The United States National Climate Assessment

Land Use and Land Cover National Stakeholder Workshop Technical Report

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Acronyms

AVHRR	Advanced Very High Resolution Radiometer
BLM	Bureau of Land Management
C	Carbon
C-CAP	Coastal Change Analysis Program
CGCM	Coupled Global Climate Model *or* Coupled General Circulation Model
CDL	Cropland Data Layer
CLU	Common Land Unit
CO_2	Carbon dioxide
CONUS	Conterminous United States
DOI	Department of the Interior
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
EPIC	Environmental Policy Integrated Climate model
EROS	Earth Resources Observation and Science
ERS	Economic Research Service
ES(D)	Ecological Site (Description)
ETM+	Landsat 7 Enhanced Thematic Mapper Plus
FASOM	Forest and Agricultural Sector Optimization Model
FEMA	Federal Emergency Management Agency
FIA	Forest Inventory and Analysis
GAO	General Accounting Office
GAP	Gap Analysis Program
GFDL	Geophysical Fluid Dynamics Laboratory
GHG	Greenhouse Gas
FAC	Federal Advisory Committee
FCIC	Federal Crop Insurance Corporation
FORE-SCE	Forecasting Scenarios
ICE	Image-based Change Estimation
IMAGE	Integrated Model to Assess the Global Environment
IPCC	Inter-governmental Panel on Climate Change
LCC	Landscape Conservation Cooperatives
LCMS	Landsat Change Monitoring System

LU/LC	Land Use and Land Cover
METORMEX	Metropolitan Meteorological Experiment
MLU	Major Land Uses
MRI	Meteorological Research Institute
MRLC	Multi Resolution Land Characteristics
MTBS	Monitoring Trends in Burn Severity
MTLC	Monitoring Trends in Landscape Change
NASA	National Aeronautic and Space Agency
NASS	National Agricultural Statistics Service
NCA	National Climate Assessment
NCADAC	National Climate Assessment Development and Advisory Committee
NCCWSC	National Climate Change and Wildlife Science Center
NDVI	Normalized Difference Vegetation Index
NED	National Elevation Database
NGO	Non-government organization
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NSF	National Science Foundation
NRCS	Natural Resource Conservation Service
NRI	National Resources Inventory
OMB	Office of Management and Budget
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RCP	Representative Concentration Pathways
RSAC	Remote Sensing Application Center
RMA	Risk Management Agency
RPA	Resource Planning Act
SMAP	Soil Moisture Active Passive
SRES	Special Report on Emission Scenarios
TCC	Tree Canopy Cover
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
USFAS	United States Forest Assessment System

USFPM	United States Forest Products Model
USG	United States Government
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGCRP	United States Global Change Research Program
USGS	United States Geological Survey
VCF	Vegetation Continuous Field
WELD	Web-Enabled Landsat Data
WUI	Wildland-Urban Interface

Executive Summary

National Climate Assessment

The 1990 Congress enacted the Global Change Research Act, which established the U.S. Global Change Research Program (USGCRP). Every four years the USGCRP is required to prepare an assessment of the impacts of climate change on a variety of resources and economic sectors. In addition, the USGCRP analyzes and reports on global trends that could affect these same areas for the subsequent 25 to 100 years. In preparing the 2013 National Climate Assessment (NCA) report it was decided that creating a process that coordinates climate assessment related activities on a sustainable and continuous basis needed to be included. To help direct this on-going effort, the NCA has established a Development and Advisory Council (NCADAC). This group is composed of more than 60 climate change science and management leaders. To provide support for the decision-making process across the United States, the NCA is encouraging an inclusive, broad-based, and sustained process for assessing and communicating scientific knowledge of the risks, impacts, and vulnerabilities of the United States due to changing climatic conditions.

For the first time since the enactment of the Global Change Research Act, the 2013 NCA report will address connections and interactions across both sectors and regions. One cross-cutting topic discussed is Land Use and Land Cover (LU/LC) change. The inclusion of LU/LC as a separate chapter of the 2013 NCA report reflects the consensus that understanding LU/LC changes and their interactions with climate change is essential for food and energy security, clean water, and "smart growth" planning that recognizes that land is a fixed supply and should be allocated to the most appropriate and sustainable uses. While land use and land cover are often related, they are not interchangeable. For example, after a timber harvest land cover has changed, but the land use of that area usually has not changed. In addition, multiple land covers can occur within a single land use, and there can be multiple uses on a single parcel of land. Understanding changes in both land use and land cover are important to policy makers seeking to develop policies that address the expected impacts of changing weather patterns and growing carbon emissions while sustaining the health and productivity of all landscapes.

LU/LC Stakeholder Workshop

To address the data needs and technical input for the LU/LC chapter of the 2013 NCA, the U.S. Forest Service (USFS) and U.S. Geological Survey (USGS) organized a stakeholder workshop in Salt Lake City, Utah from November 29 to December 1, 2011, with the goal of understanding how LU/LC changes are interacting with changing climates and human societies. The workshop included land use-land cover science and policy experts from U.S. government agencies, academia, tribal lands, the NGO community, and other stakeholder groups. Presentations included discussions on how current and future LU/LC changes have and will alter climate and other environmental, economic and social systems and in turn, how those changing conditions will impact LU/LC. This is the first time the NCA has explicitly investigated climate change and land use-land cover issues as a separate topic nationally.

This report summarizes the presentations and discussions of the workshop. Stakeholder presentations are divided into three main topics: LU/LC mapping and monitoring; LU/LC modeling, scenarios and projections; and climate change and LU/LC. In addition to presentations, breakout groups discussed several key issues in LU/LC, such as trends, sensitivities, interactions with climate, key decision makers, data and gaps. Finally, participants discussed strategies for creating continuity in the LU/LC sector of the NCA in order to support the goal of a sustained NCA process.

The goal of this report is to provide technical input for the NCA's Land Use and Land Cover chapter and to summarize stakeholder discussions that took place at this initial workshop. Another technical report on LU/LC and climate change is being prepared as additional input to the LU/LC chapter of the NCA 2013 report.

Key Ideas Presented By Stakeholders

LU/LC Mapping and Monitoring

Understanding LU/LC changes over space and time provides a means to evaluate the complex interactions between human and biophysical systems, to project future conditions, and to design mitigation and adaptive management strategies. LU/LC data are required for a number of applications, including: carbon accounting, greenhouse gas (GHG) reporting, biomass and bioenergy assessments, hydrologic function assessments, fire and fuels planning and management, public health, biodiversity, economic development, and forest and rangeland health assessments.

These multiple applications of LU/LC research and monitoring efforts involve several U.S. Government agencies and academia that collect and analyze LU/LC data, resulting in products for decision-making at various levels. Three efforts to monitor LU/LC on all U.S. lands were presented at the workshop. First, the National Land Cover Database (NLCD), sponsored by a multiple Federal agency consortium (Multi Resolution Land Characteristics - MRLC), has provided 30 meter resolution land cover for the U.S., derived from Landsat images, for almost 20 years. NLCD is widely used in thousands of applications in the private, public, and academic sectors, and will play an important role in a vast array of future assessments. Second, recent efforts led by the University of Maryland in College Park have developed a system for monitoring U.S. land cover changes using MODIS and Landsat data that are calibrated and validated using high spatial resolution data made available through RapidEye. And third, USDA's Economic Research Service (ERS) has been collecting and analyzing data from multiple U.S. agencies to produce the Major Land Uses (MLU) product every five years since 1945, providing state-level estimates of land in various uses for the entire U.S.

Many additional regional and sectoral LU/LC monitoring programs are also conducted. These include the following:

- The National Oceanic and Atmospheric Administration's (NOAA) Coastal Change Analysis Program (C-CAP) produces land cover and land change information for the coastal regions of the lower 48 states, and contributes the coastal expression of the NLCD products.
- USDA's Natural Resources Conservation Service (NRCS) conducts the National Resources Inventory (NRI) to map soil and other resource data on all non-federal U.S. land.
- The U.S. Forest Service (USFS) conducts an inventory of all U.S. forest land through its Forest Inventory and Analysis (FIA) program, as well as the NLCD's Tree Canopy Cover map for the U.S. The FIA National inventory provides carbon and national GHG estimates to the U.S. Environmental Protection Agency (EPA) for U.S. national and international reporting purposes in the climate change arena.
- USDA's National Agricultural Statistics Service (NASS) produces the annual Cropland Data Layer (CDL) for mapping and monitoring cultivated agricultural land.
- USFS and USGS work together on the Monitoring Trends in Burn Severity (MTBS) project, assessing the environmental impacts of large wildland fires and identifying trends in burn severity across the U.S.
- Through their NPScape program the National Park Service (NPS) uses existing datasets to conduct landscape scale analyses that extend beyond park boundaries in order to inform their general management plans and natural resources applications nationally.

- USGS produces a weekly Vegetation Drought Response Index (VegDRI) dataset to identify areas where vegetation is either stressed or vigorous.

In addition to these existing mapping and monitoring programs, there is an emerging effort to establish a monitoring system, known as Monitoring Trends in Landscape Change (MTLC), that can serve as an overarching framework for integrating both existing information systems as well as newly developed data sources. One part of the MTLC system is developing a national Landsat Change Monitoring System (LCMS) that provides land cover and land use change data on all lands within the U.S. for the longest possible historical period and annually into the future. Over the next two years an LCMS science team will be conducting a survey of existing data and efforts, identifying the greatest needs and gaps in landscape monitoring, and developing the initial algorithms needed for the project.

LU/LC Modeling, Scenarios, and Projections

Land use and land cover modeling can be useful for forecasting future LU/LC changes given various economic, population growth, ecological, and climate change scenarios, and the relative strengths of each factor in affecting LU/LC change. They can also be used to understand the implications of past or projected LU/LC changes on socio-economic factors, natural resources, and carbon sequestration.

Three modeling efforts were presented during the workshop. USFS conducts land use forecasting for the decadal Resources Planning Act (RPA) resource assessment that explores the land use implications of various scenarios for economic and population futures in the U.S. USGS has also developed specific regional scenarios based on International Panel on Climate Change (IPCC) Special Report Emissions Scenarios (SRES) and scenario-based regional land cover forecasts. Finally, researchers at Ohio State University have linked two global models- a dynamic vegetation model and a dynamic model of forest timber markets and land use- in order to understand and predict land use change impacts on timber markets and forest carbon sequestration. There may be other independent efforts underway that merit recognition as well and will need to be factored into the NCA discussions in the 2013 Report and in future NCA Reports as these discussions mature.

Climate Change and LU/LC

Several workshop presentations focused specifically on the interactions of climate change and LU/LC, including how LU/LC changes are being impacted by a changing climate, how downscaling LU/LC-related climatic data and projections are needed for addressing climate risks and vulnerabilities, the carbon implications and accounting in LU/LC change, and some emerging issues in LU/LC and climate change.

LU/LC changes are impacting and being impacted by climate change. To understand LU/LC changes prior to 2000, the USGS has used an ecoregion-based sampling strategy along with Landsat imagery to document ecoregional rates and drivers of change from 1973 to 2000. That study shows a gradual reduction of forest cover and cropland, significant increases in grassland and shrubland, and a steady increase in developed land. However, this study also shows that there is significant geographic variability in U.S. land cover change characteristics. Studies have also linked observed LU/LC changes to climate impacts. For example, vegetation changes in the Western U.S. detected through remote sensing are partially due to increased fires, insect infestation, and drought linked to climate change. While climate changes impact LU/LC change, LU/LC changes also impact climate; for example, strong LU/LC contrasts near urban areas in the Midwest increase warm season precipitation and intensify thunderstorms in downwind areas.

The impacts climate change and LU/LC change have on human populations, and options to deal with these impacts, were also discussed during the workshop. Even with significant mitigation measures, society will face increased climatic hazards for at least several decades. To effectively plan for these hazards there is a need to understand downscaled climatic data and its applicability to local and regional conditions, identify the areas that will be exposed to hazards, and identify vulnerable populations and infrastructure. Optimal actions to deal with these hazards are not yet clearly defined, largely because of difficulties in identifying the location of and magnitudes of vulnerabilities and future exposure to climate-related hazards.

Since LU/LC change affects carbon emissions and sequestration, multiple agencies collect and analyze data for understanding the carbon implications of LU/LC change. USFS estimates forest carbon stocks and fluxes annually for the U.S. for both national estimates and international reporting under the United National Framework Convention on Climate Change (UNFCCC); forestland carbon offsets approximately 16 percent of U.S. GHG emissions. During the next few decades, Eastern forests are expected to continue to sequester C through favorable response to elevated CO_2 and higher temperature, while Western forests may begin to emit C through expanded fire and insect disturbance. The EPA coordinates the submission of the country's annual GHG inventory to the UNFCCC following International Panel on Climate Change (IPCC) guidelines, and includes the estimates provided by USFS for the forestry sector. IPCC guidelines require annual reporting of LU/LC change. The National Land Cover Database, National Resources Inventory, and Forest Inventory and Analysis datasets are all used for compiling and reporting LU/LC change and the resulting carbon implications.

Key Findings from Stakeholder Discussions

The third day of the workshop was devoted to gathering input from all participants on five key LU/LC questions.

The first question addressed the primary trends in LU/LC and how they interact with climate change to affect ecosystems, human health, economics, and social well-being. Participants emphasized that the accurate quantification of LU/LC change is complex since it is difficult to definitively attribute LU/LC changes directly to climate variations; many other factors such as policies and natural processes also affect change. Nevertheless, there was some consensus on natural, agricultural, and developed land trends in LU/LC, while acknowledging that regional differences in these trends can be large in the U.S. LU/LC changes linked to climatic variability and impacts from stressors such as warming, droughts, fire, and insects, are affecting ecosystems in terms of their biodiversity, resiliency, and other complex measures. Participants also discussed how LU/LC and climate change interactions are adversely impacting human health, such as in urban heat islands where heat-related deaths can occur, and social and economic well-being, such as by intense storm events that impact large populated areas and result in high economic loss.

The second question addressed the sensitivities of different land uses and regions to climate change, and what LU/LC adaptations can occur to mitigate negative impacts. Four important themes emerged from this discussion: 1) accurately downscaling modeled climate data to a landscape level is essential for understanding localized LU/LC sensitivities to climate change and determining appropriate adaptations; 2) economic considerations from local to national levels often drives decision-making; 3) focusing on short-term versus long-term priorities can result in opposing decisions; and 4) local to national policies have a significant impact on LU/LC change. Participants identified several land areas with high sensitivity to climate change, including forestland, agricultural land, areas where fire plays an important role in driving landscape level vegetation dynamics and use, coastal areas, high latitude areas such as Alaska, areas affected by climate-related hydrological changes, and tribal lands which may be affected by a patchwork of tenure and land uses. Some adaptations identified to address these sensitivities were effective land management planning, sustainable land use planning specifically designed to address local and regional impacts of climate change and related stressors, sustainable landscape and urban design, valuation of ecosystem services, and farmland protection policies.

The third question addressed the effects that LU/LC changes are having on weather and climate and vice versa, and how these impacts might affect future decisions and goals related to LU/LC. To approach this question an important distinction was made between biophysical and sociophysical drivers and responses, where biophysical drivers are primarily related to land cover, and sociophysical drivers are primarily related to land use. The discussion was classified based on NCA sectors: Water Resources, Agriculture, Forestry, Ecosystems, Transportation, Human Health, and Energy Supply and Uses. In each sector participants discussed how weather and climate interact with both biophysical and sociophysical processes in these sectors, and what the potential approaches are for addressing the impacts on each of these areas.

The fourth question targeted identification of the LU/LC decision-makers and the tools necessary for them to make informed decisions. Participants identified both public sector and private sector decision makers, and noted that the States, private land owners, and tribes need to be a focus for outreach on LU/LC and climate change planning. Four main themes emerged regarding decision-making tools: 1) potential risks and uncertainty regarding climatic variability and the robustness of predictions needs to be well-communicated; 2) the economic impacts of various decisions need to be evaluated and communicated; 3) specific examples where climate change impacts are being observed should be emphasized; and 4) traditional knowledge should be linked with scientific knowledge for informing decisions. Participants noted that decision-makers need access to tools that translate the best available science into understandable climate change scenarios and outputs, such as through web-based visualization tools.

The fifth and final question addressed the effectiveness of current LU/LC tools, the availability of data for decision making, and the perceived gaps that affect the decision-making matrix. Participants agreed that the U.S. has more comprehensive land cover data than land use data. In terms of processes for analyzing and using data, participants made several important observations: 1) it may not always be possible to understand why changes are occurring even where it is possible to document LU/LC change; 2) a national framework needs to enable data collection and analysis to meet regional and local needs, and ways for local data to feed up into a national framework, especially in sectors where on-the-ground national inventory and monitoring programs do not exist; and 3) continuity of data collection needs to be a sustained priority. Participants identified gaps in data and tools, including lack of LU/LC data to match older climate and population data for comparative analysis, lack of socioeconomic data linked to land use and land cover data, and limited understanding of when land use change does/does not result in land cover change. Process gaps were also identified, such as policy issues that prevent dissemination and exchange of many datasets among agencies, and from national to local levels and vice versa. Participants also discussed two new tools that could help decision-makers: valuation of ecosystem services and web-visualization.

Creating a Sustained NCA Process for the LU/LC Sector

Since one of the goals of the current NCA process is to create a sustained process for assessing climate change, on the final day of the workshop participants discussed strategies for creating continuity in the LU/LC sector of the NCA. They discussed possible models of interagency collaboration that could be used for the continuous collection and analysis of LU/LC data. In addition, participants made two main recommendations that would facilitate a sustained process: 1) Define goals of where we want to be in several years, and what we need to get there, in order to determine where to make investments; and 2) Invest in data synthesis efforts.

National Climate Assessment

The United States Global Change Research Program (USGCRP) has been tasked with providing a coordinated strategy and implementation plan for assessing the changing climate and potential impacts on the nation. This strategy is being developed with the intent to both provide critical support to the third National Climate Assessment (NCA) and establish a mechanism for an ongoing assessment capability. It is expected that an ongoing NCA process will be established and sustained through a cooperative effort that incorporates a multitude of Federal, State, local governmental agencies, tribes, non-governmental organizations, and private interests. The NCA process should lead to enhanced coordination of the various climate assessment efforts and create a strong linkage between stakeholders and data providers. Once an ongoing assessment capability has been established, it is expected that assessment reports will be produced on a more regular basis, with less emphasis on producing a single major report every four years.

The National Climate Assessment Development and Advisory Committee (NCADAC), a Federal Advisory Committee (FAC), is charged with conducting the assessment. It is comprised of approximately 60 individuals from academia, the non-profit sector, industry, and the Federal government. The NCADAC will examine a variety of inputs from scientists and regional and sectoral assessment data and reports, collectively termed technical input products, to build chapters for the 2013 report. They are also tasked with encouraging an inclusive, broad-based, and sustained process for assessing and communicating scientific knowledge of the impacts, risks, and vulnerabilities of a changing climate in support of decision-making across the United States.

Assessment Process Guidance

The NCADAC has established a number of working groups that are developing guidance on various topics for the assessment process, including: risk-based framing; confidence levels and uncertainty; documentation, information quality, and traceability; engagement, communications, and evaluation; adaptation; international/global context; scenarios; and sustained assessments and research needs. Technical input teams are being asked to use this guidance as they prepare their products for submission to the NCADAC.

The NCADAC has also established a working group to identify a system of indicators. This working group has established a basic framework to ensure that the suite of indicators chosen will include a relatively small number of policy-relevant indicators designed to provide a consistent overview of major trends and variations in climate impacts over time. There will also be an effort to ensure that physical, societal, and ecological indicators are well integrated.

Risk-Based Framing

The NCA encourages using a risk based framework for framing the sectoral and cross-sectoral areas under discussions. Risk is the product of likelihood and consequence. Risk management can be based on either quantitative or qualitative representations of likelihood and consequence; however, a written traceable account to sources used and the rationale behind the quantitative and qualitative judgments, respectively, must be provided. Iterative risk management is a concept in which implemented adaptation and management plans are revisited regularly following monitoring and assessment.

For example, the NCA Forestry Sector Report includes a risk assessment framework for species range shifts, wildfire, water, carbon and wildlife which has helped frame the discussions under these sections in terms of risks and consequences to aid decision-making. Another specific example of incorporating this framework can be taken from the New York City Panel on Climate Change (Rosenzweig et al. 2009).

The frequency of days in which air temperature will exceed 90°F is forecasted to increase from a baseline of 14 per year, to 23–29 per year in the 2020s, 29–45 in the 2050s, and 37–64 in the 2080s. The range is dependent upon future greenhouse gas emissions and the decisions taken in the near-term. As time progresses, the likelihood of impact on city infrastructure increases from low to high, and the magnitude of consequence increases from medium to high. Risk management actions would therefore progress from a "watch" state to a state in which strategies are developed to mitigate the impact.

The Current NCA

The current NCA approach differs in multiple ways from previous U.S. climate assessment efforts, being more focused on: 1) supporting the Nation's activities in adaptation and mitigation and on evaluating the current state of scientific knowledge relative to climate impacts and trends; 2) a long-term, consistent process for evaluation of climate risks and opportunities and providing information to support decision making processes within regions and sectors; and 3) establishing a permanent assessment capacity both inside and outside of the Federal government. The NCA will therefore be an ongoing process that draws upon the work of stakeholders and scientists across the country. Assessment activities will support the capacity to do ongoing evaluations of vulnerability to climate stressors, observe and project impacts of climate change within regions and sectors, allow for the production of a set of reports and web-based products that are relevant for decision-making at multiple levels of space and time, and develop consistent indicators of progress in adaptation and mitigation activities. Products of the NCA process should be useful within management and policy contexts.

In addition, the 2013 NCA report will for the first time address connections and interactions across sectors and regions through multiple cross-cutting sector chapters, including one on Land Use and Land Cover (LU/LC).

LU/LC Stakeholder Workshop

To address the data needs and technical input for the LU/LC chapter of the 2013 NCA, the U.S. Forest Service and U.S. Geological Survey (USGS) organized a stakeholder workshop in Salt Lake City, Utah from November 29 to December 1, 2011 (see Appendix A for Workshop Planning Committee members). The workshop featured presentations and discussions around LU/LC that were identified as important for the NCA at pre-workshop framing and planning discussions that included representatives from the Federal government, academia, NGOs, and management.

The goal of this workshop was to understand how LU/LC changes are interacting with changing climates and human societies. Discussions and presentations included how current and future LU/LC changes have and will alter climate and other environmental, economic and social systems and in turn, how those changing conditions will impact LU/LC. This is the first time NCA has explicitly investigated climate change and LU/LC issues. The workshop included experts in land use and land cover from U.S. government agencies, tribal lands, the NGO community, academia and stakeholder groups (see Appendix B). Through presentations and break-out sessions (see Appendix C), the discussion centered around the following questions:

- What is the status of LU/LC and what are the primary trends in LU/LC change?
- Of these trends, which sectors and regions are most affected by weather and climate variability? What land uses and regions are more or less vulnerable, and what changes will occur or do we want to occur, to reduce mortality, morbidity, loss of property and loss of services?
- How are the composition and structure of land cover changing due to weather variability?

- How are land use practices adapting to climate change? How do we assess and mitigate climate related hazards by building on or influencing changes in development patterns, infrastructure, ecosystem structure and function, technologies or economic and social choices?
- How are LU/LC patterns and conditions affecting weather and climate?
- How effective are current land resource assessment data and practices in addressing the information and trend data needs required to understand the impacts of climate change on LU and LC? Are there gaps and, if so, how might these gaps be addressed?
- What tools are required by decision-makers to assess and implement mitigation and adaptation actions in this area?

This report summarizes the key ideas and discussions from the workshop. Another technical report on LU/LC is also being produced. Both of these reports will be key inputs to the LU/LC chapter of the NCA 2013 Report.

LU/LC and Climate Change

Our Challenge: Looking Ahead 50 Years

As climate changes, assuring food and energy security and clean water for a growing population—both here in the United States and abroad—will require finding the "right" balance among land uses and policies that foster sustainable management of associated land covers. Finding the "right" balance is about "smart growth" planning; planning that recognizes that land is a fixed supply and how it is allocated to various uses is a critical issue for policy makers at the local, tribe, State, and Federal levels.

Tensions currently exist among almost all land uses, and especially among urban/suburban land uses and agriculture, range, and forest land uses. Shifting land from one use to another creates impacts on the goods and environmental services that the land is providing. One example is subdivisions expanding into what were croplands, which forecloses crop production as an option and increases impervious surfaces that can create storm water runoff management issues.

Sustainable management of land covers not only requires managing existing forests and croplands more efficiently and productively to meet the wood products and food needs of a growing population, it also needs to focus on the environmental services that the land covers provide. For example, retaining an overstory of trees in a new suburban development can reduce power consumption for residential cooling, keep the trees sequestering carbon from the atmosphere, and increase quality of life for residents. Keeping trees growing in riparian zones in agricultural areas can reduce nutrient and sediment runoff into streams and improve fish habitat.

Land Use and Land Cover are Different Dimensions of the Landscape

At first glance, the distinctions between "land use" and "land cover" may seem clear, yet the difference between the two can cause some confusion. For national level discussions which encompass jurisdictional definitions based on Federal Agency mandates, it is important to acknowledge these differences especially when land cover, carbon and green house gas estimates are being prepared so that a nationally consistent set of estimates is made available for decision-making. A number of participants at the workshop, as well as report reviewers, urged for clarification as the terms are often used interchangeably by researchers working on LU/LC issues. A classic example here is the word "Forest." Is it a land use or a land cover? "Forest" is sometimes used as a land use, and sometimes as a land cover. Further, if timber is harvested from a "forest", is there a change in land use or just a change in land cover? If some trees are removed, opening up the overstory, then the percentage of "tree cover" in the "forest" has been reduced. But if the land management activity has been planned with the intention of allowing the harvested area to reseed naturally from the remaining trees or if seedlings are planted, then the land use—forest—has not changed even though there has been a change in the percentage of tree cover—a temporary change in tree cover until the new trees become established and their canopy closes. From an ecosystem management perspective, it is true that a temporary change in tree cover does affect the environmental services provided by the particular acres affected. However, results from longer term monitoring at finer scales need to be examined to determine the impacts to long-term sustainability of environmental services from the forest land use sector. U.S. forest inventory data at a national level indicate that there are no statistically significant changes that are likely to occur at a national level to forest cover in the long term from these activities, as long as these areas remain under "forest" use. Consider a situation where roadways are cleared and houses are constructed beneath a forest overstory. In this case there are changes both in the land use and in the percentage of tree cover. While it is true that the remaining trees may continue to provide some of the services they formerly did as part of an intact forest, the act of opening up the forest to residential or commercial development may create a more permanent, long-lasting reduction in the goods and services normally derived from an intact forest.

The point is that a clear taxonomy of land uses and land covers is needed that recognizes that not every acre of land in the forest land use is 100 percent tree cover, nor are trees absent from other land uses. Therefore, one must be careful when summarizing estimates of land use change and land cover change. In particular, the area of forest land use is highly unlikely to equate to the area of tree cover across any sizable landscape. Further, because all trees contribute to climate change mitigation through their removal and long-term storage of carbon dioxide from the atmosphere, it is not only the trees in the forest that are making a direct contribution, but trees in other land uses are also making contributions. Therefore, astute analysts and policy makers will pay attention to changes in both land covers and land uses since changing weather patterns affect both land uses and land covers.

What Is Driving Land Use and Land Cover Changes?

Large-scale social and economic changes are the most important drivers of land use trends. Looking back to the 1800s, large-scale immigration from Europe to the United States drove settlement westward from the original 13 colonies. Technological shifts enabled transportation, industrial, and residential fuel demand to shift in the 1880s from predominately wood to predominately coal. As a result, the acreage of forest land in the United States has varied less than 5 percent over the past 125 years. More recently, current major regional to national drivers include economics, globalization, technology, and public policy. At specific landscape levels suburban development patterns since the mid-20th Century have been strongly influenced by the emergence of the automobile and truck as transportation competitors to the railroad and the construction of highways in the post-WWII years facilitated use of these new dominating transportation technologies.

Land cover changes have been less influenced by these large-scale social and economic changes. But changing weather patterns for precipitation and air temperatures are projected to have greater influence on the presence and type of tree covers and the crops and varieties selected for production. Of course, tree species mixtures and crop selections will respond to economic conditions and policies, such as the emergence of a steady market for biomass energy. But the shifts in rainfall patterns and temperatures are likely to have a more widespread, and less controllable effect, than changing economic situations.

Therefore, policies must be sufficiently influential to alter land use choices and land cover choices into more sustainable and resilient uses and covers as the effects of changing weather patterns become more pronounced; however, the appropriate mix of policies to meet this challenge is likely to be complex, and context specific. Will it be easier and more effective to manage this transition to a more resilient and sustainable future using packages of incentives or packages of regulatory policies? Should the policies focus directly on land use and land cover decisions or should indirect, second-order influences be chosen as a more politically palatable approach for altering social and economic choices?

Consider for a moment the Conservation Reserve Program (CRP). This program used incentive payments to take sensitive land out of crop production and put it into continuous vegetative cover. This program met multiple objectives—lowering surplus commodity production, reducing environmental impacts, increasing wildlife habitat quantity and quality—and also enjoyed widespread political support. Developing such integrated policy proposals that meet multiple objectives and enjoy widespread political support will be a challenge for policy makers, landowners, and land managers seeking to mitigate the adverse effects of climatic changes. Managing natural ecosystems to improve resiliency, while at the same time providing a continual flow of food and fiber to improve food and energy security, will be challenging.

The Bottom Line

Land use and land cover are different dimensions of the landscape. Changes in both are important to policy makers seeking to develop policies that mitigate the undesirable effects of changing weather patterns and growing carbon emissions. Balancing these dimensions is critical to sustaining the health and productivity of forest, rangeland, and agricultural landscapes.

Finding the right mixture of incentives and regulations to create landscapes whose land use and land covers are both sustainable and responsive to social and economic needs will be challenging.

Providing the scientific foundation for those policy assessments and developing options is the role of the NCA.

Key Ideas Presented By Stakeholders

LU/LC Mapping and Monitoring

Land use and land cover play a significant role as drivers of climate and environmental changes. Understanding LU/LC changes over space and time provides a means to evaluate the complex interactions between human and biophysical systems, to project future conditions absent policy changes, and to design mitigation and adaptive management strategies. LU/LC data are also core to applications including: carbon accounting, GHG reporting, biomass and bioenergy assessments, hydrologic function assessments, fire and fuels planning and management, forest and rangeland health assessments, conservation, public health, and economic security.

These multiple applications of LU/LC research and monitoring efforts involve several U.S. Government agencies and academia that collect and analyze LU/LC data, resulting in products for decision-making at various levels. Specific efforts that were presented during the workshop are discussed below and summarized in Table 1.

Efforts Covering All U.S. Land

1. The National Land Cover Database

The National Land Cover Database (NLCD), sponsored by a multiple Federal agency consortium (Multi Resolution Land Characteristics - MRLC), has provided 30m-resolution land cover for the U.S., derived from Landsat images, for almost 20 years. Their four major data releases include a circa 1992 conterminous U.S. land cover dataset (NLCD 1992), a circa 2001 50-state/Puerto Rico land cover database with three thematic layers (NLCD 2001), a change product designed to facilitate direct comparison between NLCD 1992 and NLCD 2001 (NLCD 1992-2001 Land Cover Change Retrofit) and a circa 2006 conterminous U.S. update of land cover and imperviousness products that quantifies change between 2001-2006 (NLCD 2006). With the release of NLCD 2006, the NLCD now provides national monitoring of land cover change on a five year cycle. Accuracy assessment for the NLCD 2006 product is currently underway. These data provide a valuable portrayal of U.S. land cover composition – overall, and regionally (Figure 1)- and the ability to monitor land cover change by land cover class over time (Figure 2).

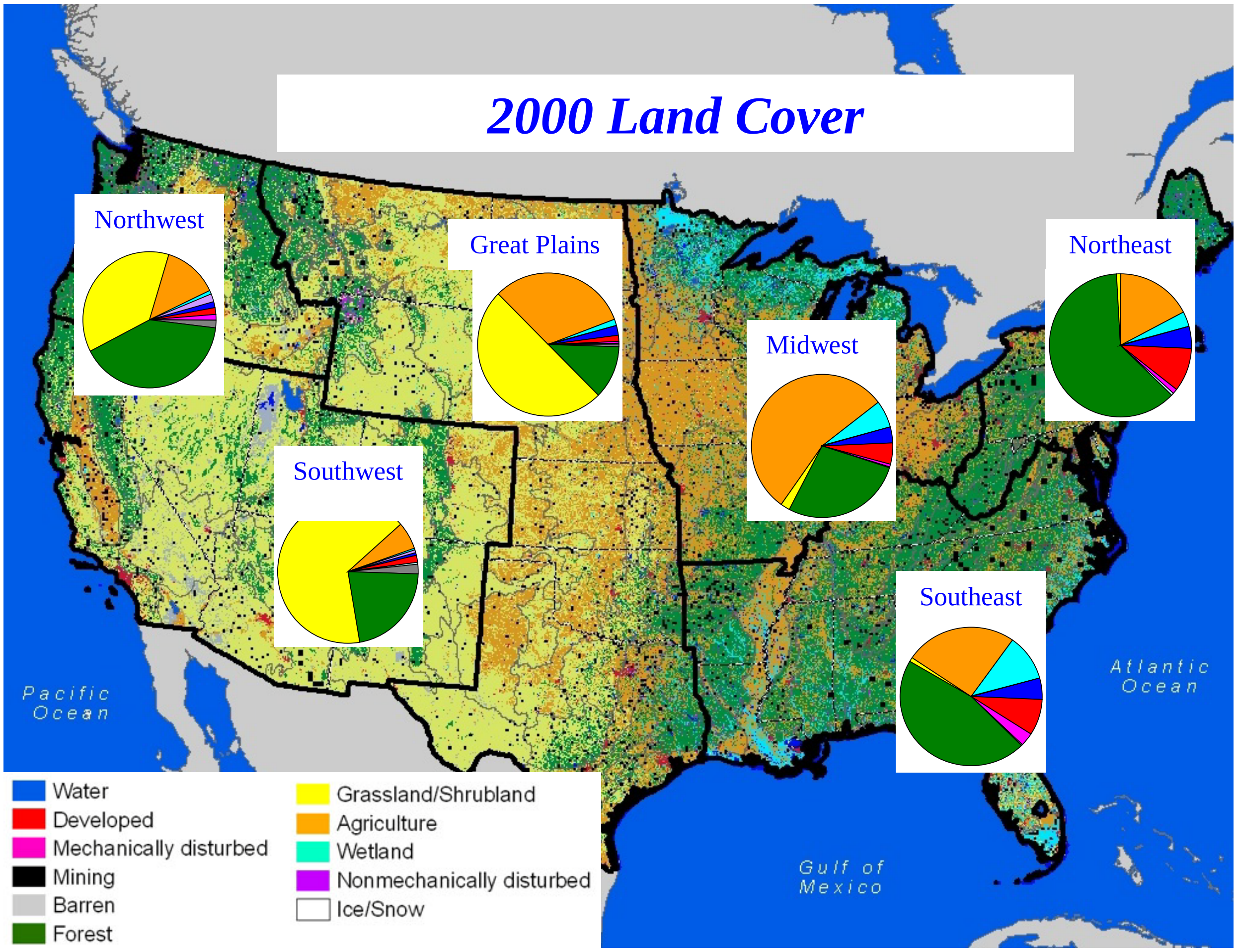

Figure 1: 2000 Conterminous U.S. Land Cover, nationally and by region, based on NLCD data (Source: Homer et al. 2004).

Research and development for the next iteration of NLCD products using Landsat imagery with a nominal date of 2011 is nearly complete. Operational prototype maps for several Landsat path/rows throughout the U.S. have been tested. Preliminary results show several improvements over previous maps, especially for agricultural and wetland classes where mapping protocols were revised to include additional ancillary data layers and derivatives in the classification process. Land cover change analysis and classification began in October 2011 with a target completion date in 2013.

NLCD is used in thousands of applications in the private, public, and academic sectors, and will play an important role in a vast array of future assessments.

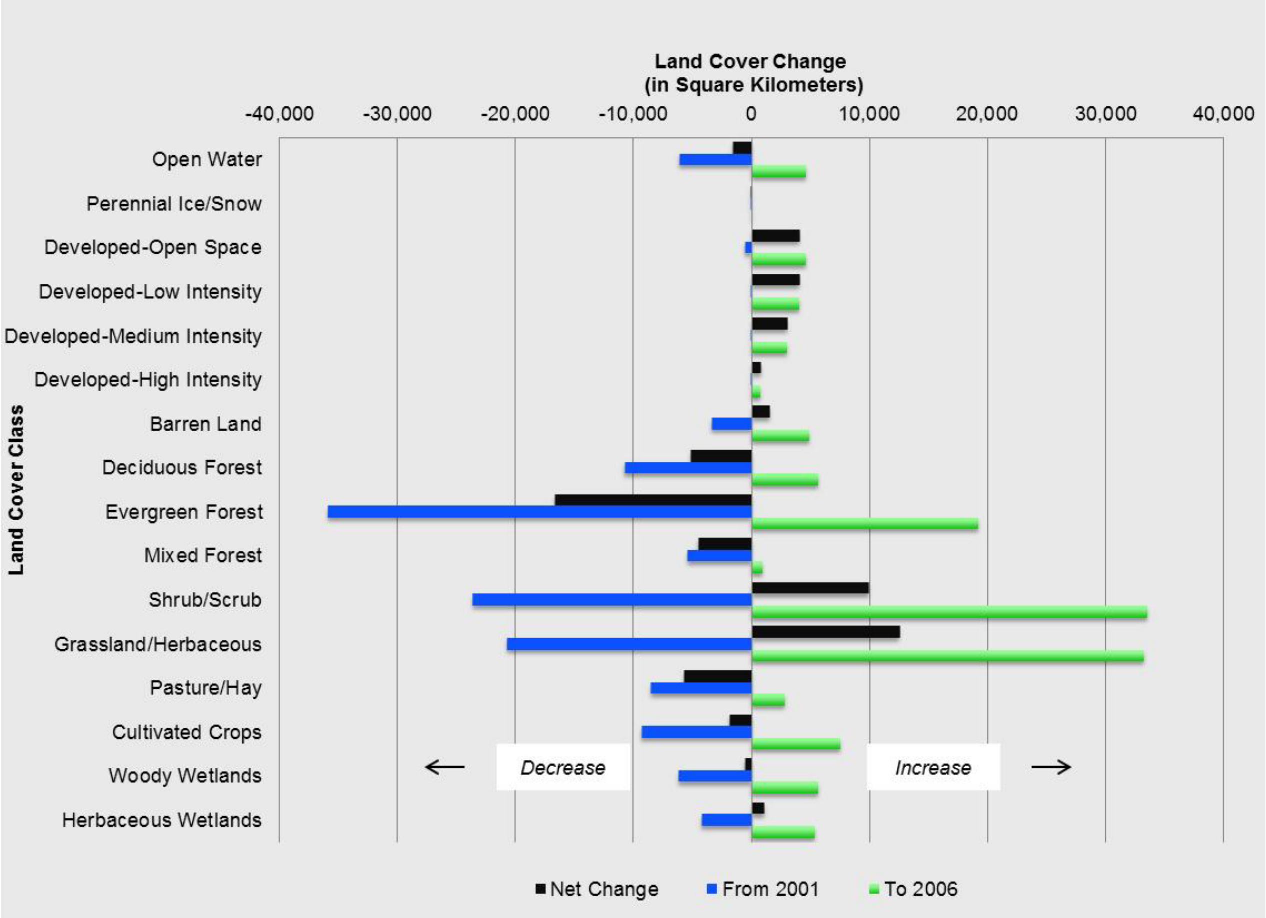

Figure 2: U.S. land cover change by land cover class from 2001 to 2006, using NLCD data (Source: Fry et al. 2011).

NLCD- Tree Canopy Cover

The NLCD-Tree Canopy Cover (TCC) layer is one of the primary tree-related national datasets. The percent tree canopy cover data layer is used to model and monitor change in tree cover in both forest lands and in areas not traditionally considered forest across the rural to urban gradient. Percent tree canopy cover is part of both international and U.S. forest land definitions. Knowing where trees are is an important first step in managing tree resources and quantifying carbon sequestration; it is an essential measure for assessing forest health and watershed condition; it is critical input for assessing fire fuels and fire behavior modeling; and it is a primary measure for evaluating the success of land management plans related to landscape restoration. It is also an important data element for characterizing fragmentation, which is one of the primary threats to biodiversity in forests. Beginning in 2011 the U.S. Forest Service Forest Inventory and Analysis (FIA) program is collaborating with the Forest Service Remote Sensing Applications Center (RSAC) to deliver the 2011 TCC data layer to the NLCD following a design that is explicitly linked to the FIA plot grid (see below) for consistent map-based and inventory-based forest estimates.

2. U.S. Land Cover Change Monitoring Using MODIS and Landsat

National-scale monitoring at moderate spatial resolution (10-100m) requires dependable data provision, including: 1) systematic acquisitions, 2) free data access, 3) easily accessible, and 4) pre-processed imagery. MODIS and Landsat data meet these requirements and can be used operationally to map national-scale land cover. MODIS has daily coverage at resolutions ranging from 250m to 1000m. A single Landsat sensor has 16-day repeat coverage of 30m imagery. For the U.S., every Landsat overpass is collected for both Landsat 7 and Landsat 5. Given regular and freely available data such as these, operational national-scale monitoring is possible. Two methods are discussed here.

The first is using MODIS data as an indicator product, whether for a specific land cover, such as forest or soybean cover, or for a change dynamic, such as forest cover loss or bare cover increase. MODIS-scale cover extent or change can be used to target sample-based analyses of Landsat data for estimating area for a given cover theme. For example, research shows the U.S. to have relatively high forest loss from 2000 to 2005 compared with countries that have greater than one million hectares of forest cover (Hansen et al. 2010). MODIS, with Landsat and very high resolution satellite imagery (e.g., RapidEye), can also be used for the mapping of crop type; for example, soybeans in estimating annual soybean cultivated area. This approach is very efficient and provides national to global scale area estimate with known uncertainty.

Large area monitoring products using MODIS have been produced for the entire record of MODIS data (1999 to the present). Borrowing from this experience, similar products can be generated from Landsat data, which are available from 1972 to the present. The second example for conducting national-scale monitoring with regular and freely available data is to use Landsat 7 data to characterize land cover and change at the national scale. Vegetation Continuous Field (VCF) layers of 30 m percent tree cover, bare ground, other vegetation and probability of water have been derived for the conterminous United States (CONUS) using Landsat 7 Enhanced Thematic Mapper Plus (ETM+) data sets from the Web-Enabled Landsat Data (WELD) project (Roy et al. 2009; Hansen et al. 2011). Turnkey approaches to land cover characterization were enabled from systematic WELD Landsat processing. Results illustrate the ability to perform Landsat land cover characterizations at continental scales that are internally consistent while retaining local spatial and thematic detail.

Per pixel processing of Landsat data, as with MODIS, is key to this method and relies on a robust quality assessment of each Landsat observation. Given a viable quality assessment system, all of the high quality land observations can be used to map national-scale land cover. The initial approach for quantifying change employed four years of WELD data, 2006 to 2010, to assure a national synthesis. Forest cover loss and bare ground gain were mapped over the period. Using a 30 percent cover definition of forest, pixels experiencing stand-replacement disturbance were mapped at the national scale. Results found the Southeast U.S. to be a region of intense agroforestry. The Mid-Atlantic and New England are relatively absent of forest cover disturbance, except Maine. The inter-mountain West exhibits large-scale dieback from Mountain Pine Beetle infestation and the Southwest loss from fire. The upper Midwest and Pacific Northwest exhibit loss due to logging[1]. The bare ground gain results highlight urban expansion, with a particular dynamic near airports. Outside of metropolitan areas, mining is a significant dynamic leading to more exposed bare ground. West Virginia and Kentucky are a

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[1] Causation of change patterns was determined by using ancillary information, such as pine beetle infestation reports, and spatial pattern analysis.

particular hot spot of this dynamic. Overall, results illustrate the viability of mass-processing for monitoring national-scale land cover change. Such products can inform carbon assessments when combined with carbon stock data and emissions models.

Regardless of the method, it is recommend to use very high spatial resolution data (<=5m), such as RapidEye to calibrate and validate Landsat-based area estimation. For many landscapes and change dynamics, Landsat pixels are mixed and preclude unambiguous area estimation. A probability-based sample of very high spatial resolution data can ensure robust area estimation with Landsat. For example, RapidEye was tasked during the peak growing season to inform estimating cultivated soybean cover using MODIS and Landsat data in the first method discussed above. RapidEye was recommended since it is the only system that provides a tasking capability that largely ensures data acquisition in narrow temporal windows. This is key to the calibration/validation procedure.

In summary:

- Operational monitoring of the United States for high-level land cover dynamics is achievable.
- An annual change product is the goal, but the quality of the results will depend upon the temporal density of the acquisitions.
- More robust validation protocols and investments are needed – data such as that from RapidEye are one way forward in quantifying uncertainty[2].

3. Major Land Uses

The Major Land Uses (MLU) data series is produced by USDA's Economic Research Service (ERS). ERS has been producing major land use estimates in the United States for over 50 years (Figure 3), and the related U.S. cropland used for crops series dates back to 1910. The Major Land Uses (MLU) series is the longest running, most comprehensive accounting of all major uses of public and private land in the United States. Since 1945 in roughly 5-year increments, ERS has combined and reconciled data from various agencies to develop state-level estimates of land in various uses for the entire U.S. Various agencies produce land use and land cover data but they differ widely in definition, collection criteria, and coverage. For example, the U.S. Forest Service produces forest land statistics, the Bureau of Land Management produces public grazing land acreage statistics and the National Agricultural Statistics Survey collects information on cropland and rangeland, but only if the land is classified as being "land in farms." Various other Federal and State agencies provide data on parks, fish and wildlife areas, roads, railroads, defense installations, and other categories. The MLU data series serves as the source of land use estimates in official publications including the annually produced Economic Report of the President[3] and the Statistical Abstract of the U.S[4].

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[2] Some workshop participants did not recommend using RapidEye due to its high collection costs, but instead view the freely available Landsat combined with the National Agriculture Imagery Program (NAIP), which provides 1 to 2 meter resolution, as alternatives. Other participants noted that ground data should also play a role in quantifying uncertainty.

[3] The 2011 report is available here: http://www.whitehouse.gov/sites/default/files/microsites/2011_erp_full.pdf.

[4] The 2012 abstract is available here: http://www.census.gov/compendia/statab/.

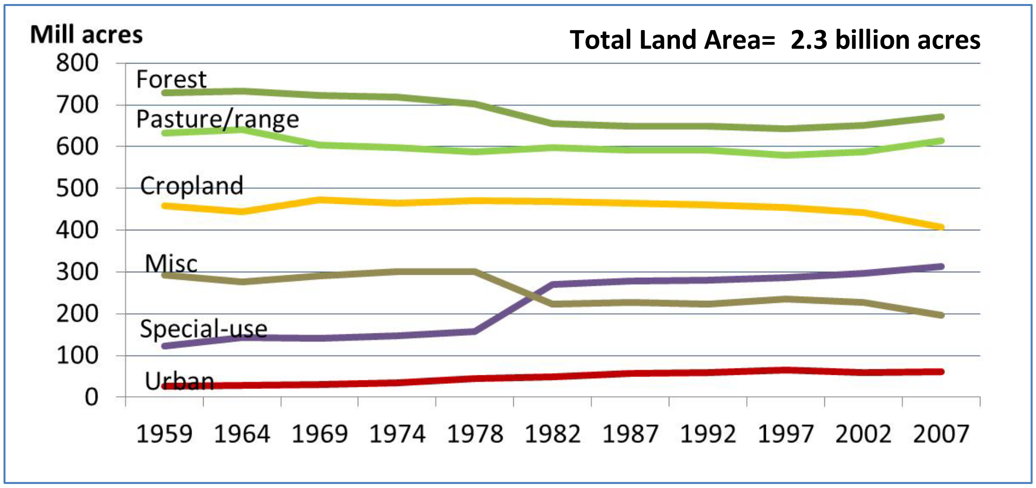

Figure 3. ERS Major Land Uses (MLU) series trends in all U.S. land (Source: Original, by C. Nickerson, created from Table 2 of Nickerson et al. 2011).

Regional and Sectoral U.S. LU/LC Efforts

4. Coastal Change Analysis Program

NOAA's Coastal Change Analysis Program (C-CAP; http://www.csc.noaa.gov/landcover) produces nationally standardized land cover and land change information for the coastal regions of the U.S. These products provide inventories of coastal intertidal areas, wetlands, and adjacent uplands (using documented, repeatable procedures) with the goal of monitoring these habitats every five years. C-CAP products are developed using multiple dates of remotely sensed imagery including Landsat and consist of raster-based land cover maps for each date of analysis, and data that highlight what changes have occurred between these dates and where the changes were located. This program has been in existence since the mid-1990s, and now has three dates of land cover information available (1996, 2001, and 2006) for all the coastal areas of the lower 48 states (as well as additional dates of historic land cover in several select coastal geographies). NOAA coordinates its land cover mapping activities with the MRLC Consortium and C-CAP contributes the coastal expression of the NLCD products.

In addition to these regional monitoring products NOAA has also developed a higher spatial resolution land cover product line. These products are developed as a compliment to those regional products for targeted hotspots where more spatial detail is required.

To make these data accessible to decision-makers and the public, NOAA has created web-based visualization tools that allow users to view regional land cover data, explore land cover changes and trends, and create maps of potential sea level rise and flooding. Some of the tools available are:

- C-CAP Land Cover Atlas - www.csc.noaa.gov/landcoveratlas
  Enables users to view regional C-CAP land cover data and explore land cover changes and trends
- Landscape Fragmentation Tool - www.csc.noaa.gov/digitalcoast/tools/lft/index.html
  Maps the type of fragmentation present in a specified land cover feature and produces a data set containing results
- Nonpoint-Source Pollution and Erosion Comparison Tool - www.csc.noaa.gov/digitalcoast/tools/nspect/index.html
  Examines land cover to measure runoff, nonpoint source pollution, and erosion (extension to ArcGIS with Spatial Analyst)

- Habitat Priority Planner - www.csc.noaa.gov/digitalcoast/tools/hpp/index.html
  Helps to identify priority locations for conservation and restoration planning (extension to ArcGIS with Spatial Analyst)
- Coastal County Snapshots – www.csc.noaa.gov/snapshots
  Coastal County Snapshots turn complex data into easy-to-understand stories, complete with charts and graphs.
- Sea Level Rise and Coastal Flooding Impacts Viewer – www.csc.noaa.gov/slr
  Creates maps of potential impacts of sea level rise along the coast and provides related information and data for community officials

5. Forest Inventory and Analysis

The Forest Inventory and Analysis (FIA) program of the USDA Forest Service, initiated in the 1930, is the nation's forest inventory across all land ownerships in the U.S. (http://fia.fs.fed.us/). FIA is managed by the Research and Development organization within the U.S. Forest Service in cooperation with State and Private Forestry and National Forest Systems. FIA maintains a national systematic sampling grid (Bechtold and Patterson 2005), with one sample plot every approximately 2,430 hectares. Data from this sample support FIA reporting in a number of different areas: forest area and location; the species, size, and health of trees; total tree growth, mortality, and removals by harvest; wood production and utilization rates by various products; and forest land ownership. Plots are surveyed every 5-10 years, but because the inventory is built upon an annualized panel design, rolling estimates of forest area and condition are continuously available. Several utilities for creating customized reports from survey data can be found at: http://www.fia.fs.fed.us/tools-data/.

FIA reports of the status and trends of U.S. forests include straightforward estimates of uncertainty at a variety of scales. These reports are central to the planning process for a variety of clients, including State Foresters, the forest industry, and the National Forest System. FIA also provides State-level forest area and carbon density information for the EPA-led greenhouse gas report submitted to the United Nation's Framework Convention on Climate Change (Figure 4). The contribution of carbon sequestration measured by FIA is large; it represents almost 70 percent of total sequestration across all U.S. land uses, and offsets approximately 16 percent of U.S. emissions.

FIA is also one of the largest providers of national-scale ecological indicator data. FIA measurements directly intersect with a number of climate-sensitive indicators, including: forest health, invasive species, ozone effects, and soil quality. Plot data are also foundational for national satellite-based mapping activities such as LANDFIRE[5] and NLCD, as well as NASA's upcoming Carbon Monitoring System. FIA is operational in every state (excluding the interior of Alaska), and looking forward, the long-term stability of its sample design and measurement protocols should supply the basis for nationally consistent climate change analysis across the country's forested ecosystems.

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[5] LANDFIRE is a joint USFS and Department of Interior effort to provide data products that facilitate national and regional strategic fire planning and reporting of fire management activities.

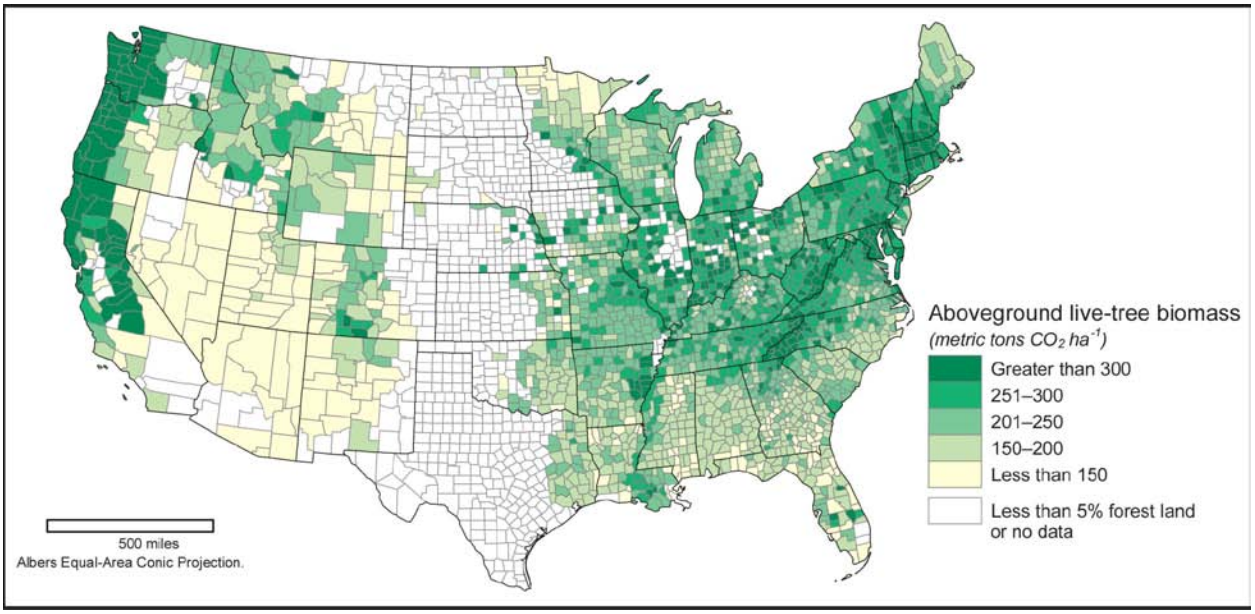

Figure 4. FIA survey data support estimates of forest characteristics such as biomass density, shown at the county level across the conterminous United States. FIA's design provides uncertainty context for every estimate (Source: Smith et al. 2007).

6. National Resources Inventory

The National Resources Inventory, conducted by USDA's Natural Resources Conservation Service (NRCS) in coordination with Iowa State University's Center for Survey Statistics and Methodology, is a longitudinal statistical survey of land use and natural resources on non-federal U.S. lands. NRI is designed to allow for analysis of soil properties and other resource characteristics, and show trends in the effects of human use and management of the land in order to inform agricultural and environmental policy development and program implementation.

The survey includes 800,000 samples sites covering all U.S. counties. Data methodologies include aerial photographs, on site protocols for ground data collection in various land types, farmer interviews, satellite data, and soils information. Three different classification systems are used- land cover/use, earth cover, and use of land- in addition to including data on vegetation composition, management practices, irrigation, and forest cover type. They collect data annually and release results every five years.

With these data NRCS has documented the following trends on non-federal lands: 19.3 percent of non-federal U.S. land, or 300 million acres, has undergone a land cover or land use change in the past 25 years; 40 million acres of land were newly developed between 1982 and 2007; 17.1 million acres of forests were developed; and 14 million acres of prime farmland have been lost since 1982.

For the past ten years NRI has also conducted non-federal rangeland surveys, the first results of which were released in 2010. They have also been capturing imagery on Federal lands for the past 10 years, plus data on Federal rangelands, but have not yet integrated these data into their products. Finally, NRI is working with Colorado State University on a soil monitoring network for carbon estimation/GHG reporting purposes.

7. Cropland Data Layer

The National Agricultural Statistics Service (NASS) produces an annual Cropland Data Layer (CDL) that is used throughout Federal and State government, universities, and the public for research, monitoring and assessing climate impacts on agriculture (Boryan et al. 2011). Beginning with the 2008 crop year, the CDL covers all 48 contiguous states. Prior to 2008, CDL production was concentrated on the Midwest, Great Plains, and Mississippi Delta Regions covering high value market sensitive crops. The CDL contains crop specific digital data layers suitable for geospatial analytics. The CDL Program annually focuses on producing digital categorized geo-referenced output products using imagery from the Disaster Monitoring Constellation, Resourcesat-1 AWiFS, and Landsat 5 TM satellites.

The 2011 operational CDL product had high classification accuracies with acreage estimates generated for 41 states and 18 different crops. The CDL is used to augment traditional surveys. NASS CDL estimates/statistics are one of many different estimates/indicators that come under review before the final number is published. Operational estimates are generated for NASS internal consideration for the statistical reporting process throughout the growing season. Early season winter wheat estimates were generated for the June Acreage Report, followed by corn and soybeans for the August Production Report, and corn, soybean, rice, and cotton for the September Production Report, all small grains for the September Small Grains Report and all crops and nearly all states for the October Production Report.

NASS relies on cooperation from a multitude of Federal Agencies to derive the CDL. The USDA/Foreign Agricultural Service provides access to their Satellite Imagery Archive for a set annual fee, providing growing season access to moderate-resolution satellite imagery. The USDA/Farm Service Agency provides the Common Land Unit (CLU) and associated 578 Administrative Data which contain current planted farmer signup data. The CLU and 578 data are linked together and serve as the basis for agricultural ground truth and this dataset is updated throughout the growing season. USGS provides the NLCD non-agricultural domain of the CDL process, and proportional samples are drawn from this dataset to separate the non-agriculture component. Additional USGS ancillary layers, i.e., percent imperviousness and percent forest canopy are utilized as well as the National Elevation Dataset (NED), to build an operational crop specific land cover classification.

In January 2011 NASS launched a web portal called CropScape, a new web exploring service to provide user access to the CDL (http://nassgeodata.gmu.edu/CropScape/). CropScape delivers data visualization tools directly into the hands of the agricultural community without the need for specialized expertise, GIS software, or high-end computers. This new service offers advanced tools such as interactive visualization, web-based dissemination and geospatial queries, and automated delivery to systems such as Google Earth. Future CropScape upgrades will include map printing, change detection, and cultivation masks.

The CDL is considered highly accurate in the agricultural domain, with higher accuracy in major crops that cover large areas, such as corn and soybeans. Accuracies can be expected to be in the high 80s to mid-90s percent accuracy throughout the country, given adequate ground truth and image acquisitions. The CDL is not evaluated for accuracy in the non-agriculture domain, as the sample points are drawn from the NLCD classification, with has its own level of accuracy. Land cover monitoring accuracies improve over time as methods evolve from new research and development efforts. It should be noted that the NLCD and CDL programs both use the same software and similar methods to derive their respective land cover classifications since the 2001 NLCD and 2007 CDL. Additionally, while satellite monitoring capabilities and analysis methods improve, it may be difficult to backcast prior results without similar sensors and techniques, but it would be regretful to degrade land cover science and statistical analysis when opportunities for improvement arise.

A four year national product is now available, and it is possible to derive a cultivated agriculture mask. These masks indicate the presence of prior cultivation activity. The cultivated mask project will focus on the following; building the most accurate state level cultivated data sets based on historical CDLs; effectively measure changes in cultivation over time; input to the NASS Area Frame stratification process – the basis of the June Agricultural Survey; and would serve as the basis for potential climate modeler inputs.

The CDL serves as the basis for other NASS geospatial applications once the area component is defined. NASS is operationalizing corn and soybean yield estimates in the major production states. NASS is working cooperatively with George Mason University on a Crop Progress and Condition NASA science grant to develop quantitative metrics to improve crop progress/condition analytics. NASS was selected by NASA as an "early adopter" for the forthcoming NASA Soil Moisture Active Passive (SMAP) mission to improve soil moisture metrics. NASS is also providing real-time remote sensing support for disaster assessment monitoring in flood, drought, hail, and other natural disasters. NASS also hopes to develop carbon monitoring capacity sometime in the future.

8. Monitoring Trends in Burn Severity

The Monitoring Trends in Burn Severity (MTBS) project, jointly implemented by the Forest Service's RSAC and the USGS Earth Resources Observation and Science (EROS) Center, has mapped severity, size, and other attributes of wildland fires nationwide from 1984 to the present using Landsat data (Eidenshink et al., 2007). The MTBS project (http://www.mtbs.gov/) was initiated in 2005 by the Wildland Fire Leadership Council to provide better information for monitoring the effectiveness and effects of the National Fire Plan (National Fire Plan 2004) and the Healthy Forests Restoration Act. MTBS data were specifically designed to assess the environmental impacts of large wildland fires and identify the trends of burn severity on all lands across the U.S. These data have been validated using pre-fire and post-fire measurements from FIA and related field plots. Fire effects on vegetation, biomass, and carbon stocks have been estimated and quantified. The MTBS project is a valuable tool for obtaining monitoring data used widely by the scientific and operations communities, and serves as a useful example of an interagency business model to operationally develop landscape change data.

9. NPScape- Monitoring Landscape Dynamics of Parks

The National Park Service uses available LU/LC data for monitoring change over time at a variety of scales. In Alaska, for example, NPS is monitoring glacier changes and ice phenology in the parks. In addition, NPS's Inventory and Monitoring (I&M) program (http://science.nature.nps.gov/im/) is looking at changes over time through a change vector analysis, or stacks of satellite imagery analyzed to understand fluctuations and changes over the landscape over time.

While the I&M program is focused on park lands, three years ago NPS began the NPScape program (http://science.nature.nps.gov/im/monitor/npscape/index.cfm) to conduct landscape scale analyses that extend beyond park boundaries using existing national datasets. The goal of the program is to set up processes where park staff and I&M networks can get online access to data and analyses that inform their general management plans and natural resources applications.

During Phase 1 of the program NPS determined which metrics to analyze, including measures on housing, population, roads, and land cover. Many measures were simplified; for example, land cover was divided into natural or converted. The data were then processed to provide acceptable products to the parks that help them understand the impacts of the various metrics on the Park Service lands.

NPS has also identified their future needs for LU/LC data in relation to climate change. These include: a continuous time series, both annually and seasonally; validated data; ability to attribute causes to observed changes by incorporating ground or ancillary data that improve understanding of why the change has occurred; comparison of climate change impacts on fragmented versus more intact ecosystems; data that go back in time as far as possible; data at appropriate spatial resolution for questions being asked; and classification detail that is appropriate for the scale being looked at.

10. VegDRI

In addition to investigations of land cover change, the USGS also addresses land condition. The weekly Vegetation Drought Response Index (VegDRI) dataset uses daily images from global polar orbiting satellites (NOAA AVHRR and NASA MODIS) to identify areas were vegetation is either stressed or vigorous. When combined with land cover data, VegDRI provides a valuable perspective on climate-related land cover issues. VegDRI products are available from 1989 to the present.

Table 1. Summary of the LU/LC mapping and monitoring efforts presented during the workshop.

Dataset	**Coordinating agency**	**Focus area**	**Data sources**	**Website**
NLCD	USGS	Entire U.S. land cover	Landsat	http://www.mrlc.gov
Monitoring using MODIS and Landsat	NASA	Entire U.S. land cover	MODIS, Landsat, Rapid Eye	N/A
MLU	ERS	Entire U.S. land use	Combines data from various agencies	http://www.ers.usda.gov/Data/MajorLandUses/
C-CAP	NOAA	Coastal regions land cover	Landsat	http://www.csc.noaa.gov/landcover
FIA	USFS	Forest area, type, health, above and below ground carbon for the conterminous US across all ownerships	Ground and satellite data	http://www.fia.fs.fed.us/
TCC	USFS	Tree cover	Landsat	N/A
NRI	NRCS	Soil/Land use on non-federal land	Aerial, ground, satellite	http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/nri
CDL	NASS	Cropland	Satellite data from multiple sources, ground data	http://nassgeodata.gmu.edu/CropScape/
MTBS	USFS/USGS	Fire area, severity	Landsat	http://www.mtbs.gov/

NPScape	NPS	Landscape monitoring within and around NPs	Uses existing datasets like NLCD, C-CAP, and others	http://science.nature.nps.gov/im/monitor/npscape/index.cfm
VegDRI	USGS	Drought monitoring	AVHRR and MODIS	http://eros.usgs.gov/#/Science/Climate_Change/Vegetation_Monitoring/VegDRI

Comparability of LU/LC Datasets

ERS Study

Agencies producing land cover data have utilized advances in satellite imaging and GIS techniques to offer comprehensive coverage and unparalleled detail on the distribution and pattern of land cover in the U.S. Several agencies produce these land cover statistics including NASS (the Cropland Data Layer), and USGS (NLCD). NRCS produces the NRI, which surveys all non-federal land. Yet in most cases, decision-makers are interested in how policies, market forces and other factors affect land use changes – which in turn can induce land cover change – and it is not always clear to what extent land cover can proxy for land use. For example, errors in satellite data increase for non-program crops (crops for which administrative data are not available to assign reflectances to land use types) and satellite data cannot readily distinguish between some land uses, such as grazed and ungrazed forests, or hayland and pasture.

An ERS project examined the comparability of land use estimates to several well-known land cover datasets. Comparisons between the MLU land use data series, NLCD and the NRI for several major land categories - at the national level for the 48 contiguous States - reveals some estimates are quite similar while others are very different. For example, after adjusting for major differences in cropland definitions and coverage, the correspondence between the estimates of cropland use and cropland cover is very close. The same is true for forestland, at least for the most recent 2002 and 2007 estimates. On the other hand, the three data sources yield very different estimates for pasture/range and urban/residential uses, even after adjusting for major differences in definitions.

Reasons contributing to differences in datasets include:

- Variability in definitions: Merging land use estimates from various sources requires understanding each source agency's set of criteria for classifying land in different categories.
- Precision: Individual agencies developing LU/LC estimates tend to focus on particular land categories resulting in varying degrees of precision in the estimates for different categories. Taken together, these issues can give rise to substantial overlaps and gaps when comparing and merging the estimates from different sources. Estimates of grassland pasture and range have less reliable data sources than cropland and forest-use areas, in part because these lands generally are not enrolled in farm programs – so administrative data are not available against which to benchmark the estimates. Thus, this estimate is particularly subject to revision when other data sources improve their estimates.
- Timing: Data are produced in different intervals, complicating comparability.
- Mapping vs. inventory approaches can produce different results.
- The geographic extent of the survey or map area varies across datasets.

Major Data Needs:

- Satellite data provide opportunities for annual updates to land use estimates, but there is a need to improve our understanding of how well land cover data captures land uses.
- Linking LU/LC data to socioeconomic data is critical. For example, linking information on market prices and factors affecting net returns to land in alternative uses is critical for modeling changes in land uses and in land cover transition probabilities. Also, ownership type matters since different owner types (private vs. government vs. tribal ownership) have different objectives when making land use and land management decisions.

Land use inventories and land cover inventories can provide estimates of all land uses/covers, and understanding how the two inventories relate to each other will be important. Natural resource surveys, such as the NRI, are a subset of the land use and land cover inventories and as such could have both land use and land cover characteristics attached to the data points. For a subset of NRI points, economic data, land management data and land ownership data would ideally be attached that would allow modeling the factors affecting both changes in land use and land cover.

NPS Study

As part of the NPScape program NPS conducted an analysis on the available national datasets, such as NLCD, LANDFIRE, National Gap Analysis Program (GAP) and Regional Gap Analysis Program (ReGAP), LandScope, and C-CAP, to understand their similarities and differences and draw some conclusions about how to use each one most effectively. To begin the analysis, NPS reclassified all the datasets to an Anderson Level 1 category, summed the areas by class, and looked for consistencies. Data were compared to the much more detailed I&M vegetation maps. Using an example from Rocky Mountain National Park, NLCD, LANDFIRE, ReGAP, and LandScope were compared within and around the park. Results revealed large differences in the datasets' classification of some lands, such as developed land, grasslands, and wetlands. Even though the raw data for these datasets is often the same, differences result due to different land cover definitions and the use of different models for interpreting images. There were also errors in the datasets, such as land classified as agriculture when it was in fact wetlands. However, since these national datasets were not intended for such local level use, this kind of error is expected.

NPS performed these comparisons for a handful of parks and came up with recommendations on which datasets were the most appropriate to meet different needs. NLCD was the most effective dataset for measuring change. Given the dynamic nature of the datasets and the regular improvements each of them are making, NPScape is planning to repeat these analyses.

Emerging Efforts

Landsat Change Monitoring System

USFS, USGS, and other agencies and partnering institutions have recently initiated the conceptual design of a hierarchical monitoring system known as Monitoring Trends in Landscape Change (MTLC). The MTLC system relies on the information content available in various remote sensing and in situ datasets and establishes an overarching framework for integrating both existing information systems as well as newly developed data sources. Workshops and meetings involving agency program sponsors and scientists have resulted in consensus that existing, largely independent systems can be integrated into a flexible, adaptive framework that operationally provides multiple scales of landscape change information with the consistency necessary for long-term monitoring.

One part of the MTLC hierarchy is the development of a framework for using remote sensing data that provides the most geographically and temporally comprehensive depiction of the earth's surface at a high spatial resolution (fine grain). An assessment of existing agency information requirements, data availability, and institutional activity suggests the greatest return on efforts to establish a national landscape change monitoring system will be in developing a Landsat-based information system. Characteristics that make Landsat data particularly well suited to comprehensive change monitoring include the longest data record of any synoptic optical satellite sensor (1984 to present), relatively fine spatial resolution (30 meters), spectral and radiometric properties that enable vegetation change detection, no-cost availability and accessibility, future data continuity, and a rich history of scientific investigation. Given the spatial and temporal extent, scalability, and widespread scientific and operational application, Landsat data currently provide the most cost-effective and established basis for a scientifically robust monitoring platform.

A workshop, co-sponsored by the USGS and the Forest Service, was held in Sioux Falls, SD at the EROS Data Center in November of 2010 to begin collaboratively developing the framework for a national Landsat Change Monitoring System (LCMS). The explicit objectives of the workshop were to: 1) bring together program managers, remote sensing scientists, and fire scientists to identify existing operational and scientific activities relevant to national change detection; 2) document the primary objectives of a proposed national LCMS program; 3) establish a baseline organizational framework for scientific, operational, and user participation; and 4) begin dialogue on integrating and enhancing existing program activities to meet national monitoring objectives. The results of this workshop, in conjunction with results from an earlier workshop held in Salt Lake City to discuss the MTLC concept, form the basis for the LCMS framework.

The principal objective of a national LCMS is to provide land cover and land use change data on all lands of the United States for the longest possible historical period and annually into the future. Design criteria of this system include:

- Coverage of all 50 states and U.S. territories
- Encompassing of all lands/ownerships/conditions
- Inclusive of all major human-caused and natural changes
- Historically consistent
- Annually current
- Methodologically adaptive & transparent
- Inclusive of compatible programs/data

In terms of next steps, over the next two years an LCMS science team will be conducting a survey of existing data and efforts, conducting an Independent Needs Assessment to identify greatest needs and gaps in landscape monitoring, and developing the initial algorithm/structure for the project.

Image-based Change Estimation

The recently developed Image-based Change Estimation (ICE) project is designed to respond to greater LU/LC change needs identified by the National Association of State Foresters (NASF). Specifically, a recent resolution from the NASF reflects both the importance of land cover change and land use change data in generating reliable estimates of change. The NASF resolution suggests an enhanced FIA program and specifically identifies the FIA program and the Remote Sensing Applications Center (RSAC) in suggesting a project of this nature. It specifically states: "Use of remote imagery to track harvest intensity, land-use change, and land cover change. This could be done in conjunction with RSAC and aligned State and Federal institutions" (NASF State Forester Resolution 2009-6). A pilot project was conducted last year and a prototype in Colorado and Georgia is currently underway.

Caveats in Remotely-Sensed Image Interpretation and LU/LC Classifications

Satellite images or aerial photographs can clearly show changes in land cover. For example, many medium to large-sized trees on an image from a prior point in time followed by fewer trees on a subsequent image indicates a decrease in tree cover. The core question is, what meaning do image interpreters ascribe to the change in tree cover observed? When a particular 160 acres is considered, the removal of trees is a shift in the location of the wood harvested—from standing trees to wood products, some of which may ultimately store carbon for a much longer time than if the trees were left standing in the forest. The removal also results in a change in the environmental services provided by that particular 160 acres. But that change is temporary, lasting as long as it takes for the new stand of trees to mature and provide similar services to the harvested trees. Over time, there will always be forests of different ages and sizes across the landscape, and a stasis reached where the environmental services provided across the landscape are continually flowing. Absent an ability to interpret what is happening across a landscape and over time, the interpretation of images from two points in time for a particular location may result in a short-term interpretation of what is actually happening across a landscape over the long-term[6].

Land cover and land use classifications can also be complicated by the fact that diverse land covers can occur within a single land use and vice versa. For example, forests are diverse ecosystems. Within most forests, open grassy glades are often found. In the Eastern U.S., it is not uncommon for crops to be planted in forests. Some State wildlife agencies and private owners deliberately create openings and plant clover, sorghum, corn, and brassicas to provide food for white-tailed deer. Those food plots show up clearly on remotely sensed imagery. Further, streams and ponds exist in forests—water land cover—and dirt roads and cabins occur in forest—human-built evidence of development activities, or in the case of dirt roads, perhaps just for fire protection. Often, these covers are not sufficiently large or prevalent across the forest to warrant making fine-scale distinctions or account for these different land covers as altering the basic land use classification—e.g. forest. Similarly, trees occur in agricultural land uses; windbreaks and shelterbelts around farmsteads or between fields reduce wind erosion and trees along streams mitigate runoff. Normally, these tree covers aren't sufficiently large to warrant identifying zones of forest land use within the agriculture land use. And one must not forget pecan and almond groves, fruit orchards, and Christmas tree plantations—all normally classified as agriculture land use, but with tree cover. Tree cover clearly exists in urban areas, in some places so large and so dense that "urban forests" are named. Therefore, astute analysts and policy makers will pay attention to changes in both land covers and land uses—because changing weather patterns affect both land uses and land covers.

An example of policies focused on tree cover is found in Maryland. The State of Maryland has a state-wide goal of "no net loss of tree cover." Montgomery County, Maryland zoning officials interpret that goal stringently. If even a small area with trees—5 to 10 thousand square feet—is cleared, the landowner must replant an equivalent area somewhere else on their property, or in a "tree bank" approved by the County, and a bond must be posted to assure the required planting density and survival rate of the trees planted over three to five years. This example of a regulatory approach focused on tree cover will have long-term impacts on sustaining the environmental services provided by trees in the county. But it's not clear that it will have a long-term impact on retaining a constant level of "forest" as a land use. The other side of this coin would be a policy that controlled growth through restrictive

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[6] One reviewer noted another limit in remote sensing- inference from reflectance values can lead to errors of omission and commission. Thus it is important to augment image-based inference with survey-based data such as NRI and FIA.

zoning of land uses but allowed complete liquidation of the existing over-story tree-cover. Both policies can rely on regulatory power, but that does not make them interchangeable and the ecosystem services implications for the alternative options may be substantially different.

LU/LC Modeling, Scenarios, and Projections

Land use and land cover modeling can be useful for forecasting future LU/LC changes given various economic, population growth, ecological, and climate change scenarios, and the relative strengths of each factor in affecting LU/LC change. They can also be used to understand the interactions of past or projected LU/LC changes with socio-economic factors, natural resources, and carbon emissions. Three LU/LC modeling efforts were presented during the workshop.

Land Use Forecasting: Linking Economic Drivers to Resource Implications

Land cover patterns reflect a multitude of land use decisions. Human uses of land define the mosaic of land cover, the condition of native ecosystems, and the flow of ecosystem services from managed and unmanaged lands (e.g., Chen et al. 2006; Sala et al. 2000). Predicting future landscape conditions and the flow of services from those landscapes requires an understanding of the choice dynamics that undergird land use changes. U.S. land use forecasts that organize the analysis of resource impacts are conducted by USFS for the decadal Resource Planning Act (RPA) resource assessments, as directed by the Forest and Rangeland Renewable Resources Planning Act of 1974.

Land use forecasting models developed for the RPA explore the implications of scenarios regarding economic and population futures in the U.S. Forecasts are rarely context free, and this land use forecasting has an explicit information setting defined by interacting models of demographic, macroeconomic, and climate changes called the U.S. Forest Assessment System (USFAS). The USFAS forecasts forest conditions in the United States, based on consistent FIA forest inventories (see Miles et al. 2001) applied across all states and driven largely by worldviews and climate projections developed by the IPCC (2007). Within the USFAS, land use projections are needed to define future forest area in the United States at the county scale as it responds to a relatively small set of driving variables determined by the interlinked models within which the analysis is nested. Land use forecasts also enter the analysis of resource conditions related to wildlife/biodiversity, water, and recreation.

Model Choice: Development of a land use model for the USFAS was guided by at least three important criteria. One was the ability to connect social/economic conditions to land use outcomes using empirical data—i.e., a model that reflected historical human choices. Another was a need to build the model projections from information contained in or readily derived from the IPCC scenarios. A third criterion was the ability to interface with the existing FIA forest inventory in a way that supported forecasting of future forest conditions in part determined by land use changes.

NRI data provided the foundation for the land use modeling because it provides the only source of comprehensive land use data measured at a common date. Land use models fit to these data evaluated land use change using a two stage approach with urbanization first being driven by changes in population and income levels. Rural land uses change in response to the urbanization dynamic and to differential returns to rural land use options. Separate models were estimated for each ecological section in the conterminous 48 U.S. Models were estimated using county-level land use totals to allow for links between the NRI land use changes and the area frame of the FIA forest inventory. For the latter, county forest totals are used to “expand” the thousands of field plots which comprise the population estimates for various forest attributes (see Wear 2011 for details).

Land use forecasts build directly from the IPCC Scenarios as downscaled to the U.S. RPA databases include county-level forecasts of population and income tied to the IPCC A1B, A2, and B2 emission scenarios[7]. Statistically downscaled climate projections are provided from three Global Circulation Models (GCMs) for each emission scenario. Market conditions for forest products are determined by an interacting U.S. Forest Products Model (USFPM; Ince et al. 2011).

Results: Estimated models indicate that urbanization dynamics dominate future landscapes. Urban area is forecasted to expand by 1 to 1.4 million acres per year between 1997 and 2060 depending on the forecasts of population and income, and this urbanization results in losses in other land use classes (Figure 5). Income interacts strongly with population in these forecasts, indicating that with higher incomes, additional population growth yields higher rates of urbanization. Forest land is forecasted to decline by 24 to 37 million acres and cropland and rangeland are forecasted to decline by 19 to 28 million acres and 8 to 11 million acres respectively over this period.

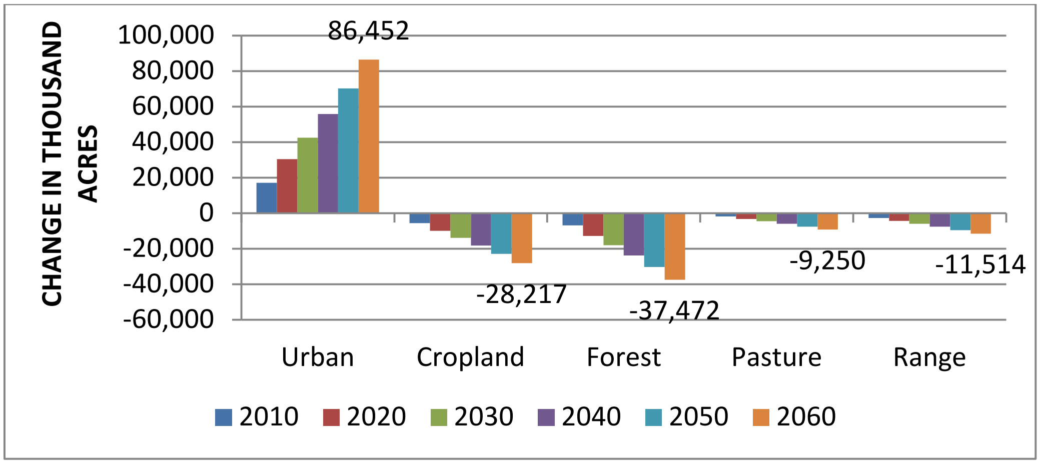

Figure 5. Forecasted LULC changes over time for the entire U.S. under the A1B scenario (Source: Wear 2011).

Land use changes are not evenly distributed across the regions of the U.S., reflecting the uneven distributions of current land uses and expected changes in human demographics and incomes. For example, about 90 percent of forecasted forest land losses are found in the Eastern U.S. and more than half of total losses are located in the Southeast (Figure 6). This is largely because population is forecasted to continue to grow most rapidly in the South. While the areas of developed land in the South and North were roughly equivalent in 1997, by 2060 the South's area of developed land could be 30 percent greater than that in the North (under the A1B scenario).

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[7] A1B scenario is characterized by: rapid economic growth; world population growth to 9 billion by 2050, then gradually declining; quick spread of new and efficient technologies; a convergent world where income and way of life converge between regions; balanced energy sources (fossil fuel-based and non fossil-fuel based).
B1 scenario is characterized by: rapid economic growth, world population growth to 9 billion by 2050, then gradually declining; less material consumption; increased clean technology; emphasis on global solutions to economic, social, and environmental issues.
B2 scenario is characterized by: moderate economic growth; moderate population growth (less than in A1B or B1); emphasis on local solutions rather than global solutions to economic, social, and environmental issues; less rapid and more fragmented technological change than in A1B or B1.

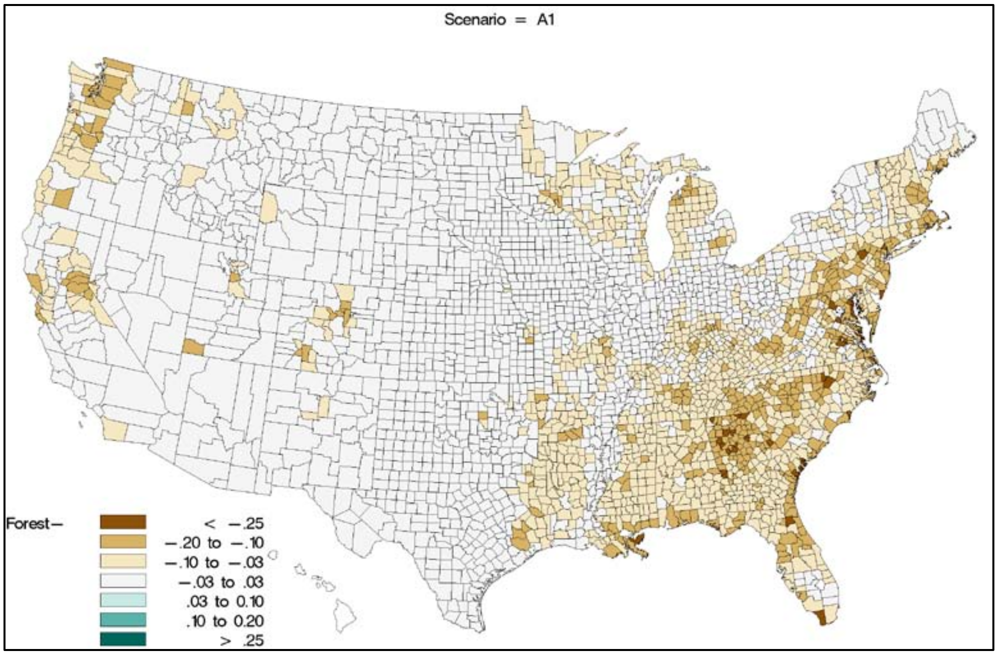

Figure 6. Forecasted change in the proportion of non-federal land that is forest (1997-2060) under the A1B scenario (Source: Wear 2011).

Conclusion: Historical land use dynamics indicate that useful predictions of land use and land cover require an accounting for basic social/economic dynamics. The current RPA land use models attempt to account for these in a way that can be bridged to broader scenarios regarding global futures. Future land uses clearly hold implications for future climate conditions. However, it is also true that climate changes could alter patterns of land use changes either through altered migration patterns of human populations, changes due to policy responses, or through climate effects on productivity for various rural uses (e.g., Schlenker and Roberts 2009). These factors have not yet been integrated into the RPA land use models (or other comprehensive land use models) and remain an important challenge for subsequent work.

Land use forecasts described here provide a foundation for national and regional assessments of forest conditions and ecosystem services conducted by the USFS. An important example is the Southern Forest Futures Project, a multi-year research effort that forecasts changes in Southern forests between 2010 and 2060 (Wear and Greis 2011). Building from the Southern Forest Resource Assessment completed in 2002, the project aims to provide information to land managers and policy makers about the future of Southern forests based on its forecasts. Using future scenarios, the Futures Project forecasts the effects of urbanization, bioenergy use, weather patterns, land ownership changes, and invasive species on the South's forests over the next 50 years and discusses how those influences may affect water, wildlife, fire, and other issues. More than 30 Forest Service scientists and experts from state agencies and universities used computer models and expert analysis to develop this first comprehensive look into the future of Southern forests. Public input from meetings in all 13 Southern states framed the study (Wear et al. 2009).

Past and Future U.S. Ecoregional Change

USGS's Climate and Land Use Change Mission Area has a substantial research and assessment focus on land change science – the interdisciplinary knowledge of the patterns, processes, and consequences of changes in land-use, land-cover, and land condition at multiple spatial and temporal scales that is associated with the interaction between human activities and natural systems. This emphasis considers the complex scale of land change, and especially how the impacts of local changes reach beyond the local scale, and can accumulate and have global impacts.

To understand changes prior to 2000, the USGS Land Cover Trends project has used an ecoregion-based sampling strategy along with Landsat imagery to document ecoregional rates and drivers of change from 1973 to 2000 (Loveland et al. 2002). That study shows a gradual reduction of forest cover, significant increases in grassland and shrubland (particularly from the mid-1980's forward), and a steady increase in developed land (Figure 7). It is also important to recognize that land cover change is a relatively rare event. An 8.8 percent average change rate between 1972 and 2000 means that the average annual amount of land that changes from one cover type to another is approximately 0.33 percent.

However, this study also shows that there is significant geographic variability in U.S. land cover change characteristics (Drummond and Loveland 2010; Drummond et al. 2012). For example, the ecoregions of the desert Southwest and the Blue Ridge of Appalachia experienced very low change rates (<3 percent overall) between 1973-2000, while some Pacific Northwest and Southeast ecoregions experienced very high change rates (>30 percent). Overall change rates for the 1973-2000 period ranged from 0.5-34.0 percent, and the average rate of ecoregion change was 8.8 percent. For the six conterminous U.S. NCA regions, the overall percent of land changed from 1973-2000 were:

- Northeast – 6.9 percent
- Southeast – 16.0 percent
- Midwest – 5.7 percent
- Great Plains – 8.7 percent
- Southwest – 4.0 percent
- Northwest 12.7 percent

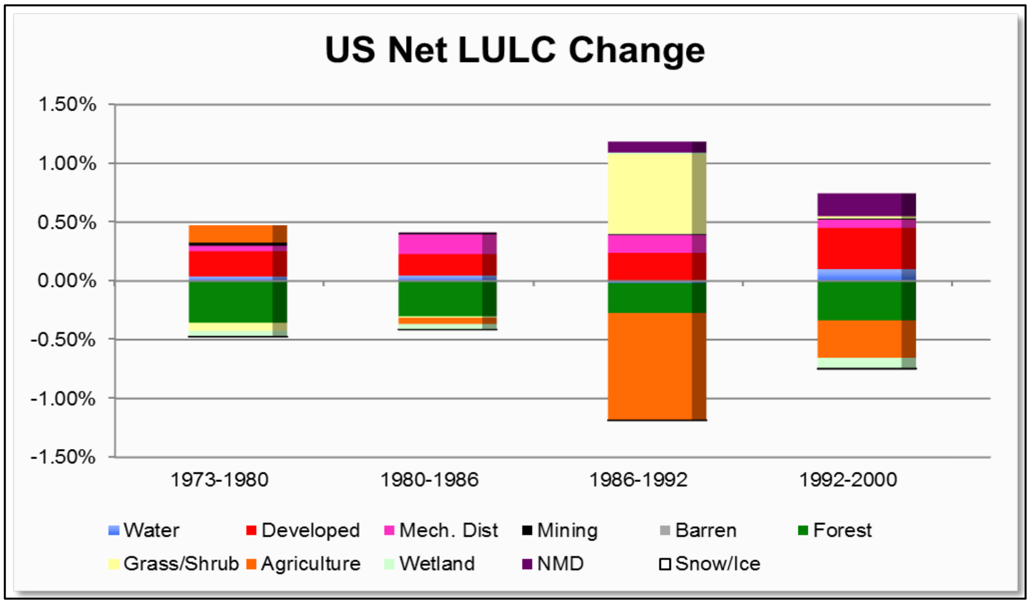

Figure 7: Net LULC change by LULC category in increments from 1973 to 2000 (NMB means "nonmechanically disturbed"). (Source: Original, by T. Loveland).

An accurate understanding of land cover and land use change can best be gained by looking at regional land change processes and characteristics since the interaction of geology, topography, climate, and other environmental conditions either restrict or enable certain types of changes.

As we look toward a process to assess the interrelated connections between climate and land use and land cover change, we need to recognize land use and cover changes occur because of the interaction of major drivers that are enabled or constrained by resource potential and settlement history. We must also recognize the link between use and cover. Changes in land cover impacts natural processes, including the exchange of energy and water with the atmosphere, and land use change, and the economics of land use decisions, can be significantly impacted by changes in weather and climate.

The USGS Land Cover Trends results are contributing to the development of regionalized IPCC- Special Report on Emission Scenarios (SRES) land use and land cover change scenarios for the U.S. The USGS LandCarbon Assessment was initiated in response to section 712 of the 2007 Energy Independence and Security Act (EISA) which called for the Department of Interior to estimate baseline carbon stocks and sequestration and future potential capacities while evaluating anthropogenic and natural controlling processes such as land-use change, climate change, and wildfire. Part of the EISA requirement was to develop and publish a peer reviewed methodology and prototype describing the future assessment which was completed in 2010 (Zhu et al. 2010). The methodology calls for development of a set of future LU/LC scenarios, consistent with future projected changes in climate, as the basis for the assessment. Identified scenario characteristics include:

- The underlying scenario framework is grounded in socio-economics.
- It should include both quantitative and qualitative components.
- The framework should serve as reference conditions and therefore be absent any integrated climate policies or assumptions.
- There must be corresponding climate projections from a range of circulation models.
- The framework should be scalable and transportable.
- Assumptions should be transparent and clearly articulated.
- The scenarios should not be predictive.

To meet these criteria the IPCC Special Report on Emission Scenarios (SRES) was selected as the scenario framework. Simulations for the four marker scenarios from the Integrated Model to Assess the Global Environment (IMAGE) 2.2 were used to drive demand for major land use categories. Downscaling IMAGE projections was the primary objective and it was necessary to preserve some form of consistency with the original source data and existing local scale data (i.e. Trends), be transparent and internally consistent in a well-defined methodology, and ensure the outcomes are plausible (van Vuuren et al. 2007).

To meet the needs of EISA and the LandCarbon project, USGS land change scientists developed a modular approach to development and downscaling of global LU/LC scenarios. The modeling approach uses two distinct modules, one to handle scenario “demand” and another to create spatially explicit projections of LU/LC. To handle LU/LC demand, the USGS developed a scenario-based downscaling accounting model to create national scale scenarios and then downscale them to nested hierarchical ecoregions using land use histories developed by the Land Cover Trends project (Sleeter et al., in review). Land use demand from IMAGE model simulations are used to drive demand in four primary land use classes. Land use histories and expert judgment are then used to simulate a comprehensive set of LU/LC changes resulting from changing demand across land-use sectors. Scenario downscaling involves the process of allocating national scale land-use projections to ecoregions of the United States.

The four downscaled SRES scenarios (A1B, A2, B1, and B2) cover changes across 16 LULC classes, for 84 Level 3 ecoregions, and extend from 2005 through 2100 (Figure 8).

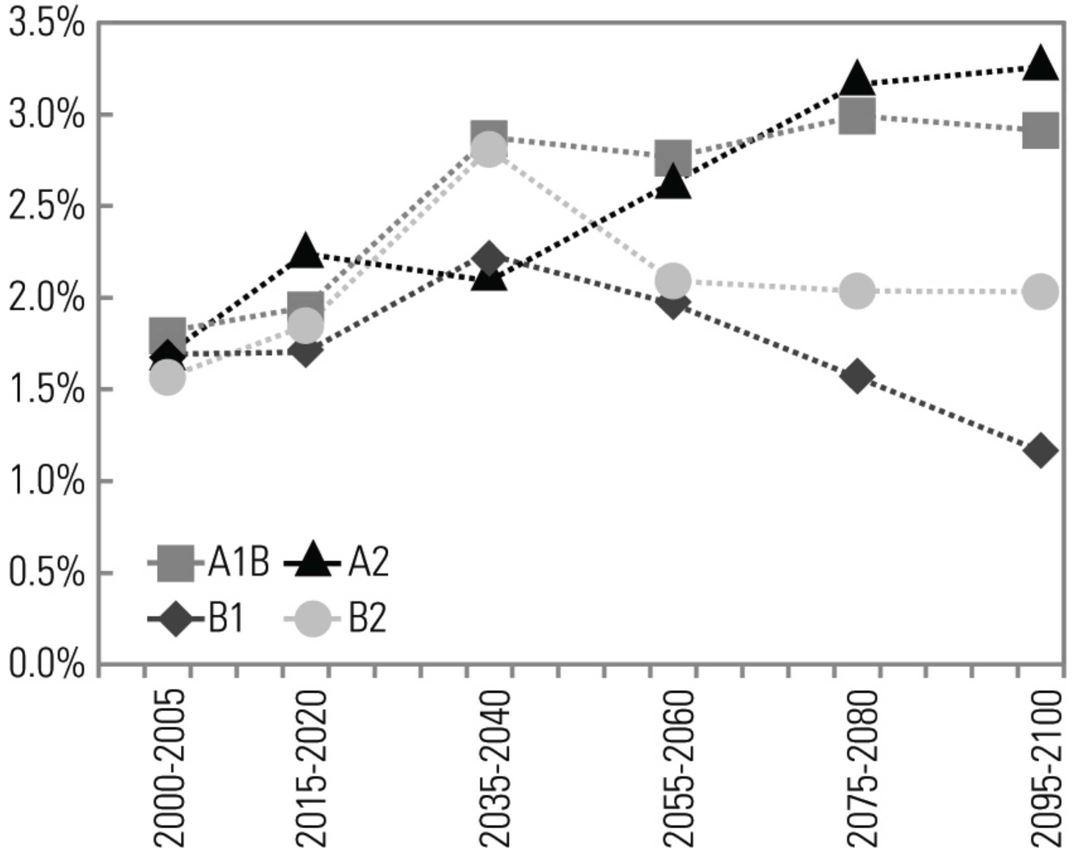

Figure 8. Projected percent change over time in all LULC classes in the contiguous United States under four scenarios (Source: Sleeter et al, in review).

Scenario demand is then handed off to the FOREcasting SCEnarios (FORE-SCE; Sohl et al., 2007) land use model which is used to produce annual spatially explicit maps of LU/LC at 250 meter resolution (see Figure 9 for an example). FORE-SCE uses a unique “patch library” approach to reduce computational requirement. Forest stand age is also tracked and is based on interpolated FIA data. Suitability surfaces for each LU/LC class in each Level 3 ecoregion are created and are the main determinant of the placement of changes in LU/LC.

As of December 2011 the USGS has completed scenario development for 60 percent of the ecoregions of the United States. Draft scenarios are complete for the remaining 40 percent of the country and will be finalized by March 1, 2012. Spatial mapping of the scenarios is complete for approximately 35 percent of ecoregions with the remainder slated for completion by October 1, 2012. Future work includes the development of downscaled Representative Concentration Pathways (RCPs), LU/LC backcasting, and a range of model improvements, including the ability to model vegetation transitions occurring due to climate variability and change. Several impacts related projects have started using SRES LU/LC scenarios, including the LandCarbon assessment and work to assess the impact of LU/LC change on radiative forcing and albedo.

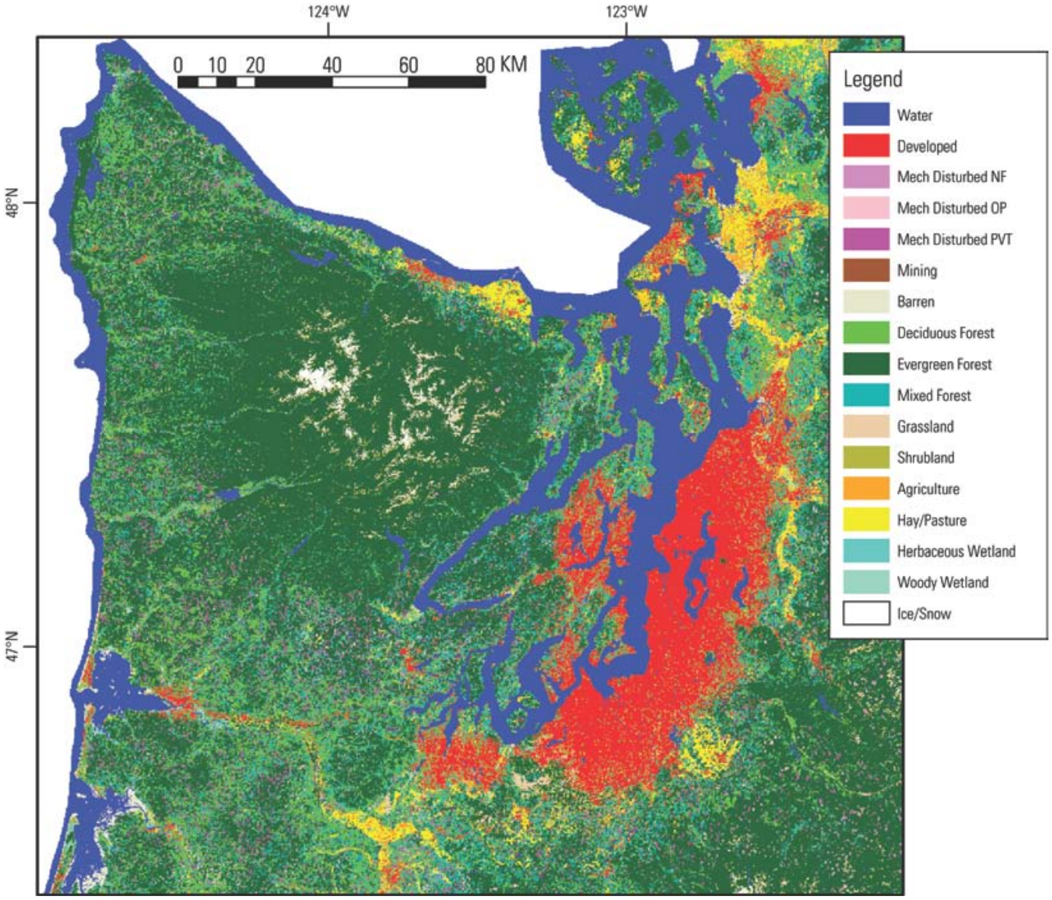

Figure 9. LU/LC projections for western Washington State in 2100 under the B2 scenario (Source: Original, by B. Sleeter, created using methodology documented in Zhu et al. 2010 and Sohl et al. 2011).

Climate Change Impacts on LU/LC in the U.S.: Using MC1 and Related Economic Models

There is now substantial literature on climate change impacts on forested ecosystems and land use and management. Most of the research that carries impact assessment through to economic analysis of land use and management focuses on linking ecosystem models to economic models. For the most part these efforts have so far focused on one-way links from ecosystem outputs to economic outputs. This likely cannot adequately capture the potential ecosystem impacts given that human management is such an important part of disturbance. Thus, an important future direction will be to develop full model interactions where human systems are affecting the ecosystem models as well (see Buck et al. 2009).

The analysis presented accounts only for the one-way linkages from ecosystem models to economic models. Further, the analysis uses only one set of ecosystem models (the MC1 model – see Bachelet et al. 2003) and one economic model (see Sohngen and Mendelsohn 2007). The economic model manages forests globally in age classes, determining optimal rotation ages, optimal management inputs, and optimal land areas in forests.

The ecosystem model makes a number of annual predictions by 0.5º grid cells globally, including the ecosystem type, net primary productivity, total ecosystem carbon, proportion of stock that is burned by fire, among other things. These outputs are first aggregated by ecosystem type and model region (using the 16 regions in the economic model). The timber types in the economic model are then linked to specific ecosystem types and the outputs from the ecological model for those ecosystem types are used to perturb the economic model.

Two scenarios were developed. Scenario 1 assumes that changes in total ecosystem carbon can capture the full range of ecosystem effects on timber stocks over time, thus for this scenario changes in total ecosystem carbon are used to adjust annual growth in timber. The assumption is that the change in annual timber growth is proportional to the change in total ecosystem carbon; therefore, if total ecosystem carbon increases by 4 percent, then annual growth is assumed to increase by 4 percent as well. As a result, scenario 1 simply accounts for the net effects of all processes on stocks and flows in forests using total ecosystem carbon. Scenario 2 models two types of impacts- disturbance effects on existing timber stock and growth effects. The disturbance effects are linked to the proportion of timber that burns each period. We directly adjust timber stocks in the model proportionally to the amount burned each year. We allow for salvage in areas where standing timber is burned. In addition, we adjust annual timber growth using net primary productivity, assuming the change in growth is proportional to the change in net primary productivity. While scenario 1 assumes that changes in total ecosystem carbon net out the effects of disturbances and growth, scenario 2 directly models stock and growth effects separately and determines the resulting economic impact.

The results are preliminary. They are presented for the two scenarios described above, and for 6 climate scenarios, encompassing the A1b and A2 SRES scenarios from the IPCC and three General Circulation Models. Overall, the economic model results indicate that the overall global price effects in timber markets are fairly modest. For scenario 1, the price effects range from -2 to +3 percent, while for scenario 2 they range from -7 to +2 percent. It is not surprising that the price effects in the scenario with disturbance modeled directly leads to greater price effects. Disturbance tends to rise due to climate change (although not in all locations), which increases the amount of wood that is available for markets through salvage. This leads to lower prices.

The market impacts for the U.S. are markedly different depending on which scenario is considered. U.S. timber output generally rises for scenario 1, and generally falls for scenario2. By 2035, output rises by 15 to 20 percent in scenario 1 and by 10 to 50 percent by 2095. In scenario 2, output falls by around 15 percent by 2035 and by around 20 percent by 2095. These losses in output in scenario 2 are driven by the effects of increasing disturbance on investments.

In addition to considering the results on U.S. timber output, Haim et al. (2011) recently examined the implications of climate change for U.S. land use using a U.S. only land use model. The model links the same ecosystem scenarios to the U.S. land use model. The results of their analysis suggest that over the next 50 years, the primary contributor to land use change in the U.S. will be development. Climate change will have relatively small impacts above and beyond the implications of changes in land rents due to population and income growth.

In conclusion, this analysis illustrates one set of methods for integrating ecosystem results into economic models. The results illustrate that the economic outcomes are heavily dependent on how the ecological effects are integrated into the economic model. Approaches that include stock and growth effects have far different economic implications than approaches that model only growth effects. It is likely as well that the overall results will depend on whether the ecological models have used economic inputs, a question that was not addressed here. The results also suggest that U.S. timber outputs could be heavily influenced by climate change, either positively or negatively, depending on how the ecological results are implemented in the model. Finally, the modeling described here suggests that the effects of climate change on land use will be relatively modest, although land use changes could be large in the next 50 years, due to rising incomes and shifts in population growth.

Climate Change and LU/LC

Several presentations focused specifically on the interactions of climate change and LU/LC, including how LU/LC changes are being impacted by and impacting climate changes, how downscaling LU/LC and climate change trends is needed for addressing climate risks and vulnerabilities, the carbon implications and accounting in LU/LC change, and some emerging issues in LU/LC and climate change.

Sensitivity and Response of Land Uses and Regions to Climatic Variability and Change

Vegetation Changes in the Western U.S.

Landsat data acquired over the previous 25+ years are being used to assess status and trends of forest and rangeland condition in the Western United States. In a study conducted by USGS/EROS, trends in vegetation condition are being assessed using Landsat Thematic Mapper and Enhanced Thematic Mapper Plus time series data acquired from 1984 to present. Current study areas under investigation include the Four Corners region of the Southwestern U.S., the Olympic Peninsula of western Washington, the Uinta Mountains of Utah, the Permian Basin of western Texas (and adjacent portions of New Mexico), the Wind River Range in Wyoming, the Black Hills of South Dakota, and a region in southeastern Nevada that has recently experienced heavy wildfire activity. Remotely-sensed trends information is being compared with precipitation and temperature trends information derived from the Parameter-elevation Regressions on Independent Slopes Model data set (PRISM; Daly et al. 1994; Prism Climate Group 2011) to determine potential connections between the surface change trends and the climate conditions.

Thus far researchers have found evidence in the Landsat time series data sets of “gradual” systematic vegetative change in all of the study areas examined. The most pervasive gradual change observed is associated with conifer forests undergoing declining conditions related to insects (Vogelmann et al., 2009; 2011). It is noteworthy that many of these insect-damaged areas are also located in areas of decreased precipitation as depicted by the PRISM precipitation data. In general, few of the examined areas are showing evidence of increased canopy cover or greenness, although there are some notable exceptions. Exceptions include the zone located at the interface between conifer forest and alpine vegetation communities located at the higher elevations in the Uinta Mountains, as well as within a conifer-dominated area in the Olympic National Park. In the case of the Uinta Mountains, the trends are consistent with what might be expected when warming occurs at higher elevations (i.e., conifer vegetation at the high elevation “fringes” of where conifers can normally grow become healthier, and the canopies become denser and may “migrate” up the slopes). In the case of the Olympic Mountains, the greenness increases are diffusely scattered throughout a broad area. It is noteworthy that this latter region surrounds the Olympic National Park glaciers, which are showing evidence of ice retreat in the Landsat data used (1985-2010 timeframe). While admittedly of very coarse spatial resolution, the PRISM data indicate evidence of a subtle warming in the central part of the Olympic Peninsula (i.e., increasing annual maximum temperature values). While remotely-sensed trends are most apparent in conifer-dominated areas, there is evidence of gradual change in other vegetated communities as well, including rangelands.

Continued analyses of time series data using multi-spatial scenes and covering multiple years are required in order to develop accurate impressions and representations of the changing ecosystem patterns and trends that are occurring throughout the Western United States. The approach of the research presented here demonstrates that Landsat time series data are very effective for assessing gradual ecosystem change across large areas. Researchers anticipate expanding coverage of Landsat time series analyses such that they can develop a truly regional perspective of the gradual changes taking place throughout the different Western U.S. vegetation communities. Comparison of regional Landsat-derived trends data sets with PRISM data will provide important information that will enable the establishment of relationships between terrestrial vegetation change and condition information and climate variation. This is the scale at which the PRISM data, which are rather coarse compared with Landsat-scale observations, will be most trustworthy and valuable[8].

LU/LC Modifications in Middle-Latitude Continental Areas, and Interactions with Climate

LU/LC interacts with climate on a range of spatio-temporal scales. In continental interior regions of the Northern Hemisphere, especially the Central U.S., rain-fed and irrigated agriculture have significantly modified regional-scale energy and moisture budgets compared to the pre-existing natural vegetation. In these areas, there is a close feedback between the land surface and atmosphere as revealed, for example, in measure of the “recycling” of precipitation by evaporation. As in the Great Plains, the close negative association between anomalies in land surface temperature in the warm season and precipitation anomalies in the antecedent spring season is also evident in the Corn Belt. This relationship is mediated, primarily, by the soil moisture: positive (negative) anomalies of soil moisture tend to “predict” negative (positive) anomalies of summer temperature over the long haul. Associations with summer precipitation are less clear.

Deforestation in the Eastern U.S. and Corn Belt region over the past 150 years has significantly modified climate parameters. The reduction of canopy height has reduced the aerodynamic roughness, which affects momentum exchange between the land surface and atmosphere. A similar reduction in leaf-area index over the same period increased the surface albedo, particularly in the Midwest, and also increased the heterogeneity (i.e. patchiness) of land cover. This has altered the regional surface energy budgets.

Both rain-fed and irrigated agriculture have been implicated in recent climate trends in the U.S. Midwest. For example, a strong increase in extreme (high) dew-point temperatures since the mid-1970s is possibly related to evaporation from crops, and cooling in irrigated areas of Nebraska has occurred in the post-1945 period. Although large-scale LU/LC maps of the Corn Belt depict a relatively undifferentiated land cover, satellite-retrieved indices of vegetation activity, such as the Normalized Difference Vegetation Index (NDVI), reveal strong heterogeneity in the early warm season that is related to soil moisture, crop stage of development, and vegetation type. The presence of long yet relatively narrow boundaries between extensive croplands and remnant forest serve to enhance convective cloudiness and rainfall during the warm season, and support Anthes (1984) hypothesis that widely-spaced rows of trees may initiate or intensify deep convection, at least in the sub-tropics. This effect is most evident when the synoptic-scale atmospheric circulation favors weak winds in the free atmosphere. It is hypothesized that the large height differences between trees and crops help loft air parcels above the condensation level when the humidity is high in the layer of air closest to the ground. The vegetation boundary association with precipitation appears to be seasonally-varying, and tied to phenology differences between the croplands and surrounding forest areas. Early in the warm season, longer and wider boundaries help promote more precipitation, while later in the summer shorter and narrower boundaries have associated higher precipitation amounts. It is hypothesized that the seasonal switch in maximum NDVI between the forests and croplands changes the “moisture pooling” along the vegetation boundaries

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[8] One reviewer noted that while Prism data are coarser than Landsat data and subject to error from the interpolation process, Prism data are capturing monthly weather variables which are not subject to the same spatial discontinuities as LU/LC data.

The strong LU/LC contrasts near larger urban areas such as St. Louis and Indianapolis serve to increase warm season precipitation and intensify thunderstorms in downwind areas, likely from a combination of mechanical effects, greater particulate pollution, and the urban heat island phenomenon. The Metropolitan Meteorological Experiment (METORMEX) of the 1970s, and more recent NASA-supported satellite-based studies of urban impacts on climate show that urban areas increase precipitation particularly on the right-downwind quadrant. This is due to the input of moisture and energy from the south, important in deep convective activity. The explicit inclusion of meso-scale LU/LC variation into regional climate models should help improve rainfall prediction in the warm season for the U.S. Corn Belt and the larger Midwest region.

Accounting for the Ecological Implications of LU/LC Change in NRCS Programs

Understanding the spatiotemporal patterns of land use and land cover change at a variety of scales is critical to the cost effective development of NRCS policy, programs and management guidelines. Assisting land managers in achieving their goals involves implementing practices to reach land management objectives, identifying threats to sustainability, and devising conservation systems and practices to overcome them. In particular, changes in land use and land cover at a variety of scales can result in the creation of 'novel' ecosystems which possess attributes that may threaten the ecological processes that support production and delivery of ecosystem services important to land managers and society. NRCS technical assistance relies upon developing information delivery systems that are helpful to planners and land managers in identifying fundamental soil and vegetation attributes associated with sustainability. The National Cooperative Soil Survey and Ecological Sites are two technologies critical to generating and organizing that information.

Ecological Sites (ES) are groupings of soils within a climatic region based on their ability to produce vegetation and respond to changes in management. Ecological Site Descriptions (ESDs) are the documents that provide the supporting information for the groupings of soils and for describing the dynamics of vegetation change and management implications for each site. The components of an ESD are: 1) physical setting (soil attributes, landscape position and climatic characteristics); 2) vegetation dynamics (graphic and textual descriptions of changes in plant communities in response to management); 3) use and management interpretations; and 4) reference materials. While the concepts behind ES have been accepted for more than two decades, the applications are only now sufficiently extensive and comprehensive to provide a sound basis for quantitative evaluation of organizing principles and a foundation for next steps. Challenges for the future include integrating ES information at the plant community level into landscape and regional scale analyses and assessments, including interpretations of a broader range of ecosystem services and developing a system that can respond to advances in science and policy. The goal is a transparent, credible and useable system of land management information that has utility for a wide variety of users.

Accurate and timely land use and land cover change information can greatly inform the development of NRCS technical assistance products. Similarly, NRCS soils and ecological site information can help other organizations predict how land use and land cover changes are likely to affect important ecological processes and the resulting impacts on sustainability.

Addressing where Climate Change Hazards and Humans Intersect

A rational land use and land cover response to climate change would proceed along at least two fronts. The first front focuses on how land use or land cover might be altered to reduce climate change, by reducing GHG emissions, increasing sequestration, or affecting albedo or other system characteristics. The second front, which is the focus in this section, notes that climate changes are occurring and will continue occurring, even with significant GHG reductions and/or sequestration. Effective adaptation would be aided by an analysis of the exposed human populations and desired services at local to regional scales. This is useful irrespective of the causes of climate change, may be pursued independently or in concert with mitigation efforts, and can be based on extrapolation of past trends, forward climate modeling, or both.

Large scale climate changes are well documented. Increased temperatures and increasingly variable precipitation have already been observed and are a predicted trend caused by higher atmospheric CO_2 concentrations. The measurement record documents consistent decades to centuries-long changes in air temperature, sea temperature, growing seasons, snow cover, ice-free periods, and snow melt. In addition, the frequency and severity of storms, floods, fires, and droughts, seem to be increasing, although current observational time series may be too short for many variables to detect changes in variability. There is a well-documented increase in the costs of natural disasters (Kunkel et al. 1999), possibly due to increased frequency and intensity of disturbance, and certainly due to increased vulnerability, as population and infrastructure has increased in areas with higher risk, leading to natural disasters that more often affect densely populated areas.

Unfortunately, downscaling the trends of hazard and exposure from global to regional or local levels is difficult. For planning purposes, climate trends and characterization of changes in variability at a regional and local level is necessary. Records are too short and data are lacking for making these localized analyses possible. While models can help fill the gap, there is often still too much uncertainty to adequately inform or influence planning. Therefore, the science of downscaling needs improving, moving from global means and variabilities to regional and local means and variabilities.

In addition to the need to improve downscaling in order to better understand localized climate impacts, there is also a need to improve the way we respond to climate change, specifically by addressing risks. Risk is a function of hazards (a natural event that can do harm), vulnerability (susceptibility to an event), and exposure (intensity and duration of an event). Managing GHG concentrations in the atmosphere is an attempt to reduce hazards and exposure. Effectively addressing risk requires answering the following questions at a local level: What are the hazards? ; What are the vulnerabilities- to populations, infrastructure, ecosystems, agriculture, commerce, etc.?; What are the thresholds at which exposure to the hazard becomes problematic?; What actions can reduce risk by addressing vulnerability or exposure? More information and research is needed to answer all of these questions. While hazards cannot be controlled in the short-term, their impacts can be mitigated by an understanding of vulnerability and exposure. This understanding may lead to appropriate actions to decrease both.

Identifying communities at risk requires knowing where the people are, information that is lacking at a national level for many low density areas. The U.S. population census has adopted a block as the smallest sampling unit, with limits on the number of people in a block group, but there is no upper limit on the area. Blocks may vary from smaller than an acre to 100s of square miles, although most are less than a few square miles. However, there are typically a few tens to hundreds of people in these areas over most rural and many suburban blocks, which comprise a small minority of the total population, but a large majority of the surface area of the country. Almost 80 percent of the country is occupied by less than 3 percent of the total population. While some high resolution national maps are available, and cities and counties often have data on where their population is located, combining this information with downscaled hazard data is challenging, but ultimately necessary for identifying vulnerable communities.

In summary, climate changes are happening irrespective of what mitigation measures we might take to reduce GHG emissions. Given the inertia of global systems, even with substantial output reduction or sequestration tomorrow, society will face increased climate hazards for at least several decades. To effectively plan for these hazards we need to understand downscaled climate impact, identify areas that will be exposed to hazards, and identify vulnerable populations and infrastructure. Optimal actions are not yet clearly defined, largely because of difficulties in identifying the location of and magnitudes of vulnerabilities, and the location and magnitudes of future exposure to climate-related hazards.

Carbon Accounting and Reporting for LU/LC

LU/LC and Carbon Estimation

The Forest Service Forest FIA program compiles estimates of forest carbon stocks and fluxes each year as a contribution to the national GHG emissions inventory submitted by the EPA to the United Nations Framework Convention on Climate Change (UNFCCC). Forestland currently accounts for much more carbon sequestration than the other land uses combined, representing an offset of approximately 16 percent of total U.S. GHG emissions. UNFCCC reporting is relevant to NCA efforts to address LU/LC because UNFCCC stocks and fluxes are identified specifically by land use.

An important distinction in the resource monitoring associated with each land use is between area estimation and determination of average carbon density per unit area. For forests, FIA provides both. FIA maintains a systematic sample grid of one plot per approximately 6000 acres; plots are established on this grid without regard to land cover or land use. Crews are sent to plots for which pre-field review indicates the potential for a “forest” land use. Inventory results are used to estimate the area of forest at a variety of scales; UNFCCC reporting occurs at the state level. The carbon density of some forest carbon pools are measured relatively directly (e.g. measured tree diameters are allometrically converted to biomass), while other non-measured pools (e.g. soil carbon) are modeled using correlates such as measured stand age and forest type.

Starting in 2010, land use has been recorded for all FIA plots not meeting the definition of forest. This means that, moving forward, the FIA grid has the potential to provide a consistent land use measurement framework across the U.S. The UNFCCC reporting process currently uses estimates of the area of non-forest uses from the NRI compiled by NRCS on non-federal lands. Areas of Federal non-forest lands are derived from the NLCD. Aside from complexities related to reconciliation of potential differences in the area of forest estimated by these three sources, the NLCD maps used on Federal lands actually relate land cover, not land use.

While estimates of carbon densities on non-forestland would still have to come from sources such as the NRI, FIA will soon (less than 5 years) be able to offer nationally coherent estimates of the area of both major land uses and land cover. This may be of use in the long-term NCA strategy.

FIA’s carbon team is also working on several improvements to the process of estimating carbon density in forests. These improvements include: improving allometric models used to measure carbon in live trees from diameter/species measurements; introducing direct measurements for some pools which are currently modeled; and improving models used in pools for which no field measurements are available.

Continued ground inventory data will be critical as the climate continues to change in the foreseeable future. We know that the distribution of the land base among different LU/LC categories varies over time and in response to a variety of factors. Trends in productivity and/or disturbance related to climate change may become an important driver in these changes. Moreover, such changes may also affect the carbon densities we attribute to each LU/LC category. Particularly in light of ongoing improvements, FIA should provide a standardized national framework for monitoring these developments into the future.

Representation of Land Use and Management in the U.S. Greenhouse Gas Inventory

The U.S. submits its GHG inventory annually to the UNFCCC following IPCC methodologies. The submission is coordinated by the EPA with input from multiple agencies and academic institutions. The inventory provides the total emissions profile for the country and also evaluates the relative importance of different emissions in terms of their magnitude. The inventory also provides emissions trends over time since 1990.

Reporting annual land use and land use change in the inventory is part of the IPCC guidelines. The U.S. is required to have a complete and consistent representation of managed land and land use over time, categorized into the six IPCC land use categories: settlements, cropland, forestland, grasslands, wetlands, and other. Transparency is required, and met through the inclusion in the inventory of explanations for exactly how the land use classification was conducted and what data were used. The inventory also provides the necessary information for carbon inventories in land use and land use change and management: the Forest Service does the forestland carbon inventory, while USDA and Colorado State University collaborate to estimate carbon in agricultural soils.

The general steps for preparing the land use and land use change portion of the inventory are: 1) define managed land and land uses; 2) identify databases to use; 3) classify all lands using IPCC categories; 4) combine all data into a single dataset/product; and 5) estimate carbon stock changes. Each step is described in more detail in the paragraphs that follow.

In defining managed land and land uses, IPCC allows each country to determine their own definitions, within certain boundaries, so that these definitions tie in climate change policy with existing country programs. In the U.S., managed lands are defined as areas where there’s an impact of anthropogenic activity on GHG emissions on that land. Many countries consider all of their land managed; however, in the U.S. there are still wild areas, such as in Alaska, where there is little to no human impact on emissions from the land. For the land use classes, the inventory uses the following definitions: NRI definitions for settlements, cropland, and grassland; FIA definition for forestland; and the IPCC definition for wetlands. Other lands include bare soil, rock, ice, and any lands that don’t fit any of the other categories. Since some definitions have overlap (i.e. agroforestry, urban forests), the following classification priority is used, where land that fits multiple categories is assigned to the highest classification: settlement > cropland > forestland > grassland > wetland > other.

After establishing definitions, databases are selected. Ideally the selected databases should be the same ones that inform Federal policy and programs. In combination they also need to account for land use on all U.S. lands, and the total managed plus unmanaged land must add up to the total land area. With these considerations, the inventory team selected the following data: FIA for forest data, NRI for non-federal lands, and NLCD for everything else (such as non-forested Federal lands)[9].

Using these data all land is classified into one of the 6 IPCC land use categories, which results in 36 combinations of land use and land use change. Data are reclassified to match the IPCC categories, starting with NRI for non-federal lands and FIA and NLCD for Federal lands, and this classification happens at a state level. When there is a difference between the databases in land use classification, it is

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[9] It is important to note that NLCD represents land cover and so there is uncertainty when using this dataset to infer land use. Evaluating the time series of land cover in the NLCD can improve the classification of land use, given that land cover can change but revert back to the original land cover over time. This pattern would imply that the land use did not change. An example of this pattern would be a forest stand that is harvested, and appears as grass and scrubby cover for a few years, but then trees re-grow over time and re-establish the forest cover. In this case, the land use likely did not change for the parcel of land.

reconciled in a systematic way. For example, FIA provides the official U.S. estimates for forestland, and so NRI and NLCD data are adjusted to match the forest area from FIA. To ensure that no area is lost or double-counted, there are concurrent adjustments to wetland and grassland areas in NRI and NLCD to account for any change in forest area.

Following the classification it is possible to report on the total area of each land use type, and the gross land use change over time (Table 2). Management data that are relevant for GHG emissions are also reported. For example, reporting on croplands includes information on tillage, irrigation, fertilization, crop sequences, and Conservation Reserve Program enrollment.

Table 2: Size of Land Use and Land-Use Change Categories on Managed Land Area by Land Use and Land Use Change Categories in thousands of hectares[a] (Source: U.S. EPA 2011).

Land Use & Land Use Change Categories	**1990**	**2000**	**2005**	**2006**	**2007**	**2008**	**2009**
Total Forest Land[10]	**236,878**	**268,790**	**271,322**	**272,107**	**272,891**	**273,677**	**274,462**
FF	257,180	253,080	255,444	256,181	256,917	257,655	258,392
CF	1,266	2,793	2,976	2,983	2,991	2,998	3,006
GF	4,879	11,347	11,122	11,157	11,193	11,229	11,264
WF	63	201	205	205	206	207	207
SF	101	268	303	304	305	306	307
OF	389	1,102	1,273	1,276	1,279	1,283	1,285
Total Cropland	**170,632**	**164,401**	**163,192**	**163,178**	**163,164**	**163,151**	**163,137**
CC	155,433	144,004	145,531	145,518	145,506	145,493	145,481
FC	1,105	1,101	805	804	803	802	802
GC	13,298	17,834	15,513	15,513	15,513	15,512	15,512
WC	163	264	234	234	234	234	234
SC	470	886	825	825	825	825	825
OC	162	311	283	283	283	283	283
Total Grassland	**269,643**	**263,092**	**260,565**	**260,012**	**259,458**	**258,904**	**258,350**
GG	260,064	245,460	243,839	243,395	242,951	242,506	242,061
FG	1,463	3,048	2,787	2,773	2,759	2,745	2,730
CG	7,502	13,303	12,632	12,541	12,451	12,360	12,270
WG	230	373	339	338	338	337	336
SG	129	255	255	253	252	250	249
OG	255	653	714	712	709	706	704
Total Wetlands	**27,788**	**27,560**	**27,173**	**26,983**	**26,793**	**26,603**	**26,412**
WW	27,179	26,155	25,701	25,519	25,338	25,157	24,976
FW	138	378	401	398	395	393	390
CW	134	348	351	348	344	341	338
GW	286	633	675	672	670	668	665

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[10] Several presentations and discussions summarized in this report claim a decrease in forest cover over the same time period, while these compiled EPA estimates report an increase in forest land. Estimates of forest cover showing a net loss of forests could be a result of using remotely sensed images for specific periods when forest land is under management interventions such as harvesting. These interventions are likely to affect forest cover for particular rotational periods and will be picked up by remotely sensed images. Largescale fires and insect and pathogens may also show a reduction in cover at specific time periods but if these areas remain under forest land, carbon estimations across the U.S. indicate that there is a net carbon gain nationally. Differences could also be the result of differences in methodologies used for estimations.

SW	< 1	3	3	3	3	3	3
OW	51	43	43	42	42	42	42
Total Settlements	**39,518**	**47,558**	**49,247**	**49,238**	**49,229**	**49,220**	**49,212**
SS	34,742	34,055	34,975	34,966	34,958	34,949	34,941
FS	1,842	5,480	5,872	5,872	5,872	5,871	5,871
CS	1,373	3,599	3,673	3,672	3,672	3,672	3,672
GS	1,498	4,183	4,479	4,479	4,479	4,479	4,479
WS	3	29	32	32	32	32	32
OS	60	212	217	217	217	217	217
Total Other Land	**14,385**	**14,443**	**14,346**	**14,327**	**14,309**	**14,290**	**14,272**
OO	13,397	12,286	12,104	12,087	12,069	12,051	12,033
FO	193	506	559	559	559	559	559
CO	279	440	499	499	499	499	499
GO	458	1,085	1,058	1,057	1,057	1,056	1,056
WO	55	115	114	114	114	114	113
SO	3	11	12	12	12	12	12
Grand Total	**785,845**	**785,845**	**785,845**	**785,845**	**785,845**	**785,845**	**785,845**

[a] The abbreviations are "F" for Forest Land, "C" for Cropland, "G" for Grassland, "W" for Wetlands, "S" for Settlements, and "O" for Other Lands. Lands remaining in the same land use category are identified with the land use abbreviation given twice (e.g., "FF" is Forest Land Remaining Forest Land), and land use change categories are identified with the previous land use abbreviation followed by the new land use abbreviation (e.g., "CF" is Cropland Converted to Forest Land).

Those involved in compiling the land use and land use change portion of the inventory have noted several areas for improvement. First, they identify a need to better account for land use and land use change in Alaska and the territories. While a land use categorization is now available from NLCD for Alaska, the times series is not yet available for conducting an analysis of land use change. Neither land use nor land use change analysis has taken place in the territories. Second, there is a need to fill gaps in activity data like grazing management and grassland condition; in general there is very little information about rangelands. Finally, the process for combining the data could be improved. There are discussions of potentially using a physiographic or regional scale for combining the data instead of a State scale. Ideally there will be an integrated product for land use of all U.S. lands in the future, possibly combining the official data from NRI and FIA with NLCD.

Emerging Issues in LU/LC and Climate Change

Climate Assessment and Crop Insurance

The role of USDA's Risk Management Agency (RMA) is to help producers manage their business risks through effective, market-based risk management solutions. RMA's mission is to promote, support, and regulate sound risk management solutions to preserve and strengthen the economic stability of America's agricultural producers. As part of this mission, RMA operates and manages the Federal Crop Insurance Corporation (FCIC). RMA was created in 1996; the FCIC was founded in 1938. The Federal Crop Insurance Corporation (FCIC) promotes the economic stability of agriculture through a sound system of crop insurance and providing the means for the research and experience helpful in devising and establishing such insurance. The corporation takes actions necessary to improve the actuarial soundness of Federal multiperil crop insurance coverage, and apply the system to all insured producers in a fair and consistent manner.

RMA has released the study "Climate Change Impacts on Crop Insurance," (Beach et al. 2010). This report was recommended by the General Accounting Office (GAO) in its 2007 report, "Climate Change—Financial Risks to Federal and Private Insurers in Coming Decades Are Potentially Significant." The GAO recommended that RMA and the Federal Emergency Management Agency's National Flood Insurance

Program separately analyze their Agency's potential long-term fiscal implications of climate change and report their findings to Congress.

This study dealt exclusively with the impacts of climate change on the ranges and yields of important agricultural crops as they responded to various climate change scenarios. Climate change and associated LU/LC change were modeled using IPCC Climate Scenario A1B: Rapid economic growth and technological improvements which assumes balanced growth in energy use across alternative energy sources.

Scenarios were run for the following Global Circulation Models: GFDL-CM2.0 and GFDL-CM2.1 models developed by the Geophysical Fluid Dynamics Laboratory (GFDL), USA Coupled Global Climate Model (CGCM) 3.1 developed by the Canadian Centre for Climate Modeling and Analysis, Canada; Meteorological Research Institute (MRI) coupled atmosphere-ocean General Circulation Model (CGCM) 2.2 developed by the Meteorological Research Institute, Japan Meteorological Agency.

Scenario data were then fed into the Environmental Policy Integrated Climate (EPIC) model which uses GCM output to estimate crop yield effects, the Forest and Agricultural Sector Optimization Model (FASOM) to assess market outcomes given yield effects, and then RMA's actuarial model to assess change in yield distributions (Figure 10).

The study identified yield effects at a national level with overall decreases in Central and South, and increases in North and West. The results were consistent with other studies.

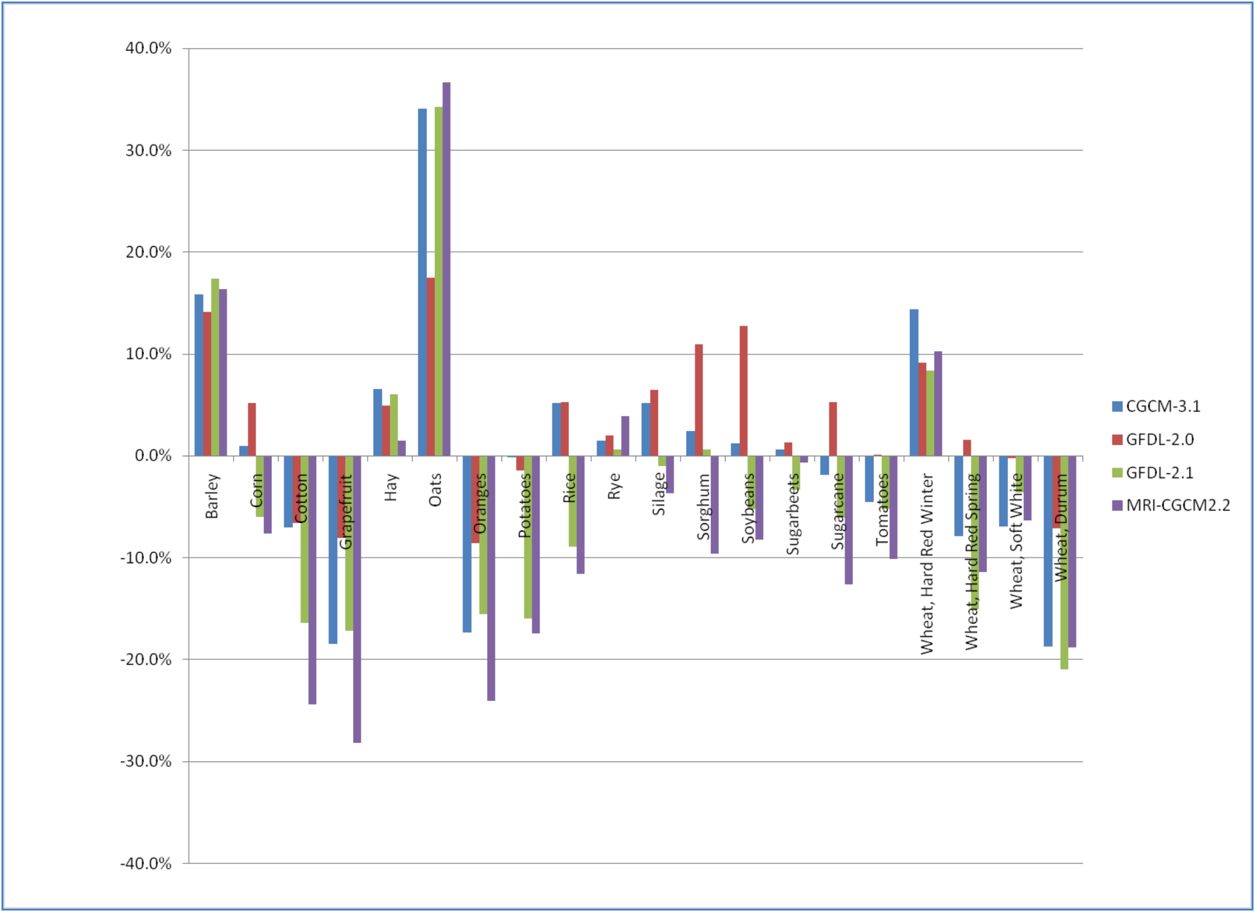

Figure 10. Simulated equilibrium changes in national average yields per crop under four scenarios (Source: Beach et al. 2010).

Crop insurance provides agricultural producers with a mechanism to manage their risks when adapting to climate change. Incentives, like proactive setting of premium rates, can act as a price signal to the grower about risk and the value of mitigation or adaptation. These incentives can reduce the hazards of planting crops where they may no longer be viable due to climate changes. These incentives can be related to managing the insurance deductible, adaptive yield guarantees, and in the loss adjustment process.

As the primary production agriculture risk management tool (insuring over 1-million producers and 275-million acres of farmland) crop insurance is in a prime position to provide significant incentives to mitigate risk, and to protect fragile lands (swamp-busters, sod-busters) from LU/LC change associated with climate change. These incentives may include policies that accommodate adaptive/mitigation responses by growers and the revision of program/policies to reflect evolving agronomic practices.

Crop insurance is designed such that the grower is better off with a good crop than a bad one, and that a grower shares in substantial portion of risk. Effective crop insurance policies provide financial stability for growers and are frequently required by lenders. A financially stable grower is more likely to invest in new growing practices to adapt to climate change.

Key Findings from Stakeholder Discussions

The third day of the workshop was devoted to gathering input from all participants on five key LU/LC questions that were selected during pre-workshop, multi-stakeholder planning sessions. Using a small-group conversation method called World Café[11], designed to get input from all stakeholders on all questions/topics being addressed, workshop participants provided input to the following key questions:

1. What are the primary trends in LU/LC change and how might these trends interact both directly and indirectly with climate change to affect ecosystems, human health, and economic and social well-being?
2. How sensitive are land uses and regions to climatic variability and change, and what LU/LC related adaptations will occur or do we want to occur, to reduce mortality, morbidity, loss of property, and loss of services? Are there documented examples/case studies/vignettes for the possible changes, as well as adaptation and/or mitigation options publicly available? How have these affected risks?
3. How are the direct and indirect effects of LU/LC patterns and changes on weather and climate likely to affect future LU/LC decisions (e.g., through green infrastructure or carbon sequestration), and how might those goals conflict with other goals driving LU/LC dynamics?
4. Who are the key LU/LC public and private sector decision-makers that need to make climate adaptation and mitigation decisions, and what tools do they need to assess and implement desired actions?
5. How effective are current land resource assessment data, practices, information systems, and models in addressing the information and trend data needs required to understand the impacts of climate change on LU and LC? Are there gaps and, if so, how might these gaps be addressed through future research? Are new scientific insights and decision tools available for use by decision-makers, including both private land owners and public policy-makers?

Participant responses to each question are summarized below.

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[11] For more information on this method, see: http://www.theworldcafe.com/overview.html.

Question 1: LU/LC Trends

What are the primary trends in LU/LC change and how might these trends interact both directly and indirectly with climate change to affect ecosystems, human health, and economic and social well-being?

A key point noted in discussions around this question was that many LU/LC changes are difficult to attribute directly to climate change since policy, market forces, culture, and other natural processes (like ecological succession) are also affecting LU/LC change and, in some cases, interacting with and being impacted by climate change as well. In addition, while the mechanisms of LU/LC change might be understood, quantification of change is complex, and results documenting change depend on land class definitions, classification systems, scale, and methodologies used.

Nevertheless, there was some consensus on natural, agricultural, and developed trends in LU/LC in the U.S., while acknowledging that regional differences in these trends can be large.

Some trends in natural ecosystems that participants noted are:

- A decrease in permanent ice cover due to warming temperatures
- An overall decrease in forest cover due to increased disturbances (such as fire and insects) and encroachment
- A shift from sagebrush to the invasive cheatgrass
- Rangelands shifting to shrubs and more woody vegetation, likely due mainly to management practices
- Long term trends of succession from agricultural to forest, particularly in the Southern U.S.
- Decreased water levels in alpine lakes due to changes in precipitation and snow melt patterns linked to climate change
- Changes in logging trends, such as decreased logging on public lands and increased logging on private lands

Agriculturally, participants noted the following trends:

- Spatial shifts in crops ranges, such as corn growing in North Dakota, that could be linked to climate change and genetic advances
- Changes in types of crops being grown, such as soybean to corn or vice versa, that is linked to genetics and policy and market forces
- An increase in monocultures due to policy and market forces
- Intensification that increases yields due to new technologies and other innovations

Finally, developed trends noted by participants include:

- Increased suburbanization due to population increase
- Increased wildland-urban interfaces (WUI) as people move into less developed areas
- Increased energy exploration and mining, especially coalbed methane extraction
- Increased biofuel production internationally that is impacting LU/LC and GHG emissions globally

The participants discussed how these LU/LC changes are affecting ecosystems. Species' habitats are changing. For example, tree species are moving to higher elevations as temperature is warming, followed by the animals that inhabit those forest types. Locally, change vectors like fire, insects, disease and flooding are impacted by climate change and affecting LU/LC. Globally, climate change-linked change vectors like weather patterns and sea level rise are also impacting LU/LC. Participants also discussed how biodiversity is decreasing, and ecosystem resilience and redundancy may be declining, complex changes that are likely impacted by climate change in addition to policies and management practices.

In terms of human health, participants noted an increase in asthma due to more dust storms, a trend linked to land cover change. Heat deaths in urban areas are also increasing, where heat islands result from decreased natural vegetation. Human deaths also increase as more homes are built in fire-risk WUI areas.

Finally, economic and social well-being are affected by LU/LC changes. In California agricultural lands are decreasing as a result of drought, while in other parts of the country agricultural food production in decreasing as a result of biofuels production due to policy decisions. Heavy storm events in urban and suburban areas are impacting infrastructure and homes and disrupting the lives of residents. In tribal areas, cultural changes and subsistence livelihood changes might result from the changing environmental conditions. Finally, participants discussed how over time human migration patterns in the U.S. will change as people abandon less favorable areas (due to heat, water stress, disturbance events, and overpopulation) for more favorable ones, a change that is both linked to climate change impacts on LU/LC, as well as impacting LU/LC changes in the future.

Question 2: LU/LC Sensitivities and Adaptations

How sensitive are land uses and regions to climatic variability and change, and what LU/LC related adaptations will occur or do we want to occur, to reduce mortality, morbidity, loss of property, and loss of services? Are there documented examples/case studies/vignettes for the possible changes, as well as adaptation and/or mitigation options publicly available? How have these affected risks?

Several important themes emerged from discussions of this question: 1) Downscaling assessments to a landscape level is essential for understanding localized LU/LC sensitivities to climate change and appropriate adaptations; 2) Economics drives decision-making, and understanding local to global economic drivers on LU/LC change can inform current and projected LU/LC changes and the development of adaptation strategies; 3) Short-term and long-term priorities often result in opposing decisions, with long-term thinking being necessary for making sustainable LU/LC decisions; and 4) Local to national policies have a significant impact on LU/LC change.

In terms of sensitivity to climate change, participants noted significant regional variation in both LU/LC changes resulting from climate change, and the ability to detect and quantify those changes (i.e. glacier retreat is easier to define and monitor than agricultural shifts). Specific climate-related LU/LC sensitivities that were discussed, with some examples, are:

- Forest cover is very sensitive to climate changes due to climatic interactions resulting from fire, insects, and pathogens. *Examples*: Mountain pine beetle populations in the west interacting with warmer temperatures; fire frequency and magnitude increasing.
- Agricultural lands are already shifting due to temperature and precipitation changes linked to climate change. Some lands are at risk from long-term droughts while others are benefiting from increased precipitation and moderate temperatures. Management and mitigation for climate change impacts can only be effective to a certain point. *Examples:* Historic crop ranges in the California Central Valley are moving; farmers are growing corn in the upper Midwest.
- Anywhere fire plays an important role in ecosystem functioning could experience significant LU/LC changes due to climate change.
- Coastal areas are seeing loss of wetlands, sea level rise, saltwater intrusion, and increased disturbances as a result of climate change. *Example*: U.S. Fish and Wildlife Service is considering closing some beaches on Chincoteague Island, Virginia due to erosion and sea level rise.

- High latitude areas like Alaska are more sensitive to changes. *Examples*: Retreating glaciers; habitat loss/shifts for polar bears and pika.
- Hydrological changes due to warmer climate are impacting many areas. *Examples:* Spring flooding in the Red River Valley; changes in snow melt and runoff in the Colorado River Basin.
- Tribal lands are fixed areas and climate-related LU/LC impacts here will have permanent impacts on the tribal communities and culture, especially where a patchwork of ownerships exists and the land use decisions of surrounding areas can impact sustainable natural resource management and subsistence livelihoods on tribal lands.

Participants also discussed that ecotones, or the transition zones between ecosystems, are based on physical conditions, including climate, and may shift along with climatic changes.

Adaptations to address these sensitivities were also discussed, including:

- **Land management** plans that consider current and predicted climate change impacts and develop appropriate adaptation strategies can be extremely useful in forestry, rangelands and agriculture. These landscapes can also be managed for their mitigation potential in order to ameliorate climate change. Collaborative ecosystem management where landowners across multiple jurisdictions come together to reach consensus on landscape-level goals and strategies can be used in areas where ecosystem level planning is especially important for environmental or social reasons, such as in tribal areas that are affected by management on adjacent non-tribal lands. *Example*: Anchor Forests in Washington State where Federal, State and tribal forests are collaboratively managed.
- **Land use planning** from local to higher levels should consider and be responsive to climate change impacts. Participants noted that land use planners should utilize market forces, such as insurance, ecosystem services, and property values, as a tool for determining best land uses in an area. Policies sometimes enable poor land use decisions, for example by subsidizing home insurance in risky coastal or fire prone areas. Policies informed by market forces, on the other hand, can support smarter land use planning that considers climate change sensitivities.
- **Landscape and urban design** can be effective for both adaptation and mitigation. For example, increasing urban forest cover can improve microclimates and also absorb carbon. Maintaining significant wildlife habitats and establishing wildlife corridors to allow for species migration resulting from climatic changes is another design measure that can decrease species loss from climate change, although some participants noted that not all species are capable of migration or will be able to migrate quickly enough for these kinds of efforts to protect at risk species. Finally, providing more space for wetlands in coastal areas is an adaptation measure for coastal and near coastal environments.
- **Valuation of ecosystem services** can help protect ecosystems in economic-driven land use decision making. As long as the services ecosystems are providing are not economically valued, including those services for adaptation and mitigation purposes, many land use and policy decisions will not consider the full benefits they provide as measured against the economic potential of alternative land uses that are more fully quantified.
- **Farmland protection policies** that preserve productive farmland for agricultural purposes are essential for food security.

Question 3: LU/LC Interactions with Climate

How are the direct and indirect effects of LU/LC patterns and changes on weather and climate likely to affect future LU/LC decisions (e.g., through green infrastructure or carbon sequestration), and how might those goals conflict with other goals driving LU/LC dynamics?

To approach this question an important distinction was made between biophysical and sociophysical drivers and responses, where sociophysical refers to how human activities and interactions impact a place. Biophysical responses were generally seen as related directly to land cover change – how the landscape changes in response to changes in the physical environment. Land use was seen as the underlying sociological uses of the land by people – some of these uses directly impact land cover changes, while some do not. The question of how changes in weather and climate affect both the biophysical and sociophysical responses is complex. To better organize participant input, the discussion was classified based on NCA sectors: Water Resources, Agriculture, Forestry, Ecosystems, Transportation, Human Health, and Energy Supply and Uses.

Water resources. Critical biophysical processes discussed that might affect and/or be affected by changes in climate from a water resource perspective include: earlier snowmelt, flooding and drought. Each of these has implications that cross sectors. For example, changes in water resource availability have direct implications for agricultural systems, ecosystems and forestry. The over or under availability of water resources in these systems can alter growing paradigms, which in turn has biological, social and economic implications.

An overabundance or a lack of water availability also indirectly impacts human health by affecting potable water supplies and changing disease vectors. Surface water fluctuations can affect urbanization and other land use patterns in indirect ways; sea level rise is one example, timing and quality of snowmelt is another. Snow represents a freshwater reservoir system that can be a net positive when it is released slowly, but negative when that release time is speeded up due to climate changes.

Sociophysical changes in surface water infiltration, generally a function of land use change, can affect the speed and storage requirements of surface water management, which can impact a host of downstream effects, including losses in biodiversity. In terms of water quality, the availability of fresh water is slowly being compromised in coastal zones across the U.S. by the diffusion of saltwater into historic freshwater supplies due to erosion and sea level rise. These biophysical responses can have sociophysical implications into the foreseeable future.

According to participants, the combination of sociophysical and biophysical changes are having a profound impact on U.S. water resources in very direct ways. For example, water withdrawals in the Southeastern U.S. due to population growth and urbanization, coupled with extended periodic regional droughts, are causing water shortages in a typically water rich part of the U.S. Although the most serious implications of changes in water resources are most heavily borne by dry climate zones, irrigation and population increases in the face of fluctuations in rainfall are also affecting remote tropical corners of the U.S. like Hawaii. Another example given is the water resource implications of changes in energy policy, such as ethanol production and the massive water requirements of wet-mill production.

According to the participants, direct Federal responses to water resource issues should include changes to Federal Emergency Management Agency (FEMA) regulations, reservoir development and construction, changes in land acquisition strategies, a more aggressive strategy in implementing storm water best management practices, and market driven potable water conservation strategies such as changes in water rates and water use policy shifts.

Agriculture. Participants mentioned how U.S. agricultural systems are affected both directly and indirectly by changing climate patterns. Changes in albedo and water availability can directly affect the types and productivity of crops, disease probability, and the frequency of crop failure. Climate changes can also force changes in energy inputs – grain transport systems (water based), irrigation (timing and quantity needed), and fertilization and pesticide/herbicide applications. Sociophysical land use changes from low impact uses like forest cover to high impact uses like agricultural systems can affect the magnitude of climate effects, which in turn can have implications for human health, culture, and vulnerability to climate impacts.

Changes in water amounts such as flooding, and the timing of its availability (seasonal changes and changes in snow melt patterns) impact agriculture. This will not only affect production, it will also have regulatory implications in terms of crop insurance expenses, and could have cultural implications in rural areas of the U.S. that have been built around specific cropping varieties.

Positive impacts of climate change include improvements in the growing seasons in parts of the country, although losses in other parts of the country might balance this out. There is also a possibility that an increase in atmospheric nitrogen and CO_2 might improve crop productivity. However, there is evidence that we may be fast approaching saturation, at which point these increases will no longer have a positive impact.

Approaches in addressing agricultural issues include: planting adaptable species, changing seed zone and stock, changing incentives by cover (forest to corn), crop insurance reform, and affecting food processing policies. Another key recommendation is finding ways to improve the connection between people and their food supply. The degree of separation in our current agricultural system between producers and consumers is increasing rapidly.

Forest Resources. Forest resources are affected by direct biophysical and indirect sociophysical processes that result from climate changes. The growth of forest resources are limited by water availability, limits to atmospheric nitrogen, forest genetics, and disease. Changes in forest cover can directly impact albedo in a positive feedback loop of increasing forest cover, decreasing albedo, and increasing snowmelt – although this phenomena is restricted to northern climes and higher altitudes.

The benefits forest resources provide- valuable carbon sinks, critical habitat, temperature regulation, ground water recharge areas, and shade, among other benefits- are affected by the forest clearing process (logging, burning, etc.) that is part of a harvest cycle or change in land use to urban or agricultural uses.

Forested areas provide valuable sequestration opportunities through improved replanting efforts, aggressive forest land management and acquisition strategies, and the creation of durable and long lasting forest products. An added benefit of durable wood product sequestration is that it can also offset the use of more energy intensive, fossil based products.

According to the workshop group, approaches to improve forest resource availability and use include: the inclusion of carbon accounting regulations, a better assessment of woody biomass resources and regrowth periods, a better assessment of biomass use (and potential misuse) as an energy source, sequestration opportunities, and a better understanding of forest resources in strategic landscape interventions as potential microclimate solutions.

Ecosystems. This discussion was infused in the other subtopics. An important component of the discussion however, was the improvement of our understanding of ecosystem services and their role in human health and quality of life.

Transportation and Land Use. The workshop discussion around these areas focused on urbanization and the rapid pace of LU/LC changes that have occurred around urban centers. The implications from a climatic perspective include: fragmentation (biodiversity losses), increases in impermeable surfaces, changes in urban surface temperatures (a positive feedback of surface temperature increases, increases in air conditioning, which leads to increases in urban surface temperatures), vulnerable populations (as part of this feedback – some are unable to afford conditioning costs), and cultural implications (the ways in which we live are being modified by isolating increases in temperature).

Approaches to deal with these issues include providing more detailed information to local decision makers, more public-private interactions, urban form regulation (density improvements), and mass transit improvements. One critical suggestion was improving ways in which profits are determined (i.e. greening the bottom line) as a way to improve developments and decrease negative outcomes.

Energy. The energy discussion revolved mainly around supply questions and its connection to biophysical resource scarcity. Clearly fossil energy extraction and use is a critical connector between biophysical land cover processes and sociophysical land uses. GHG mitigation efforts cannot succeed without changes in our approach to land use, especially in urbanized areas. Adaption to climate change also requires critical changes in the way we connect energy systems to the land and vice versa.

Participants discussed how changes in fossil energy use – near term shifts to natural gas for example (a positive in terms of GHG emissions), are impacting sociophysical relationships with the land. One example of this is the way that newfound efficiencies in natural gas extraction (fracking) are having both direct and indirect effects on land use changes; direct effects include well pad and road construction, while indirect effects include an increase in secondary materials needs. For example, sand mines in the Midwest are expanding rapidly due an increase in demand for sand as part of the fracking operations. Improper disposal of fracking fluids can also affect land cover, as observed in one study that found severe damage and mortality of ground vegetation following the application of fracking fluid (Adams 2011). Also according to the group, the social consequences of these fracking processes are not well understood or considered.

As noted above, water resources are also directly affected by energy use. Ethanol production is a good example of an energy system that relies heavily on water use. Shifts in energy production to biofuels can heavily impact water availability.

The use and development of bio char as part of a shift to bio fuels was also noted as an important potential solution for further study and consideration. The need for changes in market incentives was noted as needed to induce changes in energy production and use. Changes in how landscape sinks are evaluated was also noted as an important component in the discussion. CO_2 storage was also discussed but not seen as part of a viable solution set.

Human Health. The direct relationship between human health and changes in climate through sociophysical processes was noted as important and over looked. Increases in asthma, diabetes, obesity, and cancer rates have all been directly connected to the ways in which we use land. Recent, alarming findings on childhood obesity and the increasingly distant relationship of children with the land was also cited.

Biophysical process changes that also potentially impact human health were also discussed, including the positive feedback loop in urban heat islands and cooling systems, humidity increases in parts of the Southwestern U.S. due to irrigation, and the implications of warming and rainfall changes on potential disease vectors.

Conclusions. The group discussions centered on how changes in weather and climate affect both biophysical and sociophysical processes. The implications and feedbacks that connect the two processes are most critical. Fundamental ecological change due to the connections between these processes that were discussed included: flooding, siltation, ecosystem services, development patterns, and erosion, among others. One participant noted the increase in desertification as fundamental to this discussion (the pattern of forest to people to deserts) – and its place in our cultural history (the Greek over use of the land in past centuries was noted).

Steps to Improve the connection between biophysical and sociophysical understanding were noted, such as: changes in non-market based activities, ecosystem service based payments and decision making evaluations, and changes in current processes that result in risk shifting from private to public entities. Energy independence and political shifts were also seen as critical. All were noted to potentially lead to different land use outcomes than are currently produced. It was noted that national level solutions should be stressed to avoid further burden on States and to avoid jurisdictional disparities and parochialization.

Question 4: LU/LC Decision Makers

Who are the key LU/LC public and private sector decision-makers that need to make climate adaptation and mitigation decisions, and what tools do they need to assess and implement desired actions?

For the first part of this question participants discussed key public and private decision makers.

1. Public decision makers: local officials, tribal leaders, special districts, State and Federal agency officials like planners and land managers, State and Federal elected officials. Participants noted that States play a significant role in LU/LC and should be a focus of outreach for informed LU/LC and climate change planning.
2. Private decision makers: Land owners, land managers and tenants, investors like real estate and timber companies, insurers. Since most land in the U.S. is privately owned, reaching private owners, especially at a local level, is important.

These decision-makers can be influenced by many individuals and groups, including: community leaders, civil society organizations, professional groups like planners, business and industry interest groups, and scientists.

Decision-makers need to be provided with information and tools for making environmentally sound LU/LC decisions based on the best available information. In discussing decision-making tools, the groups merged on four overarching concepts: 1) certainty and uncertainty regarding climate change predictions needs to be communicated in an understandable and non-threatening ways; 2) the economic impacts of various decisions need to be evaluated and communicated to decision-makers; 3) specific examples where climate change impacts are being observed should be emphasized; and 4) traditional knowledge should be linked with scientific knowledge for informing decisions.

Specifically, data and web visualization tools that translate the best available science into understandable climate change scenarios and outputs can be used by decision-makers and made available to the public to support more informed decision-making and create a more educated public on climate change. Some tools that serve these purposes are already available, such as NOAA's C-CAP that allows for visualization of predicted climate change impacts near wetlands and coastal areas. Decision-makers and the public should be made aware of the availability of tools like these and how they work. Additional tools like C-CAP that are easy to use and have meaningful outputs need to be developed and made available as well. Removing barriers like data access and lack of coordination of research efforts would facilitate the development of better decision-making tools. Cross-sectoral tools are also needed to understand climate effects on specific sectors or groups, such as public health impacts of predicted heat waves or climate impacts on infrastructure, in order to assist communities in preparing for and responding to climate-related impacts on health, infrastructure, and other sectors.

In addition to visualization tools, evaluating trends in private sector investments and insurance can be used to understand where the private sector is willing to invest and insure. They are likely conducting their own research and/or consolidating data for making predictions on flooding, sea level rise, storm risk, and fire risk, that is informing their investments and can therefore be used as one metric for evaluating climate change impacts.

Related to this, understanding how incentive programs are working, such as tax policies or insurance rates, can also be used as a tool for understanding some of the driving forces of land use change in an area, and can then be used to influence land use changes by creating incentives and disincentives that support land use goals for the area. Many land use changes are also spurred by infrastructure, and these links need to be better understood.

Participants also identified information needed for adaptation and mitigation planning. For adaptation, decision-makers need analyses of the economic impacts of climate changes and how to mitigate those through adaptation planning. They need to understand the impacts and alternative strategies for both specific groups (human populations and species) and specific places (scenarios). In terms of mitigation, land use impacts on land cover needs to be better understood. Participants emphasized the need to instill a sense of land stewardship among populations and managers as a way to conserve landscapes for mitigation and adaptation purposes. Finally, participants discussed Landscape Conservation Cooperatives (LCCs), collaborative public-private partnerships for landscape level land management across political and jurisdictional boundaries, as tools that can support better decision-making for landscape level adaptation and mitigation planning.

Question 5: LU/LC Data and Gaps

How effective are current land resource assessment data, practices, information systems, and models in addressing the information and trend data needs required to understand the impacts of climate change on LU and LC? Are there gaps and, if so, how might these gaps be addressed through future research? Are new scientific insights and decision tools available for use by decision-makers, including both private land owners and public policy-makers?

In addressing the effectiveness of current data, systems, and models, participants agreed that the U.S. has more comprehensive land cover data given the technologies' inherent ability to produce integrated national level images across the landscape. On the land use front, because ownership and jurisdictions vary, monitoring shifts in land use from changes in rotational cycles in agriculture and forestry, to changes in development patterns, agricultural use and delineation of grasslands, requires integrated approaches across several jurisdictional landscapes. When land cover data are combined with land use data, the integrated picture of both land cover and land use can enhance the data needed for effective policy analysis. Leading edge work is ongoing across the country in developing the algorithms required to combine land cover images with ground-truthed land use data to produce integrated LU/LC products for decision making in response to a changing climate. In terms of processes for analyzing and using data, participants made several important observations:

- Understanding why LU/LC changes are occurring is not always possible, even when the changes themselves are understood
- A national framework needs to enable data collection and analysis to meet regional and local needs, and ways for local data to feed up into a national framework
- Continuity of data collection needs to be a priority, such as Landsat and stream gauges whose continuity depends on government funding

Specific gaps the groups identified were:

In data and tools:

- LU/LC data do not go as far back in time as climate and population data

- The granularity of socio-economic data is not sufficient for hazards assessment
- Data on remote areas in Alaska are limited
- More field data are needed to validate satellite data and connect broad-based assessments to the local level
- Data on soil moisture and roads are limited
- Consistent Lidar data for spatially explicit vegetation height maps and high resolution topo maps are lacking and cost prohibitive at national levels
- Land use and land cover characteristics for urban areas, especially on the fringes of urban areas, is lacking
- The value of ecosystem services for various land uses is often poorly understood
- Globally, there are significant data gaps in LU and LC

In processes:

- Policy issues prevent dissemination and exchange of many datasets among agencies, and from national to local levels and vice versa
- Good information at higher levels does not lead to prioritization of where to improve upon or focus data efforts
- Local level observations need to be incorporated in order to better evaluate how risks will change with likely climate scenarios
- Collecting oral histories, including in tribal areas, could be used for improving historical climate records with anecdotal and correlated evidence
- The private sector, like Google, could play a role in addressing data and communication gaps

Participants discussed two new tools that are available to help decision-makers. First, new attention on valuing ecosystem services can assist decision-makers in making economically-driven LU/LC decisions that consider the full economic benefits of ecosystems as weighed against alternative land uses. However, more research is needed to improve economic valuation of ecosystems, and locally-relevant data needs to be available at local levels. Second, web-based visualization tools can help connect communities to the best available science on predicted climate change impacts in an understandable way. However, more tools like this are needed and their availability and use needs to be communicated broadly across the U.S.

Finally, in terms of new insights into processes for improving decision-making, participants made several observations: 1) making observations locally relevant with local examples is helpful in communicating with the public; 2) engaging citizenry in data collection can lead to more meaningful local participation and help fill data gaps; and 3) building sustained interdisciplinary teams could help characterize and explain the complexity of LU/LC change.

Creating a Sustained NCA Process for the LU/LC Sector

Since one of the goals of the current NCA process is to create a long-term and sustained process for assessing climate change, on the final day of the workshop participants discussed strategies for creating continuity in the LU/LC sector of the NCA. The questions they addressed and their responses are summarized below.

How do we bring the various LU/LC efforts together?

The discussion here focused on examples of interagency collaboration that could be good models for LU/LC work, including:

- Landscape Conservation Cooperatives (LCCs) for integrated resource management in strategic habitats have a system for sharing data and working together.
- The National Wildfire Coordinating Group in Boise, Idaho is an operational group where each participating agency brings its own funding but as a group they identify common themes and work together in wildfire management.
- NOAA/NASA/NSF work together in a joint center for some specific weather-related tasks, such as hurricane forecasting and response.
- USGS coordinates the National Climate Change and Wildlife Science Center (NCCWSC), which works with scientists and land managers at national, regional, and local scales to provide resource managers with the tools they need to address climate change.
- EPA coordinates annual GHG reporting to the UNFCCC by collecting and reviewing data from all relevant agencies. However, while the agencies all report to the EPA they do not work with one another, so this might not be an appropriate model for collaborative LU/LC work.
- Under the Energy Policy Act multiple agencies come together to report on how well conservation and energy goals are being met. This is very well-funded by energy agencies.
- Under the MRLC multiple agencies shared costs of acquiring Landsat data, when it was expensive, and pre-processed the data to common specification that everyone could use. This evolved into producing national land cover maps (see NLCD discussion above). Each involved agency has assigned several people who will come together annually. However, this group does not have a legislative mandate, while the NCA does.
- Under the auspices of Interagency Council on Agricultural and Rural Statistics (formed in support of the “Global Strategy to Improve Agriculture and Rural Statistics” of the United Nations Statistical Commission) an interagency 'Land Use and Land Cover Working Group' was formed to take steps to improve the comparability of major Federal land use and land cover datasets. Nine Federal agencies are represented on the working group.

Participants also mentioned that interagency cooperation needs to emphasize the return on investment for participating agencies. For example, the MRLC has huge benefits for each participating agency. Participants also noted that if data are made publicly available, others (i.e. researchers, NGOs) will begin using, processing, and analyzing it in novel ways that could be widely informative.

What is the capacity we can build to support assessing CC and LU/LC in a sustained way?

Participants discussed that NGOs have high capacity and could be more engaged in NCA processes. NCA net does have a process for identifying relevant NGOs and reaching out to them for input and collaboration.

What is the capacity we can build to support assessing CC and LU/LC in a sustained way?

For the near term, participants recommended two actions to support sustained CC assessments:

1. Define goals for where we want to be in several years, and what we need to get there (strategy). This would help define where we need to make investments.
2. Invest in data synthesis efforts. There are census databases, health and economic databases, resource datasets, etc., and not many teams are working across sectors. If people get together for data synthesis efforts, data gaps will be identified and investments can be made there. Some

also noted that existing agency inventories could be synced with NCA year needs to support better data synthesis.

Participants noted a lack of data on land use at a similar scale to climate, meaning that downscaled climate data that could be used in the assessment does not synchronize with land use either temporally or spatially. This is a major gap both historically and moving in to the future. Whatever the data needs are determined to be, a geographical and classification framework needs to be established that is seamless from the past to the future.

Participants discussed the need to put more effort into long-term scientific work on LU/LC, and this research needs to draw in expertise from the climate side to better sync LU/LC efforts and data with climate science. There is also a significant need to understand how climate changes and LU/LC changes are influencing policy, which then in turn influences future LU/LC changes. Land use might ultimately be more affected by policy than by climate, and both need to be better understood.

Finally, it was noted that so far the LU/LC discussions have not been put in the context of a risk assessment framework. Some chapters of the NCA will have a better risk approach than others. There should continue to be thinking and discussions on how a risk assessment framework can be applied to LU/LC.

Conclusion and Future Needs

The presentations and discussions during this workshop reflect the breadth of LU/LC and climate change work and expertise that exists in the U.S. They also reflect the widespread use of LU/LC data in multiple applications related to LU/LC change monitoring, LU/LC modeling and projections, climate change adaptation and mitigation planning, carbon accounting, land use planning, and natural resources management, among other uses. Enhancing the country's ability to monitor and understand LU/LC and climate change issues at the national, regional and local levels is essential for improving LU/LC decision-making and climate change planning. This will require coordination among entities collecting and using LU/LC data, additional resources for downscaling LU/LC-related climatic data and projections to more areas, and interdisciplinary research to improve the understanding of the social and environmental impacts of LU/LC change from a climate change perspective. Addressing variability in definitions will help inform national discussion in the LU/LC sector. Merging land use estimates from various sources requires understanding each data source agency's set of criteria and jurisdictional differences for classifying land in different categories.

In addressing the effectiveness of current data, systems, and models, the U.S. has more comprehensive land cover data given the technologies' inherent ability to produce integrated national level images across the landscape. On the land use front, because ownership and jurisdictions vary, monitoring shifts in land use from changes in rotational cycles in agriculture and forestry, to changes in development patterns, agricultural use and delineation of grasslands, requires integrated approaches across several jurisdictional landscapes. When land cover data are combined with land use data, the integrated picture of both land cover and land use can enhance the data needed for effective policy analysis.

The **valuation of ecosystem services** is a critical area for LU/LC discussions from both an adaptation and mitigation perspective and can help protect ecosystems in economically-driven land use decision making. As long as the services ecosystems are providing are not economically valued, including those services for adaptation and mitigation purposes, many land use and policy decisions will not consider the full benefits they provide as measured against the economic potential of alternative land uses that are more fully quantified. Development of an ecosystems valuation methodology that can be applied at multiple landscapes levels for both land use and land cover is much needed.

Climatic variability is a driver of regionally episodic fires and endemic insect outbreaks, therefore “new” science on climate and ecological disturbances is principally concerned with quantifying the mechanisms and variability in relationships between climate and ecological disturbance. From an ecosystem perspective, thresholds can be reached either through cumulative effects of individual disturbances over time or one large event, and can lead to new forest composition, land cover, and landscape patterns. However, more information is needed on the interaction of ecological disturbances and other environmental stressors, especially for large spatial and temporal scales in the LU/LC cross-sectoral area. Another area of critical importance in the LU/LC discussion is the issue of species range shifts and their impacts on land use and land cover patterns. A significant level of effort is needed in this area from a mitigation and adaptation perspective.

Although risk management frameworks have been used (often informally) in natural resource management for many years, it is a new approach for projecting climate-change effects, and some time may be needed for both scientists and resource managers to feel comfortable with this approach. Risk assessment for climate change should be specific to a particular region and time period, and needs to be modified by an estimate of the confidence in the projections being made. Further work is needed to refine and expand existing risk management frameworks to better address climate change vulnerabilities and potential effects in the LU/LC area.

To inform stakeholders nationally, regionally and locally on land use and land cover trends we will need to continue discussions to further work in this area for the NCA 2013 Report, the subsequent 2017 Report, and beyond. Interim products that shed light on shifting land use and cover trends that have been discussed above will continue to be made available by various Federal Agencies. These can provide interim access to the NCA efforts as we move forward.

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Appendix C: Workshop Agenda

Tuesday • November 29, 2011

8:30 Registration

9:00 Opening – **Toral Patel-Weynand** and USFS **Tom Loveland**, USGS

9:20 Process and Introductions – **Nancy Walters**, Facilitator, USFS and **Richard Zabel**, Meeting Logistics Contractor, Western Forestry and Conservation Association

9:40 Keynote Address – **Richard Guldin**, Director, Research and Development, Quantitative Sciences, USFS

10:00 Break

10:30 In Harm's Way - The Murky Geography Where Hazards and Humans Intersect: A Think Piece – **Paul Bolstad**, University of Minnesota

10:55 National Climate Change Assessment: Overview and Expectations for NCA LU-LC Sectorial Report – **Kathy Jacobs** and **Ralph Cantral**, US Global Change Research Program

11:20 Risk Assessment Framework – **Gary Yohe**, Wesleyan University (by phone)

11:45 Lunch on your own

Sensitivity and Response of Land Uses and Regions to Climatic Variability and Change

1:00 Vegetation Changes in the Western US – **Jim Vogelmann**, USGS

1:25 Accounting for Ecological Implications for LU-LC Changes – **Joel Brown**, NRCS

1:50 LU-LC and Carbon Estimations – **Sean Healy**, USFS

2:15 Break

2:45 LU-LC Modifications in Middle-latitude Continental Areas and Interactions with Climate – **Andrew Carleton**, Penn State University

3:10 Regional to National Perspectives on U.S. Land use, Land Cover, and Climate Variability – **Tom Loveland**, USGS

3:35 Discussion Session

Emerging Issues

4:00 Climate Assessment and Crop Insurance – **James Hipple**, Risk Management Agency

4:30 Adjourn

Wednesday • November 30, 2011

7:30 Continental breakfast

8:30 Workshop opening

Land Use and Land Use Change Modeling, Scenarios and Projections

8:35 Land Use Forecasting: Linking Economic Drivers to Resource Implications – **David Wear**, USFS

9:00 Land Use Histories and Regional SRES Consistent Land Scenarios – **Ben Sleeter**, USGS

9:25 Break

9:55 Climate Change Impacts on LU-LC in the U.S: Using MC1 and Related Economic Models – **Brent Sohngen**, Ohio State University (By Phone)

10:20 Discussion Session

Data and Applications

10:40 Using the National Resources Inventory to Examine Changes in LU-LC Patterns – **J. Jeffery Goebel**, USDA – NRCS

11:05 National Park Service: LU-LC Data Uses and Needs – **Mike Story**, NPS

11:30 Lunch on your own

1:00 National Land Cover Monitoring: The Cropland Data Layer – **Rick Mueller** National AG Statistics Service

1:25 Landscape Change Monitoring System: Moving Toward a Comprehensive Landscape Monitoring Information System – **Brian Schwind**, USFS

1:50 Reconciling Remote Sensing with National Inventory Data for Land Use and Carbon: A National Approach for all Lands – **Ken Brewer**, USFS

2:15 Break

2:45 Representation of Land Use and Management in the US Greenhouse Gas Inventory – Stephen Ogle, Colorado State University (by phone)

3:10 Estimating Land Uses: Data Gaps and Data Needs – **Cindy Nickerson**, ERS

3:35 Coastal Land Cover Change: Trends and Tools – **Nate Herold**, NOAA

4:00 Monitoring U.S. Land Cover Change – **Matt Hansen**, NASA

4:25 Discussion

5:00 Adjourn

Thursday • December 1, 2011

7:00 Continental breakfast

8:00 Envisioning the NCA Chapter on LU-LC – **Colin Polsky**, Clark University (by phone)

8:30 Break-out Sessions to gather input for the chapter

Topic 1: Trends
Topic 2: LU-LC Sensitivity to Climate Change
Topic 3: LU-LC Goals
Topic 4: Tools for Decision Makers
Topic 5: Data Needs

12:00 Lunch on your own

1:00 Summary and response session

2:15 Break

2:30 USGCRP/NCA discussion on how we envision moving forward on the 2013 NCA and beyond for the LU-LC Sector – **Kathy Jacobs**, USGCRP

2:55 Break-out Sessions

5:30 Adjourn

Friday • December 2, 2011

9:00 to 12:00 Planning Meeting (Writing Team and Logistics Team)