Progress Report for the NASA Land Cover Land Use Change Program

Monitoring Forest Response to Past and Future Global Change in Greater Yellowstone

Principle Investigators

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Team Members at MSU

Scott Powell – Ph.D. student

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Jeremy Littell – M.S. student

Jeremy Lougee – Research Assistant

Lew Stringer – Research Assistant

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Background

Have the forests of Greater Yellowstone responded to global change in recent decades?
What have been the consequences of past forest change for carbon, fire, and biodiversity?
Can a monitoring strategy be designed to allow early detection of future change?

Understanding past global change provides an important context for designing monitoring protocols to detect future change. New data from the Greater Yellowstone Ecosystem indicate that vegetation change has been dramatic over the last century. Conifer forests have both increased in density and expanded into previously unforested areas. Concurrently, hardwood, shrubland, and grassland habitats have declined. Fire exclusion by humans may explain these forest dynamics. However, pilot dendrochronological studies of tree growth rates suggest climate variability has also contributed to conifer expansion. These vegetation dynamics appear to have important implications for carbon sequestration, fire and risk to humans, and biodiversity. The responsiveness of vegetation to past land use and climate, and the climate changes predicted for the GYE in the future, suggest that the GYE is an important site for monitoring for early detection of global change. The objectives of the this study are:

1. Quantify change in forest cover, density, and composition across the GYE during 1950-2000.
2. Assess the consequences of this change for carbon sequestration and biodiversity.
3. Devise a monitoring strategy to detect future change in forests of the GYE.

We are quantifying change in forest composition and structure over the GYE for 1975-2000 using Landsat imagery calibrated with reference data from aerial photographs and for rapid change transects for 1950-2000 using aerial photographs. The consequences of these changes for carbon accumulation will be quantified by estimating carbon storage for each cover type based on allometric relationships and field data. Habitat functions will be used to estimate change in the abundances of several bird and shrub species. A monitoring strategy will be developed for locations of rapid change and for the GYE as a whole.

Key Words: Research – biodiversity, change detection, carbon cycling
Geographical Area - North America, temperate forest
Remote Sensing – aerial photographs, Landsat
Methods/Scales – GIS, regional scale

Questions, Goals, Approaches

Questions
NASA ESE Science Questions Addressed: Land cover/use change; consequences of change in land cover/use.

Proportion of Study Devoted to Social Science: 0%

Proportion of Study Devoted to Key Themes: carbon -25 %; water - 0%, nutrients -0 %, GOFC - 50%, biodiversity – 25%.

Goals
Proposed Timetable

Task	2000				2001				2002			
	S	S	F	W	S	S	F	W	S	S	F	W
Aerial photo reference data	---	---										
Reclassify cover type maps for 1975, 1985, 1994		---	---									
Select rapid change transects		---										
Collect field data along rapid change transects					---	---			---	---		
Develop methods for assessing consequences					---	---	---	---	---	---		
Finalize Landsat classification methods and do cover maps for 1950, 1975, 1985, 1994, 2000								---	---	---	---	---
Analyze consequences of vegetation change								---	---	---	---	---
Make results available											---	---

Goals for this Period as Outlined in Proposal

1. Aerial photo reference data collection
2. Reclassify cover type maps for 1975, 1985, 1994
3. Select rapid change transects

Progress During Period

Project management

- Recruited an outstanding Ph.D. student (Scott Powell) and additional technicians for the study (Jeremy Lougee, Lew Stringer).
- Refined proposal into detailed study plan.

Aerial photo reference data collection

- Developed a system for collecting reference data from aerial photographs that includes: stratified-random selection of photo sites, aerial photo management, a key to cover type interpretation, stereoscopic viewing, and an Arc View interface for entering data.

- Purchased aerial photographs for six transects for the years 1971, 1981, 1995, and 1999 for Landsat scene one.
- Collected reference data for Landsat scene one. Three of six transects in scene one were completed for the four time periods.

Reclassify cover type maps for 1975, 1985, 1994

- Acquired Landsat ETM+ data for 1999 and 2000 for the study area.
- Evaluated the feasibility of detecting conifer forest expansion for the period 1975 to 2000 from aerial photographs and from Landsat data based on various classification methods. Concluded that relatively fine-scale forest change is detectable between 1975 MSS, 1995 TM, and 2000 ETM+.

Select rapid change transects

- Rapid change transects were designated for Landsat Scene One.
- Obtained aerial photographs for 1950 for rapid change transects in scene one.

Additional Resources

- Obtain funding for related studies and coordinate this project with these related studies. These are listed under Products.

Evaluation of Original Approach and Methods

All major goals for the first year have been met except the land cover classification is about one month behind schedule. The classification was delayed because of our concern that forest change which is fairly dramatic over a 100 year period would not be detectable from Landsat data during 1975-2000 because of the coarse resolution of MSS and the short time period (1985-2000) for which TM was available. We performed a pilot study to evaluate detectability, which involved rigorous evaluation of aerial photographs and the three types of Landsat imagery (Figure 1). We concluded that areas of rapid change are detectable both from 1975 MSS to 2000 ETM+ and from 1985 TM to 2000 ETM+. We expect to complete the classification of the first scene by late May 2000.

Beyond the specified goals, we also were able to do an initial analysis of conifer forest change during 1975-95 for one Landsat scene based on our previous land cover classification, conduct symposia, secure additional resources from USDA NRI, NSF, and USFS for related studies (see Products).

Narrative Statement on Progress

During this first 10 months of the study we made progress in four areas: study initiation; initial analysis of forest change, conceptual synthesis via symposia, and funding and initiation of related studies.

We made substantive progress launching the study in terms of recruiting a research team, obtaining key imagery, and collecting reference data for cover classification. Scott Powell, a Ph.D. student who comes from Duke University, is leading the cover classification and change detection. Jeremy Littell, a M.S. student, is working on a closely related study of fire history. Ute Langner, a Research Associate on our staff, is conducting GIS analyses. Jeremy Lougee and Lew Stringer are lab technicians conducting aerial photo interpretation. The full research team held a workshop in May 2000 to refine methods and the MSU portion of the team has met monthly throughout the year. Also, Rick Lawrence, a consultant in the study with expertise in remote sensing, has met with us regularly to refine methods. Landsat imagery and aerial photographs for multiple time periods have been obtained and cataloged. An integrated system for reference data collection was developed which includes Arc View as a software platform for cross referencing satellite data and aerial photographs and entering the resulting reference data. This system has been used to collect reference data for 4 time periods across one Landsat scene.

We completed an initial analysis of conifer forest change for one Landsat scene using cover maps from our previous LCLUC study. The change analysis was based on 1975 Landsat MSS and 1995 Landsat TM imagery. We found that area of conifer cover expanded by 7.1% during this 20-year period (Figure 2). Across the scene 30.2% remained conifer, 2.2% changed from conifer to an herbaceous or hardwood class, and 4.5% changed from a herbaceous or hardwood class to a conifer class. The rate of encroachment of conifer into herbaceous and hardwood classes varied with biophysical setting, being most pronounced at lower treeline, . This analysis provided preliminary indication that conifer forests are expanding in the study area and apparently increasing carbon storage and reducing habitat for native species dependent upon grassland, shrubland, and hardwood habitats.

As a means of synthesizing current knowledge, we organized three symposia on the topics of global change and biodiversity, change in western mountain ecosystems, and on land cover and use change in rural America. Forest dynamics and implications for carbon and biodiversity were discussed at each of these symposia. In addition to summarizing the current state of knowledge, new networks of scientists were developed through these symposia.

Finally, we were successful in obtaining funding and initiating research on topics closely related to forest expansion. New studies on climate and fire history (funded by NSF and USDA NRI) provide an opportunity to evaluate forest expansion over a longer time period (100-300 years) and assess climate change and fire exclusion as potential drivers of forest change. New research on aspen (funded by USDA Forest Service) will focus on which biophysical settings are associated with rapid encroachment of conifer into aspen stands. An EPA-funded study aimed at modeling future rural residential development will provide a framework for future studies of the consequences of forest expansion for risk to humans. A study of biodiversity potential across the Pacific Northwest US (eastern Rockies to the Pacific) is developing data sets that will be useful future efforts to scaling up forest expansion research from the GYE to this larger region.

New Findings

- Preliminary analyses indicate that conifer forests have expanded by 7.1% in a portion of the study area during 1975-95. This rapid rate of change has important implications for carbon storage and biodiversity.
- Forest encroachment is most rapid at lower tree line. Monitoring to detect future forest change should focus on this biophysical settings.
- Climate experienced decadal-scale variation during the period of interest for this study (1950-2000). Forest change during the 1975-1995 period (Landsat period) occurred under conditions that are drier than the previous several decades (Figure 3). These finding further motivate us to integrate the NASA-funded study, with other funded projects that examine forest change over the past several centuries.

New Potential

- An integrated system was developed in the GIS software Arc View for collecting reference data for satellite image classification from aerial photographs.

New Products

- Preliminary maps of conifer forest change in a portion of the GYE.
- Graphics summarizing long-term climate indices for the GYE.

Proposals Funded

Brown, K. and A. Hansen. A Landscape Approach to Aspen Restoration: Understanding the Role of Biophysical Setting in Aspen Community Dynamics. USFS Northern Rockies Fire Lab. $35,000.

Graumlich, L. Dynamics of Climate, Fire, and Land Use in the Greater Yellowstone Ecosystem, US Dept. of Agriculture NRI, $65,000.

Graumlich, L. Precipitation variability in the Greater Yellowstone Region as inferred from 1000+ tree-ring records. National Science Foundation, Earth System History Program. $239,000

Hansen, A.J., B. Maxwell, R. Rasker. Demographic Change in the New West: Exurban Development Around Nature Reserves. EPA. $400,000.

Hansen, A. and J. Rotella. Riparian Habitat Dynamics and Wildlife along the Upper Yellowstone River. US Army Corps of Engineers. $115,567.

Hansen, A.J, and R. Waring. Biodiversity hotspots in the Pacific and Inland Northwest. National Council on Air and Stream Improvement. $125,000.

Symposia Organized

Hansen, A.J. and V. Dale. August 2000. Global Change in Forests: Interactions among Biodiversity, Climate, and Land Use. Ecological Society of America Annual Meeting.

Hansen, A.J. and D. Brown. September 2000. Changing Landscapes of Rural America. . Yellowstone National Park, WY. Sponsored by NASA Land Cover Land Use Change Program.

Peterson, D.L., and L.J. Graumlich. August 2000. Stressors in Western Mountain Ecosystems: Detecting Change and its Consequences. Ecological Society of America Annual Meeting.

Conclusions

Considerable progress was made in initiating this study and we envision no hurdles to completing the objectives of the study. In addition to initiating the study, we conducted three major symposia on topics closely related to the study. We also secured funding and initiated related research on climate and fire history, aspen dynamics, rural residential development, and regional biodiversity potential. Several publications on topics related to forest expansion were generated by our team.

Publications

Burrough, P.A., J.P. Wilson, P.F.M. van Gaans, A.J. Hansen. 2001. Fuzzy k-means classification of topo-climatic data as an aid to forest mapping in the Greater Yellowstone Area, USA. Landscape Ecology. In Press.

Gallant, A.L. A.J. Hansen, J.S. Councilman, D.K. Monte, and D.W. Betz. In Review. Vegetation Dynamics under fire exclusion and logging in a Rocky Mountain watershed: 1856-1996. Ecological Applications.

Graumlich, L.J. 2000. Global change and wilderness areas: Disentangling natural and anthropogenic changes. In Proceedings: Wilderness Science in a Time of Change. Proc. RMRP=P-000. Ogden UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Center.

Gorham, E., G.S. Brush, L.J. Graumlich, M.L. Rosenzweig, and A.H. Johnson. In press. The value of paleoecology as an aid to monitoring ecosystems and landscapes, chiefly with reference to North America. Environmental Reviews.

Hansen, A.J., and V. Dale. 2001. Biodiversity in U.S. Forests Under Global Climate Change. Ecosystems (4):000-000. In Press.

Hansen, A.J. and J.J. Rotella. 2001. Nature Reserves and Land Use: Implications of the "Place" Principle. Pages 57-75 in Dale, V. and R. Haeuber, eds. Applying Ecological Principles to Land Management. Springer Verlag, New York, NY. In Press.

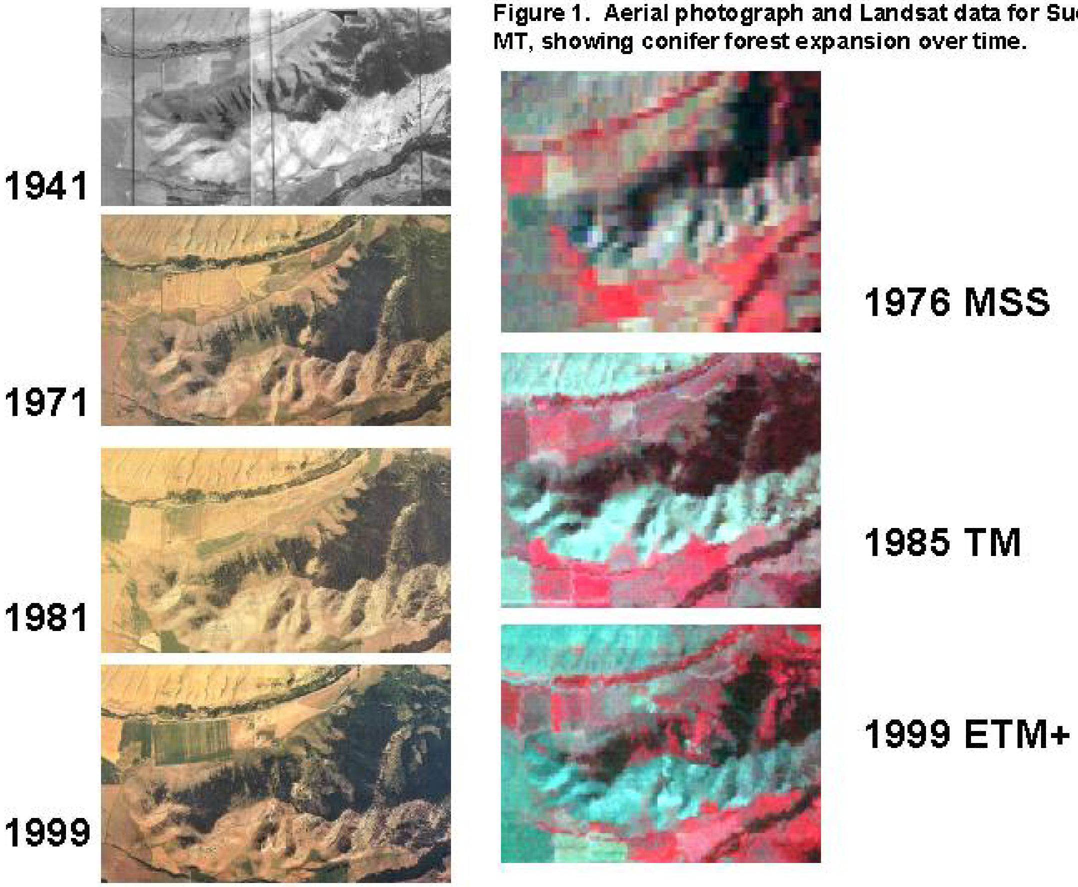
Hansen, A.J., and J.J. Rotella. In Review. Rural Development and Biodiversity: A Case Study from Greater Yellowstone. For: Levitt, J., ed. Conservaton in the Internet Age. Island Press.

Hansen, A.J., R. Rasker, B. Maxwell, J.J. Rotella, A. Wright, U. Langner, W. Cohen, R. Lawrence, J. Johnson. In Prep. Ecology and socioeconomics in the New West: A case study from Greater Yellowstone. BioScience.

Joyce, L., A.J. Hansen. In Review. Climate change: Ecosystem restructuring, natural disturbances and land use. Trans. North American Wildlife Conf.

Wright, A., A. Hansen, W. Cohen, R. Kennedy, A. Gallant, R. Lawrence, R. Aspinall. In Prep. Land Cover Classification and Change Analysis in Greater Yellowstone: 1975-95. For Landscape Ecology.

Figure 1. Aerial photograph and Landsat data for Suce Creek, MT, showing conifer forest expansion over time.



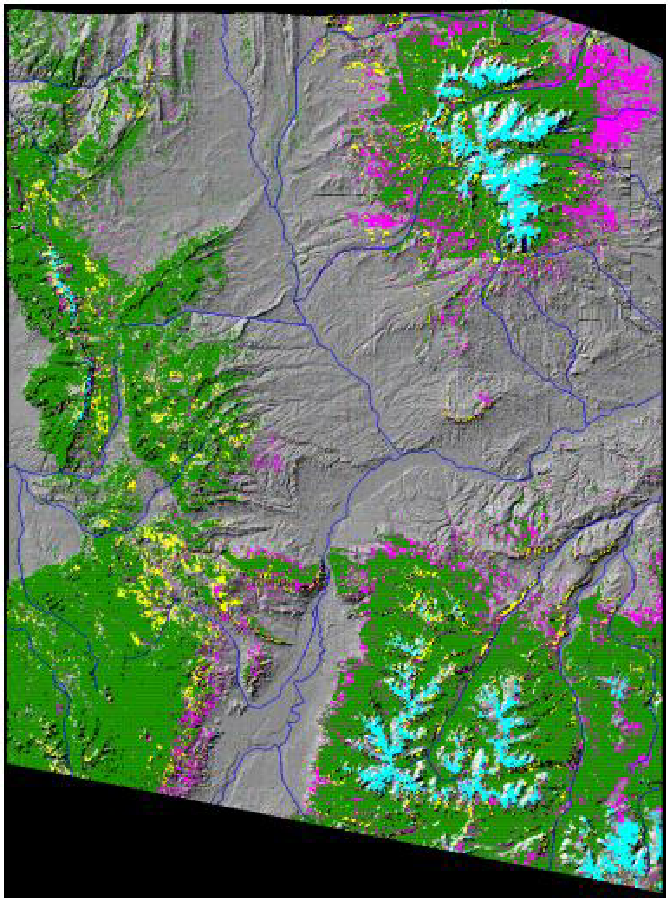


Figure 2. Forest change for a portion of the GYE study area during 1975-1995 based on Landsat MSS and TM imagery. Areas in purple exhibited encroachment of conifers into non-conifer cover types.

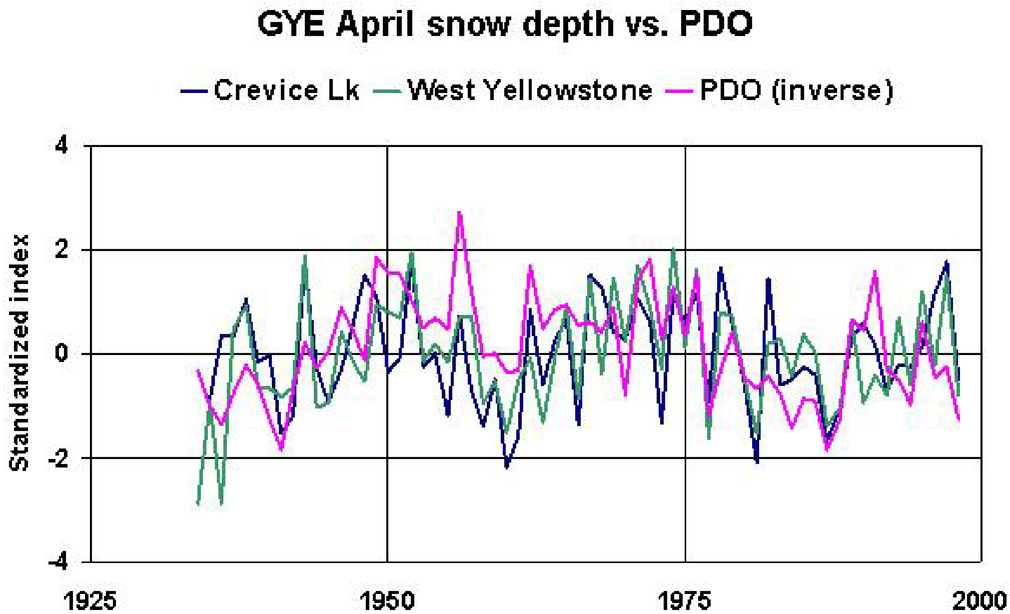


Figure 3. April snowpack for two sites (Crevice Lake and West Yellowstone) plotted against Pacific Decadal Oscillation (PDO), a set of sea-surface temperature anomalies. April snowpack is an index of soil moisture available for plants during the growing season. These data indicate that the period of interest in this study (1950-2000) is characterized by decadal-scale variation in moisture, which could influence rates of conifer forest encroachment. We are currently analyzing how PDO drives multi-decadal episodes of above and below normal moisture in the study area and how this may influence forest dynamics.