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How much does leaf leaching matter during the pre-drying period in a whole-tree harvesting system?

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ABSTRACT

In European temperate forests, whole-tree harvesting increases nutrient exports and could compromise soil fertility in long term, especially when leaves, nutrient-rich compartments (leaves, fine and small wood) are exported. Pre-drying felled trees may allow leaves, twigs and branches to fall down or break during skidding, thereby remaining in the stand. However, the recommended pre-drying time is often based on expert estimates, and currently ranges from two to three months.

In this study, we developed an experimental device to quantify nutrient leaching *via* rainfall (pH: 6.8 ± 0.4) from fully developed leaves (collected in summer period) of four broadleaf species. We first set up an outdoor experiment under natural rainfall conditions to monitor the kinetics of nutrient leaching over around two and a half months. Second, we set up two controlled experiments under simulated rainfall conditions to investigate the effect of rainfall intensity and frequency on nutrient leaching.

Foliar K was highly leached 60–79%, followed by Mg: 19–50%, P: 22–30% and only small proportions for Ca and N, < 16%. Nutrient leaching was positively correlated with rainfall amounts of < 30 mm but small rainfall amounts < 4 mm were more effective in leaching per unit (mm) than heavier rainfalls. More nutrients were leached out when the same rainfall amount was fractioned into small rainy events over several days.

However, leaf leaching remains unsatisfactory because a large part of nutrients is still exported by foliage. Total nutrient exports by whole-tree harvest including foliage increased nutrient exports by 1.2–1.6 times compared to conventional harvesting. The exports by foliage are of equal importance as fine and small wood exports and thus leaving the foliage on the forest would increase significantly nutrient saving. We therefore recommend harvesting during the leafless period when possible and otherwise, letting all the leaves fall to the ground before skidding not only for nutrient returns but also because easily degradable organic matter is very important for soil biological activity.

1. Introduction

The European Union has set high targets to promote the use of energy from renewable sources. The revised directives establish a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023 (EU, 2018). These targets are mostly driven by climate change concerns and an increased interest in the utilization of forest biomass for energy to mitigate greenhouse gas emissions and reduce energy dependence on fossil fuels. The use of forest biomass for energy has grown substantially over the last two decades because of the emergence of new biomass mobilization techniques such as mechanized harvesting systems. The mechanization degree varies greatly among European countries: the percentage is close to 100% in the Nordic countries, United Kingdom and Ireland, and notably smaller in Eastern Europe (Asikainen et al., 2011). However, this new practice, in which all the parts of the tree above the stump are harvested, may adversely affect soil properties and tree growth because of the large quantities of nutrients exported in the foliage and fine wood. (Thiffault et al., 2011; Aherne et al., 2012; Achat et al., 2015; Augusto et al., 2015; Johnson et al., 2016). This practice is called whole-tree harvesting, in contrast to stem-only harvesting where only the trunk and the largest branches [$d > 7$ cm] are harvested. The stem-only harvesting is considered to have less impact on site productivity because the nutrient content of the stem wood removed is rather low and the most nutrient-rich components (leaves, twigs and small branches) are left on site (Wall, 2012). Since forest soils are a slowly renewable resource and are on average poorer than agricultural soils (Bonneau, 1995), it is crucial to maintain soil fertility by adopting

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