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climate FACTS

FOREST SERVICE – PACIFIC NORTHWEST REGION

for the greatest good

vegetation change IN THE PACIFIC NORTHWEST

How does climate change affect forest and grassland vegetation?

Many plants have the adaptive capacity to survive, grow, and reproduce under a wide range of conditions. They withstand daily or even hourly weather changes. They can cope with differences in seasons, and the inter-annual variability in air temperature and precipitation. However, climate change will necessitate that plants survive under new climatic conditions, including increased seasonal and inter-annual variability.

Climate change also indirectly affects vegetation by influencing the size and frequency of disturbance events which can lead to quick and drastic shifts in the relative abundance of species on the landscape.[1]

Plant community structure and composition will likely shift over the next century under climate change in response to both the **direct** effects (increasing temperatures and atmospheric CO_2, changing precipitation) and the **indirect** effects of changing disturbance regimes.

Vegetation response to climate change.

Effects of climate change will be complex and difficult to predict. However, some generalizations can be made:

- Warmer temperatures affect plant physiology (e.g., increases photosynthesis/respiration rates) and phenology (life cycle timing). Plant productivity typically increases given adequate moisture.[2]
- Climate change may intensify the seasonality of the annual water balance. Hotter, drier conditions induce plants to close stomatal openings in order to reduce transpirative water loss.[2]
- Higher atmospheric carbon dioxide (CO_2) concentrations can increase water use efficiency and thus offset drought effects by reducing a plant's need to transpire.[2]
- Plants respond not only to changing climate and limiting resources, but also to biotic interactions (e.g., competition, facilitation, herbivory).[1,2]
- Response depends on ecological scale. An individual can continue to survive while its population declines and is replaced by other species. Concurrently, the entire ecosystem could potentially see increased rates of productivity and nutrient cycling under warmer conditions.[2]

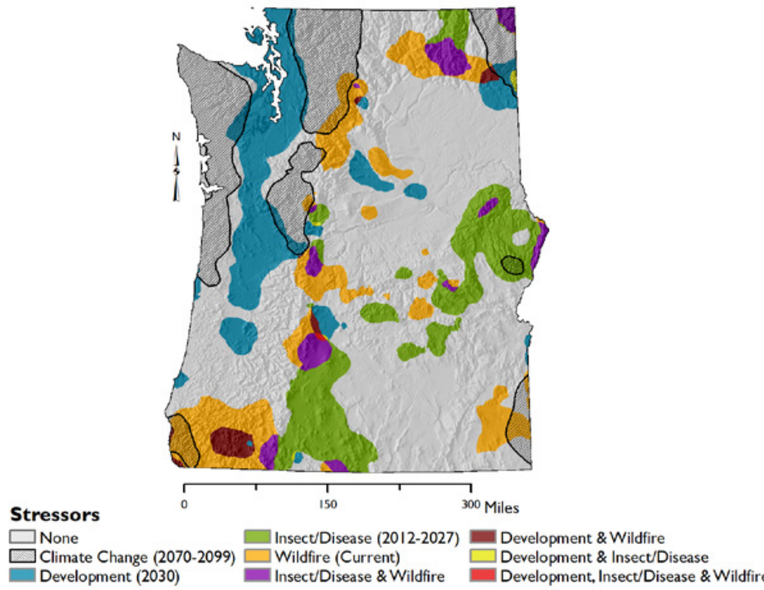

Figure 1: Regional map of major concentrated stressors identified by broad-scale analyses: Development (>6.17 houses/km^2), mortality risk from insects/disease (>25% basal area), and wildfire risk (high to very high). Climate change stress is defined by the difference between a suite of climatic variables for the reference period (1960 -1989) and the future period (2070 -2099). Climate change will influence future insect, disease, and wildfire effects. Scale of data is appropriate for regional level planning. (Source: Kline et al., 2013, Kerns et al., 2016)[4,5]

Disturbance

Plants have some ability to cope with long term changes in average conditions through genetic variation and adaptive traits (such as delaying seed production and/or germination until conditions are favorable). However extreme heat and drought events are expected to increase in frequency leading to larger, more intense disturbances like wildfire.

- Under a new climate regime, an ecosystem's ability to buffer against these extremes is lessened.[3]
- Climate change can make areas already prone to stressors more vulnerable (Figure 1).
- Post-disturbance conditions may have no historic analog, which can lead to fundamental changes in the plant community, and/or increased abundance of invasive species (See Box - Opposite Page).[1]

Invasive Species

Climate change may enhance expansion of invasive species in ecosystems by giving non-natives an advantage over stressed native species.[1] Disturbances can provide the mechanism for non-native invasion to occur. A Central Oregon case study showed levels of native plant regeneration and exotic cheatgrass invasion in a dry forest varied depending on climate moisture deficit (CMD), a measure of an ecosystem's available water, eleven years after a stand replacing fire (Figure 2).[6] Similarly, rangeland resilience to disturbances and/or management treatments and resistance to cheatgrass invasions also depend on climate in conjunction with other landscape factors.[7] With CMD projected to increase in parts of the region, areas dominated or co-dominated by exotic grasses could increase causing large and lasting changes to how these ecosystems function.

Figure 2: Photos representative of post-fire effects of climate moisture deficit (CMD) on plant species establishment in a dry forest in Central Oregon. **Photo A** – native perennial shrubs in a low CMD, high elevation area of the fire. **Photo B** – native annuals in a moderate CMD, mid-elevation area. **Photo C** – exotic grasses in a high CMD, low elevation area. Although other factors can be involved in post-disturbance establishment, CMD is projected to increase in the region which may favor exotic grasses (Photo Source: Dodson and Root, 2015).[6]

Drought Stress

- Warmer temperatures and more extreme drought events will increase the intensity and duration of soil water deficits throughout many parts the region (Figure 3).[1,2,8,9]
- Drought conditions have potential to stress plants beyond their tolerance leading to mortality. Die-off events may become more common over the next century.[2]

Insects & Disease

- Warmer temperatures increase survivorship and reproduction for some forest pests and can leave drought-stressed trees more susceptible to attack.[1,2,9]
- Insects and diseases usually attack one species, so an outbreak has major potential to alter the compositional structure of forests.[2]

Fire

- Warming will affect the fire season by drying fuels earlier and increasing windows of fire weather occurrence.[1,2,10] By the 2080s, area burned in the region may increase 2-3 fold.[11]
- In the short term, forests with high woody fuel loads may be susceptible to large, intense fires.[2,10,11]
- In the long term, a fire or series of fires may facilitate a new environmental setting that ushers in a new plant community under a new disturbance regime.[2]
- Fire regime response in rangelands is uncertain, but it will likely be sensitive to the relative abundance of exotic grasses[2]

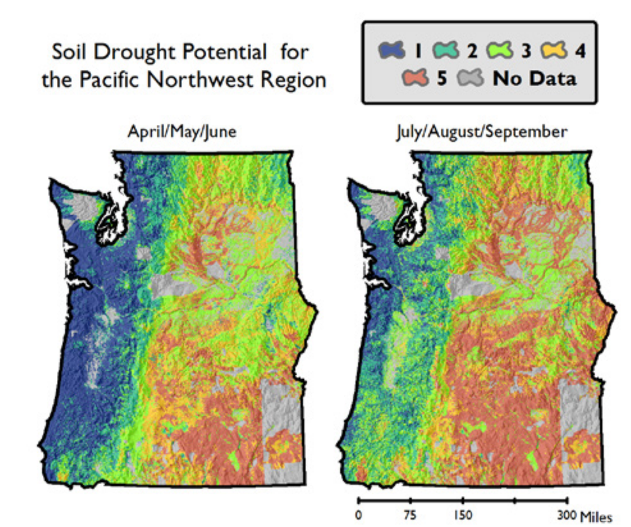

Figure 3: Droughty soil index (1: low to 5: high) for the U.S. Forest Service Pacific Northwest Region. Derived from a combination of a soil type's water holding capacity and climatic data describing an area's average atmospheric water demand from transpiration. Useful for identifying drought vulnerability, these maps can aid in prioritizing for management activities to enhance forest resiliency.

Estimating Potential Vegetation Change

Vegetation models are valuable tools for projecting potential change on the landscape and gaining a better grasp of the potential long-term, broad-scale processes at work under various climate change scenarios. Several types are available, each with its own set of assumptions and conceptual approach.

- Empirically-based models use assumptions about current climate and species distribution to infer what may happen in the future.
- Process-based models compile and encapsulate the current knowledge of ecosystems represented through equations and parameters that estimate and/or simulate vegetation response to climate change.
- While there are many uncertainties associated with model-based projections, they show a window into potential futures, and can help managers explore possible future conditions. They do not replace on-the-ground observations and local expertise, but instead provide complementary information. Checking for agreement among multiple independent models is one way to assess the reliability of projections.
- Different models can produce a range of possible futures that make specific predictions about future vegetation problematic. However, some conclusions about the future of the region's major biomes have started to emerge from multiple regional modeling projects. Climate change science and ecological modeling will continue to evolve and advance in the years to come.

Alpine & Subalpine Communities

- Multiple vegetation models generally agree this is the most sensitive biome type. Models project total loss of this biome in some areas, with the North Cascades and other scattered high-elevation areas serving as the main end-of-century refugia.[2,5,12,13]
- High elevation tree species may be vulnerable because of their limited distributions, and susceptibility to pests. They also have low seed production, dispersal capability, and drought tolerance (Figure 4).[1,14]
- Models project a region-wide response, but local factors like microclimate, soils, topography, and seed sources mediate climate factors like snowpack and growing season length. Local factors are an important influence on fine-scale responses like meadow loss, tree invasions, or treeline movement.[2,5,15]

Moist Maritime Forests

- Vegetation models show some degree of vulnerability for this biome type. Areas where higher drought stress is expected, such as the southwestern portion of the region, show the most potential for habitat loss.[2]
- Low to mid-elevation species that are assessed as vulnerable tend to be so because of reproductive capacity, habitat affinity, insects/diseases, or adaptive genetic variation.[14]
- Temperatures will still be in the range for Douglas-fir dominance. Warmer temperatures could enhance or reduce productivity in these forests depending on future precipitation patterns and their effect on local soil moisture.[2,11]
- Increased summer drought may change fire regimes.[16]
- Though not certain, the Pacific Ocean could ameliorate climate effects near the coast meaning habitat suitability would remain similar for current resident species.[2]

Migration

Plants could respond to climate change by migrating. Fossil pollen and other evidence from the region show past movement of species poleward and upward in elevation during past warm periods.[2,17] Several important concepts have been developed to help explain migration dynamics.

Climate velocity describes the rate which organisms must move to track the conditions they currently inhabit under a changing climate. **Refugia** are pockets of habitat that remain suitable despite a large climatic shift elsewhere in their range. Refugia are important for preserving diversity and setting the stage for range expansion once conditions become more favorable. **Leading and trailing edges** describe the dynamics of plant invasion and extirpation (local extinction) along the boundaries of a species' range.[2]

A recent study using U.S. Forest Service Forest Inventory Analysis (FIA) data from the west coast shows that, across 46 species, current seedlings have made a significant shift towards cooler environments since the time of establishment of currently mature trees.[17] By using an extensive study area with a dataset as large and varied as FIA, this research supports the hypothesis of large scale plant migration in response to climate change.

Figure 4: Subalpine fir stand in John Day Ranger District, Umatilla National Forest. The plant species within subalpine, cold upland forest types like this one are expected to be at most risk to loss from climate change. (Photo: Dave Powell, USDA Forest Service (retired), Bugwood.org).

Dry Forests

- Modeling evidence for dry forests, which typically feature ponderosa pine, is inconsistent. Drier conditions and altered disturbance regimes could make them vulnerable, but new habitat may develop if soil moisture increases.[2]
- Ponderosa pine is a drought tolerant species and has life history strategies to cope with drier and warmer conditions.[2]
- Atypical fuel buildup from the recent past puts dry forests at risk from wildfire. Mature trees can persist in drier conditions, but drier conditions may prohibit post-fire regeneration.[2,6]

Woodlands, Grasslands, & Shrub-Steppe

- Fewer modeling projects have focused on rangelands. Sagebrush shrub-steppe may decline but the estimated magnitude is highly variable.[2] Drought tolerant grasses may start to dominate current grasslands and some shrublands.[8]
- This biome has high sensitivity to precipitation patterns, and there is high uncertainty associated with climate model precipitation projections. How climate change will affect disturbance is also uncertain. These two issues make projecting vegetation response difficult.[2]
- The region's rangelands could increase in productivity with higher CO_2 concentrations assuming no change in species composition or disturbance.[18]
- In a project focusing on Central Oregon, the relatively recent expansion of western juniper is expected to continue until the middle of next century when it slows under increased fire and less favorable growing conditions.[19]
- The same study suggests native shrub-steppe will decline due to fire and be replaced by exotic grasses. Invasion into previously forested biomes may offset some of these losses.[19]

Looking for More?

Please see the cited references (located on the back) for more in-depth information about climate change impacts in the region.

The US Forest Service Climate Change Resource Center hosts a wide array of information from basic science to forest impact topics – **www.fs.usda.gov/ccrc**

Climate Facts is produced by the Pacific Northwest Region 6 Climate Change Team. US Forest Service, 1220 SW 3rd Ave., Portland, OR 97205.

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