

Appendix D

USFS Examples of Remote Sensing Applications

Authors' note: This chapter was extracted from a paper written by Tom Bobbe, Manager of the U. S. Forest Service's (USFS) Remote Sensing Applications Center (RSAC) in Salt Lake City.

Resource agencies, and particularly those in the federal government, have access to extensive archives of historic and current satellite imagery and other remote sensing through agreements and partnerships with other federal agency remote sensing programs. These agencies include the USGS EROS Data Center, NASA Earth Observation System (EOS) Land Process Distributed Active Archive, USDA Foreign Agriculture Service, and the National Imagery and Mapping Agency (NIMA). Federal agencies make extensive use of government satellite imagery assets, but they also acquire imagery from international and private sources as described above. State agencies also have access to civilian federal resources and private resources, sometimes through federal contracts which can result in significantly reduced costs. However, states may not have the necessary approvals to utilize classified satellite products unless in partnership with federal agencies.

The U.S. Forest Service has conducted and is currently working on many projects testing and utilizing remote sensing. While this document reports on remote sensing in SFOs, the following list and description of current and past USFS projects illustrates applications that could be undertaken in SFOs. The descriptions of the following projects were provided by and reproduced with permission from Tom Bobbe, Manager of the USFS Remote Sensing Applications Center (RSAC) in Salt Lake City (Bobbe, 2002).

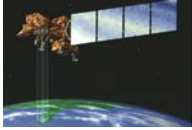
Forest Assessment, Planning, Protection, Conservation and Acquisition

Remote Sensing Implementation on a Ranger District: Black Hills National Forest

The Northern Hills Ranger District of the Black Hills National Forest is engaged in an accelerated program of vegetation management, including timber stand improvement, fuel reduction, and commercial timber production. Currently, the District gathers project information primarily through expensive ground surveys. This project is developing a prototype for a Ranger District-based program that integrates remotely sensed data interpreted by local resource specialists. High resolution imagery including scanned, orthorectified digital aerial photographs and Quickbird satellite imagery are being tested. Direct observation of individual trees, roads, fuels, etc. are important for addressing resource issues at the field level. These prototype uses of remote sensing will be automated to the degree possible so that analysis can be done by field specialists.

Forest Plan Monitoring & Change Detection: Mark Twain National Forest

The Forest Land and Resource Management Plan sets standards for vegetation change by management prescription area. These Forest Plans cover a ten-year period and require a mid-point review at five years to monitor Plan accomplishments. This project used LANDSAT TM imagery in conjunction with GIS to determine the type and amount of vegetation change that had occurred during the first five years of the Forest Plan for the Mark Twain National Forest. Since this forest has approximately 50% other ownership within its proclaimed boundaries, past Forest Plans had only addressed change occurring on National Forest System lands. The use of satellite imagery allowed changes to be documented across all lands, regardless of ownership.



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Forest Fragmentation Analysis: Medicine Bow-Routt National Forest

Recent studies indicate that past management practices on the Medicine Bow-Routt National Forest have modified landscape patterns. How these landscape patterns translate into aspects of ecosystem function and species habitats is not clear. In addition, current data, which are often used for landscape pattern studies, are collected for other purposes and at scales different from those used in the analysis. Rocky Mountain ecosystems have a certain degree of heterogeneity, which is often not captured with traditional timber stand delineations used in landscape pattern analysis. This greatly compounds discussion and analysis of effects associated with management, which alters the forest canopy. This project investigated the effectiveness of remote sensing for determining forest fragmentation at the landscape-level in the Sierra Madre Range of Wyoming.

Forest Characterization

Most Similar Neighbor Vegetation Analysis: Umatilla National Forest

The Most Similar Neighbor (MSN) procedure uses statistical methods to extrapolate detailed samples of stand data to similar stands in areas for which detailed data are lacking. The similarity measures, which are used to extrapolate stand data, makes use of coarse, but commonly available data like digital elevation models, LANDSAT ETM, or data from photo-interpretation. Potentially, the best use of MSN is for generating forest-wide stand mapping products. However, there are few sources of technical information concerning the robustness of this procedure with different sources of data and forest conditions. This project is assessing MSN procedures as part of a program of work to develop new landscape simulation methods to support national forest planning efforts.

Forest Structure Mapping (LIDAR): Tongass National Forest

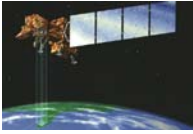
Maps of forest structure provide important insights for wildlife modeling, forest ecology and timber management. However, detailed information about tree size distribution and spacing (i.e., forest structure) at relatively fine scales is arguably one of the most difficult things to map; yet represents critical information for resource specialists. Obtaining forest structure information from traditional remotely sensed data has been problematic. A pilot project on the Tongass National Forest demonstrates the utility of LIDAR products for mapping vegetation characteristics, including biomass, volume, tree density, and size class.

Forest/Nonforest Inventory (MODIS): North Eastern Research Station

LANDSAT imagery has provided good results for estimating forest parameters for the Forest Inventory Analysis (FIA) program. However, this nationwide inventory requires imagery for the entire U.S. Large area coverage using LANDSAT is expensive and difficult to obtain in a cloud free form. Additionally, temporal resolution is limited, thus capturing certain short-term forest health changes, such as gypsy moth defoliation can be difficult. MODIS imagery, with very high temporal resolution (twice daily) and moderate spatial and spectral resolution, may provide forest inventory information at less cost. This project is evaluating MODIS as a tool for deriving forest characteristics in a timely, less costly fashion.

Large Scale Aerial Photography Forest Inventory & Analysis (FIA): Rocky Mountain Research Station

Field-based forest inventories are an important source of information for forest managers and are used by states and counties for estimating and allocating forest resources. Many forested



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areas are difficult to access due to terrain or ownership and are thus under-sampled. This project demonstrated that GPS controlled aerial photography can be used to locate FIA plot centers, locate individual trees and measure tree heights (photo-based measurements statistically insignificant from field measurements), identify tree species to accuracies equal to or greater than 90%, and make other FIA tree and plot condition measurements. Results from this project led the way to using photo-based measurements in a multi-phase sampling scheme.

Forest Health

Invasive Species Inventory (Hyperspectral): Multi-agency cooperative project near Grand Junction, Colorado

Tamarisk (*Tamaricaceae*) is an exotic shrub invading riparian areas in the western U.S. Current inventories are inadequate to provide information on which to base effective and comprehensive management. Well established seed sources in the Colorado River system are providing a seed bank for the spread of Tamarisk to non-infested areas. This project is evaluating the potential of remote sensing, including hyperspectral airborne imagery, for early detection of Tamarisk infestations.

Hazardous Substances from Mining (Hyperspectral): Grand Mesa, and Gunnison National Forest

Hazardous substances released by abandoned mine lands degrade the health of watersheds. Natural resource managers are responsible for identifying the extent of resource damage due to the release of hazardous substances. Remotely sensed data may be helpful in determining the areal extent and total impact of hazardous substances released from abandoned mines. Hyperspectral sensors, such as the Airborne Visible Infrared Imaging Spectrometer

(AVIRIS), record radiance with several hundred narrow contiguous spectral bands in the visible and infrared part of the electromagnetic spectrum. The analysis of these spectra has proven successful in detecting the presence of oxidation products of the major acid generating mineral pyrite. This project is investigating which remote sensing and other geospatial technologies are suitable for assessing and mapping the spatial extent of resource damage caused by chronic hazardous substance release.

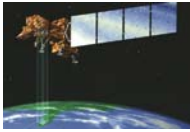
Aspen Decline Mapping: Beaverhead-Deerlodge National Forest

Quaking aspen (*Populus tremuloides*) plays a very important role in the ecosystems of the Intermountain West. Historical records indicate an overall decline of aspen in the West, and over the last 100 to 150 years, there has been an estimated loss of 75% of the aspen throughout the Rocky Mountains. This project mapped aspen and aspen decline using remote sensing and GIS over a 184,000 hectare study area in southwestern Montana using LANDSAT TM imagery from 1992. Historic aspen populations were mapped for a 2,400 hectare area using 1947 aerial photography. Results of this comparison showed that aspen populations decreased by 45% over the 45-year period, and that most of the change was due to succession by conifer species.

Water, Wetlands, and Watersheds

Soil Erosion Monitoring: Uinta National Forest

A watershed restoration plan is being developed for the Strawberry Valley Watershed in eastern Utah. Of particular concern are soil erosion issues throughout the watershed. Areas experiencing high erosion rates need to be identified and prioritized in the restoration plan. This technology transfer activity is evaluating the use of existing geospatial data sets, including



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digital orthophotos for deriving information about eroded areas. These inputs from high resolution remote sensing will be integrated into soil erosion models as part of the restoration plan.

Impervious Surface Urban Area Mapping: Northeastern Research Station

Urban forests are an important component of global carbon studies, yet very little information about the extent of urban forests exists. This project has focused on developing automated methods for classifying percent tree cover and impervious surface using LANDSAT ETM and high resolution digital aerial photography. The methods are particularly well suited for developing urban forest estimates. Deliverables for this project included a set of software tools (C++ and ERDAS Imagine applications) for performing the analysis and software “hooks” for using hierarchical classification trees generated by Cubist in ERDAS Imagine. Maps of percent tree cover and impervious surface for USGS mapping zone 41 (central and northern Minnesota) were completed as a part of this project.

Watershed Analysis Vegetation Mapping: Malheur National Forest

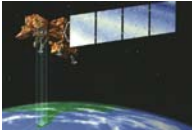
Vegetation attributes, including canopy closure, tree size class, and species are required for many forest planning activities on the National Forests. Since most forests cover in excess of 400,000 hectares, remote sensing is an important component of the vegetation mapping process. This project illustrated the use of LANDSAT ETM for developing forest-wide vegetation attributes. The methods developed used a combination of spectral and textural information derived from ETM and digital orthophotos. An important component of the project was to transfer skills and tools to key resource specialists.

Riparian Stream Morphology Mapping: Umatilla National Forest

Riparian areas are generally recognized for their distinctive ecological characteristics and importance in providing multiple benefits and functions. Riparian areas are also spatially complex and highly diverse ecosystems that are difficult to map with sufficient detail for management over large areas. Information on the extent and character of riparian areas is needed for watershed assessments, inventory and monitoring, and restoration planning. This project developed and tested methods for characterizing stream geomorphology, mapping the extent of the riparian area, and classifying riparian vegetation using remotely sensed data. The use of aerial photos provided satisfactory results for characterizing streams associated with riparian areas. Models, based on digital elevation model derivatives and stream attributes, were used to predict the extent of smaller riparian areas that could not be mapped from aerial photos.

Subsurface Hydrology: Umatilla National Forest

There is a critical need to find cost effective ways to characterize physical and biological attributes of riparian/wetland areas on National Forest land. This information is essential for a variety of planning activities including Forest-level planning, watershed assessments, and the design of site-specific restoration projects. Of special interest is a way to identify “hydrologically functioning” wetlands that contribute subsurface water to rivers in late summer. During these periods, riparian habitats of endangered aquatic species are degraded by low flows and high temperatures. Part of this problem may be a result of riparian channel down cutting caused by forest management practices and/or other disturbances. This project examined the spring and summer progression of



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plant phenology along segments of stream networks and adjacent meadows in order to characterize associated vegetation.

Stream Temperature Profiling: Oregon State University

Thermal infrared (TIR) images acquired from airborne platforms have recently become a significant data source in stream temperature monitoring and analysis programs. Thermal imagery is useful for detecting and quantifying warm and cool water sources, calibrating stream temperature models, and identifying thermal processes. TIR imagery has also found application in the mapping of groundwater inflows and the analysis of floodplain hydrology. These remotely sensed data sources provide a spatially continuous map of temperatures within a watershed and complement temporally continuous, but spatially limited, point monitors traditionally employed to assess stream temperature. The report for this project provides an overview of the characteristics, applications, costs, and implementation of TIR remote sensing for monitoring water temperature in rivers and streams.

Other Natural Resources

TEUI Geospatial Toolkit: Washington Office

The Terrestrial Ecological Unit Inventory (TEUI) is an interdisciplinary program within USFS. Development of ecological management units based on geology, soils, potential natural vegetation and other ecological predictors is a long-term goal of USFS. Products from TEUI provide resource information for sustainable natural resource management and for project planning, watershed analysis, and Forest Plan Revisions. The goal of this project is to develop a geospatial TEUI toolkit combining image analysis and GIS software to facilitate the

mapping of core TEUI elements and other natural resource inventories. The toolkit will be based upon ERDAS Imagine™ and ArcGIS™ capabilities.

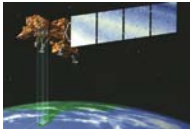
Land Cover and Landscape Ecology

Montane Range Utilization: Apache-Sitgreaves National Forest

Range production estimates are normally collected at the plot level providing a reliable estimate of biomass for that spot on the ground, but tend to not be representative of larger management units, like range allotments. Furthermore, a lack of financial resources often restricts frequently collected and evenly dispersed plot level information, which is needed to support sustainable management activities. This project is assessing the ability of remote sensing, particularly multi-temporal, moderate resolution satellite imagery (MODIS and LANDSAT ETM), to improve the efficiency and reliability of collecting resource information. Information from remote sensing will address such issues as range readiness, utilization, and prescribing durational periods for the grazing seasons.

Range Allotment & Forage Mapping: Beaverhead-Deerlodge National Forest

Local range managers are the public land stewards responsible for updating the plans on active range allotments. They develop and use Allotment Management Plans (AMPs) as tools for regulating and monitoring local land activities. Since this land is public and managed for multiple-use, managers must balance the capabilities of the resource with the short and long-term needs of the public. This project developed methods for mapping range vegetation on range allotments to facilitate the updating of AMPs. The methods integrate multiple scales and sources of remote sensing



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with traditional rangeland mapping techniques.

Detecting Ozone Vegetation Impacts: National Forests of North Carolina

Current ozone exposures in many portions of the eastern United States are large enough to cause visible symptoms, seen as red stippling, on the upper surface of sensitive plant species. Sensitive plants that are exposed to high levels of ozone typically experience growth reductions and/or chronic stress that, in turn, can potentially alter competition among plant species in the forest environment. This project evaluated the use of a color infrared digital camera to detect coloration changes associated with ozone symptoms, with promising results, for the ozone sensitive blackberry.

Fire and Emergencies

Wildfire-Riparian Burn Intensity Mapping: Salmon-Challis National Forest

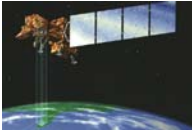
Little information exists about the role and effect of fire in riparian areas. Current fuel and fire planning efforts are based on models and assumptions that are accurate for broad landscapes but do not differentiate for finer features such as riparian areas. This project is examining the use of remote sensing to determine if riparian area characteristics like slope, adjacent vegetation, and channel type influence susceptibility to high-intensity burns. LANDSAT ETM and SPOT imagery collected over the Clear Creek Fires Complex (August 2000) on the Salmon-Challis National Forest is being analyzed to determine how riparian areas burn in comparison to upland areas. This work will assist in the planning process and contribute towards meeting the objectives of the National Fire Plan.

Wildfire Severity Mapping: Mendocino National Forest

Burned Area Emergency Rehabilitation (BAER) teams in the Forest Service and other federal and state agencies gather information on fire-induced watershed conditions after large fires to determine threats to life, property, or natural resources. BAER interpreters traditionally use aerial surveys and ground measurements to map burn intensities and initiate rehabilitation measures. Mapping and analysis of burned areas and recommendations for rehabilitation must be submitted within five days of fire containment. This project developed procedures to use remote sensing and other geospatial technologies to map burn intensities within the mandated timeframe.

Monitoring Vegetation Changes and Fuel Loads: Superior National Forest

The Superior National Forest is using prescribed fire within the Boundary Waters Canoe Area Wilderness (BWCAW) to reduce the risk of a wildfire exiting the wilderness and threatening life and property. This activity is in response to a windstorm that ripped through northern Minnesota in July 1999, blowing down trees on approximately 144,000 hectares within the BWCAW. Because of the remoteness of this wilderness, monitoring the effects of the blowdown and prescribed burns on vegetation and fuel loads has proven challenging. This project assessed the use of remote sensing, such as high resolution IKONOS satellite imagery and airborne digital color infrared imagery, for monitoring fuel load conditions and management activities in this remote wilderness area. It also provided visualization of existing situations and treatment alternatives proposed in the Environmental Impact Statement prepared for the Fuel Treatment Plan.



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Economic and Rural Development

Forest Sustainability Criteria & Indicators: Inventory and Monitoring Institute

The Local Unit Criteria and Indicator Development (LUCID) is an initiative by USFS to develop comprehensive monitoring programs to ensure sustainable land management. This initiative is based on the Montreal Process Criteria and Indicators (C&I) that were developed to measure national progress in achieving goals of sustainable land management. Currently, six areas: the Allegheny, Modoc, Mount Hood, Ottawa, and Tongass National Forests, and the Blue Mountains Province, are participating in the LUCID test process. The Blue Mountains Province includes the Wallowa-Whitman, Umatilla, and Malheur National Forests. This project reviewed remote sensing technologies for applicability to each of the Ecological C&I developed by the Blue Mountains team.

Recreation

Wilderness Visitor Use (Airborne Thermal Scanner): Uinta and Wasatch-Cache National Forests

Estimates for the number and distribution of users in the wilderness are difficult to derive. Since the number of users changes throughout the year as well as from year to year, a single measure will not provide the ranges of visitor numbers or a good estimate of the average number of users per day. However, measuring use and distribution during peak visitor use is a meaningful and obtainable indicator. Current remote sensing systems exist that provide sufficient spatial resolution to observe and evaluate wilderness use. However, wilderness areas are often forested, making it difficult to assess ground conditions or number of visitors in an area. This project explored an alternative

remote sensing approach to measure indicators of peak visitor use. Thermal infrared imagery, which detects heat sources, was flown over campfires in the wilderness and was used as an indication of the location and distribution of overnight visitors in the wilderness.

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