Progress Report for: The Dynamics of a Semi-Arid Region in Response to Climate and Water-Use Policy

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Ongoing developments in this project can be found at the following web site:
http://www.planetary.brown.edu/planetary/LCLUC_Owens

A paper describing the analytical methods for remote sensing is currently in review:

Elmore, A., J. F. Mustard, D. Lobel, S. Manning, and A. Steinwand, Quantifying percent live cover in multitemporal data of a semi-arid region: Comparison between spectral mixture analysis and NDVI, *Remote Sensing of Environment* (*in review*), 1999.

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Introduction

Since receiving funding for this project, we have accomplished a number of the stated goals for the first year of this effort. First year graduate student Andrew Elmore became involved with the project last September and has made significant contributions to the data reduction and analysis phases for the project. Over the fall, we identified 13 Landsat TM scenes from the EROS data center archives that met our criteria for a) date (August-September) and b) minimal clouds. In order to encompass the critical field site, which sits astride two TM rows, the scenes were ordered with a scene shift. We were able to acquire a scene for each year from 1984-1996, and plan to acquire a 1997 and 1998 scene when available. From this data set of 13 scenes, we extracted the core data that encompassed the elements of Owens Valley that were required to achieve our science goals.

The multitemporal satellite data base was then internally coregistered and georeferenced. Our assessment of the coregistration was that this first order correction was sufficient to begin the analyses, but will need to be refined over the next 6 months to achieve a higher level of fidelity for the more stringent data analyses planned. The scenes were then radiometrically intercalibrated using ground invariant points with low, intermediate, and high reflectances. The root-mean-square correspondence of the scene radiances across the dates and channels was typically greater then 0.99.

A trip to the field site was conducted in November of 1997 which included the principal investigator and most of the co-investigators. During this trip, we met with the Inyo County scientists who are co-investigators of this project and outlined the near-term and long-term project goals. We established a number of common themes for continued collaboration. During this site visit, we surveyed a number of the important field sites, including the permanent monitoring sites and a range of potential calibration targets. Measurements of surface reflectance were made using the portable field spectrometer, and samples were collect for characterization in the laboratory. In addition, we deployed the ground penetrating radar (GPR) experiment, which we plan to use for characterization of subsurface soil stratigraphy, pedogenic horizons, and depth to groundwater. This was done in areas with well characterized subsurface stratigraphy, as well as a number of sites representative of major surface types. Subsequent analyses of the GPR data verifies the ability of this technique to discriminate important sedimentological properties, pedogenic profiles, and the definition of the groundwater table. This allows us to characterize these properties over vertical scales of several meters, and horizontal scales of 10’s to 100’s of meters.

Progress in Data Analysis

Field observations of vegetation abundance have been acquired since 1987 for 33 sites across the valley. These permanent monitoring sites include areas assumed to be affected by groundwater pumping and control sites not affected. Each of the monitoring sites which show distinct change characteristics during the drought and exhibits a pronounced, and unique response after the drought. It is these effects which we are interested in quantifying and classifying using remotely sensed data.

The thirteen annual Landsat TM scenes, between 1984 and 1996, were chosen from those acquired during September of each year since September is after summer growth has stabilized and annuals have passed into senescence, but before the winter rains occur. A linear spectral mixture model was derived for the 1992 scene. The endmembers selected were image endmembers (radiance spectra taken from the scene itself) to best model the reflectance properties of the bajada and valley floor materials. We determined that two types of soil, dense green vegetation, and shade were the required endmembers: Additional endmembers may be required for complete and accurate modeling of the soils, but the addition of another endmember did not change the fractional abundance calculations for the vegetation endmember, and led to fraction ambiguity among the soils.

The endmembers derived for the 1992 scene were then applied to each of the other Landsat TM scenes. Since the scenes have been radiometrically intercalibrated, the resulting fraction images (the surface abundance is, in essence, the areal % of each pixel covered by a particular endmember) can then be quantitatively analyzed for change. Standard ratio methods of extracting vegetation information from remotely sensed data, such as NDVI, are limited in that they use only two spectral channels and do not quantitatively measure a physical abundance in the image. The results from mixture models can immediately be used as a measurement of percent vegetation abundance.

A first look at these vegetation abundance images showed extreme variability across the 13 years, particularly in areas where heavy pumping occurred.

The mixture model vegetation endmember images were compared to the field results by entering the geographic coordinates of each field site into the georeferenced image data base and extracting the vegetation abundance information. Due to the 30 by 30 meter pixel size and field site location uncertainties, a special routine was developed to find the most appropriate pixel to represent the field site. The rational behind this approach, was that the pixel defined by the GPS location might not be representative of the vegetation community for which the site was set up to measure. A nearby road or different vegetation community could change the response of this pixel, thus an adjacent pixel could represent the desired community with a higher correlation to the field results. The pixels which were found by this routine to most accurately represent the field site were always within 3 pixels, or 90-m of the center of the field site, which itself was 100-m in diameter.

There are 6 dates between 1990 and 1996 (one each year) for which we have both field and satellite derived measurements of vegetation abundance for the 33 permanent monitoring sites. We calculated the correlation coefficient between each of these data sets. This assessment shows correlation to field measurements was as good as 99% for selected sites and at and average of 89% over 33 field sites.

Change images were produced by subtracting the 1984 vegetation image from the vegetation image of each year. Response of communities to the coupled climatic and anthropogenic forcing functions was seen to vary across the valley floor. As expected, areas that show the largest decrease in vegetation abundance are those affected by groundwater pumping. The tremendous variety of responses seen on the valley floor are coupled to groundwater recharge, community drought tolerance, and other factors that we are investigating.

The first results from the satellite data analysis were presented at the 1998 Association of American Geographers meeting in Boston (Elmore, A. and J. F. Mustard, 1998, Vegetation Response to Climatic and Anthropogenic Forcing Functions in a Semiarid Ecosystem, Annual Meeting of the Association of American Geographers Abstract Volume).

Future Plans

Field work this summer includes the characterization of each of the field sites in terms of land use history, geology, and community type. All sites in which the image data did not correlate well to the field data must be studied to see if this discrepancy can be accounted for. In the coming months, each of the change classes will be studied to determine their significance in the valley vegetation. By combining the vegetation change class data with the existing GIS of vegetation communities, our change classes will be linked to physical parameters and processes in the valley. A critical near-term objective is the integration of the validated satellite observations with the valley-wide, intensive GIS. This is expected to be accomplished this summer. Then we will be able to address the major questions of the characteristics of surface response to the combined anthropogenic and atmospheric forcing functions.

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