Marina Melanidis
24/04/17

# FOREST ECOSYSTEMS AND THE CARBON CYCLE

The continuous flow of carbon from the land and water through the atmosphere and living organisms makes up the global carbon cycle [1]. It contains reservoirs where carbon is stored and features dynamic flows of carbon between the carbon pools [2]. Forests are one of the largest reservoirs of carbon on Earth [1], and therefore their storage and release of carbon have a great impact on the global carbon cycle. With 10% of the world's forests, Canada's carbon balance is especially dependent on the flow of carbon into and out of forest ecosystems [3].

## FOREST CARBON SEQUESTRATION AND RELEASE

Forests absorb carbon from the atmosphere through carbon sequestration, which describes the uptake of carbon through photosynthesis. This carbon is then used to create new plant biomass, such as leaves, roots and wood [4]. Carbon makes up about half of the dry weight of wood. Young forests have high growth rates and therefore sequester carbon at a faster pace than older forests. While they pull carbon out of the atmosphere quickly, at these early stages of development they do not yet store large amounts of carbon [2]. Older forests can store carbon in much larger quantities as these trees have been growing for longer periods of time and have built up large carbon stocks. However, the rate at which forests can sequester carbon from the atmosphere declines with age, meaning that older forests cannot take in carbon as rapidly as forests at a younger developmental stage. In addition to being stored within living plant biomass, carbon is also stored in detritus (such as leaves, branches and downed wood) and soil [2].

Forests continually release carbon back into the atmosphere as trees respire and as dead plant matter decays. Natural disturbances such as insect outbreaks and wildfire can drastically increase tree mortality, increasing the amount of decaying plant matter. This can result in sudden, large releases of carbon to the atmosphere, especially in the case of fire which releases carbon from biomass and litter. In 2014, where total forest area burned was above normal averages for the province, wildfire in B.C. released 19 Mt of $CO_2e$ directly into the atmosphere [8].

Human activity can impact forest carbon levels as well. Producing products with harvested wood removes carbon from the forest ecosystem and stores it within the wood product, where it remains for the length of the product's life [2]. The majority of wood harvested from B.C forests is converted to building products [11, 12]. Residues from harvest activity and wood product processing are sometimes used as fuel for bioenergy, an activity that can result in a net reduction in greenhouse gas emissions if the bioenergy is displacing high emission fossil fuels [5]. See the third blog in our series to learn more about carbon storage in harvested wood products. Other human activities, like deforestation and afforestation, also impact a forest's carbon storage capability. Climate change impacts the forest carbon balance of forests as well by influencing forest productivity (both positively and negatively), decompositions rates, and natural disturbance regimes [2, 6].

## FORESTS: A CARBON SINK OR A CARBON SOURCE?

Forests can fluctuate between acting as a carbon sink or as a carbon source, depending on the relative balance between the uptake and release of forest carbon in a given year [7]. Forests act as carbon sinks when they absorb more carbon than they release, resulting in a net carbon removal from the atmosphere. Conversely, forests act as carbon sources when they release more carbon than they absorb, resulting in a net carbon emission.

Historically, Canada's managed forests have usually been carbon sinks when accounting for carbon both in the forest and in harvested wood products. However, in the last decade they have transferred into becoming carbon sources [1]. In B.C., forests shifted from being sinks to being sources in 2003, and have largely remained sources since [12]. These shifts are due to an increase in the frequency and severity of natural disturbances, especially insect outbreaks and wildfire, caused by the current warming trend in climate [6]. This increase in disturbances has also resulted in an increase in harvest in B.C.

The unprecedented mountain pine beetle outbreak in B.C. was largely responsible for converting the province's forests from a sink to a source, as higher tree mortality decreased photosynthesis rates and increased the release of carbon from decaying biomass and increased harvest. The largest annual impact the mountain pine beetle outbreak had in B.C. was equivalent to 73 Mt of $CO_2$ [6], which is approximately equivalent to the emissions released from Canada's entire Land Use, Land-Use Change, and Forestry Sector in 2014 [9]. In contrast, B.C.'s harvest activities in 2014 transferred 61 Mt of $CO_2$ out of forests, some of which was kept stored in wood products [9].

## FOREST CARBON BALANCE AND MITIGATION STRATEGIES

In B.C., natural disturbances have the strongest impact on the forest carbon balance, even more so than harvesting. Less than 0.4% of managed forests are harvested per year in B.C. and all harvested areas must be regenerated, a process that absorbs carbon and allows for new carbon storage [10]. In addition, about 40-60% of carbon in harvested trees remains in the forest, stored in dead organic matter (such as root systems and leaves and branches that are not collected). About a third of the wood that is removed is used to produce long-lived wood products such as timber and panels for buildings, which continue to store sequestered carbon for the entirety of their life span and, if they are recycled at the end of use, for even longer [7].

Due to the potential of forests to sequester and store a significant amount of carbon, there is a great opportunity for the forest sector to mitigate climate change. Therefore, the aim of all mitigation strategies for the forest sector is to reduce forest carbon sources and increase forest carbon sinks, a goal that is especially important as a warming climate continues to impact natural disturbance regimes [6].

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