SQUIB - None of the existing information services available to the wildfire community address the specific needs of post-fire stabilization and restoration planning and monitoring vegetation recovery for semiarid lands. To assist the effort to manage savanna fires, we are developing an automated decision support system called the Rehabilitation Capability Convergence for Ecosystem Recovery (RECOVER).

A new application to facilitate post-fire recovery and rehabilitation in Savanna ecosystems

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Abstract

[1]The U.S. government spends an estimated $3billion per year to fight forest fires in the United States. Post-fire rehabilitation activities represent a small but essential portion of that total. The Rehabilitation Capability Convergence for Ecosystem Recovery (RECOVER) system is currently under development for Savanna ecosystems in the western U.S. The prototype of this system has been built and will have real-world testing during the summer 2013 fire season. When fully deployed, the RECOVER system will provide the emergency rehabilitation teams with critical and timely information for management decisions regarding stabilization and rehabilitation strategies.

Introduction

Each year wildfires consume an average of 4.2 million acres, long term average recent decade average is even higher, of land in the United States, according to the National Interagency Fire Center. Fire suppression activities have been employed since the early 1900s to preserve land and protect people and infrastructure. National coordination of fire suppression activities between federal agencies is performed by the National Interagency Fire Center in Boise, Idaho. Fire management begins when a fire is named and an incident command team is assigned; it progresses through the stages of fire suppression including initial and extended attack, followed by containment, control, and extinguishment. The Burned Area Emergency Rehabilitation (BAER) teams are assigned, if necessary, when a fire is “controlled.” These teams have seven days to make an assessment of post-fire conditions, and to develop a preliminary stabilization and rehabilitation plan once a fire has been controlled and 21 days to submit a final plan [1].

Over the past two decades, major advancements have occurred in remote sensing technologies and Geographic Information Systems (GIS). These data and software have been employed by fire managers and those who support them to map and characterize fire locations and their extent. These maps can be combined with other geospatial data depicting resources, infrastructure and population centers to identify areas of strategic importance.

The majority of attention in mapping burned areas has historically focused on forested areas [1-3]. However, the current project focuses on savanna fires, which research suggests can account for carbon emissions equivalent to or exceeding fossil fuel combustion by automobiles [4] . For purposes of this study, savannas in the U.S. are defined as semi-arid grass and shrub dominated regions and are all located in the Western U. S. (figure 1). Much of these savannas are considered primary habitat for sage grouse, mule deer, and pronghorn antelope and are also used for livestock grazing. Fires can have profound short-term and long-term effects on the ecosystem.

The current process of preparing a fire rehabilitation plan typically begins with the BAER team leader requesting a fire severity product. A difference normalized burn ratio (dNBR) [5, 6] layer derived from Landsat imagery is generally the product that is delivered. This product may be integrated with other data, such as topographic information, soil properties, land use, presence of threatened or endangered species, threats to life and property, historic and recent conditions of soil moisture to create the knowledge base upon which a remediation plan is crafted.

This data assembly, analysis, and decision-making process must happen quickly in order to meet the statutory requirement of producing a preliminary BAER plan within seven days. However, right now, this process involves substantial human intervention, and the information gathered depends on the availability of staff, time, and data for a particular region. Even though there are a wide array of information services for the wildfire community, they tend to focus on research coordination, information sharing, pre-fire prediction, active fire management, and fires on forested lands. None of the existing services address the specific needs of post-fire stabilization and restoration planning and monitoring vegetation recovery for semiarid lands.

To assist the effort to manage savanna fires, we are developing an automated decision support system (DSS) called the Rehabilitation Capability Convergence for Ecosystem Recovery (RECOVER). This system compiles all the necessary datasets for the BAER teams rehabilitation planning and provides them in an easy to use Web Mapping Service (WMS). The objectives of this work are to introduce the RECOVER DSS; show some early results using historical fires; and define the path forward.

RECOVER Concept

Critical site-specific information that could otherwise improve wildfire outcomes does not become part of the decision-making process unless it is immediately available to the BAER teams. RECOVER is an automatically deployable, context-aware, site-specific DSS for savanna wildfires that brings together in a single application the information necessary for BAER team post-fire rehabilitation decision-making and long-term ecosystem recovery monitoring. In a canonical scenario-of-use, a RECOVER instance would be created automatically in response to a fire detection event using the rapid resource allocation capabilities of cloud computing. Earth observational data and derived decision products are automatically generated and refreshed throughout the burn so that when the fire is declared under control, BAER teams have at hand a complete and ready-to-use RECOVER instance customized for the target wildfire. The RECOVER instance will contain all the decision products required for impact assessment and rehabilitation decisions. Additionally, it will become the portal for long-term monitoring of ecosystem recovery for the site. The complete RECOVER capability will comprise (1) its key decision products, (2) the RECOVER DSS proper, (3) cloud deployment capabilities, and (4) the training and end-user support needed to assure BAER team usability.

The RECOVER DSS is made up of a RECOVER client and a RECOVER data server. The client provides a simple graphical user interface (GUI) that enables convenient access to a wildfire's two primary site-specific decision products, the Rehabilitation Priority Map and Ecosystem Recovery Maps (figure 2). The RECOVER client is implemented using Idaho State University's (ISU) GIS Training and Research Center's (TReC) web services and web mapping capabilities and has two functions. First, it allows the user to initiate a fire event by creating a new name and extent. Second, it implements the user-controlled multi-criteria decision analyses. Our concept is a visualization-driven interface that uses slider controls to vary weights on the multi-criteria evaluation (MCE) inputs and, in real time, provides qualitative feedback about priority target areas for stabilization and rehabilitation. A simple scenario of use includes the following steps:

1. Data collection for a new fire is triggered by providing the RECOVER server with a name and a spatial extent for the new fire site.
2. The RECOVER server connects through web services and automatically collects pre-determined, commonly used data products tailored to the new fire site.
3. Derived products and other types of site-specific ancillary data are manually staged to the RECOVER server as needed. All data products are projected to the same coordinate system and clipped to the spatial extent defined in step 1.
4. Data acquisition continues throughout the burn to maintain coverage and currency.
5. When the fire is contained, all of the data layers, the RECOVER server and the RECOVER client are ready to use by the BAER team.

An innovative aspect of this work is our use of the integrated Rule-Oriented Data System (iRODS) to implement the RECOVER data server. iRODS is data grid middleware that provides policy-based control over collection-building, managing, querying, accessing, and preserving large scientific data sets. The RECOVER data server functions in the background to acquire, subset and reproject the necessary data for the RECOVER client. The subset and reprojection functions are handled by the open source software Geospatial Data Abstraction Library (GDAL).

RECOVER's Primary Decision Products:

RECOVER's Rehabilitation Priority Map (RPM) is the major output product of the system. Identifying priority areas for rehabilitation must take into account fire severity, fire intensity, and other intrinsic factors of the landscape. As a result, constructing the RPM requires the integration of several types of data and derived data products.

Once initiated, the RECOVER server will build the static datasets needed for the fire and begin collecting the necessary time series data (Landsat, MODIS, and others). Data collection will continue in an automated fashion until user intervention indicates the process is no longer needed (i.e. the BAER team completes their work and tells the system to stop). At this point the Ecosystem Recovery Map (ERM) processes (discussed in the next section) will continue to collect the needed information for a period of up to three years after the fire is out.

The list of data products to be used in the RECOVER prototype has been provided by the initial users at the Idaho Department of Lands and the U.S. Bureau of Land Management and can be seen in Table 1. This list can be updated on the server side, with the constraint that the data need to be freely available on a public data server.

Table 1: List of input files for the RECOVER DSS.

Stage 1 Static/Historical Data Collection	Stage 2 Derived/Time Series Data Collection
Normalized Burn Ratio (NBR)	Difference in Normalized Burn Ratio (dNBR)
Normalized Difference Vegetation Index (NDVI)	Fire Severity (FS)
Fraction of Photosynthetically Active Radiation (fPAR)	Fire Intensity (FI)

Net Primary Production (NPP)	Fire Regime Condition Class (FRCC)
Topography Aspect (TA)	FRCC Percent Departure (dFRCC)
Topography Elevation (TE)	Historic Fires 1936-2012 (H0)
Topography Slope (TS)	Historic Fires 2002-2012 (H1)
Soil Texture (ST)	
Soil K Factor (SKF)	
Biophysical Setting (BPS)	
Geology (GEO)	
Existing Vegetation Cover (EVC)	
Exiting Vegetation Type (EVT)	
Environmental Type Potential (ETP)	

One of the biggest potential benefits of this project, as well as one of its biggest challenges, is finding soil moisture estimates at sufficiently fine resolution to be useful. Soil moisture data from the Soil Moisture Active Passive (SMAP) mission will provide daily measures of soil moisture at 3-9 kilometer spatial resolution. This is the finest resolution global soil moisture product to be generated on such a short time scale. We expect there will be efforts within the SMAP applications community to create even higher resolution products using the 1 kilometer half-orbit radar data from SMAP.

In preparation for this new data set, we designed the RECOVER DSS to accept soil moisture as an input using existing soil moisture data from Aqua's Advanced Microwave Remote Sensing Radiometer (AMSR-E). Testing is also underway to determine if the MODIS ET product can be used as a proxy for soil moisture data.

The final post-fire RPM will be the result of an MCE, in which factors, such as severity, intensity, slope, and soil type that are weighted by the user. The default weighting will follow a uniform distribution with total model weight summing to 100. Multiple-criteria decision analysis explicitly considers multiple criteria in decision-making environments. The main advantage of multi-criteria models is that they make it possible to consider the large number of data, relations, and objectives that are generally present in a real-world decision. Typically, a unique, optimal solution for such problems does not exist; however, MCE provides a consistent framework for structuring complex problems, which generally leads to more informed and better decisions. The GIS TReC has successfully used this approach to develop BLM fire susceptibility maps in the past.

The Ecosystem Recovery Map (ERM)

The RPM must be provided as soon as possible to the BAER teams; the Ecosystem Recovery Map, in contrast, is produced after stabilization and rehabilitation treatments (i.e., reseeding, water/erosion control structures) have begun and allows long-term monitoring (generally up to five years) of recovery and vegetative health. The MODIS fraction of photosynthetically active radiation (fPAR) will be used for the ERM. The fPAR is directly related to the top-of-canopy spectrum and measures the proportion of available radiation in photosynthetically active wavelengths that the canopy absorbs. Recent work has demonstrated fPAR's effectiveness in assessing the success of post-fire reseeding over large scales in savanna ecosystems, particularly when coupled with field survey confirmation. RECOVER will automatically assemble monthly fPAR-based ERMs to provide a longitudinal record of rehabilitation trends that can be viewed as animations and still scenes to visualize the recovery process. ERMs can be used as criteria in updated RPMs to refine recovery management. Over time, ERMs from historical fires could become an important resource for understanding recovery performance and setting priorities for managing future fires. While simple and requiring little to implement, ERMs provide a potentially significant return.

Prototyping with Crystal Fire, Idaho

Initial system prototyping has been done using the Crystal Fire near Pocatello, Idaho. This fire occurred in 2006, burning more than 220,000 acres of savanna. The RECOVER server has been implemented in the Amazon Elastic Compute Cloud (EC2) environment to maximize portability and accessibility. The RECOVER client is being implemented in a desktop environment at the ISU GIS TReC and has been exercised using the bounding coordinates for the Crystal Fire. In preliminary tests, the RECOVER server is able to automatically aggregate site-specific data from two-dozen web services in a little over 1 minute, providing a significant improvement in the time and costs associated with this crucial data assembly task (figure 3). Some of the more important layers being collected this way are shown in Table 1. At this stage, the RECOVER client displays the collected data layers in a convenient, feature-rich web map client (figure 2). These capabilities were presented in a special session at the 2013 Intermountain GIS Conference held in Boise, ID, in March. Feedback from our agency partners in the Bureau of Land Management and the Idaho Department of Lands has been very positive. The prototyping activity will culminate during the fire season 2013, when we plan to evaluate use of the RECOVER system by a BAER team on one or more active fires.

Conclusions

The RECOVER DSS is an automated data assembly and multi-criteria decision support system that allows a BAER team to not only expedite the process of creating a post-fire rehabilitation plan but also enhance the output by using additional datasets and providing the data in a common format for ease of use. When implemented, the ERM will permit the land managers to monitor the status of recovery at the burned site and the effectiveness of the reseeding and other rehabilitation strategies. The system prototyping will continue in summer 2013 by shadowing the activities of an active fire and receiving direct feedback from a BAER team.   Feedback from the BAER teams and the parties responsible for post-fire recovery monitoring will guide further development and operationalization of the system.

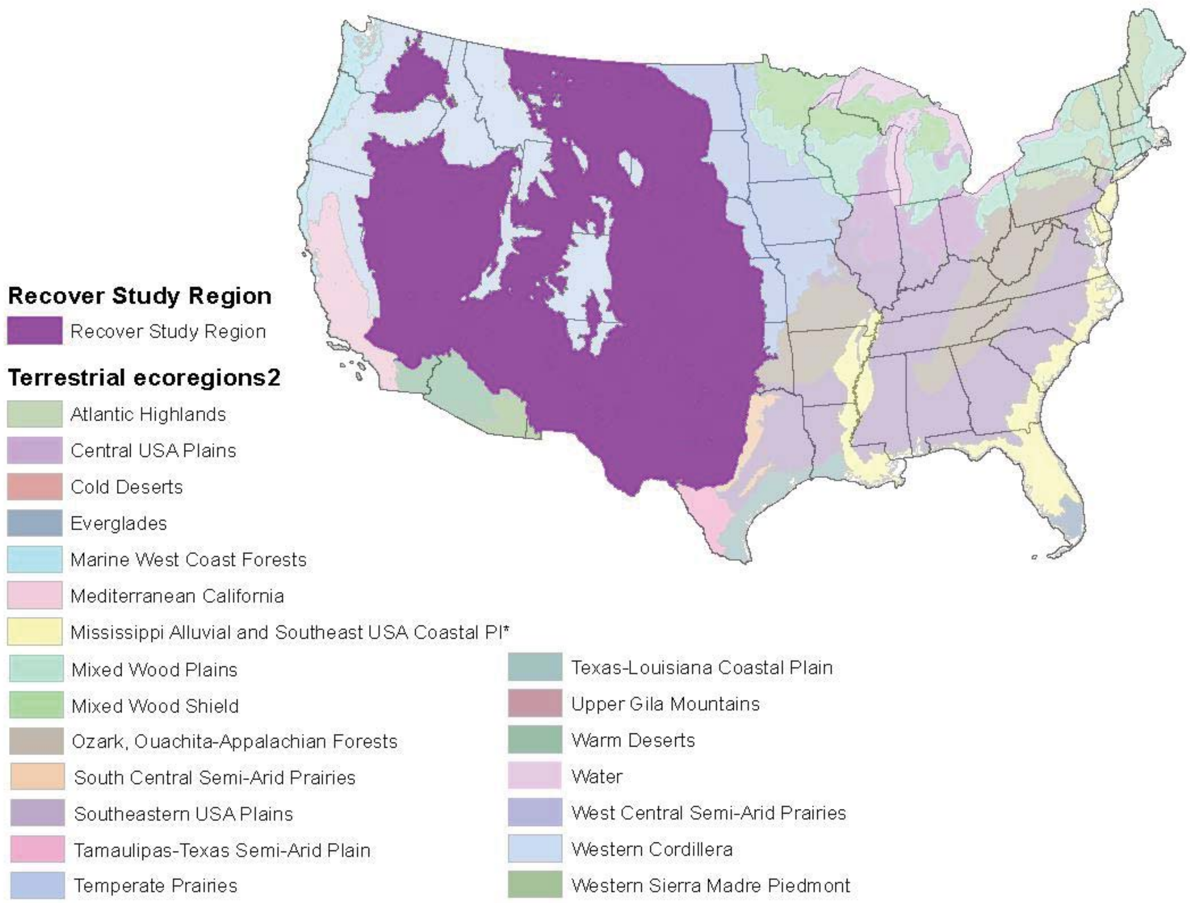

Figure 1 Overview map of Savanna ecosystems of the United States that would be served the RECOVER system. (image by Akiko Elders)

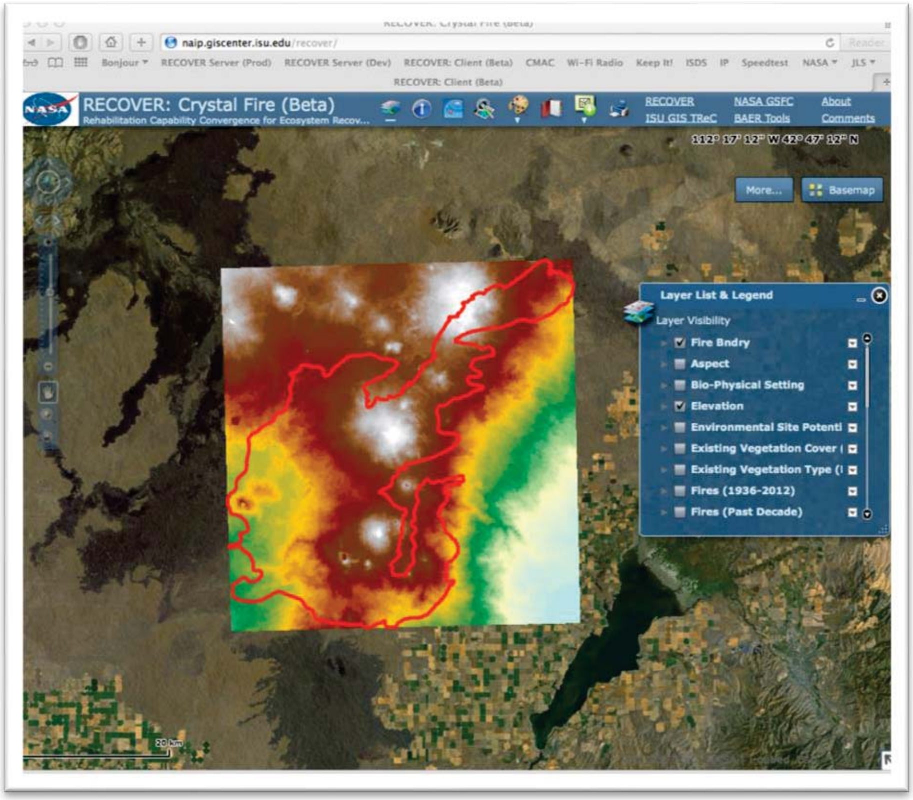

Figure 2 Prototype of the RECOVER client showing results from the Crystal fire (burned in 2006) with fire perimeters and elevation as a backdrop. (image by George Haskett)

Figure 3 The RECOVER server compiles and formats all needed data for a fire event and makes it available to the user via the client. (image by Roger Gill)

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