The Economic Implications of Climate Change for Oregon

Steven J. Dundas, Susan Capalbo, and James Sterns

Assessments of the economic impacts of a changing climate on key sectors in Oregon and the Pacific Northwest have been included in previous Oregon Climate Assessments (Dello and Mote 2010; Dalton et al. 2013, 2017; Mote et al. 2019; Dalton and Fleishman 2021). The first and second Oregon Climate Assessments provided in-depth overviews of the methods and approaches used to value these impacts and the challenges and opportunities to designing policies to enhance mitigation and adaptation. Collectively, the previous five assessments provide content on the economic impacts that remains pertinent, and we encourage readers to refer to them for further background on methods and regional economic impacts.

Here, we update previous Oregon Climate Assessments in two ways. First, we provide a more robust discussion of economic concepts and tools to better understand Oregon's climate challenges and opportunities and associated public policies and programs. Second, we highlight recent insights on climate change impacts as they relate to Oregon sectors and economic activity or to similar sectors in the Pacific Northwest. This chapter begins with a few observations from past research that are brought to bear on the design of our economic assessment efforts, continues with a discussion of climate change economics and policy tools, and then presents an update on sector-specific economic impacts in Oregon and the region.

Two Decades of Research

Oregon's economy and gross domestic product (GDP) remain highly impacted by the changing climate (e.g., increases in temperature, increased variation in the timing and intensity of precipitation). As noted in the first Oregon Climate Assessment (Dello and Mote 2010), it is nearly impossible to provide a comprehensive economic assessment of the effects of climate change on Oregon due to the breadth and diversity of Oregon's natural-resource based economy; the complexity of the interactions among sectors, climate variables, and climate-related variables; and limited empirical assessments in key areas, such as public health, migration, and sector-specific agricultural markets. Prior Oregon Climate Assessments also emphasized that many assessments have sidestepped the issue of behavioral responses and instead projected economic impacts under business-as-usual scenarios. Although business-as-usual projections provide useful information, they are best viewed as an upper bound on costs or impacts of climate change, capturing the likely impacts assuming that groups such as producers, stakeholders, and land managers do not adapt or respond to changing economic, social, biological, or physical conditions.

Over the past decade, frameworks for conducting economic assessments and for integrating site-specific evidence on the level and extent of changes in underlying biological and physical conditions into empirical findings have improved. Real-time, site-specific economic and behavioral data, better data-transfer technologies, and increases in the breadth and resolution of biological and physical information contribute to a more robust foundation of information for these assessments. Increases in stakeholder engagement are providing stronger pathways to understand and design effective policies for addressing climate change at local and transformative extents (Moore et al. 2017, Auffhammer 2018, Antle 2019). Furthermore, behavioral responses to extreme climate events that are being observed in real time can serve as the basis for ground-truthing and refining economic frameworks and predictions.

The magnitude of regional impacts of climate change hinges on the magnitude of the impacts (i.e., net costs) to local communities and businesses, changes in natural assets and ecosystem services, and behavioral responses both to these climate-induced changes and to climate policies and programs. Economists have made substantial progress in addressing the challenges associated with estimating the cost of climate impacts and valuing changes in ecosystem services and natural capital. The information in this section on key sectoral impacts in Oregon and the Pacific Northwest is testimony to such efforts. Applying sound economic principles and values to ecosystem changes conveys to society that ecological services contribute to human well-being (Figure 1). As noted nearly 25 years ago by Geoffrey Heal (1998:3), "we are coming to realize, in part through the process of losing them, that environmental assets are key determinants of the quality of life."

Figure 1. Changes in the timing and form of precipitation have substantial effects on Oregon's economy and the well-being of its residents. Photograph by Erica Fleishman.

Climate Change Economics and Policy Tools

Much of the current economy involves, directly or indirectly, the combustion of fossil fuels, which results in emissions of greenhouse gases (GHGs). The core economic problem with GHG emissions is that those who produce the emissions do not pay for that privilege, and those who are harmed are not compensated. Since the beginning of the industrial revolution, Earth's atmosphere and oceans have been treated as free resources that absorb emissions from industrial activity.

When one buys corn from a supermarket, they pay for the costs of producing the corn, and the farmers and retailers are compensated for their provision of the corn to the consumer. But when production of that corn requires the combustion of fossil fuels, whether to pump the water that irrigated the corn field or to fuel the truck that delivered the corn, an important cost is not covered: the social damage caused by GHGs that are emitted. Economists call such costs *externalities* because they are external to the market. An externality is a byproduct of economic activity that causes damages to a third party that did not participate in the market transaction.

Modern life is full of externalities. Some are harmful, such as when runoff of agricultural fertilizer enters a river, kills fish, and degrades water quality. Others are beneficial, such as when researchers discover a polio vaccine. Climate change is likely the most complex of all externalities because it involves so many activities, affects the entire planet, has enduring effects, and no individual can do much to slow the changes.

Economics teaches one major lesson about externalities: markets that fail cannot solve the problems they generate. In the case of externalities from GHG emissions, unregulated markets produce too much because markets do not put a price on the external damages from those emissions. The market price of gasoline does not include the costs imposed on society by GHG emissions, and so gas is cheaper, people drive more, and more emissions are generated. Because an unregulated market sets prices incorrectly, governments must step in and regulate, control, or tax the activities that have significant harmful externalities. Climate change is no different from other externalities: it requires considerable governmental action to reduce harmful spillovers. This leads to a second economic challenge: a collective action problem. This problem arises when the best outcome for all would be cooperation to solve climate challenges, but many individuals, firms, and governments choose their own economic best interests, which often conflict with joint actions.

Economic Challenges to Effective Policy Decisions

Addressing the externalities that contribute to climate change, and the collective action needed for effective climate policies, present distinct challenges for five core economic reasons: the need for global cooperation, scale and irreversibility of impacts, intergenerational nature of impacts, uncertainties involved in climate systems and estimation of impacts, and unequal distribution of those impacts. In other words, the effects of climate change are likely to be costly, irreversible, unequally distributed, and experienced by current and future generations. Definition of policy goals must address uncertainties in future outcomes and the global nature of the problem.

These five challenges are complex and sometimes daunting to overcome. Regardless of where GHGs are emitted, they mix uniformly into the atmosphere and cause problems for all. Incentives exist for a collective action problem in climate change mitigation efforts because economic damage may not occur in the country that generated the emissions, and the emissions-generating country may not benefit from incurring expenditures to mitigate the problem. Low-income countries have argued that high-income countries have historically received a large share of the benefits of GHG emissions and should now bear the costs of mitigating climate damages.

Because climate change does not respect national boundaries, effective policy solutions require global cooperation. This has been a contentious debate in international discussions since the Kyoto Protocol in 1992. The economic threat from climate change often is not as recognizable as the threats that have galvanized international support for action (e.g., the Montreal Protocol to protect the stratospheric ozone layer). The fact that climate change is both external to markets and requires global cooperation is the central hurdle that policymakers must overcome if they are to slow the pace and avoid the dangers of climate change.

Providing a sense of the magnitude of impacts, an insurance industry report suggested that economic damages associated with climate change could reduce global GDP by up to 14 percent by the year 2050 (Swiss Re Institute 2021). That percentage reduction reflects damages of up to $23 trillion per year. Furthermore, many of the damages are irreversible—Earth's climate is likely to change for up to 1000 years after emissions stop due to the nature of the interaction of GHGs and the atmosphere. This suggests that some increases in temperature, aridity, and sea levels have been unavoidable since the beginning of the industrial revolution. Those effects are likely to continue further into the future the longer humans continue emitting GHGs, casting a long shadow on people and natural systems. The problem of intergeneration equity can best be described as the consequences for future generations of harm done by the current generation. Climate change experts have cited myopia, or short-term thinking, as a barrier to action on climate policy. Fundamentally, humans are an impatient species: we would rather benefit from something now and pay for it later. This innate tendency slows progress on climate policies when the effects are not yet fully visible. It takes considerable political will to advocate for taking costly action now that will result in an uncertain amount of benefits for future generations.

Climate change requires individuals and governments to make long-term decisions with incomplete knowledge about future impacts. Knowledge of the climate system is incomplete, and future projections have uncertainties that complicate measurement of economic impacts. Economic analysis can contribute to identifying and reducing such uncertainties and informing public policy on climate change even when knowledge of how risks may play out is incomplete, but many uncertainties are likely to persist. The primary sources of uncertainty include future emissions trajectories, future changes in societal preferences, modeling limitations, measurement errors, and feedback loops. Uncertainty can affect a policymaker's degree of confidence about possible outcomes of specific decisions. Uncertainty works in both directions: the effects of climate change could be less severe than currently estimated, but could also be much more severe. Economist Marty Weitzman long argued that it is important to incorporate uncertainty and the potential for low-probability but high-impact climate events into economic and policy decisions about mitigating climate change (e.g., Weitzman 2009). The concept of irreversibility also creates its own uncertainties. On the one hand, there are well-acknowledged tipping points in the climate system (e.g., rapid melting of the Greenland ice sheet; Figure 2) that generate additional incentives to policymakers to mitigate GHG emissions now to avoid potentially catastrophic impacts. On the other hand, investments from policy actions that are not easily reversible, such as shifting economies away from fossil fuels to renewable technologies, may create a value to waiting for more information before making extensive changes. These two forms of irreversibility compound uncertainty-related issues in crafting effective climate policy (Pindyck 2021).

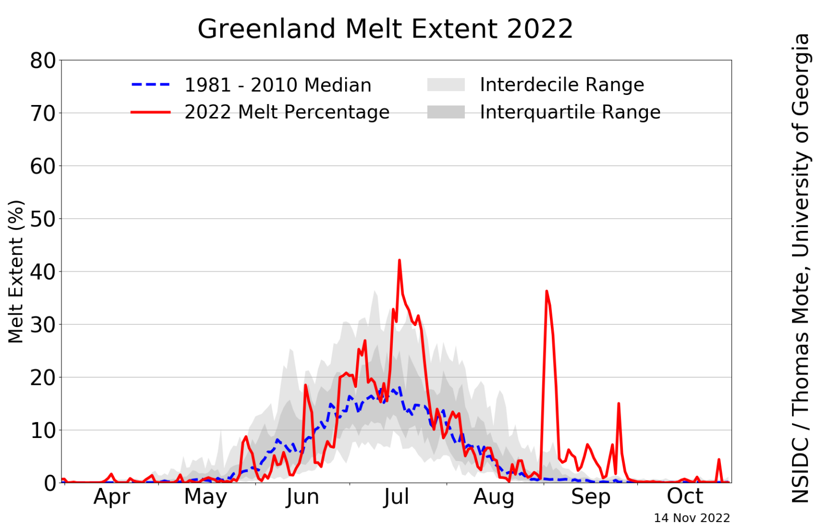

Figure 2. Recent and longer-term melting of the Greenland Ice Sheet. Source: National Snow & Ice Data Center.

The impacts of climate change vary across geographic location and social and economic status. For example, climate change is predicted to continue having a larger impact on the poorest, most vulnerable people, and there is evidence that climate change has already increased economic inequality among countries by about 25 percent (Diffenbaugh and Burke 2019). The poorest countries (and poor areas of high-income countries) are facing the worst effects of climate change, yet they are least responsible. In a system where global natural resources are shared, people often prioritize their self-interest instead of the common good, which disadvantages marginalized groups.

In the United States, there is some good news. According to the World Resources Institute, between 2005 and 2017, 41 states reduced GHG emissions while increasing their economic output (GDP), suggesting a decoupling of economies and fossil fuel use (Saha and Jaeger 2020). Oregon was one of the 41 states that achieved decoupling, although it ranks near the bottom of the list in terms of GHG reductions (6 percent, compared to top-ranked Maryland at 38 percent).

Assessing the Economic Impacts of Climate Change

Economic impacts from recent climate-related extremes reveal substantial vulnerability and exposure of human and natural systems to climate variability. These impacts have economic consequences across a range of goods and services, such as food production and water supply, housing and transportation, and human health and mortality. For example, the Fourth National Climate Assessment suggested that climate change could reduce GDP in the United States by up to 10 percent by the year 2100 (Reidmiller et al. 2018).

Understanding the magnitude of the economic and ecological impacts of climate change is critical because most policies that can be used to reduce emissions and impacts are costly. For example, funding is needed to research and develop new technologies to make homes and other buildings more energy efficient. Market-based approaches, such as a carbon tax, would increase the cost of goods and services produced with methods that contribute significantly to climate change. An effective climate policy design would have to account not only for the economic costs that arise from policy implementation, but also for the benefits of mitigating future impacts of climate change. Estimating these impacts, and therefore the potential benefits of taking action now, is difficult. There are uncertainties in emissions trajectories, climate model outputs, and human behavior in response to policy changes. Estimation of impacts often is based on models that include sets of assumptions about the range of potential outcomes and how systems will respond to change. Hence, as recent research has shown, global economic impacts of climate change are often hard to identify and estimate because these efforts have covered a variety of economic sectors and relied on different foundational assumptions, such as the discount rate and responses to catastrophic changes.

An additional key challenge in estimating economic damages from climate change is understanding the causal links among elements of the climate system and society. Attribution of climate impacts must be separated from the impacts of day-to-day weather while accounting for humans' adaptive capacity. As explained in the fifth Oregon Climate Assessment, attribution of climate phenomena is "the process of evaluating the relative contributions of multiple causal factors to a change or event with formal assessment of confidence." For example, it was estimated that the intensity of precipitation during Hurricane Harvey, which generated extreme flooding in Texas in 2017, was 20 to 40 percent greater due to climate change (Risser and Wehner 2017). Attribution more commonly is applied to estimate changes in the likelihood of an event or class of events because of human activities than to gauge whether climate change caused a certain event.

Improving attribution can support estimation of the quantity of damage from climate change, but prices also are needed to value economic impacts of climate change. An important economic price in this context is the social cost of carbon (SCC). The SCC is an estimate, in dollars, of the economic damages that would result from a marginal change in emissions (an additional ton of GHGs) and its consequent effects on climate change, society, and ecosystem function. The impacts are estimated in dollars to help policymakers understand the outcomes of decisions that would increase or decrease emissions. The SCC is used by local, state, and federal governments in the United States and other countries to inform billions of dollars of policy and investment decisions. The SCC in the United States is around $185 per ton of carbon dioxide (Rennert et al. 2022).

Valuation of market impacts can translate climate to physical changes in economic output and then use market prices, or the SCC, to estimate damages. However, there is no market for important features of society and the natural world, such as ecosystem services, wildlife species, and human well-being and health (Figure 3), and these are often not included in SCC estimates. Although these items are not bought and sold in a manner that can reveal an economic price, they have economic value and warrant consideration when estimating impacts from climate change. Three primary sources of nonmarket economic value are likely to be affected by climate change. The first, use value, is the utility or benefit an individual receives from consuming a good or using a service. The second, option value, is a value that is placed on maintaining the environment or a particular resource so an individual has the option of enjoying it in the future even if they currently do not use it. The third, nonuse value, is the value that people assign to goods even if they never have and never will use the good. Examples include existence values, where people receive benefits from knowing that a particular resource exists (e.g., an endangered species), and bequest values, where benefits arise from preserving the availability of a resource to future generations.

Figure 3. There is no market for many features of the natural world. Photograph by Erica Fleishman.

Although many tools exist to estimate nonmarket values, the magnitude of economic loss from nonmarket environmental damage remains difficult to assess at scales relevant for integration into global climate policy discussions.

Climate Policy Options: Economic Efficiency Versus Political Feasibility

There are two primary policy avenues to address the economic effects of climate change: mitigation and adaptation. Mitigating the effects of climate change requires actions to limit the magnitude and rate of change, typically through reducing emissions of GHGs. Climate mitigation often focuses on reducing the use of fossil fuels by limiting energy production from fossil fuels, switching to low carbon fuels or renewable energy production, or increasing systems' energy efficiency. Damages can also be mitigated by enhancing the capacity of carbon sinks by preserving or restoring natural ecosystems, such as forests, or inventing new carbon-capture technologies. Adaptation involves practical and realistic actions to manage risks from climate change, protecting and strengthening communities, and improving resilience of the economy to future effects of climate change.

The primary goal of mitigation policies is to stabilize GHG levels in a time frame sufficient to allow humans and ecosystems to adapt naturally to climate change, to ensure, for example, that agricultural systems can maintain levels of production to prevent food shortages. The three general policy strategies to mitigate GHG emissions are market-based approaches, regulatory approaches, and voluntary agreements. Economists often support market-based policy instruments such as carbon taxes or cap-and-trade (i.e., collectively determining the price of carbon) as an incentive-compatible strategy to reduce the use of fossil fuels. Carbon pricing policies function to charge the parties responsible for emissions of GHGs. These strategies are considered cost-effective for four primary reasons. First, a carbon price will minimize the societal costs of emissions reductions. Second, carbon pricing provides firms with flexibility to find the least costly way to reduce emissions. Third, carbon pricing encourages more reduction in GHG emissions than conventional regulations because it also provides an incentive to reduce demand for fossil fuels. Fourth, a price on carbon offers potential for a new revenue stream for government use to invest in renewable energy, offset distributional impacts of the pricing policy, or reduce other distortions in the economy.

Regulatory approaches include technology and emissions standards, product bans, and government investment. An example of regulatory efforts in the transportation sector is the 2020 Safer Affordable Fuel-Efficient (SAFE) vehicles rule, which seeks to increase fuel efficiency standards to reduce GHG emissions from passenger cars and light trucks (model years 2021–2026). Voluntary agreements are made between governments and private actors to achieve an environmental goal. The U.S. Environmental Protection Agency partners with the public and private sectors to oversee voluntary programs aimed at reducing GHG emissions and increasing clean energy adoption (e.g., the Energy Star program, www.energystar.gov).

The aim of adaptation policies is to reduce society's vulnerability to the harmful effects of climate change. In terms of policy options, two important questions are the timing of action and the economic agents. Adaptation can be either reactive—in response to an event or stimulus—or anticipatory, where actions are taken before impacts are observed. An example of reactive adaptation is a farmer planting a new, more drought-tolerant crop this year because of drought-related crop losses last year. An example of anticipatory adaptation is a government agency, such as the Federal Emergency Management Agency, providing funding to homeowners in a floodplain to elevate their homes now to avoid potential future flood damages. Adaptation actions can be taken by different entities. Private adaptation is a behavioral response by one individual for their own benefit. For example, an individual in Oregon might install air conditioning in their home in response to higher temperatures. Joint or public adaptation actions benefit many individuals simultaneously. For example, in Florida and other states, the U.S. Army Corps of Engineers adds sediment to widen beaches with the goal of creating a buffer to protect homes and infrastructure from storms.

Some policy options can achieve both mitigation and adaptation objectives. For example, coastal wetlands are a carbon sink, and restoration could enhance their capacity to capture and store GHGs. Wetlands also can absorb water from storm surges and protect infrastructure and homes nearby, providing a public, anticipatory adaptation to climate change. A recent coastal restoration project in Oregon suggested that a single policy intervention can meet both mitigation and adaptation objectives while also providing economic benefits at state and local levels (Shaw and Dundas 2021).

Sector-Specific Economic Impacts in Oregon

Agriculture

The breadth and economic importance of Oregon's agricultural sector is reflected in summary statistics derived from the U.S. Agricultural Census (Sorte et al. 2021). In 2017, the total value of Oregon's agriculture, food, and fiber industry was approximately $42 billion, with farm gate production accounting for $5.5 billion. Almost seven percent of Oregon's jobs directly depended on the agricultural sector. Sixteen million acres in Oregon (60 percent of private land) were dedicated to farming, and over 225 agricultural commodities were produced in the state. This diversity is an economic strength but makes it challenging to draw generalizable themes about the impacts of climate change on Oregon's agricultural sector.

Research on agriculture's role and opportunity in climate policy for mitigating GHG emissions began in earnest more than 30 years ago. A robust body of research has provided measures of the impacts of climate change on agricultural productivity and net returns, and identified policies and programs that could reduce the rate of emissions from agricultural sectors and contribute to net-negative carbon emission goals (Paustian et al. 2006). Technologies and innovations to reduce emissions will only be effective if they are adopted by agriculture and food sector stakeholders, so site-specific research is needed on the economic feasibility and long-term sustainability of proposed climate policies and related changes to production practices and processes.

Several factors limit the impacts of mitigation efforts. One is additionality. The goal of climate policy should be reductions in GHGs above and beyond those that farmers or other stakeholders, including forest owners, would make absent the climate policy. Another issue is permanence. Some changes in agricultural management, notably the sequestration of carbon in soils through photosynthesis and root growth, and incorporation of organic matter into the soil, can be reversed through disruption of the soil by tillage (see *Regenerative Agriculture*, this volume). While the lack of permanence in farm-related carbon sequestration programs has been a long-standing concern, there is some value to creating incentives for temporary carbon sequestration policies to provide more time for permanent solutions to be adopted (Antle et al. 2003). A third issue is leakage or slippage. A policy of encouraging planting and maintaining trees rather than harvesting can raise the price of wood elsewhere and cause more harvesting, thus offsetting the global benefits of the policy. Similarly, conservation policies in a large country such as the United States—for example, the Conservation Reserve Program, in which farmers receive an annual payment to remove erosion-prone land from agricultural production and plant species that will improve environmental quality—can increase the area cultivated elsewhere, releasing carbon stored in soils.

Reliance on voluntary action by consumers or farmers is unlikely to realize the full potential for agriculture to contribute to mitigation because reducing emissions, changing production practices or crops, and sequestering carbon usually is costly to farmers. For example, adoption of precision management technology, such as variable-rate seed and fertilizer applications enabled by machinery equipped with global positioning systems, varies across the United States and is not necessarily economically superior to conventional, uniform management (Basso and Antle 2020). Agrivoltaic farming—co-locating increases in agricultural productivity and generation of renewable energy—is a counter-example of an innovative, voluntary action that may have net gains (Box 1).

Farm-scale decision tools or software enable growers and researchers to better understand the economics of climate trends or changes in site-specific production practices, and provide insights and information on options to modify production practices (Capalbo et al. 2017). Decision-support tools that link with research on climate change and productivity and allow agricultural managers to better understand novel options and opportunities are fundamental to translating research to outcomes. AgBiz Logic™, the Profitability Decision Tool, and the Tradeoff Analysis Project exemplify recent decision tools that are incorporating climate change impacts.

AgBiz Logic™ provides economic, financial, and environmental decision tools for assessing alternative technologies and innovative processes. For instance, the tool has been used to incorporate projected climate changes in farm-based decision planning by apple growers in Washington (Box 2).

The Profitability Decision Tool (www.pnwlit.org/profitability-decision-tool) assists exploration of alternative rotations in dryland farming systems of the inland Pacific Northwest. Alternative cropping rotations can provide feasible options as springs become wetter and summers become drier and hotter. The tool can be used to compare the economic and financial impacts of changing to an alternative crop rotation.

Box 1. Agrivoltaic Farming

Food production and climate change impacts are typically framed in a negative context. The emphasis is often on issues such as changes in growing conditions, frequency and severity of harmful weather events, and a general deterioration in production capacity. Positive contexts, however, also exist, particularly with respect to technological innovations spurred on by anticipated needs to mitigate negative climate change impacts. An example is ongoing development of agrivoltaic farming. The goal of this technology is to combine production of solar energy and food on the same plot of land. "The hallmark characteristic of agrivoltaics is the sharing of sunlight between the two energy conversion systems: photovoltaics and photosynthesis. It essentially mimics what humans have been doing for hundreds of years with agroforestry—think shade-grown coffee—intentionally creating partial shade to create multiple layers of agricultural productivity on the same piece of land" (Macknich as quoted by Gordon 2022). Numerous approaches to agrivoltaic farming are being researched and developed (Figure B1), including placement of solar panels on dry, unirrigated farmland to increase crop yields via reduction of water use and heat stress on plants and grazing animals (Adeh et al. 2019).

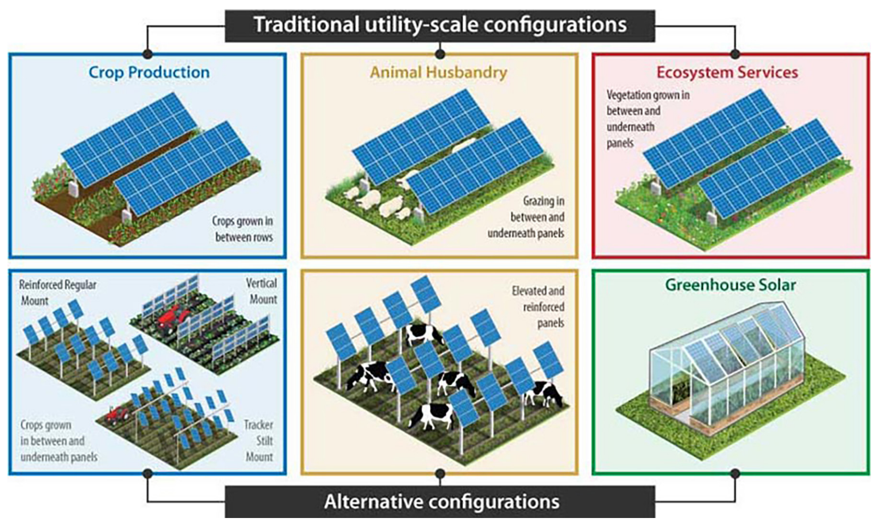

Figure B1. Agrivoltaic systems can be installed in the same basic row layout as a traditional large-scale solar plant. Alternatively, they can be modified to provide extra space for light, animals, or farm equipment to move under and among them. Source: Dreves 2022.

The Tradeoff Analysis Project (agsci.oregonstate.edu/tradeoff-analysis-project) develops modeling tools that can be used to improve understanding of agricultural system sustainability and inform policy decisions. The software is based on the whole farm system (crops, livestock, aquaculture, non-farm income) and simulates economic indicators (per-capita income, income-based poverty) and mean and threshold indicators for economic, environmental, or social outcomes associated with the systems. An application of this tool examines impacts of climate change on the winter wheat sector in the Pacific Northwest and indicates higher yields on average from future climate scenarios, although there are both winners and losers due to variations in weather and biophysical and socioeconomic conditions. (www.reacchpna.org/sites/default/files/tagged_docs/6c.2.pdf).

Specialty fruit crops represent a substantial portion of the value of agricultural production in the Pacific Northwest. Climate change will most likely threaten water sources, lengthen the dry season, raise temperatures during both the winter chilling period and the growing season, and facilitate the

Box 2. Incorporating climate impacts in farm-based decision tools

Van Name et al. (2017) discussed the use of AgBiz Logic™, a decision tool that measures the economic effects of climate change, and illustrated the use of this tool with apple production in the Pacific Northwest. In 2015, snowpack levels in the Pacific Northwest were the lowest on record. Snowpack levels strongly affect the volume of water available for irrigation by those with water rights in the area. Most irrigation replenishes water lost through evapotranspiration, but irrigation also is used to cool crops in hot weather. AgBizClimate, part of the AgBiz Logic™ suite of economic, financial, and environmental decision tools for agricultural businesses (Seavert 2015), was used to inform growers about impacts due to low snowpack. Still in development, AgBizClimate is an online application that delivers essential information about climate change to farmers and land managers, including relevant climate variables modeled into the 2040s.

Van Name et al. (2017) surveyed growers with the goal of obtaining insight into the types of weather that have the greatest effects on crop yields. Apple growers based in Yakima and Wenatchee, Washington, indicated that they most frequently monitored snowpack, accumulated growing degree days, the number of consecutive extremely hot days, and the number of nights below freezing (Table B1).

Variable thresholds and comments
Number of days above freezing • Determines the developmental stage of the fruit
Number of nights below freezing • Winter injury to fruit trees from November through March, spring frost from March through May • Overnight low temperatures in spring can freeze fruit buds • Contributes to cost of frost protection to save fruit buds
Number of consecutive extremely cold days • Three or more days of temperatures below 0°F (-18°C) can cause winter injury to fruit trees
Number of consecutive extremely hot days • Three or more days above 95°F (35°C) can cause sunburn on fruit skins
Accumulated growing degree days • Drives models of pests (especially codling moth [*Cydia pomonella*]) from April through August. Pests can increase chemical costs and the number of chemical applications.
Accumulated chilling hours • Certain apple varieties require more than 400 chilling hours to avoid blush coloring on the skin of the fruit
Snowpack • Amount of snowpack is 100% of the seasonal supply to all water rights holders in the Yakima River basin • Affects the severity of drought, which affects and limits irrigation and overhead cooling strategies

Table B1. Examples of grower-defined thresholds.

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spread of fungal diseases and insects. Such changes have the potential to substantially reduce net returns due to increased input costs and altered yields and product quality. Houston et al. (2018) highlight changes in climate and key vulnerabilities that are already influencing specialty fruit crop production in the Northwest and identify adaptation strategies and actions that improve both yields and quality of crops and retain the economic viability of specialty fruit crops in the region. Many management strategies that are already being used to prolong growing seasons in marginal production areas and to improve production and quality in established production regions may also be useful as adaptation strategies under a changing climate. These near-term strategies involve moderating temperatures through use of overhead sprinklers and shade netting or compensating for mismatches between phenology and seasonal weather conditions. Longer-term strategies include investment in new varieties.

Climate change also appears to be impacting the frequency and severity of wildfires. The 2020 wildfires in Oregon significantly impacted the agriculture, food, and fiber sector (Sorte et al. 2021). Concerns and damages ranged from the taste of the food produced from the tainted crops to the crops absorbing toxicants in the smoke. The Oregon Wine Board estimated approximately a 20 percent decline in industry revenues in the 2020 crop year (Sorte et al. 2021). In Oregon, wine growers are experimenting with alternative varietals. One grower reported that their estate had worked with 28 different varietals in 2019, in part as a "way to be ahead of a changing climate" (Gruber 2020). Both growers and wineries are developing integrated risk management strategies to deal with the ever-increasing likelihood of droughts and wildfires. A

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To use AgBizClimate, the grower selects previously generated enterprise budgets from AgBiz Logic™ that best reflect their personal economic situation, whether grower data or representative returns and costs from readily available university budgets. These budgets serve as a baseline for estimating subsequent climate impacts. Modifying the base budget (e.g., for Gala apples, Figure B2) for alternative climate and productivity or cost assumptions decreased net returns. In all four scenarios, climate change substantially reduced the net returns per acre, indicating that higher losses of packed fruit sold to the fresh market resulted in a greater loss to net returns than additional chemical costs and application rates.

The AgBiz Logic™ results for apple production illustrate that changes in climate will have a large effect on current agricultural practices and overall net returns in Pacific Northwest apple orchards. With no changes in management practices, apples in the Pacific Northwest will on average fare better during winter due to decreases in winter injuries to trees. Apples will fare worse during summer as the increased frequency of consecutive extremely hot days and accumulated growing degree days affects fruit quality and insect pressures. The downscaled information from AgBizClimate on projected changes in yield and production inputs are the impetus for producer-generated adjustments in input use, management, and technology adoption that may alleviate the negative impacts or take advantage of adaptation opportunities.

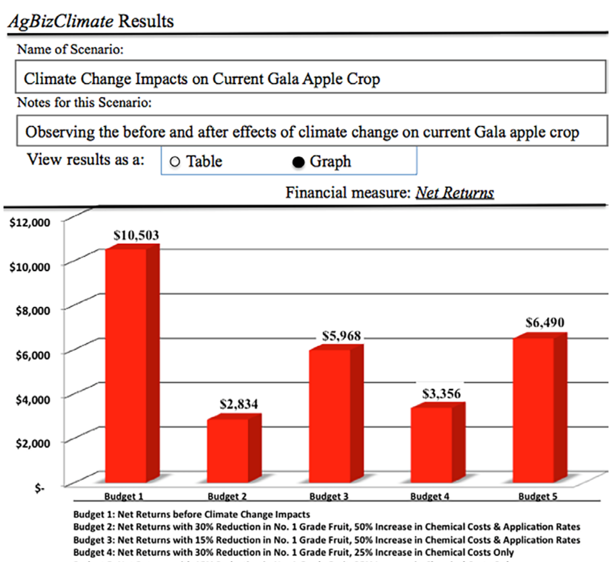

Figure B2. Example AgBizLogic™ results for Gala apples.

group of researchers in the western United States have launched a multi-state, multi-year project to develop best practices in response to drier, more extreme weather and smoke events (Box 3).

Similarly, wildfires in northern California adversely impact wine grape growers and wineries directly, via destruction of property (vineyards and facilities), and indirectly, by making the grapes unsuitable for wine production (Kropp and De Andrade 2022). In 2020, over $600 million of wine grapes went unharvested. Wildfires have resulted in changes in contracts among growers and wineries and changes in purchasing of crop insurance policies to mitigate direct and indirect risks to this sector. A record number of grapes under contract were rejected in 2020, representing nearly a 20 percent decline in tons of crushed grapes relative to 2018 (Kropp and De Andrade 2022).

Climate change also has the potential to significantly affect irrigation practices and the availability and use of scarce water in Oregon. Bigelow and Zhang (2018) provided a direct assessment of climate adaptation through the lens of agricultural irrigators in Oregon. The findings highlighted how agricultural producers in Oregon have already adapted to changing climate by acquiring supplemental irrigation rights, which allows producers to diversify their irrigation water sources. Supplemental water rights give irrigators access to another source of water if they cannot withdraw the full amount of water granted to them through the primary water right from the primary source (e.g., if junior surface water users are regulated off in a given basin, a supplemental groundwater right could be used to make up the shortfall). Olen et al. (2016) highlighted how three primary aspects of irrigation decision-making (share of farm irrigated, irrigation water application rate, and technology adoption) change with climate conditions and drought across various production specialties. The general findings suggested that temperature is a more important driver of these choices than precipitation. The study went on to highlight how these decisions are altered when the motivation for irrigation is to mitigate damage resulting from heat versus frost.

Research on water scarcity in the Willamette River basin and policies to mitigate and adapt to changes in water scarcity due to climate change have focused on changes in the availability of water that are priced and exchanged in markets (e.g., urban water) and changes in the values of resources not exchanged in markets (e.g., instream flows, forest health, flood risk protection, recreational opportunities) (Jaeger et al. 2017, 2019). This research projected trajectories of change on the basis of interactions between biophysical and human processes and is used as a tool to describe a range of future conditions associated with climate and water scarcity scenarios. The project indicated that a decline in snowpack in the next 80 years will reduce the amount of snowmelt runoff by 600,000 acre-feet of stored water. Reduced snowpack, when combined with higher summer temperatures, will increase stress on upland vegetation and increase the risk of wildfires. Furthermore, precipitation will have a far greater role than snowmelt in determining spring stream flows in the Willamette River basin. The project found that climate change is projected to result in earlier crop planting, which will lead to more crop growth during the months when temperatures are cooler and soil moisture is greater. Earlier planting will also lead to an earlier start, and completion, of irrigation. Moreover, the potential use of stored water to expand irrigation to farmlands that currently do not have irrigation water rights is limited by economic realities; conveyance costs are high relative to the economic gain from irrigating. Also, the project concluded that thirteen federal storage reservoirs in the Willamette River basin reduce the risk of flooding. This benefit has been estimated to be more than $1 billion per year. As urban areas expand and climate change leads to increases in the frequency and magnitude of high flows, the value of potential damages associated with flood events will rise.

Box 3. Research on threats of wildfire smoke to the wine industry

For the West Coast wine industry, the 2020 growing season left an enduring and unsettling memory. Large wildfires that burned across California, Oregon, and Washington destroyed some wineries and vineyards. Moreover, smoke circulated and settled into some vineyards for an extended period. Persistent exposure to smoke compromises the quality and value of wine grapes and adversely affects wines. The estimated financial loss of $3.7 billion will extend into 2023 because many wineries decided to not produce wine from grapes grown in 2020, and winery sales lag for more than one growing season because wines are aged and stored before sale (Adams 2021).

Image by Jill Wellington from Pixabay.

A team of researchers from Oregon State University, Washington State University, and University of California, Davis, supported by a $7.5 million grant from the U.S. Department of Agriculture, is collaborating to better understand how smoke density and composition affect grapes, grape vines, wine composition, and sensory perception of wine in a glass. They also aim to provide decision-support tools and guidelines to assist the grape and wine industries during future smoke events.

Reimer et al (2020) used a multi-sector economic simulation tool to estimate the overall robustness and resilience of the Hermiston economy to environmental shocks due to a changing climate. Regions with vulnerabilities in their food-energy-water nexus are likely to have economic vulnerabilities, and steps to address any environmental vulnerabilities (such as increasing water scarcity as a result of climate change) may conflict with regional and county-level concerns about employment and overall economic health as measured in terms of current and near-term economic vitality. The Hermiston area's water is allocated to different uses, such as electricity generation, farmland irrigation, municipal water, fisheries, and data center cooling. The multi-sector simulation model predicted that a one percent increase in surface water availability would lead to a $1.05 million increase in the size of the Hermiston economy, which translates into a little less than one percent.

A few takeaway messages for assessing the economic impacts of changes in climate, water availability, and resilience of local economies with a multi-sector simulation tool are as follows. First, it is important that economic models account for availability of key ecosystem services and levels of natural resources, and likewise that engineering models include behavioral information on how economic decision-makers reallocate resources under scarcity scenarios. Additionally, when a simulation tool provides information on the overall robustness and resilience of a local or regional economy to changes in water availability or other environmental shocks due to a changing climate, the tool also can provide further information on the benefits and costs to the local economy of actions to enhance other environmental outcomes such as ecological restoration, recreation, or wildfire mitigation.

Forests

Nearly 47 percent of Oregon is forested, and forestry contributes ~2.1 percent to the state's GDP. Annual timber harvests average ~3.8 billion board feet, and the industry supports around 3 percent of jobs (~62,000) in the state (OFRI 2022). Oregon is the leading U.S. producer of softwood lumber, plywood, and value-added engineered wood products. Early economic work on the impacts of climate change on forests in the United States suggested that timber stocks may expand and market benefits are possible (Sohngen and Mendelsohn 1998). The state's forests also support outdoor recreation, provide habitat for endangered species, and protect water supplies.

Forests can mitigate climate change by acting as carbon sinks, absorbing GHGs from the atmosphere and storing them in biomass and soils. When cleared, degraded, or burned, they can become sources of GHG emissions. In Oregon, forests act as a carbon sink, removing nearly 31 million metric tons of carbon dioxide from the atmosphere each year (Christensen et al. 2019). This estimate accounts for GHG absorption by live tree growth, net emissions from harvesting, and mortality events (including wildfire). The economic value of this ecosystem service, assuming $185 per metric ton as the social cost of carbon (Rennert et al. 2022), translates to a benefit of over $5.7 billion per year. This economically significant service suggests that forest management plays a crucial role in climate policy.

Although nearly 62 percent of forest carbon-storage capacity in Oregon is from national forests (Christensen et al. 2019), private timberland management also plays a role. Net carbon flux from forest management can be impacted by decisions on both the intensive (i.e., choices such as rotation length and thinning) and extensive (i.e., changes in size of forest or forest type) margins. A vast literature on the topic suggests that incentives (e.g., subsidies or taxes) could induce landowners to sequester carbon by planting or maintaining trees as a cost-effective means to meet policy goals (e.g., Lubowski et al. 2006), although consensus on the best approach has not been reached (Li et al. 2022). In fact, a carbon tax may lead to net emissions and loss of forest, suggesting that the climate policy tools applicable to land use may be different than those applicable to other regulated sectors of the economy (Li et al. 2022).

Box 4. Switching from Douglas-fir to ponderosa pine

Climate change may bring significant changes to private timberland in Oregon and the western United States (Hashida and Lewis 2019). Author David Lewis said, "About half of all non-federal forestland that is harvested in Oregon and Washington is currently replanted with Douglas-fir by landowners. But Douglas-fir will be less productive in a warming climate. The tree's ability to sequester carbon will diminish and landowners are more likely to switch to other trees." The proportion of land planted with Douglas-fir may decline to 25 percent by 2100 as landowners change their planting decisions in response to climate change (Hashida and Lewis 2019).

Hashida and Lewis (2019) also explored the impact of a policy that would pay landowners to delay or forgo harvest in order to sequester carbon. Current policy examples of carbon sequestration in forests include the use of carbon offsets in California's cap-and-trade program for carbon, which was a model for a program in Oregon that was proposed but not passed by the legislature. Such a carbon pricing policy would accelerate the transition from planting Douglas-fir to planting hardwoods and ponderosa pine. This policy, combined with landowner adaptation decisions, would further reduce the proportion of land planted with Douglas-fir to 15 percent (Figure B3).

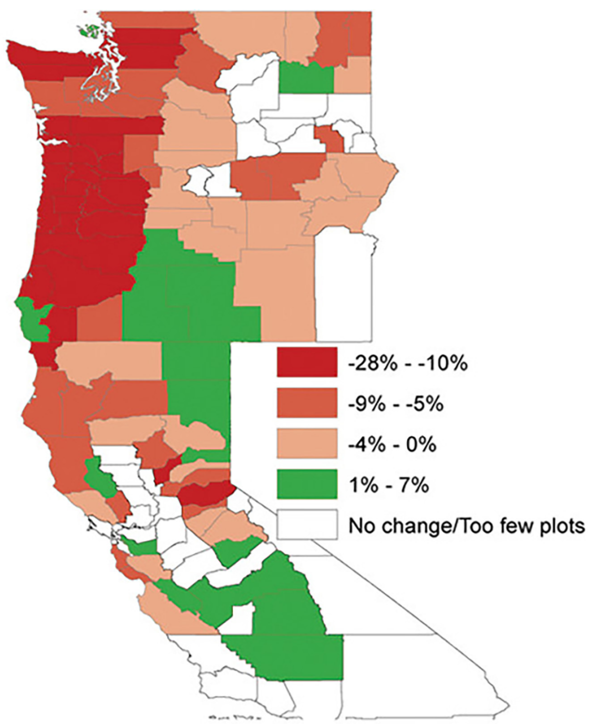

Figure B3. Effects of climate change and carbon pricing on Douglas-fir planting. Source: Hashida and Lewis 2019.

Climate change also has the potential to change the compositions of Oregon's forests. It is estimated to be a contributing factor to reducing the productivity of Douglas-fir (*Pseudotsuga menziesii*) across western states (Crookston et al. 2010, Restaino et al. 2016, Weiskittel et al. 2012) and reducing post-fire viability of Douglas-fir (Davis et al. 2020). A warmer and drier climate is projected to induce a gradual shift by private landowners in Oregon away from Douglas-fir, the state's currently most valuable tree species, toward hardwood species (Hashida and Lewis 2019; Box 4). An economic model estimated that climate change will induce a loss of private timberland value of 39 percent by the year 2050 in western Oregon and Washington (Hashida and Lewis 2022). The results of these economic studies are also consistent with a recent simulation that suggested climate change and increased wildfire activity will drive a shift from coniferous forests to shrubland-hardwood forests in the Klamath region (Serra-Diaz 2018).

Furthermore, recent modeling efforts demonstrated that there are likely to be additional trade-offs associated with a transition from Douglas-fir to other trees. For example, the projected total loss of habitat for 35 species of amphibians, birds, and mammals of conservation concern in the western states exceeded the total area of habitat gained, and the net loss of habitat accelerated over time as climate changed (Hashida et al. 2020). Accordingly, adaptations by private landowners to climate change can induce social costs to non-landowners (Hashida et al. 2020).

Oceans and Coasts

Oregon's coastline stretches over 575 km (360 mi) from the California border to the Columbia River. The coastal zone is home to 225,000 people, less than 7 percent of the state's population, but supports vibrant tourism and fishing industries. According to Travel Oregon (2022), tourism in Oregon generates $5.4 billion (~2 percent of state GDP) annually. Tourism along the Oregon coast supports nearly 253,000 jobs and $1.93 billion in visitor spending each year, with a significant increase over the last decade (Travel Oregon 2022). Commercial fisheries in the state also generate substantial revenue and employment. In 2019, commercial landings generated nearly $560 million in statewide income and supported 9200 jobs (The Research Group 2021). Dungeness crab is the most valuable commercial fishery in the state, representing about one-third of the economic value from the industry. Recreational fisheries also generate considerable economic returns ($120 million in income, 2000 jobs supported in 2019; The Research Group 2021).

Climate change is already affecting tourism and fishing in Oregon, and an organization representing Dungeness crab boats is suing oil and gas companies for climate damages for harmful algal blooms caused by warming ocean waters (Box 5). Dungeness crab and Pacific oysters are valuable commodities that are also susceptible to ocean acidification, which has potential to result in loss of fisheries productivity and reduced economic opportunity. Action plans at the state level aim to develop solutions to mitigate these potential economic impacts (Whitefield et al. 2021).

Oregon's oceans and coasts are also an area for harnessing wave and offshore wind energy in an effort to expand capacity for renewable energy production. The U.S. Department of Energy recently funded PacWave (pacwaveenergy.org) to develop a wave energy testing facility off the coast of Lincoln County. The facility, which was granted a license by the Federal Energy Regulatory Commission to begin operations, will be the first commercial-scale grid-connected test site for wave energy. In September 2022, the Biden administration announced plans to develop floating platforms for offshore wind off the Oregon coast (Daly and McDermott 2022). The economic implications of increasing Oregon's renewable energy capacity are uncertain, but a government report suggested that offshore wind could generate up to $5.7 billion in economic activity and support 66,000 jobs during the construction phase, and billions in state GDP and thousands of employment opportunities over the long term (Jimenez et al. 2016).

Salmon in the Pacific Northwest are also susceptible to the effects of climate change. All salmon are anadromous, spawning in fresh water but maturing in oceans, and most spawn only once before dying. Pacific salmon are threatened by water diversions, dams, and logging when in their freshwater habitats. For populations to remain viable, adults must migrate to spawning habitat, and survival of the eggs and larvae requires cool water, gravel substrates, and sufficient water flow and oxygen. There also must be enough water flow to support migration back to the sea. Climate change is affecting all of these elements in ways that threaten the survival of salmon runs, and several of the region's populations may be approaching physiological temperature tolerances (Crozier et al. 2019).

Maintaining salmon populations as climate changes will require restoration of large patches of connected habitat. Residents of the Pacific Northwest place significant value on such restoration efforts for threatened Oregon Coast coho salmon populations (Lewis et al. 2019, 2022). A nonmarket valuation survey estimated that the regional willingness to pay for restoration efforts that increase coho runs by 100,000 fish approaches a half a billion dollars per year (Lewis et al. 2019). Restoration of salmon habitat in coastal and marine environments could also provide co-benefits of carbon sequestration and buffers against sea level rise and storm surges (Dundas et al. 2020).

The risk that erosion will affect coastal housing and infrastructure in Oregon is increasing due to climate change effects on winter storms, El Niño–Southern Oscillation (ENSO) events, and sea level rise. Increased erosion creates a fundamental tension between coastal property owners who want to protect their homes and investments, often with hardened shoreline armoring such as sea walls or rip-rap revetments, and the public right to recreate on the coast as codified by the 1967 Beach Bill. Recent research examined the economic value to coastal housing markets generated by state land-use regulations that limit armoring (Dundas and Lewis 2020). Homes in areas with the option of hardening the shoreline for erosion protection sold for 13 to 22 percent more than similar homes without the option of protection. Additionally, the right to armor may impose costs on neighbors that are not eligible to armor, reducing their land value by nearly 8 percent. Landowners' decisions about whether to armor their shoreline are highly influenced by the observed actions of neighbors (Beasley and Dundas 2021). Scenario-based simulations suggested that private armoring along the Oregon coast would increase 70 percent if Goal 18 land use regulations (www.oregon.gov/lcd/OP/Pages/Goal-18.aspx) were removed. Currently, Goal 18 limits private shoreline armoring to properties that existed prior to 1 January, 1977, when the armoring prohibition went into effect. Coastal land-use policy generates value and loss, and may be a key factor in how the Oregon coast adapts to climate change.

Box 5. Oregon's Dungeness crab fishery sues 30 fossil fuel companies

An extensive area of unusually warm water in the northern Pacific Ocean in the mid-2010s, known colloquially as The Blob, led to a surge in toxic algae. These events led to an increase in domoic acid, a neurotoxin that cost the West Coast Dungeness crab fishery more than $150 million in 2015. This disruption, and other season delays in subsequent years, led to many boats moving to different fisheries or going out of business. In 2018, the Pacific Coast Federation of Fishermen's Associations, which represents commercial harvesters and onshore processors and wholesalers, decided climate change was the culprit and initiated a lawsuit against fossil fuel companies for actively covering up their role in climate change. The lawsuit also sought damages for anglers impacted by these events. This was the first time a private organization attempted to sue the oil and gas industry for climate damages. As of November 2022, the legal case is ongoing.

Image by Sabrina Eickhoff from Pixabay

Other Important Economic Impacts

Public Health

Nationwide, the impact of climate change on public health, including mental health, is receiving serious attention. Oregon Health Authority (OHA) provided two reports, one each in 2014 and 2020 (OHA 2014, 2020). The message of the 2020 report is clear: climate change is a public health threat disproportionately affecting lower income communities, communities of color, tribal communities and frontline workers. " . . . agricultural workers, fishers, forestry workers and hunters account for 20 percent of heat-related deaths in the United States . . . In urban areas, people who work and reside in urban heat islands (i.e., construction workers) are also more at risk of climate-related health hazards" (York et al. 2020:39). The report notes that lower income and rural Oregonians have a harder time adapting to climate change because they have fewer options available to them and less financial stability. They also tend to work in jobs that are outside or on the front lines and live in hotter areas that will be more vulnerable to climate-related food and housing insecurity. Additionally, recent research suggests that rates of traumatic injuries for outdoor workers (e.g., heat stroke, dehydration) are significantly higher during hotter weather, especially for agricultural workers (Evoy et al. 2022).

In recent summers, Oregonians have experienced unprecedented wildfires and record setting heat waves. These heat waves bring an increase of heat-related hospitalizations and respiratory illnesses, in addition to increased water insecurity, ozone pollution, airborne pollutants, molds, and allergens in the air. The OHA 2020 report notes, "if greenhouse gas emissions remain high, most of the state will experience significantly more days with temperatures above 86°F . . . by the year 2040." This projection was borne out in record-setting heat waves from June through August of 2021 and 2022. The Oregon Environmental Council (OEC) summarized the OHA 2020 report, noting estimates of the health costs of climate change on selected health outcomes (heart disease, stroke, asthma and premature births) at nearly $10 billion per year (oeconline.org/oha-report-climate-crisis-a-current-and-growing-threat-to-the-health-of-oregonians).

Increasing frequency of wildfires also produces public health concerns for Oregon. Dittrich and McCallum (2020) provide a review of the health impacts of wildfire smoke and economic approaches to estimate damages, with a focus on the Pacific Northwest. Their findings suggest costs could be in the billions of dollars, driven mostly by increases in premature mortality related to smoke exposure. Fine particulate matter ($PM_{2.5}$) in wildfire smoke can increase the incidence of violent crime (Burkhardt et al. 2019), worsen health outcomes (Bishop et al. 2018, Deryugina et al. 2019), and reduce labor productivity (Graff Ziven and Neidell 2012). Furthermore, current government policies that rely on individuals to protect themselves from wildfire smoke, such as by staying inside or buying air filters, are likely to have minimal benefits that are likely to be unequally distributed across household-based income (Burke et al. 2022).

Recreation

Outdoor recreation contributed 1.8 percent (~$375 billion dollars) to U.S. GDP in 2020 (Bureau of Economic Analysis 2021). The contribution of outdoor recreation to Oregon's state GDP (2.2 percent) is higher than the national average. In Oregon, outdoor recreation supported 224,000 full-time jobs and $15.6 billion in spending in 2019 (Mojica et al. 2021).

Recent empirical research suggests that climate change is likely to affect many forms of outdoor recreation and that impacts are likely to vary across seasons, locations, and activities. Increases in the incidence of days with extreme heat are likely to have negative economic effects on marine recreational fishing, but the magnitude of the impact will depend on the adaptability of recreators to adjust the timing of fishing (Dundas and von Haefen 2020). By contrast, climate change may improve economic welfare for the cycling sector by expanding recreation windows in spring and autumn (Wichman and Chan 2020). Recent research suggests some Oregon-specific impacts of climate change on winter recreation. Peak annual snowpack in the Oregon Cascade Range may decline by 25 percent by 2050 and 75 percent by 2100 (Siirila-Woodburn et al. 2021). Reduced snowpack in the Oregon Cascade Range may result in nearly $19 million annually in total damages to activities related to skiing, and damages are projected to $425 million per year in California (Parthum and Christensen 2022).

Wildfires also are likely to have substantial negative impacts on outdoor recreation. Not only do wildfires create smoke, which may limit many types of outdoor recreation across a large geographic area, but they also precipitate closures of popular recreation areas in the name of public safety. For example, in late September 2022, hundreds of kilometers of forest roads and nearly 150 trails were closed due to the Cedar Creek Fire in the Willamette and Deschutes National Forests. The U.S. Forest Service also closed 86 recreation sites, including 28 campgrounds, and large sections of the Pacific Crest Trail across the two national forests. These closures came on the heels of the 2020 Labor Day fires (e.g., Beachie Creek, Lionshead), which led to closure of 19 popular trailheads, eight recreation sites, and numerous forest roads. Many of these closures may persist until summer 2023. The full economic impact of these and other recent fires, such as the Eagle Creek fire in the Columbia River Gorge, on Oregon's outdoor recreation economy has not yet been estimated. More assessment is also needed to understand the economic impact of a recreation experience that is affected by a prior wildfire (e.g., hiking through a burned area rather than an old-growth forest). Initial work suggests that the Eagle Creek fire may have reduced overall recreational visits to the area and induced a spatial redistribution of visits to specific sites (White et al. 2022).

Migration

Key factors in people's motivation to live in Oregon are the local environmental quality and the amenities associated with our climate. In other words, climate is a key factor in state residents' quality of life. A recent national analysis of predicted quality-of-life changes due to climate change suggests declines across much of the country (Albouy et al. 2016). Areas of Oregon west of the Cascades are an exception, and people in that region may benefit from climate change because of improvements to climate amenities in the future (Albouy et al. 2016). This result suggests people may want to move to Oregon due amenity shifts from climate change.

Climate migration is the temporary or permanent movement of a person or groups of persons, primarily in response to sudden or progressive changes in the environment due to climate change, within a country or across an international border. Although transboundary climate migration receives the most media attention, the majority of migration is within-country. Challenges result from the speed of climate change the number of people it affects. Temporary migration in response to climate stressors is already happening on a regular basis (e.g., evacuation associated with wildfires). The ability to migrate is a function of mobility and resources. Accordingly, the people most vulnerable to climate change are not necessarily those most likely to migrate.

In the United States, 162 million people—nearly half of the country's population—will most likely experience hotter temperatures and less rainfall. By 2070, if carbon emissions continue to rise, at least four million Americans may live in places outside the ideal range of conditions for human life (Xu et al. 2018). One in 12 residents of the southern United States may move toward California, the Mountain West, or the Pacific Northwest over the next 45 years because of climate influences alone (Fan et al. 2018). Such a shift in population is likely to increase poverty and widen the gulf between the rich and the poor. It will accelerate rapid urbanization of cities not prepared for the burden. People are likely to move to Oregon in response to climate change, and the population and economic production of the Pacific Northwest and Intermountain West may increase by 15 percent and 10 percent, respectively, by 2065 due to climate migration from other areas of the country (Fan et al. 2018). On paper, increased population and economic productivity may be viewed favorably, but such changes may create economic disruption, such as housing shortages and stressed infrastructure, if areas receiving migrants are unprepared for the magnitude of the change.

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