AVHRR AND MODIS VEGETATION INDEX DATA FOR RANGELAND DECISION SUPPORT

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RangeView (http://rangeview.arizona.edu) was designed and implemented as a decision support tool for natural resource managers and decision makers (Figure 1; Marsh et al. 2007). Local and regional level federal, state, and tribal agency personnel as well as private land managers are currently utilizing this tool. It provides an excellent capability to visualize, evaluate and analyze multi-temporal vegetation dynamics by providing users with vegetation index data, contextual geographic information layers and the ability to zoom to anywhere in the conterminous U.S., northern Mexico and southern Canada and then run a time series animation of vegetation index imagery. The 1km 14-day composite AVHRR NDVI data (Eidenshink 2006), for any sequence from 1989 to the present and 1km and 250m 16-day composite MODIS NDVI/EVI data (Huete et al. 2002) from 2000 to present for the western U.S are made available in an easy to interpret image format. It also permits side-by-side comparisons of different periods and standard and derived greenness products (difference from average, difference from last period, and difference from last year) and their relationship to rainfall (provided through PRISM) and ENSO data (derived from the Modified ENSO Index). RangeView also provides spatial information about the Quality of all the MODIS VI imagery by translation of the quality assurance (MODIS QA) data in the form of a color coded image with information about the presence of snow, clouds or bad data. This allows RangeView users to conduct historical analyses for planning and to develop forecasts of future conditions. Feedback from end-users has demonstrated that RangeView is a powerful tool for natural resource decision making.

Figure 1: Web interface for RangeView – a web-based decision support tool for natural resource managers.

To efficiently integrate MODIS products, several preprocessing steps must precede the data assimilation. These steps have been automated to a large extend in RangeView, e.g. a DBMS was developed that incorporates the MODIS data, the 1200x1200 km tiles are downloaded from the data pools (LP DAAC), mosaicked together, reprojected (from Sinusoidal to Lambert equal area) in a common projection and data format (Geotiff, binary) for the areas of interest. The development plan includes two major components – Image Processing and GIS. Both must be enabled to move into and support new applications. A new image analysis framework is being developed to process all images in an integrated environment to minimize replication and disparity and to optimize automation. It is intended to make a scalable system that is robust and allows for near and off line archiving and storage associated with a DBMS. It intends to support different media and maintain an FGDC compliant archive.

Potential applications and impact include: - 1) Forest Service use of RangeView as an additional data visualization and decision support tool for their existing MODIS Active Fire Mapping Program, 2) delivery of Forest Service direct broadcast MODIS data for use in RangeView, 3) Arizona assistance to Forest Service personnel to fully exploit the MODIS data products, 4) joint development of new decision support tools within RangeView for deployment at the National Forests and 5) use for drought and landscape vulnerability monitoring. Discussions with National Park Service have focused on the use of a variety of remote sensing and other geospatial technologies for inventory, monitoring (e.g. vegetation phenology) and reporting at the national level. Based on user workshops and questionnaires, an overview of RangeView utilization and its impact are summarized in Table 1.

We will continue implementation of these collaborative processes to develop a more robust and substantive set of decision support tools for rangeland monitoring and ecological forecasting applications. RangeView will continue to develop the capability to integrate products from process-based Earth system models (to improve the reliability and the value of information content). By providing this suite of dynamic and predictive products, RangeView can play an integral role in these systems, providing critical input to static ecological decision support systems.

Uncertainty in Vegetation indices - Various factors contribute to uncertainties in vegetation indices, including those associated with 1) vegetation index input variables, 2) vegetation index formulation and 3) vegetation index product creation. Examples for these three respective categories are a) spectral response function, vicarious calibration, field of view and sun-view geometry, radiance/reflectance values, atmospheric parameterization of perturbations, satellite orbital drift, and variable pixel resolutions across swaths, b) inclusion of artifacts related to daily variability in cloud cover, snow, dust, soil backgrounds, and vegetation cover characteristics; and c) co-registration, compositing rules, time interval, sub-pixel clouds, scale, and data aggregation.

The usability of data distribution systems, tools, and formats in which the vegetation index (VI) products and metadata are provided plays an important role in the successful transfer of vegetation index uncertainty information to the user community. A user friendly VI data rating system with levels of confidence or uncertainty for each VI image could be created through companioning visually interpretable, spatially explicit quality assurance data (or our level of confidence in each pixel value). Implementing a feedback mechanism between VI developers and end-users would also generate new perspectives on the utility and visualization of VI products and their associated uncertainty fields (van Leeuwen and Orr 2006).

Table 1. Utilization and Impact of RangeView as Described By the RangeView User Community.

Federal User	Use	Impact
USDA – Forest Service	1) RangeView will help them design and monitor Allotment Management Plans (AMP's). 2) Track droughts, identifying hot spots and changes that may occur in previous fire areas for range, wildlife and timber management. 3) As a tool to better explain Forest Service recommendations and decisions to the ranching community. For the NEPA process - annual pasture rotation plans and ad hoc requests.	1) Better initial plan writing and monitoring will lead to long term cost savings. 2) Saving money by relying less on ground data. 3) Enabling previously, un-exploited areas to be grazed
USDI - National Park Service	RangeView will be used for- 1) The mapping and modeling of potential and current fires, as well as for prescribed burns. 2) Understanding the impact of illegal immigration through the Organ Pipe Cactus National Monument. In can also be used in future educational endeavors.	Better ability to control fires sooner and prepare for prescribed burns.
State User	**Use**	**Impact**
Arizona Game and Fish Department	1) Understand the changes in vegetation conditions for rangeland used by wildlife. 2) Understanding the effects of drought on greenness in near urban areas. Difference between natural and urban area greenness in drought years and potential wildlife corridors.	Prevent overgrazing by domestic cattle that is currently causing a decrease in the population of mule deer.
Arizona State Parks Department	1) Evaluating the changes in greenness for each of the state parks and assisting in park management decision-making. RangeView will be used to help understand which changes are due to natural conditions versus management decisions on rangeland parcels. 2) The tools will also be used to monitor impacts of urban encroachment on riparian areas.	Better management decisions and preservation of riparian corridors.
Arizona Department of Environmental Quality (ADEQ)	1) Comparing conditions of rangeland and forest areas in which state and federal agencies are requesting prescribed burns. 2) Post-analysis of prescribed burns – comparing the impact of the burn request with the actual reported burn impact. 3) Evaluating the timing and spatial extent of prescribed and wild fires. 4) Understanding impact of pollution on certain areas and subsequently forecasting pollution advisories.	Will save time and money and provide new information to the Arizona Smoke Management Program (which is run jointly with the USDA-FS). ADEQ will save money by not having to make ad hoc satellite image purchases.
Other User	**Use**	**Impact**
Arizona Cooperative Extension	1) Provide information for short-term climate change for specific geographic regions. 2) Use in vegetative reports on weed monitoring, range trends and historical growth of vegetation. 3) Training instrument for use in helping ranchers understand changes to their land.	Direct incorporation of RangeView products and capabilities in Cooperative Extension Newsletters.
Arizona Ranchers	1) As a predictive tool to help ranchers understand possible likely scenarios using rain gauge and NDVI data. 2) A subjective information provider in discussion with the USDA-FS Range Con's. 3) Challenge specific agency rulings from ground data that is perceived as faulty. 4) Ad hoc pasture rotation decisions based on recent or unpredicted changes in weather. 5) Educating "new" ranchers that have limited range management backgrounds.	Monetary benefit will occur on both the cost and revenue sides. Costs can be saved by cutting back on the amount of ground inspections by only visiting areas with unexpected greenness patterns. Knowing when cattle should be pulled in times of drought will also save money. Ranchers also hope government agencies will allow more cattle in applicable areas.

User needs - Enhancement of Earth Observation image and information products will include: 1) making MODIS biophysical products (e.g. LAI, NPP, Snow, etc.) available, 2) continued investigation of AVHRR-MODIS continuity (van Leeuwen and Orr 2006, van Leeuwen et al. 2006), and 3) development of phenology metrics like onset and duration of greenness (Reed et al. 1994), trend (magnitude, direction and variability in change in NDVI), and drought measures.

Interface development will have to address: 1) data and date matching (for data of different time steps), 2) a pixel value and area-of-interest "grabber" for site-specific graphing and temporal analysis, 3) session-based memory retention, allowing visitors to return to previous settings, 4) integrating and matching image and graph time steps, 5) adding "extract and report" functions for report generation and off-line product utilization, 6) developing a platform for incorporating MODIS direct broadcast daily product in collaboration with RSAC, and 7) a metadata developer following OGC standards for information products.

In support of local and national ecological monitoring and forecasting DSS objectives, software development will also need to be focused on interactive and on-line modeling capabilities, including parameter selection and algebraic functions.

Educational outreach and empowerment efforts will center on developing: 1) an on-line wizard for users visiting the website for the first time, 2) context-sensitive help, 3) a trouble-shooting guide, 4) data interpretation guide, and 5) a RangeView newsletter and desktop help CD.

DSSs for the user-community should be developed using MODIS rapid response products and used in semi-real time, ideally the next day. These daily products will be useful for *ad-hoc* and biodiversity conservation analysis but not for long term change analysis. Rapid response products lack some geo-rectification and atmospheric correction and cannot be compared to historical long-term time series or averages.

Level 3 MODIS products will be more useful to assess biodiversity and sustainable development since they are consistent in time and space. A five year average can be used as a standard as well as a comparison with other years to aid the forecasting models. Timeliness, consistency and coverage remain some of the most important criteria for assimilating new MODIS data products into Earth system decision support tools. However, as federal agencies develop new initiatives directed at expanding tools for ecosystem assessments and for evaluating the effectiveness of measures that are put in place to conserve the ecosystems, scientists, natural resource managers, conservation organizations, and government entities will all benefit from increased access to these data-sets and the ability to easily visualize their effect.

Generally, risks that can be identified that have an impact on DSS missions and requirements include: 1) lack of continuous access to national level multi-spectral observations (e.g. AVHRR and MODIS), 2) the delay in receiving timely remote sensing data, 3) obstacles to operational use of Remote Sensing data within DSS's (i.e. facilities and CI resources, training), and 4) the lack of baseline or historical information. The impact of these risks on DSS missions can be mitigated through integration of several Earth science data products and technologies. These include:

- Land MODIS remote sensing products (e.g. MODIS Rapid Response Products, MODIS vegetation index products, MODIS land-cover product)
- Multispectral and multitemporal ASTER/LANDSAT like data for accuracy assessment
- Extend the current suite of decision support tools for sustainable development and biodiversity conservation
- Facilitate the adoption of new technology.

Sustainability - The cumulative effect of activities undertaken during earlier development phases has been an increased convergence between user preparedness for adoption and product development to meet acceptable application possibilities. To maintain sustainability, RangeView will continue to pursue efforts in diffusion and user acquisition, and partnerships with other entities, public or private competitive grants and contracts.

Under this RangeView project umbrella, the Arizona Remote Sensing Center at the University of Arizona has implemented a prototype of a user-friendly system that has allowed for the integration of current and new NASA data products into the RangeView decision support

tools. The University of Arizona has worked with NASA, the DAACs, and JPL to benchmark DSSs before and after the integration to demonstrate the effect of enhancements and attainment of system and user requirements. The expected benefits to RangeView's evolving DSS include: 1) improved quality of ecological sustainability and conservation assessment and decisions, 2) improved communication among its users, 3) cost reduction, 4) increased productivity, 5) and improved user satisfaction. RangeView continues to improve in user-friendliness, and its capacity to conduct special analysis. In addition, benchmarking of the value provided by new or anticipated NASA products (e.g.: MODIS, VIIRS, OCO) will provide clear answers as to how these data and information products can help to improve RangeView effectiveness and mitigate or reduce risks associated with meeting RangeViews' mission.

A NIDIS (RangeView) application - The goal of this virtual project would be to enable public, private and nonprofit end-user organizations to adapt or adopt NASA Earth System science measurements and predictive capabilities through use of a NIDIS Decision Support System on a sustained basis. The physical outcome of this project would be an enhanced, user-friendly decision support system (DSS) capable of automatically ingesting temporally- and spatially-explicit data and information products to produce time-series analyses and visualization assessments guided by expert knowledge and coupled with a drought data interface and information delivery system (Figure 2). Such a system would have a direct impact on access and usability of disparate data sets and information products to a diverse user community and therefore greatly improve early warning and forecasting of drought across the U.S. This project would set the stage for systemic change in how advanced research products and official forecasts can serve a broad range of users facing a wide range of challenges, and enabling more rapid and effective transition of climate and drought research into practical applications.

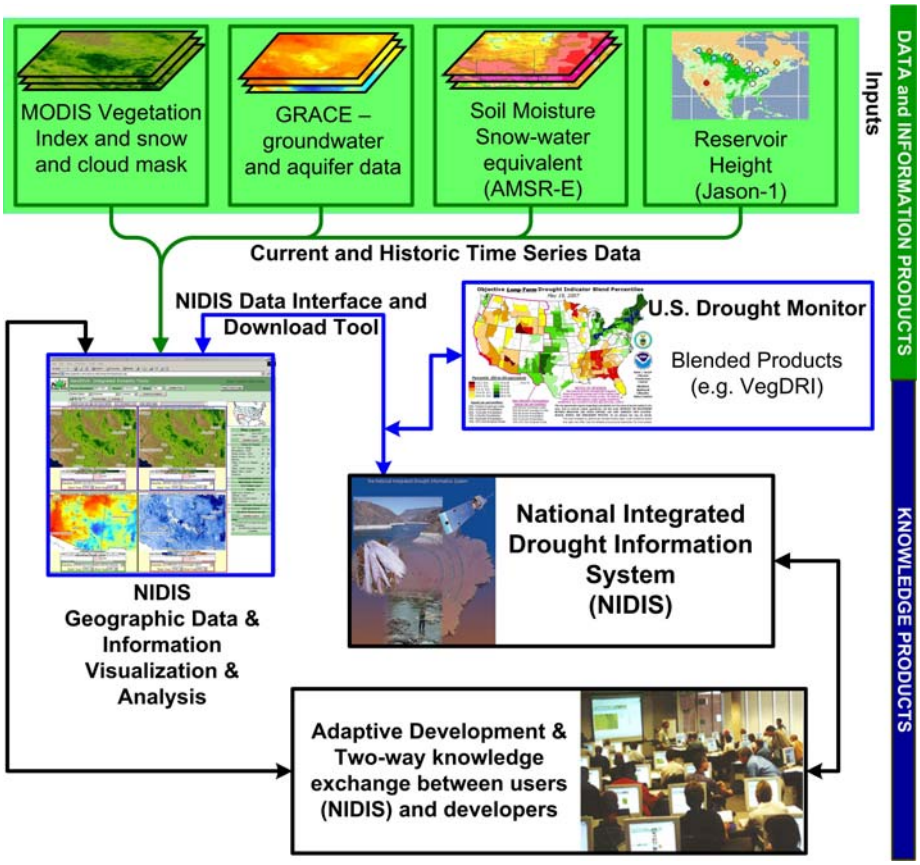

Figure 2. Conceptual framework for adaptation and integration of NASA and USDM data and models into NIDIS.

Acronyms

ASTER – Advanced Spaceborne Thermal Emission and Reflection Radiometer
AVHRR – Advanced Very High Resolution Radiometer
CI – Cyber Infrastructure
DBMS – Data Base Management System
DSS – Decision Support System
ENSO – El Niño-Southern Oscillation
EVI – Enhanced Vegetation Index
FGDC – Federal Geographic Data Committee
JPL – Jet Propulsion Laboratory
LAI – Leaf Area Index
LP DAAC – Land Processes Distributed Active Archive Center
MODIS – Moderate Resolution Imaging Spectroradiometer
NASA – National Aeronautics and Space Administration
NEPA – National Environmental Policy Act
NDVI – Normalized Difference Vegetation Index
NIDIS – National Integrated Drought Information System
NPP – Net Primary Production
OCO – Orbiting Carbon Observatory
OGC – Open Geospatial Consortium
PRISM – Parameter-elevation Regressions on Independent Slopes Model http://www.prism.oregonstate.edu/ *Accessed 12-21-07.*
QA – Quality Assurance
RSAC – Forest Service's Remote Sensing Applications Center
USDM – U.S Drought Monitor
VI – Vegetation Index
VIIRS – Visible/Infrared Imager/Radiometer Suite

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