Landscape Dynamics and Land-Use Land-Cover Change in the Great Basin-Mojave Desert Region

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Abstract From Original Proposal

The proposed research seeks to determine the relative importance of environmental changes occurring in semiarid regions, their drivers, and the implications for future climatic, land use, and land cover scenarios. Quantifying the relative importance of the drivers and impacts has the potential to guide future decisions in semiarid regions. We propose to address these long term goals through an analysis of the Great Basin-Mojave Desert (GBMD) ecoregion of the SW US using a multitemporal and multsensor analysis of remotely sensed data, regional environmental data, and integration of results from other case studies focusing on semiarid regions.

There are three focus Land Use Land Cover Change (LCLUC) areas of investigation for this research: regional invasion by non-indigenous plants, expansion of pinyon-juniper woodlands, and loss of wetland communities. These three areas have important implications for LULCC in semiarid regions as they impact large regions and/or critical environments, changes in land cover due to these processes are strongly controlled by anthropogenic factors, the changes may have profound effects on the capacity of this semiarid region to deliver ecosystem goods and services, and the changes will effect water and nutrient cycling on the landscape. The native ecological communities of the Great Basin-Mojave Desert region are adapted to a highly variable climate and will respond to its variability in predictable ways. Land cover exhibiting a response significantly different from that expected if the cover were a native community will be in areas affected by anthropogenic drivers of land cover change. This is referred to as anomalous response and can be defined as: (1) Interannual change in vegetation is decoupled from climate variability or from the response of native communities. (2) Interannual change in vegetation cover that is coupled with climate variability, but the change is amplified relative to native systems

Recognition of anomalous response associated with these LCLUC processes, quantifying the impacts across the region of the GBMD, and determination of the relative impacts requires a multisensor, multitemporal remotely sensed data approach. High temporal, coarse spatial resolution data provide the capability to identify locations of significant change across the region, while high spatial, but low temporal resolution data provide details of the processes. Integration of such observations with in situ, socio-economic, and regional land use data provides the information required to determine the drivers and impacts behind the processes.

We propose a coupled bottom-up<=>top-down approach to the analysis. The bottom-up approach capitalizes on complete research and extensive in situ data in Owens Valley CA. LCLUC processes recognized in the field and at Landsat TM resolution will be scaled to AVHRR

Keywords:

Research Fields: Change detection, invasive species, land abandonment, land degradation, vegetation recovery and dynamics

Geographic Area/Biome: North America, grassland, semi-arid, desert:arid

Remote Sensing: AVHRR, Landsat

Methods/Scales" Regional scale, local scale, time-series analysis, mixture modeling

Project Objectives, Goals, and Approaches

This project addresses, on one level or another, the NASA ESE scientific questions:
What are the changes in land cover and/or land use (monitoring/mapping)?
What are the causes of land cover-land use change?
What are the consequences of land cover-land use change?

The proportion of social science in this work is 0-25%, carbon is related to 10%, water 75%, nutrients 10-15%, and GOFC specific goals 0%.

The specific goals of this work are to address the following basic questions:

- What are the most significant land cover changes occurring in the GBMD region?
- What is the relationship of these changes to current or past land use?
- What are the relationships to water resources and their management?
- What are the impacts on ecosystems, carbon, and nutrient cycling?

To identify regional land cover changes, we adopted the following hypothesis based on our previous LCLUC research:

> The native ecological communities of the Great Basin-Mojave Desert (GBMD) region are adapted to a highly variable climate and will respond to this variability in predictable ways. Land cover exhibiting a response significantly different from that expected if the cover were a native community will be in areas affected by anthropogenic drivers of land cover change. This is referred to as anomalous response and can be defined as:
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> 1) Interannual change in vegetation is decoupled from climate variability or from the response of native communities.
> 2) Interannual change in vegetation cover that is coupled with climate variability, but the change is amplified relative to native systems

We have identified three broad LCLUC processes important to the GBMD region to investigate: invasion by non-indigenous species, expansion of pinyon-juniper woodlands, and loss of wetland communities. We address the goals and questions of this research by the following tasks: 1) quantify the response of semiarid systems in Owens Valley, CA to changes in water availability and assess the impact of land use history that response; 2) Scale the Owens Valley results up to the GBMD through regional remotely sensed data(e.g. AVHRR); 3) Identify anomalous regions of response across the Great Basin, and 4) Investigate in detail anomalous response regions with field, ancillary, and high resolution remotely sensed data (e.g. Landsat) to address project questions and NASA ESE scientific questions. The specific goals for year 1 were to complete task 1, investigate methods for implementing task 2 and to have conducted sufficient work in task 2 that candidate sites were identified for task 3. Tasks 2, 3, and 4 were planned to be ongoing throughout the project, though task 2 needs to progress sufficiently during the early phases of the research to begin task 3 during the first year.

Project Progress

The project is basically progressing as anticipated. We have completed Task 1 and will submit a publication on this topic within the next few months. A major paper upon which much of this research rests was also just accepted for publication in Ecological Applications (Elmore et al., 2002). This documents the response of semi-arid vegetation in Owens Valley to stochastic environmental stress. It makes extensive use of extensive field data and a very well calibrated Landsat TM time series of annual scenes from 1984-2001. Furthermore we have documented in a very strong way an environmental threshold for semi-arid phreatophytic communities. This work shows that when the groundwater table is lowered to a threshold depth beneath the communities, they exhibit a catastrophic collapse in vegetation. With recovery of the groundwater table, the species make-up of the community changes, thus demonstrating that these systems are not elastic in their response. This work is also near completion and will be submitted for publication in a few months. In summary:

Task 1 is complete and will be submitted for publication shortly.

Task 2 has progressed along two parallel paths. The first was to scale up from the previous LCLUC work using TM data in Owens Valley. This was not overly satisfying as relating the TM results to AVHRR data is problematic. However, we instead have focused on using AVHRR to identify anomalous response and validating the methods to do this in the Owens Valley region where we have excellent ground control. We have just completed an analysis of AVHRR data to detect anomalies using the following approach:

1) Bi-weekly composite NDVI AVHRR data set of the GBMD from 1989-1999 were acquired. The data were processed to remove scenes of poor quality and to re-register all scenes to a higher degree of co-registration.
2) An annual 26-week average NDVI data set was created from the 10 year data set.
3) The average was removed from all dates to create a "residual" data set that showed, on a pixel by pixel and 14-day period, the deviations in NDVI from the 10-year average
4) The 10-year trend of the residual was fit with a line from which a slope and root-mean-square difference were calculated for each pixel. Using large, homogeneous, and largely barren regions, we determined what the long-term trend in NDVI residual was that was apparently due to instrumental and other effects. Also, the expectation is that most of the region will not show a trend using this approach. The average trend in the residual is 0.6 NDVI/year and the slopes show a normal distribution about this average. The results are rather exciting as the basic trends identified through mixture modeling of Landsat TM data in Owens Valley are well represented in the AVHRR residual slope maps.
5) We are now investigating these results in the context of the overarching questions and specific goals for this project. We have thus begun on Task 3 as anticipated.

Next Steps:

a) Investigate candidate regions identified as anomalous by the AVHRR average-trend-residual anomaly mapping. This will involve determination of the dominant vegetation types represented in the anomalies, removing anomalies related to fire, correlating climate parameters including temperature and precipitation. The goal is to identify 3-5 sites for detailed investigation.
b) Prioritize the 3-5 sites and acquire high resolution ETM+ and TM data. Priorities determined on the basis of field data availability, quality of remote sensed data available,

and consistency with overall project goals. Dates to be selected based on the AVHRR mapping.

c) Determine the % live cover of the regions mapped with ETM+ and TM using spectral mixture modeling and analyze in the context
d) Integrate results with field and social science data.

Conclusions

As discussed above, we are proceeding as anticipated on this project. Over the next year similar progress is anticipated. As we are finishing the first year of the three year project, we do not have any particularly note worthy results or products. However, we do anticipate that following the assessment of the anomaly mapping and characterization, new and interesting results of interest to a wide group will be available.

Publications Related to this Research:

Elmore, A. J., J. F. Mustard, and S. J. Manning, Regional patterns of great basin community response to changes in water resources: Owens Valley, California, (*in press*) *Ecological Applications* 2002.

Elmore, A. J., J. F. Mustard, and S. J. Manning, Precision and Accuracy of Earth Observing-1 Advanced Land Imager Data for Semiarid Vegetation Studies, IEEE Trans. Geosci. Rem. Sens. (submitted), 2002.

Elmore, A. J. and J. F. Mustard, Thresholds to the depth to water of semi-arid groundwater communities, (submitted), Science, 2002.

Elmore, A. J., J. F. Mustard, and S. J. Manning, Thresholds in semi-arid phreatophytic communities to declining water tables determined with remotely sensed data, (in preparation), 2002.

Elmore, A. J., J. F. Mustard, S. H. Hamburg, and S. J. Manning, Land-use legacy identified in species composition and vegetation response in a semi-arid system, (in preparation), 2002.