## RESEARCH QUESTIONS, 1999-2003

To emphasize the logic of our ongoing work and its relation to past work (described in the preceding section), we have categorized the research questions we are currently addressing (Table 1) according to spatial scale (vertical axis) and agents of pattern formation (horizontal axis).

| **TABLE 1.*** | Physical template | Disturbance | Biotic processes | Models & integrative tools |
|---|---|---|---|---|
| Individuals & forest stands | **Question 1** | | **Question 2** | **Question 3** |
| Sierra Nevada landscape | | **Question 4** | **Question 5** | **Question 6** |
| Western Mountain region | | **Question 7** | **Question 8** | **Question 9** |

* For the time being, empty cells have been adequately addressed. Some questions have components in several cells.

**Question 1:** *What is the relative importance of topography and soil on site water balance in the Sierra Nevada, and how well does this compare with model predictions?* Two independent models suggest that local effects of soils and topography can profoundly alter site water balances in the Sierra Nevada, sometimes with an effect equivalent to a halving or doubling of regional precipitation. These models suggest that effects of slope aspect and soil water holding capacity on site water balance should be of comparable magnitude, but of fundamentally different effect on forest pattern (Fig. 8). Yet, actual forest patterns suggest that slope aspect may have much less effect than soil water holding capacity; that is, models predict that the elevation of a given forest type should be >500 m higher on a south-facing slope than on a north-facing slope, yet the observed difference is <200 m. Given the profound influence local conditions are likely to have on site sensitivity to climatic

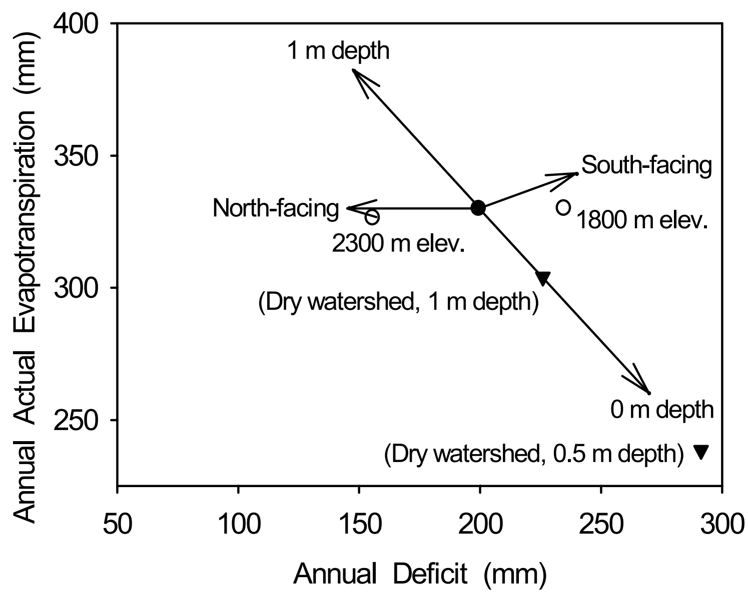


Figure 8. Effects of soil, topography and watershed on local site water balances. From Stephenson 1998.

change (Urban et al. in press), it is important that we reconcile this apparent contradiction in order to have confidence in our model projections. To do so, we are gathering micro-meteorological and soil moisture data from a network of sites.

**Question 2:** *What is the role and importance of reproduction in determining forest pattern and forest sensitivity to climatic change? By what mechanisms does climate control reproduction, and therefore forest sensitivity to climatic change?* Forests are dominated by long-lived organisms that often exhibit inertia in their demographic response to change. Thus, there is a clear need to consider indicators that are likely to be sensitive to change, such as reproductive biology and growth rates. Of particular note here is the tantalizing suggestion from of our earlier research, that, in agreement with recent findings from eastern deciduous forests (Pacala et al. 1996), recruitment and death rates play a much greater role than growth rates in driving forest dynamics. This contradicts some of the basic assumptions of many forest dynamics models, and suggests that reproductive life history stages may be most sensitive to climatic change, and may ultimately drive forest change. As noted by Bennett (1998), seed dispersal and subsequent seedling establishment may be the most critical determinants of the rate of forest response to climatic change. Our permanent demography plots provide an opportunity for quantifying seed dispersal and seedling demography for the dominant species under a range of physical settings and biotic backgrounds.

**Question 3:** *How do seed dispersal, seedling dynamics, and fine-scale variations in topography and soils interact with climatic change to affect forest sensitivity and change at local scales?* To provide an integrative framework for understanding current forest conditions, investigate landscape sensitivity to future climate scenarios, and evaluate potential management options, we will incorporate the new results of field studies related to Question 2 into our forest dynamics models (Zelig and its derivatives).

**Question 4:** *How does climatic change affect the spatial extent, landscape pattern, and severity of fires?* Our modeling has made extensive use of our reconstructions of past fire frequencies along elevational gradients for conceptual development and for comparison with model outputs. Our models predict that, as climatic change affects fuels, ignitions, and fire spread patterns, there will also be changes in distribution of fire size and severity. Does the fire history record confirm the patterns and details of these model predictions? What can we learn about past fire sizes and severities from both modeling and tree-ring reconstructions that will aid managers in deciding upon ecologically appropriate prescribed fire characteristics under different climatic scenarios? Further feedback with the models requires more explicit spatial reconstructions of past fire regimes (and a greater range of sites represented) in relation to past climatic variation.

**Question 5:** *What are the relative importances of tree recruitment, death, and growth rates, and their interannual variabilities, in determining forest response to climatic variation in space and time?* Our research to date has suggested that recruitment and death rates play a much greater role than growth rates in driving forest dynamics. This contradicts some of the basic assumptions of many forest dynamics models. We are now working to verify our preliminary results by quantifying the relative importances of demographic rates and growth rates, on a species-by-species basis, for comparison with Zelig outputs and in a format useful for modifying the model, as needed.

**Question 6:** *What portions of Sierra Nevada landscapes are most sensitive to climatic changes (temperature, precipitation, and seasonality), what are the implications of this for a greenhouse world, and what are the implications for land managers?* While our earlier modeling efforts mostly were at the scale of forest stands (e.g., 0.1-10 ha), we will now scale up to landscapes (10,000-100,000 ha). Spatially-explicit models of landscape sensitivity can help land managers focus monitoring efforts on those areas most likely to respond to climatic change, and predict which portions of the landscape are highest priority for mitigation efforts.

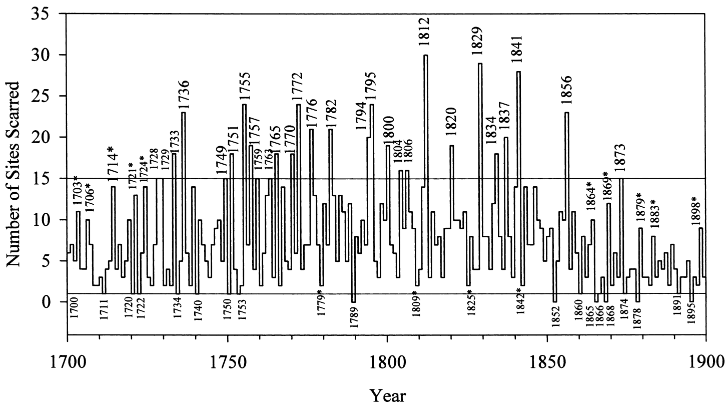


Figure 9. Time series of the number of Sierra Nevada sites recording a fire each year from 1700 to 1900. The largest and smallest fire years are labeled. From Swetnam et al. 1998.

**Question 7:** *Does climate synchronize fire regimes at subcontinental scales? If so, what large-scale climatic phenomena drive the synchrony?* One of the most interesting and important patterns from our earlier reconstructions of past Sierra Nevada fire regimes is fire synchrony over periods of several centuries and over vast landscapes (Fig. 9). Synchrony at these spatial and temporal scales is the hallmark of climatic influence. In addition to the Sierra Nevada and the Southwestern U.S. (Swetnam and Betancourt 1990, 1998), regional synchrony also has been reported by Dr. Thomas Veblen (*pers. comm.*) in the Colorado Rockies -- a result of global change research in BRD's broader Western Mountain Initiative. Regional synchrony is also suggested in Barrett et al.'s (1997) compilation of northern Rocky Mountain fire histories. We seek to identify *inter*-regional (sub-continental scale) fire synchrony, if any, and to determine the major atmospheric and oceanic phenomena driving it (e.g., the Aleutian Low, Great Basin High, Southern Oscillation, position and sinuosity of the jet stream, and dominant storm tracks). Such information, in addition to its immediate use by fire agencies wishing to predict the likely upcoming severity of fires in a given year, can be used with GCM output to predict future patterns of fire occurrence in western North America.

**Question 8:** *Can agents of pattern formation and mechanisms of forest change be generalized at subcontinental scales?* Based on our integrated models of paleoecology and contemporary forests, we are developing a detailed picture of the controls of forest structure, composition, and dynamics in the Sierra Nevada. How much overlap is there between our findings and those of other regions in western North America? We must address this if we are to draw broad generalizations on the effects of climatic change on montane forested ecosystems. To this end, we have formalized the coordination of efforts initiated by BRD's Western Mountain Initiative (*http://www.nrel.colostate.edu/brd_global_change/theme_mountain.html*).

**Question 9:** *How do the relative importances of agents of pattern formation vary among different climates? Is our understanding of mechanisms of forest change sufficient for a single model to explain forest dynamics at several different sites across the continent?* The relative importances of different agents of pattern formation are likely to differ among regional climates. For example, wet (energy-limited) forests will respond most strongly to temperature change, whereas dry (water-limited) forests will respond most strongly to precipitation change. Additionally, as increasing temperature converts energy-limited forests to water-limited forests, fire is likely to increase in importance as an agent of pattern formation. Understanding and prediction of forest response to significant climatic change requires models flexible enough to accurately model shifts in the relative importances of agents of pattern formation.

## RESEARCH ACCOMPLISHMENTS, FISCAL YEAR 1999 AND PLANS FOR FISCAL YEAR 2000

**Question 1:** *What is the relative importance of topography and soil on site water balance in the Sierra Nevada, and how well does this compare with model predictions?*

Urban's field crew established about 40 new georeferenced sample plots stratified within the Kaweah watershed, bringing their total to 99 samples over three years. Within each plot vegetation was sampled, tree growth rates measured, soil samples collected for lab analysis, and topographic variables were recorded. Urban's crew also installed remote data-loggers within each of three of the global change program's long-term forest demography plots: one each in low, mid, and high elevation forest. Each data logger recorded air and soil temperature, precipitation, and soil moisture at two depths on a continuous basis during the growing season. Urban's graduate student (Ken Pierce) and the TECO field crew also established a network of about 24 HOBO temperature loggers, mostly in clusters of 3-4 loggers on contrasting slope facets at similar elevation. The goal is to use these data to develop regression-based methods of extrapolating temperature over complex terrain. Preliminary analyses of data from summer 1999 suggest that large-scale topographic features such as those governing cold air drainage may be more important that smaller-scale topographic features measured over 10's to 100's of meters.

In fiscal year 2000 we plan to re-install and maintain the remote data loggers across the elevational gradient, and to install about 20 longer-lasting temperature loggers this summer (HOBO pro's which will last a full year), focusing on larger-scale features of the Kaweah Basin.

**Question 2:** *What is the role and importance of reproduction in determining forest pattern and forest sensitivity to climatic change? By what mechanisms does climate control reproduction, and therefore forest sensitivity to climatic change?*

This was the initial year of this component of our program. In each of 22 of our long-term forest dynamics plots (see Question 5, below), at least two 25×25 m seedling dynamics quadrats were established, for a total of 47 quadrats (2.9 ha total). All seedlings <1.37 m tall were counted by size class, amounting to several tens of thousands of seedlings which, over the coming years, will be checked annually for growth and mortality. Additionally, a total of 415 seed traps (0.5×0.5 m) were established around the perimeters of the seedling quadrats; these will be emptied annually to determine variation in seed rain both through space (within plots and along the climatic gradient) and time (interannual climatic variation).

During Fiscal Year 2000, all plots will be re-censused, a thorough literature review of Sierra Nevada seed and seedling dynamics will be completed, and preliminary data analyses will be conducted. Additionally, we will initiate a parallel study of recruitment dynamics at two new treeline sites, one each in Yosemite (whitebark pine) and Sequoia-Kings Canyon (foxtail pine).

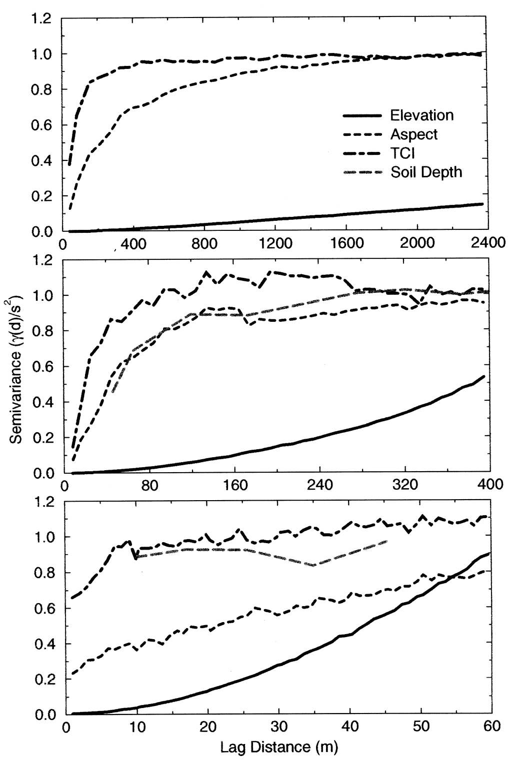


Figure 10. Spatial scaling, as semivariograms for elevation, aspect, topographic convergence, and soil depth at three scales. (top) The 90,000-ha Kaweah Basin in Sequoia National Park. (middle) The 50-ha Log Creek Watershed in the Kaweah Basin. (bottom) A 2.5-ha mixed conifer stand in the Log Creek Watershed. From Urban et al. (*in press*).

**Question 3:** *How do seed dispersal, seedling dynamics, and fine-scale variations in topography and soils interact with climatic change to affect forest sensitivity and change at local scales?*

The fullest expression of this modeling effort must wait until we have several years of field data related to Questions 1 and 2, above. However, using data from earlier work by Dr. Pat Halpin in Sequoia National Park, we began to explore the latter part of the question (related to topography and soils) in a manuscript accepted for publication in *Landscape Ecology* (Fig. 10; see publications, below). Additionally, we are using data on recruitment rates at treeline from Sequoia National Park (Dr. Andrea Lloyd) and Yosemite National Park (Dr. Lisa Graumlich; and Dr. Connie Millar, USFS collaborator) to modify our forest stand simulation model to address ecotone dynamics. Also, during 1999 Ken Pierce adapted the FACET gap model to incorporate seed dispersal, using dispersal distance functions developed from Ruth Kern's seed trap data (see Clark et al. 1999, listed below). Ken used the model to explore possible feedbacks between the spatial scales of seed dispersal as compared to the scale of topographic gradients. Our hypothesis is that, if dispersal distances are short relative to topographic gradients, then seed dispersal will act as a pattern amplifier, reinforcing species distributional patterns along gradients. Ken will present preliminary results of these model experiments at the annual Landscape Ecology Symposium in Ft. Lauderdale in April 2000.

**Question 4:** *How does climatic change affect the spatial extent, landscape pattern, and severity of fires?*

Analysis continued on existing fire scars within tree rings collected across four Sierra Nevada climatic (elevational) transects (Fig. 11), and within the Giant Forest sequoia grove, the site of our intensive study of spatial patterns. Data were entered into the fire history database. Fire history transects were revisited, where we developed and tested field strategy for characterization of vegetation. While most of our sampling has focussed on dead trees, a preliminary assessment was made of the impact of past fire scar sampling on live trees (usually fire-scarred pines). Some tree failures and some mortality were noted. Failures resulted from mechanical weakening of the stems. Mortality (other than failures) was most likely incidental and due to drought or other factors affecting numerous trees in the Sierra Nevada. Tree failures can be avoided in most cases by careful sampling procedures and avoiding trees with existing structural defects such as extensive heart rot. Quantification of these observations should be possible after we visit the remaining sites in the context of our stand characterization objective.

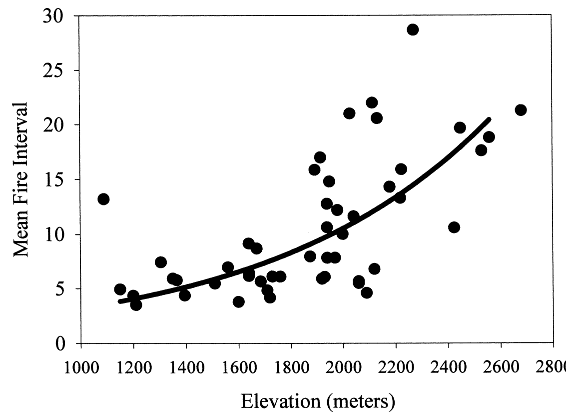


Figure 11. Mean fire intervals (at least 25% of trees scarred) pooled over all sites and plotted versus elevation. From Swetnam et al. 1998.

During the summer of 2000, we will address our failure to successfully date fire-scar samples in a number of north-facing and high-elevation sites will be addressed, where possible, by additional sampling. These difficulties were most pronounced in Yosemite and our efforts will be concentrated there.

Our newly-developed field strategy for characterization of vegetation will be applied in Yosemite and Sequoia-Kings Canyon. The removal of the Selective Availability from GPS signals should assist in this effort by allowing more accurate real-time application of hand-held GPS devices.

**Question 5:** *What are the relative importances of tree recruitment, death, and growth rates, and their interannual variabilities, in determining forest response to climatic variation in space and time?*

Our 23 long-term forest dynamics plots, established 1982 - 1994 and ranging in size from 0.9 to 2.5 ha, are arranged along a climatic (elevational) gradient from lower treeline (1500 m) to upper treeline (3100 m) (Fig. 12). All trees >1.4 m in height are tagged, mapped, and identified by species within each plot. In 1999, each of the ca. 18,000 living trees within the plots received its annual mortality check. If a tree had died, probable causes of death were determined. Tree diameter remeasurements were completed in the eight plots that were due for their 5-yr remeasurements. In the past, ingrowth (new trees reaching 1.4 m height) were only tagged and recorded every five years. In 1999 year we permanently changed our protocols to record ingrowth annually, so as to avoid the possibility of some seedlings surpassing 1.4 m height, then dying before we have a chance to record them. Stephenson completed a simple mathematical model for exploring the relative importance of growth rates and demographic rates in determining forest carbon dynamics, and exercised the model using data from the forest plots.

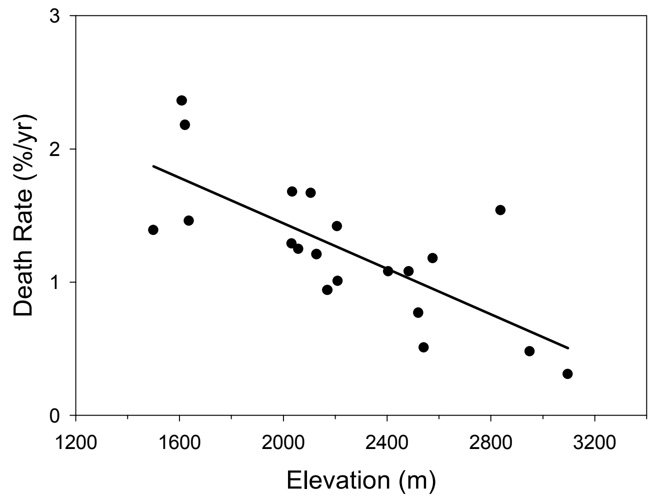


Figure 12. Tree death rates relative to elevation. From Stephenson et al. *unpublished data*.

In Fiscal Year 2000, all plots will again be re-censused as described above. Data analysis and manuscript writing will focus on two broad topics: (1) What is the relationship between tree size, growth rates, and death rates, broken down by causes of death? (2) What are the relative importances of tree birth rates, growth rates, and death rates in determining forest carbon dynamics?

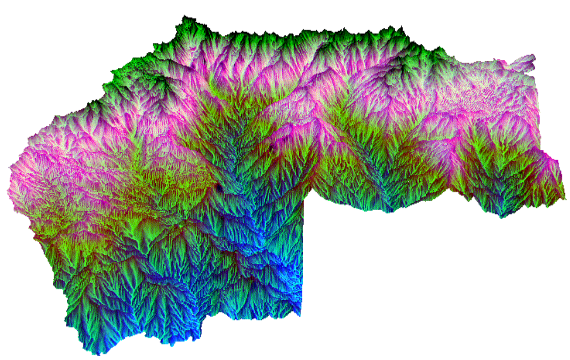

Figure 13. False-color composite image of Kaweah Basin in Sequoia National Park, illustrating relative sensitivity to climatic change. Red scales with increasing sensitivity to temperature change; blue, to change in precipitation. Green scales with increasing uncertainty due to the local influence of topographic drainage on soil moisture. Thus, magenta colors are those sites that are most sensitive to variability in temperature and precipitation. From Urban (*in press*).

**Question 6:** *What portions of Sierra Nevada landscapes are most sensitive to climatic changes (temperature, precipitation, and seasonality), what are the implications of this for a greenhouse world, and what are the implications for land managers?*

Urban submitted to *Ecological Applications* (and had accepted for publication) a manuscript using his Zelig model and its derivatives to determine which portions of the southern Sierra

Nevada landscape are most sensitive to climatic change (Fig. 13), and how this knowledge can be applied by managers to design monitoring programs.

**Question 7:** *Does climate synchronize fire regimes at subcontinental scales? If so, what large-scale climatic phenomena drive the synchrony?*

Fire-scar chronology networks were compared among the west slope of the Sierra Nevada (45 sites), the Southwestern U.S. (63 sites), the east slope of the Cascades in Washington, and the Blue Mountains in Oregon were compared (6 sites for Washington and Oregon combined). Each of these regional networks showed a tendency for high and low fire occurrence to be synchronized during certain years. Over the period 1700 to the present, high and low fire occurrence years were compared among the regions with an independent network of drought reconstructions from tree-rings (Cook et. al. 1999, Journal of Climate, 12:1145-1162), resulting in two primary observations: (1) During particular decades, high fire occurrence years in the Southwest correspond with low fire occurrence years in Washington and Oregon, and vice versa. During other decades there are no clear patterns of synchrony or asynchrony between the Southwest and Northwest. During some years the Sierra Nevada fire regime appears to be synchronized with the Southwest, and during other years it is synchronized with the Northwest. These patterns of decadal synchrony and asynchrony are evident during the two centuries analyzed with fire scars (i.e., 1700s and 1800s), as well as in time series of area burned derived from 20th century documentary records. (2) There are strong correlations between the spatial patterns of drought over the western United States and the patterns of synchrony and asynchrony of fire years in particular regions. Overall, we expect that these spatial-temporal patterns are important clues about the changing climatic controls over fire regimes at regional to continental scales, and probably reflect very broad-scale climatic patterns and their impacts, such as the El Nino-Southern Oscillation and the Pacific Decadal Oscillation.

During fiscal year 2000, additional statistical analyses of the spatial and temporal climate and fire data will be carried out. For example, we plan to develop composite maps of the drought patterns during particular combinations of synchronous and asynchronous fire years for the different permutations of the region. We also plan to conduct various types of time series analyses in comparison of the different fire history network and drought time series.

**Question 8:** *Can agents of pattern formation and mechanisms of forest change be generalized at subcontinental scales?*

At the 1999 meeting of the Ecological Society of America in Spokane, Washington, Stephenson organized and facilitated a meeting of the USGS-BRD Western Mountain Initiative global change research sites (Olympic, Glacier, Colorado Rockies, and Sierra Nevada). The group re-confirmed that its domain extends to all western mountains (not just the core research areas centered on National Parks) and that it studies global changes in the broadest sense of the term, including atmospheric deposition, habitat fragmentation, land use changes, and invasive species, in addition to climatic change. Synthetic efforts of the Western Mountain Initiative will include most or all of the following: (1) analysis and interpretation of changing tree growth rates (lead: Peterson and Graumlich); (2) exotic species invasions and invasibility of ecosystems along climatic gradients (lead: Stohlgren); (3) consequences of increasing nitrogen deposition (lead: Baron); (4) climate-fire relations at a subcontinental scale (lead: Swetnam and Veblen); (5) changing forest dynamics along climatic gradients (lead: Stephenson); (6) vulnerability assessments (identify site sensitivities) (lead: Urban); and (7) integrate and interpret palynological data at a regional scale.

In Fiscal Year 2000, the Western Mountain Initiative (WMI) will present preliminary syntheses on several of these topics at a WMI-organized symposium ("Stressors in Western Mountain Ecosystems: Detecting Change and its Consequences") at the annual meeting of the Ecological Society of America. The Sierra Nevada Global Change Research Program will contribute heavily to three of the seven symposium talks: "1000 years of climate change and ecological response in western montane forests" (Graumlich); "Altered disturbance regimes: fire, fuels, and forest structure" (Stephenson, Swetnam, and Veblen); "Exotic species and biodiversity in mountain forests" (Stohlgren, Keeley, and Graber).

**Question 9:** *How do the relative importances of agents of pattern formation vary among different climates? Is our understanding of mechanisms of forest change sufficient for a single model to explain forest dynamics at several different sites across the continent?*

This ambitious and seminal effort is the brainchild of Dr. Dean Urban (Duke University), and has been supported largely by his NSF Terrestrial Ecosystems [TECO] grant IBN #96-52656, with heavy local collaboration and integration with the Sierra Nevada Global Change Research Program. The TECO project is a model-based comparison of montane forest systems in the Oregon Cascades (H. J. Andrews Forest), the White Mountains of New Hampshire (Hubbard Brook Experimental Forest), and the southern Appalachians in western North Carolina (Coweeta Hydrologic Lab).

In Fiscal Year 2000, Urban will apply to NSF/LTER for a continuation of funds in support of this cross-site comparison effort. Urban will use summer 2000 to conduct a pilot study of two new sampling methods developed as part of this new proposal.

## PARTNERSHIPS AND COLLABORATION

Beyond our integral and indispensable collaboration with our principal investigators at Duke University (Dr. Dean Urban), Montana State University (Dr. Lisa Graumlich), and the University of Arizona (Dr. Tom Swetnam), the Sierra Nevada Global Change Research Program includes the following partnerships and collaborations.

### University of Washington and Oregon State University

A productive collaboration was established with Dr. Jerry Franklin, University or Washington, and Dr. Steve Acker, Oregon State University. Franklin and Acker have generously supplied forest demographic data similar to those collected by the Sierra Nevada Global Change Research Program, but from Mount Rainier, Washington. The Rainier data will provide a valuable contrast to the Sierra Nevada data, allowing us to look for broad generalities about relationships between climate and forest dynamics.

Franklin and Acker are working with the Sierra Nevada principal investigators in writing a manuscript presenting preliminary results.

**University of California**

Collaboration continued with Kurt Menning, doctoral candidate, and Dr. John Battles, assistant professor at U.C. Berkeley. Stephenson serves on Menning's doctoral committee, which is chaired by Battles. Menning's dissertation focusses on changes in forest pattern at landscape scales, particularly as influenced by the reintroduction of fire after a long period of exclusion (Fig. 14). His approach is to analyze remote imagery before and after prescribed fires in Sierra Nevada mixed-conifer forest, and link changes that are evident in the imagery to changes recorded in two hundred ground-truth plots. Battles is investigating causes of a severe die-off in sugar pine (*Pinus lambertiana*) that is occurring in both burned and unburned stands.

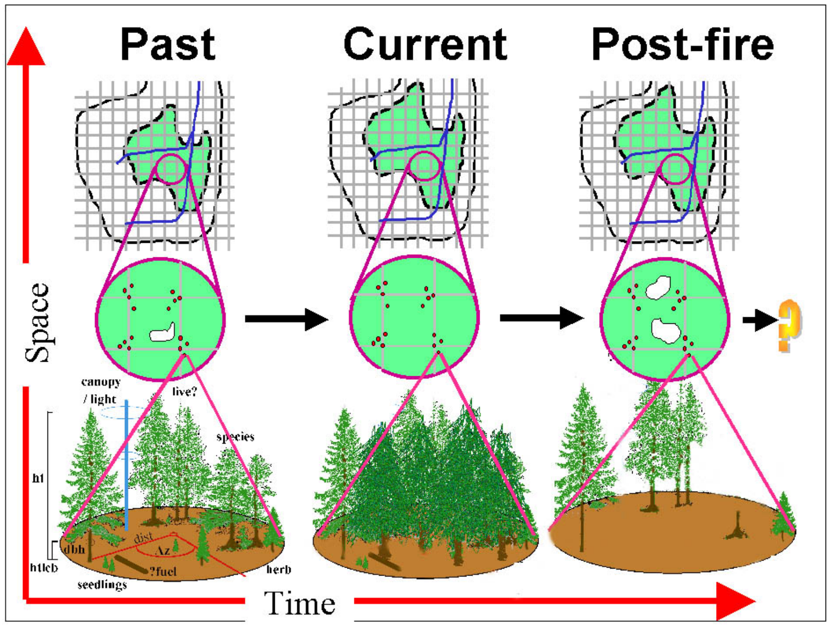

Figure 14. Potential Sierra Nevada forest structure with and without the application of fire. From Menning (*unpublished*).

**Department of Interior/U.S. Forest Service, Joint Fire Science Program**

Keeley and Stephenson have been key players in developing a proposal for a national program to determine the ecological consequences of different approaches to forest fuels management (*http://ffs.psw.fs.fed.us/*). The five-year, multi-site, multi-million dollar proposal has been funded through the Department of Interior/U.S. Forest Service Joint Fire Science Program (*http://www.nifc.gov/joint_fire_sci/index.html/*). In the southern Sierra Nevada, research will begin in fiscal year 2001, and will focus on determining the ecological consequences of different seasons of prescribed fires. The study will benefit from previous findings of the Sierra Nevada Global Change Research Program, and in turn will nicely complement that program by enhancing our understanding of the role of fire in forest dynamics, particularly regeneration.

**U.S. Forest Service**

The Sierra Nevada Global Change Research Program welcomed the addition of Dr. Connie Millar, U.S. Forest Service, Pacific Southwest Forest and Range Experiment Station, as a formal collaborator. Dr. Millar has extensive experience in the genetics, history, and paleoecology of Sierra Nevada forests, with several study sites on National Forest land adjacent to the Program's primary study sites in the national parks. While Dr.

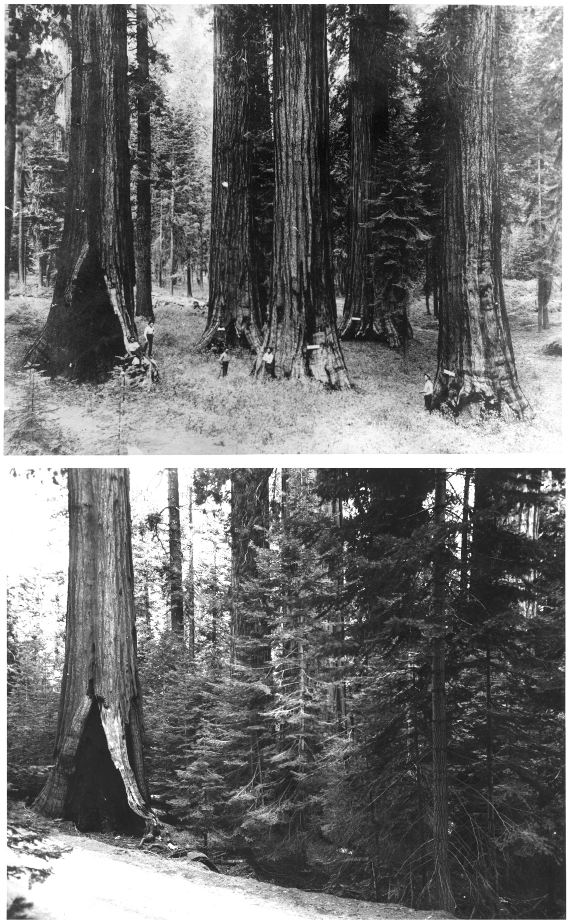

Figure 15. Comparisons of historic (top) to current (bottom) photographs show dramatic changes in forest structure in the Sierra Nevada. From Stephenson 1999.

Millar initially will be collaborating most extensively with Dr. Graumlich on studies of Sierra Nevada treeline dynamics, further collaborations on dynamics of lower-elevation forests are under discussion.

**National Interagency Fire Center**

Keeley and Stephenson secured funding from the National Interagency Fire Center (Boise, Idaho) to determine changes in Sierra Nevada forest structure since the late 1800s through repeat photography (Fig. 15). This study will supply land managers in the Sierra Nevada with information needed to set structural goals for forest restoration, and will supply the Sierra Nevada Global Change Research Program will valuable information on the relationships between changing climate, fire regimes, and forest structure. This study will differ from past repeat-photography studies in that it will (1) attempt to provide an unbiased view of forest changes, rather than selecting the photo pairs that demonstrate the most dramatic changes; (2) attempt to quantify changes in surface fuels and tree sizes and densities, rather than presenting qualitative results; and (3) focus some efforts on the lower forest-shrubland ecotone, which appears to have shifted over the last century but has generally not been studied.

**U.S. Geological Survey's Western Mountain Initiative**

As described earlier in this report, the global change research programs of the USGS-BRD Western Mountain Initiative (WMI) -- Olympic, Glacier, Colorado Rockies, and Sierra Nevada -- are collaborating to draw generalizations that extend beyond their individual sites (Fig. 16). In Fiscal Year 2000, the WMI will present preliminary syntheses on several topics at a WMI-organized symposium ("Stressors in Western Mountain Ecosystems: Detecting Change and its Consequences") at the annual meeting of the Ecological Society of America. The Sierra Nevada Global Change Research Program will contribute heavily to three of the seven symposium talks: "1000 years of climate change and ecological response in western montane forests" (Graumlich); "Altered disturbance regimes: fire, fuels, and forest structure" (Stephenson, Swetnam, and Veblen); "Exotic species and biodiversity in mountain forests" (Stohlgren, Keeley, and Graber).

**Yosemite and Sequoia and Kings Canyon national parks**

The global change staff continued its close working relationship with personnel in the Division of Science and Natural Resources Management at Sequoia and Kings Canyon National Parks. Both groups share many common goals and data sets. Interactions include mutual assistance in experimental and monitoring design, mutual field assistance, assistance in data analysis, exchanges of related data sets, and exchange of relevant research findings.

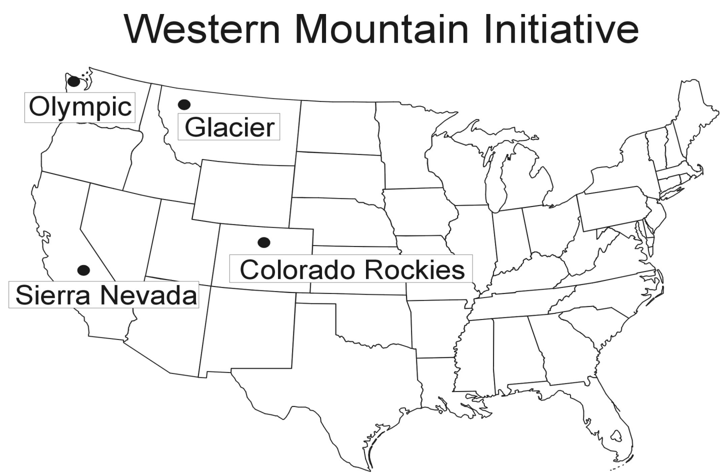


Figure 16. The Western Mountain Initiative sites.