Low Impact Forest Harvesting at the Urban Interface

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ABSTRACT

Active forest management at the urban interface is becoming more important to address issues such as poor stand health, fire risk and wildlife habitat. Residential forested housing is increasing in popularity and fragmentation of large tracts into smaller holdings of individual landowners continues. With the support of the Virginia Department of Forestry, this study examined the productivity, soil impact, and residual stand damage of an agricultural tractor based "low impact" harvesting system. The study site was typical of a small Appalachian mixed-hardwood woodlot that had been high graded in the past. Two silvicultural treatments were applied; a crop tree release and a even-spaced thinning. Prior to and immediately following the harvesting operation, visual soil disturbance categories were recorded every meter and soil cores were taken every ten meters along line transects at 20 m spacing. The soil cores were used to determine micro porosity, macro porosity, K saturated, and bulk density. Average production for this system was 3.2 m^3/PMH, and residual stand damage, visual disturbance, and soil impact were minimal.

Introduction

Urban and rural areas merge together to form a region that is characterized by lower population densities than urban areas and higher amounts of development than rural areas (Shelby et al. 2004). This transitional area is referred to as the urban interface. The rapid expansion of urban and suburban populations has resulted in the urban interface expanding into areas that used to be entirely rural (Shelby et. al 2004). In 1996, the number of non-industrial private landowners in the United States reached 10 million, a 20% increase over the previous 15 years (Erickson et al. 2002). According to Birch et al. (1998), approximately 86% of the 15.1 million acres of forest in Virginia belongs to non-industrial private landowners.

Forest harvesting has traditionally occurred in remote locations and on large tracts of lands, but the influx of people and development into these areas has created a need for forestry to operate on the urban interface (Shelby et al. 2004). As more people move into rural areas, forestland is being divided from large contiguous forests into smaller blocks of land with different owners (Birch et al. 1998).

The expanding urban interface will change the way forest harvesting is conducted (Hull et al. 2004, and Shelby et al. 2004). In Virginia, 75% of all forestry operations occur on non-industrial private land (Birch et al. 1998). This dependence on non-industrial private land allows forest landowners to have a great deal of influence over the way forestry is practiced. Increasing urban interface populations and forest fragmentation may have negative effects on the timber supply network by limiting the amount of land available for harvest and reducing the cost effectiveness of harvesting small tracts (Hull et al. 2004, Shelby et al. 2004, and LeDoux and Huyler 2000).

Many non-industrial private landowners distrust the ethics, motivation, and level of environmental concern displayed by foresters and loggers and as a result traditional forestry risks loosing access to these forest lands (Hull et al. 2004). Multiple surveys of landowners have determined that the primary goal of most small forestland owners is not generating revenue (Erickson et al. 2002, Hull et al. 2004. Shelby et al. (2004) reports that 98% of respondents in their Oregon survey listed ecological impacts as important considerations, followed by aesthetic concerns at 90%, and wildlife at 88%. A survey of Virginia landowners ranked generating income between not important and neutral, but ranked amenities like preserving nature and seeing wildlife very important (Hull et al. 2004).

These diverse and complex goals are not easily met with traditional harvesting equipment. Large skidders or forwarders may cause residual stand damage or high levels of soil disturbance when they are used to conduct partial harvests (Shaffer 1992). Because public scrutiny is focused on every aspect of the harvesting operation and public pressure demands that recreation and aesthetics be considered, forest harvesting costs may increase when operating on the urban interface (Shelby et al. 2004).

High capital investment, transportation costs, and operating expenses may prevent traditional harvesting systems from being able to operate in small woodlots (Shaffer 1992). Profit in forest harvesting is a function of timber value and volume (Hull et al. 2004). Traditional forest harvesting systems operate on small profit margins, face stiff competition, and are focused on productivity (LeDoux and Huyler 2000). The reduction in harvest volume on small woodlots and the diverse goals of landowners is a compelling argument for using less expensive, small scale harvesting systems (LeDoux and Huyler 2000).

While harvesting timber is not the top priority for small forest landowners, 49% of landowners would consider harvesting timber if other forest amenities could be protected, and the majority of landowners surveyed are interested in using “small” equipment and technologies to harvest and process timber (Hull et al. 2004).

Harvesting systems that are appropriate for operating on the urban interface have been developed by modifying existing equipment and converting agricultural equipment to forestry applications. Specially equipped agricultural tractors are lighter and smaller than traditional equipment and can be used effectively on partial harvests of small woodlots (Shaffer 1992). These systems are widely used in Central Europe, but are rare in the United States. Tractor based systems are well suited for operating in small woodlots due to their maneuverability and low initial investment, but their low productivity may limit there use in commercial systems (LeDoux and Huyler 2000).

Figure 1. 4wd John Deere Tractor used for extraction

Most landowners form their opinions about the quality of a harvesting operation based on visual information. Activities such as chipping slash, removing trash, minimizing mud on the roads, and maintaining clean vehicles and equipment can greatly improve a landowner’s opinion of the harvesting operation (Hull et al.

2004). These types of activities in addition to reduced harvest volumes can make harvesting on small woodlots unprofitable (Hull et al. 2004).

To make harvesting small woodlots economically feasible, it may be necessary to vary the payment percentage of the timber sale according to tract size and timber value. Another possibility is to remove the timber sale from the payment equation by adopting a service industry mentality and selling services such as improving wildlife habitat, stand health improvement, and aesthetic modifications (Hull et al. 2004).

An estimated $15 billion dollars is spent annually in the United States on professional garden and tree care, but forestry accounts for very little of these expenditures (Hull et al. 2004). Forest harvesting on the urban interface has the potential to become a major part of the forest industry if foresters can demonstrate to landowners that harvesting can be done in an environmentally sensitive way that promotes the diverse amenities of the forest (Hull et al. 2004).

This study investigated a small scale harvesting system in a typical Appalachian hardwood stand. The objective of this study was to establish if a harvesting system based on a modified agricultural tractor is in fact low impact. The level of impact was determined by visually classifying soil disturbance, measuring soil bulk density and hydrological properties, and determining residual stand damage,

Site description

The study site was located at the Shenandoah Valley Agricultural Research and Extension Center located at McCormick Farm in Steeles Tavern, VA. The site was typical of small woodlots in VA. It was an uneven aged, mixed hardwood stand that had been high graded and grazed by cattle in the past. A crop tree release was conducted on 3.5 acres and an even spaced thinning was conducted on 1 acre of the study site.

Methods

The harvesting operation was conducted using motor manual felling and a model 950 John Deere agriculturual tractor for extraction (Figure 1). The tractor was 4 wheel drive and equiped with a skidder plate and PTO driven pulling winch. Directional felling was used to increase skidding efficiency and reduce residual stand damage.

System Productivity

Productivity of the system was determined by conducting a time study during the harvesting operation. The time study was based on the methods used by Kluender and Stokes (1994). For each extraction cycle, times were recorded for travel from the deck to woods (travel out), bunching and choking logs (acquire), travel from the woods back to the deck (travel in), and unhooking (decking). Extraction productivity was determined using times recorded during 33 extraction cycles. Distances were measured along the skid trails, and estimated from the individual accumulating locations to the skid trails. For pulpwood turns, the number of stems per turn was recorded, and for saw log turns, the diameter and length of each log was measured using a logger’s tape. Field data and volume tables were used to determine the volume for each turn (Kluender and Stokes 1994).

Soil Disturbance

The soil disturbance data were collected using line transects spaced 20m apart throughout the harvest areas. Transects were placed perpendicular to the expected path of the skid trails. The same transects were used to collect the pre-harvest and post-harvest data.

Visual estimates of soil disturbance are widely used to quickly determine the level of impact that occurred during a harvesting operation (Aust et al. 1998). A visual soil disturbance class was determined and assigned at 1m intervals along each transect. The visual disturbance classes are the same as the system used by Aust et al. (1993).

The disturbance classes are:

- Class 1 – Undisturbed
- Class 2 – Slightly disturbed
    a. litter still in place
    b. litter removed and mineral soil exposed
    c. mineral soil and litter mixed
    d. mineral soil deposited on top of litter
- Class 3 – Deeply disturbed, surface soil removed and subsoil exposed
- Class 4 – Rutted, compacted
    e. 0-15.2 cm
    f. 15.2-30.5
    g. >30.5
- Class 5 – Depression deposit, soil deposited in low spot
- Class 6 – Covered by slash to depth that will hamper regeneration
- Class 7 – Nonsoil, streambed, stump, etc.

Residual Stand Damage

Residual stand damage was determined by counting damaged trees that were within 2m (1m on each side) of each transect during the post-harvest sampling. This number was used to estimate the number of damaged trees per acre. A damage class was assigned to each damaged residual tree to help explain which part of the harvesting operation caused the damage. It was assumed that stem damage resulted from extraction and crown damage resulted from felling.

The residual stand damage classes are:

- Class 1: undamaged
- Class 2: minor stem damage (<10cm^2)
- Class 3: major stem damage (>10cm^2)
- Class 4: minor crown damage (<1/3 crown)
- Class 5: major crown damage (>1/3 crown)

Soil Impact

Soil core samples were taken at 10m intervals along each transect using a bulk density hammer and 5.1cm x 5.1cm aluminum cylinders. The bulk density core samples were analyzed in the forest soils lab to determine total porosity, macro porosity, micro porosity, saturated hydraulic conductivity, and bulk density. Comparisons between pre harvest and post soil data were made using a paired t-test.

Porosity

Macro, micro, and total porosity were determined using the water desorption method described by Danielson and Sutherland (1986). Using this method, porosity is determined by draining a saturated soil sample by steps. Macro porosity was calculated using the formula (saturated weight – drained weight)/volume. Micro porosity was calculated using the formula (drained weight – dry weight) /volume. Total porosity was calculated by adding macro and micro porosity.

Saturated Hydraulic conductivity

Saturated hydraulic conductivity was determined using the constant head method described by Klute and Durksen (1986). Using this method, a column of water is placed over a known volume of saturated soil, and the volume of water that travels through the sample and the length of time are recorded. Each soil core was left in the apparatus for a minimum of 1 hour or 3 full 500ml flasks. Saturated hydraulic conductivity (K_S) was calculated using the formula $K_s = VL / (AtH)$**.** Where V is the volume of water, L is the length of the soil core, A is the cross-sectional area of the soil core, t is the amount of time elapsed and H is the head.

Bulk Density

Bulk densities were calculated using the core method described by Blake and Hartge (1986). The soil cores of known volume were placed in a 105^o C oven and dried for a minimum of 48 hours. Bulk density was calculated by dividing dry weight by the sample volume

Results

The results from the productivity study showed that an agricultural tractor is not a high production machine for timber extraction. 33 skidding cycles were measured in the field, and the average skid distance was 119 m. Total production for this system was 3.2 m^3/PMH (108.4 ft^3/PMH). Acquiring each turn, which consisted of bunching, choking, and winching logs up to the tractor, took the most time and accounted for 54% of the total cycle time (Table 1).

Table 1: Mean times for each skidding cycle component (n =33)

	Mean time (min)
Travel out	2.59
Acquire	9.21
Travel in	1.87
Deck	3.47
Total cycle	17.14

Residual stand damage was minimal. The harvesting operation resulted in 14 trees/acre with minor stem damage and 4 trees/acre with minor crown damage. No trees with major damage were found**.**

Visual disturbance was recorded a total 881 times along the transects. The visual survey prior to the harvest classified the entire harvest area was classified as undisturbed. Immediately following the harvest operation, the visual survey showed that 11% of the harvest area had been disturbed. All 97 of the disturbed points were classified as a category 2 (slightly disturbed). Table 2 shows the individual frequencies of the disturbed points.

Table 2: Post harvest frequencies of visual disturbance class categories

Disturbance Category	# of points	% of harvest area
1 (undisturbed)	784	89%
2a (litter still in place)	57	6%
2b (litter removed)	33	4%
2c (litter & soil mixed)	6	0.7%
2d (soil on top of litter)	1	0.1%

Bulk density is the dry weight divided by the volume of the sample, and can be used to measure soil compaction. Laboratory analysis of the soil cores showed that 95% of pre-harvest bulk densities were between 0.61 Mg/m^3 and 1.29 Mg/m^3 with a mean density of 0.93 Mg/M^3, and 95% of post-harvest bulk density were between 0.53 Mg/m^3 and 1.25 Mg/m^3 with a mean density of 0.88 Mg/m^3. Most forest soils range from 0.13 Mg/m^3 to 1.0 Mg/m^3, and densities greater than 1.2 Mg/m^3 hinder root growth (Wenger 1984).

The high mean density of both the pre- and post- harvest samples may have been caused by the previous practice of grazing cattle in the harvest area. Equipment traffic during harvesting operations can increase bulk density. However, in this study, mean bulk density decreased by 0.05 Mg/m^3. We are not implying that the harvesting operation caused the decrease in bulk density, only that it did not cause further compaction.

Porosity is a measurement of the amount of space in the soil that can be occupied by air or water (Danielson and Sutherland 1986). Macro porosity refers to the ratio of non-capillary pores to the volume of soil. Micro porosity is ratio of capillary pores to the volume of soil.

Total porosity is simply the sum of macro and micro porosity (Fisher and Binkley 2000). Laboratory analysis showed that porosity increased after the harvesting operation (Table 3). Porosity is inversely related to bulk density, and the increase in mean porosity is probably a result of the decrease in mean bulk density after the harvest.

Table 3: Pre- and post- harvest porosity (%)

	Pre harvest	Post harvest
Macro avg.	13.5	14.8
95% range	5.8 to 23.2	7.3 to 27.0
Micro avg.	41.4	46.7
95% range	28.2 to 48.3	35.4 to 57.7
Total avg.	54.9	61.5
95% range	45.9 to 64.6	47.9 to 71.8

Hydraulic conductivity is a measurement of the soil's ability to transport water (Klute and Durksen 1986). Laboratory analysis showed that saturated hydraulic conductivity decreased after the harvesting operation. The 95% range of pre-harvest saturated hydraulic conductivity was 0.0031 cm/min to 1.45 cm/min with a mean of 0.26 cm/min, and post-harvest ranged from 0.0008 cm/min to 1.42 cm/min with a mean of 0.19 cm/min. This was not a significant change at the alpha = 0.05 level ($p = 0.0746$).

The reduction in saturated hydraulic conductivity was the only soil property that changed in the expected direction. However, hydraulic conductivity is directly related to porosity, and it is difficult to explain why porosity increased and hydraulic conductivity decreased after the harvest. The most likely explanation is the presence or absence of pipe flow. Pipe flow is when a root channel or other soil macro pore allows water to drain directly through the soil sample. Paired samples could have similar bulk densities and porosities, but the presence of a direct passage for water will result in drastically different hydraulic conductivities for the samples.

Discussion

As with similar studies, this study showed that agricultural tractors are not highly productive when compared to conventional timber harvesting systems. Productivity is important to equipment owners and operators, and conducting low volume and/or value timber harvests on small woodlots magnifies the need to operate quickly and efficiently. Pre-harvest planning is critical for an efficient harvesting operation. During pre-harvest planning, the skid trails should be laid out to increase efficiency and reduce overall skid distances, and property boundaries, fences, SMZs or any other control points should be located so they can be avoided with out slowing the operation down.

Directional felling is important not only because it increases production, but it also reduces residual stand damage, and it further illustrates the need for pre-harvest planning. An experienced choker setter using a second set of chokers could increase productivity by bunching and chokering the next turn of logs while the skidder is traveling to the deck and back into the woods. Harvesting systems using agricultural tractors can increase production by becoming as efficient as possible, but even the most efficient tractor based system will still be much less productive than conventional harvesting systems.

Most owners of small woodlots value aesthetics, wildlife, and low ecological impacts much higher than timber production. Focusing on meeting the landowner's objectives and adjusting the fee structure accordingly, helps to take some of the pressure for high production off of the harvesting system. With the incentive to increase production removed, the operator can focus reducing residual stand damage and the overall impact of the harvesting operation.

Conclusion

This study showed that harvesting systems that use agricultural tractors for extraction are not high production systems. However, agricultural tractors are lightweight and maneuverable which allows them to be used to conduct thinnings or partial harvests with a minimum of residual stand damage and soil impact. Situations where the landowner is more concerned about aesthetics and impact than production are ideal for harvesting with an agricultural tractor.

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