HARVESTING TECHNICAL NOTE

HTN10-01
2018

Integrated biomass harvesting for New Zealand operations

Summary

Integrated harvesting of forest biomass is a well-established approach to residue recovery operations in many parts of the world. It involves the processing of biomass alongside conventional timber harvesting and provides the potential for improved product quality and overall efficiency of operations. However, there are also many issues which need to be considered for successful operations, such as the impact on mainstream production, cost, value recovery and efficiency of the overall supply chain. This report reviews examples of successful operations in North America and Europe and discusses integrated harvesting operational strategies, as well as factors that influence them. Recommendations for setting up a system are discussed along with potential opportunities for New Zealand in the near term future, including opportunities within centralised log sort yards and small scale landing recovery operations.

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INTRODUCTION

Integrated harvesting is defined as the harvesting of forest biomass in such a way that biomass products are produced alongside conventional log assortments (Figure 1).

Figure 1: Integrated harvesting of conventional round wood and biomass residues in a yarder operation (from forestenergy.org)

Integrated harvesting systems are single-pass or double-pass operations, depending on the system adopted for harvesting conventional assortments. Single-pass operations are associated with whole-tree harvesting: trees are felled and extracted to the forest landing, where separation into conventional log products and energy products takes place, or where whole trees are loaded onto secondary transport vehicles for moving to a central processing yard.

Double-pass operations are associated with cut-to-length harvesting, which are defined by stump-site processing. In this situation, residues are left on the cutover and need to be moved to a landing before they can be processed and/or dispatched to the user plant [1].

A further distinction is based on the timing of the biomass recovery operation, and whether this is concurrent with the harvesting of the conventional log product mix, or postponed until after the main harvest has been completed and the conventional operation relocated. Each option has its own advantages and disadvantages, especially with regard to synergy, interference and landing space requirements.

In both cases, different levels of integration can be identified, with varying degrees of complexity and interdependence. In principle, the higher the integration level, the higher the potential for technical and economic optimisation, which may lead to increased profits. On the other hand, a high integration level also requires a stronger commitment from producers and involves higher risk [2].

INTEGRATED HARVESTING ISSUES

Regardless of the level of integration, whenever biomass production is associated with the production of conventional log assortments, the issues of production, cost, value of biomass recovered and supply chain efficiency have to be considered.

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Impact on mainstream log production

Integrated biomass harvesting may require the adaptation of current harvesting operations, and/or generate additional workload on the equipment normally used for manufacturing conventional log sorts. Even when that is not the case, biomass recovery will need additional space at the landing. All these changes may affect the manufacturing of the main log products that are more valuable than the additional biomass recovered. The first thing to be done is to determine the impact, whether it is beneficial and results in productivity increases instead of productivity losses (Figure 2).

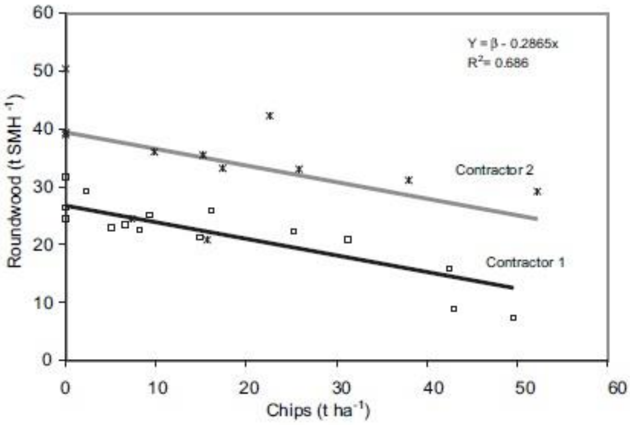

Figure 2: Hourly round wood production as a function of tons of chips harvested per hectare in South-Eastern US pine plantations [3]

Estimating any production losses is relatively straightforward, because these data are regularly monitored by harvesting managers and contractors. If there is indeed an impact, its cost should be estimated and weighed against the revenues accrued from the additional biomass harvest.

Cost of biomass recovery

The next question arising from the considerations regarding impact on mainstream log production is the cost of biomass recovery. The answer is not as simple as one may think. There are different ways of costing the biomass component of an integrated harvesting system. The marginal cost approach will charge the specific additional cost of handling the biomass component only, whereas all costs incurred when handling the two components together will be charged on the conventional log assortment. With this approach, the cost of felling, extraction, delimbing and processing in whole-tree harvesting will be borne entirely by the main log assortments, and the cost of biomass will only include piling, loading and carting the biomass to the user. If the biomass is chipped at the landing the cost components would only include piling, chipping and carting chip.

Conversely, the joint-cost approach is based on distributing all harvesting costs on the two components (logs and biomass) based on their relative proportions. This approach applies only to those tasks where the two components are jointly handled. Obviously, the impact of costing method choice is proportional to the abundance of the biomass component, and therefore costing method choice is especially important when biomass represents a relatively large proportion of the total harvest [4].

Neither of the two methods is preferable to the other, because the principles underlined by both are equally valid. Opting for either method mainly depends on the general strategy of the user, and where they want the cost burden to lie. Neither method creates or removes revenues, as the total combined cost is always the same for both methods.

Value of biomass recovered

Once a costing method has been chosen, costing the biomass recovery may be a relatively simple exercise. Attributing a value is however more difficult, because some of the market factors that determine the price of a product are often beyond the control of the producer.

Much depends on the potential users, their distance from the harvesting site and the specifications various users set on their suppliers (Figure 3). Furthermore, some of the most stringent specifications can only be met through the skilful processing of certain residue types.

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Figure 3: Good quality chips generally obtain a higher price, but they are more expensive to produce.

Therefore, alternative product strategies can be elaborated and compared, based on the end-user, the raw material type and the technical and economic feasibility of more or less complex processing methods.

Efficiency of supply chain for any given set of conditions

Determining which supply chain is the best depends on the specific given set of conditions. Some conditions possibly justify a relatively complex supply chain, in view of increased value recovery and better economy of scale. However, the simplest and most straightforward solution is generally the most economical, because extra cost is added each time the biomass is handled.

This simple principle has been demonstrated over and again in recurrent studies using sophisticated and powerful techniques such as Linear Programming (LP) and Discrete Event Simulation (DES) in different regions of the world, including Europe [5, 6], North America [7] and specifically New Zealand [8].

The easiest and cheapest way is generally to cart biomass directly to the end user, where the residue is processed and converted into energy. Additional steps may be included in the process, but the revenue these additional steps generate must be higher than the costs that they incur.

The cost of any further processing will be lower if conducted at a central site, where scale economies can be accrued, which is seldom the case at in-forest landings. There, the amount of biomass accumulated on site is generally too small for deploying large, expensive but highly productive equipment.

REVIEW OF INTEGRATED HARVESTING OVERSEAS

A comprehensive and updated summary of all the integrated harvesting solutions adopted outside New Zealand is difficult. However, a general overview is given of the mainstream commercial systems currently used in Europe and North America, where energy biomass has a large and growing market. It may be useful to review the main factors that have determined the choice of these solutions, in order to understand the origin of the eventual differences.

The choice of a specific biomass recovery system is generally determined by:

- the price and the specifications of the biomass, the two things being generally correlated; and
- the method adopted for harvesting conventional log assortments, which is seldom modified for the sake of biomass production.

North America

In North America, whole-tree harvesting is the main harvesting method. The main customer is represented by large power stations that offer relatively low prices (about US$20 per green tonne, or NZ$29.40 as at May 2018) but are relatively liberal with fuel quality specifications.

As a result, residues are generally concentrated at the landing, and can contain various degrees of contamination, since the low price offered does not justify special care during handling. This is especially the case for postponed biomass harvesting, where the biomass recovery operation reaches the landing after the main operation has been moved. In this case, the biomass operation often has to deal with large entangled residue piles that have been bladed to

the side in a hurry, to free space for the incoming log loaders.

Figure 4: A residue chipping operation in California, USA

For this reason, American operators tend to favour grinders over chippers, due to their better tolerance to contamination. Conversely, chippers are preferred in concurrent biomass recovery, because here the operator has better control on residue handling and can reduce contamination. Furthermore, chippers can be sourced that are smaller in size than grinders, which is a major asset in concurrent operations, where space is at a premium and material flow is too small for matching the capacity of a large industrial grinder.

Northern Europe

Deployment conditions vary in northern Europe, where there is a wide variety of biomass users, and medium and large size district heating and power stations represent the main customer base. These customers generally offer moderate prices (about 200 SEK per MWh, or NZ$33/MWh in May 2018). Fuel quality specifications are variable, but they are generally tighter than in North America. The most important difference is that cut-to-length harvesting is dominant in all the Nordic countries, and residues are left on the cutover. Therefore, residues must be moved to a landing, either before comminution or after comminution, depending on the system used.
Today, in most cases, residues are moved to a landing in loose uncomminuted form, using a forwarder with enlarged loading space (Figure 5). Forwarding is simpler, and minimises contamination compared to whole-tree harvesting.

Figure 5: Collecting residues from the cutover using an enlarged-space forwarder

In turn, minimal contamination favours use of powerful drum chippers, which are more productive and fuel-efficient compared with grinders (Figure 6). Another good reason for using chippers instead of grinders is the better quality of the hog fuel, which is generally rewarded with higher prices.

Figure 6: Powerful truck-mounted drum chipper at a roadside landing in Finland

Central and southern Europe

In central and southern Europe the situation is even more diversified, due to the presence of the widest range of user types, from large power stations to small-scale residential users. Use of biomass fuel is especially common in mountain regions, where the colder climate results in a large demand for heat and justifies the additional

investment required by a modern biomass plant. If the cold season is long enough, then the savings accrued when using cheaper biomass fuel (compared with gas or oil) easily offset the higher price of a relatively more complex plant, designed to accept solid biomass fuel, instead of easier-to-handle liquid fossil fuel.

Relatively small-scale plants set tighter quality specifications on their biomass fuel, but the savings in displaced fossil fuel are so high that the biomass is still competitive when sold, commonly at prices between € 50 and € 80 per green tonne (NZ$85-135 per green tonne in May 2018).

Such high prices often justify considerable efforts towards quality improvement, including extended storage, raw material selection, screening and even active drying.

Furthermore, in the mountain regions of central and southern Europe, harvesting is often performed through cable yarding, and residues are recovered only if they come to the landing as part of a whole tree extraction (Figure 7).

Figure 7: Italian cable-yarder operation hauling whole trees

This is because it is never profitable to yard logging residues after stump-site processing. Fortunately, the overwhelming success of mechanised processors has caused a decisive shift towards whole-tree harvesting, and residues are commonly extracted to the landing.

Residue accumulation at yarder landings involves a disposal problem, because forest owners generally demand their removal due to the potential negative effects on forest health (such as insect infestations) and landscape amenity considerations.

Fortunately, there is often a biomass user within reach, and the extraction method generally prevents heavy contamination. Residues are generally comminuted using a drum chipper in a postponed operation, given the small size of most landings. The price for quality biomass is often good enough to also justify chipping low-value conventional log assortments, such as pulpwood and low-grade saw logs.

Common misconceptions with integrated biomass harvesting

Some of the European biomass harvesting technologies have been consistently misunderstood by foreign observers, who have tried to apply them to their own conditions without a proper understanding of what these systems had been designed for, thus obtaining disappointing results. The two examples below stand out both for the steady attention they have received over the years and for their consistent negative results.

Chip forwarders

Chip forwarders are industrial chippers mounted on a forwarder base and fitted with a container capable of holding between 15 and 20 m^3 of chips (loose volume).

The name and configuration has led many people to believe that such machine was designed for chipping and forwarding to a landing. While such practice could be justified under exceptional conditions, it is not designed to use the forwarder-mounted chipper, which is rated at €250 per hour (NZ$420 per hour) for doing the job of the forwarder that costs €90 per hour (NZ$150 per hour). This is especially true as the payload of the chip forwarder is capped to 20 m^3 at best, when a normal forwarder equipped with a bin can carry at least 30 m^3 loose volume, if not more.

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There are two ways to operate a chip forwarder successfully, and they both involve hauling chips over short distances. These are:

- the chip forwarder can move the residues from the cutover, but is supported by one or more chip shuttles and uses its own bin just as a buffer, so it can keep working whenever the chip shuttle is delayed (Figure 8).

Figure 8: Chip forwarder emptying its own bin into the bin of a low-cost chip shuttle

- the chip forwarder is used to chip residue accumulated at a landing and to dump the chips into truck containers suitably parked on the same landing (Figure 9).

Figure 9: Chip forwarder emptying its own bin into a truck container parked at the landing

Since the exact location of the chip containers will change, use of a mobile chip forwarder offers the convenience of a completely independent system that can reach the site after the main operation has moved and the empty containers have been parked, and then easily move the short distance to empty its own bin into those containers. This movement is regardless of terrain conditions (another big advantage).

Bundlers

Dedicated forest residue bundlers became available in the mid-1990s and have attracted much attention for two decades (Figure 10). However, the results have been disappointing, despite the theory being sound that bundling would increase the efficiency of extraction, transportation and comminution, as had been predicted by the experts. Furthermore, bundled residues did store better than both chips and uncomminuted loose residues.

Figure 10: Logging residue bundler in Finland

However, the cost of bundling turned out to be higher than the sum of all savings accrued through its many benefits, except under particularly favourable conditions.

And yet, if baling works with hay, straw and other agricultural products, why should the same principle not work with forest residues? Probably, the differences between agricultural and forest residues are such that a forest residue bundler cannot be built at sufficiently low cost and operated at high enough productivity to be competitive, not to date at least. That does not mean that bundling should be excluded categorically from the range of alternatives, but just that all factors should be weighed very carefully before deciding whether bundling is a

viable solution. It may well be that in some situations bundling is a viable solution, but the odds are not in favour of that conclusion.

SETTING UP THE SYSTEM

When setting up an integrated harvesting system, proper consideration should be given to the following basic elements: interaction, space requirements, and contamination. Success will depend on how well these elements are managed, and a good understanding of these fundamental principles will make it easier to spot new opportunities under any given set of circumstances.

Interaction

Chipping operations are often characterised by a high level of interaction, since a chipper normally discharges into a chip van or bin truck and cannot work if no trucks are available. Furthermore, if residues are fed to the chipper as the loads arrive to the landing in a concurrent recovery operation, then the chipper may incur additional waiting delays. The result is low chipper utilisation.

Either this low utilisation level is accepted and the impact minimised by parking a low-cost pre-owned chipper at the landing for intermittent use (and other tasks are found for the chipper operator when the machine is not in use), or chipper utilisation is improved through two main strategies:

a) minimising interaction by creating appropriate buffers upstream from the chipper by letting a large enough pile of residues accumulate before moving the chipper in;
b) minimising interaction by creating appropriate buffers downstream from the chipper, most typically by discharging chips on to the ground and accepting some product losses, estimated at 4-5% of volume (Figure 11). Alternatives to discharging to the ground include using set-out truck trailers and moving them around and under the chipper with any of the machines available on site [9], or installing proper surge bins on site (but this is generally feasible only at large semi-permanent sites) [10].

Figure 11: Discharging chips onto a heap on the ground

Space Requirements

A residue recovery operation has obvious space requirements, which will change with operation type. Much less space is necessary for the collection and removal of loose uncomminuted residues than for chipping the residues into trucks, bins or heaps.

A postponed biomass recovery operation installed after the main operation has moved out, implies that the landing is large enough for accumulating all the residues while the main operation is in progress. Regardless of operational strategy, residue recovery requires planning for adequate space.

Contamination

Mixing logging residues with dirt negatively impacts product quality and production efficiency for the following reasons:

1) it makes it impossible to turn the biomass into a quality product and
2) it makes it necessary to use a less efficient grinder.

Therefore contamination with dirt must be avoided (Figure 12). Poor handling of residues is justified only when the market is not going to reward quality anyway, and work pace is so fast that residues must be pushed to the side in a hurry, to avoid interfering with the main log production process.

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Figure 12: Contamination of biomass with dirt

OPPORTUNITIES FOR AUTOMATION OF LOG LANDINGS

The concept of a new centralised robotic sort yard as proposed by the new PGP programme managed by FGR offers two new and important conditions for effective integrated harvesting. These are space and volume, respectively representing the physical and the economical requirements for installing specific infrastructure that could not be set up on conventional landings.

In turn, the new infrastructure can be designed to achieve both higher efficiency and better product quality.

Higher efficiency
Biomass production efficiency can be increased in a number of ways.

Figure 13: Chipping into semi-permanent surge bins at a centralised landing in Oregon, USA

First of all by dramatically reducing the potential for interaction delays in the chipping process, through the creation of suitable buffers. In particular, proper large-volume surge bins could be installed, so that the chipper and the trucks would become independent from each other (Figure 13).

The chip would then discharge straight into the bins, and the trucks would fill up directly from them, as in most large scale mills (Figure 14).

Figure 14: Loading straight from the surge bins in Oregon, US

This solution could fall within the scope of the new landing concept, representing the biomass equivalent of the proposed "automatic truck loading gantry" for loading log trucks.

Efficiency can also be increased by deploying an electric powered chipper, rather than one powered by a diesel engine. Under equal conditions, an electric chipper will have a lower cost and will be more efficient than a diesel-powered chipper, which is why most stationary chippers installed at mills are electric.

In addition, the chipper used at a centralised sort yard does not need to be stationary: the electric chipper can be installed on a truck base and moved between neighbouring centralised yards if the amount of material accumulated at each yard is not enough to guarantee high machine utilisation.

Truck-mounted hybrid-electric chippers designed to run on an electric motor and a diesel engine

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like modern hybrid-electric cars may soon become available (Figure 15).

Figure 15: Prototype hybrid-electric chipper in Finland

These hybrid machines are specifically conceived for increasing fuel efficiency, but they could easily be adapted to dual use, so they can run exclusively on power when an outlet is available, and then work independently on their diesel-hybrid system in the absence of a power outlet. That would allow using the same machine at both the centralised log sort yard and at smaller conventional landings, depending on requirements.

Better product quality

When product quality is rewarded, then a centralised log sort yard offers great opportunities for biomass quality improvement. This can address moisture content as well as particle-size distribution, and can be obtained in several ways.

Moisture content reduction will raise the value of any fuels by reducing bulk density (kg/m^3) and increasing energy density and transportation efficiency at the same time (Figure 16).

The simplest way to reduce moisture content is to store the uncomminuted biomass until it dries to the desired level. That will usually require several months' storage, depending on the target moisture content and the micro-climate at the storage site.

Furthermore, air drying can be especially slow with solid wood elements, such as offcuts and unmerchantable (cull) logs, which have a relatively small surface-to-volume ratio.

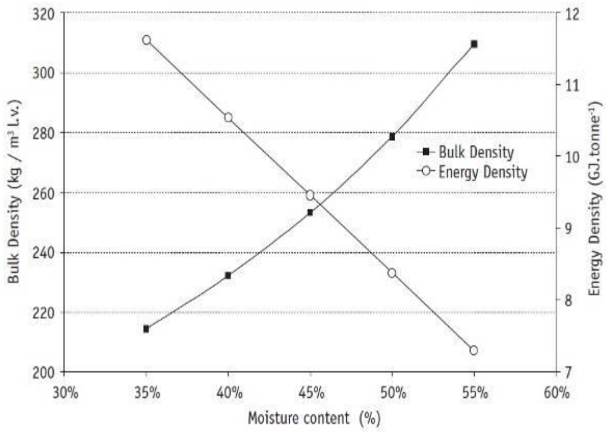

Figure 16: Relationship between moisture content, energy density and bulk density - from Talbot and Suadicani [11]

In this case, drying can be sped up by splitting [12]. This operation also offers the advantage of reducing log diameter to the benefit of smoother chipping and lower chipper wear (Figure 17).

Figure 17: Splitting cull logs before chipping

Chip size distribution is the other fundamental quality attribute for industrial chips. In general, particles must be as even as possible, and the product must contain minimum amounts of oversize particles and fines. Furthermore, different users have different preferred size specifications. For instance, many gasification plants require 40 mm-long chips, whereas small-scale residential heating boilers target chips in the 20 mm-length range.

Particle-size distribution targets are generally obtained by adjusting chipper settings and selecting suitable raw material. Nevertheless, it's almost impossible to produce a load that contains absolutely no fines and no oversize particles. If customer specifications are very tight (and if they are supported by appropriate pricing), then screening is the best solution. This has been in use at many European sort yards (Figure 18).

Figure 18: Portable oscillating screen at a chip sort yard

Screening can be performed with different equipment, each characterized by specific capabilities and cost, as follows:

- static sieves, consisting of a simple frame and a steel net with the appropriate mesh size. This is the cheapest solution, but not the most common or effective for wood chip applications;
- oscillating screens, available in stationary or mobile versions and commonly used for removing oversize particles from energy chips;
- rotary screens, also available in stationary and mobile versions, and especially popular with composting plants for separating dirt from coarse elements;
- star screens, generally mobile and relatively new, but increasingly common in large wood chip sort yards.

All the screening options listed above represent mature technology that can be observed at work under real operational conditions. However, the innovative development of centralised robotic log sort yards for New Zealand may justify exploring new and more ambitious concepts, such as optical and pneumatic sorting [13].

Type of residues

One final question concerns the type of residues to be handled at the centralised robotic log sort yards. If whole trees or tree lengths are moved to the yards, then most of the offcuts and cull logs will be generated at the yards. However, tops and branches will likely be removed at the landing, and if log manufacturing is done at the log landings (as proposed) then log making residues will also accumulate there.

If it is economic to recover those portions of the tree stem, the easiest way is to move this material as uncomminuted loose slash with bin trucks - possibly using extended volume bins and/or compressing frames. If increased bulk density becomes a requirement because of the long transportation distance and/or volume size limitations, then postponed chipping will probably be the best option.

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