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Management of Forests and Woodlands

Climate Change and Variability in the Southwest Ecosystem Series

Management decisions in the past have left some forests and woodlands in the Southwest with high tree densities, making them more susceptible to bark beetle outbreaks and stand-replacing wildfires (Covington and Moore 1994a, 1994b; Kolb et al. 1994). Forest stands with an unnaturally high density of trees and biomass (i.e., collective dry weight) can experience increased mortality during periods of low precipitation and potentially could be negatively affected by even slight increases in average temperature during the growing season (Kolb et al. 1998, Covington et al. 1997).

Although there is a large degree of uncertainty about how precipitation regimes will change with global warming, climate models generally agree that there will be higher temperatures and an increase in the variability of precipitation in North America (IPCC 2001), which is already high in the Southwest (Sheppard et al. 2002). These climatic changes will have severe impacts on forest communities, in that water availability is the most limiting factor to tree growth and reproduction in the Southwest (Adams and Kolb 2005). Increasing temperatures can reduce water availability to plants through increasing evaporation rates, while increased variability in precipitation may increase the frequency of drought. Increasing temperatures already are being linked to an increase in the number of acres burned in western wildfires, particularly in some mid-elevation Rocky Mountain forests (Westerling et al. 2006). Model projections predict rising temperatures will further increase the number of days of high fire danger in the western United States (Brown et al. 2002) and the frequency of and number of acres burned in global wildfires (Price and Rind 1994). This, in turn, will lead to an increase in efforts to restore large areas.

Decisions on restoration in the Southwest will be increasingly challenging due to predicted changes and disturbances in climate regimes. Models predict numerous changes in species and habitat at the regional scale, but these predictions are difficult to translate into local management practices. Reforestation in the Southwest already is challenging due to dry spring conditions in most years, though foresters like to have vegetation in place before monsoonal rains increase the risk of erosion. As the Southwest becomes even warmer, reforestation efforts after stand-replacing fires and other large-scale disturbances will become even more challenging.

Effects of Climate Change on Wildfires

Many forests will become increasingly susceptible to wildfires as a result of increased temperatures and reduced precipitation. For Southwest ponderosa pine communities, large fires are more prevalent now than in the past based on historical records (Swetnam 1990, Dahm and Geils 1997, Swetnam and Betancourt 1998, Westerling et al. 2006). However, past and present forest management practices such as fire suppression, grazing and timber harvesting can complicate the interpretation of this observed increase in the context of climate (Swetnam and Betancourt 1998, Lenart 2006).

Management practices like timber harvesting can reduce wildfire hazard in certain forest types, such as ponderosa pine (Strom 2003). For instance, Fiedler et al. (2002) found that reducing a stand's basal area — i.e., total cross-sectional area of the tree in square feet measured at breast height — to 50 square feet per acre could reduce the risk of crown fire to a "low" hazard rating. Reducing a stand's basal area to 80 square feet per acre generally left the stand in a "moderate" hazard condition. However, the U.S. Forest Service generally receives little additional federal funding for large-scale thinning projects despite the 2003 passage of the Healthy Forests Restoration Act, funding generally comes from existing regional budgets (Lenart 2006). In addition, it remains challenging to convince homeowners of the importance of thinning the stands on their own property in many wildland-urban interface areas. The forest managers of the Rural Communities Fuels Reduction Partnership in northern Arizona have observed that most homeowners are willing to reduce fire hazard, but are rarely willing to reduce stand basal area to 50 square feet per acre (Art Matthias, Coordinator, pers. comm.).

Effects of Climate Change on Species Composition

Land managers may need to decide whether to try to re-create formerly existing ecosystems or to anticipate which species will thrive under the changing climate and manage for them instead. If the new climate is wetter and warmer, it may be possible to select genotypes (varieties of the same species) that will do well with the new conditions. If it is warmer without increased precipitation, then it may be that different plant communities will replace some ecotones. Woodlands may replace forests, or grasses and shrubs may replace forests and woodlands.

Changes in fire and climate patterns will affect plant species in several ways. Plant species have different tolerances to drought; temperature, including extremes; frost occurrence and duration; snow cover (or lack of it); soil moisture; and fire exposure and intensity. Many of these factors will directly influence plant growth, seed and fruit production, and seedling recruitment and survival. As a result, changes in these factors with global warming will alter the composition of plant communities across the Southwest.

Global warming in the Southwest, with its profound elevational gradients, will likely drive elevational shifts in tree species distribution and could lead to the loss altogether of species at the higher elevations. When a species dies out at a higher elevation that has become too warm and/or dry for its competitive survival, it will leave habitat for bordering species to move upward in elevation and occupy a site that prior to warming was too cold for survival. For instance, piñon pine (*Pinus edulis*) may move upward in elevation to occupy sites now supporting ponderosa pine (*P. ponderosa*) when drought and high temperatures take their toll. These species intermingle at the upper elevation range of piñon and the lower elevation range of ponderosa.

Effects of Climate Change on Insect Outbreaks

Insects can have undesirable effects on forests and woodlands during outbreaks when their population abundance and densities are high. Global warming will likely change the frequency patterns of disturbance from insects by lengthening the frost-free season, impacting insect development and survival rates, reducing tree defenses via drought, and changing the abundance of natural enemies, competitors and microbes associated with insects (Ayers and Lombardero 2000). Higher elevation forests on Arizona's Mount Graham and other peaks in the Pinaleño Mountains were facing outbreaks in 2003 from a variety of insect pests, including newly arriving species such as the spruce aphid (personal communication, U.S. Forest Service entomologist Ann Lynch, as described in Lenart 2004).

There is evidence that temperature increases contributed to increased tree mortality in the Southwest in 2002-2003 from drought and herbivores like bark beetles (Breshears et al. 2005). The 1950s drought and subsequent beetle invasions caused ecotone shifts in the piñon-juniper woodland and ponderosa pine forest (Allen and Breshears 1998). Similarly, extreme drought between 2002 and 2004 resulted in ecotone shifts in habitat types from bark beetle outbreaks through much of the Southwest. For example, extremely dry conditions occurred during the winter of 2002 after three years of below-normal annual precipitation rates (Western Regional Climate Center 2005). This resulted in an abundance of beetle-susceptible trees and massive mortality in many piñon stands in Arizona and, to a lesser degree, ponderosa stands (USDA-FS 2004). It remains to be seen if piñon will move upslope where large areas of ponderosa died. Meanwhile, the widespread death of piñon has converted some piñon-juniper stands into juniper stands (Shaw et al. 2005), at least for the short term.

How will climate change affect land management?

Global warming will pose additional challenges for forest management. In addition to the challenges of dealing with increased pest outbreaks and changing wildfire patterns, climate change will influence decisions dealing with land productivity and grazing capacity; preservation of watersheds; maintenance of native flora and fauna; prevention and control of invasive species; and forest stand timber yield, stocking and density.

Many land management plans that are currently in place may not be appropriate in the near future. For instance, forest plans will have to be readjusted to prepare for unpredictable future land conditions. Managers will need to be flexible with regard to planning. A site that is currently productive may become more susceptible to fire, erosion or drying with increased warming.

Management responses to these challenges are complicated by restrictions set by local, regional, and national guidelines. National standards set by the National Fire Plan, the National Environmental Policy Act (NEPA), and the Endangered Species Act (ESA), for example, may restrict the ability of land managers to address shifting environmental conditions at the local scale in response to climate change. Furthermore, the general public and non-governmental organizational (NGOs) interest groups constrain ecosystem managers with concerns about fire risk, smoke, aesthetics of thinning, forest health and other forest-related issues.

Ponderosa pine forest stands of high density will likely face increased mortality from drought, insects, and catastrophic wildfires. Guidelines for thinning stands may not be adequate based on predicted climatic changes and management plans for particular sites. Managers may consider thinning to lower densities on all sites where available moisture goes down. For instance, thinning stands to basal area values of 50 square feet per acre or less, levels found in some ponderosa pine forests before the influx of European settlers, would improve stand resiliency to drought while decreasing the risk of crown fire. As temperature and evaporation rates increase, forests maintained in a less dense conditions will likely be more resistant to both insects and fire than those with higher density conditions.

Along with thinning, managers may consider establishing, within existing or rehabilitated stands, smaller populations of species deemed likely to thrive within the future climate. Sites that may be more resilient to change, such as those with deeper, moisture-holding soils, may serve as long-term refuges for local species from which populations could expand if surrounding conditions became favorable again. The species composition of some less resilient sites (i.e., those on the edges of ecotones or otherwise more susceptible to climate change) may well change regardless of management efforts.

Maintaining a diversity of landscapes and natural communities is a good strategy to prepare for changing environmental conditions (Allen et al. 2002). A diverse landscape will allow for species to shift, establish, and acclimate to potentially suitable sites as environments change.

What additional research is needed?

There are many areas in which we lack adequate information in order to make management decisions. Some of these topics include:

Plant selection and productivity: What tree species or mosaic of species will best grow on particular sites? What are our options? More baseline data specific to the Southwest is needed on genotypes, varieties, species or mixes of species that will thrive under particular climate conditions within the margins of interspecific competition.

Wood market and products: Improved methods to develop markets for future wood products, particularly for small-diameter wood and other non-traditional products.

Thinning guidelines: How will stands under different thinning regimes respond to climate variability and change, as well as other factors such as invasives and wildfire? What other options are there to reduce drought impacts and decrease the probability of wildfires?

Spatial scale: Improved assessments and efforts to link local information to landscape scales. For instance, how do managers incorporate ideas tested on 10 or 100 acres to 1,000 or 10,000 acres?

Models of future environmental conditions: What will local site conditions be like in five, 10, or 15 years? Will wildfires be more frequent, greater in magnitude, and more intense within particular sites or regions? A better understanding of the rate of warming and environmental trends could help guide management.

Further information on this topic can be found at the following sources:

Ecological Restoration Institute's series of Working Papers in Southwest Pine Forest Restoration. Northern Arizona University, Flagstaff, AZ.

Friederici, P., editor. 2003. Ecological restoration of southwestern Ponderosa pine forests. Island Press, Washington DC. 561 pp. (ISBN 1-55963-652-1)

Greenpower Institute paper describes the value of using trees for biomass energy production. http://www.thegreenpowergroup.org/

Northern Arizona University, School of Forestry, Flagstaff, AZ.

Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ.

Society of American Foresters, Journal of Forestry.

U.S. Forest Service Rocky Mountain Research Site has a variety of publications available, many of them as downloadable pdf files. http://www.fs.fed.us/rm/publications/index.shtml

U.S. Forest Service, local offices and the regional office in Albuquerque, NM.

White Mountain Apache Tribe website map showing how thinning treatments affected the spread of the Rodeo-Chediski fire: http://www.wmat.nsn.us/lgprogmap.html

Bibliography

Adams, H.D. and T.E. Kolb. 2005. Tree growth response to drought and temperature along an elevation gradient in a mountain landscape. Journal of Biogeography 32:1629-1640.

Allen, C.D. and D.D. Breshears. 1998. Drought-induced shift of a forest-woodland ecotone: Rapid landscape response to climate variation. Proceedings of the National Academy of Sciences USA 95:14839-14842.

Allen, C.D., M. Savage, D.A. Falk, K.F. Suckling, T.W. Swetnam, T. Schulke, P.B. Stacey, P. Morgan, M. Hoffman, and J.T. Klingel. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: A broad perspective. Ecological Applications 12(5):1418-1433.

Ayers, M.P. and M.J. Lombardero. 2000. Assessing the consequences of global change for forest disturbance from herbivores and pathogens. Science of the Total Environment 262:263-286.

Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Myer. 2005. Regional vegetation die-off in response to global-change-type drought. Proceedings of the National Academy of Sciences 102:15144-15148.

Brown, T.J., B.L. Hall, and A.L. Westerling. 2003. The impact of twenty-first century climate change on wildland fire danger in the western United States: an applications perspective. Climatic Change 62: 365-388.

Covington, W.W. and M.M. Moore. 1994a. Southwest ponderosa forest structure and resource conditions: changes since Anglo-American settlement. Journal of Forestry 92:39-47.

Covington, W.W. and M.M. Moore. 1994b. Post-settlement changes in natural fire regimes and forest structure: ecological restoration of old-growth ponderosa pine forest. Journal of Sustainable Forestry 2:153-181.

Covington, W.W., P.Z. Fule, M.M. Moore, S.C. Hart, T.E. Kolb, J.N. Mast, S.S. Sackett, and W.R. Wagner. 1997. Restoring ecosystem health in ponderosa pine forests of the southwest. Journal of Forestry 95(4):23-29.

Dahm, C.W. and B.W. Geils. 1997. An assessment of ecosystem health in the Southwest. U.S. Forest Service General Technical Report RM-GTRH-295.

Fiedler, C.E., C.E. Keegan III, S.H. Robertson, T.A. Morgan, C.W. Woodall, and J.T. Chmelik. 2002. A strategic assessment of fire hazard in New Mexico, final report submitted to the Joint Fire Sciences Program, February 11, 2002, in cooperation with the USFS Pacific Northwest Research Station.

IPCC (Intergovernmental Panel on Climate Change) (2001). *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the IPCC*, Edited by J.T. Houghton et al. Cambridge: Cambridge University Press. Available online at: http://www.ipcc.ch/pub/reports.htm .

Kolb, T.E., M.R. Wagner, and W.W. Covington.1994. Concepts of Forest Health. Journal of Forestry 92(7): 10-15.

Kolb, T.E., K.M. Holmberg, M.R. Wagner, and J.E. Stone. 1998. Regulation of ponderosa pine foliar physiology and insect resistance mechanisms by basal area treatments. Tree Physiology 18: 375-381.

Lenart, M. 2004. Beetles devastate forests in response to drought. Pages 2-4 of May 2004 Southwest Climate Outlook, a publication of the University of Arizona's Climate Assessment for the Southwest available at the following website: http://www.ispe.arizona.edu/climas/forecasts/swarticles.html

Lenart, M. 2006. Collaborative stewardship to prevent wildfires. Environment 48(7): 8-21.

Price, C. and D. Rind. 1994. The impact of a 2 X CO2 climate on lightning-caused fires. Journal of Climate 7: 1484-1494.

Shaw, D.J., B.E. Steed, and L.T. DeBlander. 2005. Forest inventory and analysis (FIA) annual inventory answers the questions: What is happening to pinyon-juniper woodlands. Journal of Forestry 103:280-285.

Sheppard, P.R., A.C. Comrie, G.D. Packin, K. Angersbach, and M. K. Hughes. 2002. The climate of the US Southwest. Climate Research 21:219-238.

Swetnam, T.W. 1990. Fire history and climate in the southwestern United States. Pages 6-17 in J.S. Krammes, technical coordinator. Proceedings of symposium on effects of fire in management of southwestern U.S. natural resources, November 15-17, 1988, Tucson, Arizona. U.S. Forest Service General Technical Report RM-GTRH-191.

Swetnam, T.W. and J.L. Betancourt. 1998. Mesoscale disturbance and ecological response to decadal climate variation in the American Southwest. Journal of Climate 11:3128-3147.

Strom, B.A. 2005. "Pre-fire Treatment Effects and Post-fire Forest Dynamics on the Rodeo-Chediski Burn Area, Arizona," Thesis for master of science in forestry, Northern Arizona University. Posted at the following website: https://library.eri.nau.edu:8443/bitstream/2019/269/1/StromNAU2005.pdf (Last accessed September 10, 2006).

U.S. Department of Agriculture Forest Service. 2004. Forest insect and disease conditions in the southwestern region, 2003. USDA Forest Service Southwestern Region R3-04-02.

Westerling, A. L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increases western U.S. forest wildfire activity. Sciencexpress 6 July 2006/1-10.1126/science.1128834.

Western Regional Climate Center. 2005. http://www.wrcc.dri.edu/summary/climsmaz.html

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THE UNIVERSITY OF ARIZONA
COLLEGE OF AGRICULTURE AND LIFE SCIENCES
TUCSON, ARIZONA 85721

TOM DEGOMEZ
Associate Specialist, Natural Resources
MELANIE LENART
Research Associate with ISPE, Institute for the Study of Planet Earth

This information has been reviewed by university faculty.
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