Ground disturbance and root breakage diameter after stump harvesting

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Summary: Stumps are an alternative energy source to fossil fuels but their extraction can have environmental impacts. Of particular concern is the degree of ground disturbance, which is dependent on the type of harvesting head used and site conditions. This type of impact was investigated in two studies using excavators as base machines. In the first study, a Biorex30 stump extraction head was used at two glacial till sites, one six and the other 18 months after clear-cutting. The ground disturbance and root breakage diameter were measured. In the second study, a conventional stump rake and a stump drill were used on peat land and the ground disturbance was measured. No differences in measured variables were found between the till sites, but many fine roots were extracted on both sites. On peat land, the mean area disturbed by the conventional stump rake was about 10 times larger than after the stump drill. Stump harvesting is likely to cause a greater disturbance on peat land than on mineral soil. On peat land, conventional heads should not be used due to the large ground disturbance which can severely reduce the ground's bearing capacity. Stump drills may be an environmentally-friendly alternative.

Introduction

Tree stumps are one possible source of renewable fuel. There are benefits and drawbacks with stump harvesting (Walmsley & Godbold, 2010). Stump harvesting generates fuel wood which substitute fossil fuels, reduces root rot in the next forest generation, and improves the quality of soil scarification. The drawbacks of stump harvesting are removal of nutrients, increased soil compaction, loss of habitat for fungi, mosses and insects as well as soil disturbance, which reduces the carbon stored in mineral soil and can increase soil erosion (Walmsley & Godbold, 2010; Grelle et al., 2013).

Stump harvesting is not carried out in winter conditions (Laitila et al., 2008). Harvesting stumps in such conditions would be difficult on mineral soils as the soil contamination is difficult to remove, resulting in low quality fuel with a high ash content (Anerud & Jirjis, 2011). As a result, contractors cannot carry out stump harvesting all year round. Stumps from peat land would produce a better quality of fuel. This is because the peat that sticks to the stumps has a high fuel value (Leckner, 2007).The bearing capacity of peat is mainly due to the roots and vegetation that reinforce the ground (Uusitalo & AlaIlomaki, 2011).The low bearing capacity makes it uncertain as to whether conventional stump harvesting heads can be used, even in winter conditions, as many roots are removed. It is, therefore, important to study the ground disturbance produced after using different stump harvesting heads in different conditions. It was hypothesised that the ground disturbance varies for different stump harvesting heads and soils, possibly making stump harvesting justifiable on peat lands using some types of head.

The nutrient content of the fuel is important from a fuel quality point of view. Higher concentrations of nutrients lead to more ash and nitrogen oxide emissions. Roots have an increasing nutrient content with decreasing root size (Hellsten et al., 2013). This is especially true for N but also for P, K, Ca Mg and Na (Hellsten et al., 2013). The N content can become quite high (0.05 – 0.35%) for roots below 60 – 80 mm in diameter. The content is higher (~1 %) in small fine roots <2 mm (Gordon & Jackson, 2000). Currently, there is no information on how many fine roots are harvested in a conventional stump harvest. This is of interest for both the fuel quality and the quality of soil nutrition.

Material and Methods

The ground disturbance caused by stump harvesting was studied in two studies. In study I, a Biorex30 stump harvesting head was used to extract spruce stumps at two glacial till sites, here referred to as New and Old, six and 18 months after clear-cutting. In study II, a conventional stump rake and a stump drill (harvesting the stump core only) were used to extract pine stumps on peat land in winter conditions. Overlapping holes were not measured. The area of total ground disturbance was measured. The diameter of the stump drill's disturbance was measured in two directions. The disturbance after conventional heads was measured by placing a net with a 15x15 cm grid over the disturbed area and counting all squares with more than 50 % disturbance.

In study I, the root breakage diameter was measured on one stump piece in every heap (pile of stump pieces). The root breakage diameter was measured at the point where roots had broken off. Roots below 20 mm in diameter were measured in one direction while larger roots were measured in opposite directions. On average, 70 roots were measured per stump piece. Both the arithmetic mean and basal area weighted (BAW) mean root breakage diameters were calculated for each stump piece. The diameter of the stump that the stump piece had come from was estimated from the root's section of the stump cross-section.

An ANOVA ($y_i=\mu+\alpha_i$) was carried out for both sets of measurements. If the response variable in the ANOVA was correlated to the diameter at stump height (DSH), then the DSH was used as a covariate in an ANCOVA. For all statistical analyses, 5% was set as the significance level. All statistical analyses were carried out using RStudio version 0.97.511.

Results

No difference in the ground disturbance was found between lifting stumps on the Old site and the New glacial till site in study I (Table 1).The mean size of the ground disturbance for each stump was 6.06 m^2 (min 1.29, max 21.06 m^2). A difference between the stump drill's and the stump rake's ground disturbance was found on peat land in study II (Table 1). The ground disturbance from the stump rake was, on average, 9.0 m^2 (ranging from 3.58 – 20.73 m^2) and the disturbance from the stump drill was, on average, 0.9 m^2 (ranging from 0.69 – 1.56 m^2). No difference between the Old site and the New site was found for the root breakage diameter. The mean arithmetic and BAW root breakage diameter for each stump piece was 4.6 mm (from 1.9 – 14.9 mm) and 29.5 mm (from 4.7 – 121.3 mm) respectively.

Table 1. The correlation (corr) between the response variable and the diameter at stump height (DSH) with the p-value for the correlation shown in parentheses. P-value (p-value) for the response variable and adjusted R^2 value (R^2 adj) in the ANOVA or ANCOVA to test differences, the p-value for the DSH was used as a covariate (Cov) in the ANCOVA analysis. The response variables were the arithmetic (Art) and basal area weighted (BAW) root breakage diameter, the ground disturbed area when lifting stumps on new and old clear cuts on mineral soil (Age), and when lifting stumps on peat land with different harvesting heads (Head) **.**

Variable	**corr**	**p-value**	**R^2 adj**	**Cov**
Art all stumps (mm)	0.20 (0.630)	0.084	31.9	-
BAW all stumps	0.67 (0.067)	0.157	18.7	-
Age (m^2)	0.73 (0.042)	0.670	36.4	0.136
Head (ln(m^2))	-	<0.001	93.5	-

Discussion

The ground disturbance caused by stump harvesting seems to depend on the soil and harvesting head used, but not on the time since clear-cutting. Technical improvements are therefore the only option if stump harvesting is to be included in the management plan. It is likely that the ground disturbance caused by conventional stump harvesting is larger on peat land than on mineral soil, even though there are differences between the Biorex30 and conventional stump rake. There is a clear difference in ground disturbance on peat land where the stump rake created 10 times more disturbance than the stump drill. This means that conventional stump heads cannot most likely be used on peat lands at all. This is because the ground disturbance severely reduces the bearing capacity, making forwarding difficult. Stump drills could well prove themselves to be an environmentally-friendly alternative for winter harvesting of stump biomass on peat lands. This could prolong the stump harvesting season but could lead to a situation where the contractors need two harvesting heads. This situation has to be analysed to judge whether it is economical or not. Stump harvesting and forwarding in winter conditions would also assume a more hot procurement system as snow falls can cover stumps and heaps.

Many fine roots are harvested during a conventional stump harvest which reduces the fuel quality. If only roots above 50 mm in diameter were harvested, the harvested stump volume would decrease to 73 – 93 % for pine and 72 – 77 % for spruce of the potential volume from harvesting all roots down to 5 mm in diameter (Petersson & Stahl, 2006; Marklund, 1988). This should be viewed favourably as it would reduce the environmental impact of stump harvesting and also improve the fuel quality.

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