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Impacts from Harvests and Prescribed Burns to the Nutrient Cycle of Pine Plantations

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Introduction

Forest trees require 16 basic nutrient elements to grow and maintain health. Three of these elements, oxygen, carbon and hydrogen are derived from water and air. The rest are supplied by the soil. The "Big Three" macronutrients, Nitrogen (N), phosphorus (P), and potassium (K), comprise over 67% of the nutrients found in plant tissue and are used in large quantities by forest trees (Landis 2003). Calcium, magnesium, and sulfur are used in smaller quantities but are just as important to plant health and vigor. The seven micro-nutrients, boron, chlorine, copper, iron, manganese, molybdenum, and zinc, while used in very small amounts are essential to plant metabolism.

The nutrient cycle is a process where the mineral nutrients are absorbed by the tree and then returned to the soil to be used again. The mineral nutrients are provided from the decomposition of the organic material found on the forest floor (leaves, twigs, other vegetation, and animal matter) and the weathering of minerals within the soil. Trees also absorb nutrients from the air and precipitation.

The nutrient cycle in a typical loblolly pine site is usually in balance. Nutrient losses from leeching, runoff, and erosion are offset by nutrient gains from precipitation and atmospheric gases (Swank 1984). Forests rely on internal cycling to provide nutrients for plant growth. These nutrients accumulate in the tree biomass, the needles and organic matter of the forest floor, and the mineral soil. Harvesting and site preparation activities, such as prescribed burns, disrupt the cycle by removing biomass (i.e. stem, branches, foliage, and bark) and disturbing the forest floor. In a pine plantation only 13 % of the total N per acre is the tree biomass and another 13 percent in the forest floor (Jorgensen and Wells 1986). A vast majority of the nutrients are in the mineral soil, about 74% of the N, 83 % of the P, and 62 % of K , and therefore not greatly affected by a timber harvest.

Controlled burning is a widely accepted forestry practice in the Southeast and a common site preparation practice at Bladen Lakes State Forest in North Carolina. A prescribed burn is used to eliminate residual logging debris, reduce vegetative competition, and improve accessibility for tree planting. Ultimately, the goal is to enhance the success of seedling establishment.

This paper reviews the impact harvest and prescribe burning for site preparation on the nutrient cycle of forest trees.

Harvest Impacts

Harvesting removes nutrients by removing biomass. A majority of the nutrients located in the tree biomass are concentrated in the foliage, branches, and root system. The stem has the lowest concentration of nutrients. Nutrient removal is greatly effected by the harvest method used. Whole tree harvest removes about 11 percent of the total N, 7 percent of the extractable P, and 25 percent of the extractable K from the site. This amounts to 81 percent of the nutrients of the tree biomass (Jorgenson 1975). Conventional harvest, which removes only the stem to a 4 inch top, extracts about 4 percent of the N, 3 percent of the extractable P, and 12 percent of the extractable K from the site or about 60 percent of the nutrients available from the tree biomass. Conventional harvest removes one-third as much nutrients as the total-tree harvest but yields only two thirds of the total woody material. Because harvesting impacts only a portion of the nutrient pool it has small effect on long-term nutrient availability.

Rotation Length

Rotation length also affects nutrient levels. Nutrient accumulation is at its highest during a pine tree first 20 years before reaching equilibrium by age 40 (Switzer 1968). During the early growth, the mineral soil supplies the nutrients and through that time becomes somewhat depleted. It recharges when the stand is between 20 and 40 years and the forest floor has accumulated a level of nutrients required for healthy tree growth. Short rotations do not allow the mineral soil enough time to recharge leaving the mineral soil more depleted. For poor soils, such as the deep, well-drained sands common at BLSF, the depletion can occur quickly and result in lowered productivity. Planting longleaf pine, which requires fewer nutrients to maintain growth, on a longer rotation is suggested.

Prescribed Burning

Prescribe burning consumes the forest floor which removes nutrient containing material. It is estimated that prescribed fire consumes 30- 50% of the litter layer (Schultz 1997). Litter rapidly accumulates after a fire and can reach equilibrium by age 16 (Jorgensen and Wells 1986). Additionally, losses of N in the forest floor occur through volatilization. High intensity fires increase the amount of volatilization (Jorgensen and Wells 1986). The loss of nutrients is offset by an increase, at least in the short-term, of decomposition rates and N mineralization which release N and other nutrients and act to fertilize the stand (Schoch and Brinkley 1986). Davey estimates that 26 to 178 lbs./acre/year of N can be added to a site from microbial activity and N-fixing plants (Davey and Wollum 1979). One growing season after a site preparation burn the number of herbaceous species can double (Stransky 1986). A flush of understory growth of both legumes and non-legumes following a prescribed burn provide a potential future source of N and other nutrients. This vegetation replaces the nutrients cycled by the tree foliage following harvest.

About 45-135 lbs. per acre of N are lost when logging debris is burned for site preparation (Vitousek 1983). The immediate significance of logging debris burning is low since N becomes available to the total N pool as the woody material decomposes. Additionally, Voss and Swank reported a loss of 20% of the total available soil N from burning of both the litter layer and the logging debris (Voss 1993).

Significant sources of N are contained in the forest floor and woody material. Hence, the amount of nutrient loss is proportional to the to the amount of logging slash and forest floor consumed by the fire. Maintaining on intact forest floor should be an objective of the burning prescription. A balance between the objective to reduce logging slash while minimizing litter layer consumption must be found. Maintenance of the litter layer also reduces losses from erosion and leeching.

Pine stands recover quickly from the prescribed burning. Studies on the impacts of varies intensities of site preparation, including burning, found no significantly different soil nutrient and organic matter levels after 2 years (Tuttle et.al. 1984 and Miller 1984). Burger reported similar results finding no significant differences in soil organic matter and total soil N content between the chop and burn treatment and the unburned check (Burger 1988). Knoepp, et.al. found a fell and burn treatment had no effect on total N concentrations (Knoepp 2004). However, as site preparation intensity increases soil nutrient content decreases, since more biomass is removed and more litter layer disrupted.

Frequent low intensity burns do not significantly affect soil N and P or foliar nutrients, but can reduce the moisture holding capacity of the surface and subsurface soils and increase surface soil bulk density (Boyer and Miller 1993).

Summary

While major pools of nutrients are located in the forest floor and vegetative biomass, a vast majority of the available nutrients are found in the mineral soil. Prescribed burning reduces the amount of nutrients by consuming biomass and the forest floor fuels, but does not impact nutrients in the mineral soil. Nutrient losses from prescribed burning are not significant and do not seem to impact site productivity.

Nutrient losses are minimal because prescribed burning are infrequent and consume a small portion of the nutrient pool (Wollum and Davey 1974). Harvest rotation greater than 40 years allow the nutrient levels in the biomass and mineral soil time to recharge. It is estimated that as little as 20% of the available nitrogen is lost from prescribed burning. Soil nutrient levels recover quickly and can return to pre-burn conditions within 2 years after burning. Conventional harvest methods that utilize only the stem reduce biomass losses and the nutrient pool they contain. Measures that minimize the consumption of the forest floor will further reduce losses of N, C, and other nutrients.

Nutrient poor soils are likely more affected by site preparation burns than are nutrient rich soils. Since herbicide treatment do not disrupt the litter layer, remove woody debris and increase the short term supply of nutrients from dead foliage, herbicide only treatments should be considered as an alternative. Also, consider planting longleaf pine, which has low nutrient requirements, on these sites.

Citations

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