Geographic Analysis and Monitoring Program

5 – Year Program Plan

2008 - 2013

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I. Executive Summary

Geography is an interdisciplinary science that offers great potential for integrating important environmental and social processes in order to improve and maintain both human well-being and environmental quality. Moreover, it has the potential to identify spatial variations in these processes, so as to facilitate a more "place-specific" solution to environmental problems, including reductions in risk to hazards and options for greater adaptability to an uncertain future.

The Geographic Analysis and Monitoring (GAM) Program, part of the United States Geological Survey's (USGS) Geography Discipline, conducts geographic analyses that monitor the Earth's land surface, models the processes that shape it, and develops products that aid environmental decision making. Its goal is to understand the Nation's urgent environmental, natural resource, and economic challenges. The Program embraces an integrative, analytical approach of: implementing land surface monitoring strategies; identifying the causes and consequences of change; and developing decision-support tools and alternative future scenarios that promote environmental sustainability and reduces vulnerabilities and risks. Monitoring strategies focus on quantifying the rates and trends of recent land surface change due to both natural and anthropogenic causes. Researchers use these data in hypothesis-driven analyses and computer models to identify key drivers of change and possible impacts on the environment. Such information is critical for developing decision-support tools and alternative future scenarios that enable knowledgeable place-based decisions on resource allocation and use.

The GAM Program's research agenda for 2008 – 2013 is guided by four goals:

- Characterize and quantify land surface status and trends to provide a framework for understanding change patterns and processes from local to global scales.

- Understand past, present, and future environmental consequences of land change to support better management of their effect on people, environment, economy, and resources.

- Improve the scientific basis for vulnerability and risk assessment, mitigation, response, and recovery related to the human and environmental dynamics of land change.

- Develop credible and accessible geographic research, tools, and methods to support decision-making related to the human and environmental consequences of land change.

These goals focus the Program's activities on land surface analyses, analyzing and evaluating the impacts of both natural and anthropogenic change on human and ecosystem processes, as well as using the resultant information assessing hazard vulnerabilities and improving resource decision-making.

II. Introduction

Geographic research is concerned with space, place and location, as well as the distribution, arrangement, patterns and flows of people and resources on the Earth (NRC 2002). As a field of study, geography is unique because it allows us to understand the processes that shape the Earth's surface, as well as the spatial interactions that dictate the movement of people and resources. Geographic research provides a more complete picture of the world by (USGS 2005):

> (1) furnishing a place-based perspective focused on understanding environmental conditions
> (2) analyzing the movement of matter, energy, commodities, and people across the landscape and the resulting surface patterns
> (3) integrating knowledge from multiple disciplines or fields to provide a holistic perspective
> (4) using unique geographic tools ranging from maps to spatial visualization and data mining tools

Geography is a multidisciplinary science, integrating important environmental and social processes in order to improve and maintain human well-being and environmental quality. It provides a methodology for integrating information from a wide variety of fields, enabling the answering of complex environmental and social questions. Moreover, it identifies variations in spatial processes, so as to facilitate a more "place-specific" solution to environmental problems, including reductions in risk to hazards and options for a greater adaptability to an uncertain future. Scale, the level of resolution in environmental data, is a fundamental concern in geographic research. By accounting for differences in scale, data from intensively studied local sites can be properly extrapolated to broader geographic regions and incorporated into environmental models. This results in more comprehensive solutions to environmental problems, as well as the broader application of research results.

These characteristics make geographical scientific research more relevant than ever. As the human population increases, congruent with its resource needs, we make use of the planet's resources in increasingly complex and potentially conflicting ways. Thus, it is more important than ever to monitor the Earth's surface, understand the forces shaping it and predict the impacts of changes. Resource managers and scientists at local, regional, national and global scales require reliable, comprehensive and scalable scientific data on the condition of the land and the services it provides, as well as the tools to use this information in decision-making. To address these issues, the Geographic Analysis and Monitoring (GAM) Program was created as part of the Department of Interior's US Geological Survey.

Department of the Interior

The Department of the Interior (DOI) is the Nation's principal Federal conservation agency. Its mission is to protect and manage the Nation's natural resources and cultural heritage, provide scientific and other information about those resources, and honor its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities. To meet its mission, the DOI drafted a strategic plan that seeks to strengthen its scientific endeavors, improve the management of natural resources and promote partnerships with local communities (DOI 2003). The plan calls for science programs to focus their efforts on data

collection and integration, as well as understanding, modeling and predicting impacts on natural systems. It acknowledges rigorous and relevant science as the foundation for informed resource management decisions. In addition, the plan identifies preparedness for natural disasters such as wildfire and drought as critical competencies, and highlights the need for impartial, peer-reviewed science as the underpinning for understanding and preparing for such events.

U.S. Geological Survey

The U.S. Geological Survey (USGS) is the DOI's principal science agency. It provides unbiased, independent data and information on the Earth's hydrology, geology, geography, and biology. Specifically, the USGS serves the Nation by providing reliable scientific information to describe and understand the Earth, minimize loss of life and property from natural disasters, manage water, biological, energy, and mineral resources, and enhance and protect our quality of life. Included in the USGS mission are requirements to conduct systematic analyses and investigations to inform natural resource decision making (USGS 2002). To achieve its mission, the USGS continues to improve the quality and usefulness of its long-term data sets, and where appropriate, work with partners (other federal, state, tribal, and local governments; academic and research institutions; and private organizations) to acquire the necessary data. In the fall of 2006, a ten year science vision that delineated seven strategic directions for the Bureau was submitted to the Bureau Planning Council (BPC) (USGS 2006):

1. Understanding ecosystems and predicting ecosystem change
2. Role of the environment and wildlife in human health
3. A water census of the United States
4. A national hazards, risk and resilience assessment program
5. Climate variability and change
6. Energy and minerals for America's future
7. New methods of investigation and discovery

Each of the strategies emphasizes both local scale, place-based investigations and regional scale, nation-wide assessments and products. Linking local information to regional and national assessments requires robust, geographical analyses capable of being implemented across spatial scales and integrating, multi-disciplinary research results.

Geography Discipline

In August 2004, the Geography Discipline was created, encompassing the Geographic Analysis and Monitoring (GAM) and Land Remote Sensing (LRS) Programs. Its purpose was to strengthen the Bureau's geographic research, as well as manage the Landsat satellite system. The Discipline's fiscal year 2008 budget was $77.7 million. In addition to these congressionally appropriated funds, the discipline receives reimbursements from other federal, state, and international organizations. After 16 months of intensive study, the USGS in April 2005 released *Geography for a Changing World: a Science Strategy for the Geographic Research of the U.S. Geological Survey, 2005-2015*. This plan presents the vision and mission of USGS geographic research (USGS 2005):

Vision: The USGS will lead the Nation in advancing geographic science by improving and expanding earth observation and by integrating natural and social science knowledge for more informed decision-making.

Mission:

1. Understand the human and environmental dynamics of land change.
2. Provide leadership in sustaining the nation's core geographic competencies: regional geography; the integration of natural and social sciences; and the remote sensing and modeling of earth systems.
3. Develop and apply innovative methods to understand and improve linkages between science and decision-making.
4. Establish creative and synergistic partnerships nationally and globally to create new knowledge, leverage resources and support the geographic mission of the USGS.

The Plan also provides a series of nine interrelated science goals that together define a scientifically challenging and vital research program for the next ten years:

1. Characterize and quantify land surface status and trends to provide a framework for understanding change patterns and processes from local to global scales.
2. Identify local, regional, national, and global drivers of land change to forecast plausible land change scenarios over the next 20-50 years.
3. Understand past, present, and future environmental consequences of land change to support better management of their effect on people, environment, economy, and resources.
4. Improve the scientific basis for vulnerability and risk assessment, mitigation, response, and recovery related to the human and environmental dynamics of land change.
5. Develop credible and accessible geographic research, tools, and methods to support decision-making related to the human and environmental consequences of land change.
6. Develop and test hypotheses about the use of geographic regions to understand the human and environmental dynamics of land change.
7. Observe the Earth at all scales using remote sensing to understand the human and environmental dynamics of land change.
8. Provide timely, intelligent access to new and archived USGS geographic data needed to conduct science and support policy decisions.
9. Develop innovative methods of modeling and information synthesis, fusion, and visualization to improve our ability to explore geographic data and create new knowledge.

Geographic Analysis and Monitoring Program

The GAM Program forms the nucleus of the Geography Discipline's research program, concerning itself with all aspects of land-surface change that influences both the current and future social welfare of the United States. It conducts long-term studies of the land cover and disturbance histories of the United States and selected overseas areas, as well as research leading to improved understanding and knowledge about geographic processes. These geographic processes include climate change, urbanization and agricultural development, resource extraction, invasive species and disease distributions. The GAM Program also compiles, interprets, and publishes, at global, national and regional scales, data and information on significant land-surface changes. In addition, it conducts research and develops methods for monitoring environmental hazards through the creative use of geographic analysis tools. These investigations are designed to lead to the operational implementation of products and techniques that inform resource managers and provide early warning of adverse impacts on human populations and ecosystems.

The primary users of products for the GAM Program are the scientific community, local, state and federal agencies, and public organizations that make land management decisions. It works closely with stakeholders within the DOI Bureaus having management roles by providing geographic analysis expertise. Multi-agency environmental monitoring activities, such as LANDFIRE and the Gap Analysis Program (GAP) are supported by the GAM Program's land cover monitoring projects. The GAM program directly supports DOI's participation in the Nation's Climate Change Science Program (CCSP) through direct active representation on the USGS's Global Change Policy Coordination Committee and by representing DOI on CCSP Interagency Working Groups. In addition to aligning with DOI, USGS, and Geography Discipline directions, GAM activities are relevant to and support many international organizations, initiatives and conventions related to earth observation and landscape change including: the Group on Earth Observation (GEO); the Committee on Earth Observation Satellites (CEOS); the Integrated Global Observing Strategy/Integrated Global Observations of Land (IGOS/IGOL); and the International Geosphere-Biosphere Programme (IGBP). The GAM Program provides direct, active representation to the Global Earth Observing System of Systems (GEOSS) Secretariat in Geneva, thus helping to guide the conceptualization and design of a new and integrated Global Land Observation System. It works closely with other USGS Programs from all of the other disciplines, incorporating data on water, geologic and biological resources, while providing data on land resources and tools for communicating scientific information.

Program funding is provided in the following table:

Table 1. GAM Funding by Fiscal Year

Fiscal Year	Allocation (SIR) (in thousands)*
2001	16,408
2002	16,338

2003	16,374
2004	15,238
2005	14,628
2006	14,705
2007	16,926
2008	16,266
2009 (proposed)	10,550

*For the period 2001 – 2008 these amounts include approximately $2,000,000 for the Priority Ecosystems Studies Program.

Every fiscal year, two million dollars of GAM's budget are slated for the Priority Ecosystems Studies (PES) Program. This Program funds research in six study units: South Florida/Everglades; Chesapeake Bay watershed; Platte River watershed; Greater Yellowstone Ecosystem; Mojave Desert and San Francisco Bay.

Current Scientific Accomplishments

The previous five year plan (http://gam.usgs.gov/pdf/GAM_5year_plan_Sept27.pdf) was approved in 2002 and described the GAM Program as addressing four fundamental science goals:

- Understand what changes are occurring on the land surface and why,
- Understand the impacts of these land surface changes on ecosystem health, climate variability, biogeochemical cycles, hydrology, and human health,
- Understand how these impacts may in turn affect the land surface through feedback mechanisms, and
- Understand what the best methods are to incorporate GAM science findings in the decision-making process.

The following paragraphs provide brief descriptions of projects undertaken in response to these four goals.

The goal of the National Land Cover Database (NLCD) is to produce a land cover database populated by multiple datasets that describe the land surface of the US. The first dataset (1992 NLCD) was completed in 2000, with the next iteration (2001 NLCD) scheduled to be completed in 2008. The 1992 dataset includes only land cover classes and covers only the conterminous US. In contrast, the 2001 dataset includes land cover, percent impervious surface, and percent canopy cover and encompasses all 50 states and Puerto Rico (http://www.mrlc.gov/). A major accomplishment of the NLCD has been the completion of the first moderate resolution land cover dataset of Alaska. The NLCD is the only comprehensive, moderate resolution land cover dataset of the US and is the basis of many regional and national environmental assessments, including the Heinz Center's State of the Nations Ecosystems and EPA's Report on the Environment. It is also a critical component in assessing the impacts of land cover change on

water and air quality, wildlife habitat, through the GAP Program, and wildfire behavior through the LANDFIRE Project...

The Land Cover Trends Project (http://eros.usgs.gov/LT/) documents the rates, causes, and consequences of land use and land cover change for the conterminous US between the years 1973 - 2000. It is based on statistical samples distributed across the ecoregions of the US. Research results are used to produce a series of reports that highlight the nature, causes and consequences of the land cover changes taking place. These reports address issues such as the current state of the Nation's land surface, the forces driving land use change, regional trends, and the environmental, social and economic effects of the changes taking place. The first report, A Status and Trends of the Eastern US was digitally published in FY 2006 and highlighted the impact of loblolly pine plantation operations in the south-eastern US (http://eros.usgs.gov/LT/coverpage.html). In June 2007, the project was reviewed by a panel of external experts who determined that the project was proceeding well, meeting important scientific objectives and recommended that it be completed.

Through the NLCD, Land Cover Status and Trends reports, as well as other research activities, the USGS has taken the lead in mapping and monitoring land cover. In order to highlight USGS leadership in these areas, the GAM Program organized and managed three conferences whose purpose was to promote the use of land cover information in scientific analyses and resource management plans. These three conferences were:

1. An internal USGS conference was held in September 2004 that brought together scientists from across the Bureau to discuss land cover analyses, the causes of land cover change and its impacts.

2. An internal Department of Interior conference was held in January 2005 that brought together scientists and resource managers in discussions on how land cover information can be used in effective land management programs.

3. The final meeting was held in September 2006, the North American Land Cover Summit and included scientists and managers from a number of government agencies including: the USGS; EPA; USFS; Agriculture and Agri-Food Canada; Natural Resources Canada (NRC) and the Instituto Nacional de Estadistica Geografia e Informatica (INEGI). Its purpose was to highlight the need for cross border cooperation on land management issues and scientific research.

The GAM Program has partnered with several governmental and non-governmental organizations to advance our understanding of land-cover change on the landscape by developing tools and methodologies for use by resource managers. Three tools have been developed, the Global Data Toolset (GDT) (http://rockyitr.cr.usgs.gov/gitan/), the Rapid Land Cover Mapper (RLCM) (http://edcintl.cr.usgs.gov/rlcm/index.php) and the Land Cover Analysis Tool (LCAT) (http://lcat.usgs.gov/). The GDT is used for presenting and analyzing environmental and conservation datasets, while the RLCM allows for the easy land-cover classification of remote sensing imagery. Both of these tools have been accepted and used by a number of international partners with the RLCM successfully used to map critical biodiversity habitat in Paraguay. The LCAT was developed to provide enhanced public access to the NLCD, allowing users to quickly locate, analyze, display, and download data.

The GAM Program has partnered with other federal agencies and academia to advance a research agenda on valuing ecosystem services for improving decision making on resource use and conservation. A workshop was conducted in October 2007, highlighting the tools and methods that combine ecological, physical, and economic information into models supporting decision-making. The research agenda supported two broad goals:

- Better understand how information on the value of ecosystem services can improve decisions by resource management and conservation agencies; and
- Advance efforts to combine scientific and economic information and models.

This workshop also served as a planning session for the 2008 National Conference on Ecosystem Services. The National Conference will bring together a comprehensive group of researchers, managers, and policy makers to assess the status of current knowledge and to advance a research agenda, resulting in published proceedings.

The GAM Program has supported research on the environmental impacts of the US road network through The Road Indicator Project (TRIP). Roads encroaching into undeveloped areas generally degrade ecological and watershed conditions, simultaneously providing access to natural resources, land parcels for development, and recreation. A metric of roadless space is needed for monitoring the balance between these ecological costs and societal benefits. The project has introduced a metric, roadless volume (RV), which is derived from the calculated distance to the nearest road. The projects results were published in the journal *Science* (Vol. 316. no. 5825, pp. 736 – 738)

Working cooperatively with American Forests, the USGS has developed a web-based tool that utilizes land cover data to estimate the economic value of trees in urban areas. The tool combines measures of tree canopy and impervious surface with scientific and engineering equations, as well as estimates of construction and remediation costs to estimate the economic benefits of urban tree cover. A website (http://rns03767.er.usgs.gov/Website/citygreen/citygreen.html) contains analyses of land cover for 2000 US urban areas with estimates of the corresponding savings to these cities due to reduced runoff, improved air and water quality, and carbon sequestration. By using the application provided, users can extract an approximate value of the ecological services produced in any urban area in the country.

Carbon dioxide in the atmosphere plays an important role in regulating the climate of the Earth system. The continuing increase of atmospheric CO_2 concentration has the potential to significantly alter our living environment and affect the economy at the regional to global scales. Land cover change information derived from Landsat imagery was used for assessing carbon storage change for the conterminous US, with results indicating that the U.S. landmass has been a significant carbon sink since 1973 (http://edcintl.cr.usgs.gov/carbon_cycle/). However, its strength has decreased from 1973 to 2000. It also revealed that large portions of the Nation's soil organic carbon are in high latitudes on lands managed by the DOI. A set of 523 soil profiles in Alaska were evaluated to establish a baseline for monitoring future changes in soil carbon. The monitoring will be essential for evaluating programs for carbon sequestration, and for assessing the potential for unintended feedbacks in which climate change may influence the carbon flux rates.

The GAM Program has developed methods and tools that combine natural science and socioeconomic information to inform public policy decisions on vulnerability and risk to natural and environmental hazards. The Land Use Portfolio Model (LUPM), a model and decision tool that applies financial portfolio theory to help communities understand and evaluate vulnerability and risk from natural hazards is a key example. It uses inputs identified by stakeholders, such as hazard data, mitigation costs, number of locations mitigated, and planning horizon, to assess the regional impacts of hazardous events with different mitigation or land use strategies. The LUPM has been applied to earthquake mitigation planning in Watsonville, CA and Memphis, TN, as well as in Squamish, BC to assess flood risks (http://geography.wr.usgs.gov/science/squamishFlood.html). The LUPM approach is currently being used to analyze ecosystem portfolios in South Florida (http://geography.wr.usgs.gov/science/GISFlorida.html) and multiple hazards in Southern California.

Although there is considerable energy focused on assessing natural hazards associated with tsunamis in the U.S. Pacific Northwest, little has been done to understand societal vulnerability to these hazards. In response to this knowledge gap, the GAM Program is helping state and local planning practitioners understand variations in land cover, demographics, and economic assets through innovative uses of GIS technology and community workshops (http://geography.wr.usgs.gov/science/tsunamis.html). Results of a regional GIS-based analysis suggest that human occupation and development of hazard-prone land varies considerably along the Oregon coast and that differences in community exposure and sensitivity vary in relation to city size. They also suggest that in the absence of socioeconomic data or local knowledge, the integration of hazards information and land-cover information derived from Landsat imagery may be a useful first step in comparing community vulnerability for regional hazards. USGS scientists are also conducting community workshops to improve the integration of scientific knowledge and local values in post-disaster resilience and recovery planning.

Health problems caused by emerging infectious diseases are a growing concern, prompting research in the geographic analysis of disease and in landscape epidemiology. The spread of West Nile virus (WNV) across the United States highlights the shortcomings in our understanding of the spread of vector-borne diseases. It illustrated our limited ability to detect the presence of pathogens in the environment and to measure and predict their extent and virulence. USGS scientists conducted several studies on WNV to obtain a better understanding of the current and future geographic distribution of WNV. One study found that non-passerine species richness was significantly negatively correlated with both mosquito and human infection rates, whereas there was no significant association between passerine species richness and any measure of infection risk. Our findings suggest that non-passerine diversity may play a role in dampening WNV amplification rates in mosquitoes, minimizing human disease risk. As part of a collaborative effort with the Centers for Disease Control and Prevention, maps showing current WNV activity in the United States are posted every Tuesday on the USGS web site (http://diseasemaps.usgs.gov/).

In an effort to better support USGS scientific modeling and forecasting activities, and to identify opportunities for sharing and collaborating in environmental modeling across the Bureau, GAM conducted a survey of USGS scientists in all disciplines and regions on the types of models used in environmental analyses. The resulting searchable database contains a detailed description as well as system and data requirements for each submitted model and is a useful reference tool for

researchers and managers alike. Models were submitted by scientists in the Biology (39), Geologic (23), Water (22), and Geography (14) Disciplines as well as the GIO (1). Hydrology (37%), habitat (25%), landscape ecology (24%), and water quality (21%) models were the most commonly identified subjects indicated by model developers and users. Results gained from this survey were used to identify key issues and opportunities for the First USGS Modeling Conference held in Nov 2005.

GAM Future Initiatives and Scientific Directions

The GAM Program's research agenda for 2008 – 2013 is guided by the USGS' geographic science plan: *Geography for a Changing World*. The Discipline's senior staff has identified four out of the original nine goals as having higher priority (1, 3, 4, and 5). These four goals encompass ten strategic actions (SA):

Goal 1. Characterize and quantify land surface status and trends to provide a framework for understanding change patterns and processes from local to global scales.

SA1.2: Expand capabilities to map and measure land cover and land-cover change at multiple scales that are locally relevant yet globally consistent

SA1.3: Determine how much of the national and global land changes result from natural and human influences

SA1.4: Establish an operational ecosystem monitoring system that continuously measures and characterizes the current status of ecosystem goods and services to estimate and explain deviations from normal conditions

Goal 3. Understand past, present, and future environmental consequences of land change to support better management of their effect on people, environment, economy, and resources.

SA3.1: Conduct research on the consequences of land change on climate, water, carbon cycle, ecosystems, invasive species and societal concerns

SA3.2: Conduct research on specific consequences of land-use and land-cover patterns and changes for environmental health and public safety issues, particularly at the boundaries between developed and wildland areas

SA3.3: Conduct research leading to improved capabilities to assess wildfire conditions, predict wildfire potential, prioritize treatment areas, and monitor effectiveness of fire treatments to support risk-reduction efforts in the urban-natural landscape interface

Goal 4. Improve the scientific basis for vulnerability and risk assessment, mitigation, response, and recovery related to the human and environmental dynamics of land change.

SA4.3: Improve research capacity to model vulnerability and resilience to natural and anthropogenic hazards.

SA4.6: Develop and apply innovative geographic and economic methods to assess the effects of proposed scenarios for hazard and risk management.

Goals 5. Develop credible and accessible geographic research, tools, and methods to support decision-making related to the human and environmental consequences of land change.

SA5.4: Develop a national toolbox of metrics, indicators, models and decision support systems that characterize the environmental, social, and economic consequences of land change.

SA5.5: Conduct multidisciplinary case studies to support environmental policy analysis and hazard risk-reduction efforts.

These strategic actions form the basis of the GAM Program's five year goals and focus its activities on land surface analyses, identifying the impacts of change on ecosystem processes and using the resulting information in assessing hazards and improving resource decision-making. Priority will be given to those projects that combine the goals of multiple strategic actions, support Departmental and Bureau priorities and produce results that aid in the development and implementation of decision-support tools.

III. Program Five – Year Goals

Goal 1: Characterize and quantify land surface status and trends to provide a framework for understanding change patterns and processes from local to global scales.

Strategic Action 1.2: Expand capabilities to map and measure land cover and land-cover change at multiple scales that are locally relevant, yet globally consistent.

Objective: Complete the NLCD database for 2006 and initiate the 2010 database.

Objective: Analyze methodologies for down-scaling moderate resolution data in order to conduct local environmental asessments

Strategic Action 1.3: Determine how much of the national and global land changes result from natural and human influences.

Objective: Identify the amount of land change caused by human activities and natural processes using both the status and trends data and the NLCD 1992-2001 change product.

Objective: Apply remote sensing and geographic analysis to determine the nature and extent of drought impacts on the landscape in the U.S. and abroad.

Strategic Action 1.4: Establish an operational ecosystem monitoring system that continuously measures and characterizes the current status of ecosystem goods and services to estimate and explain deviations from normal conditions.

Objective: Directly participate in the Global Earth Observing System of Systems (GEOSS) to help complete the first report on the Global Land Observation System (GLOS).

Objective: Co-Lead the GEOSS tasks related to Global Ecosystem Mapping and the Global Carbon Observing System.

Objective: Develop the methodologies and tools necessary to conduct vegetation and ecological status mapping at varying scales, and support the delivery and use of this information by both scientists and the public.

Objective: In association with the National Phenology Network (NPN), develop and implement methodologies for extracting seasonal metrics from time-series satellite imagery in order to identify phenological shifts associated with climate, or land cover changes.

Objective: In association with the Environmental Protection Agency, develop an ecosystem services atlas that delineates the environmental characteristics of locations providing required resources.

Goal 3. Understand past, present, and future environmental consequences of land change to support better management of their effect on people, environment, economy, and resources.

Strategic Action 3.1: Conduct research on the consequences of land change on climate, water, carbon cycle, ecosystems, invasive species and societal concerns

Objective: Investigate the relationship between land use change, ecosystem health, wildfire behavior, and invasive species dynamics.

Objective: Model quantitatively the effects of land change on regional carbon dynamics, thus identifying carbon sources and sinks.

Objective: Measure and monitor vegetation changes due to resource extraction activities, permafrost loss, fire, or insect damage in highly-sensitive ecosystems.

Objective: Pioneer the mapping and modeling of standardized ecosystems for the US and selected overseas sites.

Strategic Action 3.2: Conduct research on specific consequences of land-use and land-cover patterns and changes for environmental health and public safety issues, particularly at the boundaries between developed and wildland areas.

Objective: Incorporate land cover change models in assessments of future hazard risk analyses and mitigation strategies.

Objective: Establish a remote sensing based phenology monitoring network focusing on identifying and documenting long-term vegetation changes.

Strategic Action 3.3: Conduct research leading to improved capabilities to assess wildfire conditions, predict wildfire potential, prioritize treatment areas, and monitor effectiveness of fire treatments to support risk-reduction efforts in the urban-natural landscape interface.

Objective: Complete a systematic assessment of wildfire risks and consequences on DOI lands.

Objective: Investigate the use of remote sensing to detect, map and monitor fire fuel dynamics in and around the wildland-urban interface.

Goal 4. Improve the scientific basis for vulnerability and risk assessment, mitigation, response, and recovery related to the human and environmental dynamics of land change.

Strategic Action 4.3: Improve research capacity to model vulnerability and resilience to natural and anthropogenic hazards.

Objective: Expand the capabilities of models, such as the Land Use Portfolio Model, to incorporate multi-hazards assessments, so that vulnerability and risk from natural and anthropogenic hazards are realistically understood.

Objective: Develop methods identifying and assessing ecological goods and services, so that they can be incorporated into multi-scale vulnerability assessments.

Objective: Identify and test key variables associated with community vulnerability to natural and anthropogenic hazards.

Strategic Action 4.6: Develop and apply innovative geographic and economic methods to assess the effects of proposed scenarios for hazard and risk management.

Objective: Investigate developmental pressures and urbanization trends in critical regions, in order to assess the impacts of urban growth on water availability and quality, as well as future vulnerabilities to hazards.

Objective: Develop methodologies to detect and track pollutants and sediment plumes using remotely sensed data during flood events.

Objective: Identify the impact of land cover change on the presence and amounts of waterborne pollutants, as well as on vulnerability to flood events.

Objective: Develop a national framework for analyzing vulnerability and risk to natural and anthropogenic hazards.

Goal 5. Develop credible and accessible geographic research, tools, and methods to support decision-making related to the human and environmental consequences of land change.

Strategic Action 5.4: Develop a national toolbox of metrics, indicators, models and decision support systems that characterize the environmental, social, and economic consequences of land change.

Objective: Develop a national land cover change modeling system that incorporates climate change, both natural and anthropogenic disturbance and disaster scenarios to assist managers in land use planning, watershed management, and environmental restoration activities.

Objective: Identify the value of ecosystem goods and services and the influence of location and spatial configuration on these goods and services.

Objective: Develop systematic methods for synthesizing and integrating multiple sources of remote sensing, biophysical and socio-economic datasets for use in decision-support tools.

Strategic Action 5.5: Conduct multidisciplinary case studies to support environmental policy analysis and hazard risk-reduction efforts.

Objective: Develop and apply decision support tools and geographic information system databases to assess and communicate risk and mitigation/adaptation strategies from multiple natural hazards (earthquakes, tsunamis, fires, landslides, extreme coastal storms, droughts and floods).

Due to the fact that geography is a multidisciplinary science that allows for integrating both environmental and social information, all of the GAM Program's objectives contribute to a number of strategic directions delineated in the Bureau's ten year science vision. The following four tables illustrate how the Program's objectives support the vision's strategic directions.

Goal 1 - Characterize and quantify land surface status and trends to provide a framework for understanding change patterns and processes from local to global scales.		
GAM Objectives	**Geography Strategic Actions**	**USGS Science Strategy**
Complete the NLCD database for 2006 and initiate the 2010 database.	1.2 - Expand capabilities to map and measure land cover and land-cover change at multiple scales that are locally relevant, yet globally consistent.	Understanding ecosystems and predicting ecosystem change A water census of the United States Climate variability and change New methods of investigation and discovery
Identify the amount of land change caused by human activities and natural processes using both the status and trends data and the NLCD 1992-2001 change product.	1.3 - Determine how much of the national and global land changes result from natural and human influences.	
Apply remote sensing and geographic analysis to determine the nature and extent of drought impacts on the landscape in the U.S. and abroad.		
Directly participate in the Global Earth Observing System of Systems (GEOSS) to help complete the first report on the Global Land Observation System (GLOS).	1.4 - Establish an operational ecosystem monitoring system that continuously measures and characterizes the current status of ecosystem goods and services to estimate and explain deviations from normal conditions.	
Co-Lead the GEOSS tasks related to Ecosystem Mapping and the Global Carbon Observing System.		
Develop the methodologies and tools necessary to conduct vegetation and ecological status mapping at varying scales, and		

support the delivery and use of this information by both scientists and the public.		
In association with the National Phenology Network (NPN), develop and implement methodologies for extracting seasonal metrics from time-series satellite imagery in order to identify phenological shifts associated with climate, or land cover changes.		
In association with the Environmental Protection Agency, develop an ecosystem services atlas that delineates the environmental characteristics of locations providing required resources.		

Goal 3 - Understand past, present, and future environmental consequences of land change to support better management of their effect on people, environment, economy, and resources.		
GAM Objectives	**Geography Strategic Actions**	**USGS Science Strategy**
Investigate the relationship between land use change, ecosystem health, wildfire, and invasive species across the western US.	3.1 - Conduct research on the consequences of land change on climate, water, carbon cycle, ecosystems, invasive species and societal concerns	Understanding ecosystems and predicting ecosystem change A water census of the United States Climate variability and change
Model quantitatively the effects of land change on regional carbon dynamics, thus identifying carbon sources and sinks.		
Measure and monitor vegetation changes due to resource extraction activities, permafrost loss, fire, or insect damage in highly-sensitive ecosystems.		
Pioneer the mapping and modeling of standardized ecosystems for the US and selected overseas sites.		
Incorporate land cover change models in assessments of future hazard risk analyses and mitigation strategies.	3.2 - Conduct research on specific consequences of land-use and land-cover patterns and changes for environmental health and public safety issues, particularly at the boundaries between developed and wildland areas.	Understanding ecosystems and predicting ecosystem change A national hazards, risk and resilience assessment program Role of the environment and wildlife in human health
Establish a phenology monitoring network focusing on identifying and documenting long-term vegetation changes.		
Complete a systematic assessment of wildfire risks and consequences on DOI lands.	3.3 - Conduct research leading to improved capabilities to assess wildfire conditions, predict wildfire potential, prioritize treatment areas, and monitor effectiveness of fire treatments to support risk-reduction efforts in the urban-natural	Understanding ecosystems and predicting ecosystem change A national hazards, risk and resilience assessment program New methods of investigation and
Investigate the use of remote sensing to detect, map and monitor fire fuel dynamics in and around the		

wildland-urban interface.	landscape interface.	discovery

Goal 4 - Improve the scientific basis for vulnerability and risk assessment, mitigation, response, and recovery related to the human and environmental dynamics of land change.		
GAM Objectives	**Geography Strategic Actions**	**USGS Science Strategy**
Expand the capabilities of models, such as the Land Use Portfolio Model, to incorporate multi-hazards assessments, so that vulnerability and risk from natural and anthropogenic hazards are realistically understood.	4.3 - Improve research capacity to model vulnerability and resilience to natural and anthropogenic hazards	A national hazards, risk and resilience assessment program Role of the environment and wildlife in human health A water census of the United States New methods of investigation and discovery
Develop methods to identify and assess ecological goods and services, so that they can be incorporated into vulnerability assessments.		
Identify and test key variables associated with community vulnerability to natural and anthropogenic hazards.		
Investigate developmental pressures and urbanization trends in critical regions, in order to assess the impacts of urban growth on water availability and quality, as well as future vulnerabilities to hazards.	4.6 - Develop and apply innovative geographic and economic methods to assess the effects of proposed scenarios for hazard and risk management	
Develop methodologies to detect and track pollutants and sediment plumes using remotely sensed data during flood events.		
Identify the impact of land cover change on the presence and amounts of waterborne pollutants, as well as on vulnerability to flood events.		
Develop a national framework for analyzing vulnerability and risk to natural and anthropogenic hazards.		

Goal 5 - Develop credible and accessible geographic research, tools, and methods to support decision-making related to the human and environmental consequences of land change.		
GAM Objectives	**Geography Strategic Actions**	**USGS Science Strategy**
Develop a national land cover change modeling system that incorporates climate change, both natural and anthropogenic disturbance and disaster scenarios to assist managers in land use planning, watershed management, and environmental restoration activities	5.4 - Develop a national toolbox of metrics, indicators, models and decision support systems that characterize the environmental, social, and economic consequences of land change.	Understanding ecosystems and predicting ecosystem change A water census of the United States Climate variability and change New methods of investigation and discovery
Identify the value of ecosystem goods and services and the influence of location and spatial configuration on these goods and services.		
Develop systematic methods for synthesizing and integrating multiple sources of remote sensing, biophysical and socio-economic datasets for use in decision-support tools.		
Develop and apply decision support tools and geographic information system databases to assess and communicate risk and mitigation/adaptation strategies from multiple natural hazards (earthquakes, tsunamis, fires, landslides, extreme coastal storms, droughts and floods).	5.5 - Conduct multidisciplinary case studies to support environmental policy analysis and hazard risk-reduction efforts	A national hazards, risk and resilience assessment program New methods of investigation and discovery

IV. Implementation Strategy

The Program's strategic approach will be to implement research and assessment activities in a systematic manner, working with our partners to identify research needs and geographic locations of interest. Programmatic resources will be distributed as needed, depending on Bureau, Discipline, Program and Regional priorities on an annual basis. The Program Coordinator will work with other Geographic personnel in implementing this plan. High priority will be given to the land cover data assessments, due to their being the basis of many of the other GAM research projects. A number of themes are central to conducting the Program's research and assessment activities:

- Understanding stakeholder needs
- Stressing the importance of synergism and interdependencies
- Setting research and development priorities
- Developing and validating statistical methods and approaches
- Considering USGS high priority geographic areas
- Collaborating within the USGS and with academia, federal agencies and others
- Managing information for use by collaborating scientists, clients and the public

The GAM Program is responsive to and works collaboratively with a large number of partners, including USGS Geographic Science Centers, other Bureau programs, universities and other research institutions, federal and state managers, and the public. All GAM research scientists are encouraged to collaborate with partners and be responsive to customers seeking information. These efforts are executed through a variety of means, including regular participation by GAM managers and scientists in USGS activities such as the: Priority Ecosystem Science national coordinating committee, Global Change Coordinating Committee, Multi-Hazard Demonstration Project (MHDP), Integrated Landscape Monitoring sites and other science thrusts.

Key customers of GAM's science activities include federal land management agencies (US Fish and Wildlife Service, National Park Service, US Forest Service, Bureau of Land Management), scientific agencies (Environmental Protection Agency, National Oceanic and Atmospheric Administration, National Science Foundation) and agencies responsible to hazard response, or mitigation (National Inter-agency Fire Center, LANDFIRE, Federal Emergency Management Agency, National Drought Mitigation Center, US Agency for International Development). In addition, state and local governments, universities, and non-governmental organizations such as The Heinz Center and The Nature Conservancy are important customers .

V. PROGRAM REVIEW

To ensure that the GAM Program continues to serve its stakeholders and partners, and remain

responsive to national and international scientific challenges, the program seeks input in various ways including, but not limited to: (1) interactions with colleagues at scientific meetings; (2) participation in inter and intra-agency working groups; (3) sponsorship of sessions at scientific meetings; (4) targeted workshops; and (5) direct contact with DOI Bureaus and other federal, state, and local government agencies and NGO's. Within the USGS, the Program Coordinator works with science center chiefs, project leaders, team chief scientists, regional science staff, and program coordinators in other disciplines to define the scope of work. Annual work plans are listed in the Geography Discipline's science plan, project work plans, and in federal budget justifications. Projects are reviewed annually for compliance with Program goals and objectives in order to insure that they satisfy all internal and external priorities. An annual program meeting is held every August to plan the next fiscal year's body of work, with all projects undergoing review by program and regional personnel. In addition, the NLCD receives special attention, with the Multi-Resolution Landscape Consortium (MRLC) conducting a review of the NLCD. The entire program undergoes an external peer-review every four years, with the last review conducted in 2005 and the next in 2009.

Products and Outcomes

Research information and products are disseminated primarily in scientific papers published in the peer-reviewed literature. Products also include documented environmental models, long-term databases, USGS reports, fact sheets, and other publications developed in cooperation with partners. Information, including publications, data, and models, are available on USGS web sites. Oral and poster presentations of research findings are presented at professional society meetings, federal and state agencies, workshops and seminars, universities, and other research institutions. Products developed with GAM Program funds conform to USGS Fundamental Science Practices.

Program performance is primarily determined at the research project level, where productivity is measured by the quality, significance, and impact of science products. Measures of success include (1) the use of USGS research findings in determining future science directions to address societal issues, (2) research results that are the basis of resource management decisions, (3) the documented success of USGS programs in meeting the expectations of other agencies, and (4) the awards presented to scientists in recognition of outstanding contributions to science.

GAM funded science contributes directly to the Bureau's Government Performance and Results Act (GPRA) and Program Assessment Rating Tool (PART) goals, including the following, which are reported to the Office of Management and Budget (OMB) and the DOI:

- Percent of the US with current land cover information
- Soundness of methodology, accuracy, and reliability of science (percent of formal USGS publications and scientific products validated through appropriate peer review)
- Number of systematic analyses & investigations delivered to customers

- Number of formal workshops or training provided to customers

VI. Future Needs

Staff and laboratories in USGS's Geography Discipline embody broad expertise in both the environmental and social sciences. Capabilities span the scientific fields of climatology, hydrology, process modeling, remote sensing science, biogeochemistry, topographic mapping, economics, hazard risk assessments and GIScience. Scientific support includes analytical labs, database management, geospatial analyses, remote sensing data analysis, visualization techniques, and science policy analysis. The USGS is well positioned to undertake broad-based landscape studies such as those outlined here. A key requirement will be the fostering of cross-discipline and cross-program avenues of communication that will allow land cover information to be used in other program's research and the resulting data to be utilized in GAM's vulnerability and risk assessments, as well as decision-support tools.

The GAM Program is often in the position of using data created, or collected by one agency, conducting analyses and then passing on the results of these analyses to still another entity. This makes the Program's activities vulnerable to funding cuts, or changing priorities in other agencies. Examples where GAM provides necessary data are the LANDFIRE and GAP projects.

The GAM Program is committed to the long-term goal of developing and strengthening the scientific capabilities of its current and future workforce of scientists, managers, and support staff. To achieve its goals, the GAM Program requires staff with expertise in system modeling, risk analysis, predictive methodologies and the ability to communicate possible impacts to decision-makers and the public. Partnerships with academic institutions and research organizations may be required to supplement internal USGS capabilities. In order for GAM research to be effective, new and novel communication channels need to be established with the public and decision-makers.

A major concern for GAM over the next 5 years and beyond is the erosion of fiscal resources and staffing required to continue critical core research, coupled with the expected further loss of expertise and experience through the retirement of long-established senior scientists. Unless these trends are reversed, the program will have difficulty in accomplishing its mission and goals, as well as meeting required metrics. Specific skill sets required for the continuing success of the Program include:

- Spatial statistics
- Evaluating ecosystem services
- Modeling environmental systems
- Incorporating scientific findings in decision-making tools
- Uncertainty analysis
- Risk assessments

VII. Bibliography

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Appendix 1: Geographic Analysis and Monitoring Program Five Year Plan Writing Team and Reviewers

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