Transportation of Woody Biomass Using Roll-Off Containers

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Abstract
One of several factors limiting the utilization of woody biomass produced during forest operations is the on-road transportation of slash or hog fuel over rough woods roads. The poor horizontal and vertical alignment of most woods roads in the western US limits the types of vehicles that can traverse these roads to smaller, more maneuverable vehicle configurations. One option is the use of roll-off containers in conjunction with hook-lift equipped trucks and trailers. This paper will review the use of roll-off containers in two production-scale trials in and around West Yellowstone, Montana and North Bend, Oregon.

Introduction
As we look toward greater utilization of forest residues for energy production, questions of supply, harvest, and transport arise. In the western US, a large volume of woody biomass is produced as slash created during forest treatments. However with current technology and markets much of this volume is uneconomical to remove from the forest and is left on site or is piled and burned. Many efforts are underway to examine the economics, efficiencies, and technical applications of various woody biomass harvesting and transportation options. The series of field trials discussed here deal with the on-road transportation of woody biomass.

Transportation of woody biomass is primarily limited by the horizontal and vertical alignment of forest roads typically encountered in the western US (Rawlings et al. 2004). Historically woody biomass has been transported in ground form (hog fuel) in standard on-highway chip vans which are limited to high-standard roads. Therefore other, more maneuverable means of transporting this material is needed. Options include short chip vans (eg. 35-foot long containers as opposed to the standard 55-foot containers), stinger-steered vans, and two-stage transportation.

The goal of a two-stage transportation option is two-fold: first, to transport woody biomass in the form of slash from the landing to a concentration yard using a vehicle suited to lower-standard roads with poor horizontal and vertical alignment, and second to increase the efficiency of the grinding operation by concentrating a large volume of slash from multiple landings in one area accessible to both a grinder and high-capacity vehicles (eg. chip vans) for the transportation of hog fuel to market.

This paper examines the use of roll-off bins coupled with a truck equipped with a hook-lift system to transport these bins. “Roll-off” refers to modular containers that are rolled onto and off of the haul truck by a hydraulic arm on the hook-lift (Han 2008), shown in Figure 1. This paper will discuss two field trials of the roll-off system for forest biomass transportation in the western US and will conclude with a discussion of how this system can be utilized to provide economical transportation of woody biomass.
**Figure 1:** Hook-lift truck unloading a roll-off bin of slash at the concentration site used in the Hebgen Lake study

**Trial Sites**
Production-level trials of the hook-lift system occurred near Hebgen Lake in southwest Montana during the summer of 2008 and are ongoing near North Bend, on the central Oregon coast. Both trials used the same 1989 Peterbilt Class 8 truck equipped with a Stellar 52,000 lb.-capacity hydraulic hook-lift. Roll-off bins measuring 24 feet long, 8 feet tall, and 8 feet wide (capacity of 54 cubic yards) were fabricated with a taper allowing up to three empty bins to be stacked and moved at once. While the equipment was constant between the two trials, the owner of the hook-lift truck and the lessee of the bins changed.

**Hebgen Lake**
At Hebgen Lake, the hook-lift truck was paired with a harwarder (forwarder modified to allow for the use of cutting heads) equipped with a hook-lift system (see Kash 2009). By utilizing a harwarder equipped with a hook-lift, slash could be picked up in the woods and placed immediately into a bin. Once back to the landing, the full bin could be offloaded, an empty bin picked up, and the cycle repeated without the harwarder having to either wait for the haul truck or unload slash onto the ground to await grinding or reload into a haul truck. The bins, therefore, eliminated the need to handle slash multiple times and the additional costs associated with this handling. With a sufficient number of bins it was hypothesized that down time would be transferred from the high cost equipment (harwarder and haul truck) to the low cost bins. Roll-off bunks were also available for the contractor to use in order to facilitate the collection and transportation of roundwood (primarily pulp and post-and-poles).

Slash from this fuel hazard reduction project was hauled by the hook-lift truck seven miles from the project site to a waste transfer site that served as a concentration yard. Here slash was unloaded from the bins by tipping the front end of the bin until the slash was in contact with the ground then driving away from the load of slash. The loads of slash remained in compact loaf-shaped piles once on the ground. With this method of unloading slash from bins there was no way to stack one load on top of another. Once the concentration yard was full, a Vemeer HG6000 (horizontal-feed grinder) was called in to grind slash directly into full-sized (55-foot containers, 30 ton capacity) chip vans. From here, hog fuel was trucked 85 miles to Rexburg, Idaho.
North Bend
At the ongoing trial outside of North Bend, Oregon, a different configuration of the same hook-lift system is used. The initial idea was to use the roll-off bins as set-out containers on the landings of whole-tree commercial logging operations as in Rawlings et al. (2004). It was found, however, that landings were generally too small for the bins to be used in this way. Instead, the hook-lift truck gets into the rotation of log trucks and, in turn, backs into the landing, unloads the roll-off bin for loading, the bin is loaded with slash and cull logs by the log loader, the bin is reloaded on the haul truck, and the slash is driven to a concentration yard with ready highway access. At least two harvest units are serviced in this way by a single hook-lift truck with one bin. Once the concentration yard is full, accumulated slash in the yard is ground into a pile. Hog fuel is loaded into chip vans using a front-end loader, taking advantage of a previously empty backhaul.

Results and Discussion
At Hebgen Lake, several inefficiencies meant that the hypothesized benefits of the roll-off system were not realized. For one, the contractor only had two bins on site. While, on average, one cycle with the harwarder to fill one bin with slash was approximately equal to the amount of time required for the haul truck to take one full bin to the concentration yard and return to the harvest site with the empty bin, it was always the case that either the haul truck or the harwarder was left waiting at the landing. Additional bins would have helped to eliminate these delays.

In order to compare grinding efficiencies between grinding at a concentration yard versus moving a grinder in between landing piles, limited detailed time-and-motion study data was collected in November 2007 near Frenchtown, Montana. This operation utilized the same grinder as at Hebgen Lake but used short (35-foot) 20 ton capacity vans to traverse woods roads. One day of grinding yielded six loads of hog fuel from dispersed landing piles created during harvesting activities the previous summer. On average, each van took 41.7 minutes to load (range 35.8 – 48.4 minutes) for 27.3 green tons per hour ($8.19/green ton at $300/hour). At Hebgen Lake one day of grinding yielded seven loads of hog fuel, averaging 41.9 minutes per load (range 34.0 – 47.6 minutes) for 37.3 green tons per hour ($11.19/green ton). In this limited comparison, grinding efficiency increased 37% in a concentration yard versus grinding dispersed landing piles, saving $3/green ton.

During the Hebgen Lake trial, the 54-cubic yard bins hauled an average of 5.5 tons of green slash. At $80.23/hour for the truck and bins, the cost to transport slash from the harvest unit to the concentration yard in roll-off containers via the hook-lift truck averaged $9.63 per green ton (Kash 2009). For this case, the cost to transport biomass from the woods to the concentration yard was likely greater than the increased efficiency of grinding biomass from a central concentration yard.

To avoid double-handling hog fuel, the grinder loaded ground biomass directly into chip vans. This system, however, depends on a constant flow of chip vans for efficient operation. Unfortunately, this did not always occur, leaving the grinder idle for hours at a time.

The grinding operation did not utilize truck scales at the transfer facility utilized as a concentration yard. As a consequence, van loads of hog fuel leaving the concentration yard
averaged 23.8 green tons in a van with a 30-ton capacity for a total of 585 tons hauled in 25 loads. By running trucks at an average capacity of 78% (range 52% – 106%) and a haul rate of $390/trip, this inefficiency added $1.00 per green ton to the transportation cost over fully-loaded vans.

By contrast, initial results indicate the North Bend trial is meeting expectations. By inserting the hook-lift truck into the log truck rotation instead of using the bins as set-out containers, the hook-lift truck spends 5-15 minutes at the landing on average. The time spent by the loader operator dealing with slash is no greater with the hook-lift bins than if the loader were instead piling slash off to the side of the landing for later burning.

As seen at the trial at Hebgen Lake, avoiding double-handling of hog fuel by grinding directly into haul trucks is efficient only when there is a constant stream of chip vans available. In the North Bend trial, chip vans delivering chips to North Bend are able to pick up hog fuel at the trial’s concentration yard on their way back to Roseburg, OR. Therefore the decision was made to grind biomass in the concentration yard at one time and to grind into a pile. As trucks become available to haul hog fuel to market, a front-end loader located at the concentration yard loads hog fuel for transportation. The first round of grinding occurred late March, 2009.

**Conclusions**
Based on the experience of these two trials, the following recommendations can be made for future study and implementation of hook-lift technology for the transportation of woody biomass:

- The cost of transporting unconsolidated (unground) slash in roll-off bins is significant and therefore should only be undertaken when larger vehicles such as chip vans cannot access the site.
- In the limited study presented here, increase in grinding efficiency was found to be 37% by grinding at a centralized landing as compared to grinding dispersed landing piles.
- Including the hook-lift truck in the log truck rotation allowed the log loader operator to clear the landing of slash by loading the roll-off bin instead of placing slash into a slash pile off to the side of the landing. This system did not cost the logging contractor any additional time (therefore money) and served as a benefit by removing the need for a slash pile at the landing.
- The choice of grinding woody biomass directly into chip vans or into a pile for later loading and transportation must be made in light of truck availability.

**Literature Cited**