NCASI Fact Sheet

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Forest Management and the Water Cycle

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Introduction

More than 15% of the world's forest acreage is found in the United States and Canada. Trillions of gallons of water originate in forested acres that are used by society and the forest products sector (NCASI 2009, 2010). From an environmental services viewpoint, forests act as reservoirs that store and release water through their influence on and interaction with hydrological processes. Coupled with sustainable forest management practices that include using regulated forest practices or forestry best management practices (BMPs), forests help provide a stable, predictable, and high-quality water supply.

Water Balance

The balance between inputs and outputs of water is known as the water balance or water budget. Mathematically, a water balance can be shown using the formula: $Q = P - ET \pm S$, where Q = streamflow; P = precipitation; ET = evaporation + transpiration; and S = storage. The water balance affects how much water is stored in a watershed, and this balance varies seasonally. During wet seasons, precipitation exceeds evapotranspiration, creating a water surplus. The resulting high groundwater levels increase surface runoff, resulting in higher discharge or streamflow. During drier seasons, evapotranspiration exceeds precipitation, creating a water deficit.

Role of Forests

For centuries, forested landscapes of North America have undergone changes driven by anthropogenic (e.g., harvesting, reforestation, afforestation, agriculture, and urbanization) and natural (e.g., wildfires and insect outbreaks) disturbances. These events have influenced the quantity of water forests provide. Forests are important for storing, transporting, and purifying water, and the public perception of forest management has always been intertwined with concerns about water resources (Ice and Stednick 2004 , Zhang and Wei 2021). Today, we have a better understanding of how forests collect, store, and discharge water (Liu et al. 2021). For example, in the United States, 89% of drinking water intakes receive water from forest lands, with 38% of drinking water intakes receiving most of their source water from forest lands (Liu et al. 2021). Similarly, in Canada, surface water supplies 2/3 of the nation's drinking water, which mostly originates from forested areas.

Forest Management

The hydrological effects of forest harvest are complex, with many contributing factors (Ice and Stednick 2004). Simply stated, forest management alters evaporation and transpiration rates. The magnitude of hydrological response to forest management varies as a function of watershed scale, soil type, species, climate, and other watershed or catchment properties

Photos: Flumes equipped with a pressure transducer and datalogger are often installed in long-term monitoring sites to quantify stream discharge. The flumes pictured here are located at Mica Creek Experimental Watersheds, Idaho.

(Zhou et al. 2015; Zhang and Wei 2021).

Observed short-term responses to annual flow – those immediately after forest harvest – include increases in surface runoff and streamflow due to decreased evaporation and decreased canopy interception. Removal of overstory vegetation, including harvest, can increase peak flows, especially during early phases of regeneration (McEachron et al. 2021). These changes can affect annual streamflow and seasonal changes (Coble et al. 2020).

Longer term, in general, streamflow follows a pattern of an initial increase in seasonal low flow in the immediate years after a timber harvest followed by declines in seasonal low flow (Coble et al. 2020) or annual flow (Du et al. 2015). However, no change or variable seasonal low flow responses have also been observed (Coble et al. 2020). These variable responses observed for streamflow across watersheds occur due to watershed location, geomorphology, species composition, and forest stand growth. For example, declines in seasonal low flow may be due to high evapotranspiration rates of younger trees, species composition that affects seasonal evapotranspiration demand, and shifts in timing of snowmelt (Coble et al. 2020). Regulations and BMPs seek to limit effects of harvesting on water and there is significant evidence that silvicultural practices coupled with BMPs effectively reduce effects on water resources (Schilling et al. 2021). For example, greater retention of trees within the watershed (e.g., streamside buffers, leave trees, etc.) can aid in reducing the magnitude of stream flow increases (Du et al. 2015).

Scale

The proportion of a catchment harvested can affect the hydrological response. While the response varies by region, in general, research suggests that harvesting more than 20% of a watershed is necessary to increase flow (Stednick 1996). As catchment size increases, the relative proportion of recently harvested areas is reduced, leading to dampened magnitude of increases in flow and less variation in flow (Zhang et al. 2017).

Climate Change

Climate change further affects freshwater resources by affecting different components of the water balance. For example, changes in type of precipitation received (from snow to rain), timing of snowmelt runoff, increases in wildfire or insect outbreaks, and increases in extreme events (e.g., floods, droughts) are also important for water quantity, both seasonally and annually.

Conclusion

Forests are critical for providing clean water. The relationship between forest management, climate, and water is complex. Forest landowners produce sustainable forest products, manage their resources to produce high quality water, and are continually striving to improve management practices. As stewards of drinking water source areas, it is important for forest owners and managers to understand how forest management affects water quantity and timing of delivery, particularly in the context of climate change.

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