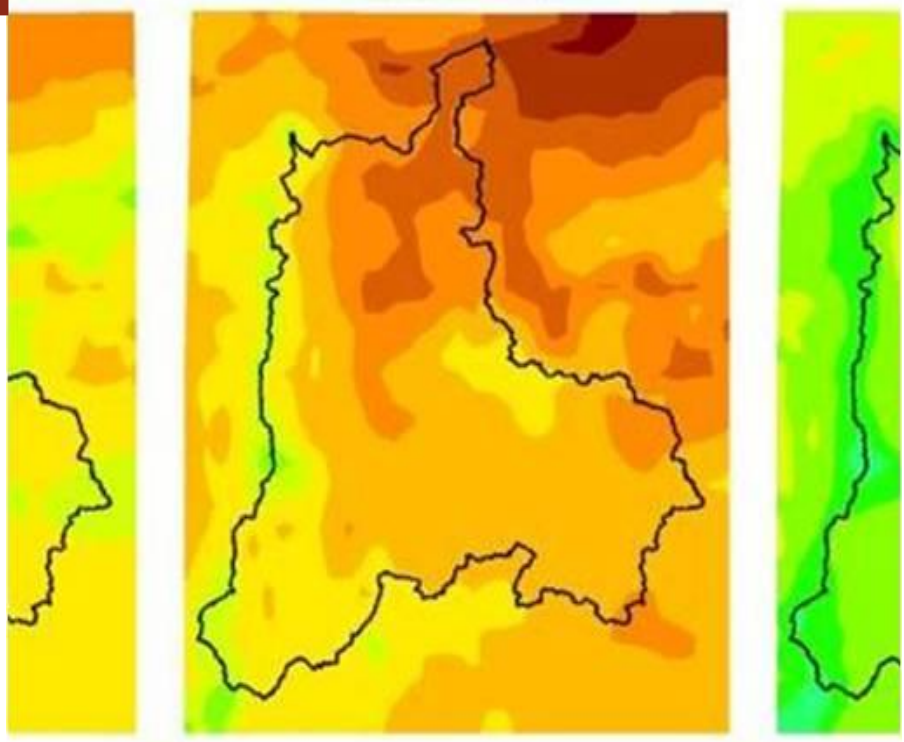
ClimateWise®

Helping communities prepare for a changing climate.

Projected Future Conditions and Sector Background Information for the Deschutes River Basin of Central Oregon



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Projected Future Conditions and Sector Background Information for the Deschutes River Basin of Central Oregon

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INTRODUCTION

The Deschutes Basin is one of the largest river basins in Oregon, draining 15,000 square miles and encompassing Crook, Deschutes, and Jefferson counties and portions of eight other counties. The basin's rich history, culture, and natural resources contribute to the quality of life for residents. Changes to this region are underway due to climate change, population growth, and shifts in the economy. The ClimateWise® process was created to help communities develop strategies that increase their resilience in the face of inevitable impacts of climate change.

Climatic changes are underway across Oregon and are likely to increase in the coming decades. These changes are likely to include more intense storms and floods, extended drought, increased wildfire, and more heat waves. These will affect native species, agriculture, forestry, and human health. Communities will need to plan for such changes to prevent potentially catastrophic consequences and/or declines in their quality of life.

This report provides (1) community members and decision-makers with local climate change projections, presented in a way to help make informed, long-term planning decisions and (2) background information on socioeconomic and natural systems, allowing readers to identify populations and resources that might be most vulnerable to impacts. By identifying vulnerabilities, local leaders and experts can develop sound strategies for preparing the Deschutes Basin and its residents for short- and long-term changes.

This report is the first step in the ClimateWise® process. It provides baseline information going into a workshop that will focus on identifying vulnerable resources and populations and developing strategies to reduce those vulnerabilities and allow for continued quality of life for residents. By developing cohesive strategies across both natural and socioeconomic systems, this process results in increased collaboration and communication within the region. Strategies developed in this process are expected to be ecologically sound, supporting important natural services (e.g., water filtration, flood abatement, livestock forage, fisheries, recreational opportunity, etc.).

Many of the impacts of climate change are inevitable due to current levels of greenhouse gas emissions already in the atmosphere. Preparing for these impacts to reduce their severity is called "adaptation" (see box below). Preventing even more severe impacts by reducing future emissions is called "mitigation."

MITIGATION: reducing the severity of climate change by reducing heat-traping emissions and increasing their removal from the atmosphere

ADAPTATION: reducing the vulnerability of natural and human systems to the impacts of climate change

MODELS AND THEIR LIMITATIONS

Climate change and its associated impacts mean the future is no longer expected to resemble the past. To determine what conditions we might expect in the future, climatologists created models based on physical, chemical, and biological processes that form the earth's climate system. These models vary in their level of detail and the assumptions upon which they are constructed. These differences stem from the range of understanding of some of the Earth's processes and feedback systems. Modeling differences result in variation among the model outputs and the future scenarios indicated (see insert "Climate Projection vs. Prediction vs. Scenario" to the right).

Most climate models project the future climate at global scales. For local managers and policymakers to make decisions, however, they need information about how climate change will impact their specific, local area. The MAPPS (Mapped Atmosphere-Plant-Soil-System) Team as the USDA Pacific Northwest Research Station adjusted global model output to a local scale (8 km x 8 km).

The Intergovernmental Panel on Climate Change (IPCC) uses numerous models to make global climate projections. The models are developed by different institutions and countries and have slightly different inputs or assumptions. The MAPSS Team chose three global climate models that offer a range of projections for temperature and precipitation. These three models are Hadley (HADCM, from the UK), MIROC (from Japan), and CSIRO (from Australia). These models include specific variables needed to run a vegetation model. Discussing the specific inputs is beyond the scope of this report, but they include such variables as greenhouse gas emissions, air and ocean currents, ice and snow cover, plant growth, particulate matter, and many others (Randall et al. 2007).

Model outputs were converted to local scales using fine-scale, historic data on temperature and precipitation patterns. The climate model output was applied to the MC1 vegetation model (Bachelet et al. 2001), which provided data on natural vegetation types that future climatic conditions might support, biomass consumed by wildfire, and carbon sequestration potential.

Climate projection
A model-derived estimate of the future climate.

Climate prediction or forecast
A projection that is highly certain based on agreement among multiple models.

Scenario
A coherent and plausible description of a possible future state. A scenario may be developed using climate projections as the basis, but additional information, including baseline conditions and decision pathways, is needed to develop a scenario.

Projection Certainty

HIGH:

Higher temperatures – Greater concentrations of greenhouse gases trap more heat. Measured warming tracks model projections.

Lower snowpack – Higher temperatures cause a shift from snow to rain at lower elevations and cause earlier snow melt at higher elevations.

Shifting distributions of plants & animals – Relationships between species distributions and climate are well documented.

MEDIUM:

More severe storms – Changes to storm patterns will be regionally variable.

Changes in precipitation – Current models show wide disagreement on precipitation patterns, but the model projections converge in some locations.

Wildfire patterns – The relationship between fire and temperature has been well documented, but other components also play a role (such as vegetation, below).

LOW:

Changes in vegetation – Vegetation may take decades or centuries to keep pace with changes in climate.

The utility of the results presented in this report lies in their ability to help communities envision what the conditions and landscape may look like in the future, including the magnitude and direction of change. Because model outputs vary in their degree of certainty, they are considered **projections** rather than predictions (see insert on previous page). Some model outputs, such as temperature, have greater certainty than others, such as vegetation type (see insert to the left).

Much of the uncertainty associated with model projections arises due to uncertainty in future greenhouse gas emissions. We urge the reader to keep in mind that results are presented here to explore the types of changes we may see; actual future conditions may be different from those depicted in this report.

Uncertainty associated with projections of future conditions should not be used as a reason to delay action on climate change.

The likelihood that future conditions will resemble historic conditions is very low,. Managers and policy makers are encouraged to begin to plan for an era of change, even if the precise trajectory or rate of such change is uncertain.

GLOBAL CLIMATE CHANGE PROJECTIONS

The IPCC (2007) and the U.S. Global Change Research Program (2009) agree that the evidence is "unequivocal", the Earth's atmosphere and oceans are warming due primarily to human activities (e.g., CO_2, methane, other greenhouse gas emissions, and deforestation). Average global air temperature has already increased by 1.4° F and is expected to increase by 3.5 - 11.5° F within the next century (Figure 1).

The IPCC emission scenario used in this assessment was the A2 model (Nakinovic et al. 2000), often referred to as the "business-as-usual" trajectory (Williams and Jackson 2007, Jylhä et al. 2008); this scenario assumes that most nations fail to lower their emissions and the recent historic trend continues. Recent growth in GHG emissions exceed A2 levels, meaning that projections and results presented in this report likely underestimate impact severity. Two of the three models we use in this report, however, provide some of the warmer projections for the Pacific Northwest. Reducing and stabilizing greenhouse gas (GHG) concentrations at lower levels will take decades (even with immediate, drastic emission reductions) due to their long-lived presence in the atmosphere. Reducing emission of these gases is vital to preventing the earth's climate system from reaching a critical tipping point, which may lead to sudden and irreversible climate changes. While mitigation is the ultimate remedy, planning for the inevitable local climatic consequences gives residents of the Deschutes Basin the best opportunity to maintain their quality-of-life as the climate changes.

Throughout this report we present mid- and late-century model outputs. Mid-century projections are highly likely, due to greenhouse gases already released, but late-century projections may change, depending on future emissions.

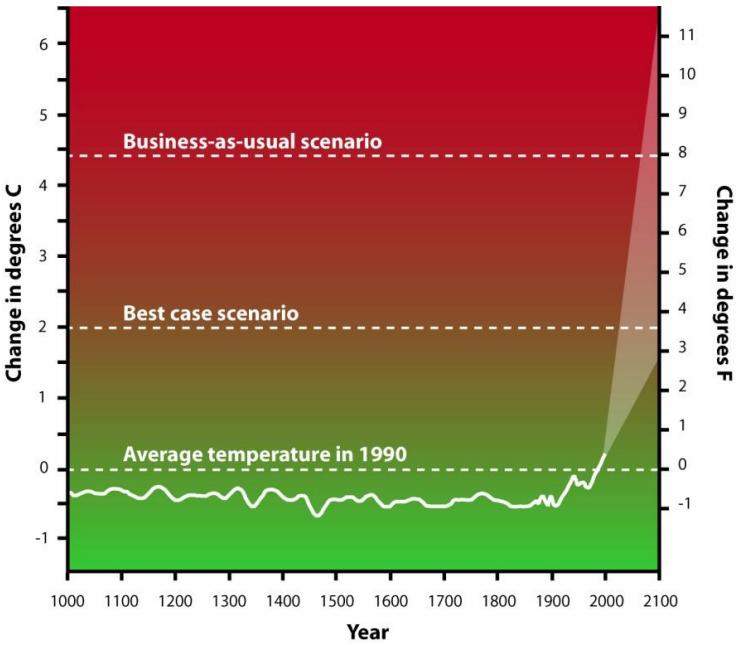


Figure 1. The last 1,000 years in global average temperatures compared to projected temperature trends through 2100. Drastic cuts in greenhouse gas emissions (best case scenario) would lead to an increase of about 3° F by 2100, while the current trajectory (business-as-usual) will lead to an increase closer to 8° F and as high as 11° F (adapted from IPCC 2007).

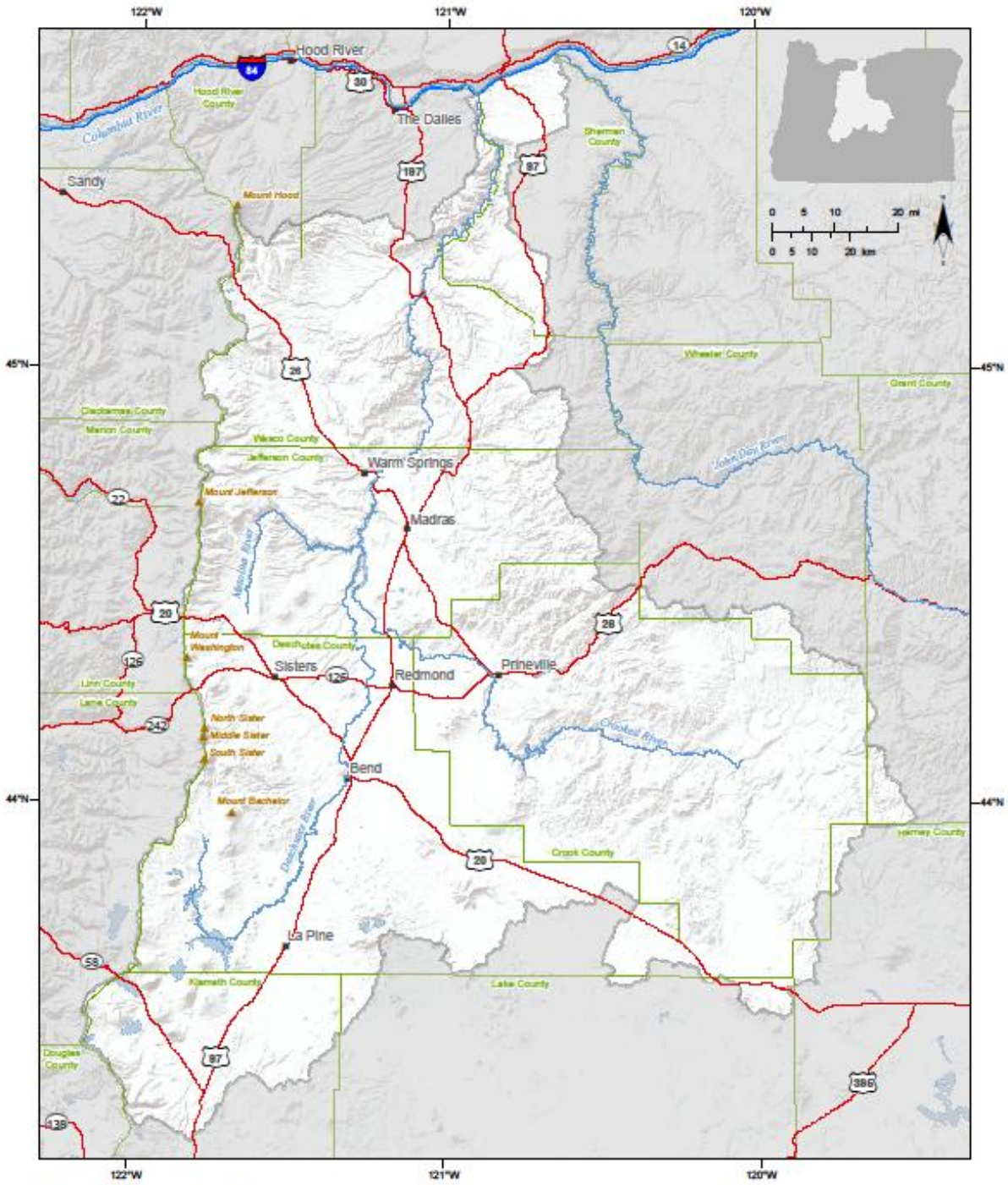
DESCHUTES BASIN PROJECTIONS

The Deschutes Basin falls predominantly within Crook, Deschutes, Jefferson, Sherman, and Wasco Counties (Figure 2). This report presents projected future climate conditions for the entire 10,500 square mile basin and focuses socioeconomic information on Crook, Deschutes, and Jefferson Counties.

Variables modeled using HADCM, CSIRO, MIROC, and the vegetation model (MC1) for the Deschutes Basin include temperature, precipitation, the distribution of growing conditions for predominant vegetation, wildfire, and carbon storage in biomass. These variables were calculated based on historical data for making baseline comparisons, and were projected out to the year 2100.

These projections represent a likely range of possible future conditions in the Deschutes Basin. As climate change plays out, we may experience surprises and unforeseen chains of cause-and-effect that could not have been anticipated or projected. However, as knowledge and understanding of these relationships increase, scientists may be able to make more certain projections.

Climate change projections are provided here in three different formats – as overall averages, as graphs that show change over time, and as maps that show variation across the region (but averaged across a number of years). We mapped climate and vegetation variables for the historical period (1961-1990) and for two future periods (2035 - 2045 and 2075 - 2085).



Deschutes Basin

Data Sources: ESRI
Created: 9/21/2010

Figure 2. Deschutes Basin, including predominant towns and major road infrastructure.

TEMPERATURE

Projections from all three models agree, with high certainty, on a warmer future for the Deschutes Basin (Table 1, Figure 4). Projected temperatures increase for each month in both future time periods (Figures 5, 6, and 7).

Table 1. Future average temperature increases in the Deschutes Basin, based on projections from three global climate models (CSIRO, HADCM, and MIROC). Future projected temperature is shown as change in degrees Fahrenheit, as compared to historic averages (1961-1990).

Season	Historic	2035-45	2075-85
Dec – Feb	30.7° F	+1.9 to +4.3° F	+4.9 to +7.7° F
Mar – May	42.4° F	+1.8 to +3.8° F	+3.5 to +7.6° F
Jun – Aug	60.3° F	+2.2 to +4.9° F	+6.8 to +13.2° F
Sep - Nov	45.6° F	+2.4 to +4.4° F	+6.2 to +9.7° F
Annual	44.7° F	+2.1 to +4.0° F	+5.4 to +8.7° F

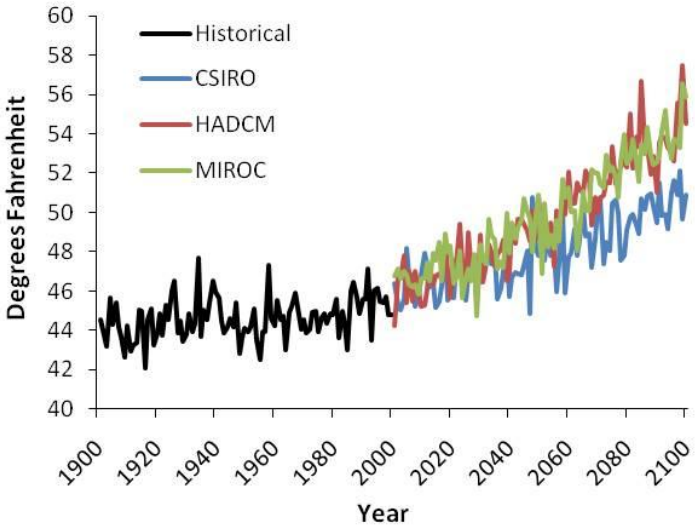


Figure 4. Average annual temperature (°F) across the Deschutes Basin from 1901 to 2000 (measured historical) and projected from 2001 to 2100 (using three global climate models).

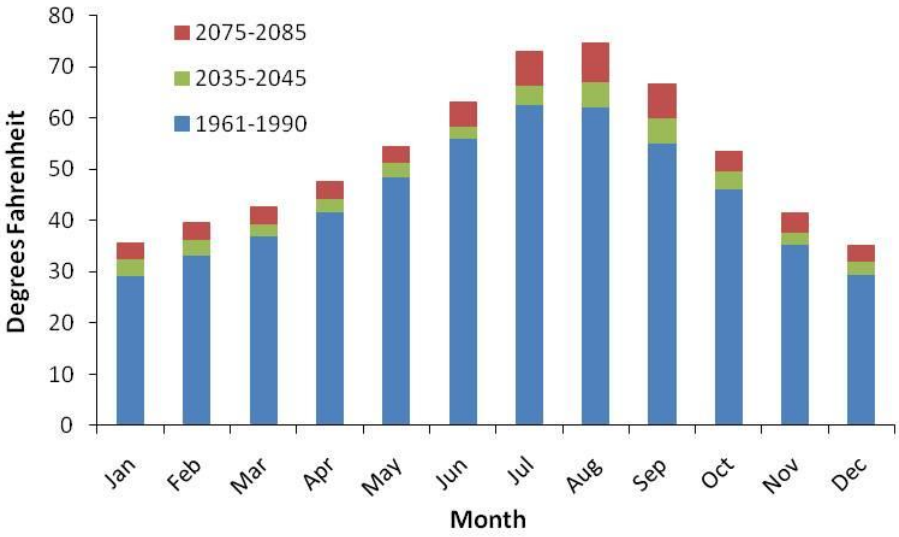


Figure 5. Average monthly temperature (°F) in the Deschutes Basin for two 11-year periods (2035 to 2045 and 2075 to 2085) as compared to the 30-year period from 1961 to 1990.

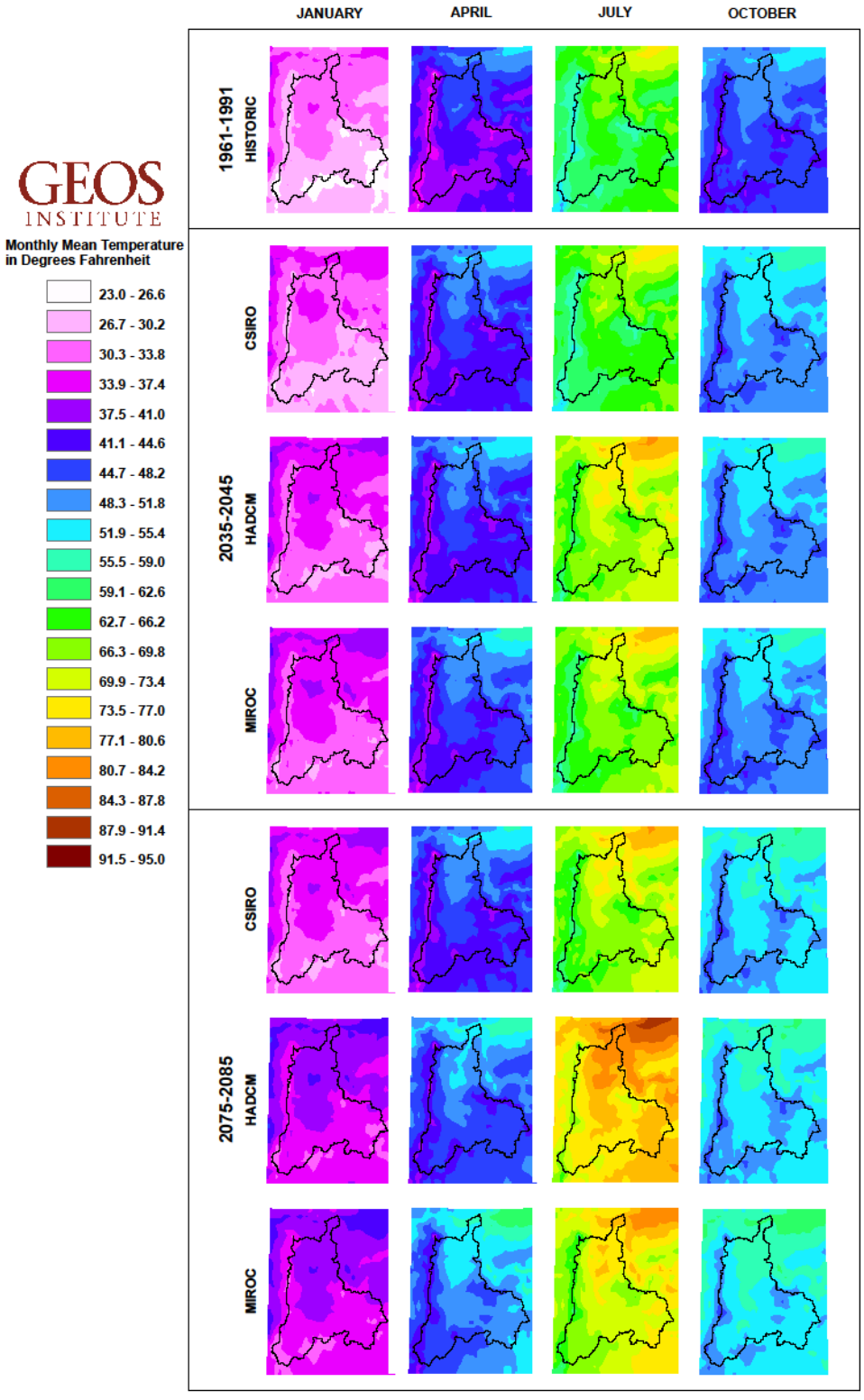


Figure 6. Average monthly temperature (°F) across the Deschutes Basin for three time periods: historical (1961 to 1990), near-term future (2-35 to 2045) and long-term future (2075 to 2085).

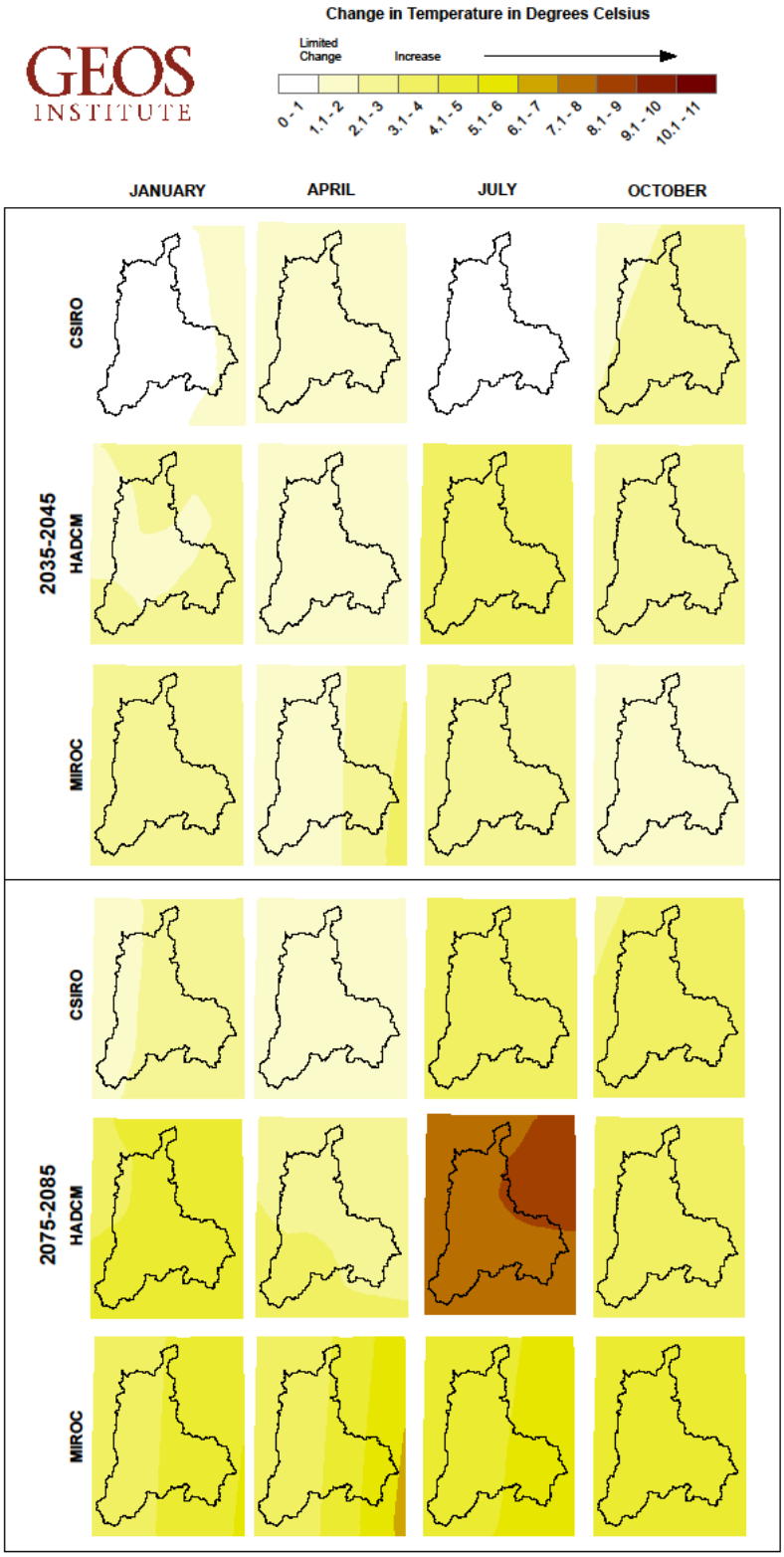


Figure 7. Change in projected average monthly temperatures (°F) from historic (1961 to 1990) to 2035 to 2045 and 2075 to 2085.

PRECIPITATION

Projections from the three models do not agree on future, annual precipitation patterns (Table 2, Figure 8). The model projections do agree that winters (December through February) will be slightly wetter in the future and that spring (March through May), summer (June through August), and fall (September through November) will be similar to somewhat drier over the near term (Table 2, Figure 9, 10, and 11). Projected precipitation patterns for these seasons in the long-term vary from wetter to drier without agreement (Table 2, Figure 9, 10, and 11). It should be noted that, even with substantial increases in precipitation, soil moisture may decline due to increased air temperature, evaporation, and water use by plants (Westerling et al. 2009).

Table 2. Future precipitation (inches) changes in the Deschutes Basin, based on projections from three global climate models (CSIRO, HADCM, and MIROC). Results are presented to show the full range of projections provided by the models.

Season	Historic	2035-45	2075-85
Dec – Feb	9.3”	+0.5 to +1.0” (+5 to +11%)	+0.3 to +2.2” (+3 to +24%)
Mar – May	5.3”	-0.5 to -0.3” (-9 to -6%)	-0.5 to +0.7” (-9 to +13%)
Jun – Aug	2.4”	-0.7 to 0.0” (-29 to 0%)	-1.0 to +0.5” (-42 to +21%)
Sep - Nov	5.8”	-1.3 to 0.0” (-22 to 0%)	-1.0 to +1.7” (-17 to +29%)
Annual	22.8”	-1.8 to +0.1 (-8 to 0%)	-1.7 to +5.1” (-7 to +22%)

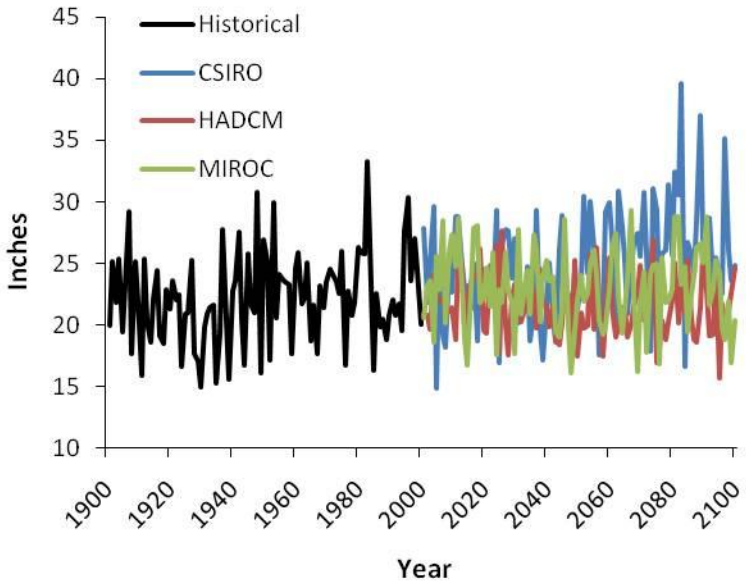


Figure 8. Average annual precipitation (inches) across the Deschutes Basin from 1901 to 2000 (measured historical) and projected from 2001 to 2100 (using three global climate models).

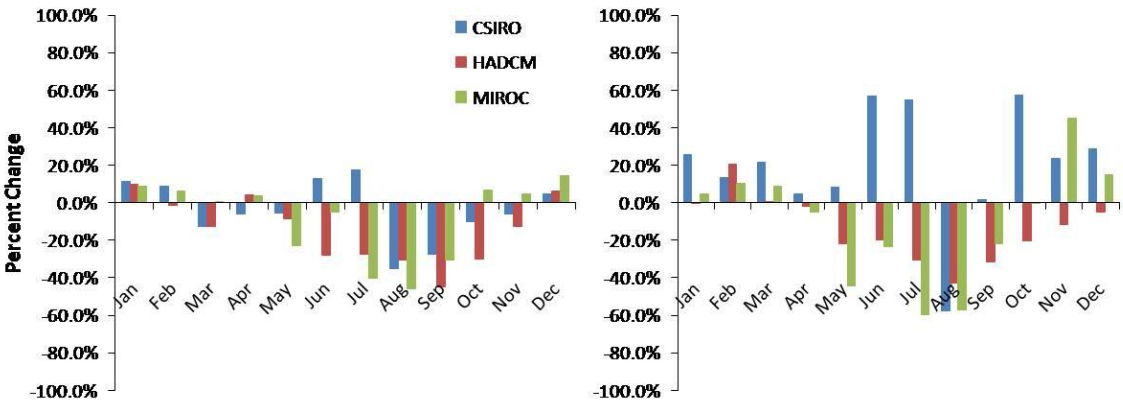


Figure 9. Percent change in average precipitation (inches) by month in the Deschutes Basin for two time periods (2035 to 2045 and 2075 to 2085) as compared to historical period (1961 to 1990).

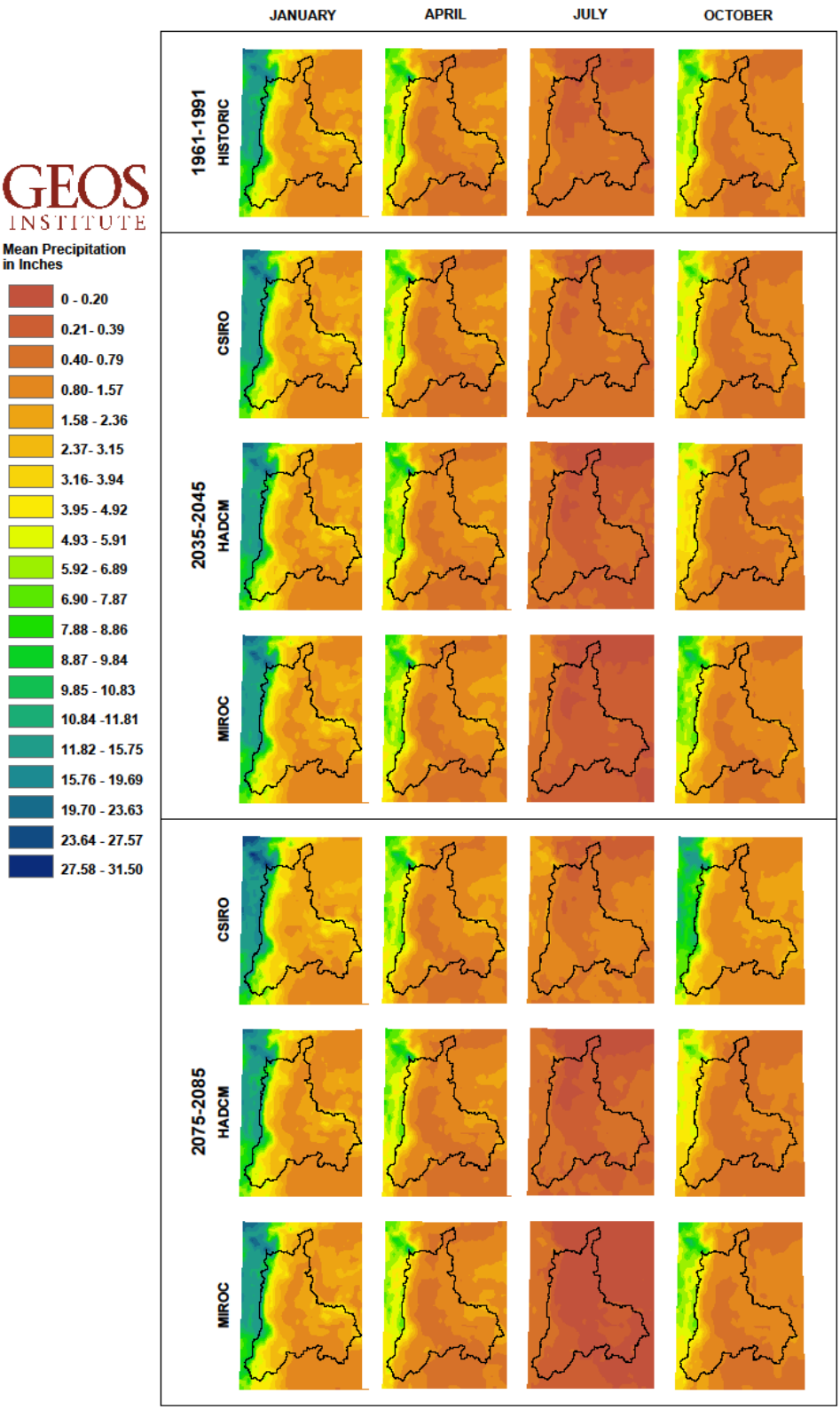


Figure 10. Average monthly precipitation (inches) across the Deschutes Basin for three time periods: historical (1961 to 1990), near-term future (2-35 to 2045) and long-term future (2075 to 2085).

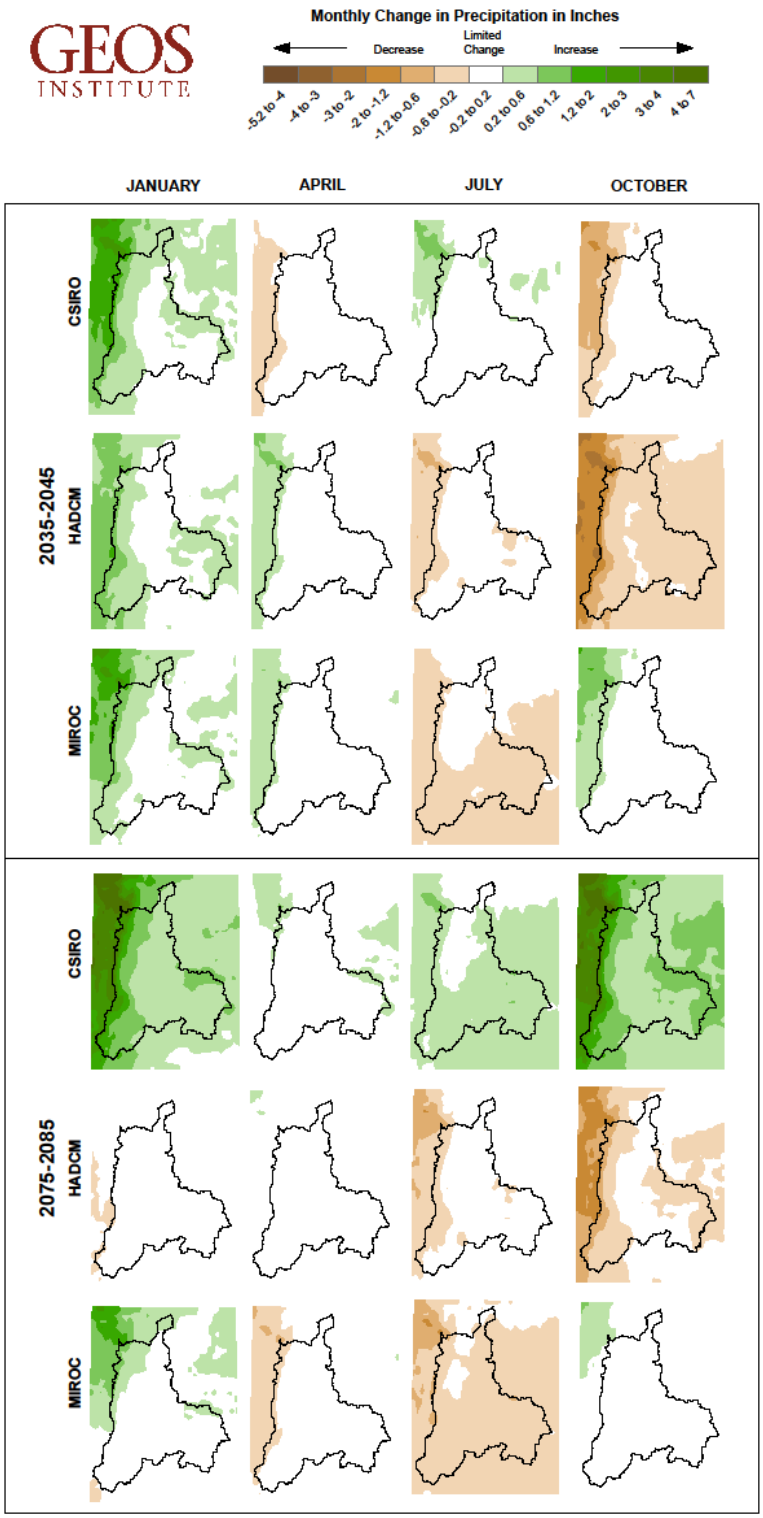


Figure 11. Change in projected average monthly precipitation (inches) from historic (1961 to 1990) to 2035 to 2045 and 2075 to 2085.

SNOWPACK AND STREAMFLOW

Considerable research has been done in the Pacific Northwest that highlights actual trends in snowpack and the resulting effect on streamflow over the past 60 years (Mote et al. 2005, Stewart et al. 2004, Chang and Jones 2010). The results demonstrate that:

- The highest flows in rivers across Oregon are occurring earlier (by as much as 10 days);
- Late summer streamflows are lower than in the past;
- Snowpack levels have declined about 60% from the mid-1900's.

As temperatures warm in the future, precipitation will increasingly fall as rain instead of snow and snow will melt earlier (Hayhoe et al. 2004, Chang and Jones 2010). Leung et al. (2004) and Mote et al. (2003) suggest that these climatic trends will result in Cascade Mountain range snowpack declines of 50 to 60% from 2000 levels by 2050.

General agreement among models on precipitation declines during summer in Oregon suggest that summer stream flows will continue to decline (Chang and Jones 2010). Hamlet et al. (2010) projected monthly streamflow for the North Fork John Day and Umatilla Rivers through 2080. The results show earlier and greater high flows. Generally, flows were projected to increase substantially from December through April and decrease slightly from June through August.

The timing of groundwater recharge is likely to shift based on precipitation pattern shifts and their effect on surface runoff (Manga 1997, Tague et al. 2008). Dettinger and Earman (2007) suggest that aquifer recharge may decline with increased evapotranspiration rates due to warmer temperature and longer growing seasons.

VEGETATION, WILDFIRE, and CARBON STORAGE

The MAPPS team vegetation model (MC1) provided projections for predominant vegetation types (the plant associations that would be favored under the projected climatic conditions). **The MC1 vegetation model only makes projections for "natural" vegetation types and does not account for land use changes (e.g., agriculture and development) that have happened or are likely to happen. The model also does not account for past or likely future introduced species (e.g., non-native grasses).** Model results show an expansion of conditions suitable for temperate evergreen needleleaf forests (predominantly ponderosa pine forests with lodgepole pine and Douglas fir as other common species) along the east flank of the Cascades and in the Ochoco Mountains (Figure 12). These are the forests that are currently found at moderate elevations along the western edge of the basin and in the Ochoco Mountains. Meanwhile, conditions suitable for maritime evergreen needleleaf forests (predominantly Douglas fir and ponderosa pine with lodgepole pine) and subalpine forests (predominantly mountain hemlock, subalpine fir, silver fir) are projected to decline. These are the forests currently found at higher elevations in the Cascades and Ochoco Mountains. Temperate shrublands are also projected to decline.

Rehfeldt et al. (2006) made projections for individual tree species distribution using climate envelope models. These models project future success of individual species on the basis of their historical distribution in relation to historical climate. Maps are produced for these species using three general circulation models and three carbon dioxide emissions scenarios (available at http://forest.moscowfsl.wsu.edu/climate/species/index.php). An examination of the projections for those species identified as the most commercially important for the Deschutes and Ochoco National Forests reveals the following trends:

- Ponderosa pine: Generally reduced abundance, particularly at lower elevations in its current range.
- Douglas fir: Slightly increased abundance at higher elevations but generally reduced abundance at lower elevations.
- Lodgepole pine: Considerably reduced abundance at all elevations, with little or none present throughout the region by the end of the century.
- White fir: Reduced abundance at all elevations where it currently occurs.
- (Shasta) red fir: seems rare in the area currently and projected to be absent by the end of the century.
- Western larch: generally reducing in abundance throughout the century and almost absent by century's end.

Differences between these projected vegetation shifts are due to different modeling approaches and assumptions. However, both sets of projections indicate considerable change in the future under projected climate conditions

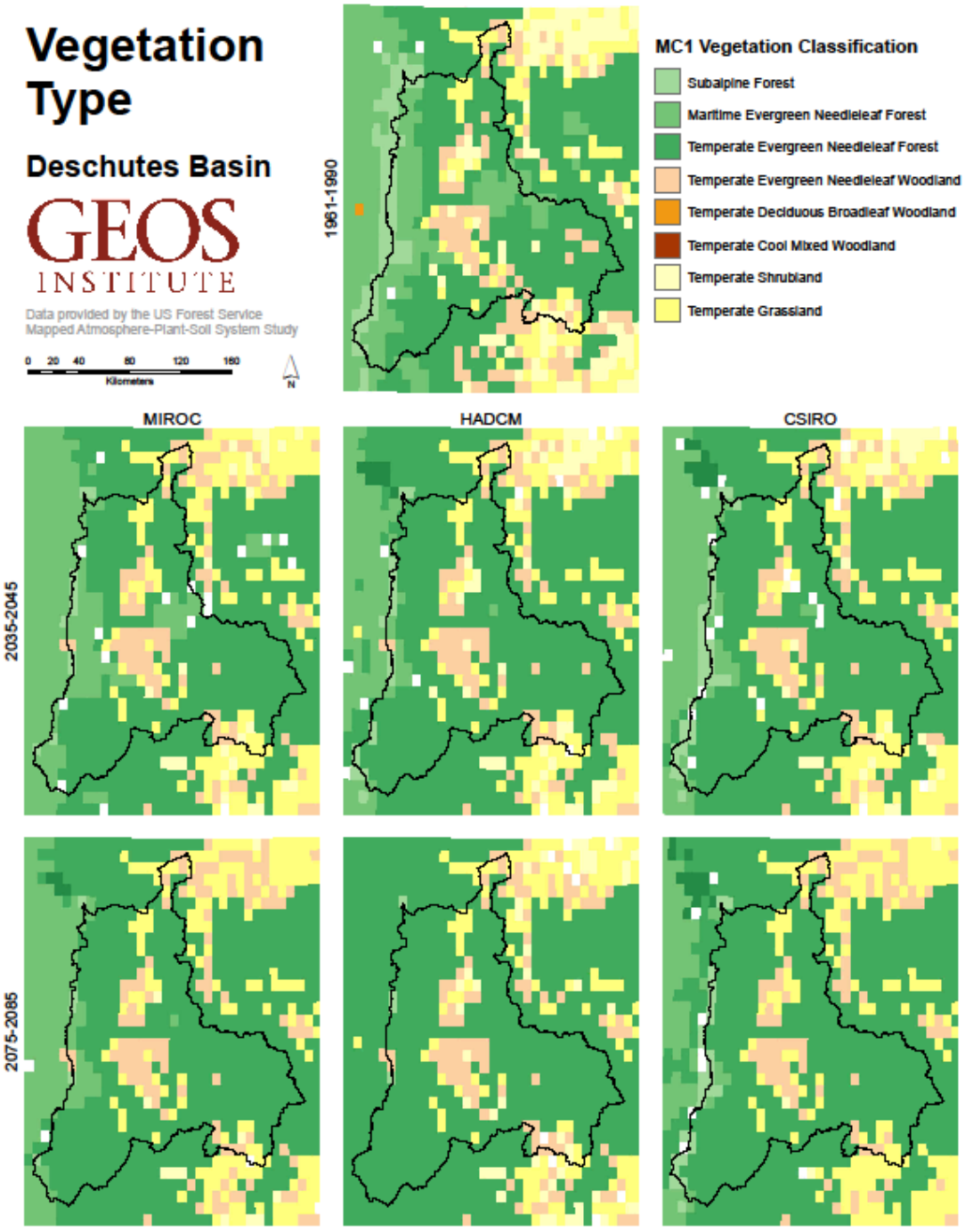


Figure 12. The MC1 model shows suitable growing conditions for native types of vegetation. This figure does not show **actual** vegetation. Land-use changes, such as agriculture or housing, are also not reflected in this figure. Actual vegetation in the future will depend not only on climate conditions, but also on land use, non-native species, and response time needed for changes from one type to another.

Despite changed growing conditions, vegetation can take decades or centuries to adjust, especially at higher elevations where climatic conditions will become more hospitable to forest but appropriate soils will take decades or centuries to develop. Mechanisms promoting vegetation change, particularly at lower elevations, are likely to be drought, fire, invasive species, insects, and disease.

The MC1 model projects increases in the average extent of wildfire annually (expressed as the average proportion of each model grid cell burned) from 11 to 16% by 2075 to 2085 compared to the historic period of 1961 to 1990 (Table 3). The model also projects a 38 to 63 % increase in biomass consumed by fire across the Deschutes Basin over the 11-year period from 2075 to 2085 (Figure 13, Table 3). Areas that show increases in biomass consumed by fire include mid and high elevation areas along the Cascades and in the Ochoco Mountains (the eastern and western portions of the basin).

Two of the three global climate models indicate an increase in carbon storage of roughly 10% by 2075 to 2085 (Table 3). The other model projects a decrease in carbon storage of 20% by late-century.

Table 3. Future average annual proportion burned, annual biomass consumed, and annual carbon stored in the Deschutes Basin, based on projections from three global climate models (CSIRO, HADCM, and MIROC). Future projected conditions are shown as change in degrees Fahrenheit, as compared to historic averages (1961-1990).

		Proportion Burned		Biomass Consumed		Carbon Stored	
Model	Time Period	Proportion	% Change	(g / m^2)	% Change	Terragrams	% Change
	Historical	3.02%		29.3		7201	
CSIRO	**2035 to 2045**	3.14%	+4.1%	34.5	+17.7%	7519	+4.4%
	2075 to 2085	3.50%	+15.9%	40.3	+37.7%	7877	+9.4%
HADCM	**2035 to 2045**	3.28%	+8.5%	42.6	+45.7%	7024	-2.5%
	2075 to 2085	3.33%	+10.5%	47.6	+62.7%	5761	-20.0%
MIROC	**2035 to 2045**	3.25%	+7.6%	34.3	+17.0%	7829	+8.7%
	2075 to 2085	3.40%	+12.8%	40.7	+39.0%	8095	+12.4%

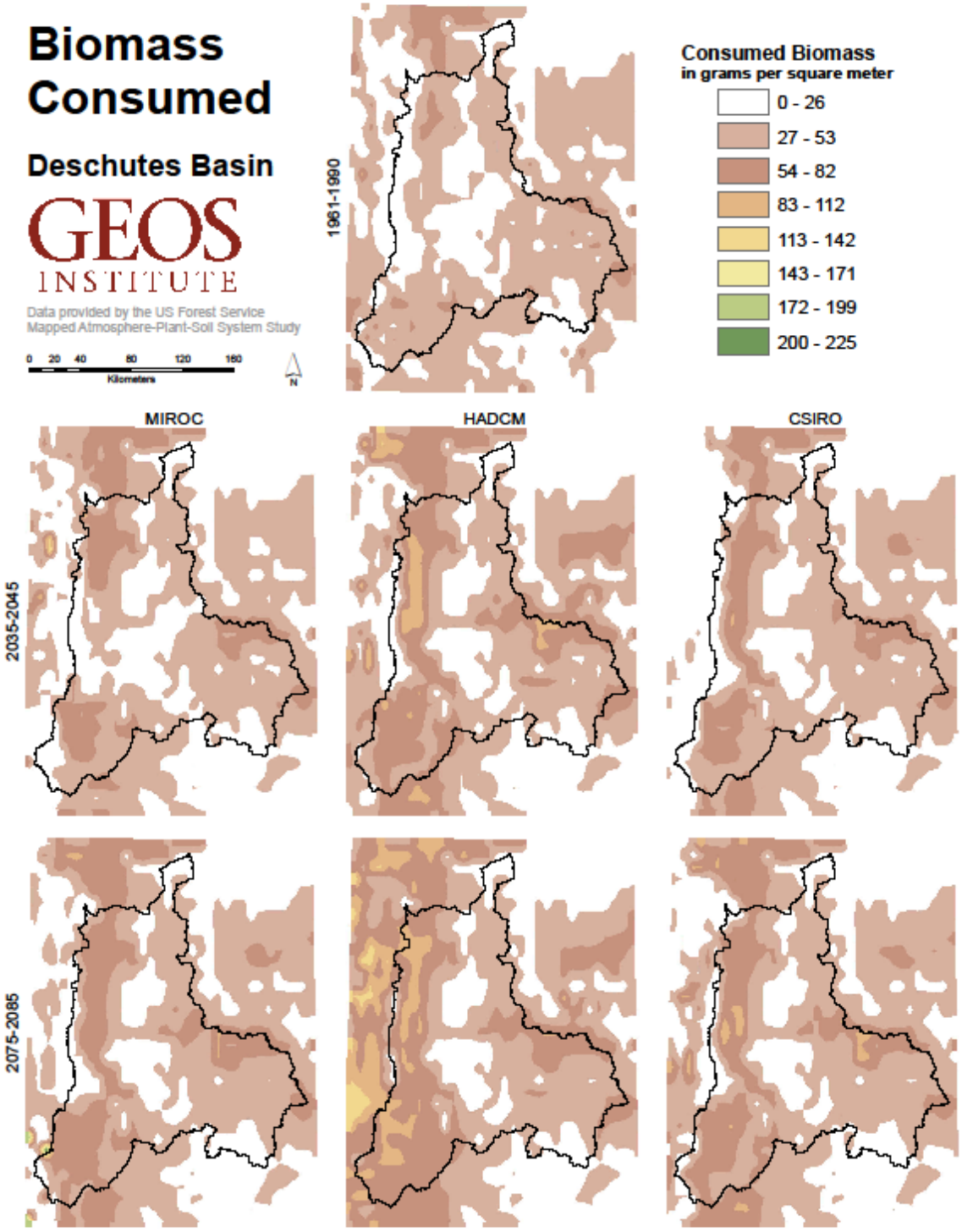


Figure 13. Average annual biomass (grams per square meter) consumed by wildfire in the Deschutes Basin, shown for the historical period (1960-1991) and projected for two future periods (2035-45 and 2075-85), using three global climate models.

SECTOR BACKGROUND

Climate change will have direct impacts on natural systems of the Deschutes Basin. These impacts will, in turn, affect socioeconomic systems. The following sections of the report will highlight important considerations for changing climate conditions on natural systems (processes, habitats, and species) and socioeconomic sectors, including population, economics, infrastructure, and health and emergency services. While the natural systems discussion is for the entire Deschutes Basin, the socioeconomic information is focused on Crook, Deschutes, and Jefferson Counties. This information is presented to stimulate thought on how communities in these counties might be vulnerable to changing climate conditions and prudent measures to decrease their vulnerability and take advantage of new opportunities.

Crook County is the oldest of the three counties (established in 1882) with Deschutes County (1916) and Jefferson County (1924) established within what were Crook County's original boundaries. With Bend, La Pine, Redmond, and Sisters as population centers, Deschutes County is the most populous of the three counties and is considered a "micropolitan" area. Crook County and Jefferson County are considerably less populated and exhibit more rural characteristics.

Much of the land in the three counties is federally managed, predominantly the Deschutes and Ochoco National Forests and the Crooked River National Grassland (Figure 14). Approximately half of the land in Crook County is federally managed with the other half in private ownership. Approximately 75 % of Deschutes County is federally managed (with 25% privately owned) while 27% of Jefferson County is federally managed (55% private and 18% Warm Springs Indian Reservation). While Crook County has a higher percentage of grassland, the others are more forested, with Deschutes supporting a higher percentage of forest than Jefferson County.

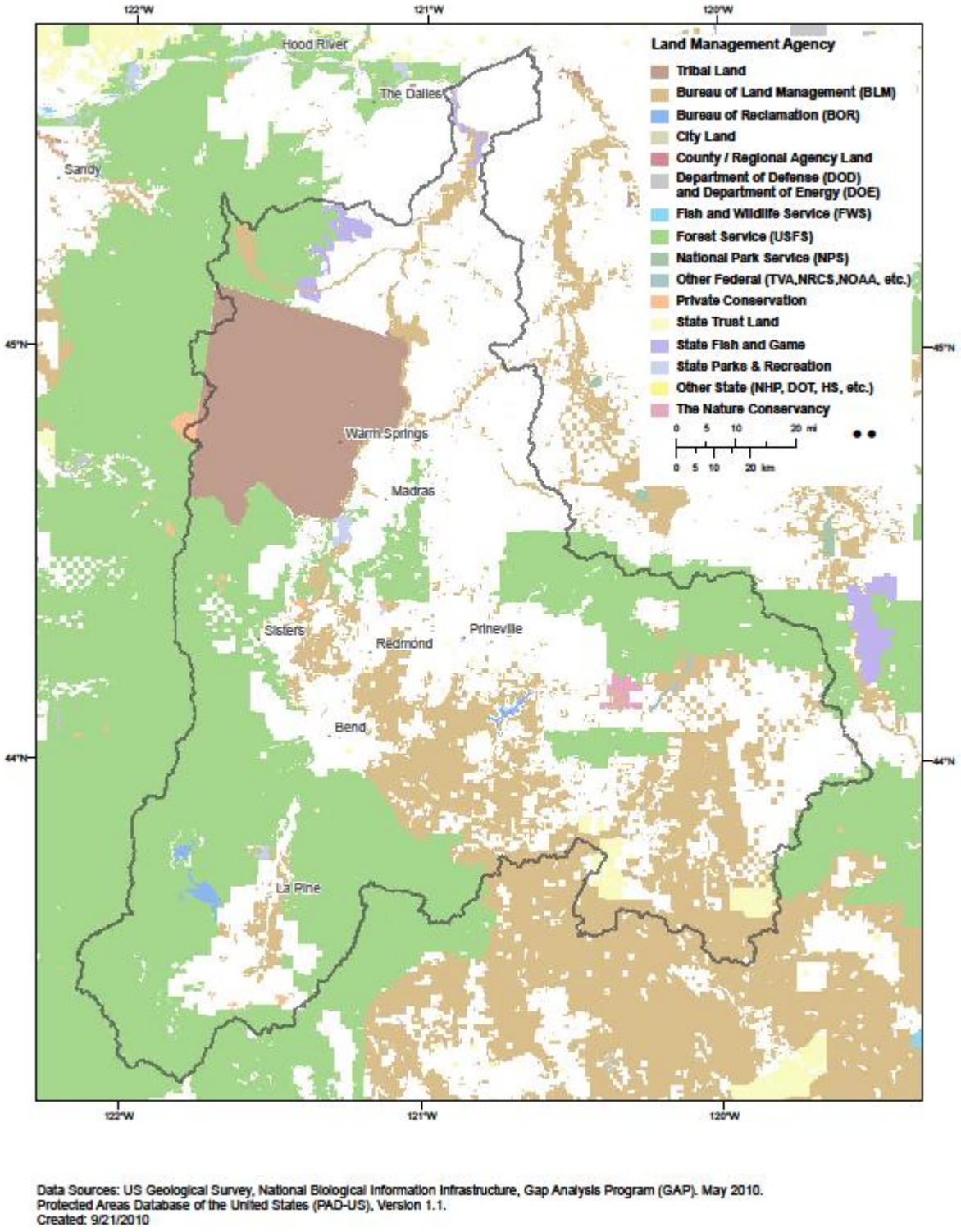


Figure 14. Land management within the Deschutes Basin.

NATURAL SYSTEMS

The Deschutes Basin supports widely variable terrain, from rugged slopes of the Cascade, Ochoco, and Blue Mountains, the high plateau between the Deschutes and John Day rivers, and the valley bottoms and plains. Oceanic influence from the Pacific causes the basin to be slightly warmer and moister than other Oregon drainages on the east side of the Cascade Mountain Range.

Three major ecoregions occur in the Deschutes – the Colombia Plateau, East Cascades, and Blue Mountains. Conifer forests cover the eastern slopes of the Cascades while western juniper dominates the Blue Mountains ecoregion. The Colombia Plateau ecoregion, once dominated by sagebrush and native grasslands, is now largely irrigated agriculture and juniper.

The Deschutes River starts high in the Cascades and flows northward, through meadows and lava plains before carving deep canyons through the adjacent shrublands. It joins the Colombia River near The Dalles, at the northern extent of the basin. The Deschutes supports wild spring Chinook populations, as well as fall Chinook salmon, and summer steelhead. Bull trout and steelhead are both listed as endangered under the federal Endangered Species Act. In summer months, a majority of the water (90%+) from the Deschutes is diverted for agriculture and other uses. Many species, including redband trout, are negatively affected by low summer flows.

Rapid population growth have led to habitat loss and fragmentation for many native species. In the eastern portion of the basin, juniper invasion, agriculture, invasive species, livestock, and fire management have led to losses of native grassland and shrub steppe habitats. Riparian and wetland degradation is common basinwide.

Priority species for conservation management include pygmy rabbit, sage grouse, pinyon jay, Colombia and Oregon spotted frog, Pacific lamprey, Tygh Valley milkvetch, Peck's penstemon, and numerous invertebrates (freshwater snails). Priority ecosystems include Palouse prairie, subalpine wet meadow, mixed sagebrush, oak woodland, riparian systems of all types.

POPULATIONS

Population trends for the three-county Central Oregon region depict an increase over the last 10 years of 46,000 and of nearly 150,000 since 1970 (Figure 15). Deschutes County has a 2010 population of 158,629, Crook County at 22,566, and Jefferson County at 19,959 for an aggregate population of 201,154.

While the population in the Central Oregon three-county region has increased substantially since 2000, much of this results from immigration (+ 39,757 residents) to the area rather than resident births (+21,429). This had consequences for home construction patterns, particularly in Deschutes County (see Infrastructure below).

Elderly, young, and linguistically isolated segments of the population are particularly vulnerable to changing climate conditions (e.g., higher temperatures, potentially increased incidence of disease, potentially higher incidence of weather and natural disaster-related emergencies). In Crook County, 5.4% of the populations is less than 5 years old and 17.5% is older than 64. In Deschutes County, 6.4% of population is under 5 years old and 14.3% is older than 64. Additionally, about 650 households are linguistically isolated in Deschutes County. Jefferson County has 8.3% under the age of 5 and 13.5% older than 65.

ECONOMICS & EDUCATION

Currently the percent of total private employment in agriculture is roughly 2.5% for the region (7.5% in Crook County and 9% in Jefferson County), while timber accounts for 6.2% of total private employment (20% in Crook County and 36% in Jefferson County). Less than 1% of total private employment in the three-county region involved growing and harvesting timber; more timber-related employment now involves wood products manufacturing.

As the timber industry declined in the 1990s, construction, real estate, and related finance services boomed in Central Oregon (Figure 16, Headwaters Economics 2010). From

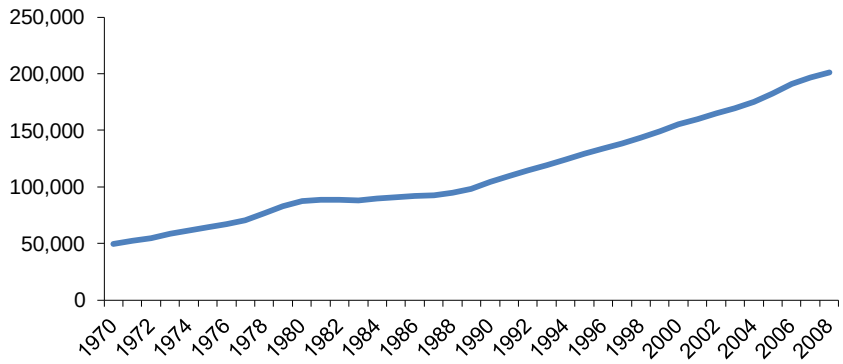


Figure 15. Population in Crook, Deschutes, and Jefferson Counties from 1970 to 2008.

1990 to 2000, construction jobs increased 100% while total employment increased 55% in the area. At the same time, tourism-related services, producer services (higher wage, higher skill labor), and non-labor income also increased. Currently, services account for 75.4% of the total private employment (up from 45% in 1990) and non-labor income accounts for 42.3% of total personal income in the tri-county area (compared to 33.4% in U.S.).These changes were all taking place at a time when large numbers of retirees (people with accumulated wealth, non-labor income) were moving to the region, as reflected in the "Populations" section above.

Personal income data show a decline in farming from 1970 to 2000 (-14%) and an increase in construction (+56%). Over the 38 years of the reported data, average earnings per job (in adjusted 2009 dollars) increased only 1.2% while per capita earnings increased 4.0%. This reflects the large influx of non-labor income to the region.

The economic condition of families may reflect a vulnerability to climate change related impacts such as increased incidence of disease and other health needs or response to weather or natural disaster emergencies. Unemployment peaked at 17.3% in early 2009 (21.2% in Crook County, 16.7% in Deschutes County, and 18.8% in Jefferson County) and is currently about 13.0%. The proportion of individuals living at or below the poverty level is 12.6% in Crook County, 10.4% in Deschutes County, and 16.4% in Jefferson. These are all close to the poverty level in Oregon overall (13.5%).

Individuals with lower educational attainment may to have a reduced capacity to handle the extreme events that may occur as the climate changes. This may be a result of lower wage-earning capacity, reduced ability to obtain and understand emergency preparedness and response information, reduced access to health care and insurance, or as a consequence of some degree of disenfranchisement from society. In

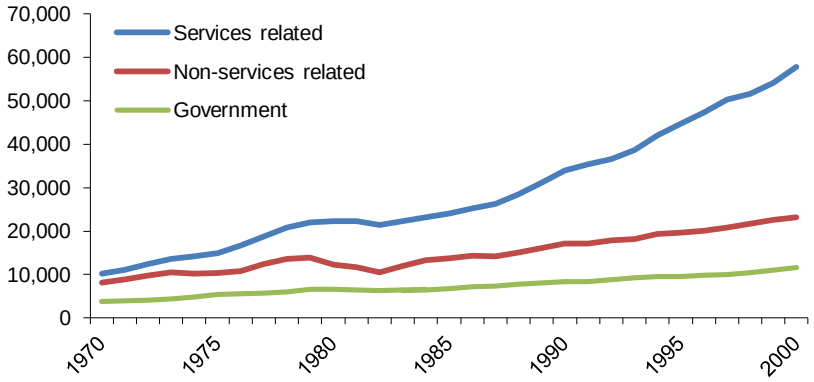


Figure 16. Employment by major industry category for Crook, Deschutes, and Jefferson Counties from 1970 to 2000.

Crook County, 13% of the residents over the age of 25 have less than a high school education, while the percentages in Deschutes and Jefferson are 7% and 19% respectively (15% statewide).

Climate change is expected to have many direct and indirect impacts to the economy of the region. Some important considerations for some of the important economic sectors in Crook, Deschutes, and Jefferson Counties include:

Agriculture:

- Longer frost-free period and earlier date for last frost will extend the growing season (Easterling 2002 in Coakley et al. 2010).
- Declining snowpack and shifting stream flow patterns may decrease water availability during summer (Capalbo et al. 2010).
- Hot summers and decreased water availability may influence rangeland and pastureland plant composition and productivity (Coakley et al. 2010).
- Warmer temperatures are likely to enhance ability of crop pests and diseases to survive through winter, increase rapidly in spring, and increase number of generations per growing season.

Forestry:

- Reduced snowpack could depress forest growth rates and increase forest fire frequency (Capalbo et al. 2010).
- Forest productivity is projected to increase at elevations above 3,300 feet and maintain or decrease slightly at lower elevations (Latta et al. 2010)

Recreation:

- The projected cost to snowpack-dependent industries in Oregon is $4.2 billion by 2060 assuming a 4.5 to 7 °F temperature increase (Capalbo et al. 2010).
- The projected loss to recreational industries in Oregon dependent on camping and hiking is $6.5 million by 2060 assuming a 4.5 to 7 °F temperature increase (Capalbo et al. 2010).

INFRASTRUCTURE

The percentage of homes owned is 74.3% in Crook County, 72.3% in Deschutes County, and 71.3% in Jefferson County (all higher than the statewide percentage, 64.3%). A high proportion of homes in the region were built before 1990 (59% in Crook County, 55% in Jefferson County, and 43% in Deschutes County), indicating structures that are less able to withstand projected climate effects (e.g., warmer temperatures). Similar concerns apply to commercial and public structures.

The percentage of the wildland-urban interface in the region that is developed is 18% (compared to 14% for the U.S.). However, the percentage in Deschutes County is 36.5% (compared to just 11.5% for Jefferson County and 5.5% for Crook County). Many of these homes were constructed as the economy shifted in the mid-1990s and the immigration

rate was high. These structures are at risk if wildfire frequency increases in these interface areas, as projected by the three models used in this report.

An extensive road network and a regional airport at Redmond provide area residents with transportation. Buses are available to shuttle passengers to rail transportation hubs. Increased incidence of flooding, likelihood of wildfire, or heavy storm frequency could impact roads, bridges, and culverts, impeding road travel and potentially air traffic (Lach et al 2010).

Electricity providers in are Central Electric Cooperative and PacifiCorp. Central Energy Cooperative receives a considerable portion of its power from Bonneville Power Administration (~82% hydroelectricity and 10% nuclear), while Pacific Power& Light generates over 80% of its electricity from coal and natural gas and just 10% from hydroelectric facilities. PacifiCorp's coal, natural gas, and operating hydroelectric facilities are all outside the Deschutes Basin. Portland General Electric and the Confederated Tribes of the Warm Springs jointly operate a 465 megawatt hydroelectric facility in Jefferson County. Warmer summers will likely increase electricity demand for air conditioning and refrigeration just at a time when hydroelectric generation potential is at its lowest due to climate change impacts to precipitation and streamflow patterns.

Lach et al. (2010) report that wildfires and higher temperatures stress power lines. This increased stress is likely to lead to greater incidence of regional or local brown-outs while demand for electricity is likely to increase due to warmer temperatures.

Aside from the three hydroelectric dams described above, a number of other large dams impound water for storage (and contribute to recreation) in the area. Old structures and dams constructed with earthen fill may be vulnerable to failure if large flooding events become more frequent. Moreover, operations of water storage facilities may need to change to account for changes in seasonal flow patterns and longer dry periods.

PUBLIC HEALTH

Among Oregon County Health Department officials throughout Oregon, 88% identified climate change as a serious or very serious problem. Vector borne diseases, drought, forest fires, water quality, and disruption of heath care services during climate change-induced emergencies are the major concerns identified by health officials (Vynne and Doppelt 2009).

Higher temperatures, especially combined with extended heat waves, have direct health implications, particularly among the sensitive (young and elderly) and vulnerable (impoverished, pregnant, outdoor workers, Lach et al. 2010). Increasing temperatures combined with heat waves have the potential to increase the incidence of cardiovascular diseases and strokes and enhance the frequency of suffering for those who experience asthma, hay fever, respiratory allergies, rhinitis, atopic dermatitis, and airway diseases (Lach et al. 2010). Those spending a lot of time outside suffer exposure to

outdoor conditions such as extreme temperature and air quality problems. Climate change will potentially expose these individual to greater risk from heat exhaustion, sunstroke, and dehydration. Since temperatures will be higher and summer dry periods potentially longer, the risk of wildfire and dust storms increases (Lach et al. 2010). An increase in smoke may contribute to an increased number of low air quality days. Throughout Oregon, prolonged growing seasons and warmer temperatures generally are likely to increase pollen counts and extend the season when these are high (Lach et al. 2010). Over the past decade, air quality at the Bend monitoring station has been good, rarely dropping into the "moderate" (125 days out of 2,560) or "unhealthy for sensitive groups" (1 day) categories (ODEQ 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, and 2010).

Statewide, climate change is likely to impact the spread of communicable diseases, including water, food, and airborne infections (Lach et al. 2010). Warmer conditions are likely to result in population increases of these pests. Lach et al. (2010) report that communicable diseases such as West Nile virus, malaria, and waterborne diseases are likely to become more prevalent. A review of West Nile virus incidence in Deschutes and Jefferson Counties showed < 0.2 documented cases per 100,000 residents from 1998 through 2007 (ODHS 2010). The rate of incidence was slightly higher in Crook County (between 0.5 and 0.9 documented cases per 100,000 residents).

CONCLUSION

The purpose of this report is to provide up-to-date climate projections for the Deschutes Basin at a scale that can be used in community planning efforts. By providing information that local managers, decision-makers, and community members need to make day-to-day decisions and long-term plans, we hope to spur climate change adaptation planning.

Many of the impacts of climate change are already progressing and will continue to accelerate throughout the next few decades, regardless of future emissions. For instance, projections for the time period of 2035 to 2045 are likely to become a reality. Whether we limit climate change to this level or continue to progress towards the level projected for 2075-2085 will depend on whether the U.S. and other nations choose to lower emissions drastically and quickly.

The projections provided in this report are intended to form the foundation for city, county, and regional adaptation planning for climate change. Our program, called ClimateWise®, strives to build co-beneficial planning strategies that are science-based, developed by local community members, and increase the resilience of both human and natural communities in a cohesive manner.

The ClimateWise® program is structured to begin the planning process in local communities, and to "scale up" management strategies to the state and federal level by identifying needed changes in policy and governance structure. During the local planning process, experts from different sectors will identify barriers to sound management, allowing us to address these limiting factors by collaborating with lawmakers.

Please contact Brian Barr at Geos Institute for more information (brian@geosinstitute.com; 541-482-4459 ext 304).

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