Deschutes Land Trust Climate Change Strategy: Guidance for Climate-Responsive Conservation and Stewardship in the Deschutes Basin

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Strategy Organization and Purpose

The Deschutes Land Trust Climate Change Strategy (Strategy) has three broad sections: (1) information on climate change science, impacts, and current research, with a focus on Oregon and the Pacific Northwest; (2) mitigation and adaptation information and actions related to Central Oregon and the Deschutes Basin; and (3) knowledge and action applications for conservation, stewardship, community engagement, and organizational sustainability. Based on these sections, the Strategy serves a dual purpose: to provide information on climate science and to suggest locally appropriate responses to this information. The comprehensive nature of the Strategy is such that a person with any level of climate change background should be able to understand the key issues and solution opportunities relevant to the Land Trust without necessarily needing to consult further resources.

Executive Summary

In the last ten years, many land management agencies and organizations have begun to integrate climate change strategies into their work. These plans range from mandatory climate actions to more general considerations of the ways that climate change will impact land and natural resources. The Land Trust has long talked about creating a climate change strategy—and set the goal of creating one by 2018 in its 2017-2027 Strategic Plan—but has not, until now, formally incorporated a climate change response into its conservation, stewardship, and community engagement work.

Climate change threatens the Land Trust's core mission of conserving and caring for the lands and waters that sustain Central Oregonians—human and natural—for generations to come. In that regard, responding to climate change is like an insurance policy for land trusts. This Strategy formalizes a commitment to long-term climate change action in the Deschutes Basin, recognizing that the Land Trust must include climate change action into every facet of its operations in order to effectively conserve lands across Central Oregon for generations to come.

Climate change has already begun to affect—and will continue affecting—almost every aspect of the ecological function of Central Oregon, mostly due to increased atmospheric temperatures and more precipitation falling as rain. Snowpack will decline, farms will experience improved yields in the short term and water shortages in the long term, streams will exhibit earlier peak flows and lower low flows, and forests will become more susceptible to fires and diseases, among other impacts.

To ameliorate or prevent these issues, the Land Trust will have to engage in concerted mitigation and adaptation efforts. Mitigation includes actions that prevent or sequester emissions of carbon dioxide (CO_2) and other greenhouse gases that contribute to warming the Earth's atmosphere. Forests, soils, and wetlands can play a major role in storing carbon, so the Land Trust can help mitigate local climate change impacts by properly protecting and managing these resources on its conservation easements and preserves.

Adaptation includes any action that facilitates human and natural systems' ability to anticipate or respond to the effects of climate change; in other words, it is the ability to avoid the possible harms caused by a rapidly changing climate. For the Land Trust, reasonable adaptation actions will mostly take place under the purview of stewardship and restoration, and should focus largely on building climate resilience across habitats and ecosystems. This can include protecting or creating climate refugia, reconnecting floodplains, reforesting or afforesting properties, and ensuring habitat connectivity, among other actions.

Conservation can play a role in mitigation by preserving lands with significant carbon storage potential, and it can help ecosystems and species adapt to climate change by protecting resilient lands that provide topoclimate diversity and habitat connectivity. Over the next several months, the Land Trust will create a strategic conservation plan that takes into account an interrelated suite of factors—including climate change—that will guide future land acquisition.

Climate-responsive stewardship can further contribute to adaptation efforts by restoring ecosystems in ways that allow them to engage their natural, dynamic adaptive processes. To fully understand where and what kind of stewardship activities might best enable adaptation, the Land Trust should develop a comprehensive climate change vulnerability assessment as part of its property monitoring and evaluation system.

Developing a strategy for climate change-related community engagement will round out the Land Trust's efforts to mainstream climate change action. The Land Trust can use its voice as a conservation organization to help landowners, supporters, and members of the general public understand climate change impacts and potential solutions in Central Oregon.

This Strategy offers a framework for the role of a land trust in combatting climate change, and suggests several routes for concrete participation in local adaptation and mitigation efforts. Although this document is by no means exhaustive, it should serve as a starting point for building strategic and lasting climate change responses into the Land Trust's work.

Introduction

Climate change is an ongoing phenomenon that will severely impact nearly all aspects of Earth's terrestrial and aquatic ecosystems, and has already begun to do so across the Pacific Northwest (PNW). From increased wildfire, to sea level rise, to species extinction, the on-the-ground effects of climate change will be vast and irreversible, and overcoming these impacts will require concerted local, regional, and international mitigation and adaptation efforts. As a conservation organization, the Land Trust can substantially contribute to mitigating the effects of climate change on local habitats and ecosystems, and can help facilitate species' adaptations to altered landscapes throughout the Deschutes Basin.

The Strategy outlines many of the anticipated impacts of climate change on the Deschutes Basin, Oregon, and the rest of the PNW. It also provides science-based recommendations for adaptation and mitigation actions that may be implemented through the Land Trust's conservation, stewardship, and community engagement programs. Finally, the Strategy suggests possible avenues for future work and points out knowledge and resource gaps relevant to the Land Trust's mission and capacity for responding to climate change.

It is worth noting that some of the most significant contributions the Land Trust can make to climate change adaptation and mitigation will be terrestrial, which may require somewhat of a shift away from the more traditional foci of the organization, such as rivers and fish. That being said, the impacts of—and associated solutions to—climate change do not neatly fall within the bounds of ecosystems. As such, the Strategy outlines ways the Land Trust can integrate terrestrial and aquatic climate change actions in order to comprehensively respond to the challenges the Deschutes Basin faces.

The Strategy stems from an identified need to mainstream climate change into the Land Trust's work, and it builds on a previous effort to articulate the relationship between climate change and conservation (Gruenwald, 2015). This Strategy is neither definitive nor prescriptive, and should not be used as an endpoint for conservation, stewardship, or community engagement activities. Instead, the Strategy is a living guidance document that should be employed as a planning tool for making data-driven, climate-responsive land acquisition, management, and communication decisions that protect resources and habitat in perpetuity. In this regard, the Strategy aligns with the Land Trust's mission and vision for Central Oregon.

Conservation, restoration, stewardship, and community engagement naturally provide opportunities for climate change adaptation and mitigation. The Strategy recognizes and capitalizes on these opportunities by mainstreaming climate change considerations into the normal functions of the Land Trust, thus achieving cross-cutting solutions to some of Central Oregon's most pressing ecological and climatological problems.

Climate Change Strategy Mission

The Deschutes Land Trust Climate Change Strategy provides a living roadmap for mainstreaming climate change considerations into the Land Trust's work on conservation, stewardship, community engagement, and organizational sustainability. The mission of the strategy is to ensure that the Land Trust holistically participates in adapting to and mitigating climate change in ways that will benefit the wildlife, scenic views, and local communities of Central Oregon in perpetuity.

Background: Climate Processes, Impacts, and Benefits of Action

Climate change refers to any long-term changes in regional or global climate patterns, including cooling, warming, and other atmospheric conditions (NASA). The climate changes constantly, but overall warming trends have rapidly intensified and accelerated since the industrial revolution in the late 19th century. Since then, increased burning of fossil fuels to power industries, electricity, and transportation has led to the widespread release of carbon dioxide (CO_2) and other greenhouse gases (GHGs)—methane, nitrous oxide, water vapor, ozone, chlorofluorocarbons, and hydrofluorocarbons—which retain heat and warm the Earth's atmosphere. The release of these gases is often called "anthropogenic forcing," and increased GHG concentrations contribute to feedbacks that change the Earth's atmospheric, terrestrial, and aquatic systems. This human-caused—or "anthropogenic"—intensification of GHG emissions and their associated impacts is what scientists, academics, politicians, and practitioners mean by "climate change."

The research that informs the global understanding of climate change comes from several key groups, including the Intergovernmental Panel on Climate Change (IPCC), an international group of the world's foremost climate experts that publishes international climate change Assessment Reports (ARs) every 6-8 years. In 2014, the IPCC's Fifth Assessment Report (AR5) stated that 2°C (3.8°F) is the maximum "safe" average global temperature increase from pre-industrial levels. Then in 2015, the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) drafted the Paris Agreement, an international climate change response treaty that entered into force in November 2016, with 169 nations ratifying. The Paris Agreement states that, in line with the IPCC's findings, countries must strive to collectively hold the global average temperature increase to well under 2°C compared to pre-industrial levels, with a goal of not exceeding 1.5°C. This target has become the standard for measuring successful climate change mitigation, but even this amount of warming will drastically harm and change the Earth's atmospheric and ecological functions.

Although predictions vary by climate model, research suggests that in the PNW temperatures will increase as much as 5.8°F by 2050 under a business-as-usual greenhouse gas emissions scenario (RCP 8.5). Researchers project that higher latitudes will, on average, experience more intense warming than lower latitudes, which accounts for the more rapid warming throughout the PNW than in other parts of the United States (Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

This temperature increase will instigate a wide array of other impacts to every type of social and ecological system, and the PNW will face its own unique set of challenges. In Central Oregon, climate models predict changes in precipitation and snowpack, increased fire, and habitat degradation. Population and development pressures will compound these impacts, further increasing the imperative to quickly find and execute solutions.

Scientists use a variety of methods to track climate change and its impacts globally and regionally. The prevailing prediction technique is modeling, which uses current and past trends in temperature, precipitation, circulation, and other metrics to project future climate conditions. The IPCC (2013) has emphasized the importance of using General Circulation Models (GCMs) to represent atmospheric, oceanic, cryospheric (frozen water), and terrestrial responses to increasing GHG concentrations. Although models necessarily involve some uncertainty, GCMs provide the greatest potential to predict the impacts of climate change when combined with local and regional models. Understanding these models and their implications is a critical part of mounting a robust conservation-based response to climate change.

In strategizing responses to the impacts of climate change, the Land Trust joins an international effort to mitigate and adapt to the effects of increased atmospheric GHG concentrations. At the highest level, the IPCC and UNFCCC lead climate science and decision-making efforts, but implementation of their work must occur on a local level in order to effectively respond to climate change. Land management organizations and agencies—including land trusts—can play a significant role in implementing natural resource-based climate change mitigation and adaptation strategies rooted in local social-ecological contexts and the best available science. The vast amount of public land in Central Oregon also gives the Land Trust an opportunity to partner with state and federal agencies, which may maximize the impact of land-based climate action.

Taking action now can yield huge benefits not only for plants and wildlife, but also for people. By successfully mitigating and adapting to local climate change, the Land Trust will simultaneously protect wildlife habitat and help stave off catastrophic economic damage. Climate change threatens major economic sectors in Central Oregon, including farming, ranching, logging, and outdoor recreation, so protecting the resources that enable those industries is of paramount socioeconomic and ecological importance. Although socioeconomic benefits are secondary to the Land Trust's primary mission, they are important for the sustained human and natural wellbeing of Central Oregon.

Guiding Principles for Climate-Responsive Land Trust Actions

- Recognize interconnectedness of all actions; climate-responsive conservation cannot happen in isolation, and all decisions will have implications for other social, ecological, and/or economic outcomes.

- Prioritize functionality of ecological processes and systems rather than specific habitats or species; this aligns with the conservation philosophy of "conserving the stage."
- Engage a variety of relevant stakeholders to iteratively and regularly revisit strategies and approaches. Climate change action is necessarily experimental, dynamic, and imperfect.
- Understand and respond to local concerns and communities while keeping in national and global contexts in mind.
- Just as the impacts of climate change are not immediately discernable, climate-responsive conservation will not yield immediate results or solutions. However, this by no means diminishes the importance of acting now.
- The best available science should guide all conservation and stewardship approaches to adaptation and mitigation.

Climate Change Impacts and Feedbacks in the Deschutes Basin

Climate-induced temperature and precipitation shifts have already begun to affect ecosystems across Central Oregon, and the impacts of climate change on species, habitats, and land types are inherently interconnected. While this interconnectedness can pose challenges, it also means that climate-responsive conservation approaches may efficiently address multiple impacts. Although considerable uncertainty accompanies current research, which predicts a fairly wide range of climate change impacts based on different models, scientists have arrived at several largely agreed-upon effects of climate change on various land types. The most pertinent of these are listed below.

Forests

As the planet's largest terrestrial carbon sink, forests play a critical role in the dynamics and impacts of climate change; they simultaneously face enormous threats and present promising mitigation opportunities.

In the short-term, climate models suggest that alpine, sub-alpine, and conifer forests will contract, shifting forests to a mixed-conifer composition (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). Meanwhile, longer growing seasons and increased precipitation may lead to the expansion of forests and woodlands into parts of Central and Eastern Oregon that are otherwise typically characterized by shrublands and grasslands. This forest expansion will coincide with larger, more frequent fires throughout Central and Eastern Oregon (Shafer *et al.*, 2010). The amount of forest area experiencing high fuel aridity—a key factor of forest fires—increased 75% between 2000 and 2015, and anthropogenic climate change accounted for approximately 55% of the increase in fuel aridity between 1979 and 2015 (Abatzoglou & Williams, 2016).

Overall, between 1984 and 2015 anthropogenic climate change nearly doubled the amount of forest area burned by wildfires as compared to the expected burn area without climate change

(Abatzoglou & Williams, 2016). Natural climate variability and fire suppression have compounded the effects of anthropogenic climate change on fuel aridity and area burned. Wildfires also negatively impact carbon cycling and uptake both by eliminating carbon sinks and by producing pyrogenic GHG emissions (Meigs *et al.,* 2009).

Increased temperatures not only contribute to fuel aridity and water stress in forests, but also allow tree disease outbreaks and bark beetle invasions (Halofsky & Peterson, 2016; Bentz *et al*., 2010). Disease and infestations both lead to tree mortality, and fire and other heat stresses lower trees' resilience to such threats (Bentz *et al*., 2010). As an example of forests' responses to climate change, models suggest that the range of bark-beetle-hosting ponderosa pine and Douglas fir trees will increase 11% and 7%, respectively, by 2060, creating opportunities for large-scale infestations (Bentz *et al*., 2010). This type of climate change-species migration dynamic will most likely lead to widespread mortality of the ponderosa pine in the long term.

For the remaining forests still in timber production, the combined impacts of fire, insects, and disease could also have economic repercussions that will compound the troubles that the lagging industry already experiences. This new reality may motivate private landowners to begin participating in the burgeoning carbon market.

Snow and Mountains

Although predictions vary, models tend to project that climate change will, at least in the next hundred years or so, cause increased precipitation across Oregon (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). Due to rising temperatures, this precipitation will fall primarily as rain and will significantly reduce snowpack. In the transition to rain-dominant precipitation, rain-on-snow events will likely contribute to increased flooding and other streamflow changes. Between 1955 and 2015 Oregon already saw its spring snowpack snow water equivalent (SWE) decline by 37 percent; by the 2080s, all of the Deschutes Basin will be rain-dominant (Mote and Sharp, 2015; Raymondi *et al*., 2013).

As temperatures increase throughout Oregon, the topoclimate diversity of mountains—the range of temperature and moisture levels—will provide areas of low climate velocity and will continue to offer some of the coldest refugia for climate-sensitive species. Although the specific results of changes in snowpack-temperature interactions are unknown, evidence suggests that mountains and other topoclimatically diverse ecosystems will likely play an important role in climate-responsive conservation (Dobrowski, 2011; Dobrowski *et al*., 2013).

Rainfall, Rivers, Riparian Areas, and Wetlands

As aforementioned, increased rainfall is one predicted outcome of climate change in Oregon, since warmer air holds—and ultimately releases—more moisture than cooler air (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). One of the main phenomena associated with changes in precipitation will be an increase in the frequency of atmospheric rivers, which are streams of warm, moist, tropical air that carry water vapor to Oregon and other mid-latitude regions. In the Cascades, this means less snowfall, more rainfall, and more flooding (Warner, Mass, &

Salathé, 2015). A higher number of extreme precipitation days will accompany this increase in atmospheric rivers, particularly during the early rain season (October and November). On these days, models project overall precipitation increases of 15-39% under a business-as-usual (RCP 8.5) emissions scenario (Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

In rivers, diminished snowfall, increased precipitation as rain, and more near-term rain-on-snow events will contribute to earlier peak streamflow, will cause lower low flows, will decrease annual streamflow, and may also lead to other changes in streamflow timing (Luce *et al.*, 2013). Models also predict that less snowpack will lead to reduced mountain groundwater recharge, which will have effects that radiate throughout mountain ecosystems, impacting fish, plants, and even humans (Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

Increased atmospheric temperatures will also cause higher stream temperatures and may reduce habitat quality for fish. The salmonids native to Central Oregon require low stream temperatures to survive, so temperature increases can significantly impact fish species by altering metabolic rates and decreasing genetic diversity, while changes in streamflow may damage habitat and prevent returns of anadromous fish, including steelhead and salmon (Palmer *et al.,* 2007; Dalton, Dello, Hawkins, Mote, & Rupp, 2017).

Wetlands are another type of water-dependent ecosystem that will face a wide range of potential climate change-induced challenges. If precipitation increases across Central Oregon, wetlands may become wetter overall, but will be subject to the same seasonal variability that will impact streamflow regimes. Species may suffer from temperature changes, decreased water quality, and decreased habitat. Since wetlands are important carbon sinks, their destruction by climate change will also contribute to a positive feedback loop: fewer wetlands will mean less carbon storage, which will mean less mitigation, which will mean higher atmospheric GHG concentrations, which will further reduce the extent of wetlands.

It's also possible that the biggest impact of climate change on wetlands and riparian areas will be to compound the damage already done to these ecosystems by development, pollution, and river modifications in Central Oregon. In general, it is important to keep in mind that climate change does not act on water resources in isolation; instead, it compounds other pre-existing or on-going damages, especially in rivers and wetlands. Altered or constrained rivers have far less adaptive capacity as compared to free-flowing river systems that can dynamically respond to changes in land use and climate (Palmer *et al.,* 2008). This further magnifies the need for riparian conservation and restoration, particularly along rivers that have been dammed, straightened, diverted, or otherwise modified (Palmer *et al.*, 2008).

Sagebrush-Steppe

Sagebrush-steppe ecosystems cover most of Oregon east of the Cascades, and are part of a broader sagebrush ecosystem that extends throughout the entire Great Basin. Sagebrush-steppe habitats will likely contract as a result of climate change, which will allow woody vegetation like juniper to expand, aided by increased rainfall (Dalton, Dello, Hawkins, Mote, & Rupp, 2017; Neilson, Lenihan, Bachelet, & Drapek, 2005). Intensified fires will compound the damage done by the encroachment of woody vegetation and invasive species like cheatgrass; this new vegetation regime will provide ample fuel and may render former sagebrush-steppe ecosystems entirely grassland in the long term (Neilson, Lenihan, Bachelet, & Drapek, 2005). Increased temperatures in southern sagebrush-steppe ecosystems may also push their characteristic species northward, leading to further displacement of wildlife and vegetation elsewhere (Neilson, Lenihan, Bachelet, & Drapek, 2005). In Central and Eastern Oregon, some of the wildlife species likely to face population decline, displacement, and habitat loss include pronghorn, pygmy rabbit, western burrowing owl, mule deer, golden eagle, and greater sage grouse.

Farms and Ranches

Atmospheric CO_2 concentrations, precipitation, and temperature changes will all directly affect agriculture and ranching in Oregon, which is over 25% farmland (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). At the same time, agriculture and ranching both directly contribute to climate change, accounting for roughly 9% of total greenhouse gas emissions and creating a critical climate feedback loop in one of Oregon's largest industries (USEPA, 2017).

Significant uncertainty accompanies predictions about the agricultural impacts of climate change, but most research suggests that, in the near-term, Central Oregon will experience longer growing seasons, more frost-free days (Abatzoglou, Rupp, & Mote, 2014), and increased net primary productivity (NPP)—plants' ability to assimilate CO_2—in crops (Creighton *et al.,* 2015; Reeves, Moreno, Bagne, & Running, 2014). However, drought and heat stress, water shortages, and the encroachment of invasive weeds like cheatgrass will ultimately temper any positive impacts of climate change on farms and ranches (Creighton *et al.*, 2015; Boyte, Wylie, & Major, 2016; Eigenbrode *et al.*, 2013).

By the end of the 21st century, farmers ranchers should expect to face crop losses (Eigenbrode *et al.*, 2013), reductions in rangeland, decreased water supply, increased soil erosion due to drought, wind, heavy precipitation, and fire (Farrell *et al.,* 2015; Boyte, Wylie, & Major, 2016; Vose *et al.,* 2016), and declines in crops' nutritive value for humans and livestock (Ziska *et al.*, 2016).

Despite these looming challenges, farmers and ranchers have many adaptation options at their disposal, including conservation tillage (Lal, 2004), crop selection, timing, and rotation (Howden *et al.*, 2007), climate-smart irrigation (Creighton *et al.*, 2015), weed and pest control (Howden *et al.*, 2007), combatting erosion, and heat abatement for livestock (Creighton *et al.*, 2015).

Overall, biotic responses to changes in heat, water, and CO_2 will be complex, which hinders achieving a solid understanding of climate change's physical and economic impacts on farms and ranches in Central Oregon (Dalton, Dello, Hawkins, Mote, & Rupp, 2017). This uncertainty should motivate farmers and ranchers to adopt adaptive agricultural and grazing practices as soon as possible, and could become an element of future working lands conservation easements.

Cities and Towns

Although the Land Trust mostly works outside of the urban growth boundary of cities and towns, urban climate change dynamics will have wide-reaching impacts on Central Oregon that will also affect conservation and stewardship, even if indirectly. The two most relevant urban climate change dynamics will be population growth and land cover, both of which connect to increased development and GHG emissions.

The Land Trust works primarily in Jefferson, Crook, and Deschutes Counties, and according to Portland State University's Population Research Center (PRC), Crook and Deschutes are two of the fastest growing counties in the state, with growth rates of 2.3% and 3.5%, respectively, between 2015 and 2016 (2016). In 2015, the PRC executed Coordinated Population Forecasts from 2015 to 2065 for every county in Oregon. As of 2016, the combined population of Jefferson, Crook, and Deschutes Counties was 221,005. The PRC has projected a total population of 300,926 for the three counties by 2035 and a total of 416,764 by 2065—an 88 percent increase from 2016, with the majority of the growth occurring in Deschutes County (PRC, 2016).

With respect to climate change, Central Oregon will likely remain inhabitable further into the future than many other parts of the American West, particularly when compared to susceptible coastal regions or much hotter, drier parts of the country. The tri-county area can expect two major results of population growth: increased resource strain and further development, both of which will compound negative effects of climate change in Central Oregon.

Resource use and development will not only threaten wildlife habitats and ecosystems, but will also cause land use and land cover changes that will have negative consequences for urban carbon storage, emissions, and heat feedbacks. Removing vegetation will reduce terrestrial carbon storage capacity, and as homes, businesses, and infrastructure replace vegetation, urban environments will trap more heat and further contribute to the public health issues and feedback loops caused by climate change.

Deschutes Land Trust Preserves and Easements

Unfortunately, the Land Trust's preserves and easements—along with the rest of Central Oregon—will experience climate change impacts under any emissions scenario and regardless of stewardship efforts. While there is no way to know exactly what the type or extent of these impacts might be, the Land Trust can reasonably expect impacts such as changes in vegetation type and cover, increased fire risk, changes in streamflow timing, reduced snowpack, increased tree disease, increased presence of invasive species, significant habitat migrations, species loss, increased precipitation as rainfall, and warmer average temperatures, among other impacts. The Land Trust can and should take a variety of measures to mitigate and adapt to many of these climate change impacts.

Land Trust Mitigation Potential

The U.S. Global Change Research Program's Third National Climate Assessment (2014) defines climate change mitigation as actions "that reduce the human contribution to the planetary greenhouse effect." These actions can include reducing GHG emissions in the first place, or removing CO_2 from the atmosphere by creating or maintaining terrestrial carbon sinks.

Proper land management constitutes a significant mitigation opportunity in Central Oregon for local, state, and federal agencies and organizations. Recent research shows that using "natural climate solutions" (NCS) including conservation, restoration, and land management can substantially increase carbon storage and reduce GHG emissions (Griscom *et al.,* 2017). According to this study, natural climate solutions can account as much as 37% of the cost-effective carbon mitigation needed to reach a 66% probability of staying below a 2°C warming threshold while also improving stewardship outcomes such as biodiversity, climate resilience, soil health, and flood buffering. By continuing to prevent land conversion and by focusing on scientifically informed restoration and stewardship, the Land Trust will contribute to critical carbon storage efforts.

Soil and Forest Carbon Storage

Forests—including soils—can sequester over half of the land-based CO_2 pool, making them the world's largest terrestrial carbon sink (e.g. Hui, Deng, Tian & Luo, 2017). Conversely, the degradation, removal, or conversion of soils and forests contributes to the greenhouse effect by releasing large amounts of CO_2 back into the atmosphere. Most nations and international environmental NGOs—such as the Center for International Forestry Research—have emphasized the importance of land and forests for meeting global climate change goals (Guariguata, Román-Cuesta, & Martius, 2017).

The Pacific Northwest's forests have more carbon storage potential than any other place in the United States (Oregon Wild, 2011). All 10 of the top 10 carbon storing forests in the nation are in the Pacific Northwest, and six of these are in Oregon (Oregon Wild, 2011). Work by Oregon Wild and the Woods Hole Research Center (2011) has found that the forests with the greatest carbon storage are public lands and private reserves that have not been managed for logging and have been able to develop older age classes in their forests.

According to Griscom *et al.* (2017), reforestation is the single largest low-cost natural mitigation pathway, particularly when that reforestation simultaneously reverses the damage done by overgrazing, soil erosion, or other carbon-releasing land management regimes.

Reforestation also has multiple co-benefits, including preventing erosion, improving water quality, improving air quality, and contributing to soil fertility (Griscom *et al.*, 2017).

The additional natural climate solutions that can increase or maintain forest and soil carbon storage include afforestation and preventing deforestation. Afforestation differs from reforestation in that it adds trees (where ecologically suitable) to areas that were previously not forested. Preventing deforestation is an obvious and relatively easy way to maintain carbon storage in existing forests and create opportunities for old growth, and is also well aligned with the Land Trust's conservation goals (Pelley, 2009).

Scientists, practitioners, and governments increasingly recognize forests as a critical tool for combatting the effects of climate change through carbon sequestration. New research (Federici, Lee, & Herold, 2017) suggests that forests may be just as important for limiting temperature rise as reducing fossil fuel emissions, and forest carbon storage, reforestation, and REDD+ continue to receive significant attention in UNFCCC negotiations.

Increased soil and forest carbon storage is both critical for mitigation and extremely urgent; delaying the implementation of NCS pathways will make atmospheric GHG concentrations far worse and will make future mitigation attempts vastly more expensive (Griscom *et al.*, 2017).

ACTION: The Land Trust can contribute to local carbon sequestration by choosing projects that demonstrate a clear connection between conservation and/or stewardship and the land's ability to store carbon. This may include preventing deforestation, encouraging old growth in forests, and reforesting impacted areas.

Land Use Change and Land Cover Change

Preventing and rectifying land use change and land cover change is both a mitigation and an adaptation strategy, and it is a necessary complement to the mitigation potential of forest and soil carbon storage. The land sector accounts for 16% of current CO_2 emissions, and for approximately a third of all anthropogenic emissions since 1850 (Brown *et al.,* 2014). Land surface processes and resource distributions also contribute to and modulate heat waves, droughts, and other feedbacks that impact ecological systems; anthropogenic changes to land cover and land use interrupts these processes (Findell *et al.*, 2017). Land use change includes all actions that convert land into non-natural states, such as agriculture, deforestation, draining wetlands, and development. Land cover change refers to alterations in what physically covers the land's surface, such as crops, trees, and concrete (Lal, 2004; Brown *et al.*, 2014).

Land stewardship is one of the most effective and best-understood CO_2 removal methods, and addressing land use and land cover change constitutes a significant part of that approach (Griscom *et al.*, 2017). The two primary land use and land cover change actions the Land Trust can take are (1) preventing conversion and (2) engaging in climate smart agriculture and forestry. This type of mitigation is doubly important for the Land Trust since land use change around protected areas can cause disturbance regimes that do not stop at the border of a conservation area, thus the diminishing the capacity of easements and preserves to conserve biodiversity and restore wildlife habitat and function (Hamilton, Thogmartin, Radeloff & Plantinga, 2015).

Preventing Conversion

Land conversion refers to taking land out of its natural state in order to pursue agriculture, forestry, or development, and it is the primary source of land use-related GHG emissions. The most effective role the Land Trust can play in mitigation is preventing the conversion of naturally forested or otherwise vegetated areas (Griscom *et al.*, 2017; Houghton, Birdsey, Nassikas, McGlinchey, 2017). Removing vegetation during conversion not only releases CO_2 and prevents further emissions storage, but also directly impacts air temperature and near-surface moisture (Brown *et al.,* 2014).

To restore previously converted lands, reforestation and afforestation are two highly effective ways to reverse the negative effects of land use and land cover change (see Soil and Forest Carbon Storage).

ACTION: Engage in conservation projects that may prevent conversion of land, and forest and afforest land where forests are historically and/or ecologically appropriate.

Climate Smart Agriculture and Forestry

Research suggests that with proper action, the forestry and agriculture sectors can contribute approximately a quarter of the effort needed to achieve the Paris Agreement goal of holding atmospheric warming to 1.5°C above pre-industrial levels (Houghton, Birdsey, Nassikas, & McGlinchey, 2017). It is therefore incumbent upon the Land Trust to facilitate climate smart agriculture and forestry practices on its conservation and working lands easements.

Agricultural land use releases significant amounts of CO_2 from soils, but improving pasture and agricultural management practices can both reduce emissions and improve carbon storage. Specific climate smart agriculture actions can include conservation tillage, agroforestry, and crop selection that improves total land cover and carbon storage capacity. An added benefit of improved soil and crop management is increased resilience to climate change impacts, such as erosion, on farms and ranches (Houghton, Birdsey, Nassikas, & McGlinchey, 2017).

Despite the undeniable environmental and social benefits afforded by climate smart agriculture and forestry, land use and land management decisions are often motivated by economic interest, which may prevent many landowners from changing their practices (Pennington *et al.*, 2017). Furthermore, the Third National Climate Assessment notes in its chapter on land use and land cover change that, "the benefits of land-use decisions made by individual landowners with specific adaptation or mitigation goals do not always accrue to those landowners or even their communities. Therefore, without some institutional intervention…the motivations for such decisions can be weak" (Brown *et al.*, 2014, p. 320). This reality should be part of the Land Trust's calculus in approaching agriculture- and forestry-based mitigation.

ACTION: Facilitate conservation-oriented, climate-sensitive forestry and agriculture in working lands conservation easements. Examples may include agroforestry, conservation tillage, climate resilient crop selection, and water conservation.

Carbon Offsets

Carbon offsets are a mitigation strategy that provides economic incentives to people or businesses to not emit GHGs; or, phrased differently, to continue engaging in an activity that sequesters CO_2. The entity making the payment generally does so to offset a continued (normally high) level of pollution rather than reducing their own emissions. Utility companies, manufacturers, and other emitters may be compelled to pay for carbon offsets either by law or through market-based incentives. (*N.B.* Here, it is also worth noting that creating additional carbon credits may not actually provide economic motivation for the type of emissions behavior changes necessary for combatting climate change and may more often present additionality problems. However, the market can still have some positive impacts by rewarding emissions reductions and legitimately offsetting otherwise unmitigated greenhouse gases.)

By conserving land, including forests, the Land Trust has a natural opportunity to fund its projects through carbon credits (see more information from USFS and Ecotrust; von Hagen & Burnett, 2006). Carbon trading may be a particularly appealing and practical option for working forest conservation easements, especially given the potential for cap-and-trade legislation in Oregon in 2018. Even if the Land Trust does not directly engage in trading carbon credits, the existence of a strong credits market in Oregon may beneficially influence the appraisal of conserved lands.

Land trusts such as Downeast Lakes Land Trust in Maine and Pacific Forest Trust in California have recently become involved in the carbon market. Both organizations have financed some of their work through carbon offsets and would be able to provide information on how to effectively enter and participate in carbon credit trading. University of Washington landscape ecologist Caitlin Littlefield also conducts field verification of forest carbon resource projects and may have useful advice if and when the Land Trust decides to enter the carbon market.

ACTION: Use conservation easements—especially on working forestlands—to create carbon offset opportunities that will help fund climate-responsive stewardship in perpetuity.

Mitigation Caveat

An important caveat to all of the above mitigation options is that, in a frustrating feedback loop, climate change may diminish the effectiveness and capacity of terrestrial carbon storage by damaging forests and other vegetation (Field & Mach, 2017). This underscores the need to immediately employ natural climate solutions, and to recognize the need for a suite of other complementary mitigation responses outside of the land sector.

Land Trust Adaptation Potential

The IPCC defines climate change adaptation as "adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (2001). Adaptation actions do not prevent emissions or climate change, but may lessen the damage done by GHGs. Much of the Land Trust's work already falls naturally into the category of adaptation, which often extends and supplements mitigation efforts, but innovative adaptation efforts will be necessary to adequately respond to climate change (Mawdsley, O'Malley, & Ojima, 2009).

As a general rule, species either (1) move, (2) adapt, or (3) die (MAD) in response to environmental change, and land trusts can directly influence which route they take through proper planning, monitoring, and evaluation. Climate change represents a greater rate of system-level environmental change than most species typically encounter. Furthermore, many species' habitats have already been ruined by other environmental changes, such as overgrazing, clear-cutting, pollution, etc. Responding to climate threats may also ameliorate some of these other environmental damages (Beechie *et al*., 2012).

Schmitz *et al*. (2015, p. 192) present a clear and straightforward framework consisting of six main adaptation options for conservation under both current and future conditions. These are:

1. Protect current patterns of biodiversity.
2. Protect large, intact, natural landscapes.
3. Protect the geophysical setting.
4. Maintain and restore ecological connectivity.
5. Identify and appropriately manage areas that will provide future climate space for species expected to be displaced by climate change.
6. Identify and protect climate refugia.

Collectively, this framework provides solid and flexible guidance for incorporating adaptation into every aspect of the Land Trust's work throughout the Deschutes Basin. This list aligns with the two dominant approaches to climate change-responsive terrestrial conservation: conserving the stage and terrestrial resilience.

Conserving the Stage

Conserving nature's stage (or conserving the stage) means prioritizing the conservation of geophysical sites and abiotic features that best support biodiversity and will also withstand the effects of climate change. Studies (eg. Anderson & Ferree, 2010) have shown that geophysical characteristics and settings influence species richness and diversity; therefore, maintaining geophysical or abiotic diversity should maintain overall biodiversity in the face of climate change-induced species range shifts (Noonan, 2017).

Abiotic diversity includes topoclimate diversity, overall topography, geological formations, soil, and hydrological regimes. Among the most important factors, however, are climate refugia, landscape heterogeneity, and climate change velocity (Lawler *et al.*, 2015).

Climate refugia are areas that maintain favorable conditions to support certain species even amidst an otherwise dangerous or unsuitable climate. These areas exist within microclimates, and may be critical to successful climate-responsive conservation (Lawler *et al.*, 2015; Dobrowski, 2011).

Climate change velocity is a calculation based on dividing the rate of temperature change at a location by the spatial gradient of climate at that same location. In other words, it provides a measurement of the speed and direction in which a species would have to travel to stay within a particular set of climatic conditions. Areas with high topographic—and thus topoclimate—diversity have lower climate velocities, and may be more likely to contain climate refugia (Lawler *et al.*, 2015).

Conserving the stage connects to climate change adaptation in two main ways. First, abiotic diversity not only supports enhanced biodiversity, but also enables species to track suitable climates well into the future through relatively short migrations. As such, conserving the stage can preserve climate refugia and lower climate velocity in certain areas. Second, conserving geophysical diversity builds in a forward-thinking, climate-responsive element to conservation plans (Lawler *et al.*, 2015).

ACTION: Determine where climate refugia exist in the Deschutes Basin.

ACTION: Conserve properties with high topoclimate diversity and low climate velocity, and increase the potential for climate refugia on existing preserves and easements.

Terrestrial Resilience

Mapping terrestrial climate change resilience, part of TNC's broader approach to conserving nature's stage, consists of two primary components. The first is geophysical features—referred to as land facets—which maintain biodiversity and species richness (as aforementioned). The second component is the combination of topoclimate diversity and permeability, which lend resilience to identified land facets by allowing species to respond effectively to climatic changes. Research by Ackerly *et al.* (2010) and Dobrowski (2011) suggests that topoclimate heterogeneity can buffer the impacts of climate change. Since each species is adapted to a particular set of suitable temperatures and climates, maintaining a full spectrum land facets linked to these climates should facilitate species movement and maintain overall biotic diversity. Local landscape permeability, which allows species to track suitable climates, is a measure of natural barriers, connectedness of land cover, and the spatial layout of land facets.

When used successfully, resilience mapping is a tool that will allow the Land Trust to make conservation decisions supported by the best climate science. Stewardship approaches should complement these predictions, and will also have their own adaption and mitigation impacts.

For original papers and a full synthesis review of the methods and implications of The Nature Conservancy's work on conserving the stage and terrestrial resilience, see recommended reading.

ACTION: Facilitate species migrations by ensuring high quality habitat connectivity when selecting conservation projects and conducting stewardship and restoration activities. This is a key component of the in-progress conservation priorities strategy (see Conservation below).
ACTION: Promote biodiversity on Land Trust properties through stewardship, including actions such as ensuring forest stand diversity, encouraging native plants, and actively monitoring vegetation inventories and impacts.

Biotic and Anthropogenic Influences

Despite the effectiveness of conserving the stage and building resilience as climate change adaptation strategies, biotic factors still play a substantial role in conservation outcomes. While this idea certainly applies to the role of wildlife as drivers of change, it applies more importantly to the role of humans—which cannot be separated from other biotic entities—as drivers of biotic interactions and species distribution. Even expertly executing adaptation approaches like conserving the stage and preserving terrestrial resilience may not enable species to fully overcome the scale and rate of climate change, especially as human societies begin to employ their own adaptation strategies.

Lawler *et al.* poignantly capture this reality in their 2015 review of conserving the stage as a climate change adaptation approach:

> As we enter Earth's sixth mass extinction, biotic interactions may substantially complicate conservation efforts. Even if a diversity of abiotic settings is conserved, the rates of change may be so great and disturbances so widespread that biotic communities will become more homogenized, at least in the near term (Lawler *et al.,* 2015, p. 624).

This threat of homogenization underscores the need for concerted mitigation and adaption efforts beyond landscape conservation and building resilience, which the Land Trust should recognize as it implements the Strategy.

RESOURCE: Adaptation Partners, a collaborative organization consisting of federal agencies, academics, NGO practitioners, and other stakeholders, maintains a publicly available Climate Change Adaptation Library. This resource consists of adaptation syntheses broken down by resource types, outlining key resource sensitivities to climate change and offering adaptation strategies and tactics for each sensitivity.

Deschutes Land Trust Actions

In order to mainstream climate change action, each segment of the Land Trust should consciously incorporate climate-responsiveness in its work. The following list suggests potential climate-responsive actions and considerations related to conservation, stewardship, community engagement, and organizational sustainability.

Conservation

Climate change should be a major consideration during any land acquisition process, and the Land Trust should incorporate climate change responsiveness into the language of transactions and easements when possible.

Stewardship

Climate-responsive stewardship is the natural counterpart to climate-responsive conservation; while conservation targets areas that should be protected and/or restored in order to help species and ecosystems respond to climate change, stewardship actually executes that restoration. Conscientious stewardship can effectively mitigate climate change, but it may be even more important for facilitating species adaptations in ways that would not otherwise be possible given the rapid rate of climate change.

Community Engagement

One of the key components of effective climate change communication is using a trusted messenger (Center for Research on Environmental Decisions 2009). This places the Land Trust in a critical position for providing accurate, relevant information to its supporters and the broader communities of Central Oregon.

Organizational Sustainability

While the Strategy itself represents a significant commitment to climate change, the Land Trust could further decrease the carbon footprint inherent in its daily operations.

Monitoring and Evaluation

Monitoring and evaluation (M&E) is a critical part of strategic, adaptive conservation and stewardship in the face of rapid, uncertain environmental changes.

Monitoring refers to the ongoing collection of data on stewardship outcomes, and evaluation refers to the analysis of these data points to assess the effectiveness of stewardship activities. M&E will help the Land Trust not only understand the effectiveness of its own conservation and stewardship actions in general, but will also provide a clearer picture of the specific impacts of climate change across the Land Trust's easements and preserves. Using the results of M&E the Land Trust can continuously adapt its Climate Change Strategy.

Monitoring should include data on species presence/abundance, streamflows, tree health, and other relevant ecosystem or habitat health indicators. Since monitoring is already a component of the Land Trust's stewardship work, the only necessary change is an additional focus climate change impacts, adaptation, and mitigation. Successful monitoring could include partnering with organizations like UDWC and/or increasing research capacity through outside contractors.

The next step for the Land Trust will be to identify a manageable suite of indicators to monitor—likely linked to a vulnerability assessment, as previously described. These data points may vary by property and may include specific biotic components, where appropriate. Many other land management organizations have monitoring and evaluation plans and guidance documents that could serve as examples for the Land Trust's M&E. One example is the Wildlife Conservation Society's Climate Adaptation Fund report, "Monitoring and Evaluation in Climate Change Adaptation Projects: Highlights for Conservation Practitioners" (Rowland & Cross, 2015).

M&E can also extend beyond conservation and stewardship work in the field. The Land Trust should apply the same basic principles to the effectiveness of community engagement and organizational sustainability strategies. An example of a holistic tracking tool for organization-wide climate change action is the US Forest Service Climate Change Performance Scorecard, which offers a potential approach for tracking the success of the Land Trust's Climate Change Strategy. The National Park Service also has an Inventory and Monitoring Program that could be adapted for the Land Trust's climate change-specific needs. While neither of these agencies' monitoring and evaluation programs will directly translate to conservation and stewardship M&E, it may be useful for the Land Trust to align its M&E metrics and methods with these tools for strategic public land management.

Moving Forward: Future Actions and Considerations

Climate change adds a new, challenging element to the already dynamic process of conserving land for wildlife, agriculture, and recreation. As such, the Land Trust will need to continuously adapt its approaches to conservation in keeping with climate change research and best practices. The Land Trust will also need to provide its stakeholders with the necessary resources for responding to the impacts of climate change. The following are opportunities and recommendations for future climate change responses and considerations:

1. Given the rapidly evolving nature of both climate change and climate change research, the Land Trust should revisit this strategy on a regular basis in order to make appropriate updates to goals, approaches, and current literature.
2. Formally establish and mainstream a climate change component of the Deschutes Partnership.
3. Substantively incorporate climate change into future Land Trust strategic plans, and possibly into a more long-term organizational vision or strategy.
4. Maintain high-quality, up-to-date maps of species permeability and connectivity, topoclimate diversity, overall resiliency, and other relevant features of Central Oregon and the Deschutes Basin.
5. Continuously improve approaches to GIS, remote sensing, and other forms of data collection and analysis to guide climate change responses. This may include statistical or dynamical downscaling of climate models and projections.
6. Toolkits for landowners: Provide climate change information and decision-making tools to landowners with whom the Land Trust holds—or could potentially hold—conservation easements. This may be particularly relevant in the case of working forest, working farm, and working ranch easements.
7. Consider sending a representative to relevant conferences and meetings, such as the Northwest Climate Conference, which happens each autumn.
8. Look out for, and ideally become involved in, an Oregon-based version of the Washington Wildlife Habitat Connectivity Working Group.
9. Engage in climate change policy, mitigation, and adaptation efforts by the Coalition of Oregon Land Trusts (COLT). Encourage COLT to adopt an approach to climate change similar to that of the Washington Association of Land Trusts (WALT).

Conclusion

Climate change will affect—and has already affected—Central Oregon in diverse, interconnected ways that have ecological, economic, and social consequences. As a community-based organization with property holdings throughout the Deschutes Basin, the Land Trust is well positioned to engage in actions to ameliorate the worst of these effects for wildlife habitat, while also involving and educating interested members of the public. Through strategic conservation and stewardship, the Land Trust can enhance terrestrial resilience and habitat connectivity in ways that both mitigate and adapt to climate change. Forward-looking, climate responsive conservation, stewardship, and community engagement will enable the Land Trust to truly fulfill its mission of conserving land for wildlife, scenic views, and local communities for generations to come.

Key Literature and Recommended Reading

A wealth of resources exists on climate change impacts in Oregon and the rest of the Pacific Northwest. The Land Trust should consistently consult the most recent and relevant scientific literature to guide conservation and stewardship decisions. Some of the best locally-relevant resources include **The Third Oregon Climate Assessment Report**, reports by **The Nature Conservancy of Oregon**, and research by the **Climate Impacts Group** at the University of Washington, the **Northwest Climate Science Center, and the Oregon Climate Research Institute** at Oregon State University. These resources have all significantly guided this Strategy, and should continue to inform the Land Trust's work in the future.

For more information, the following list of recommended reading consists of well-written sources that may help Land Trust employees, board members, and supporters understand basic principles of climate change, climate science, and climate-responsive conservation and stewardship from a variety of perspectives.

Academic Articles and Reviews

Allen, K. (2016). Vegetation and Resilience on Deschutes Land Turst Properties in the Whychus Creek Watershed (35 pp.). Bend, OR: Aequinox.

Anderson, M.C. & Ferree, C.E. (2010). Conserving the Stage: Climate Change and the Geophysical Underpinnings of Species Diversity. *PLoS ONE, 5*(7).

Buttrick, S., Popper, K., Jones, A., Schindel, M., McRae, B., Unnasch, R.S., & Platt, J. (2015). Conserving Nature's Stage: Identifying Resilient Terrestrial Landscapes in the Pacific Northwest (104 pp.). Portland, OR: The Nature Conservancy.

Littlefield, C.E., McRae, B.H., Michalak, J.L, Lawler, J.J., & Carroll, C. (2017). Connecting today's climates to future climate analogs to facilitate movement of species under climate change. *Conservation Biology, 31*(6), 1397–1408.

Noonan, F.C. (2017). The Nature Conservancy's Resilient Terrestrial Landscapes and Conserving the Stage: A Review of Theory, Methods, Results, and Practical Applications (11 pp.) Bend, OR: Deschutes Land Trust.

News and Agency Reports

Dalton, M.M., Dello, K.D., Hawkins, L., Mote, P.W., & Rupp, D.E. (2017) *The Third Oregon Climate Assessment Report* (106 pp.). Corvallis, OR: Oregon Climate Change Research Institute, College of Earth, Ocean and Atmospheric Sciences, Oregon State University.

For ongoing and in-depth coverage of domestic and international climate science and policy, visit the "Climate and Environment" section of the *New York Times* website.

For the latest news and research on climate change, visit the "Articles" section of NASA's Global Climate Change website.

Books

Bennett, J.O. (2016). *A Global Warming Primer: Answering Your Questions about the Science, the Consequences, and the Solutions*. Big Kid Science.

- A fully up-to-date primer on climate change.

Hawken, P. (Ed.). *Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming.* London: Penguin Books.

- To learn about comprehensive solutions to the overwhelming problems outlined by the rest of these books.

Kolbert, E. (2014). *The Sixth Extinction: An Unnatural History.* New York: Henry Holt & Co.

- A blistering case for role of anthropogenic climate change in causing the Earth's six mass extinction.

Klein, N. (2014). *This Changes Everything: Capitalism vs. The Climate*. New York: Simon & Schuster.

- Convincingly outlines the nexus of socioeconomic and political systems with environmental issues and climate change.

Lynas, M. (2007). *Six Degrees: Our Future on a Hotter Planet*. London: Fourth Estate.

- A somewhat older but very comprehensive, science-based overview of the current and future consequences of climate change.

Romm, J. (2015). *Climate Change: What Everyone Needs to Know.* Oxford, UK: Oxford University Press.

- An easily digested primer on the science behind and impacts of climate change.

Squarzoni, P. (2014). *Climate Changed: A Personal Journey Through the Science.* New York: Abrams ComicArts.

- This is a graphic novel and personal narrative that offers a different perspective and tone.

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Appendix I: Glossary

Adaptation: Adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2001).

Additonality: Additionality occurs when—holding all other factors constant—an emissions reduction would *not* have occurred without the introduction of a specific strategy or approach. If a project would have happened regardless of its emissions impacts, it cannot be called additional. Meaningfully curbing emissions requires projects to be additional.

Afforestation: Adding trees to an area that was not historically a forest, usually to enhance carbon storage.

Agroforestry: The integration of trees, shrubs, and other elements of forests into crop cultivation and management. Agroforestry practices can reduce runoff, mitigate climate change impacts, provide shade and forage, and create socioeconomic benefits.

Atmospheric River: Narrow atmospheric regions responsible for the horizontal transport of massive amounts of water vapor from the tropics to the east side of the Pacific Ocean. Atmospheric rivers accompany most rainfall in Oregon, and are responsible for nearly every extreme precipitation and flooding event in the Pacific Northwest.

Business as Usual: An emissions trajectory that follows historical trends. In other words, this is a scenario in which all current policies and practices remain in place, and little to no mitigation occurs. "Business as usual" is often considered a type of baseline scenario to which other, more proactive climate modeling outcomes can be compared.

Carbon Offsets: An arrangement in which one entity pays another to emit less in order to offset the offsets of the entity making the payment. This is a part of the broader scheme of carbon trading, and is generally considered an emissions reduction strategy.

Carbon Sequestration: Removal from the atmosphere and subsequent storage of carbon dioxide. Sequestration can occur both naturally and artificially; natural carbon sinks include forests, peat lands, oceans, and any photosynthesizing species. Also commonly referred to as carbon storage.

Climate Change: Climate change refers to any long-term changes in regional or global climate patterns, including cooling, warming, and other atmospheric conditions (NASA).

Climate Refugia: "Areas relatively buffered from contemporary climate change over time that enable persistence of valued physical, ecological, and socio-cultural resources" (Morelli *et al.*, 2016: 1).

Climate-Responsive: For the purposes of this Strategy, any climate-responsive action—or climate-responsiveness—an action carried out in a manner consistent with climate change adaptation and/or mitigation.

Climate Velocity: "...Calculated by dividing the rate of climate change through time (e.g., degrees Celsius per year) by the spatial gradient in climate at that location (e.g., degrees Celsius per kilometer). The calculation yields an estimate of the velocity in kilometers per year and direction an organism would need to move to stay within an isocline of a given climate variable" (Lawler *et al.*, 2015: 623). Lower climate velocity may enable species' adaptation and survival.

Connectivity: The degree to which a landscape facilitates ecological flow. Connectivity is a key aspect of terrestrial resilience.

Conserving Nature's Stage: Focusing on protecting abiotic landscapes since they are more climate-resilient than their biotic inhabitants. In theory, conserving the stage in a way that preserves diverse terrestrial features will provide more habitats and will protect biodiversity into the future, even if the species composition in a conserved area ultimately changes.

Conservation Tillage: A method of crop cultivation that leaves the previous crop's residue in place before the next planting. This reduces erosion, runoff, and emissions.

Conversion: Taking lands and resources out of their natural state to use for farmland, ranchland, developments, or any other kind of anthropogenic land use.

Deschutes Basin: A section of Central Oregon that includes the entire Deschutes River Watershed, stretching from the mouth of the Deschutes in the Columbia River all the way down to its headwaters in northern Klamath County. The Basin comprises the Deschutes River and its main tributaries, including the Little Deschutes River, the Crooked River, the Metolius River, and Whychus Creek.

Double Counting: In the context of climate change mitigation, double counting happens when a single GHG emission reduction is used more than once to demonstrate compliance with mitigation targets. This inflates calculations of GHG reductions and should be avoided.

Ecoregions: Areas smaller than bioregions with similar ecosystems and biotic and geographical characteristics.

Feedback Loop: Any process that amplifies or de-intensifies an existing climate forcing (warming). Negative feedback loops reduce an initial forcing, while positive feedback loops add to an existing forcing. These feedbacks often reinforce cyclical processes, such as the carbon cycle.

Fossil Fuels: Any combustible fuel derived from the organic materials of long-decomposed plants and animals. These fuels include petroleum, natural gas, and coal, and their combustion is the number one source of GHGs on Earth.

Fuel Aridity: The dryness of vegetation that may serve as fuel in the event of a fire. In general, greater fuel aridity leads to larger and more intense fires.

Greenhouse Gases: Gases that absorb energy and radiation, which leads to the warming of the atmosphere. The "greenhouse effect" keeps the planet inhabitable, but unprecedented greenhouse gas emissions and concentrations are the leading cause of anthropogenic climate change. The most abundant greenhouse gases—GHGs—are water vapor, carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, and hydrofluorocarbons. Each GHG stays in the atmosphere for a different amount of time and has a different Global Warming Potential, which is a measurement of a gas's ability to warm the atmosphere.

Land Cover Change: Changes in the physical characteristics of the land's surface; often refers to changes in vegetation cover during land use change.

Land Facets: According to Beier and Brost (2012), land facets are "recurring landscape units of relatively uniform topography and soils." Defining and conserving land facets is a key element of conserving nature's stage and of approximating terrestrial resilience to climate change. Conserving a diversity of land facets should also facilitate habitat connectivity.

Land Use Change: Any change in the way land is used or the activities taking place on land. Oftentimes this refers to the conversion of land away from its natural state.

Mainstreaming: An approach to accomplishing climate change action, solutions, and policy by integrating it into all facets of, in this case, conservation and stewardship, rather than creating separate initiatives to achieve discrete goals.

Microclimate: A climate restricted to a small area that can differ from the climate of a broader surrounding region. Urban heat islands are one example of a microclimate. Other microclimates could exist near water or in an area of high topographic diversity, such as a canyon.

Mitigation: Any action that reduces anthropogenic contributions to greenhouse gas concentrations.

Near-Surface Temperature: The air temperature close to Earth's surface. This is correlated with changes in atmospheric CO_2 concentrations. This is one component of topoclimate diversity.

Rain Dominant: An area is rain dominant when the majority of precipitation falls as rain.

Reforestation: Replacing trees in areas that have been deforested or otherwise degraded.

Representative Concentration Pathways: Representative Concentration Pathways, or RCPs, are four distinct greenhouse gas concentration trajectories that the IPCC used to model climate change scenarios in its 2014 Fifth Assessment Report. These pathways represent various climate futures based on different amounts of greenhouse gas emissions. The RCPs are RCP2.6, RCP4.5, RCP6, and RCP8.5; these numbers refer to possible radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m^2, respectively). RCP8.5 is usually considered a worst-case scenario, in which emissions continue to increase throughout the 21st century. This is also called a "business-as-usual" scenario because of the inaction it assumes.

Resilience: Also called terrestrial resilience. Resilient lands are places where complex topography and high quality connectivity/connected land cover make conservation more likely succeed in the future, even in the face of climate change or other environmental changes.

Snow Water Equivalent: Snow water equivalent (SWE) is the amount of water in a given volume of snowpack. Put differently, it is the water depth that would result from melting an entire area of snowpack at one time.

Soil Moisture: Soil moisture helps to control heat and energy exchange between the land and atmosphere, and plays an important role in creating weather and climate patterns. Soil moisture is one component of topoclimate diversity.

Topoclimate Diversity: Buttrick *et al.* (2015) define topoclimate diversity as "the range of temperature and moisture regimes available to species as local habitat refugia under climate change scenarios." Topoclimate diversity is one component of terrestrial resilience, and more topographically diverse areas may increase species diversity and likelihood of survival across spatial and temporal scales.

Urban Heat Island: An urban area that is significantly warmer than the surrounding rural or natural lands, mostly due to land use, land cover change, and other human activities.

Vulnerability: The degree to which a region, ecosystem, or species is susceptible to the impacts of climate change. Vulnerability is a function of sensitivity, rate of change, magnitude, and ability to adapt.

Working Lands Conservation Easements: Conservation easements in which the owner is allowed to continue ranching, farming, foresting, or making some other use of the property's natural resources.

Appendix II: Abbreviations

AFOLU: Agriculture, Forestry, and Other Land Use.

AR5: Fifth Assessment Report of the IPCC.

COP21: 21st Conference of the Parties to the UNFCCC in Paris, France; also known as the Paris Climate Conference.

COP23: 23rd Conference of the Parties to the UNFCCC in Bonn, Germany; also known as the UN Climate Conference in Bonn.

CSA: Climate Smart Agriculture.

DRC: Deschutes River Conservancy.

DFIP: Deschutes Focused Investment Partnership.

ENSO: El Niño Southern Oscillation.

GCM: General Circulation Model; also known as a Global Climate Model.

GHGs: Greenhouse gases.

GIS: Geographic Information Systems.

IPCC: Intergovernmental Panel on Climate Change.

MAD: Move, adapt, die principle of species' response to environmental changes.

NCA: National Climate Assessment.

NCS: Natural Climate Solutions.

NPP: Net Primary Productivity.

NPS: National Park Service.

ODF: Oregon Department of Forestry.

ODFW: Oregon Department of Fish and Wildlife.

OWEB: Oregon Watershed Enhancement Board.

PNW: Pacific Northwest.

PRC: Population Research Center at Portland State University.

RCP: Representative Concentration Pathway.

SWE: Snow water equivalent.

TNC: The Nature Conservancy.

UDWC: Upper Deschutes Watershed Council.

UNFCCC: United Nations Framework Convention on Climate Change.

USFS: United States Forest Service.

Appendix III: Maps

1. Land use change (historical)
2. Land cover change (historical)
3. Species shifts (historical)
4. Connectivity (current/historical)
5. Climate analogs (TBD)
6. Extent of carbon storage resources (trees, soils, wetlands, other veg cover); this may be too similar to land cover data
7. Changes in carbon storage resources
8. Key streams/watersheds
9. Extent of agricultural land
10. Land facets/topoclimate diversity/refugia (if possible)

Appendix IV: Listed Resources

1. Adaptation Partners, Climate Change Adaptation Library
2. California Landscape Conservation Cooperative, Resources for Conducting a Vulnerability Assessment
3. Columbia Land Trust, Conservation Agenda
4. Ecotrust, Forest Planner
5. Land Trust Alliance, Conservation in a Changing Climate
6. NatureServe, Climate Change Vulnerability Index
7. North Florida Land Trust, Conservation Priorities
8. U.S. Forest Service, Climate Change Performance Scorecard
9. Washington Wildlife Habitat Connectivity Working Group

Wildlife Conservation Society Climate Change Adaptation Fund, Monitoring and Evaluation in Climate Change Adaptation Projects: Highlights for Practitioners