Contribution of the NASA Land-Cover/Land-Use Change (LCLUC) Program to the Northern Eurasia Partnership Initiative (NEESPI)

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Abstract – The Northern Eurasia Earth Science Partnership Initiative (NEESPI) is a rapidly growing program that involves national government agencies, academia and private organizations in the U.S., Europe, Japan and Northern Eurasia. The NEESPI Science Plan has been prepared as an integrated regional study to evaluate the role of anthropogenic impacts on the Northern Eurasia ecosystems, the hemispheric-scale interactions, and to assess how future human actions would affect the global climate and ecosystems of the region. Inversely, projections of the consequences of global changes for regional environment, the economy, and the quality of life in Northern Eurasia that is of primary importance to the nations in the region is another focus of this initiative. The NASA Land-Cover/Land-Use Change (LCLUC) Program has supported NEESPI since its inception, and currently funds over 20 NEESPI projects. More projects will join the program during this year. The NEESPI program links to the major international programs under the Earth System Science Partnership, such as IGBP and WCRP. The NEESPI activities are aligned with the Global Earth System of System (GEOSS) objectives so that the NEESPI framework can serve as a regional test bed for international cooperation in developing a system of observational systems. Currently, several NASA programs are supporting or planning to support the NEESPI. This article provides a short description of the ongoing NEESPI projects under the NASA LCLUC program that contributes to the overall NEESPI program. More information on the projects can be found at http://neespi.org or http://lcluc.hq.nasa.gov.

Keywords: *NASA, NEESPI, LCLUC*

1. INTRODUCTION

Northern Eurasia - a geographic area, which includes the territory of the former Soviet Union, northern China, Mongolia, Scandinavia and Eastern Europe – is a study area of an international, interagency program NEESPI (Northern Eurasia Earth Science Partnership Initiative, http://neespi.org). The National Aeronautics and Space Administration (NASA) is among the NEESPI major partners, with several NASA programs contributing to this initiative. The NASA Land-Cover/Land-Use Change (LCLUC) Program has been supporting the NEESPI since its inception. Northern Eurasia is of special interest for studying LCLUC processes due to (a) the dramatic socio-economic shifts throughout this region during the past decades and (b) the strong land cover - climate interactions that are not yet well understood. The rapid land-use and land cover changes create a possibility for large and significant biological and climatic regional feedbacks that could be of global importance. Significant changes in land use coupled with climate change may affect various sectors, such as forestry, costal zone and agricultural systems, and may have direct societal impacts. The NEESPI covers a vast area with numerous geo-botanic zones from arctic to forest to steppe and arid. One of the reasons the NEESPI geographic domain is important for global change studies is because about quarter of the world's forests are located in Northern Eurasia. Fires, insect invasions leading to trees defoliation, and forest exploitation by humans are the major disturbances in forests. Interactions between these disturbances and climate variability are complex, with consequences for carbon dynamics yet to be well understood. In non-boreal zone of Northern Eurasia some other aspects of LCLUC, such as changes in water resources and carbon emissions following institutional changes and the shifts in agricultural practice, come into play. NEESPI projects that are currently supported by the NASA LCLUC Program are the subject of this paper.

2. BACKGROUND

After the breakup of the Soviet Union, new opportunities have emerged for U.S. scientists to collaborate with Russian researchers. In mid-90s the NASA LCLUC Program supported a joint study between Russian and U.S. scientists to evaluate the utility of recently declassified products derived from national security data for monitoring characteristics of boreal forests. The study focused on demonstrating how these derived products can be used in combination with information collected by civilian satellites, such as Landsat, RESURS, and SPOT. This project was conducted under the auspices of the Environmental Working Group created in the summer of 1995 following the so-called Gore-Chernomyrdin agreement on economic and technological cooperation. The use of declassified information was made possible after President Clinton signed an Executive Order, directing the declassification of intelligence imagery acquired by the first generation of photo-reconnaissance satellites, such as a system code-named CORONA.[1] The results of the joint study demonstrated the utility of the information derived from national security systems and showed that the combined use of archival national security and civil satellite images provided a unique opportunity to assess changes in land-use types and percentage of forest cover, analyze qualitative changes in forest structure, and assess changes in forest health attributable to fires, insect outbreaks and forest exploitation. In conjunction with that project, the LCLUC Program supported a study led by ERIM International and University of Virginia on the effects of the development of the Baikal-Amur mainline railroad on patterns of carbon flux in southern Siberia. Another project that was conducted in the early years of the LCLUC program was a comparative study on modeling carbon dynamics and their economic implications in two forest regions (Pacific Northwestern USA and Northwestern

[1] Currently the declassified imagery is available through the U. S. Geological Survey's EROS Data Center

Russia) led by the Oregon State University (OSU) with participation of the USDA Forest Service Pacific Northwest Research Station. Both the ERIM-UVA and the OSU projects developed significant links to Russian forest scientists and remote sensing specialists that in the future provided a solid base for developing the NEESPI scientific network described later in the paper.

Bergen et al. (2003) gave a comprehensive overview of the Russian forest-related projects, supported by the LCLUC Program in pre-NEESPI years, including the two above-mentioned studies. Most of the work was based on the cooperation developed by NASA-affiliated scientists with scientists from the Russian Academy of Sciences, Russian State Forest Inventories, and Russian Federal Forest Service. Bergen el al. described selected results of completed and ongoing research projects grouped under four LCLUC categories: 1) forest dynamics, 2) fire behavior, 3) carbon budgets, and 4) new remote sensing analysis methods. Except for the OSU project, the main collaborating partners in Russia in the forest studies at that time were the Center for Forest Ecology and Productivity in Moscow, and the Sukachev Institute of Forest Research in Krasnoyarsk of the Russian Academy of Sciences. Capitalizing on considerable forest inventory data and forest ecology expertise in Russia as well as rapid advances in remote sensing capabilities after the launch of Landsat-7 and Terra satellites, the U.S.-Russia joint projects produced a large body of interesting results. The studies showcased the potential of growing databases of multi-decadal imagery accumulated by the Landsat and AVHRR programs. Coupling of remote sensing-derived information with models and inventory data significantly enhanced the information content of the remote sensing data especially when forest age and cutting history is to be determined from inventory data. Results of scientific research on disturbance, including fire behavior and the interaction of logging and fire in the Russian boreal forest, have contributed to a greater understanding of the role of Russian forests in the global carbon budget. Additionally, attempts to link forest dynamics with socio-economic factors in Russia have been initialized under these projects. Bergen et al. concluded that "using models, it is possible to project what the forest in these regions will look like in future decades and centuries". Forest gap models showed that the composition of the forest changes significantly after logging and fire and may not return to its original composition for centuries even without additional disturbance. Additionally, actual land-cover change data from remote sensing during 1975-2000 has confirmed that the composition of the Siberian boreal forest in the areas of study is indeed changing.

Much effort in the pre-NEESPI projects was directed at studying one of the major natural disturbance processes in boreal systems - forest fires. Analysis of natural and experimental fires contributes to implementation of remote sensing-based algorithms for their mapping and monitoring. In Russia, fires cover greater area than any other type of vegetation disturbance. Results of the NASA projects have shown that the impact on terrestrial carbon storage of fires in boreal forest regions has been vastly underestimated. Remote sensing-based methods for detecting burned areas and fire severity have been improved during the last several years to provide inputs into global and regional models of carbon cycling and atmospheric chemistry.

Analyses based on atmospheric data, models and forest inventories indicate that a large uncertainty in carbon budget estimates and in the spatial patterns and temporal dynamics of CO2 fluxes in the region still exists. Most studies, however, have suggested that the region is a net sink for carbon (e.g. Shvidenko, et al. 1996). U.S. scientists collaborated with several Russian organizations to study the carbon budget of forest ecosystems in St. Petersburg's region of Russia. Their integrated approach involved the use of forest inventory data, results of ecological studies, data on land-use change, and Landsat imagery (Krankina et al., 2005). That study, conducted at OSU in cooperation with Woods Hole Research Center, grew into a bigger project directed to quantify carbon change over the entire Russian Federation at coarser spatial and temporal scales by determining the current distribution of carbon storage in Russia and changes in that storage over the last decades.

The pre-NEESPI NASA LCLUC projects have fostered growing international collaboration on the individual, institutional, and national government levels. Currently, Russian and U.S. scientists work together in the NEESPI framework to further our knowledge on the influence of LCLUC on terrestrial ecosystems of Northern Eurasia. Collaborations with other countries of the NEESPI region expanded to include northern China, Ukraine, Uzbekistan, Kazakhstan and Mongolia.

3. THE NEESPI PROGRAM

The Northern Eurasia Earth Science Partnership Initiative, or NEESPI, is an evolving program of internationally-supported Earth system science research, which focuses on issues in Northern Eurasia that are relevant to regional and global scientific and decision-making communities. Until recently, NASA has been the driving force for NEESPI development relying on the well-established relationship between NASA and the Russian Academy of Sciences in the framework of the U.S.-Russia Earth Science Joint Working Group. Currently, the NEESPI involves several countries and multiple U.S. and international agencies and institutions, with the program constantly growing. It operates, as an integrated regional study, linking to the international science programs within the Earth Science System Partnership, in particular IGBP and WCRP, through five global projects: the Global Land Project, the Global Carbon Project, the Global Water System Project, the Global Energy and Water Cycle Experiment, and Climate and Cryosphere Project. More links are being established. Ultimately, the developed enhanced knowledge of this region will be applied to addressing specific concerns that face national and international decision-makers of the partnering institutions and countries. NEESPI is aimed at developing an enhanced understanding of the interactions between ecosystems, atmosphere, and human dynamics in Northern Eurasia. Changes in terrestrial ecosystems and land use represent an important component of the NEESPI science agenda (see http://neespi.org).

The NEESPI LCLUC projects aim at helping to resolve the following science questions of the NEESPI science plan:

1) What has been the role of anthropogenic impacts on producing the current status of the ecosystem, both through local land use/land cover modifications and through global gas and aerosol inputs? 2) What are the hemispheric scale interactions, and what are the local effects? 3) How will future human actions affect the Northern Eurasia and global ecosystems? 4) How can we describe these processes using a suite of local, regional, and global models? 5) What will be the consequences of global changes for regional environment, the economy, and the quality of life in Northern Eurasia?

To understand the importance of studying the Russian boreal zone one should note that it is probably the world's largest carbon pool with about 1/2 of global terrestrial carbon, whereas huge amounts of carbon are stored in soils (including permafrost) and peatlands, representing up to 70% of Northern Eurasia wetlands. To develop a comprehensive regional carbon budget scientists have been examining carbon stocks and their change in live forest biomass, coarse woody debris, peatlands, forest products, and soils. Russian boreal forests have an active high annual wildfire load, by recent estimates up to 10-15 million ha (Conard et al. 2002). Increased wildfire activity that has been predicted in response to changing climate has potential to significantly affect the carbon storage capacity of Siberian forests. Optical sensor data have been traditionally utilized for monitoring fires and assessing fire scars extent. However, due to persistent cloudiness in high latitudes, particularly in tundra, and short periods of daylight during much of the year radar data prove to be very useful in monitoring fire scars. Spaceborne radars have the ability to get images of the Earth's surface through darkness and cloud cover with the resolution comparable to the optical sensors. A combination of optical and microwave sensor data has been applied in some NEESPI LCLUC projects.

Overall, there are currently 8 NEESPI projects studying carbon and water cycle processes in the boreal zone. Northern China comprises a substantial portion of the boreal ecosystems within the NEESPI geographic domain, representing an extension of the forests across the border with Russia. Processes in the boreal zone of northern China are similar to those in the Russian Far East. Among the 8 boreal zone projects there are two NEESPI projects that are studying processes in the forest zone of northern China. Additionally, there are short-term 3-4 pilot projects on boreal zone including studies of biomass burning and land cover, reindeer mapper, and impacts of land use on biodiversity in Eastern Europe.

The NEESPI domain includes vast areas of Northern Eurasia that are non-boreal, such as agricultural regions of Russia, Ukraine, Black and Caspian seas regions and semi-arid/grassland regions of Central Asia, China and Mongolia. These areas have their own specifics in interactions between carbon cycle, land use, and climate and especially issues related to water resources. LCLUC, such as cropland abandonment and degradation of soils, have altered carbon stores and fluxes from extensive areas in the region and have potentially affected the feedback to the climate system.

In addition to interactions with carbon cycle and climate, LCLUC affects ground surface hydrology through agricultural or grazing practices, forest exploitation, urbanization, by altering runoff, ground water, soil erosion and water quality. The modifications of the social-economic situation in the region have been a primary agent of change of the land-use systems during the past century with a new cycle of changes after the break-up of the Soviet Union. The principal mechanism of LCLUC in the non-boreal part of the NEESPI domain during the past 15 years has been the disintegration of the institutions of centralized control over the agricultural sector. Currently, there are 9 projects studying carbon and water cycle processes in the non-boreal zone of the NEESPI geographic domain.

Descriptions of the NEESPI ongoing projects supported by the NASA LCLUC Program are given at http://lcluc.hq.nasa.gov or http://neespi.org.

4. SCIENCE DATA SUPPORT FOR THE NEESPI

To facilitate implementation of NEESPI science projects, the NEESPI program makes an effort to develop a solid infrastructure for providing remote sensing and in situ data and other informational support. The Northern Eurasia Regional Information Network (NERIN) is a recently formed network, which emerged within the framework of the Global Observation of Forest/Land-Cover Dynamics (GOFC-GOLD, http://www.fao.org/gtos/gofc-gold/net-NERIN.htm). The NERIN is growing rapidly as an informal network of scientists and other professionals, institutions, local observational networks, and projects active in the region. The primary goal of the NERIN is to promote and coordinate the production and provision of Earth system observations for a wide range of user communities in Northern Eurasia and to the global Earth science community. Specifically, the NERIN provides information on data availability and accessibility to the ongoing NEESPI scientific projects. NERIN is currently assembling information about the content, quality, condition, and other characteristics of data sets available to support new research in Northern Eurasia. NERIN includes two related thematic components: fire and land cover. The fire network maintains an active fire-monitoring project in Russia; the land-cover network project is at the planning stage. The NERIN is currently being formed in the boreal zone of Russia and being expanded to the northern China. The development of the non-boreal network is slower. The ultimate goal is for all the networks in the boreal and non-boreal zones to be integrated into one scientific network for Northern Eurasia - the NERIN.

Additionally, the NEESPI is planning to rely on Science Data Support Centers that are currently being established as part of the NEESPI data infrastructure for running the program. For example, ScanEx - a private company in Moscow and a primary data holder of most remote sensing data available for Northern Eurasia, and the Beijing Climate Center for East Asia – the primary center for in situ climatological data in East Asia, both have agreed to serve as a backbone for the NEESPI informational system. More centers are foreseen to join this system.

5. CONCLUSIONS

In conclusion, note that the NEESPI framework is an exemplary regional test bed for the Global Earth Observation System of Systems (GOESS) activities. The NEESPI serves as an organizational framework to build towards integrated Earth observations for a region to meet user needs including those of decision-makers. The NEESPI promotes cooperation of multiple countries-partners as contributors to international scientific programs, ensuring that the shared observations and products are accessible by the world science community. Moreover, the NEESPI promotes capacity building in Earth observations based on the existing and emerging networks, e.g. NERIN. Within the NEESPI framework advanced products for the region are being produced that will provide societal benefits in, at least, 6 areas (out of 9) outlined by GEOSS. For example, in Disaster area, fire monitoring systems for northern Eurasia, including assessment of fire damaged areas, are being developed. In the Health area, a mapping system for the reindeer herding and assessment of impacts on the native population, including health issues, are being developed. For the Climate area, the LCLUC program conducts several NEESPI projects directed to model interactions

of LCLUC, including economic aspects, with climate variability, and improve our understanding of the regional climate processes to be able to make assessments of the consequences of the climate/environmental regional changes for the Earth's global system. In the Water area, several projects on water resources, in particular water quality, are conducted for the arid areas of northern Eurasia. An outcome of these projects will be improved water management for the region. The Ecosystems and the Agriculture areas are the focus of the NEESPI program. Mapping of the natural resources and integration of space observations with in situ data provide basis for continuous monitoring of crops and ecosystems condition, including land degradation. Improvement and gap filling in observations for monitoring carbon cycle and reducing uncertainties in its budget are undertaken in several projects.

The NASA LCLUC program has been supporting regional network activities in various regions of the globe, and most recently the newly emerged network for Northern Eurasia (the NERIN). The Program made a strategic investment in advancing the knowledge on critical aspects of the role of Northern Eurasia in global environmental processes. The current projects focus on using remote sensing to study interactions of the carbon and water cycles and climate with LCLUC. NASA LCLUC may select a few more NEESPI projects during this year from the proposals submitted to the NASA LCLUC research announcement, thus making the total number of the projects exceed 20 in the end of this year. This is a substantial contribution on NASA's part to this international, multi-agency regional initiative and provides underpinning science of land surface processes to the major global international programs, in which NEESPI plays a role of an integrated regional study.

NASA's contribution to the NEESPI is not only through the LCLUC program. Other NASA programs, such as the Carbon Cycle Program, the Terrestrial Hydrology Program and the Cryosphere Program, also support the NEESPI in various ways. In the near future, LCLUC issues relevant to the International Polar Year (IPY) will be one of the foci in the LCLUC program. Coastal zone processes in the Arctic, land use and its interaction with climate change in sub-Arctic, in particular at forests-tundra margins, hydrology of sub-Arctic watersheds, carbon cycle-permafrost interactions, energy exchange in boreal ecosystems, represent only a few potential NEESP contributions to IPY anticipated during 2007-2008.

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