Proactive Grazing Management in the Valles Caldera National Preserve Using Internet Mapping Services and Remotely Sensed Forecast Models

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Abstract

The Valles Caldera National Preserve (Preserve) is a unique experiment in sustainable management, multiple use, and self-sufficiency. The use of portions of the Preserve as a working ranch is an integral part of the management mandate and continues a long tradition of cattle grazing on the Valles Caldera. The Preserve currently performs active and innovative management of these grazing lands through adaptive stock size and day-to-day monitoring of activity and impacts. This poster explores the Internet mapping service developed by the Preserve in conjunction with the University of New Mexico's Earth Data Analysis Center to address the needs of active management.

The current service is used to deliver daily Normalized Daily Vegetation Index (NDVI) data from the MODerate Resolution Imaging Spectroradiometer (MODIS). To further address the needs of active management and proactive management, the Preserve is implementing a forecast model of NDVI values as part of the internet mapping service. The forecast model is the result of the combination of high-temporal frequency remote sensing products from MODIS with precipitation products from the NEXt Generation RADar (NEXRAD). The model provides a foundation for future research in biomass estimates from NDVI, refinements to the discrete temporal resolution of the model, and season-wide simulation models. The presentation of these spatial tools allows managers to see what is occurring and forecast potential impacts of management practices.

Internet Mapping Service

The Valles Caldera web mapping application presents a combination of static data that include:

- Local high resolution aerial photography
- Moderate resolution aerial photography from the NM statewide Digital Orthophoto Quadrangle data acquisition (1 m resolution)
- Scanned USGS Topographic Quads (USGS DRG files)
- Boundaries of the Preserve and grazing allotments within the Preserve
- Preserve hydrologic data including stream, spring, and tank locations
- Preserve road locations

These data are presented in combination with daily vegetation index values (NDVI) derived from NASA's MODIS Aqua and Terra remote sensing platforms. These data were acquired from the USGS MODIS Direct Broadcast system from May 2006 until the service was discontinued in early February 2007. We are now setting up acquisition of the same remote sensing products from the Center for Rapid Environmental and Terrain Evaluation (CREATE) at the University of New Mexico.

The acquisition and processing of MODIS imagery has been automated so that the entire workflow of data download, format conversion, reprojection, subsetting, and classification is accomplished through prescheduled routines that integrate the end products into the web mapping client. The client automatically makes each day's data as soon as the products are generated. This general workflow is illustrated in the following figure (Figure 1).

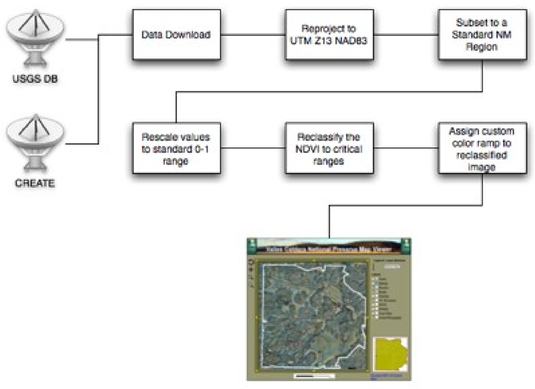


Figure 1: Illustration of the general workflow for the display of MODIS data.

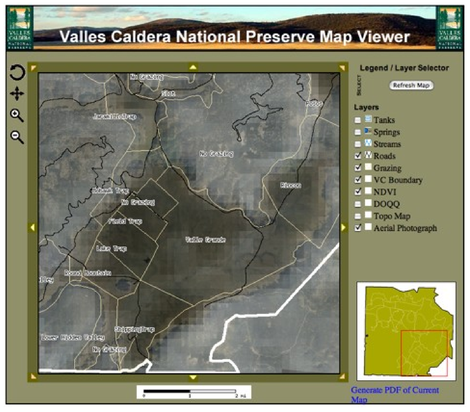
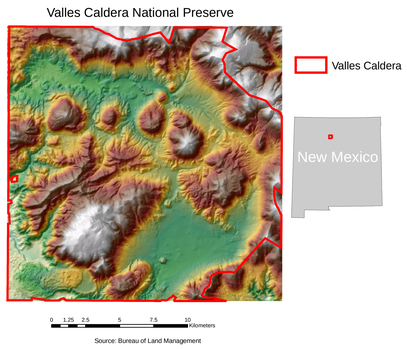


Figure 2: Illustration of the online mapping service client.

The workflow is built upon a combination of Open Source tools including Red Hat Enterprise Linux, GRASS GIS (as a collection of geoprocessing functions), and shell scripts that bring together a combination of operating system and GRASS commands to complete the processing. MapServer is an Open Source Internet mapping server that provides the base platform for the online mapping client, which has custom functionality written in the Python scripting language.

The capabilities of the mapping client include the following basic functionality:

- Pan (movement of the map image horizontally or vertically)
- Zoom (increasing or decreasing the area depicted in the map)
- A dynamic reference map that shows the current map area relative to the Preserve boundary
- An ability to enable and disable the display of individual data layers



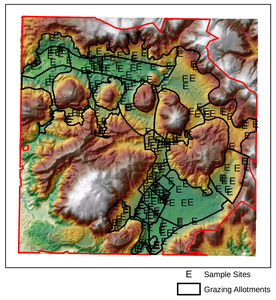


Figure 3: Map of sample locations used for the study.

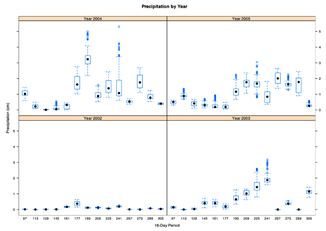


Figure 4: Boxplot series of yearly precipitation variability and distribution by 16-day time period.

Valles Caldera Mixed Linear Model Results

Parameter	Estimate	Pr > t
Intercept	0.1579	< 0.0001
Year 2002	-0.08474	< 0.0001
Year 2003	-0.02161	< 0.0001
Year 2004	-0.04435	< 0.0001
Year 2005	0	
Season 1	-0.02551	< 0.0001
Season 2	0.06338	< 0.0001
Season 3	0.08437	< 0.0001
Season 4	0	
Precipitation	-0.04107	< 0.0001
Lag Precipitation	0.09803	< 0.0001
Lag Vegetation	0.3549	< 0.0001
Lag Precipitation * Lag Vegetation	-0.1005	< 0.0001

Table 1: Results from MEL model run using Valles Caldera

Forecast Modeling

Methods

Data for this study consisted of two primary remote sensing products from two platforms, MODIS derived Normalized Difference Vegetation Index (NDVI) and Next Generation Radar (NEXRAD) derived precipitation. MODIS data from the Terra satellite were obtained in 16-day temporally discrete scenes from the NASA Earth Observing System Data Gateway Distributed Active Archive Center (NASA 2006). NEXRAD data were obtained from two sources: (1) The National Oceanographic and Atmospheric Administration (NOAA) Hydrologic Data Systems Group Western Gulf River Forecast Center archive (NOAA 2006a); (2) NOAA National Centers for Environmental Prediction National Stage IV QPE Product inventory (NOAA 2006b). The use of two data sources was necessitated by an incomplete archive available at any one source. Both sources of NEXRAD data required a further processing step to compile the data into 16-day temporal units coincident with the NDVI data. Both the NDVI and NEXRAD system use the same zero hour (Greenwich Mean), so times and days are coincident between data types. The final product used for analysis represents accumulated precipitation (in centimeters) during the 16-day period. A random set of points was generated and used to sample data for time periods encompassing the growing season, early April through mid-November, for the years 2002-2005. The point locations have been constrained by the established grazing boundaries of the Valles Caldera (Figure 3).

The results of this study will provide a proactive management tool useful to land managers charged with overseeing large areas of grazing land. Montano (2006) established the application of a mixed effect linear (MEL) model utilizing an autoregressive term (AR(1)) for both vegetation and precipitation. The model also incorporates indicators for seasonal variability as well as year. By assigning a qualitative measure (i.e. drought, average, etc.) to the yearly variability of rainfall illustrated in Figure 4, the model can adapt to the variability, thus providing a better fit to the results (see Results discussion). The final model takes the following form:

$$V = 2002 + 2003 + 2004 + 2005 + S1 + S2 + S3 + S4 + P + Lag\ P + Lag\ V + Lag\ P * Lag\ V$$

Where: V = Vegetation; P = Precipitation; Lag P = Lagged Precipitation; Lag V = Lagged Vegetation; Lag P * Lag V = Interaction Term; S1 –S4 = Seasonal Indicator Variables; 2002-2004 = Year Indicator Variables

Results

The results obtained from the MEL model run (Table 1) indicate some variability in parameter estimates for year as well as significant difference in variability for season, which is to be expected. [The zeros for Year 2005 and Season 4 are artifacts of the solution for the model and are incorporated into the intercept term with results interpreted as a deviation from this value.] The results indicate a diminished response in the early part of the year (Season 1) with an increase for the early growing season in Season 2 and the highest values obtained in Season 3, which incorporates the monsoon period. Current period precipitation does not appear to be a driver of growth. Both preceding period precipitation and existing vegetation contribute positively, but these contributions are constrained as seen in the interaction term; as lag precipitation increases, lag vegetation decreases (this works conversely as well).

The MEL model results were used to build a spatial model allowing validation of the results against actual NDVI values. Multiple spatial model runs were generated for each season of each year of the study and correlated to measured NDVI for the corresponding period (Figure 5). To confirm the value of the addition of an indicator of year, models were also generated omitting the year variable. Results of the correlation tests indicate an improvement of model fit for several seasons. In particular, Season 1 benefited from allowing years to vary individually rather than average over all years with a mean correlation of 0.67 for the four individual years versus 0.41 for the no-year model. Similarly, Season 3 improved to a mean correlation of 0.66 from 0.33 for the no-year model. However, results for Seasons 2 and 4 have diminished slightly (Season 2 mean year = 0.73, no-year = 0.82; Season 4 mean year = 0.68, no-year = 0.87), making the exploration of model selection based on season alone for these periods a possibility. Overall, the various model results indicate a good fit with actual data, thus allowing managers to make inferences about future grazing conditions.

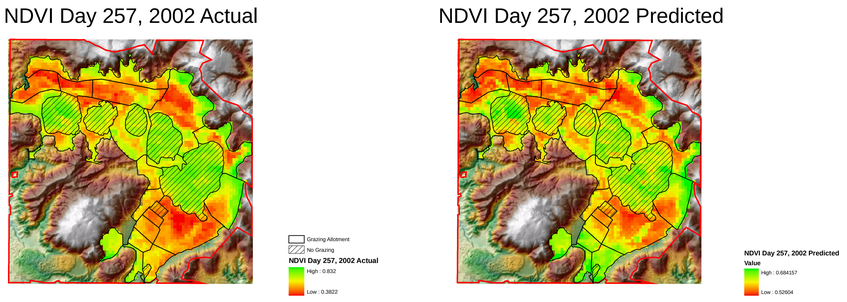


Figure 5: Maps of measured NDVI and predicted NDVI for day 257 (Sept. 14-29), 2002. The model is able to sucessfully capture the spatial variability of NDVI values for the grazing areas.

Conclusion

Effective management requires both prudent planning and monitoring of ongoing operations and the effectiveness of management plans. By providing condition data to managers and field personnel, cattle can be relocated to pastures showing the highest productivity thus maximizing grazing efficiency and avoiding environmental damage through overgrazing. The map viewer provides an efficient and cost effective means of delivering near real-time environmental data to the science and management personnel of the Valles Caldera National Preserve. The web mapping service is designed to provide data delivery and mapping services to light-weight clients with only minimal processing capabilities. The ultimate goal is to provide data access and mapping on low-cost hand-held devices for delivery to field personnel using wireless internet protocols.

Future versions of the mapping service plan to include the following enhancements:

- Estimates of biomass;
- New temporal NDVI composites;
- Interactive queries and display of temporal NDVI profiles;
- Seasonally adjusted condition threshold warnings.

The addition of condition models further extends the capability of the service to forecast the impact of activities and allows managers to adjust accordingly. Future plans for modeling research include:

- Season-wide simulation models;
- Refined temporal scales;
- Addition of winter precipitation as a factor leading into the growing season;
- Exploration of the application of continuous time-series models.

The Valles Caldera National Preserve is forging new approaches to the science-based management of public lands. The map viewer and associated research are providing a basis for near real-time integration of remotely sensed data and forecast model products into this process. The combination of such powerful spatial tools allows improved management of public lands for a sustainable future, balancing natural resources preservation with recreational and economic use.

References Cited

Montano, E.L. 2006. Fusing MODIS and NEXRAD for Predictive Modeling of Seasonal Grassland Greenness in New Mexico. Thesis. Department of Geography. University of New Mexico.

NASA. EOS Data Gateway 2006 [cited. Available from http://delenn.gsfc.nasa.gov/~imswww/pub/imswelcome

NOAA. HDS Group Western Gulf River Forecast Center 2006a [cited. Available from http://dipper.nws.noaa.gov/hdsb/data/nexrad/nexrad.html
———. NCEP National Stage IV QPE Product Inventory 2006b [cited. Available from http://wwwt.emc.ncep.noaa.gov/mmb/ylin/pcpanl/stage4

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