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Great Basin Integrated Landscape Monitoring Pilot Summary Report

Open-File Report 2010-1324

U.S. Department of the Interior
U.S. Geological Survey

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By Sean P. Finn, Kate Kitchell, Lori Anne Baer, David Bedford, Matthew L. Brooks, Alan L. Flint, Lorraine E. Flint, J.R. Matchett, Amy Mathie, David M. Miller, David Pilliod, Alicia Torregrosa, and Andrea Woodward

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SI to Inch/Pound

Multiply	By	To obtain
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hectare (ha)	2.471	acre

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Abstract

The Great Basin Integrated Landscape Monitoring Pilot project (GBILM) was one of four regional pilots to implement the U.S. Geological Survey (USGS) Science Thrust on Integrated Landscape Monitoring (ILM) whose goal was to observe, understand, and predict landscape change and its implications on natural resources at multiple spatial and temporal scales and address priority natural resource management and policy issues. The Great Basin is undergoing rapid environmental change stemming from interactions among global climate trends, increasing human populations, expanding and accelerating land and water uses, invasive species, and altered fire regimes. GBLIM tested concepts and developed tools to store and analyze monitoring data, understand change at multiple scales, and forecast landscape change. The GBILM endeavored to develop and test a landscape-level monitoring approach in the Great Basin that integrates USGS disciplines, addresses priority management questions, catalogs and uses existing monitoring data, evaluates change at multiple scales, and contributes to development of regional monitoring strategies. GBILM functioned as an integrative team from 2005 to 2010, producing more than 35 science and data management products that addressed pressing ecosystem drivers and resource management agency needs in the region. This report summarizes the approaches and methods of this interdisciplinary effort, identifies and describes the products generated, and provides lessons learned during the project.

Introduction

We are living during a period of unprecedented environmental change. Patterns observed across the landscape result from natural processes and management decisions of individuals and Federal, State, county, and private organizations. Contemporary resource managers are challenged to achieve multiple, sometimes contradictory, agency mandates in the context of this changing environment. Understanding the impacts of natural processes and human actions, predicting their effects, and developing models and tools to evaluate different scenarios on the landscape are critical to ensuring sustainable economies, societies, and ecosystems. A landscape perspective is necessary when managing a local resource because such actions are subject to regional and global processes, as well as the cumulative effects of individual management actions. Resource managers would benefit from tools that can improve their ability to prioritize resources, predict how resources respond to changing climate and land use, and determine the direct and indirect effects of management actions. A cross-discipline (integrated), broad-scale (landscape), long-term (monitoring) program can provide such a tool by supplying regional managers and scientists with a consistent source of data, models, and decision support, set within an adaptive management framework responsive to changing conditions and improved knowledge.

The Great Basin Integrated Landscape Monitoring Pilot project (GBILM) was one of four regional pilots to implement the U.S. Geological Survey (USGS) Science Thrust on Integrated Landscape Monitoring (ILM). Other pilots were conducted in Puget Sound, Northern Prairies, and Lower Mississippi River. The ILM thrust was initiated in 2005 to increase collaboration, summarize and synthesize existing environmental information, foster communication among scientists and stakeholders, and jointly set priorities for research and monitoring needs on the landscape. The ILM thrust sought to improve the ability to understand and model landscape change; in that sense, monitoring becomes a key tool in a broader objective. The stated goal of ILM was to:

> Observe, understand, and predict landscape change and its implications on natural resources at multiple spatial and temporal scales and address priority natural resource management and policy issues.

This report describes the approach and outcomes of GBILM, an interdisciplinary effort to pioneer landscape-level monitoring in the Great Basin and identify and develop tools for managers to effectively use monitoring data. We conclude with a brief outline of the steps we deem necessary to move toward a long-term, integrated landscape monitoring program.

Statement of the Problem: Why Focus on the Great Basin?

The Great Basin is undergoing rapid environmental change stemming from interactions among global climate trends, increasing human populations, expanding and accelerating land and water uses, invasive species, and altered fire regimes. These factors are influencing dramatic ecosystem changes and social conflicts. Climate-driven changes documented in recent decades include the upslope movement of ecotones (Beever and others, 2005), warming of streams (Melack and others, 1997), and altered snowpack melting and peak streamflow timing (Stewart and others, 2005). Because mountain tops and arid valleys are isolated, “sky-islands” and “desert-islands,” climate effects may reduce refugia for endemic alpine and arid basin species and communities. Local and regional human alterations of the landscape combined with climatic influences may shape community compositions, processes, and configurations potentially in a non-linear fashion.

Mid-elevation shrubsteppe plant communities in the Great Basin are crucial habitat for populations of greater sage-grouse (*Centrocercus urophasianus*), mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), pygmy rabbit (*Brachylagus idahoensis*) and numerous sagebrush-dependent birds. Sagebrush habitat is vital to viable populations of greater sage-grouse; extensive loss, degradation, and fragmentation of sagebrush habitat have contributed to the long-term population declines of this species (Connelly and others, 2004). At the same time, sagebrush habitat is important to the livelihood of local communities that gain economic benefits from livestock grazing, hunting, mineral extraction, and recreational uses.

Sagebrush shrublands in the Great Basin also are experiencing dramatic environmental change with the increase in wildfires due to fine fuels buildup from invasive species such as cheatgrass (*Bromus tectorum*; D'Antonio and Vitousek, 1992). Cheatgrass, which provides a spatially continuous fuel source, can become locally abundant and significantly increase the likelihood of recurring wildfires that prevent recovery of the shrub-steppe community. At higher elevations, sagebrush steppe habitat is converting to pinyon pine and juniper woodlands (Miller and Wigand, 1994) as a result of changing climate, fire, and land-management regimes. Woodland expansion is affecting plant community structure and composition, wildlife habitat, water availability, and fire cycles.

Water, the primary limiting factor throughout the Great Basin, is increasingly being tapped for human use and consumption. Large groundwater extraction and inter-basin transfer projects are underway or planned for the next decade. The ecological effects of such large projects are unknown, but currently under study [for example, Desert Research Institute (no date), accessed October 17, 2010, at http://www.barcas.dri.edu/]. Climate impacts on water resources (snowpack, timing and amount of streamflow, and groundwater recharge/discharge) will exacerbate conflicts over water use among different user groups in this region.

The majority (> 76 percent) of the Great Basin region is under the federal stewardship of nine agencies representing four departments (Interior, Agriculture, Defense, Energy; table 1). The Department of the Interior (DOI), which manages 65 percent of the region, is mandated with providing multiple-uses, restoring ecosystems, conserving special-status species, managing water resources, and controlling wildfire. Coordination among Federal agencies and State and local partners is necessary for effective management of the landscape. Consequently, DOI agencies and partners place a high priority on projects and partnerships that address landscape-scale issues. GBILM is one example.

GBLIM tested concepts and developed tools to store and analyze monitoring data, understand change at multiple scales, and forecast landscape change. The GBILM endeavored to develop and test a landscape-level monitoring approach in the Great Basin that integrates USGS disciplines, addresses priority management questions, catalogs and uses existing monitoring data, evaluates change at multiple scales, and contributes to development of regional monitoring strategies.

Area of Interest

The Great Basin includes more than 45 million ha of land in five Western States (Nevada, California, Oregon, Idaho, Utah; fig. 1). About 76 percent of these lands are under public ownership, the majority of which are managed by the Bureau of Land Management (BLM; table 1). For regional monitoring, GBILM defined an area-of-interest that includes Omernik's (1987) Northern and Central Basin and Range Provinces and the Great Basin Restoration Initiative's focal area (*http://www.blm.gov/id/st/en/prog/gbri/map.html*; U.S. Bureau of Land Management, 2000). GBILM's boundary includes areas adjacent to the hydrologic Great Basin that are floristically and ecologically similar to the interior basins, an area totaling more than 67 million ha. Throughout this document, we refer to the polygon depicted in figure 1 as the 'Great Basin.'

The Great Basin is a semi-arid mosaic of diverse shrublands, grasslands, and montane forests incised with rare but critical riparian corridors and aquatic resources. The region has a growing list of Federal- and State-listed species and species of concern [for example, Carson wandering skipper (*Pseudocopaeodes eunus obscures*), Owen's Valley vole (*Microtus californicus vallicola*), greater sage-grouse, pygmy rabbit, and Brewer's sparrow (*Spizella breweri*)]. The Great Basin contains more than 130 endemic plant species or subspecies, 95 of which are of conservation concern. A driver of this high endemism is the patchy nature of many habitat types and the fluidity of patch connectivity across the landscape and over geological time. Within 20 km, a single basin can host environments that range from treeless, alpine meadows and rocky slopes to montane coniferous forests, mountain shrublands, pygmy woodlands of pinyon pine and juniper, lower slopes of sagebrush and grasses, lake shores, barren sand dunes, and playas (table 1).

Much of the Great Basin is uninhabited or rural but it includes some rapidly growing cities and urban areas that exert increasing demands on natural resources. Many human land uses (including urban expansion, road development, surface and groundwater development, mineral and hydrocarbon extraction, renewable energy installations, livestock grazing, and agriculture) are having increasing impacts on the composition, structure, and function of native ecosystems.

Wildfires have burned more than 25 percent of these lands in the past decade and are expected to continue with greater frequency. Changes in the fire cycle are leading to large-scale replacement of native vegetation with exotic annual grasses, which further accelerates fire return intervals (D'Antonio and Vitousek, 1992) leading to reduced rangeland health and productivity, and affecting species at risk.

Extensive drought conditions and growing human demands on surface water and groundwater have a substantial impact on ecosystem function. Today, the consequences of diversifying land uses, invasion of non-native species, and altered disturbance regimes have affected virtually the entire Great Basin. These changes have resulted in the region's designation as one of the most endangered ecosystems in North America (Noss and others, 1995).

Goals and Objectives

The GBILM pilot established a set of science and institutional goals to develop and test an interdisciplinary (that is, the five USGS science disciplines of Biology, Geology, Geography, Water Resources, and Geospatial Information) approach to detect landscape change across the Great Basin. The GBILM has placed an emphasis on documenting this approach to guide future integrated landscape-scale monitoring efforts.

The Science Goal: To develop and test an integrated landscape-level monitoring approach that addresses priority management issues and provides capabilities to detect and predict landscape change.

Science objectives:

- Understand cumulative effects of local actions/events.
- Understand change at the landscape scale.
- Develop capability to predict landscape change.
- Develop or refine monitoring strategies.
- Prioritize actions such as mitigation and restoration.
- Maximize use of existing data.

The Institutional Goal: To develop and document an approach for integrated landscape-level monitoring that may be applicable to other ecosystems and monitoring programs.

Institutional objectives:

- Facilitate, use, and develop expertise and resources from all USGS disciplines for landscape-level monitoring.
- Assure relevant, useful, and focused landscape-level monitoring by engaging stakeholders and ongoing related efforts at key steps throughout the process.

Process and Approach

To achieve our institutional goals, we developed a web-based communication network to carefully document and communicate project development. We also assembled an outreach team to engage relevant experts, partners, and stakeholders in the project. To achieve our science goal we initiated a staged approach (fig. 2) to understand ecosystem processes in the Great Basin and address priority resource monitoring needs. Preliminary stages included formulating an interdisciplinary team, delineating the area-of-interest boundary, explicitly defining the problem, identifying and prioritizing critical ecosystem drivers and management issues, interfacing with ongoing USGS research programs, and matching USGS and partner capabilities with regional monitoring needs.

After the preliminary stages were underway, we began analyzing existing data and identifying data gaps (see section, “Sub-Pilot Projects to Refine and Test ILM Approaches”). The team completed this pilot by developing integrated, landscape-scale analyses and modeling strategies that draw from the concepts, information, and techniques developed by these projects. An integrated science product describes 30-year trends in land-cover change and the process steps required to elucidate and understand the specific and interactive drivers of change (Flint and others, 2009; Flint and others, *written communication*).

Description of Team Including Partner Participation

GBILM assembled a team of subject matter experts in each USGS discipline and several partner agencies including the Bureau of Land Management (BLM), National Park Service (NPS), and U.S. Fish and Wildlife Service (USFWS). In total, 58 professionals representing six Federal agencies, one state agency, and two universities made significant contributions to GBILM (appendix A). Active participants shifted over the 3 years although a core group of USGS and partner agency personnel maintained continuity and performed most of the work. Many others contributed during some phase of the pilot (appendix A). An Executive Committee representing USGS Biology, Water Resources, Geology, and Geography disciplines managed the interdisciplinary team. The executive committee solicited input from team members when appropriate; pilot-level decisions regarding science and institutional direction and funding allocations were made by consensus whenever possible. Project-level working groups formed based on subject matter and technical expertise.

Conceptual Modeling

GBILM created conceptual ecological models for the Great Basin to serve as a foundation for all studies and fill a regional void. Conceptual ecological models express a progression of scientific thought that starts with exploring key ecological components and ends with a summary of our current understanding of causal orderings and relationships among them. Conceptual models are specific tools for planning, communicating, and prioritizing these ecological components and relationships. Conceptual models focus and define the scope of a monitoring program and are best viewed as working hypotheses rather than end products themselves. The GBILM pilot created a set of conceptual ecosystem models to characterize landscape function, identify key ecological processes and services, guide development and prioritization of the most pressing resource management questions, inform regional monitoring strategy development, and identify critical information gaps (Miller and others, 2010).

Our conceptual models begin by distinguishing precipitation event-driven systems (‘Dry’ systems) from surface-water and groundwater systems (‘Wet’ systems), which respond to precipitation at longer time scales. The Wet and Dry systems were described in a hierarchy of models (fig. 3), with each tier successively more focused on specific ecological habitats and processes (Miller and others, 2010). We constructed the highest-order Framework Model to coarsely describe our current understanding of the interactions among Wet and Dry response systems and two primary driver-contributing systems: Atmospheric and Human Social Systems (fig. 3). Successive System-, Control-, and Stressor-level models describe finer detailed interactions and hypothesize potential ecosystem responses to stressor interactions (Miller and others, 2010).

Ecosystem Drivers

While documenting a basic understanding of regional components and processes, we identified key ecosystem drivers (table 2) using a Delphi process (after Linstone and Turoff, 2002) involving representatives from all USGS disciplines and several partner agencies. We prioritized ecosystem drivers in terms of their temporal and spatial relevance to ecosystem integrity through an iterative process and incorporated these drivers into our conceptual models (fig. 4). See appendix B and Miller and others (2010) for a detailed description of the priority drivers.

Management Questions

We used a question-driven process as a way to effectively address landscape-scale, multi-jurisdictional problems facing land managers. Team discussions on management questions were conducted in parallel with the development of conceptual models forging integration of the two pilot components. Management questions that reflected compelling real-life needs of our management agency partners were emphasized. The selection was based on a review of Great Basin resource management documents, interviews with regional natural resource managers, and synthesis with the ecosystem driver and conceptual model development process. The questions identified are important because they bring focus and relevance to subsequent work and provide the basis for evaluating interactions among management actions, other environmental factors, and landscape change. We prioritized management questions associated with each of the selected drivers (table 2; U.S. Geological Survey, 2007, accessed October 17, 2010, at *http://www.usgs.gov/features/greatbasin/program/questions.html*; and section, "Pilot Projects,") based on their importance to the management community and the quality of data available to answer them. Management questions led to research questions that could drive inquiries about landscape-scale conditions and projected changes. We expect these questions will be regularly reviewed and refined with partners to accurately reflect management and science needs.

The integration of management questions and conceptual models facilitates a salient understanding of the linkages among biotic components of the ecosystem with the abiotic elements on which they depend.

Sub-Pilot Projects to Refine and Test ILM Approaches

A fundamental ILM research question was "how much can be accomplished using existing data?" To address high priority management questions using existing monitoring data, a short list of projects with a high likelihood of completion were selected to refine, test, and implement science questions derived by the GBILM team. These projects are described in detail in section, "Sub-Pilot Projects." Existing data were compiled and cataloged across jurisdictional boundaries and evaluated for data quality. In many cases, data from multiple sources were fused and enhanced through analytical and statistical means. The GBILM team identified data gaps, worked with partner agencies to improve their data documentation and quality, and shared project results in on-going working sessions as described below.

Data Management and Delivery

We compiled a list of regional datasets and sources and drafted data standards to promote consistency throughout the pilot as team members initiated and completed projects. Identified datasets included satellite imagery, aerial photographs, and framework data (for example, topography, digital raster graphics, roads, etc.) accessible through USGS seamless data servers, national map, national atlas, and various state-level sources. Additional source data were cataloged from regional-scale projects including SAGEMAP (U.S. Geological Survey, 2009, accessed October 17, 2020, at *http://sagemap.wr.usgs.gov*), the Conservation Assessment for Greater Sage-grouse and Sagebrush Habitats (Connelly and others, 2004), the Great Basin Ecoregional Assessment (Wisdom and others, 2004), the Interior Columbia Basin Ecosystem Management Project (Quigley and others, 1999), and other sources. Most of these data are available through the SAGEMAP GIS data portal. Additional national-level programs providing baseline data include the USGS Geographic Analysis and Monitoring (GAM) Program and USGS Ecosystem Mapping program. Unique spatial data layers created by each project (see page 8: "Sub-Pilot Projects" and appendix C) were documented with metadata, archived in the GBILM records, and provided to SAGEMAP for distribution.

The large area of interest, the need to handle many kinds of spatial data and evaluate these spatial data in a temporal context, suggested that our data management needs were going to be difficult to meet. A comprehensive solution was not available at project's inception; therefore, we explored and tested a variety of available technologies to accomplish the data management task. The advantages to this approach were continuity throughout the project and high levels of quality control. The disadvantages of not having a comprehensive data warehouse included long wait times for data exchange, lack of fully developed metadata and piecemeal quality to the data collection. GBILM identified the need for a consistent, reliable data sharing mechanism to facilitate information exchange, support data synthesis, and encourage an integrated approach for analysis and applied scientific research. GBILM science project leads were tasked with managing data and coordinating the exchange of data developed by their project.

Existing tools that could have provided the central repository for an integrated solution to spatial data management and that were available at no charge through existing vendor contracts, were not accessible due to lack of in-house capacity to enable their use. Lacking a central tool that was reliable and robust enough to handle the project's data needs, the team used several agency-provided resources, such as Lotus® Quickr, the my.usgs.gov portal, the USGS enterprise FTP site, EarthWhere™ Spatial Data Provisioning System, and USGS WebEx to share data and information. Throughout the project, we worked closely with Geospatial Information Office personnel to outline project needs and test prototypes (such as my.usgs.gov portal).

In the final year of the ILM project, a geospatial data service based on ArcGIS Server was in place and beta-tested. This framework allowed team members real-time access to standardized datasets shared editing capability. Although this tool did not become operational in time for GBILM use, beta-testing contributed to refinement and it continues to be developed for regional, integrative projects (for example, Wyoming Landscape Conservation Initiative *http://www.wlci.gov/catalog/WLCI/item/search* and the Great Northern Landscape Conservation Cooperative).

Strengths and weaknesses of the various tools include:

Lotus® Quickr

A secure collaborative workspace on the web where several people can manage projects across time zones and networks with partners inside and outside the USGS. Quickr allows users to store and share content, including documents, images, rich-media files, podcasts, attachments from Lotus® Notes, and files from Microsoft© Office.

Strengths—Relatively easy access for USGS and partners; does not require 3rd party (administrator) account assignments; documents easily uploaded with check-out procedure for editing text- and spreadsheet-based files; discussion forum provided.

Weaknesses—Moderate overall functionality with many unexplained failures (that is, page errors); no geospatial or mapping component; file size limitations.

My.usgs.gov Portal

MyUSGS is a suite of content management and collaboration tools for USGS science teams and their external partners. MyUSGS, a component of what has been termed an "Integrated Information Environment," consists of a growing set of public websites that share content from within this environment as well as a wide variety of online intranet/extranet communities.

Strengths—Handles medium (about10 MB) file sizes; allows customizable web page development; allows access to multiple communities through one user account; Wiki© function allows for easy editing of draft material and facilitates idea-building.

Weaknesses—requires a 3rd party (system administrator) to assign user accounts and permissions for non-USGS personnel; file structure and navigation are complex and confusing (for example, file sharing functions not directly linked with Wiki© discussion boards).

USGS eFTP

The eFTP service provides a centralized file transfer system for use between USGS personnel and external collaborators. The service is deployed in a private/public configuration that utilizes two servers.

Strengths—Handles large file sizes and all types of files; directory structure intuitive to computer users.

Weaknesses—Not a permanent solution as the files are automatically erased on a regular basis. Transfer protocols to-from partner agencies can be confusing and firewall issues may block uploads.

EarthWhere™ Image Server Provisioning System (*http://rmgsc.cr.usgs.gov/earthwhere/*)

EarthWhere™ is a spatial content management tool that helps organize and manage spatial data holdings providing immediate access to spatial datasets from data archives. USGS Rocky Mountain Science Center ably manages an EarthWhere™ site.

Strengths—Handles and delivers raster data intuitively and quickly; easy to use map-based interface and query function; self-contained users guide and tutorial; provides thumbnail views and metadata before download.

Weaknesses—Not designed for external project support (Rocky Mountain Geographic Science Center data managers managed and delivered imagery for GBILM gratis); only handles raster-based spatial data.

USGS.webex.com

WebEx is an Internet-based communication tool that combines real-time desktop sharing with phone conferencing.

Strengths—Extremely easy to use; facilitates discussion on complex spatial and conceptual issues by providing distributed presentation capacity to all team members. Superb real-time information sharing tool.

Weaknesses—Recording capabilities require additional hardware (for desktop storage) or large amounts of server space (if stored on Webex servers). Not a data archive.

GBILM ArcGIS Server

ArcGIS Server software provides the ability to create, manage, and distribute GIS services over the Web to support desktop, mobile and Web mapping applications.

Strengths—Central repository with capacity to deliver for metadata and spatial data; manages data versioning; automatically documents processing steps during data generation; multiple access options from simple viewing of spatial data to full download of spatial data; robust security structure.

Weaknesses—Best for spatial data and tabular data associated with spatial data; not a mechanism for non-spatial project information.

Sub-Pilot Projects

Project 1: Land-Cover Change Detection through Remote Sensing

High-quality remotely sensed data and its accurate interpretation are cornerstones of successful broad-scale, regional monitoring. By leveraging funds provided by the USGS Land Remote Sensing Program, GBILM acquired more than 270 Landsat Multi-Spectral Scanner and Thematic Mapper imagery covering the entire Great Basin in 5-year increments from 1975 to 2005. We also acquired commercial Digital Globe™ Quickbird imagery for a 1,000-km^2 area including Great Basin National Park. Scenes were cataloged and stored in the USGS EarthWhere™ Image Server Provisioning System located in Denver, Colo. EarthWhere ™ is an intuitive user interface that delivers user-defined imagery products. It stores data location, metadata, image properties, geographic locations, and thumbnails so that the data can be quickly located and viewed in the EarthWhere ™ interface. The application provides complete web-based geospatial (map) and metadata (attribute) search and provision capabilities and delivers specified imagery for download. Most imagery GBILM acquired was downloaded from GLOVIS (U.S. Geological Survey, no date, accessed October 17, 2010, at *http://glovis.usgs.gov/*); the remainder was acquired from EROS Data Center.

We used a subset of the imagery to document and quantify land-cover change over a 32-year period within a *ca.* 9,800-km^2 (1 Landsat scene) portion of the Great Basin. Unlike subsequent sub-pilot projects, this effort was not specifically question driven. Rather it was an exploratory effort to generate baseline data describing long-term land-cover change. Our initial objectives were to detect and predict land-cover change in an area with high topographic relief under diverse land-management regimes and to develop repeatable methods to characterize land-cover change. We completed interpretations and conducted change-detection analyses for the Landsat scene (Path 39, Row 33) in seven time-steps from 1975 to 2007.

Processing

We performed a reflectance transformation to normalize pixel values, which is important for quantitative, multi-temporal time series analysis. We then ran a Tasseled Cap transformation – a sensor-specific linear transformation that corresponds to scene phenomena – to output brightness, wetness, and greenness indices. The greenness band was used for subsequent land-cover change detection. We estimated land cover for each transformed time-series image using the Southwest ReGAP land-cover map (circa 2000) as our baseline. We then classified areas that changed between consecutive dates using a maximum-likelihood classification and generated the following products:

1. Land-cover classifications for each time step (n = 7);
2. Change masks for each paired comparison that indicate the proportion of the scene changed since the last image (fig. 5); and
3. Classified land-cover change grids that specify changes by cover class.

These GBILM products are being used to evaluate interactive landscape-change drivers. For example, many land treatments (such as the two shown in fig. 5) are not well documented by archived management records whereas our land-cover change analysis readily identified it. Subsequent analyses quantified less easily identified change by overlaying climate, soils, invasive species, and hydrology data on the land-cover change products (Flint and others, 2009).

In FY08–09, we leveraged support through the USGS APS Simplified Acquisitions Branch and contracted NatureServe© to replicate the analysis described above for a Landsat scene (Path 40, Row 32) adjacent to the previously analyzed scene. This product, provided to GBILM in July 2009, has been archived and placed on SAGEMAP.

Examples of management applications using land-cover change data include an enhanced ability to (1) understand cumulative effects of local actions/events, (2) develop or refine treatment and monitoring strategies, and (3) prioritize management actions, such as mitigation and restoration.

Project 2: Ecosystem Driver — Water Extraction

Water-level changes can be caused by anthropogenic (for example, groundwater pumping, irrigation) and natural (climate) drivers. Monitoring data suggests water tables are decreasing across the region (Welch and others, 2007) potentially leading to loss of springs and wetlands. Therefore, we delineated aerially significant phreatophyte vegetation communities that could be affected by groundwater level change (fig. 6).

Priority Management Questions

Where are phreatophyte communities located, and what are their baseline landscape characteristics? How and where will increased water extraction impact phreatophyte communities? Can changes to phreatophytic land cover act as indicators of impacted groundwater systems?

Science Questions

How will changes in groundwater levels affect the Great Basin landscape? How will groundwater dependent ecosystems in particular be affected?

We defined phreatophytes as plants that derive a significant portion of the water they use from groundwater and are dependent on groundwater for long-term survival. This definition includes water-sensitive wetland and riparian species as well as more drought-stress-tolerant species that utilize groundwater from greater depths (≤10 m). Phreatophytic land cover of the Great Basin is a function of geomorphology, vegetation species composition, elevation, and hydrology. We identified plant species and communities meeting this definition from the plant ecology literature and spatially identified gross land-cover types with such dominant species on existing vegetation maps (ShrubMap, CA GAP, and WY GAP land-cover datasets). We refined phreatophyte community locations by removing playas (obtained from Soil Survey Geographic Database soils data) and performing a conditional analysis with MoRAP-derived landform data defining plains and river channels. The final phreatophyte land map was quantitatively compared to other smaller scale studies (that is, the Basin and Range Regional Carbonate-rock Aquifer System [BARCAS]) to assess the final product. Much of this information will become available as a USGS Scientific Investigations Map in 2011. That product has been peer reviewed and is in the final states of editorial review. It includes a (1-km resolution, 1:100,000 scale) map and descriptions of the methods and results obtained from the combinations of multiple existing datasets.

These products will provide land managers and researchers with previously unavailable spatial data describing groundwater dependent vegetation communities in the region. The phreatophyte map represents a baseline for future forecasting and monitoring of the distribution, health, and vigor of groundwater dependent systems, while providing land managers with an additional land-use planning tool.

Project 3: Ecosystem Driver—Land Treatments

The Great Basin is constantly undergoing change through forces such as fire, grazing, and invasive species. Land managers attempt to mitigate changes by planning and implementing a range of land treatment applications including post-fire seedings, removal of invasive or exotic vegetation, fuels management, and wildlife habitat enhancement. Treatment areas are usually monitored for varying amounts of time to evaluate treatment effectiveness. When summed, land treatments affect a significant proportion of the landscape. However, this impact currently cannot be quantified because planning, implementation, and monitoring for land treatments are not uniform across the Great Basin, and records and monitoring data are not centrally stored.

Priority Management Questions

What are implementation characteristics of treatments? Which treatments are effective (meet objectives) and under what conditions? What are the most effective monitoring approaches for treatments?

Science Questions

What is the landscape configuration of treatments, and how does this influence wildlife habitat and other disturbances (for example, fire, invasive species spread)? What are the cumulative influences of treatments and interacting drivers?

The Land Treatment Digital Library (LTDL; Pilliod, 2009) was developed to provide a centralized digital library for Bureau of Land Management (BLM) land treatments throughout the Great Basin. GBILM provided funds for development of the LTDL structure (fig. 7) and initial population of data. Specifics of the LTDL include (1) data on multiple treatment types within projects, (2) links between GIS data and projects or treatments, (3) details of each treatment (if available) including type, date, funding source, method, equipment used, and many other treatment-specific data, (4) details of seeding treatments (species planted, rates), and (5) links to all original documentation (if available) including plans, reports, monitoring data, paper maps, and photographs. The pilot data entered into the LTDL focused on two focal BLM field offices: Ely, Nevada and Fillmore, Utah. With GBILM support, we compiled data from 450 projects detailing 1,607 treatments from the Ely and Fillmore field offices. We developed a public website describing the focus and goals of the LTDL (U.S. Geological Survey, 2010, accessed October 17, 2010, at *http://greatbasin.wr.usgs.gov/ltdl/Default.aspx*) and a factsheet (Pilliod, 2009).

LTDL functionality and utility have been evaluated by regional land managers who have reported favorably on its potential value to managers. Example management applications include the ability to: (1) quickly search through and access all treatments that have been conducted in an area, (2) match treatment results to covarying factors, such as climate conditions, soil type, elevation, or grazing regime, and (3) evaluate proposed treatments in terms of previous techniques used. Landscape ecologists also will benefit from the LTDL, which allows a comprehensive view of management-oriented land-cover change not previously available (table 3). Researchers (for example, Knutson and others, 2009) will be able to evaluate trends in land cover in a more informed fashion and evaluate which land treatments produce desired (and undesired) effects under which conditions.

As part of the integrated monitoring effort of the GBILM, we used the treatment information in the LTDL to identify and locate areas within the focal study region (a Landsat scene path 39, row 33) where vegetation had been manipulated for management purposes (for example, post-fire seedings, fuel reduction). This information contributed to a mapping effort designed to document climate-driven changes in vegetation from 1980 to present by excluding areas with land treatments. Through additional funding from the Joint Fire Science Program and the BLM, we have expanded the scope of the LTDL to include all treatments within the 11 western continental United States. We have further refined the webpage (accessed 11/4/10 at *http://greatbasin.wr.usgs.gov/ltdl/*) to allow BLM employees and other authorized scientists to access LTDL data through the Internet. Complete data will be available in 2014.

Project 4: Ecosystem Driver—Fire-Invasive Species Interactions

GBILM addressed questions to determine what can be learned regarding current and potential future fire regimes in the Great Basin using existing information. Specifically, we evaluated the influence of a suite of abiotic factors on fire within a repeatable framework that can be revisited in the future as part of a long-term monitoring program.

Priority Management Questions

How should land managers prioritize their efforts to manage fire regimes with the goal of retaining and restoring desired plant communities in the Great Basin? What can land managers do now to manage current and potential future fire regimes and associated vegetation changes (for example, relative to fuels management, fire suppression tactics, and emergency stabilization, rehabilitation, and restoration activities)? What is the best way to monitor changes in fire regimes and associated vegetation change over time?

Science Questions

What are the recent patterns of fire regime variables in the Great Basin? How do these patterns relate to landscape characteristics (biophysical properties, rainfall patterns, land-use history)? How do these patterns compare to estimates of historical conditions? What evidence do these patterns and relationships provide for shifts in fire regimes caused by invasions of non-native plants, annual grasses in particular (that is, the grass/fire cycle)? How may these patterns and relationships potentially change in the future given alternative climate regime scenarios?

We described past patterns of burning across the entire Great Basin and identified and evaluated the primary factors influencing these patterns. These results were used to infer general fire regime characteristics with the eventual goal of predicting how future climate change scenarios might affect how fire regimes are distributed across the Great Basin. Fire perimeters from the USGS/USFS Monitoring Trends in Burn Severity Program (accessed October 17, 2010, at *http://mtbs.gov/*) were modeled in response to varying vegetation community types (LandFire PNV coverages); landscape ruggedness; winter (immediately before the fire season and 1 year prior) and summer (during the current fire season and 1 year prior) precipitation; human population densities; and road densities. We included the perimeters of previous fires in the Mojave Desert in some of the analyses to infer the potential effects of future hotter and drier conditions in the Great Basin; however, other potential predictor variables (that is, lightning strikes, cheatgrass dominance over time, vegetation community type over time, land-use histories) that were not readily available for the entire region were not used in this analysis.

The preliminary modeling results indicated that variation in fire size was most closely associated with road density, winter precipitation immediately before the fire season, and summer precipitation during the current fire season. We found that fire size was inversely correlated with road density presumably because roads provide fuel breaks and facilitate fire suppression; the effect is significant even though roads also serve as human ignition points. In the Great Basin, high winter rainfall followed by low summer rainfall produced the largest fires; the positive winter rainfall correlation was less strongly correlated with fire size than the negative summer rainfall correlation (fig. 8). In the future, we expect that increased intra-annual variation in precipitation (especially high winter versus low summer) will produce larger fires (Brooks and Chambers, *written communication*).

The final product of this analysis will be a peer-reviewed journal article that describes patterns of burning across the entire Great Basin, the factors influencing fire size and their influence on fire regimes, the expected effects of potential future climate change scenarios, and guidelines for future monitoring and re-analysis. Follow-up analyses will test the hypotheses developed in this study at smaller scales in regions with additional spatial data (for example, land-treatment information, detailed lightning strike data) and more precise fire history data (for example, burn severity maps), for example, in the Southern Nevada Public Land Management Act project area (Clark and Lincoln Counties of southern Nevada). Those output products will be used to refine the Great Basin / Mojave fire regime model.

These results have the potential to immediately benefit land managers who now have additional tools to forecast and prepare for fire management before the fire season begins. Simple decision support tools (fig. 9) can assist fire and fuels managers to estimate the severity of a given fire season using empirically driven models provided by GBILM.

Project 5: Ecosystem Driver—Climate Change

GBILM recognized the critical role climate variation and change play in understanding historical ecological relationships and forecasting future conditions. Climate change is considered a pervasive covariate of all other ecosystem drivers in that the effects of any given driver or suite of drivers will be strongly influenced by long-term climate trend and the frequency, severity, and variance of extreme events.

Priority Management Question

What can resource managers do to mitigate the effects of climate change?

Science Questions

What are the spatial and temporal patterns of climate? How will climate change affect invasive species and fire? How will climate change affect human use (agriculture, grazing, recreation) and how will changes in human use that result from climate change affect ecosystems? How will changing climate patterns affect native plant and animal distributions?

To facilitate the ability to address these questions, we compiled and cataloged disparate, historical climate data for the Great Basin, evaluated climate-related trends in land-cover change, and monitored temperature trends at American pika (*Ochotona princeps*) occupied microclimates. American pika, especially those in the Great Basin, have been proposed as a potential biotic indicator of climate change and recently reviewed for listing as a threatened species (U.S. Fish and Wildlife Service 1020a).

- We assembled a climate stations database of more than 1,900 extant and historical weather stations in the region because a comprehensive perspective of regional climate data was unavailable. The database identifies where each climate dataset is stored and the temporal span of each stations data. GBILM has drawn on this database for specific data and the database is available to our partner agencies.

- GBILM inherited a network of temperature sensors initially used to track American pika microhabitat. The network was installed by USGS Wildlife Biologist Erik Beever in 2005 and was turned over to GBILM for management and upkeep of the sensors and data in 2008. The initial network of 178 sensors monitoring 25 historical pika sites was expanded to 239 sensors monitoring 33 sites. The network now spans more than 150,000 km^2 and elevations from 640 to 3,490 m. Sean Finn, USGS Forest and Rangeland Ecosystem Science Center, maintains the temperature data and is developing a relational database to store and deliver the data. USGS personnel used these data to inform USFWS on the 2010 American pika status review (U.S. Fish and Wildlife Service 1020a).

Project 6: Cumulative Effects of Priority Ecosystem Drivers

Effective management of public lands for species of concern, such as the greater sage-grouse requires the ability to understand and predict vegetation response to multiple drivers across time. Rangeland ecologists commonly describe vegetation dynamics in terms of state-and-transition conceptual models, which define discrete categories or states of vegetation structure and the conditions required for a given patch to transition from one state to another. State-and-transition models can be implemented using frame-based computer models, which are quantitative simulations of the response of vegetation categories to system drivers through time. In other words, the frame-based model defines the sequence of vegetation transitions based on causative factors. To make this possible, the conditions under which the transitions occur must be specified (fig. 10). When the transitions are implemented over a number of time intervals, the model can be used to predict vegetation dynamics.

Priority Management Questions

What factors best describe the heterogeneous response of the landscape to similar drivers? How do we make better site-specific resource decisions that affect priority wildlife (for example, greater sage-grouse) by taking landscape level data into account? How do we integrate long-term trends into our resource planning decisions?

Science Questions

What are the relative contributions of multiple drivers to long-term trends in landscape change? Are there synergistic effects? Are there predictable transitions in vegetation change that can be mapped across the landscape? Can data available at a landscape scale provide relevant knowledge for site-specific wildlife resource decisions?

To adopt the frame-based model approach, we used the products developed from the GBILM projects described earlier in this section along with data leveraged from other USGS projects. The GBILM land-cover change detection product defines both the spatial footprint of our area-of-interest and the temporal range for all data (for example, fig. 11). Datasets being integrated include: climate, fires, land treatment, and sage grouse lek count and habitat extent.

The multivariate, multi-stressor analysis of landscape trends provide estimates of the relative contributions of priority ecosystem drivers on land-cover change. The analysis serves two purposes: first, it provides land managers with information about how vegetation communities are shifting on the landscape, and second, it demonstrates the interdisciplinary capabilities for change detection, forecasting, and multivariate modeling that GBILM set out to accomplish (Flint and others, 2009; Flint and others, *in prep.*).

Significant Outcomes and Products

Products

GBILM has created or contributed to more than 35 science and management products since its inception in 2005. See appendix C for a complete list.

Strong and Effective Partnerships

The GBILM pilot process facilitated communication among many Federal and State partners, opened the door for increased collaborations and partnerships for USGS in the region, and set the foundation for developing interagency, interdisciplinary landscape-scale monitoring strategies. Involving management agency partners ensured that GBILM products have relevancy and efficiency across the region.

We initiated involvement from DOI partner agencies from the outset. Representatives from the BLM, National Park Service (NPS), and USFWS joined us at our first team meeting and were continuously involved in project planning, data acquisition, coordination, and outreach. GBILM held more than 25 meetings with BLM, NPS, and USFWS in Idaho, Nevada, Utah, and Washington D.C. Other partners included the U.S. Forest Service (USFS), Environmental Protection Agency (EPA), Desert Research Institute, Utah Partners for Conservation and Development, and the Great Basin Research and Management Partnership. Agency representatives at all levels expressed needs that could be readily filled through the GBILM model (for example, see U.S. Fish and Wildlife Service, 2010b). GBILM firmly cemented long-term relationships with these and other partners by fostering greater collaboration. For example, the current iteration of DOI's Healthy Lands Initiative in the Great Basin is focused on an area covering 3 states and 13 BLM field offices. BLM reached out to the GBILM team to assist with data gathering and delivery, discipline expertise, and analytical skills.

Examples where GBILM leveraged support include:

- ***The Fire-Invasive Species Interactions and Land Treatment Digital Library (LTDL)***—Projects elevated GBILMs exposure at the national level by providing novel tools and products useful at the regional scale and established effective collaboration at the local level by strengthening relationships at BLM's Fillmore (Utah) and Ely (Nevada) field offices and at Great Basin National Park. The LTDL continues to build connections at other BLM Offices, assisting with historical data management and analysis at local scales while fostering landscape-scale analyses previously not achievable.
- ***The Water Extraction Project*** interacted with existing USGS and partner agencies working on the Clark, Lincoln, and White Pine Counties (Nevada) Groundwater Development Project. GBILM provided the phreatophyte vegetation GIS layer, NDVI Greenness data, and groundwater well spatial database to the BARCAS study, a cooperative effort among USGS Nevada and Utah Water Science Centers, the Central and Western Geology Science Centers, Desert Research Institute, and the Utah State Engineers Office.
- ***Land-Cover Change Detection through Remote Sensing Project*** was used to leverage work funded by the USGS Simplified Acquisitions Branch (Solicitation Number 08HQSS037). Funds from this proposal were provided to NatureServe© to recreate the land-cover change analysis on Landsat scene (Path 40, Row 32, adjacent to our priority focal area, Projects 1, 4, and 5). The effort doubled the spatial extent of our land-cover change data at no cost to GBILM.

Timely and Relevant Landscape-Scale Tools

GBILM provides managers with conceptual tools for evaluating external and antecedent inputs into their system of interest and applying landscape-relevant principles to manage local resources. In addition to the results and management applications associated with the projects described above, a few GBILM outcomes are broadly applicable. Products recognized as immediately usable by partners include our Conceptual Models, the Land Treatment Digital Library, our imagery library along with derived land cover and land cover change analyses, and the integrated modeling approach. Specific examples include the following:

Conceptual models (Miller and others, 2010) provide a consistent view of the Great Basin landscape and are essential tools for managers charged with multiple-use objectives. Conceptual models are a foundation for all additional products to be developed. The models are useful as communication tools and hypothesis generators for managers evaluating trade-offs among competing management prescriptions. A common perception among stakeholders helps land managers, researchers, and other stakeholders focus on the important components and processes related to the issue being addressed. Our conceptual models can help land managers understand how individual management actions spatially and temporally interact and how interactions may lead to unexpected patterns or cumulative effects. When coupled with field data (for example, Land Treatment Digital Library), the conceptual models can be used to guide *in situ* field experiments designed to evaluate treatment effectiveness.

Integration Models provided with the Conceptual Modeling report (Miller and others, 2010) deliver tools for land managers working at multiple scales. Integration requires compiling data across the range of spatial scales and interpreting data so that they become useful at scales other than the scale at which data were collected allowing management questions to be answered at multiple scales. Our model integrates multiple stressors (climate change, land treatments, fire) acting at various spatial scales to give managers a landscape context. The integration model can be used as a method for scale-up the knowledge gained from site specific monitoring to explore management options across the landscape.

Management Questions to Frame Inquiry: We developed an inventory of management questions for future consideration. The questions were internally vetted in terms of feasibility, data availability, and team expertise and then presented to management agency personnel for feedback. This process is iterative with feedback welcome at any point. The iterative cycle of vetting questions, receiving feedback, and reevaluation shapes project development in the GBILM approach.

Data Development and Delivery: To date, GBILM has generated many regional or Great-Basin-wide data products and datasets that are available to USGS, partner agency staff and, when published, the general public. Examples include the Phreatophyte Vegetation map, the Land Treatment Digital Library, the satellite image library, NDVI Greenness trend spatial dataset, and the 30-year change detection product. Interim data are or will be incorporated into the ArcGIS Server application, SAGEMAP, or the public website (U.S. Geological Survey 2007a, accessed October 17, 2010, at *http://www.usgs.gov/features/greatbasin/index.html*). When published, the various data products will be available through standard USGS distribution outlets.

Increasing the Value of GBILM Investment

The GBILM approach is consistent with DOI and USGS Strategic Planning (appendix D) and addresses concerns of local resource managers. GBILM improved regional knowledge on the effects of climate change, water availability and extraction, land treatments, and wildfire on ecosystem health and species persistence. Team members continue to seek opportunities to interact with national and regional programs in Global Change science (for example, two proposals were submitted in FY08), Ecosystem Change Forecasting, the regional Arid Lands Project proposed by the USGS Ecosystem Council, and DOIs Healthy Lands Initiative.

Managers in the Great Basin critically need landscape-scale monitoring data to inform their decision making. Some very useful data exist, but large data gaps also are obvious. GBILM attempted to understand how existing data fit together and identify critical data gaps. For some existing data (for example, groundwater wells, land treatments), funds and coordination are needed to assemble and quality-check extensive but poorly documented data. In other cases (for example, downscaled regional climate models), significant work is required for data restoration and synthesis. When these datasets are integrated, comprehensive monitoring as part of an adaptive management framework will be possible.

FY10 Synthetic Goals: By drawing upon USGS multi-disciplinary capability, the GBILM Integration Team developed and tested an integrated approach for detecting and predicting landscape changes in the Great Basin by:

- Focusing on primary drivers of ecosystem change (for example, climate change, fire, invasives, land treatments, water extraction).
- Enhanced understanding of ecosystem processes and changes.
- Providing a framework for applying ILM concepts in other contexts.

Using this approach, the GBILM Integration Team is finalizing models of land-cover change within the context of a general model of disturbance-change dynamics (Flint and others, 2009). We demonstrated that scientists can work under an interdisciplinary banner while pursuing high-quality, management-focused science projects. In FY2011, the team will submit a manuscript (Flint and others, *written communication*) that applies the integration model to wildfire location and severity, climate, and soils data to forecast the amount, distribution, and connectivity of quality habitat for sage-grouse under a suite of alternate futures. The exercise will demonstrate the strengths and weaknesses of landscape-scale modeling given incomplete datasets. It also will identify critical data gaps for monitoring and forecasting sage-grouse and other sagebrush-associated populations while providing a set of products immediately useful to resource managers.

Lessons Learned

The GBILM Pilot project brought together scientists and managers from disparate locations and affiliations and focused them into a cohesive, effective group with a closely engaged constellation of advisors from many Federal agencies. How was this success achieved in just 3 years? There are many components to this story. Below we share lessons that may prove useful for other developing integrated projects.

A passion and a vision—The GBILM group began as a group of scientists and managers that passionately believed that the Great Basin was deteriorating from inattention and required sustained effort to catch up with many other "showcase" ecosystems. As important, the leaders of this group had a clear vision of how to make the fledgling project succeed, and patiently nudged the group thinking in this direction over 3 years. Together these attributes of GBILM resulted in a functional collaborative group.

Ample and organized meetings—In some contexts, meetings have a negative connotation as a drainer of energy and time, but the GBILM meetings were seen at the outset as a required element because they would allow ideas to gel and people to learn together, crossing cultural, linguistic, and operational boundaries to form a cohesive whole. Meetings were moved from place to place, allowing several locales to host them, all interested parties were welcomed to the meetings and, perhaps most importantly, meetings were carefully organized and documented. They were planned to be comprehensive, run to include all comments large and small, and they welcomed outside agency participation. Finding the balance between focus on achieving goals and openness to include all participants was a key to the success of these meetings.

Connections at all levels—The GBILM leadership established excellent connections to headquarters, DOI, and local centers for outside agencies and never ceased to improve on these connections, which strengthened GBILM and increased knowledge and awareness of the project. Excellent involvement of outside agencies resulted, as well as increased cooperation and funding from many USGS programs. In some cases, cooperation from disciplines within USGS did not reach these generally high levels, indicating that an even longer period of cross-communication is needed to bridge some institutional barriers.

Allowing time for the process—Establishing interdisciplinary science groups and integrating among many agency cultures is always a slow process, and GBILM took a patient approach to encouraging this integration. Newly initiated integrated studies must factor in 1 to 3 years of ramp-up for the integration to occur, and therefore must have longer term cycles (for example, 5 years) to ensure productivity. Planning on a nurturing phase is essential, and requires leeway from the commonly product-driven oversight groups.

Bridging the gap between workplaces—The GBILM project used many approaches to ease the difficulty of project members belonging to close to a dozen cost centers and to include outside agency personnel. Routine monthly conference calls plus the use of a variety of technologies, such as teleconferencing, WebEx, and the MyUSGS portal enabled efficient two-way communication and documentation of team progress.

Use of ecosystem conceptual and process models—The development and use of such models from start to finish served several functions including:

- Developing program direction.
- Facilitating communication and understanding.
- Identifying knowledge gaps.
- Evaluating progress.
- Guiding quantitative approaches and models.

Rewarding the participants—Integrated studies are extra rewarding as the fruits of collaboration are achieved, but scientists typically pay a price in the form of low-productivity years during the development phase and in the form of institutional roadblocks. How do we reward risk-taking at all levels? Simplest would be an institutional design that streamlines integrated efforts, bypassing financial and program-level obstacles, to reward scientists and managers with an improved working situation. Those interested in integrated study would flock to this rewarding working environment.

Focusing on relevant science needs—This focus resulted in strong communication and commitment between the science and management partners. It also built a sense of priority due to the potential for project results to be used in management and policy contexts (for example, the Conceptual Models and the LTDL database), thereby bringing a relevance that some other projects do not possess.

References Cited

Beever, E.A., Pyke, D.A., Chambers, J.C., Landau, F., and Smith S.D., 2005, Monitoring temporal change in riparian vegetation of Great Basin National Park: Western North American Naturalist, v. 65, p. 382-402.

Brooks, M.L., and Chambers, J.C., *in press*, Resistance to invasion and resilience to fire in desert shrublands of North America: Rangeland Ecology and Management.

Connelly, J.W., Knick, S.T., Schroeder, M.A., and Stiver, S.J., 2004, Conservation assessment of greater sage-grouse and sagebrush habitats: Cheyenne, WY, Western Association of Fish and Wildlife Agencies, [accessed November 4, 2010 at http://sagemap.wr.usgs.gov/ConservationAssessment.aspx].

D'Antonio, C.M., and Vitousek, P.M., 1992, Biological invasions by exotic grasses, the grass/fire cycle, and global change: Annual Review of Ecological Systems v. 23, p. 63-87.

Desert Research Institute, no date, BARCAS—Basin and Range Regional Carbonate-rock Aquifer System, accessed October 17, 2010, at http://www.barcas.dri.edu/.

Flint, L.E., Flint, A.L., Torregrosa A., Woodward, A., Welty, J., Finn, S.P., Pilliod, D.S., Garmin, S., Baer, L.A., Matchett, J.R., Brooks, M.L., and Casazza, M., 2009, Projecting future changes in sagebrush distribution in the Great Basin: Poster presented at the American Geophysical Union Fall Meeting, San Francisco, CA.

Flint, L.E., Flint, A.L., Torregrosa A., Woodward, A., Welty, J. Finn, S.P., Pilliod D.S., Garmin, S., Baer, L.A., Matchett, J.R., Brooks, M.L., Casazza, M., written communication., Projecting future changes in sagebrush distribution in the Great Basin.

Knutson, K.C., Pyke, D.A., Wirth, T.A., Pilliod, D.S., Brooks, M.L., and Chambers, J.C., 2009, A Chronosequence Feasibility Assessment of Emergency Fire Rehabilitation Records within the Intermountain Western United States - Final report to the Joint Fire Science Program - Project 08-S-08: U.S. Geological Survey Open-File Report 2009-1099, p. 20.

Linstone, H.A., and Turoff, M., eds., 2002, The Delphi Method: Techniques and applications, accessed October 17, 2010, at http://is.njit.edu/pubs/delphibook/.

Melack, J.M., Dozier, J., Goldman, C.R., Greenland, D., Milner, A.M., and Naiman, R.J., 1997, Effects of climate change on inland waters of the Pacific coastal mountains and western Great Basin of North America: Hydrological Processes, v. 11, p. 971-992.

Miller, D.M., Finn, S.P., Woodward, A., Torregrosa, A., Miller, M.E., Bedford, D.R , and Brasher, A., 2010, Conceptual ecological models to guide integrated landscape monitoring of the Great Basin: U.S. Geological Survey Scientific Investigations Report 2010-5133, 134 p. (Also available at http://pubs.usgs.gov/sir/2010/5133/.)

Miller, M.E. 2005. The structure and function of dryland ecosystems—conceptual models to inform long-term ecological monitoring: U.S. Geological Survey Scientific Investigations Report 2005-5197, 73 p. (Also available at http://pubs.usgs.gov/sir/2005/5197/.)

Miller, R.F., and Wigand, P.E., 1994, Holocene changes in semiarid pinon-juniper woodlands: response to climate, fire, and human activities in the U.S. Great Basin: BioScience, v. 44, p. 465-474.

Noss, R.F., LaRoe III, E.T., and Scott, J.M., 1995, Endangered ecosystems of the United States: A preliminary assessment of loss and degradation, Biological Report 28: Washington, D.C., National Biological Service, accessed October 17, 2010, at http://biology.usgs.gov/pubs/ecosys.htm.

Omernik, J.M., 1987, Ecoregions of the conterminous United States, Map (scale 1:7,500,000), Annals of the Association of American Geographers, v. 77, no. 1, p. 118-125.

Stewart, I.T., Cayan, D.R., and Dettinger, M.D., 2005, Changes toward earlier streamflow timing across western North American Journal of Climate, v. 18, p. 1136-1155.

Pilliod, D.S., 2009, Land treatment digital library—A dynamic system to enter, store, retrieve, and analyze Federal land treatment data: U.S. Geological Survey Fact Sheet 2009-3095, 2 p. (Also available at *http://pubs.usgs.gov/fs/2009/3095/*.)

Quigley, T.M., Gravenmier, R.A., Arbelbide, S.J., Bigler Cole, H., Graham, R.T., and Haynes, R.W., 1999, The Interior Columbia Basin Ecosystem Management Project: Scientific Assessment, CD-ROM available at: http://www.icbemp.gov/, accessed October 17, 2010.

U.S. Bureau of Land Management, 2000, Great Basin restoration initiative, accessed November 4, 2010, at http://www.blm.gov/id/st/en/prog/gbri.html.

U.S. Fish and Wildlife Service, 2010a, Endangered and Threatened Wildlife and Plants; 12-month Finding on a Petition to List the American Pika as Threatened or Endangered, 50 CFR Part 17, [FWS-R6-ES-2009-0021, MO 92210-0-0010], 34 p.

U.S. Fish and Wildlife Service, 2010b, Great Basin Landscape Conservation Cooperative: accessed October 17, 2010, at http://www.fws.gov/science/shc/pdf/DoIGreatBasinLCCFactSheet.pdf.

U.S. Geological Survey, no date, USGS Global Visualization Viewer: accessed October 17, 2010, at http://glovis.usgs.gov/.

U.S. Geological Survey, 2007a, Great Basin Integrated Landscape Monitoring (GBIM) Pilot — Management Questions: accessed October 17, 2010, at *http://www.usgs.gov/features/greatbasin/program/questions.html*.

U.S. Geological Survey, 2007b, Great Basin Integrated Landscape Monitoring (GBIM) Pilot: accessed October 17, 2010, at http://www.usgs.gov/features/greatbasin/index.html.

U.S. Geological Survey, 2009, SAGEMAP – A GIS database for Sage-grouse and Shrubsteepe Management in the Intermountain West: accessed October 17, 2010, at *http://sagemap.wr.usgs.gov/*.

U.S. Geological Survey, 2010, Land treatment digital library: accessed October 17, 2010, at http://greatbasin.wr.usgs.gov/ltdl/Default.aspx.

Welch, A.H., Bright, D.J., and Knochenmus, L.A., eds., 2007, Water resources of the Basin and Range carbonate-rock aquifer system, White Pine County, Nevada, and adjacent areas in Nevada and Utah: U.S. Geological Survey Scientific Investigations Report 2007–5261,96 p. (Also available at *http://pubs.usgs.gov/sir/2007/5261/*).

Wisdom, M.J., Rowland, M.M., and Suring, L.H., eds., 2005, Habitat threats in the sagebrush ecosystem: methods of regional assessment and applications in the Great Basin: Lawrence, KS, Alliance Communications Group.

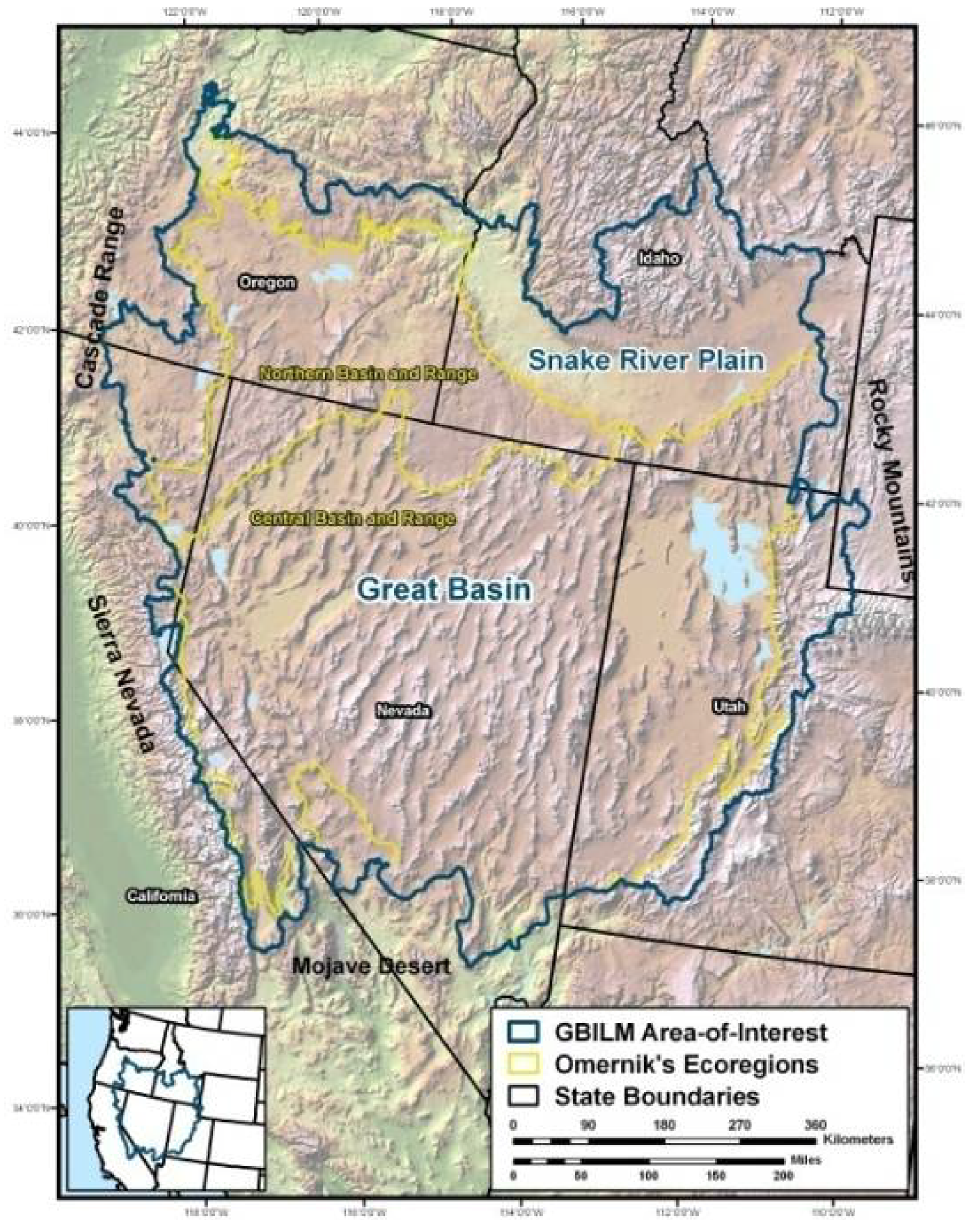

Figure 1. GBILM Area-of-Interest is a union of Omernik's Northern and Central Basin and Range Provinces (Omernik, 1987) and the Great Basin Restoration Initiative [http://www.blm.gov/id/st/en/prog/gbri/map.html] focal area.

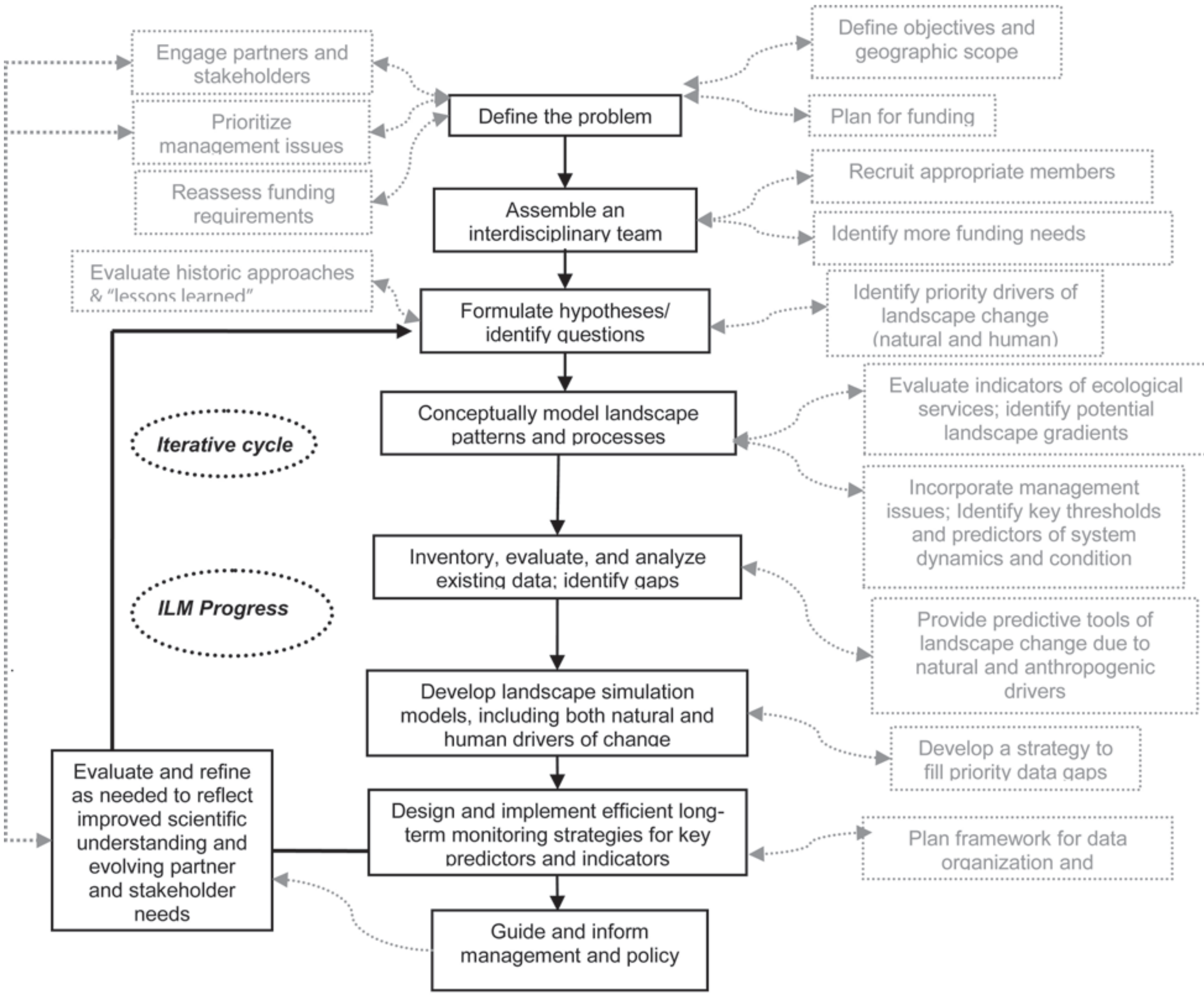

Figure 2. Flow diagram of GBILM work process. Black boxes represent necessary steps and iterations; gray boxes depict important considerations at each step.

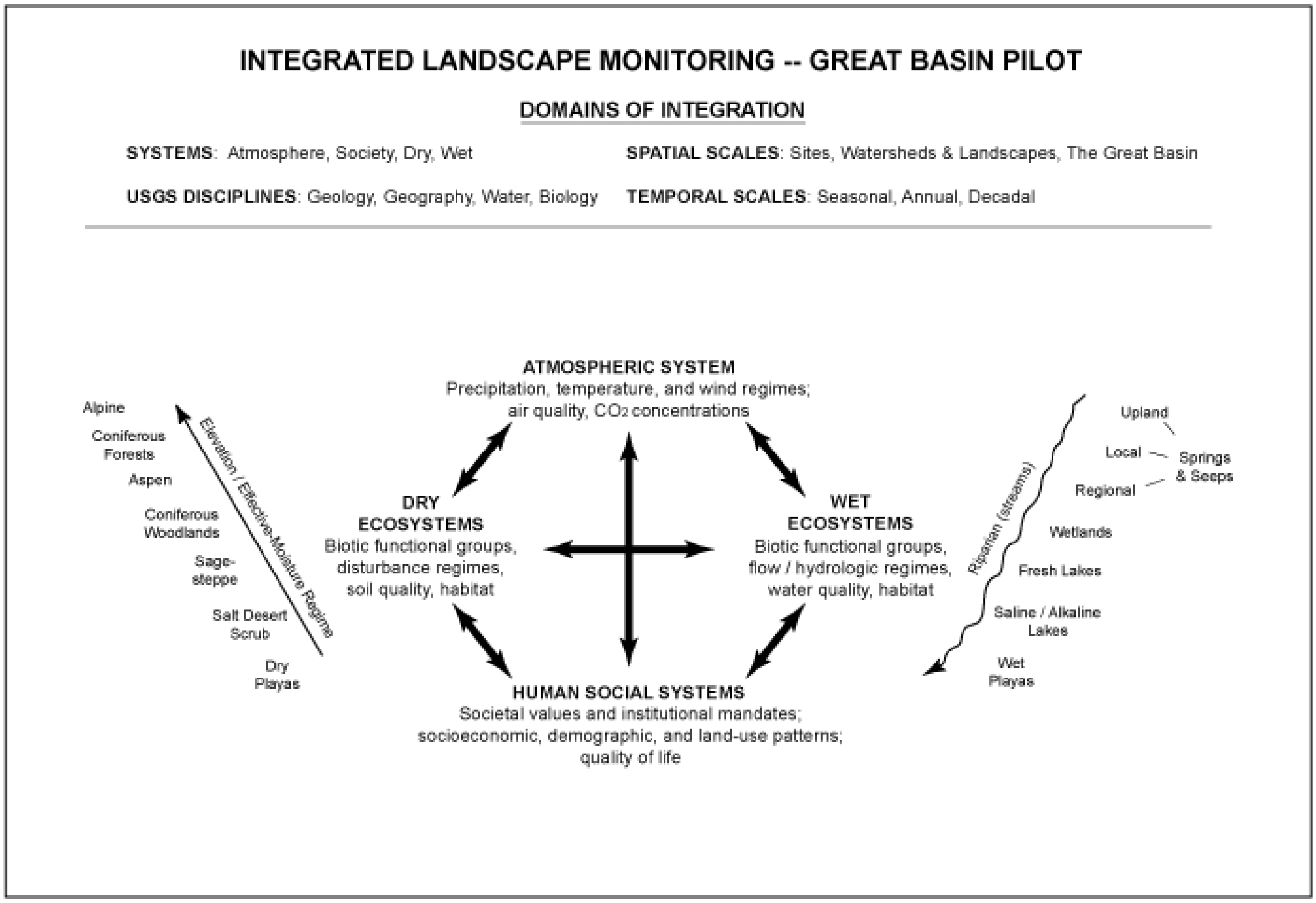

Figure 3. High-order "Framework" model illustrating Great Basin systems and functions. For detailed description and system-specific models, see Miller and others (2010).

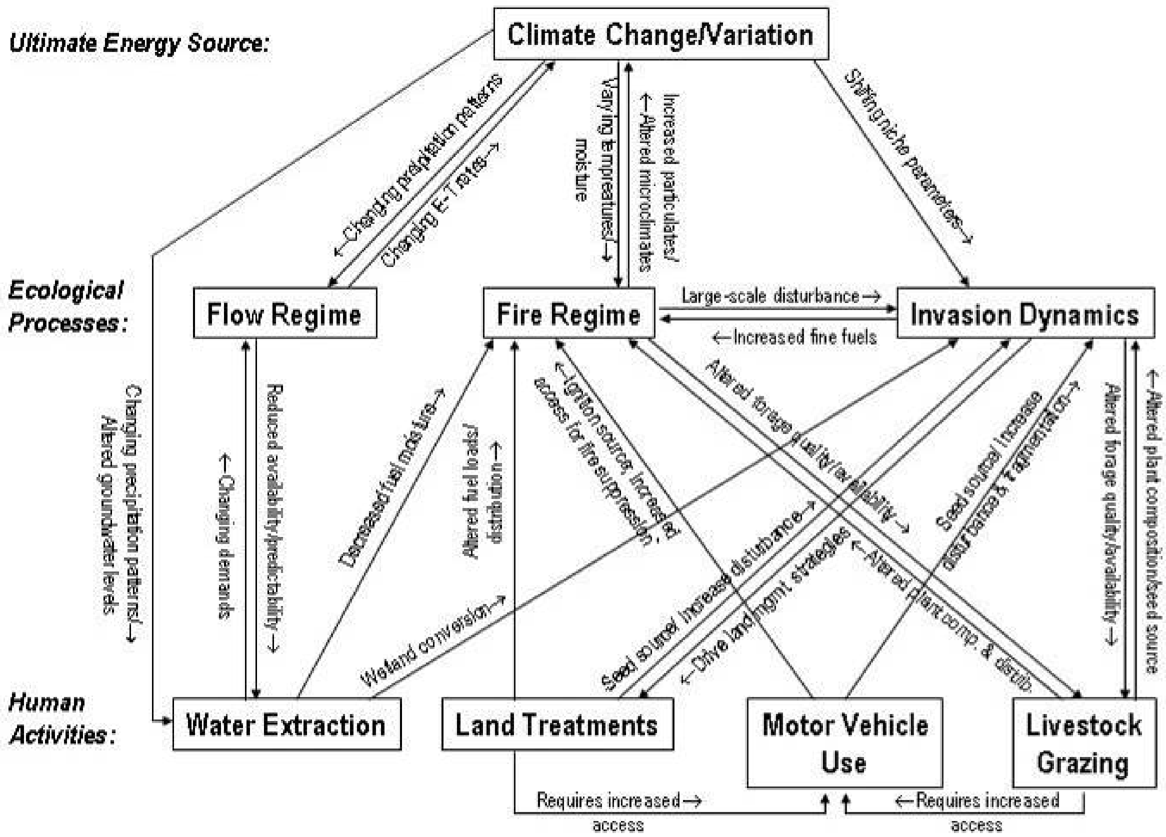

Figure 4. Diagram of principal interactions among ecosystem drivers in the Great Basin.

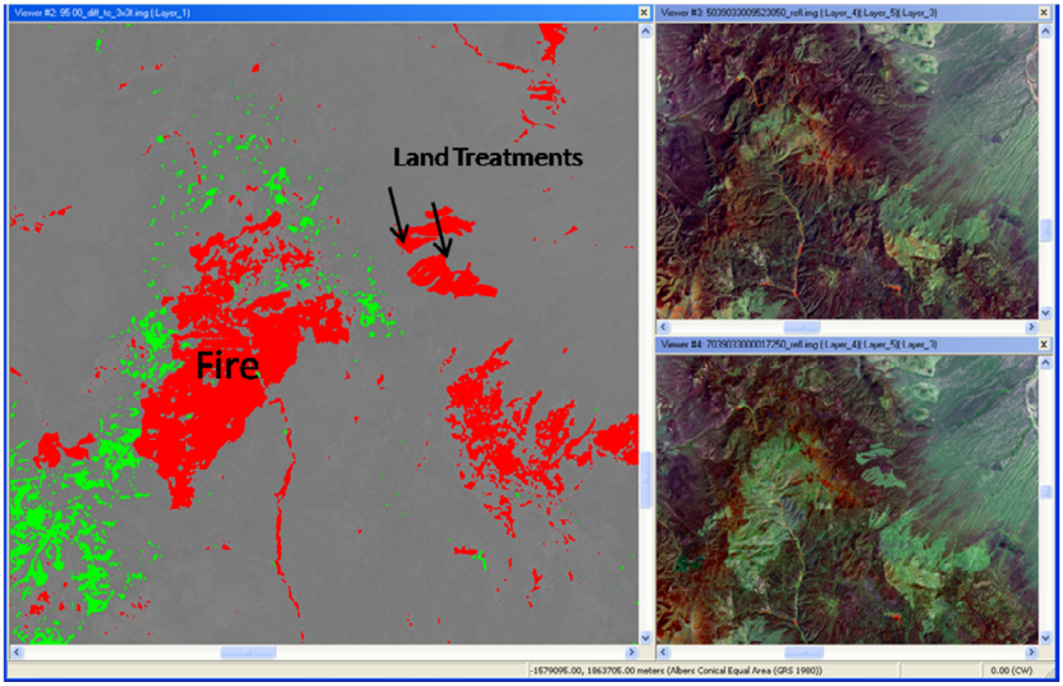

Figure 5. Example land-cover change mask for a portion of Landsat scene (Path 39, Row 33) between 1995 and 2000. Top right is the 1995 image; bottom right is the 2000 image; left panel indicates change between images (gray = no change; red = decreased greenness; light green = increased greenness). Note large fire in center of panel and the two land-treatment patches just right of fire.

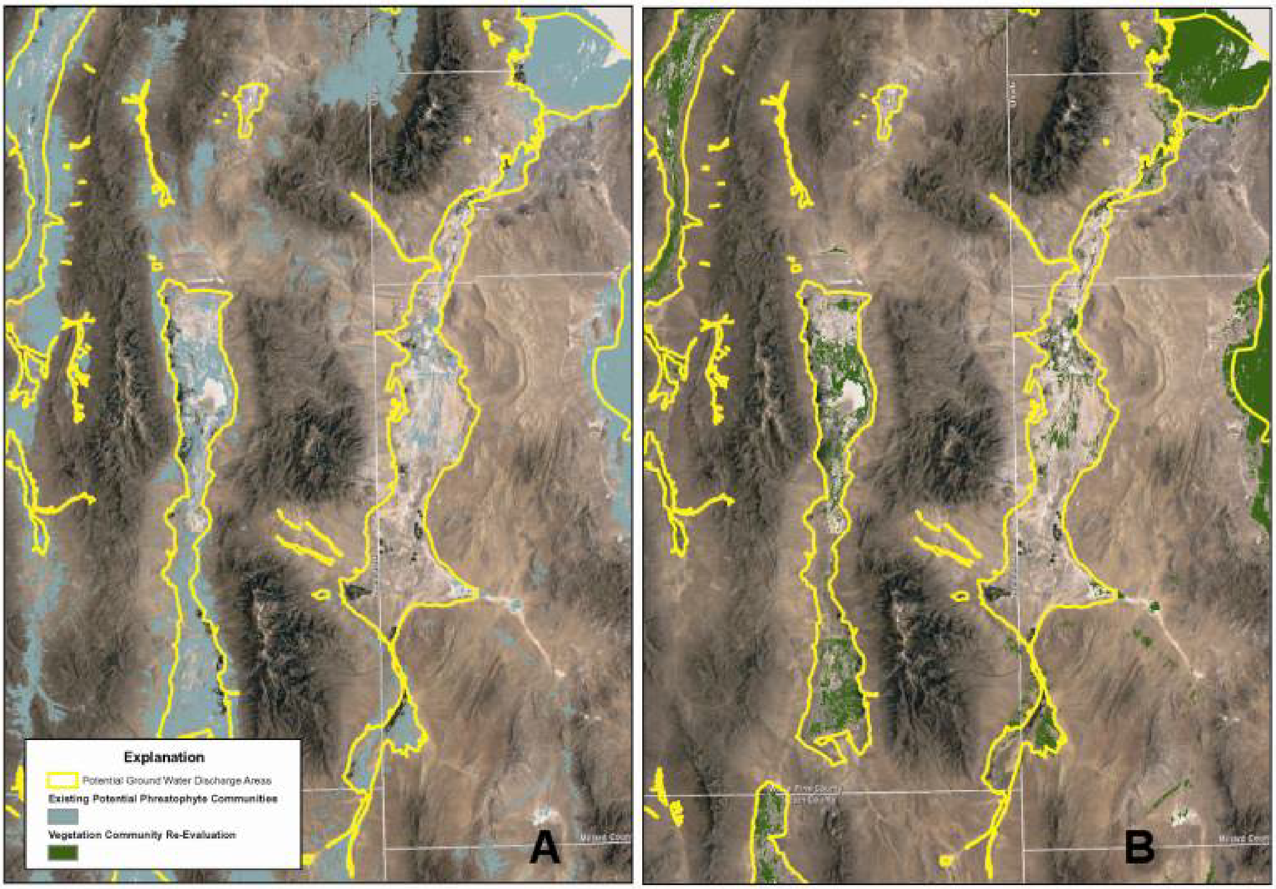

Figure 6. Example results of the phreatophyte map project. The spatial distribution of phreatophytes, shown in green, is mostly limited to the groundwater discharge areas where water levels are closer to the land surface. In Image B, the Big Sage vegetation class was removed thereby reducing much of modeled phreatophytic vegetation that Image A depicts on fans and upland benches. Vertical line just to the right of center is the Utah-Nevada State border; Great Basin National Park lies in the south-central part of the map. Map is about 115 km left to right (east to west).

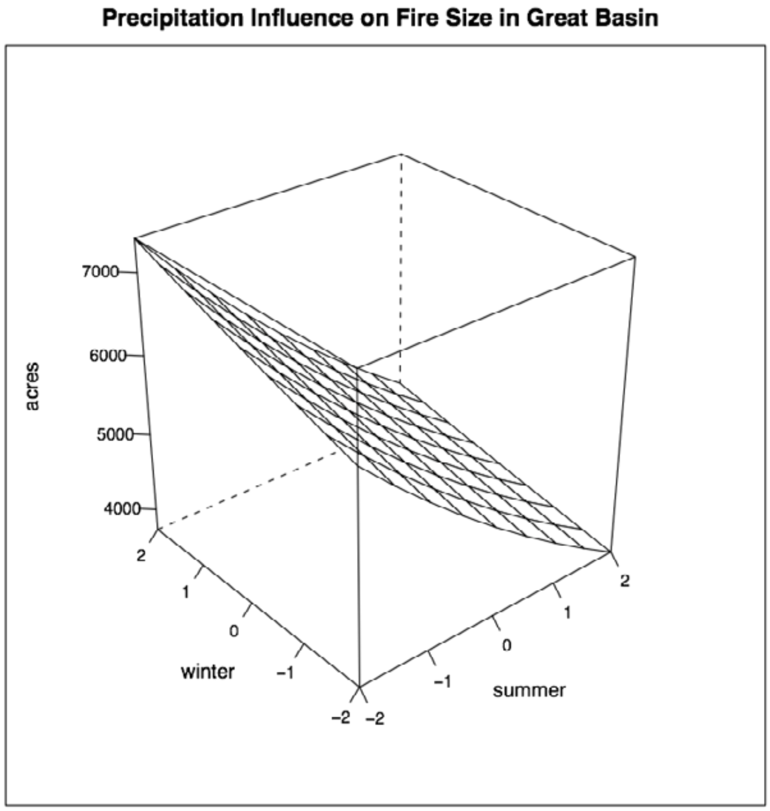

Figure 7. Two-way interaction of the effects of winter and summer precipitation on fire size (acres) in the Great Basin. The positive winter rainfall correlation was less strongly correlated with fire size than the negative summer rainfall correlation. High winter rainfall followed by low summer rainfall produced the largest fires.

		Summer Precipitation	
Winter Precipitation		lower	higher
	lower	Larger Fires *native perennials ↑↑ non-native annuals ↓	Smaller Fires native perennials ↓ non-native annuals ↓
	higher	Much Larger Fires native perennials ↑↑ non-native annuals ↑	No Change native perennials ↓ non-native annuals ↑

Figure 8. Matrix predicting relative fire size in any give year based on winter (prior to fire season) and summer (during fire season) precipitation.

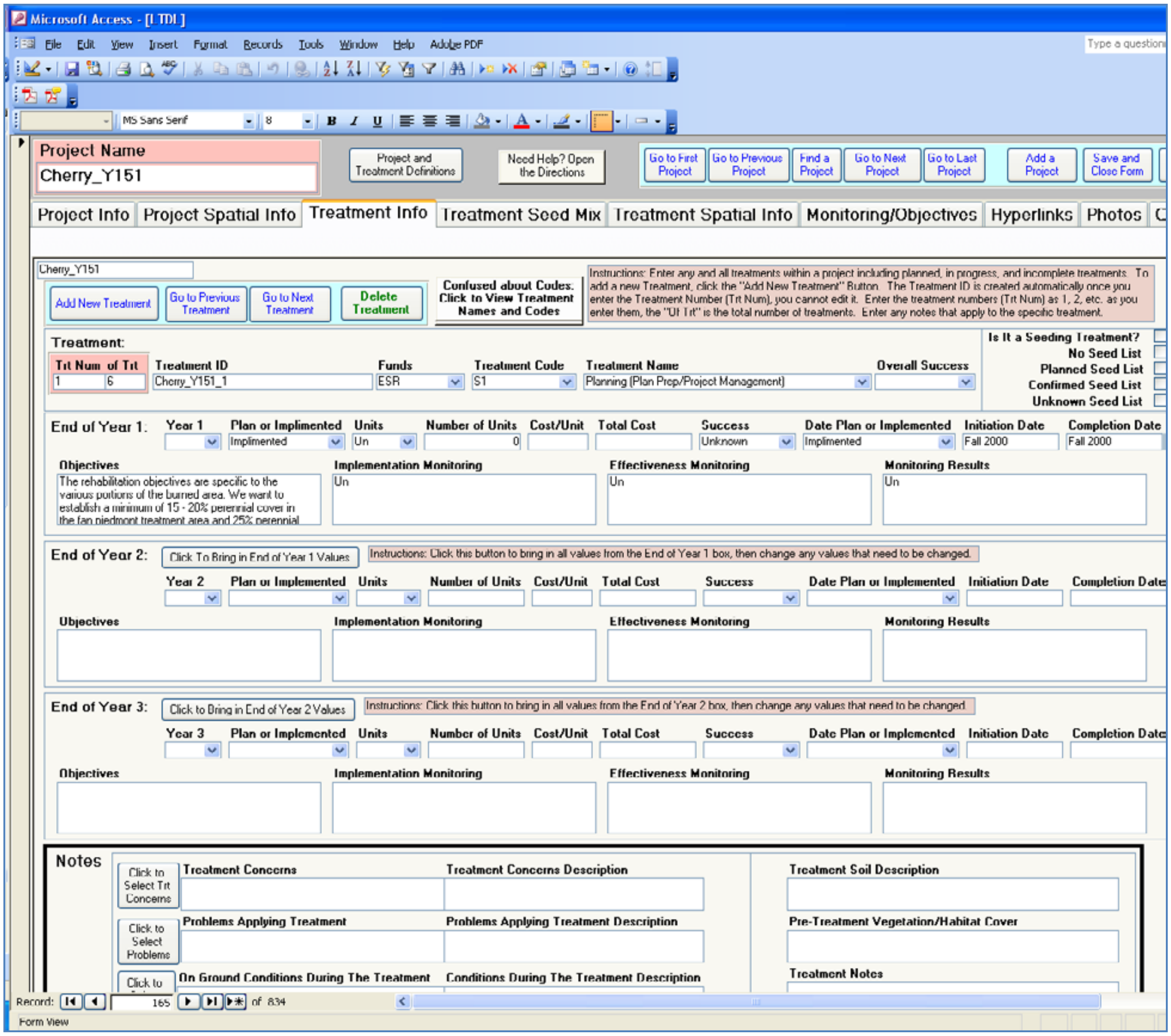

Figure 9. Data input form from Land Treatment Digital Library.

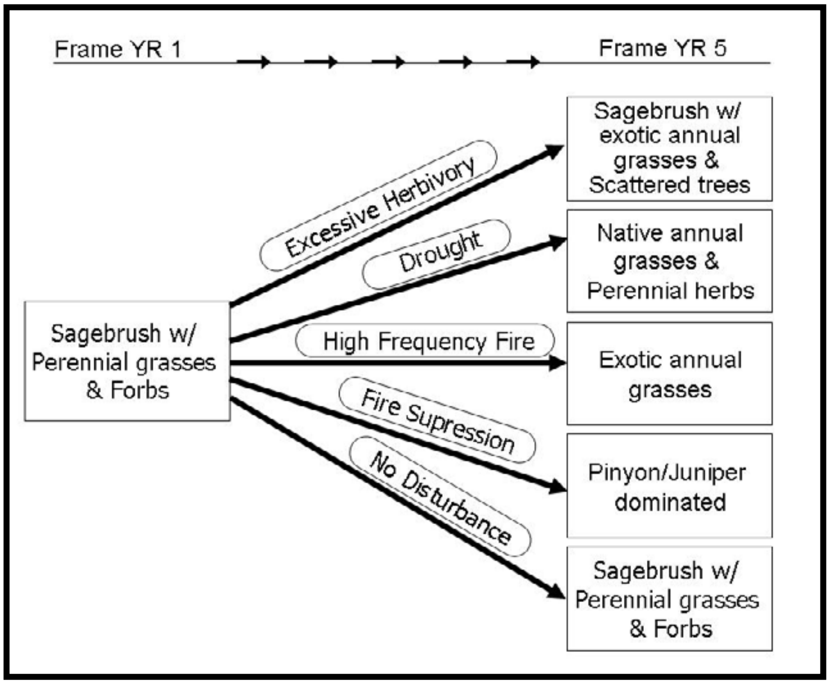

Figure 10. Frame-based model for simplified sagebrush steppe example. The single box on the left represents the state of one specific area of the map that was classified (in year one, for example, the initial condition) as "Sagebrush with Perennial Grasses and Forbes." The four boxes on the right represent the condition of the site after 5 yearly time steps (frames) under 5 different scenarios each represented by a different driver present, excessive herbivory, drought, high fire frequency or fire suppression. For simplicity sake, the driver was assumed to last for the full 5 years and the transition result (for example, Frame YR 5) for each scenario was the result of a single driver.

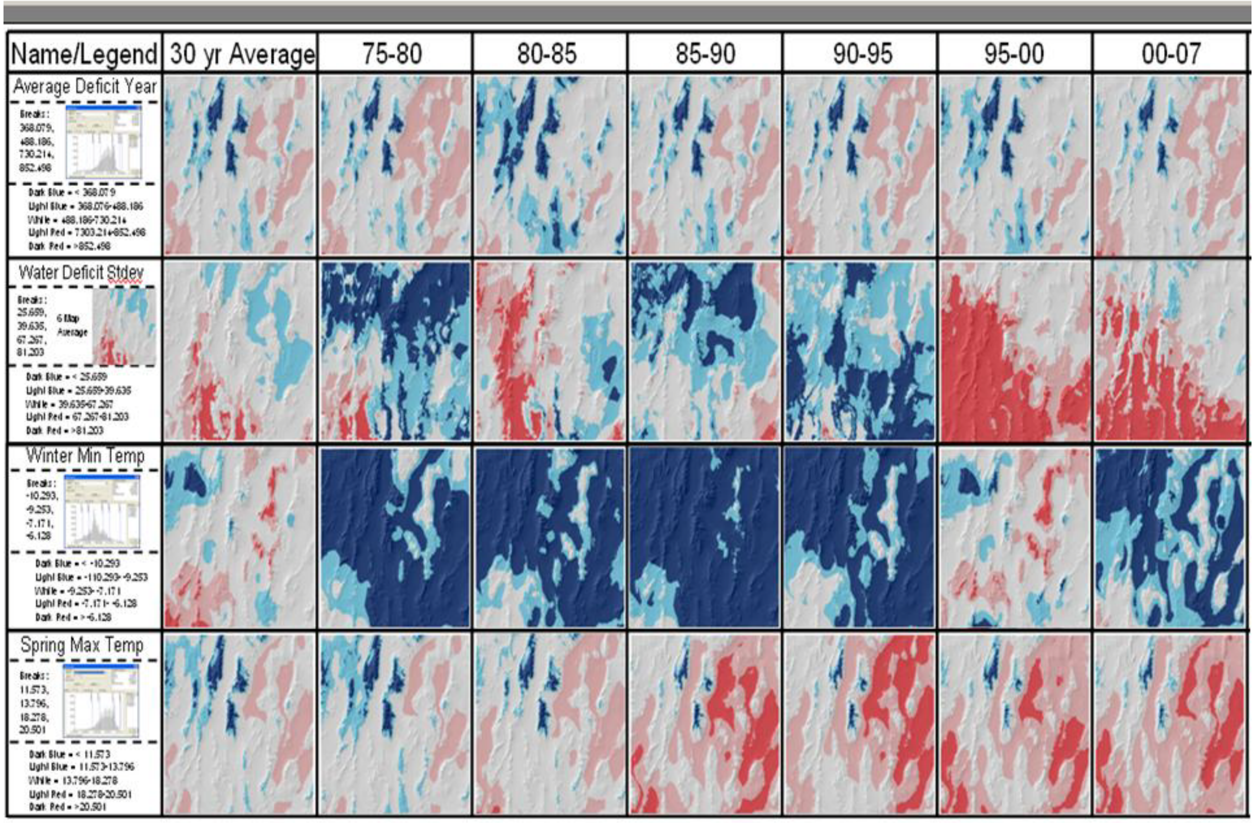

Figure 11. Climate data and modeled climatic water deficit data transformed into indexes that match the temporal format of the land-cover change detection product.

Table 1. Key habitat types and land stewardship in the GBILM area-of-interest.

Key habitat	Percent
Intermountain (cold desert) scrub	35.2
Sagebrush	12.3
Invasive grasslands and forblands	8.4
Sand dunes and badlands	7.9
Unclassified	7.1
Wet meadows	6.5
Intermountain conifer forests and woodlands	5.1
Lower montane woodlands	3.9
Lower montane chaparral	3.2
Mojave/Sonoran (warm desert) scrub	3.0
Cliffs and canyons	1.7
Barren landscapes	1.5
Alpine and tundra	1.3
Grasslands and meadows	1.1
Desert playas and ephemeral pools	0.6
Intermountain rivers and streams	0.4
Mesquite bosques and desert washes	0.4
Developed landscapes	0.3
Marshes	0.1
Mojave mid-elevation mixed desert scrub	< 0.1
Agricultural lands	< 0.1
Aspen woodland	< 0.1
Lakes and reservoirs	< 0.1
TOTAL	100

Steward	Percent
BLM	62.1
Private	19.3
USFS	7.6
DOD	2.9
State	2.6
Water	1.6
USFWS	1.5
Tribal lands	1.3
DOE	0.4
NPS	0.3
Misc. Federal	0.2
Local	0.2
BOR	0.1
USFS/BLM	0.1
TOTAL	100

Table 2. Major ecosystem drivers affecting the Great Basin landscape identified at beginning of Delphi process (after Linstone and Turoff, 2002).

[Drivers in bold-italic were those selected as the highest GBILM priority]

Agriculture	Fire suppression	***Motorized vehicle access***
Altered flow regimes	Insects and disease	Roads
Atmospheric pollution/deposition	***Invasive exotic plants***	Particulates (airborne and deposited)
Channelization	Invasive exotic animals	Pathogens
Climate change	***Land use - cover change***	Recreation
Climate variability	***Land Treatments***	Resource extraction
Economic and political	Legal mandates	Sound pollution
Erosion	Light pollution	Urban-exurbanization
Fire acceleration	Linear infrastructure	***Water extraction***
Fire regime	***Livestock grazing***	Water impoundment/diversion
Fire-invasive plant interactions	Military land use	Water pollution

Table 3. Example summary data generated from the Land Treatment Digital Library.

Confirmed treatments	<1990	1990-1994	1995-1999	2000-2004	2005-2008	Total
Aerial seeding	0	0	5	46	62	113
Ground seeding	0	0	1	2	6	9
Seedling planting	0	0	1	1	1	3
Livestock closures (confirmed)	0	0	2	14	52	68
Livestock closures (unconfirmed)	0	0	4	25	4	33
Fence construction/Repair	0	0	1	14	16	31
Monitoring only	0	0	0	0	4	4

Appendix A. Team Membership and Other Contributors to GBILM

[A, advisor; L, leadership; CM, conceptual models; O, outreach; P, project, ST, synthesis team]

USGS Core Team			
Name	**Role**	**Name**	**Role**
Robert Arkle, Biology	P	Bruce Jones, Biology	A
Erik Beever, Biology	P	Steven T. Knick, Biology	A
Matthew L. Brooks, Biology	ST, P	Jeffrey E. Lovich, Biology	A
David Busch, Biology	A	Jessica Montag, Biology	P
Michael L. Casazza, Biology	ST, P	Karen J. Phillips, Biology	A
Pete Coates, Biology	P	Steven E. Schwarzbach, Biology	A
Janet Erickson, Biology	O	John Steffy, Biology	IT
Sean P. Finn, Biology	L, CM, ST, P	Thomas Suchanek, Biology	A
Kate Kitchell, Biology, Great Basin Pilot Lead	A, L, O, ST	Tom Zarriello, Biology	IT
J. R. Matchett, Biology	P	Collin Homer, Geography	A
Mark E. Miller, Biology	CM	David L. Berger, Water	A
David Pilliod, Biology	ST, P	Robert L. Burrows, Water	A
David A. Pyke, Biology	A	Alan Flint, Water	ST
Carol Schuler, Biology, ILM Thrust Lead	A, L, O	Lorraine Flint, Water	ST
Justin Welty, Biology	P, ST	Victor M. Heilweil, Water	CM, P
Andrea Woodward, Biology	CM, ST, P	Patrick M. Lambert, Water	A
Lori Anne Baer, Geography	P	William D. McFarland, Water	A
Thomas P. DiNardo, Geography	A	Susan A. Thiros, Water	P
Beverley Friesen, Geography	P	Lee Amoroso, Geology	A
Steve Garman, Geography	ST	Benita Murchey, Geology	A
Suzie Noble, Geography	P	Richard L. Reynolds, Geology	A
Amy Mathie, Geography	P	Sky Bristol, GIO	IT
Tom Owens, Geography	L	Richard Ferrero, USGS WR	A
Alicia Torregrosa, Geography	L, CM, ST, P	Sam T. Arriola, GIO	IT, O
Anne Brasher, Water	CM	Thomas A. Sturm, GIO	IT
Kimball E. Goddard, Water	L	Brian Cole, USGS WR	A
David Susong, Water	L, P	Tracy Valentovich, Geology	P
Mary Tumbusch, Water	P		
Toby Welborn, Water	P		
David Bedford, Geology	CM, ST, P		
David M. Miller, Geology	L, CM, ST, P		

Partner-Agency Representatives	
Bureau of Land Management	National Park Service
George Buckner	Marie Denn
Bud Cribley	Debra Hughson
Scott Davis	Alice Chung-MacCoubrey
Nora Devoe	U.S. Fish and Wildlife Service
Roxanne Falise	Steve Caicco
Robert Hopper	Nathan Darnall
Mike Pellant	Environmental Protection Agency
Joe Tague	William Kepner
Jim Alegria	Nita Tallent-Halsell
Miles Brown	Utah Division of Wildlife Resources
Bill Dragt	Jim Davis
John Foster	Frank Howe,
Steve Madsen	Rory Reynolds
Linda Mazzu,	University of Idaho
U.S. Forest Service	Mike Scott
Jim Menlove	University of Nevada, Reno
David Tart	Brad Schultz
Robin Tausch	Massachusetts Institute of Technology
The Nature Conservancy	Herman Karl
Don Major, TNC	Alexis Schulman
	Siobhan Watson

Appendix B. Description of Priority Ecosystem Drivers in the Great Basin

Wet System Drivers

Water Extraction.—Groundwater withdrawals are widespread in the Great Basin, both in agricultural settings and for municipal use. Groundwater withdrawals lower water tables because recharge rates generally are low, potentially leading to loss of springs and wetlands. Accelerated groundwater withdrawals associated with urban development highlight this driver as one of special concern.

Flow Regime.—Diversion of streams for irrigation, disruption of streamflow by roads and levees, channel changes for flood control or other reasons, and climate change resulting in changing precipitation and snowmelt patterns all contribute to altered flow regime. Flow Regime describes stream function and therefore biotic habitat condition.

Livestock Grazing.—Livestock trample streambanks and wetlands altering habitat in these critical zones and changing hydrologic function. Livestock may alter species composition and contribute to degraded water quality by nutrient loading. Virtually the entire Great Basin is subject to livestock grazing and large areas host feral horses.

Invasive Exotics.—Introduction of invasive aquatic species has altered virtually every water system in the Great Basin. Specifically, sport fish have been introduced to nearly every stream. Invasive plants have altered the structure, function, and habitat value of many riparian and wetland systems.

Climate Change and Variability.—Global warming and accompanying increased climate variability has altered snowmelt periods, reducing water available for stream flow and lakes, and increasing vulnerability to intense storms, such as floods.

Dry System Drivers

Fire Regime.—Altered fire regimes attributable to past livestock grazing (fuel removal) and fire-suppression efforts have caused significant changes in vegetation structure and function of impacted systems. Mediated by changes in vegetation structure, ecosystem-level consequences of altered fire regimes can include diminished hydrologic functioning and increased erosion rates as well as increased ecosystem susceptibility to drought (Miller, 2005).

Invasive-Fire Interaction.—Introduction of Mediterranean annual grasses has led to infilling of intershrub spaces with highly combustible grass, increasing intensity and frequency of fire in shrublands of the Great Basin. Increased fire frequency alters natural fire cycles, favoring invasive grasslands over native shrubs, impacting existing soil properties, and altering wildlife habitat.

Livestock Grazing.—Grazing alters species composition, vegetation structure, and animal habitat through many mechanisms. Trampling by livestock destabilizes soils, alters hydrologic processes and nutrient cycling, and facilitates the establishment of invasive exotic plants. Stock also may alter riparian and spring habitats.

Land Treatments.—This driver ranges widely in type and scope but all treatments are meant to improve land 'quality.' Examples of land treatments are roads and trails, agriculture, crested wheatgrass and other introduced grass plantings, chained shrublands and woodlands, timber harvested forests, and even flood control basins. All treatments cause vegetation change, alter wildlife habitat, and alter soils and nutrient cycling.

Motor Vehicle Use.—Motor vehicles, used both on road and off, are potential vectors for invasive species and toxic contaminants, and effectively introduce refuse and accelerated human visitation in all but the most remote mountain areas. Off-road vehicle use promotes soil compaction and erosion, plant mortality, increased CO_2, and reduced air quality.

Climate Change and Variability.—Global atmospheric changes attributable to anthropogenic emissions of CO_2 and other greenhouse gases are expected to have significant environmental consequences during this century. Increasing levels of atmospheric CO_2, increasing soil and air temperatures, and altered precipitation patterns (including a potential increase in the frequency of extreme events) are likely to affect physiological processes and competitive relationships of vascular plants, nutrient cycles, hydrologic processes, and disturbance regimes. All these changes have the potential to greatly alter the structure and functioning of dryland ecosystems and the sensitivity of these systems to other anthropogenic stressors.

Appendix C. Key Products from GBILM through FY2010

Scientific Publications / Documents

Conceptual Ecological Models to Drive Integrated Landscape Monitoring of the Great Basin

Miller, D.M., Finn, S.P., Woodward, Andrea, Torregrosa, Alicia, Miller, M.E., Bedford, D.R., and Brasher, A.M.
Outlet: Science Investigations Report 2010-5133.
Description: Summarizes and organizes current understanding of Great Basin ecosystem structure and function by depicting ecological relationships using conceptual models. The GBILM project developed this set of models to identify key ecological functions and services, develop an overarching model of landscape function, begin the process of developing regional monitoring strategies that integrate existing capabilities, and identify critical gaps in our knowledge of ecosystems and their function.

> ***Integration Model*** (Torregrosa, Alicia and Woodward, Andrea)
> Outlet: Scientific Investigations Report 2010-5133.
> Chapter 5 of the Conceptual Model Report details a process to evaluate and forecast impacts of single or multiple ecosystem drivers across a landscape of diverse land-cover types. Predictions, in the form of landscape change hypotheses, become the basis for a monitoring strategy to detect landscape change. The Integration Model links the stressor and control models with spatial analyses that facilitate the compilation of data from multiple scales to simulate landscape change.

Conceptual Model of the Great Basin Carbonate and Alluvial Aquifer System

Heilweil, V.M., Sweetkind, D., Masbruch, M., Cederberg, J., Brooks, L., Buto, S., Flint, A., Susong, D., and Gardner, P.
Outlet: USGS Scientific Investigations Report
Description: This report includes both a description of a detailed 3-D hydrogeologic framework model and the development of detailed groundwater budgets for the 165 basins within the eastern carbonate province. Expected publication year: 2011.

Conceptual Ecological Models; Appendix G *in* Chung-MacCoubrey, A., and others, Mojave Inventory and Monitoring Network Report, Phase III (2008)

Miller, D.M., Esque, T.C., Bedford, D.R., Finn, S.P., Webb, R.H., and Hughson, D.
Outlet: Draft document available at:
[http://science.nature.nps.gov/im/units/MOJN/rpts_pubs/Downloads/PhaseIII/AppendixG_ConceptualModels.pdf] Some of the general Conceptual Ecosystem Models developed for the National Park Service's Mojave Inventory and Monitoring Network were developed in coordination with Great Basin ILM models. The two reports were developed synchronously, with some parts of Mojave informing GBILM and vice versa. (For example, some framework, system, and wet system submodels were modified from Mojave work and modified to fit GB. Some GB models were harvested intact (with permissions) from the GBILM Conceptual Model report and included as draft models in the Mojave Network I&M output.)

User's Guide to the Land Treatments Digital Library

Pilliod, D.S., and Welty, J.
Outlet: PDF document; Posted on LTDL website: http://greatbasin.wr.usgs.gov/ltdl/
Description: A companion guide to the Land Treatments Digital Library including all guidance necessary for interactions with the database. Document includes sections on data entry and data query as well as introductory material and a glossary.

Draft Project Plan, 2007

GBILM Team
Outlet: PDF document; Posted on GBILM website http://www.usgs.gov/features/greatbasin/
Documents much of the early pilot-level scoping and sub-project development based on the team's work from 2005 to 2007. It records the project's earliest attempts at discipline integration and justifications for the course taken. The Plan also lays out a workplan and product schedule through FY 2009.

Wildfire Patterns in the Great Basin, 1980–2007

Brooks, M.L., and Matchett, J.R.
Outlet: Journal article
Description: Describes the spatial and temporal patterns of recent fires in the Great Basin, evaluates their relationships with other landscape variables, and infers future changes based on climate change scenarios.

Invasive Plants and Altered Fire Regimes in the Deserts of North America

Brooks, M.L., and Chambers, J.C.
Outlet: Brooks, M.L., and Chambers, J.C., written communication, Resistance to invasion and resilience to fire in desert shrublands of North America. Rangeland Ecology and Management.
Description: Outlines our understanding of the resistance of landscapes to invasion and the resilience of the native species to fire, and provides a series of management strategies to prevent invasive plant / fire regimes cycles.

Implementing the GBILM Integration Model

GBILM science team
Outlet: Poster at American Geophysical Union fall meeting, 2009.
Description: Document the approach used by the team as described in section, “Pilots Project.” of this report.

Projecting Future Changes in Sagebrush Distribution in the Great Basin

Flint L.E., Flint, A.L., Torregrosa, Alicia, Woodward, Andrea, Welty, J., Finn, S.P., Garman, S., Pilliod, D., Matchett, J.R., Casazza, M., Books, M., Baer, L.A.
Outlet: Journal article
Description: Pilot study that correlated the detected transitions of sagebrush communities either to or from cold desert scrub or pinyon-juniper communities with climatic and hydrologic conditions, defined “bioclimatic envelopes” for each community type, provided an estimate of the direction and trend of actual land-cover change in the study area, quantified the relative influence of each ecohydrologic driver or interaction among drivers, and mapped anticipated future changes in vegetation distribution. Expected publication year 2011.

Soil and Geological Characteristics in the Owyhee Uplands

Bedford, D.R., and Miller, D.M.
Outlet: Journal article
Description: An analysis of soil and surficial geology throughout the Owyhee upland region.

Phenological Responses of Sagebrush and Western Juniper Ecosystems in the Owyhee Uplands

Torregrosa, Alicia, Hanser, S., Tumbusch, M., and Bedford, D.R.
Outlet: Journal article
Description: Phenological responses of sagebrush and western juniper ecosystems will be determined from ground-based cameras coupled with field verified vegetation data. A multi-scale remotely sensing analysis will examine the ability of various remote sensing products to detect the phenological response across the Owyhee Uplands.

Analysis of Environmental Gradients Determining the Distributions of Vegetation and Passerine Bird Community in the Owyhee Uplands

Hanser, S., Bedford, D.R., Torregrosa, Alicia, Tumbusch, M., and Knick, S.
Outlet: Journal article
Description: An analysis of the habitat, climate, and disturbance factors that lead to the distribution and abundance of vegetation types and passerine birds. Field collected passerine bird and vegetation data from 80 locations throughout the Owyhee Uplands coupled with multi-scale habitat obtained from GIS datasets will be used to develop models of multi-scale distribution and abundance. The Owyhee Uplands is a relatively undisturbed landscape and an understanding of the patterns within this landscape may help inform future management and restoration of these ecosystems in other regions.

Snow Characteristics and Thermal Gradients across the Owyhee Uplands

Hanser, S., Bedford, D.R., Torregrosa, Alicia, and Tumbusch, M.
Outlet: Journal article
Description: An examination of snow depth and persistence patterns in sagebrush and juniper ecosystems. Patterns of snow depth and persistence in the arid shrubland and woodland ecosystems of the Western United States are poorly understood. We are measuring snow depth and persistence using an Thermochron iButton® methodology at 84 locations throughout the Owyhee Uplands along elevation and vegetation gradients. This analysis will increase our understanding of the environmental characteristics, such as shrub cover and topography, which determine the characteristics of the snow pack in the region. This understanding may help future management of these systems as climate change influences winter temperature and precipitation patterns.

Vetted List of Priority Ecosystem Drivers

Miller, D.M., and others
Outlet: Included in Draft Project Plan and Conceptual Model Scientific-Investigations Report (SIR 2010-5133); Posted on GBILM website http://www.usgs.gov/features/greatbasin/
Description: Short list of Priority Ecosystem Drivers vetted through a Delphi Process (after Linstone and Turoff, 2002) by Conceptual Modeling team and then distributed through entire GBILM and DOI partner agency representatives. Initial list of 30 drivers decreased to 9 Priority Ecosystem Drivers.

Management Questions Survey Form

Finn, S.P., and Kitchell, K.
Outlet: Microsoft© Word document on GBILM website (http://www.usgs.gov/features/greatbasin/program/questions.html)
Description: After arriving at a short list of critical ecosystem drivers in the region, GBILM began developing a series of management questions. GBILM is a question-driven process. Questions were vetted internally in terms of feasibility, data availability, and team expertise, and then presented to management agency personnel in a user-friendly format (the product). Vetting process is iterative and feedback is always welcome. Vetted questions form the foundation of monitoring and management agency involvement in GBILM.

GBILM Data Standards

Finn, S.P.
Outlet: Unpublished Document posted on GBILM my.USGS.gov site
Description: Draft document defines standards for data storage, sharing, preferred formats, and file naming conventions. Standards for short- and long-form metadata (long-form metadata is FGDC standard) and preferred projections for spatial data also are included.

Modified Land-Cover Classification Scheme for GBILM Remote Sensing

Baer, L.A., and Noble, S.
Outlet: Cross-walked Microsoft© Excel Spreadsheet posted on GBILM website http://www.usgs.gov/features/greatbasin/
Description : Land-cover classification scheme based on the Nevada Comprehensive Wildlife Conservation Plans modification of the NatureServe© Ecological Classifications of the United States, as used by Southwest ReGAP. Modifications made to simplify original list and relate classes to local management definitions and land-cover characterization needs.

GBILM Remote Sensing Task Final Report

Noble, S., and Baer, L.A.
Outlet: Unpublished Report summarized in ILM Synthesis Report
Description: Final Report on Remote Sensing task, including data sources, gaps, tasks, products, link to GBILM goal, methods development.

Final Report: Great Basin Integrated Landscape Monitoring Analysis: 30 Years of Change

Hak, J., and Comer, P.
Outlet: Unpublished Report to accompany land-cover change analysis performed by NatureServe© personnel as part of USGS Contract #08HQCN0026
Description: An evaluation of land-cover change in Landsat scene (P40, R32) adjacent to area described by Noble and Baer (GBILM Remote Sensing Task Final Report).

Monitoring Plan to Track Changes in Patterns of Wildfires

Brooks, M.L., and Matchett, J.R.
Outlet: Unpublished Report summarized in ILM Synthesis Report
Description: Part of final 3-year report of the GBILM program's Fire-Invasive Species Ecosystem Driver sub-project.

Annotated Bibliography: Response of *Artemisia tridentata* to Predicted Climate Change

Tumbusch, M.
Outlet: Unpublished Document posted on GBILM website http://www.usgs.gov/features/greatbasin/
Description: One element that has the potential for being a change agent or stressor to sagebrush habitat integrity is climate change. Sagebrush steppe ecosystem responses to climate change could significantly alter plant species composition. This report is an attempt to compile information concerning the effect of predicted climate change on sagebrush communities.

Maps / Geospatial Data Layers / Models / Databases

GBILM ArcGIS Server

Steffy, J., Finn, S.P., and Kern, T.
Outlet: Distributed data management and analysis environment hosted by USGS-FORT
ArcGIS Server software connects people with geographic information through Web applications and services. The software streamlines distribution of maps and GIS capabilities over the Web to improve internal workflows, communicate vital issues, and engage stakeholders. ArcGIS Server provides geodata services for data extraction, replication, and synchronization, as well as a framework and tools for managing large spatial datasets while supporting server-based analysis and geoprocessing, including vector, raster, 3D, and network analytics, as well as models, scripts, tools and spatial editing tasks. An ArcGIS Server instance was operational during the very lates stages of GBILM. Those successes are currently being brought forward to support subsequent region-scale projects such as the Wyoming Landscape Conservation Cooperative (http://www.wlci.gov/).

Land Treatment Digital Library

Pilliod, D.S., and Welty, J.
Outlet: Digital Database served by USGS-FRESC (http://greatbasin.wr.usgs.gov/ltdl/)
Description: Annually, greater than 250,000 acres of the Great Basin are 'treated' to improve habitat, increase livestock forage, or stabilize burned areas. Techniques, monitoring, and documentation are not consistent across the region so GBILM created a searchable land treatment and monitoring database to enable standardization and effectiveness evaluation. The digital library is currently being beta-tested using more than 100 records from the Ely and Fillmore BLM Field Offices. We developed an agreement with the Conservation Registry to host part of Digital Library.

Land Cover with Phreatophytic Vegetation in the Great Basin

Mathie, A.M., Tumbusch, M., and Welborn, T.
Outlet: Mathie, A., Welborn, T., Susong, D., and Tumbusch. M., written communication, Phreatophytic land-cover in the U.S. Great Basin Ecoregion.
Description: This study utilizes existing regional datasets to predict areas of the Great Basin with great likelihood to have phreatophytic vegetation.

Geospatial Dataset of Groundwater Wells in the Great Basin

Welborn, T., Tumbusch, M., and Mathie, A.M.
Outlet: Spatial data, maps; included in GBILM's ArcGIS Server
Description: In this effort, we created a geospatial dataset of groundwater observation sites for the GBILM study area that includes: (1) site locations and basic geographic information (altitude and depth), (2) observations for period of record, (3) decadal averages, and (4) overall depth to water change and range of change. Wells include NWIS groundwater sites with observation data from inception to FY07 and State-managed well locations for entire Great Basin. Data will be mined and categorized to allow analysis of groundwater level change in the Great Basin.

Dataset NDVI Greenness Change in the Great Basin from 1989 to 2006

Welborn, T., and Smith, J.L.
Spatial data; included in GBILM's ArcGIS Server
Description: Using smoothed weekly AVHRR NDVI from the Earth Resources Observation and Science Center EROS Phenological Characterization and the Early Warning and Monitoring Program, this study developed spatial datasets of NDVI and NDVI change for the GBILM study area. The smoothed data may be used to improve applications involving the analysis of time-series NDVI data, such as land-cover classification, seasonal vegetation characterization, and vegetation monitoring.

Satellite Image Library and Access Point

Owens, T., and Baer, L.A.
Outlet: EarthWhere™ Image Server [*http://rmgsc.cr.usgs.gov/earthwhere/*]; may move to ArcGIS Server
Description: Remote sensing is a cornerstone for baseline monitoring. GBILM acquired almost 300 satellite images through funding from the USGS Land Remote Sensing Program and mounted the images on the RMGSC's EarthWhere™ image server. Images are available to all GBILM team members and partners.

Land Cover, Land-Cover Change Datasets, and LC Change Masks of Landsat Scene 39/33 and 40/32

Noble, S., Hak, J.and Comer, P. (NatureServe©)
Outlet: Spatial data, maps; included in GBILM's ArcGIS Server
Description: Products span 30 years and describe landscape at *ca.* 5-yr intervals. Land-cover classification based on the Southwest ReGAP Classification scheme (baseline information from year 2000), slightly modified to better suit GBILM goals. Land-cover change datasets showing previous and current land-cover types (for pixels that changed) between consecutive time periods. Land-Cover Change Masks depict the threshold of change utilizing the Tasseled Cap Transformation and the Greenness band 2. Dates include 2008, 2000, 1995, 1990, 1985, 1980, and 1975. Image interpretation and product generation for Scene 40/32 is being done by NatureServe© under Contract 08HQSS0037.

Spatial Data Layers Indicating Future Changes in the Influence of Invasive Plants on Fire Regimes Given Different Future Rainfall Scenarios

Brooks, M.L., and Matchett, J.R.
Outlet: Web-based distribution; included in GBILM's ArcGIS Server
Description: Data layers (maps) indicating the differential effects of invasive plants on fire regimes under four rainfall scenarios (increased and decreased summer and winter rainfall).

Climate Station Database

Valentovich, T., Miller, D.M., and Finn, S.P.
Outlet: Geodatabase; included in GBILM's ArcGIS Server
Understanding climate change in the Great Basin has proved challenging in part because of poor availability of fine-scale data. We conducted an extensive and intensive search of existing and historical climate stations in the region, focusing on those that are 'off-line' and do not deliver data on the web. The tabular product identifies the location of more than 1,500 stations in the region including contact information and active dates where available.

Temperature Sensor Monitoring Network

Beever, E.A., and Finn, S.P.
Outlet: Digital database (included in GBILM's ArcGIS Server); four journal articles (three published, one in review)
In an effort to more directly address mechanisms of stress on American pika populations, we established a network of more than 200 temperature sensors in the vicinity of 25 sites in 16 mountain ranges that span 38.2 million ha (94.4 million acres) of the hydrological Great Basin. Majority of sensors have been recording temperature continuously since spring 2005.

Climate/Phenology Sensor Array in the Owyhee Uplands

Hanser, S., Bedford, D., Torregrosa, Alicia, and Tumbusch, M.
Outlet: Relational Database
Description: Array includes 4 Onset Hobo met stations, 48 Soil moisture sensors (placed at 12 locations; 4 at each location), 368 iButtons (84 locations – 40 locations with snow depth poles), and 5 digital cameras with near infrared-red-green sensor capacity.

Additional Data Products for the Owyhee Uplands

Hanser, S., Bedford, D., Torregrosa, Alicia, and Tumbusch, M.
Outlet: Datasets
Description: Great Basin datasets organized and cataloged for multi-disciplinary and inter-agency use:

- Multitemporal Landsat imagery and derived land-cover change.
- GIS data layers representing landforms, bioclimatic zones, topographic moisture potential, surficial materials, and abiotic environmental.
- Daily field based oblique near infrared imagery for April–September 2008.
- Bird point count data at 80 locations in the Owyhee Uplands (FY07–09).
- Greater sage-Grouse pellet surveys at 80 locations in the Owyhee Uplands (FY07–09).
- Line-intercept vegetation sampling data for shrub/tree cover and height at 80 locations in the Owyhee Uplands (FY07–09).
- Herbaceous vegetation sampling data collected using Daubenmire frames at 80 locations in the Owyhee Uplands (FY07–09).
- Temperature, radiation, precipitation, soil moisture, relative humidity, and pressure data collected at four locations in the Owyhee Uplands (FY08–09).
- Snow depth at 42 locations in the Owyhee Uplands (FY09).
- Soil moisture at 24 locations in the Owyhee Uplands (FY08–09).
- Soil temperature at 80 locations in the Owyhee Uplands (FY09).

Preliminary Surficial Geologic Map of:

- Juniper Point 7.5-minute quadrangle, Malheur County, Oregon, and Owyhee County, Idaho.
- Jordan Valley 7.5-minute quadrangle, Malheur County, Oregon, and Owyhee County, Idaho, and Owyhee County, Idaho.
- Juniper Ridge 7.5-minute quadrangle, Malheur County, Oregon.
- Parsnip Peak 7.5-minute quadrangle, Malheur County, Oregon, and Owyhee County, Idaho.
- Antelope Reservoir 7.5-minute quadrangle, Malheur County, Oregon.
- Whitehorse Butte 7.5-minute quadrangle, Malheur County, Oregon.

Amoroso, L., and Miller, D.M.
Outlet: OFR (submitted)
Description: Spatial data depicting surficial geology for region specified.

Scientific Presentations / Posters

Surficial Geology of a Portion of the Owyhee Uplands, Oregon and its Relation to Plant Ecology

Amoroso, L., Miller, D.M., Keller, M., Rice, A., and Tackman, C.
Outlet: Abstract
Description: Poster (and abstract) describing geological mapping efforts presented at the 2006 Workshop on Collaborative Watershed Management and Research in the Great Basin.

Integrated Landscape Monitoring – Great Basin Pilot

Finn, S.P., BLM Assessment, Inventory and Monitoring Program Meeting, Boise, ID, June 23, 2006.

Great Basin Integrated Landscape Monitoring

Poster. Schuler, C. and others, Collaborative Watershed Management and Research Workshop, Reno, NV, November 28-30, 2006.

Integrating Disciplines and Landscapes

The GBILM Approach. Finn, S.P., USGS Snake River Field Station Brown Bag Seminar, Boise, ID, February 2007.

Climate Effects in the Changing Great Basin

A Regional Approach to Addressing Local Land-Manager's Needs. Poster. Finn, S.P., Miller, D.M., Owens, T., Bedford, D., and Brooks, M., Climate and Deserts Workshop: Adaptive Management of Desert Ecosystems in a Changing Climate, Laughlin, NV, April 9-11, 2008.

Healthy Lands Initiative

Relevant USGS Research and Monitoring Great Basin Focus. Kitchell, K. BLM Healthy Land Initiative Meeting, Fort Collins, CO, June 2008.

Great Basin Integrated Landscape Monitoring

Great Basin Climate Change. Poster. Schuler, C., Kitchell, K., Miller, D., and Goddard, K., USGS/USFWS Columbia Basin Climate Workshop, Boise, ID, June 24-27, 2008.

Monitoring Great Basin Ecosystems

Functions, Services, and Sustainability. Poster. Finn, S.P., Miller, D., Bedford, D., Beever, E., Brooks, M., Goddard, K., Kitchell, K., Matchett, J.R., Mathie, A., Miller, M., Baer, L., Pilliod, D., Pyke, D., Schuler, C., Torregrosa, A., Woodward, A., Devoe, N., and Pellant, M. A Conference on Ecosystem Services, Naples, FL, December 8-12, 2008.

Linking Plots to Landscapes

A synthetic framework for monitoring change in the Great Basin Ecosystem. Torregrosa, A. 2nd USGS Modeling Conference, Orange Beach, AL, February 10-14, 2008.

Monitoring Great Basin Ecosystems: Functions, Services, and Sustainability

Poster. Finn, S.P., Miller, D., Bedford, D., Beever, E., Brooks, M., Goddard, K., Kitchell, K., Matchett, J.R., Mathie, A., Miller, M., Baer, L., Pilliod, D., Pyke, D., Schuler, C., Torregrosa, A., Woodward, A., Devoe, N., and Pellant, M. Wildfires and Invasive Plants in American Deserts, Reno, NV, December 8-12, 2008.

Site Visits in Nevada and Utah (BLM Utah SO, Ely and Fillmore FO; Great Basin NP)

Presentations by Miller, D., Matchett, J., Baer, L., Devoe, N., Kitchell, K., and Finn, S. February 4-6, 2008.

Projecting Future Changes in Sagebrush Distribution in the Great Basin

Flint, L.E., Flint, A.L., Torregrosa, Alicia, Woodward, Andrea, Welty, J., Finn, S.P., Garman, S., Pilliod, D., Matchett, J.R., Casazza, M., Brooks, M., Baer, L.A. American Geophysical Union Annual Meeting, December 2009.

Bureau Planning Council (BPC) briefings

Schuler, C., and Kitchell, K., 2006, 2007, 2008.

Communication Tools / Information Transfer

GBILM Website

Arriola, S., and Erickson, J.
Outlet: Internet Website
Description: A vehicle for external and internal communication, the GBILM website [*http://www.usgs.gov/features/greatbasin/index.html*] features background and project-level information as well as identifying points of contact for the project. As products are readied for delivery to the public, they are posted to this website.

Great Basin 'my.usgs.gov' Portal and Wiki©

Arriola, S., and GIO staff
Outlet: Web Portal/Service
An internal communication and collaboration tool located at:
[*https://my.usgs.gov/ILMWiki/wiki/GreatBasin*]. GBILM uses the portal to post meeting notes, share documents and other internal communications, and for project support. The 'Wiki©' feature encourages input from each member of the community.

Fact Sheet: Great Basin Integrated Landscape Monitoring Pilot Project

Schuler, C., and others
Outlet: GBILM website [*http://www.usgs.gov/features/greatbasin/products/assets/FactSheet.pdf*]
General discussion of GBILM goals, practices, and accomplishment. Target audience is regional land managers, scientists, and monitoring specialists; the Fact Sheet summarizes information from the Conceptual Model report and the Draft Project Plan. The Fact Sheet is updated as needed.

Fact Sheet: Land Treatments Digital Library

Pilliod, D.S., and Welty, J.
Outlet: Digital [*http://pubs.usgs.gov/fs/2009/3095/*] and Paper PDF
Description: Concise synopsis of the Digital Library with example uses, contact information, and project outlook.

Workshops

- Henderson, 2/2006
- Salt Lake City 6/2006 (Conceptual Modeling Team)
- Reno 11/2006
- Boise 9/2006
- Portland 1/07
- Salt Lake City 9/2007
- Boise 11/2007
- Boise 10/2008
- Menlo Park 2/2009

Appendix D. Interface GBILM Objectives with USGS Science Strategy

The GBILM approach addresses aspects of each of the six science directions in the USGS Science Strategy, including:

Understanding Ecosystems and Predicting Ecosystem Change

GBILM is identifying ecosystems vulnerable to change from climate and land-use trends. We set the stage for conducting long-term research, monitoring, and modeling to understand variability at different scales and forecast responses to stressors. We expect to assess success of restoration techniques while developing multi-partner assessment of natural resource status and trends.

Climate Variability and Change

Measurement and evaluation of Great Basin climate trends is currently poor due to the regions remoteness and low population densities. Therefore, we know little about macro- and micro-trends in regional climate and in species response to predicted changes. GBILM has and will continue to expand our understanding of climate change and its effects on ecosystems. Using empirical data, global circulation models, and regional downscaling techniques, we will develop predictive models and decision-support tools for Great Basin land managers.

Energy and Minerals

GBILM identified mineral extraction and energy development as important ecosystem drivers of Great Basin systems even though they were not prioritized for initial evaluation. Currently power production and mineral extraction sites have a relatively minor footprint in the region. However, demand for resources – especially energy – is increasing and infrastructure to support these services is expanding on the landscape. GBILM partners in the Bureau of Land Management (BLM) have expressed concern about unknowns associated with energy infrastructure (production sites and transport corridors). GBILM expects to evaluate impacts of energy development on ecosystem processes.

National Hazards, Risk and Resilience Assessment

One initial research project of GBILM is evaluating aspects of wildfire relationships with invasive annual grasses in order to minimize or prevent catastrophic wildfires through understanding changing fire conditions.

Water Census of the United States

Water is the critical factor limiting biological processes and anthropogenic development in the Great Basin. Aquifer drawdown was identified as a priority driver. We are mapping groundwater dependent (phreatophytic) vegetation communities in order to evaluate the landscape effects of groundwater extraction. A part of this effort is to census and quality-check existing well data and eventually model groundwater levels based on vegetation indices captured by satellite imagery. This project will contribute to the national water census while providing techniques to efficiently evaluate groundwater status and trends in relation to climate, land use, and water use.

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For more information concerning the research in this report, contact the
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Corvallis, Oregon 97330
http://fresc.usgs.gov

Finn and others— **Great Basin Integrated Landscape Monitoring Pilot Summary Report**—Open-File Report 2010-1324