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CLIMATE CHANGE IMPACTS ON FOREST GROWTH AND MORTALITY

This May 2017 blog is written by Marina Melanidis from the PICS Forest Carbon Management Project, a multi-year collaborative effort created by the Pacific Institute for Climate Solutions, involving scientists from Natural Resources Canada (NRCan), the University of British Columbia (UBC) and other agencies.

In 2016, 197 nations signed the Paris Agreement and committed to limiting global temperature rise well below 2^{o}C [1], thus making understanding the potential for forests to mitigate climate change more important than ever. It is clear that by implementing region-specific mitigation strategies the forest sector can contribute to the reduction of greenhouse gas emissions [2]. However, while forests do have a strong influence on the environment, the environment also strongly affects forests – so much so that if global warming continues at the current rate, it will likely alter entire forest ecosystems and jeopardize the effectiveness of mitigation strategies. Therefore, to design effective mitigation strategies, the impacts of climate change need to be well understood.

HOW DOES THE ENVIRONMENT INFLUENCE GROWTH AND MORTALITY?

There are several environmental factors that influence forest growth and mortality. Forest growth describes how many trees exist and how fast trees add biomass, while forest mortality describes how many trees die within a certain area in a specific length of time. The balance between tree growth and tree mortality determines forest productivity [3]. Major disturbances like wildfires and insect outbreaks cause significant levels of mortality, but even in the absence of these disturbances competition between trees for resources results in a relatively constant mortality rate in forests. The death of trees opens up space in the forest for regeneration and young trees are able to grow. If environmental factors promote growth over mortality, a forest will be more productive.

Trees grow through the process of photosynthesis which requires light, heat, water, nutrients, and carbon dioxide (CO_2). In general, if these resources become increasingly available (e.g. an increase in annual precipitation results in greater supply of soil water), forest productivity will increase. However, increased productivity has a limit; as trees grow, their resource requirements grow as well and eventually one of the resources needed will become limited, whether that is a lack of nutrients, light, or water [3]. The availability of environmental resources will determine whether a tree will grow well or not, altering the balance between growth and mortality and therefore determining forest productivity. These factors also influence which tree

species are able to thrive in a particular region, impacting the composition and structure of forest ecosystems [4]. Whether a resource is available or limiting may change over time or by location. Humans can impact resource availability as well, on both a local scale, such as by applying nutrient fertilizer to a forest stand, and on a global scale by increasing global temperatures and atmospheric CO_2 concentrations by burning fossil fuels.

CLIMATE CHANGE PRESENTS BOTH BENEFITS AND COSTS TO FOREST MANAGEMENT

Current and projected environmental influences on forest growth and mortality present both new opportunities and risks to forest management.

Increases in temperature and CO_2 could result in increased forest productivity, especially in areas where tree growth was previously constrained by low temperatures and short growing seasons and in areas where water is not a limiting factor [3, 5]. At higher temperatures and with increases in CO_2, photosynthesis occurs at faster rates, thus increasing plant growth [6]. In fact in some forested areas of B.C., evidence suggests that warming climates and increased atmospheric CO_2 have caused forests to absorb an increased amount of carbon in recent decades [6]. In order for these productivity gains to occur however, water must not be limiting – B.C. forests that have seen increases in carbon uptake and growth are all within historically wet ecosystems [3].

Warming climates pose significant threats to forest ecosystems as well. Increased temperatures and changes in the distribution and timing of precipitation that is projected to occur will likely cause more intense drought in naturally dry ecosystems, such as Canada's western boreal forests [7]. Decreases in water availability negatively impact a tree's ability to regenerate and grow. While different species have different tolerances to water availability, droughts are overall a significant cause of mortality in most species and can have lasting impacts on forests [8].

A changing climate is also projected to alter the frequency and/or severity of natural disturbances in some forests, particularly fire and insect disturbances. While such disturbances are natural components of all forest ecosystems, helping forests to regenerate and renew themselves, increases in disturbance severities could have dramatic impacts on forest ecosystem structures, species composition, and their ability to act as carbon sinks [9, 10]. In Canada, the current increases in forested areas lost to wildfires have already been linked to climate change. Fire in particular is strongly influenced by weather and climate, and with warmer temperatures and drier climates projected to lengthen fire seasons, the occurrence, intensity, and the total area burned, will likely increase as climate warming continues [11]. Moreover, the frequency and severity of insect and disease outbreaks are also predicted to increase as temperatures rise. Warmer climates allow insects to extend their range and infect forests in areas that have historically been too cold for insects to survive [10]. The mountain pine beetle epidemic that occurred in B.C. during the 1990s and early 2000s is an example of this effect – it is the largest outbreak in area and severity that has ever been recorded in the province, and the resulting increase in emissions converted B.C.'s forests from a net carbon sink to a net carbon source [10]. Therefore, not only would further increases in mortality caused by increased drought, fire, and insect outbreaks decrease forest productivity, it would also release large amounts of carbon and impair

the ability of forests to act as a carbon sink, further contributing to climate change (this is described as a positive feedback effect).

THE LAW OF THE MINIMUM

In order to determine how a forest stand, or even how a specific tree species, will respond to environmental changes, we need to determine how changes in the environment will impact the availability of resources. If certain resources become more available but others remain limited, those limited resources will determine to what extent a tree will grow. The idea that growth depends on the most limited resource is an ecological concept first described in the 19th century known as Liebig's Law of the Minimum.

The resource that is the most limiting will differ by region. With temperatures and CO_2 concentrations continuing to increase, forest stands that have historically been limited by these resources (particularly temperature) could possibly see an increase in productivity resulting from climate change, although it is likely that the availability of another resource will limit how much productivity can rise. For forests in wet regions of B.C., a lack of nutrients will likely be the factor limiting large increases in growth [12]. Forests that typically see constraints in water availability, such as the stands in the western boreal, will likely see decreases in productivity as rising temperatures worsen drought conditions. Responses to environmental changes also differ from species to species. Evaluating how trees will respond to changes in resource availability on a species-to-species and region-to-region basis increases our general understanding of how forest stands will react to climate change, and may provide insight into which species might be best suited to which regions under a changing climate.

The forest sector has a strong impact on the surrounding environment and atmosphere, but the environment also strongly impacts the forest. Therefore, when developing and assessing potential climate change mitigation strategies for the forest sector, it is important to understand how forests will respond to climate change. The impacts of climate change on forests can be both positive and negative: some areas and some species will see increases in growth, while others will see reduced growth and increased mortality. Understanding where these benefits and losses will occur, and how significant they will be, will help to ensure that mitigation strategies are effective at reducing greenhouse gas emissions and increasing greenhouse gas removals. Through the Pacific Institute for Climate Solutions, a collaboration between the Canadian Forest Service, the University of British Columbia, the University of Northern British Columbia, the University of Victoria, and the B.C. Ministry of Forests, Lands and Natural Resource Operations has resulted in an ongoing Forest Carbon Management Project that will increase our understanding of the impacts of climate change in forest ecosystems and better inform the design of climate change mitigation strategies for the forest sector.

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