the first major theme of the solicitation, the Synthesis of prior Land Use and Land Cover Change studies.

Major institutional changes occurred throughout Eastern Europe and European Russia after the collapse of the Soviet Union in 1991, and the expansion of the EU in 2004 and ’07, resulting in substantial land cover and land use change. NASA-funded case studies led by members of our proposal team have highlighted the magnitude of these land changes. However, these case studies have not been synthesized, and we lack comprehensive datasets of land change, analysis of its economic and institutional drivers, and assessments of its environmental effects. Our first goal is to utilize recent advances in remote sensing science to a) map wall-to-wall decadal land change from Landsat data across Eastern Europe and European Russia, and b) conduct in-depth analyses of higher temporal resolution land change for dense time stacks of selected footprints.

Our prior case studies highlighted that land changes were highly heterogeneous in space suggesting that economies and institutions were important drivers of land change. However, how economic, policy, and institutional changes - and their legacies - affected
land change is not clear. Our second goal is to understand the economic, policy and institutional drivers of land change across Eastern Europe and European Russia.

Similarly, case studies by our team and others provide strong evidence for substantial effects of land change on agriculture, forestry, carbon pools and fluxes, and biodiversity. The additional remote sensing analyses outlined above would allow us to take the research on these effects to a new level, and make comprehensive assessments across Eastern Europe. Our third goal is to assess the effects of land change on agriculture, forestry, carbon, and biodiversity across Eastern Europe and European Russia.

The main outcome will be a synthesis of prior research on land change in Eastern Europe. Our prior research puts us in a unique position to provide three important outcomes: a) consistent maps of land change across Eastern Europe; b) analyses of the policy, economic and institutional drivers of the land changes that occurred; and c) assessments of land change effects on agriculture, forestry, carbon, and biodiversity.

Land use is the principal driver of global environmental change. Twenty years after the Soviet Union, and ten years after the start of NEESPI and of numerous research projects in the region, we now have a unique opportunity to synthesize findings and extract more general patterns. We propose to conduct such a synthesis and make a major contribution to our understanding of human-natural systems, and land use science.

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Marc Simard/Jet Propulsion Laboratory

**Vulnerability Assessment of Mangrove Forests in the Americas**

Mangrove forests are coastal wetlands that contribute to regional, continental and global biodiversity and act as major biogeochemical links between upland and coastal regions of the tropics. Mangrove ecosystems provide a great number of ecosystem services ranging from shoreline protection (e.g. against erosion, tsunamis and storms, nutrient cycling, fisheries production, lumber and habitat). But as a result of their location and economic value, they are among the most rapidly changing landscapes. The greatest current threats to mangroves derive from human activities such as aquaculture, freshwater diversions, overharvesting and urban and industrial development. The effects of sea-level rise (SLR) and increased extreme climatic events may also increase the vulnerability of this ecosystem to global change.

Our objective is to develop spatially explicit models of mangrove forest vulnerability to anthropogenic activity and climate change across the Americas. We propose a multi-scale nested approach with continental-scale mapping of mangroves and land cover land use (LCLU) for the entire Americas, regional-scale analyses in 18 sites, and in-depth studies in 7 local sites. These models will be produced by integrating socioeconomic datasets and local surveys with multi-sensor remote sensing of mangrove use and cover change, and eco-geomorphology.

We propose a novel LCLU classification scheme that will include proximate sources of mangrove conversion (e.g. shrimp farming, logging, agricultural expansion, hydrological
modifications leading to die-offs, growth of urban areas/fronts, etc.), and mangrove forest structural classes (e.g. height). We will use a combination of optical (i.e. Landsat) and radar (i.e. ALOS/PALSAR, JERS-1, UAVSAR, SRTM) timeseries data as well as lidar (ICESat/GLAS) to cover all mangrove regions of the Americas. These data will also be used to map canopy height and geomorphology. Importantly, canopy height will enable us to assess the potential services associated to different canopy structures and thus, their vulnerability to various drivers of change. Coastal geomorphology is a significant environmental determinant of mangrove structure, and influences mangrove resilience to SLR. But, SLR resilience also depends on soil accretion.

Sediment deposition (inorganic) and biotic processes such as root production (organic) contribute to soil volume in mangrove forests, allowing these wetlands to keep up with SLR. Within the 7 local sites, we will measure the rate of soil accretion and develop potential relationships with canopy structure and geomorphology to upscale to the Americas. Geomorphology and accretion rates will be compared to local estimates of SLR to derive local vulnerability indexes to SLR.

The remote sensing studies of mangrove regions will be coupled with commensurate, extensive ecological and social (census) datasets for 18 regions, and used to develop regional-scale models of mangrove vulnerability. Moreover, intensive assessments will be conducted for calibration and validation of the regional-scale models, relating socioeconomic activity with local changes in mangrove forest use and cover. These intensive assessments will focus on a set of 7 coastal mangrove study regions representing a wide range of socio-demographic, economic, policy and ecogeomorphic contexts found throughout the Americas. These sets of multi-scale assessments will enable upscaling of regionally calibrated models and the generation of continental scale, spatially explicit scenarios of mangrove vulnerability using widely available socioeconomic and remote sensing data products.

Charles Vorosmarty/The City College of New York, City University of New York

River systems are today experiencing a transformation that is rapid and pandemic in extent, affected by climate trends and variability plus widespread land cover change, wetland destruction, pollution, and waterworks like dams, irrigation, and interbasin transfers that distort, and often break, the basic character of land-to-ocean linkages. Impacts reverberate strongly into the coastal zone, on which a substantial fraction of the human population lives and depends for critical environmental services. A particularly sensitive part of this zone is the coastal river delta, on which >0.5B people live and which owes its existence to the interplay between water and sediment fluxes defined by upland watershed dynamics, local conditions, and ocean forcings. While problems are well-documented for single river deltas, they collectively point to a worldwide syndrome, an assertion to be formally tested here using remote sensing, modeling, and GIS.
With population growth, development, and the specter of sea level rise and changes in
storm and flood surge exposure, river deltas increasingly are a focal point for concerns
regarding human vulnerability and sustainable development. The need to understand and
forecast the rapidly changing state of these linked geophysical-social systems is the
impetus for our proposed study. This proposal aims at the Vulnerability, Impacts, and
Adaptation (VIA) element of the LCLUC program ROSES solicitation, with its emphasis
on wetlands. Our Science Goal is to analyze how the strength and variability of land-to-
ocean links, as defined by reverine sediment fluxes, local anthropogenic activities and
ocean processes, produce impacts on coastal delta systems today and into the future.

The supporting Objectives are to: 1) refine and apply a "fingerprinting" system to identify
hot spots/cold spots of risk, 2) improve understanding of key delta system response
mechanisms to environmental stressors, 3) assess contemporary societal vulnerabilities
and 4) forecast future threat.

The proposal extends ongoing work to develop river basin and coastal models and linked
Earth system modeling frameworks. Our recent work has yielded several breakthroughs
in the science of land-to-ocean coupling, including global dynamic, geospatial flux
models and demonstrations of the value of NASA remote sensing assets. Our analysis
framework integrates unique global-scale remote sensing data sets of wetland vegetation
and dynamics and land surface freeze-thaw state developed under the NASA MEaSUREs
program. The proposal takes data sets now under development and extends their domain
to address issues of regional and global significance. Principal, value-added outputs from
this proposal over our current research are: a synthesis of landmass, coastal wetland, and
coastal ocean remote sensing observations, models, and statistical inference techniques; a
global catalogue of delta systems-at-risk; and scenarios of future conditions which can be
used in the policy arena.

The proposal articulates upland as well as local coastal impacts of LCLUC on a sensitive
coastal wetland system, which serves as home to rapidly growing megacities and rural
populations. The work places these impacts into a broader perspective of sea level rise
and ocean storm-derived vulnerabilities. The aims of this proposal thus contribute to the
overall mission of NASA's Science Mission Directorate and US Climate Change Science
Program by improving knowledge on a central global change issue and distinguishing the
impact of climate from other drivers. The work supports the Directorate's aim of
assessing the capacity of multiple satellite sensors and data sets to monitor change in
biogeophysical cycles over both landmass and oceans. The subject of this proposal has
important societal implications, and PI/co-PI participation in international science
consortia and policy-relevant activities are forwarded as part of this work.
Little progress has been made in the study of the effects of Land Cover and Land Use Change (LCLUC) on regional-scale wetland distribution, extent and function. Fundamental data are few. For example, many US wetland maps are out of date and do not represent wetland dynamics; forested wetland maps are inaccurate; principle process-based regional water quality models do not explicitly incorporate wetlands; and wetland functional assessments are not quantitative. Thus, a fundamental understanding of land-water processes is severely impeded and adaptive management and conservation of wetlands is based on scant fundamental understanding.

The overall objectives of this study are to (1) develop improved wetland mapping and change detection using remote-sensing data from multiple, complementary sensors at various temporal and spatial scales; (2) study the socioeconomic and physical drivers of wetland change affecting wetland extent and function at regional scales; (3) assess the impacts of multiple environmental stressors, particularly the anthropogenic ones; and (4) quantify vulnerability of wetlands and wetland ecosystem services under multiple climate and land use change scenarios. Outputs of this project will advance scientific understanding of the types, extent and processes of LCLUC and climate change on wetland extent, distribution, and provision of ecosystem services. It should also advance the US obligations to the scientific component of the RAMSAR Treaty as well as state and local management strategies to mitigate and adapt to future changes.

The Chesapeake Bay Watershed (CBW) will be used for this study because of its wide variation in soils, topography, climate, hydrology, water chemistry, vegetation, and other factors, including human disturbance and wetland related policies. While typical, LCLUC in the CBW is extreme and it is a bellwether of the effects of accelerating LCLUC and climate change on the entire US Atlantic coast and elsewhere. The CBW extends over 165,759 km², covering parts of New York, Pennsylvania, Maryland, Delaware, West Virginia, Virginia and the District of Columbia. Due to its shallowness, estuarine wetlands are extensive around the CB, although inland palustrine wetlands are even more abundant. The high land to water surface ratio (14:1) amplifies the influence of land activities. Like many wetlands covering large areas they provide multiple ecosystem services, including regulation of water quality, biodiversity, habitat, food for humans, erosion protection, and others. A high proportion of the overall human population lives in coastal areas around the CB as in most areas of the world, and this is increasing rapidly, leading to accelerated LCLUC. The importance of the CB is recognized by its designation as an Inter-governmental Treaty RAMSAR site of international importance.

Multiple types of remote sensing data will be used with existing biophysical and socio-economic data, new field data, and outputs of land simulation and water quality models. New mapping approaches based on the fusion of passive and active remotely sensed data and weather records will be developed. Socio-economic, policy, regulatory, and economic variables, in addition to biophysical will be considered. The extensive existing
pollutant loading data for the CBW provide an unusual opportunity for model closure. The derived relationships and quantitative assessment will be spatially explicit, thus allowing for “what if” conceptual experiments to investigate alternative land uses and their effects on wetlands.

This proposal is in direct response to the LCLUC call for proposals addressing Vulnerability, Impacts, and Adaptation (VIA) (second component). It also responds to the first component of the call by synthesizing LCLUC research results from the Mid-Atlantic Regional Earth Science Applications Center (RESAC), available climate impact and vulnerability assessments, and existing wetland studies.

Mei Yu/University of Puerto Rico
Vulnerability and Adaptive Management of Tropical Coastal Wetlands in the Context of Land Use and Climate Changes

Land Use / Land Cover Changes have profound influences on the functions of coupled natural and human systems. Although deforestation has been a major topic in LULCC, reforestation can be significant in areas with economic shift. The tropical island Puerto Rico stood out as an example of reforestation because of the shift from agriculture to industry and services as a result of economic globalization after 1940s. With the abandonment of agriculture lands and subsequent reforestation, people migrated from rural to urban, and then to suburban, and sharply intensified urbanization and urban sprawl in the island. Urban sprawl often fragments the land cover, while reforestation may do the reverse. The magnitude of composite impacts of the two processes on natural ecosystems is largely unknown. Being important for flood mitigation, water purification, and biodiversity conservation for both ecological and economic values, tropical coastal wetlands are vulnerable to land use changes due to increased tourism, irrational construction, and water use. Climate change, such as drought and sea level rise, will further increase uncertainties to the future of tropical coastal wetlands. The key objective is to answer the scientific questions of: How do the land use changes (reforestation and urbanization), interacting with climate changes (drought and sea level rise), impact the vulnerability and the adaptation capacity of tropical wetlands spatiotemporally during the past 33 years in Puerto Rico? And what are the potential adaptive management plans for sustainable coastal wetlands in the context of climate change? Three hypotheses will be tested: 1) In spite of reforestation, island wide forests were fragmented by the urban sprawl, especially the low-density residential development. However, the coastal wetlands may aggregate due to the policy change, e.g., the implementation of The RAMSAR Convention on Wetlands; 2) Land use and climate changes will make coastal wetlands more vulnerable by reducing water supply, decreasing water quality, and retreating shoreline due to sea level rise; and 3) Adaptive scenarios of coastal wetlands management, such as restricted coastal development and water consumption, and wetlands restoration, will lead to more sustainable wetlands in the context of climate change.
We'll address the questions through: 1) synthesis of multi-temporal remote sensing images and existing land cover/use maps from 1977 to 2010, including Landsat TM and ETM, aerial photos, and AMSR-E (Advanced Microwave Scanning Radiometer-Earth Observing System) data for drought detection, together with demographic and socioeconomic data on population, construction, and commercial and residential water consumption; 2) integrated modeling of watershed land use change and hydrologic dynamics to assess the vulnerability and adaptation capacity of tropical coastal wetlands through building different land use and climate scenarios; and 3) collaborations with local Department of Natural and Environmental Resources and Planning Board on potential adaptive management of coastal wetlands for sustainability by socioeconomic survey and stakeholders involvement.

This proposal addresses both components of the solicitation. The land cover/land use changes in Puerto Rico, reforestation, urban sprawl, policy change, and their impacts on coastal wetlands in particular, for the last 33 years, will be synthesized. The vulnerability of coastal wetlands and possible adaptive management will be investigated by integrating models of Soil and Water Assessment Tool (SWAT) and The Conversion of Land Use and its Effects (CLUE-S), high-resolution remote sensing images (Landsat TM/ETM), AMSR-E data, Global Circulation Model outputs, and socioeconomic analysis. The proposed simulation and analysis of high-resolution and long-term satellites' images were highlighted in the NASA Science Mission and aligned with the strategic plan of US Climate Change Science Program.