

Impacts of Climate Change on Forests of the Northern Rocky Mountains



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Climate change will cause:

- *Rising temperatures*
- *Less snow, more rain*
- *Less water stored in snowpack*
- *Earlier spring snowmelt and peak runoff*
- *Lower stream flows in summer*

These changes will lead to:

- *Longer summer drought*
- *Increased water stress*
- *More insect infestations*
- *More intense wildfires*
- *Large economic impacts*

Sensitive Forests

The forests of the U.S. Northern Rocky Mountains are highly sensitive to projected climate change. Even under conservative projections of future climate change, dramatic effects on these forests are expected. Documented climatic changes in the last 50 years have significantly altered the conditions in which forests grow. Forests are already responding to observed climate change, and these changes are projected to intensify in the coming years.

Forests in relatively dry regions like the northern Rocky Mountains live in a perpetually water-limited state. During most of the growing season, when light and low temperatures do not limit growth, water is the most important limiting factor. Productivity depends on moisture conditions during the main part of the growing season. Spring, summer, and autumn temperatures, summer precipitation levels, and the previous winter's snowpack determine those moisture conditions.

Less Snow More Rain



Less Snowpack



Earlier Spring Snowmelt



Water Stress



Lower Streamflows



Climate projections for the northern Rocky Mountains over the course of this century include an annual average warming trend of 3.6 to 7.2°F. Lower emissions of heat-trapping gases will result in temperature increases near the lower end of this range and higher emissions near the higher end.

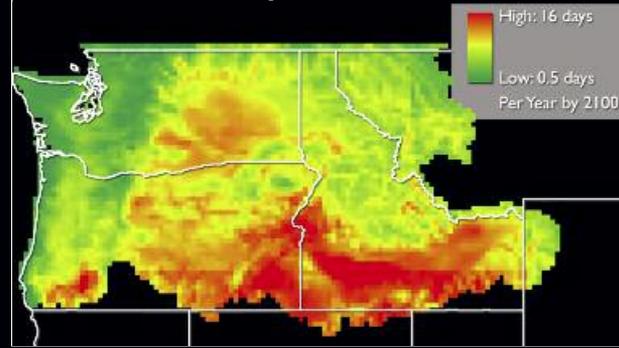
Water from Snowpack

Water stored naturally in snowpack in the Mountain West is very important. Up to 75 percent of all stream water originates from snowmelt. Further, cold-season processes play an important role in the development of summer drought and fire risk. This study confirms the well-documented shift toward earlier runoff in recent decades attributed to more precipitation falling as rain instead of snow, and earlier snowmelt. Climate models project a continuation of these trends with an average of one-month earlier peak snowmelt and a significant decline in the number of days with snow on the ground per year.

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Less snow is likely to increase the summer drought period, further increasing the number of days that trees experience water stress. At sites that presently depend on snowpack to maintain a forest canopy during summer months, models indicate that by the 2080s there would be little to no snowpack left.

Increase in Number of Atmospheric Moisture Stress Days



Key Findings

1. As temperatures rise, projected changes in Northern Rocky Mountain forests include fewer days with snow on the ground, earlier peak snowmelt, a longer growing season, and about two months of additional ecosystem drought stress each year by late this century.

2. Increasing drought stress will increase forest disturbances including insect epidemics and wildfires. These disturbances have large impacts on society and the natural world.

3. The economic impact of highest concern is the potential for a truly catastrophic wildfire in the region. There are now 360,000 people living in homes valued at \$21 billion in the forest-urban interface in this region that are directly vulnerable to wildfire.

4. If climate becomes drier, net carbon uptake would be reduced to the extent that most forests in the region would switch from absorbing carbon to releasing it by late this century.

Insect Infestations



Longer Summer Drought



Intense Wildfires



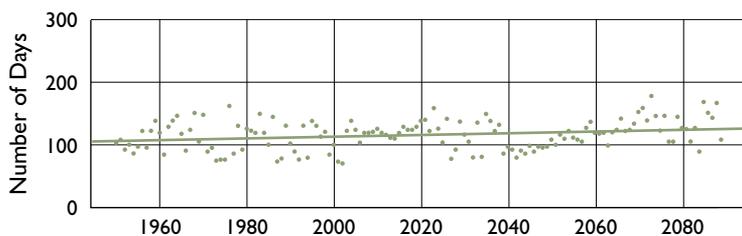


Future Climate Change

Climate projections for the northern Rocky Mountains over the course of this century include an annual average warming trend of 3.6 to 7.2°F. Lower emissions of heat-trapping gases will result in temperature increases near the lower end of this range and higher emissions near the higher end. Winter temperatures are projected to increase more than those in the other seasons. Precipitation, runoff, and streamflow patterns will also change, with both the amounts of water and the timing of runoff and streamflow being affected.

Over the course of this century, the growing season in the northern Rocky Mountains is expected to increase by about two months. Spring snowmelt will occur four to six weeks earlier, and the summer drought period will be six to eight weeks longer. The growing season will shift one to two months earlier in the spring. Late summer drought will be extended by six to eight weeks. One of the results of this extended drought will be an increased risk that small streams will dry up.

Projected Growing Season Increase at a High-Elevation Dry Site (Deer Point, ID)

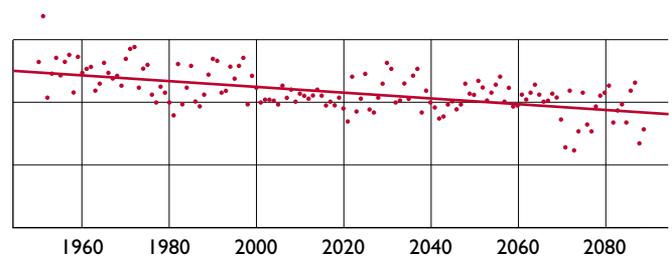


Forest Productivity

Warming increases growing season length, which is often associated with increased forest productivity, especially in high latitudes where temperatures constrain productivity in certain parts of the year, as is the case in this region. Under non-water-limited conditions, temperature is most likely a major driver of plant productivity. However, the longer and more intense summer drought period projected for this region limits the potential positive effects of a longer growing season.

A longer growing season and increased carbon dioxide in the air might be expected increase plant productivity and carbon uptake, but this study shows limited productivity increases and a one- to three-month increase in the number of days in which trees are water stressed across the region, despite increases in growing season length, suggesting that in these forest ecosystems, water availability is the main control on productivity.

Projected Snow Pack Decline at a High-Elevation Wet Site (Glacier, MT)



Projected growing season, water stress, and snow pack in the U.S. Northern Rockies based on projections from three climate models

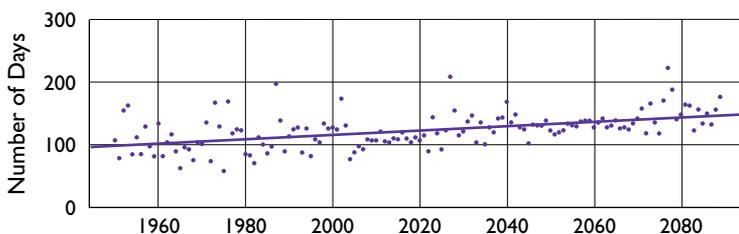


Forest Carbon Storage

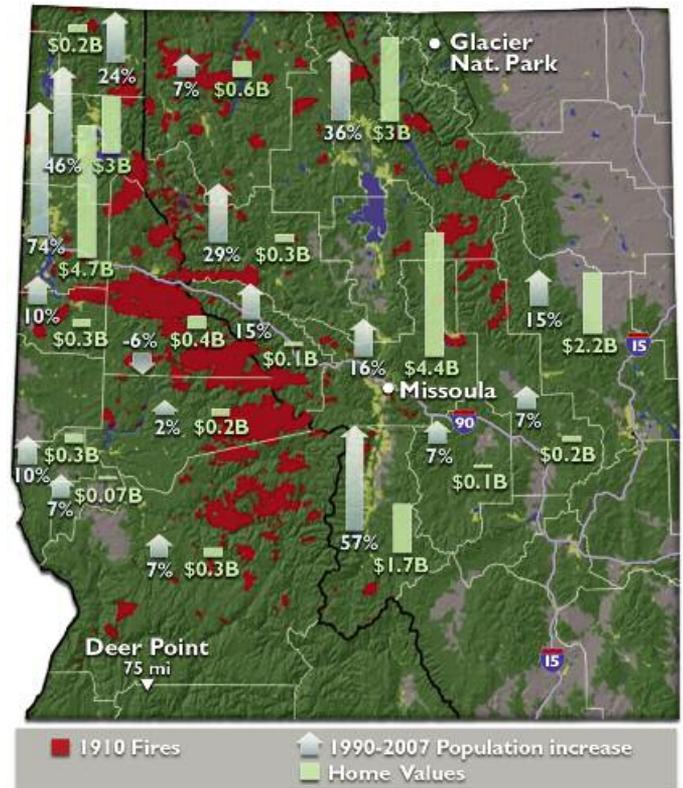
Some forests that are now net absorbers of carbon dioxide from the air on an annual basis may begin releasing carbon dioxide by the end of the century. This would occur as carbon released through plant respiration exceeds carbon taken up by photosynthesis during the longer drought season. Even more significantly, the potential for large scale insect outbreaks and wildfire will increase, causing even more carbon to be released and reducing the number of trees available to absorb carbon dioxide.

Pronounced declines in forest carbon uptake in parts of this region are projected, especially if climate becomes drier. Under drier scenarios, much of the region is actually projected to switch from absorbing carbon to releasing it – that is, becoming a carbon source rather than a carbon sink. This could have enormous significance given the importance of high-latitude mountainous forest sites in global carbon uptake.

Projected Increase in Water Stress at a Lower-Elevation Dry Site (Missoula, MT)



Increased Population and \$ Value at Risk to Wildfire



Limitations of the Study

Processes not yet included in the models, including disturbances such as fires, may initiate unforeseen feedbacks. Forests themselves have significant effects on the hydrologic cycle and atmospheric composition, but some key feedbacks are not considered in the current generation of climate models. Also not considered were changes in forest species composition, and changes in extremes of precipitation that may have potentially stronger effects on ecological systems than do changes in average conditions used in this study. Recently reported increases in drought-induced death of trees would also change the landscape and forest dynamics.

The omission that most affects this study is that of large-scale disturbances such as wildfires and insect outbreaks. These disturbances are already on the rise and are projected to increase further due to increases in the number of water-stress days and reductions in snowpack. Water stress levels and snowpack levels are the two main predictors of wildfire vulnerability and factors in insect outbreaks. Reduced winter precipitation and earlier spring snowmelt already contribute to the recent increase in large wildfire activity. The Northern Rockies forests are very sensitive to changes in the water balance. The impacts of disturbance in reducing carbon stocks and productivity have been demonstrated. The results of this study point toward increased fire and insect activity.

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