

Effects of Climatic Variability and Change on Forest Ecosystems – Empirical Evidence from the Western Mountain Initiative

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Climate and stress in Western forests

We can estimate with some confidence how large portions of forested mountain ecosystems in the western US will respond to a continued trend in temperature increase. The Western Mountain Initiative (WMI) network has used retrospective and contemporary studies to quantify how climatic variability can increase (decrease) stress in forest ecosystems, thereby exacerbating (ameliorating) susceptibility to subsequent stress. Data encompass a wide range of temporal scales (annual to millennial) for mountain-dominated national parks and protected areas throughout the West.

Forest ecosystems that are most vulnerable to prolonged drought are in arid and semiarid regions, with well documented dieback and stress in some Southwestern forests. In fact, insect outbreaks, elevated fuel loadings, and the potential for crown fire are common throughout the intermountain West. Not all the news is “bad”, however. Many subalpine forests near treeline appear to be regenerating more rapidly and growing faster in recent decades.

Summaries presented here represent a range of climatic effects on forests, from most (Southwest) to least (Central Rockies) evidence of recent change.

American Southwest

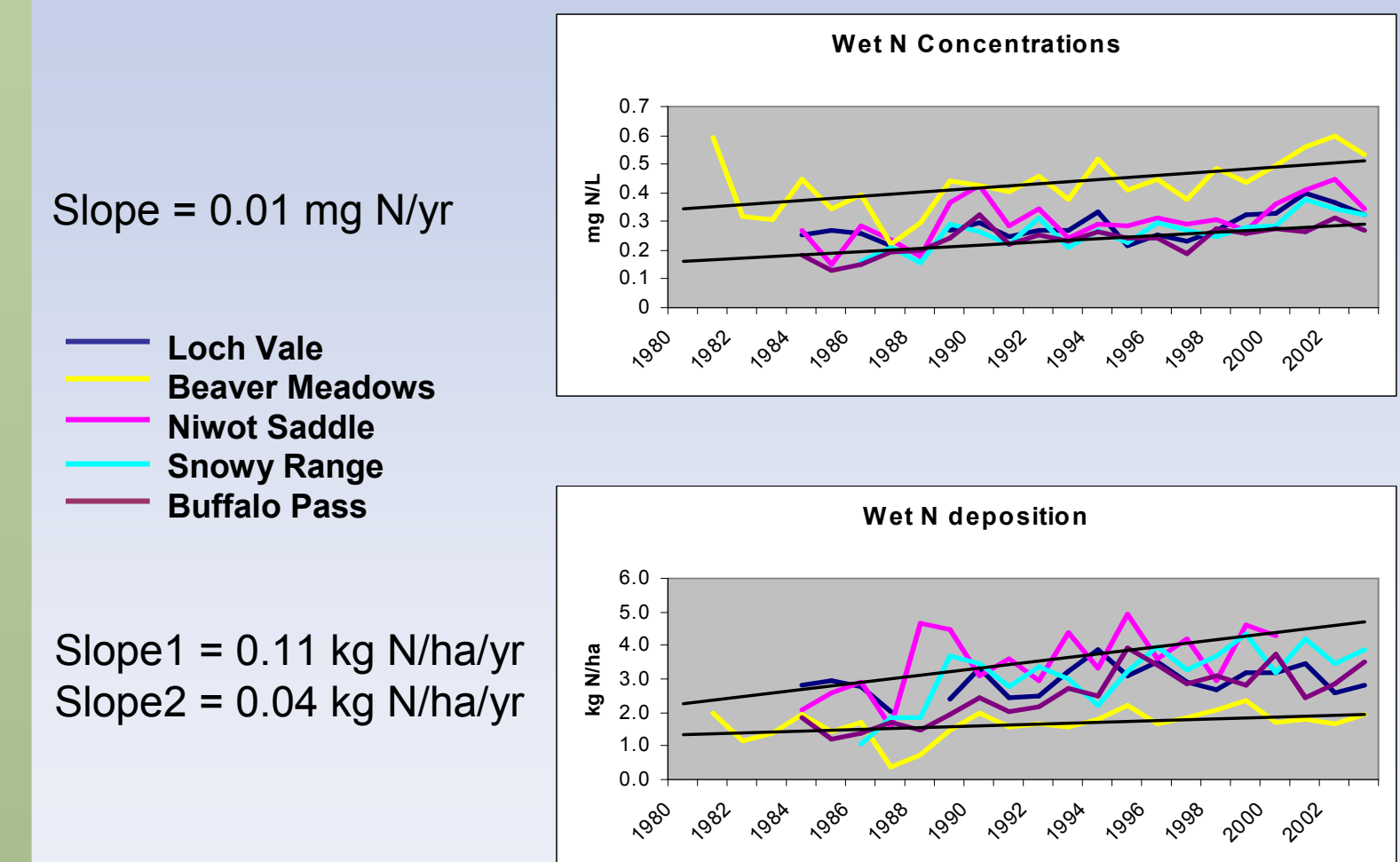
This region exhibits major effects of climatically induced stress, with extensive mortality in forest ecosystems subjected to prolonged drought. Dieback is most prominent in lower elevation and drier conifer forests, with mortality caused directly by insufficient soil moisture in combination with beetle outbreaks. Fuel accumulations throughout Southwestern mountains have created the potential for large wildfires, which are also linked to ENSO cycles (less fires during wet El Niño, more fires during dry La Niña). Southwestern forests may be exhibiting some of the first signs of the effects of climatic change in arid Western forests. It remains to be seen whether conifer forests with extensive dieback will regenerate or will convert to woodlands and shrublands.



Central Rocky Mountains

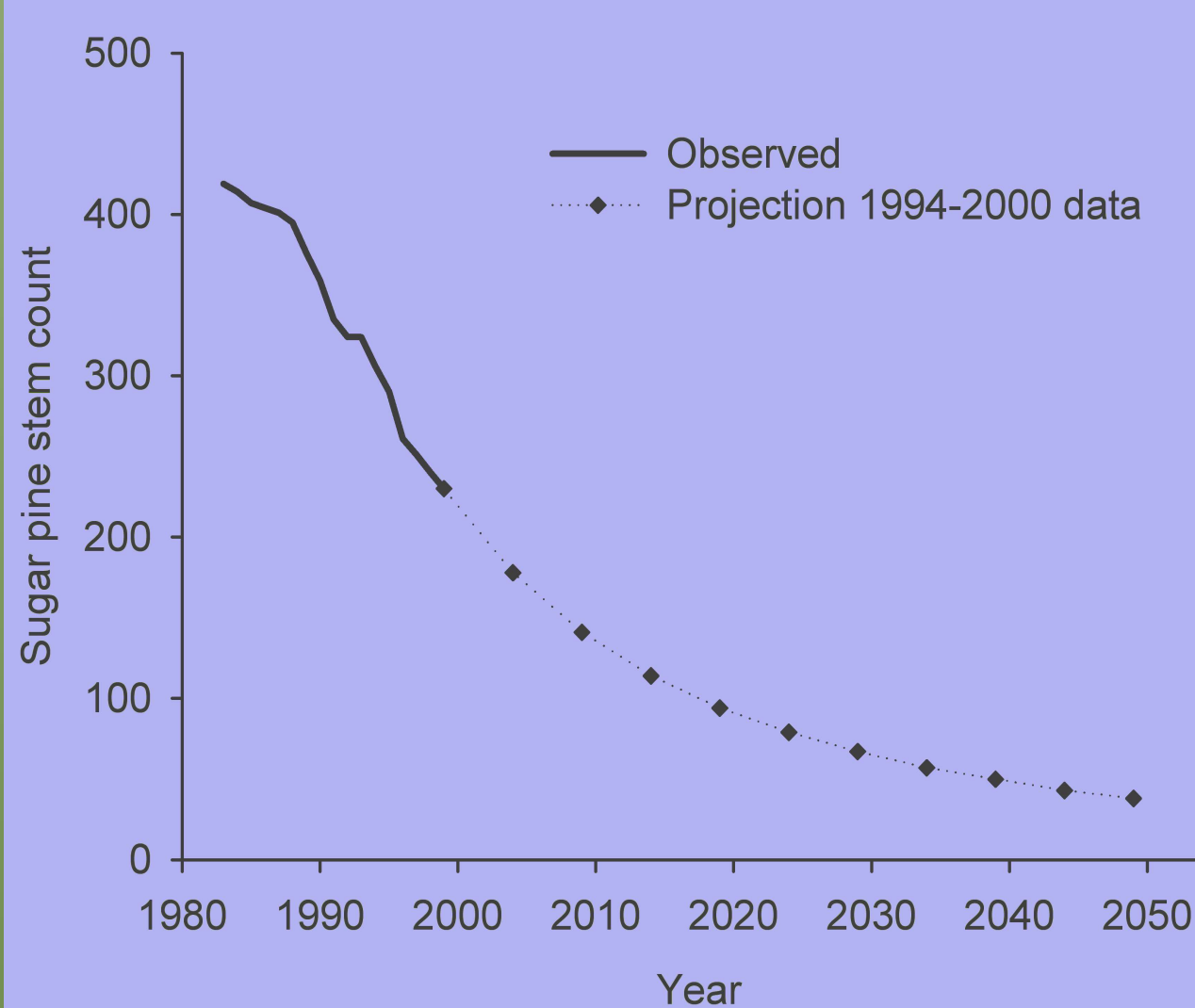
To date, climatic variability has had minimal effects on forests of this region, although some data suggest that upright growth of krummholz trees may be increasing near altitudinal treeline. Elevated nitrogen deposition at high altitude is already affecting aquatic systems, and may also have a subtle, but long-term effect on subalpine forests. Increased foliar and soil N, as well as increased microbial mineralization have been documented in high nitrogen deposition areas. Like forests throughout the West, fire exclusion has increased stand density and fuel loading in lower elevation mixed conifer forests.

Four sites in CO and WY that show increasing N concentrations and deposition over time. Data are from the NADP program.



Sierra Nevada

Mixed conifer forests in the Sierra Nevada have also experienced drought stress in recent years, with considerable mortality in some areas. These forests are particularly susceptible to large fires because of the additional effects of fire exclusion on stand density and fuel accumulation. Also, elevated tropospheric ozone reduces vigor and increases litterfall in ponderosa pine and Jeffrey pine. Finally, the exotic white pine blister rust has caused mortality of sugar pine and increased canopy and surface fuels. Paleocological data suggest that a warmer climate may cause treeline to rise significantly at some locations.



The majestic sugar pine (*Pinus lambertiana*) is declining in the Sierra Nevada, probably due to combined effects of air pollution, increased forest density resulting from fire exclusion, and an introduced pathogen (white pine blister rust). The graph shows observed decline in the Suwanee Creek area of Sequoia National Park, with future decline projected using a matrix model based on observed growth and demographic rates.

Northern Rocky Mountains

Similar to the Pacific Northwest, this region also is experiencing rapid establishment of subalpine forests in meadows. Although the location of altitudinal treeline has not changed in response to climate, there is currently a trend of more upright growth of trees from previous krummholz (shrubby) form. Tree regeneration and growth in this location are also strongly affected by the PDO, with growth and regeneration being high during warm phases of PDOs (less snow) and low during cool phases (more snow). Crown fire has spread through a large portion of lower elevation forests during the past decade.



Pacific Northwest

Current evidence of stress mostly exists on the east side of the Cascade Range, where large areas of semiarid forests dominated by ponderosa pine have experienced beetle outbreaks. These forests have high stem density and low vigor, predisposing them to the effects of drought on insects and large crown fires. Increased temperature and periods of low snow have resulted in rapid establishment of tree seedlings at higher elevations in subalpine forests, where regeneration is mostly limited by duration of snow pack. Periods of lower snow also result in faster growth of subalpine trees in all but the driest locations. Tree regeneration and growth are strongly affected by the PDO, with growth and regeneration, especially at the highest, coldest sites, being high during warm phases of PDO (less snow) and low during cool phases (more snow).



Summary – Forests in a Greenhouse World

The most important effects of future increases in temperature will be:

- Altered and accelerated disturbance regimes, especially fire and insects
- Changes in growth and productivity
- Changes in distribution and abundance of dominant species

Even a small increase in temperature will increase area burned by wildfire throughout Western mountains. Forests whose fire cycle has been disrupted by fire exclusion may burn more intensely or frequently, or both, swamping more subtle changes in growth and regeneration. Fire and all other ecological factors will continue to be modulated by various modes of climatic variability, such as the PDO.

Effects of significant changes in the amount and seasonality of precipitation would be greater than that of temperature increase alone, because most Western forests are limited by water – too little in arid locations, too much in high-snow locations. It is also possible that exotic species and multiple stressors (e.g., drought + insects + fire) will cause rapid and irreversible change in some forests. The effects of elevated CO₂ and N on ecosystem productivity are “wild cards” due to lack of empirical data on mature forests.