Appendix O

Climate Change

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El Niño Southern Oscillation and Pacific Decadal Oscillation

Northwest Washington's climate is strongly affected by the Pacific Ocean. Most of the climate variation seen in the Pacific Northwest can be attributed to two large scale patterns, the El Niño/Southern Oscillation and the Pacific Decadal Oscillation. El Niño/Southern Oscillation refers to a change in the temperature of the Pacific Ocean near the equator and changes in the strength of the trade winds. There are two types of El Niño/Southern Oscillation: El Niño and La Niña. El Niño refers to the warming and La Niña to the cooling phase of the ocean's surface temperatures based on known averages. The change in temperature of the water brings warmer weather and less precipitation in El Niño years in the Pacific Northwest and cooler winters with greater snowpack in La Niña years. Occurrences of these patterns last about six to 18 months on average (Climate Impact Group 2011).

The Pacific Decadal Oscillation also affects the surface temperatures and wind patterns of the Pacific Ocean, but is located in the northern Pacific and lasts for a much longer period (20 to 30 years). The Pacific Decadal Oscillation is described as having a warm phase and a cool phase. Analysis of events occurring between 1931 and 1999 show that warm phase winters are generally warmer and drier than average and cool phase winters are generally cooler and wetter than average (Climate Impact Group 2011).

It is not known how climate change will affect El Niño/Southern Oscillation and Pacific Decadal Oscillation due to difficulties simulating these patterns in global circulation models (Climate Impact Group 2011). However, a study by Trenberth & Hoar (1997) analyzing El Niño/Southern Oscillation events from 1882 to 1995 (updated in 1997) found that beginning in the late 1970's there was an increase in El Niño events and a decrease in La Niña events that was unusual and "very unlikely to be accounted for solely by natural variability". The conclusion of this study is that changes in climate were likely influencing El Niño/Southern Oscillation behavior (Trenberth & Hoar 1997).

What Changes Are Associated with Climate Change?

Warmer Temperatures

Warmer temperatures are expected to result in declines in water supplies, affecting salmon populations, native plant and animal populations, and wetlands (Ecology 2011). Increases in temperature and reduced water supplies can affect forest health and cause changes in the length of growing seasons (Ecology 2011; U.S. Fish and Wildlife Service 2011).

Temperature and moisture are key variables determining the distribution, growth and productivity, and reproduction of plant and animal species (Intergovernmental Panel on Climate Change 2007); therefore changes in these variables have the potential to affect growth and productivity on the OESF. Warmer, drier summers that are predicted could result in a decline in the water supply on the OESF during much of the growing season; however the growing season would also be expected to be longer. Declining water supplies and higher temperatures can cause drought stress. Drought stress can affect forest health in a variety of ways, including causing direct mortality of trees and making trees more susceptible to insects, disease, and wildfire.

Warmer temperatures can also lead to shifts in the range of tree species (Ecology 2011; Aubry and others 2011).

Reduced Snow Pack

Reduced snow pack is expected to result in earlier runoff, receding glaciers, and lower summer stream flows causing impacts to salmon populations. Reduced snow pack and associated reduced stream flow can also result in lower groundwater tables, although increases in rain may offset this. Since the increase in rain is expected mostly in winter, it may result in more stormwater runoff as opposed to groundwater recharge. Additionally, there would be a loss of recreational opportunities and hydropower generating capabilities from lower water levels, and water pollution would increase (Ecology 2011).

Extreme Weather

Climate change in Washington is expected to lead to an increase in severe weather events including windstorms, heat waves, droughts, and storms with extreme rain or snow.

The area currently known as the OESF has experienced extreme windstorms in the past, most notably on January 29, 1921. A report from the University of Washington, Department of Atmospheric Sciences (University of Washington, undated) describes this event as having sustained winds of 113 miles per hour at North Head light, located on the north side of the mouth of the Columbia River, and sustained winds of 110 miles per hour at Tatoosh Island, located at the Northwest tip of Washington. This storm resulted in the blowdown of massive amounts of timber along the Washington coast. On the Olympic Peninsula coast, from Grays Harbor north to Cape Flattery, the amount of blowdown forest ranged from 20 percent to 40 percent and the OESF is largely located within the area mapped as having experienced 40 percent blowdown. Since that time, seven major storms have struck the Washington Coast, including the damaging Columbus Day storm in 1962, which struck the coast from California to British Columbia with hurricane force winds (University of Washington undated). With continued climate change, these events could become more frequent.

Rising Sea Level

Global warming causes the temperature of the ocean to rise slightly, allowing the water to become less dense and expand. Global warming also causes ice caps to melt at the poles and more precipitation to fall as rain instead of snow, causing a rise in sea levels. Globally, sea levels rose four to 10 inches in the last century, and they are expected to continue rising. Rising sea level is expected to result in coastal land being flooded, coastal erosion and landslides, and seawater intrusion in wells (Ecology 2011). These impacts of climate change are not expected to directly affect the OESF, however flooding of coastal land and coastal erosion and landslides may affect infrastructure such as roads, bridges.

Forest Ecosystem Carbon Pools

Charts O-1 through O-6 show the amount of carbon in each of the forest ecosystem carbon pools over the 100-year analysis period for the No Action and Landscape Alternatives. Note that due to differences in the amount of carbon in each of the pools, some charts report by "millions" of tonnes and some by "thousands" of tonnes.

Chart O-1: Live tree Carbon Pools Per Decade, by Alternative

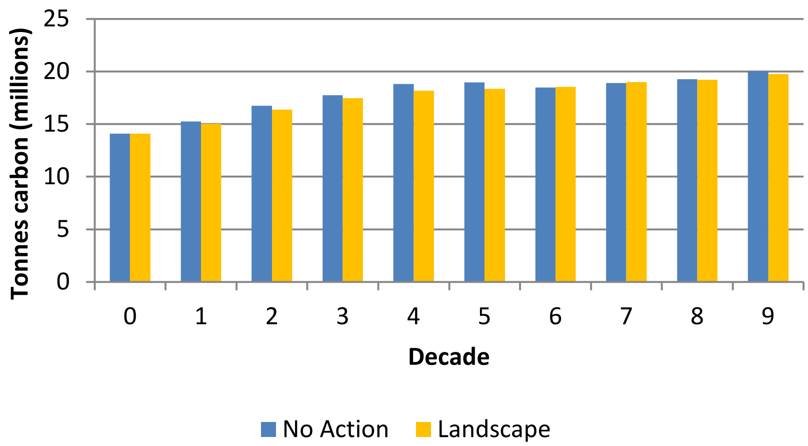


Chart O-2: Standing Dead Tree Carbon Pools Per Decade, by Alternative

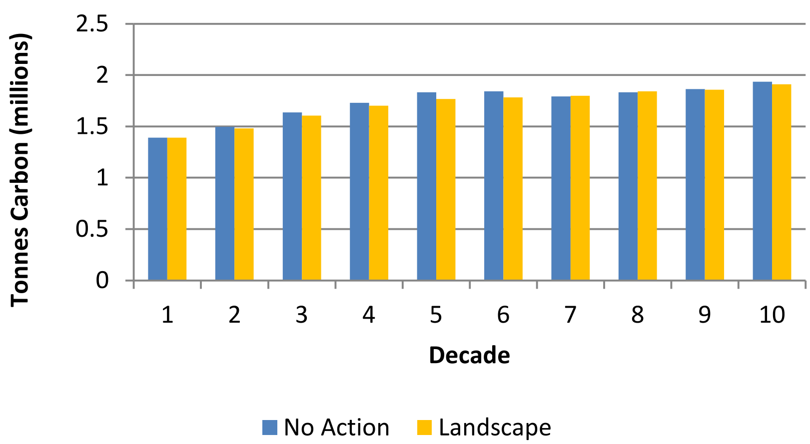


Chart O-3: Understory Carbon Pools Per Decade, by Alternative

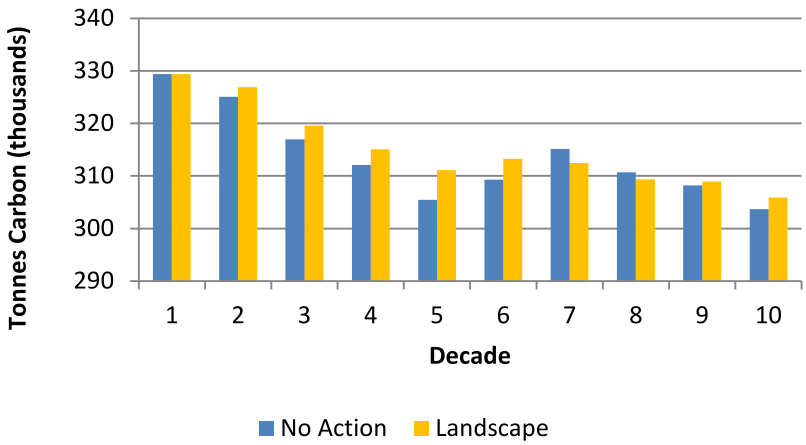


Chart O-4: Down Dead Wood Carbon Pools Per Decade, by Alternative

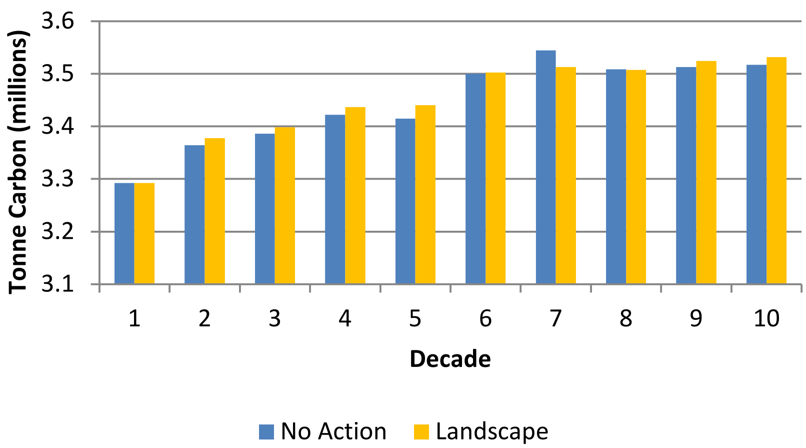


Chart O-5: Forest Floor Carbon Pools Per Decade, by Alternative

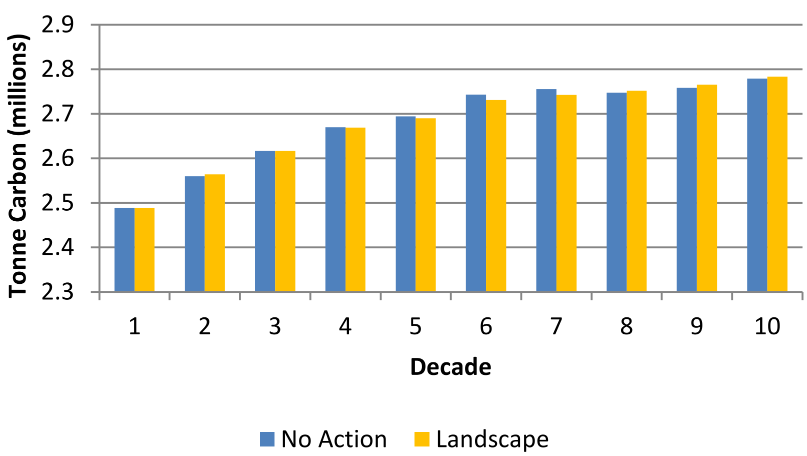
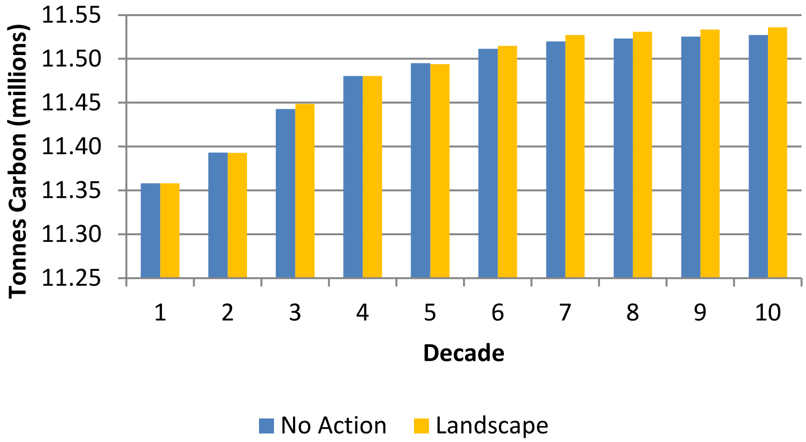


Chart O-6: Soil Carbon Pools Per Decade, by Alternative



Recent Studies Assessing Impacts of Climate Change

The following are descriptions of recent studies of potential climate change impacts in the Pacific Northwest:

- **Running (2006)**: The findings of this study suggested that earlier snowmelt, higher summer temperatures, longer fire seasons, and expanded areas of vulnerable high-elevation forests were contributing to larger, more intense fires in the west.

- **Littell and others (2009)** assessed the potential for climate change to alter the distribution of important Pacific Northwest tree species, with a focus on Douglas-fir because of its broad distribution and economic importance. The results of this study suggest that by the end of the 2060s climate will be different enough from the late 20th century to constrain the distribution of Douglas-fir in many parts of Washington, including lower elevation portions of parts of the Olympic Peninsula (Littell and others 2009).

- **Halofsky and others (2011)** identify a number of ways that increased precipitation and storm intensity associated with climate change may impact physical watershed processes. For example, increased precipitation and storm intensity in conjunction with higher snowlines and loss of snow cover may increase the rate and volume of water delivered to streams, increase landslides and debris flows, and increase the amount of sediment and wood delivered to streams. Increased precipitation and storm intensity may also increase winter and spring flow volume in streams, which would lead to increases flood-plain inundation, channel migration, and channel erosion and scour.

  Halofsky and others (2011) used three different modeling techniques to assess potential changes in vegetation on the Olympic National Forest and Olympic National Park in response to climate change. All modeling efforts in this study suggest that changes would occur, generally with shifts in the upper elevation range limits of tree species. The results of some of the models used also predicted that high summer temperatures may cause drought stress in forest types that aren't currently stressed during summer, particularly Sitka spruce. Also, more drought tolerant species such as western redcedar may become dominant in low elevation stands on the west side of the Olympic Peninsula. Halofsky and others (2011) identified a high level of uncertainty around what the extent of climate change will be and the level of impacts associated with it. Suggested methods for handling uncertainty include focusing on change that has already occurred, monitoring trends, using local knowledge, and planning for adaptability.

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