

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

Principal Investigator: Dr. John F. Mustard
Department of Geological Sciences
Brown University
Providence, RI, 02912
Phone: 401-863-1264
Fax 401-863-3978
email: John_Mustard@Brown.edu

Co-Investigators: Dr. Steve Hamburg, (Ecosystems, Landscape ecology, land-use history)
Center for Environmental Studies
Box 1943, Brown University, Providence, RI, 02912
Phone: (401) 863-3449
Email: Steve_Hamburg@brown.edu

Collaborators: Dr. James A. Young
USDA Agricultural Research Service
Exotic and Invasive Weed Research
920 Valley Road
Reno, NV 89512
Office: (775) 784-6057
FAX: (775) 784-1712
Email: jayoung@scs.unr.edu

Dr. Robin Tausch,
USDA Forest Service,
Rocky Mtn. Research Stn.,
920 Valley Rd.,
Reno NV 89512,
Office (775) 784-5329
Email: rtausch@fs.fed.us

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 multisensor 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, MODIS, 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 GOFD 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:

- 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. Our goals for the past year were:

- 1) Scale the Owens Valley results up to the GBMD through regional remotely sensed data (e.g. AVHRR)
- 2) Identify anomalous regions of response across the Great Basin,
- 3) 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.

Task 1 was completed, though we continually draw from these data and experience to refine methods. Huge and dramatic progress was made with respect to Task 2. We have identified unique and anomalous response related to invasive species (Figure 1). For the first target sites identified in Task 2 we have made excellent progress in field investigations and evaluations.

We have developed a unique approach to analyzing time series NDVI data that is capable of differentiating landscapes dominated by invasive species from those dominated by native ecosystems.

Project Progress

We feel the project is making excellent progress. Over the last year we refined the approach to identifying invasive species in the Great Basin using amplified annual response to rainfall (Figure 1). A map of predicted occurrence was generated and then spectacularly verified during a spring 2003 field campaign. We covered a region about the size of a Landsat scene (30,000 km²) in northwestern Nevada. Where we predicted the invasive species *Bromus tectorum* (cheatgrass) to be present based on 1 km AVHRR NDVI data, it was the most dominated plant species. Where we predicted it not to occur, it indeed was not present. We are in the process of finishing the validation of this analysis and plan on submitting a paper to a high profile journal by late summer.

The next steps are:

- a) refine the approach. While we were very successful in this first analysis, we realize that there are many important refinements to make. The first is to transition to the MODIS data stream. The second is to use a more process-based model to identify amplified response. This will occur over the next year
- b) Investigate the ability to identify woody species expansion. Thus far our success has been solely with invasive annuals. Our next task is to test if the expansion of pinyon juniper woodlands can be resolved. This will also be coupled with explorations of changes in wetland communities.
- c) Develop a longer-term view of the changes observed and quantify the impacts of landscape changes over the last 100 years.

New Findings: Verified that regional mapping of the invasive annual species cheatgrass is possible with biweekly NDVI time series using AVHRR data. It is based on phenological and plasticity differences between invasive species and native perennials and annuals. There is great interest in this capability, but no one has yet done it with the regional scope that our work shows. This now gives us a tool to track the progress of change related to invasive species in the west with regional data and focus in with local data to document processes and impacts.

New Potential: The time series approach to identify invasive species has excellent potential to revolutionize invasive species mapping over regional scales. We now must transition the approach to MODIS data streams and to refine the methods to be able to capture the timing of invasion.

New Products: A map of the presence of cheatgrass over the whole of the Great Basin is a product of some potential value for the LCLUC program ((Figure 1))

Conclusions

As discussed above, we are proceeding as anticipated on this project. Over the next year similar progress is anticipated. As we conclude the second year of the three year project, we are excited by the striking success of the mapping of anomalous response in vegetation in arid regions to environmental variability (Figure 1). These anomalous response regions correspond exactly with regions where invasive annual species have replaced native perennial shrubland and grassland. We are looking forward to publishing these results widely and moving forward on the other areas of this research.

Publications Related to this Research:

- Mustard, J. F., R. Defries, T. Fisher and E. Moran (2003) Land Use and Land Cover Change Pathways and Impacts. Chapter 26 in Gutman G. et al (eds) Land Change Science: Observing, Monitoring, and Understanding Trajectories of Change on the Earth's Surface Kluwer Netherlands (in press).
- Mustard, J. F. and T. Fisher (2003) Land Use and Land Cover Change and Hydrology. Chapter 15 in Gutman G. et al (eds) Land Change Science: Observing, Monitoring, and Understanding Trajectories of Change on the Earth's Surface Kluwer Netherlands (in press).
- Bradley, B. A. and J. F. Mustard, Regional mapping of cheatgrass in the Great Basin, (submitted) *Frontiers in Ecology*, 2003
- Elmore, A. J., J. F. Mustard, and S. J. Manning, Regional patterns of plant community response to changes in water: Owens Valley, California, *Ecological Applications*, 13(2), 443-460, 2003.
- Elmore, A. J., J. F. Mustard, and S. J. Manning, Precision and Accuracy of Earth Observing-1 Advanced Land Imager (ALI) Data for Semiarid Vegetation Studies, *IEEE Trans. Geosci. Rem. Sens.* (in press), 2003.
- Elmore, A. J., S. J. Manning and J. F. Mustard, Threshold responses to groundwater depth in desert phreatophytic vegetation, (submitted), *Nature*, 2003.
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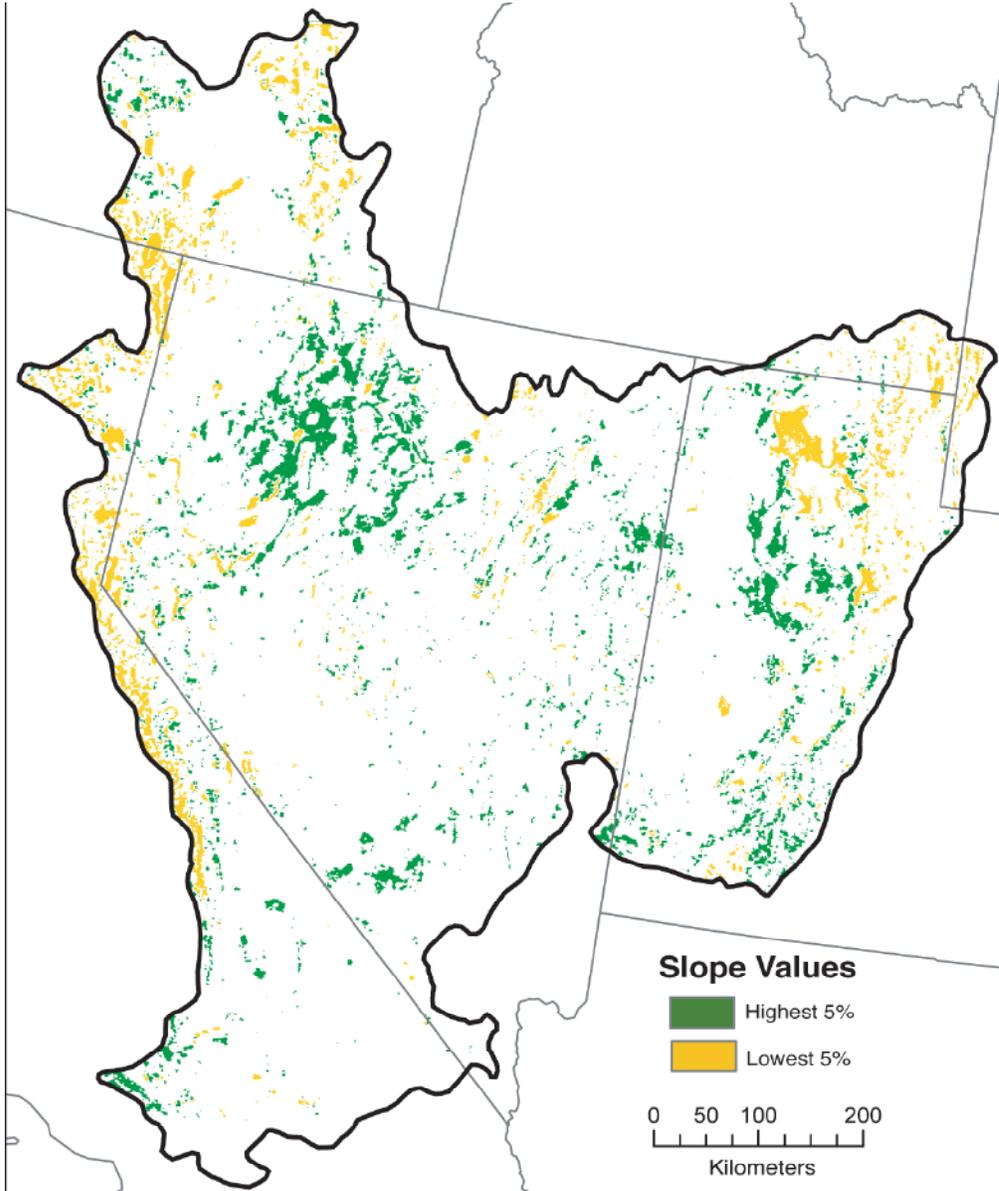


Figure 1. Using methods described in Bradley and Mustard (2003), we have mapped the presence of the non-native invasive annual *Bromus tectorum* (cheatgrass) across the entire Great Basin. The regions indicated as “Highest 5%” are those with cheatgrass. This map is valid for 1999 and was derived using AVHRR biweekly NDVI observations.