The Past and Future of Rocky Mountain Forests: Connecting People and Ecology

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The Forests

The Rocky Mountains form the backbone of the North American continent, separating waters flowing eastward to the Atlantic and westward to the Pacific. The mountain range reaches from northern New Mexico in the south to Alberta and British Columbia in the north, with elevations ranging from 1500 to 4300 m. The forests found in this extensive segment of the continent vary substantially, from semi-arid woodlands of juniper and pinyon pine at lower elevations to the south, to boreal spruce and alpine ecosystems at high elevation and to the north (Peet 2000).

Colorado sits near the southern end of the Rocky Mountains. The major issues that will shape the future of Rocky Mountain forests are shared across the range, so the situations in Colorado can be expanded to a larger scale.

The six major forest types were shaped to varying extents by the frequency and severity of fire (Fig. 1). Lower elevation forests are frequently dry enough to burn, and lightning storms are common. However, the continuity of fuels in the driest pinyon-juniper woodlands does not support the frequent, extensive fires carried by the well-developed grass and shrub understories in the ponderosa pine forests. Higher forests are generally too humid to burn, except during once-a-century droughts. The highest elevation forests burn at intervals of several centuries, if at all. Other disturbance factors have been important in these forests, including bark beetle outbreaks and severe windstorms (especially at higher elevations) (Veblen et al. 1994).

Colorado has 8.6 million ha of forests with public lands comprising about two-thirds of the forested area. Over 200,000 private land owners control 3.5 million ha; the proportion of private forest land is much greater at lower elevations. At the level of the entire state, the forests are changing rapidly. The standing growing stock of wood has increased by more than 40% over the past 50 years, to the current level of 500 million m³. The rate of forest harvest fell by more than 80% in the 1990s,
in part as environmental issues took precedence over timber harvesting goals for public lands. The forestry industry infrastructure contracted substantially, with only one major mill still operating in Colorado. Current harvests now represent less than 5% of annual growth.

This dramatic increase in wood content of Colorado forests also represents a major increase in potential fuels for wildfires, particularly at lower and mid elevations. The cessation of periodic fires allowed the density of some ponderosa pine forests to increase very dramatically (Colorado Forest Restoration Institute; http://www.cfri.colostate.edu/docs/cfri_ponderosa.pdf)(Fig. 2). Fire regimes have been less altered from historic patterns at higher elevations, but the low rates of forest harvest combined with natural stand development led to extensive landscapes occupied by old forests. For example, more than half of the lodgepole pine forests are over a century old, and only 7% of the forests are under 60 years old. The susceptibility of forests to insects and diseases often increases with stand age, and Colorado is experiencing a massive mountain pine beetle outbreak with more than 80% mortality of old trees across entire landscapes (more than 400,000 ha statewide). Warm and dry weather may also have fostered the population explosion of mountain pine beetles (Colorado Forest Restoration Institute; http://www.cfri.colostate.edu/docs/cfri_insect.pdf).

In the 1990s, foresters were concerned that normal stand development was increasing the proportion of conifer forests in Colorado at the expense of aspen (Shepperd et al. 2001). A sudden, widespread death of old aspen trees broadened concerns about the current condition and future of aspen forests. In the past 5 years, the majority of old aspen trees died across 130,000 ha. Younger aspen trees were less affected, and aspen regeneration may be high enough to recover the forests.
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if browsing by elk (same species as red deer in Europe) is not severe. The cause of the sudden aspen decline is not known with certainty, but extremely dry and hot conditions in 2002 to 2004 are suspected (Colorado Forest Restoration Institute; http://www.cfri.colostate.edu/docs/aspen_change.pdf). At the same time, many pinyon-juniper woodlands shifted to primarily juniper woodlands, as the less-drought-tolerant pines died on hundreds of thousands of hectares.

People and communities

The population of Colorado increased from two million in 1970 to five million in 2008, a rate of population growth of 2.5% annually. Colorado has attracted new residents with a desirable climate (almost 300 days of sunshine, moderate winters and summers), dramatic scenery (more than 50 peaks taller than 14,000 feet (4270 m)), and moderately strong economy. None of these factors is likely to change, so rapid population growth will likely continue.
Historically, people were concentrated in the major cities and towns at lower elevations, but the recent influx of people led to major increases in the numbers and density of forest residents. Most forest development has occurred at lower elevations, where the risks of wildfire are particularly severe. In 1960, Colorado had 475,000 ha of low density residences (1 to 10 houses/ha). This value rose to over 150,000 ha in 2000, and will likely growth to 200,000 to 300,000 within one to several decades. A “wildland-urban interface” (WUI) can be estimated, accounting for the proportion of this low-density development that occurs in the mountains (not including the plains), and the area within 1.5 km of houses. In 2005, the WUI comprised more than 300,000 ha, and this area is expected to triple by 2030 (D. Theobald, unpublished information; http://www.nrel.colostate.edu/~davet/wui.html).

Climate

Climate warming in Colorado was complex in the 20th century. Across the state, spring temperatures rose by about 1°C from 1950 to 2000 (climate information from Wolter and Doesken, 2006; http://www.colorado.edu/resources/klaus.wolter.Colorado.temps%20v2.pdf). The rate of warming appeared to accelerate in the past 30 years, although the change in the rate of warming was not statistically significant. In the southwestern part of the state, with the highest mountains and largest snowfall, springtime maximum temperatures increased by about 2°C from 1950 to 2000; summer maximum temperatures cooled by about 1°C, and winter and autumn maximum temperatures showed no trends. Similarly, springtime minimum temperatures rose by about 2°C from 1950 to 2000, with little change in minimum values for other seasons.

Precipitation is far more variable than temperature at times scales of years and decades. The coefficient of variation in precipitation is about 15% for Colorado, and droughts are common. More than half the state experiences a substantial drought every 20 to 30 years, with droughts typically lasting one to 5 years. High variation among years and decades makes it difficult to detect long-term trends, but at least some mountain locations saw a 20% decline in precipitation through the 20th century.

These trends in temperature and precipitation have led to substantial changes in Colorado’s hydrology. The rise of rivers with snowmelt in the spring shifted about 5 to 10 days sooner by the end of the 20th century, and the peak in snowmelt occurs one to two weeks sooner (Stewart et al. 2005). However, the implications of climate
changes are unclear for Colorado forests. Warmer temperatures might be expected
to increase drought stress on trees, but across the state the potential evapotranspiration showed a declining trend in the late 20th century as a result of increased relative humidity and lower surface wind speeds. Weather affects more than just the water physiology of trees; warmer winter temperatures may play a role in supporting higher populations of forest insects such as mountain pine beetles, with major impacts (and legacies) on forest ecosystems.

Connections

Forests, people, and climate connect in simple and complex ways. The historic conditions in forests resulted largely from interactions with climate, including drought years where large proportions of landscapes burned. Humans and livestock reduced fire frequency and extent in the 20th Century, but the continued accumulation of unharvested forest biomass may lead to more extensive and severe fires when droughts occur. Even in the absence of fire, droughts and changing temperatures may combine to stress trees and favor bark beetles and other mortality agents.

Climate-driven changes in forests also connect to concerns about water yields and economies. Colorado’s mountain economies rely heavily on tourism, and winter sports are particularly important. A projection of impacts for the ski resort in Aspen, Colorado included later development of snowpack (and onset of skiing season) by 2 weeks by 2030, along with thinner snowpacks, increased snowpack density (and poorer quality skiing), and four week sooner melting in spring (Aspen Global Change Institute 2006). These climate-driven changes might reduce the economic value of the ski industry by more than 50% in the next 20 years.

The forests and communities of the Rocky Mountains have undergone profound changes over the past 2 centuries, as a result of changes in population, cultures, policies, land management, and climate. In the past ten years, a variety of place-based citizen collaborations developed around Colorado, aiming to improve management of public lands, as well as the integration of land management into landscape-based approaches that encompass multiple ownerships (Colorado Forest Restoration Institute; http://www.cfri.colostate.edu/partners.htm). These collaboration groups will be fundamental to informing people (including forest managers) about changes in forests, and developing the social and political basis for active responses.

The forests of Colorado will be different in the 21st century, and climate changes may be a major contributor to a cascade of ecological and social interactions.
Table 1: Nine points uniting forests, people, and climate in Colorado

1. An intimate matrix of public and private lands complicates active forest management.
2. Colorado is an attractive place to live, and population growth averages 2.5% annually.
3. The increase in population has driven an even larger amount of new development of houses and towns in the mountain forests.
4. Development has led to a massive wildland-urban interface of 300,000 ha, and the WUI is likely to triple within 2 decades.
5. Colorado has six major types of forests, with varying natural histories and fire regimes.
6. One million ha of low-elevation forests pose a major fire risk as a result of a century (or more) without fires.
7. Most forest types are in a period of rapid change, from fires, bark beetles, and drought; the current changes may be driven partially by changing climate.
8. Changing climates will change the economic base of mountain communities, especially if snowfall lessens and snow pack melts sooner.
9. The future forests cannot be controlled by management, but place-based forest collaborative groups may play a major role in helping shape forest landscapes.

Forests commonly change at time scales of decades and centuries, and changes are not automatically good or bad. We may have the opportunity to influence some of these changes, so discussions about mountains, forests, and people will be the cornerstone for understanding, adapting, and influencing our future.

For more information:

Theobald, D. Land-use website (http://nrel.colostate.edu/~davet/)