Landing Characteristics for Harvesting Operations in New Zealand

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Abstract

Landings are an integral part of modern whole-tree harvesting operations in pine plantations in New Zealand. However, little information has been published about size of landings and the factors that influence landing characteristics. A representative sample of 142 landings was measured using Global Positioning System (GPS); 12 were recently constructed (unused), 38 were live, and the remaining 92 were older and closed out. The average landing size was 3900 m^2 (0.96 acres), with a range from 1370 to 12540 m^2. On average the number of log-sorts cut was 11, the landings were in use for four weeks, estimated daily production was 287 tons/day, 47% were manual processing (53% mechanized), and 79% were grapple loader (21% front-end loader). A regression equation to model landing size indicates that number of log sorts and production levels are the two main factors that determine landing size. Landings do tend to 'grow' over time, with used landings on average being 900 m^2 larger than recently constructed landings. The most recently constructed landings were much larger than the company design; whereas either 40x60 m or 40x80 m were common specifications. A comparable study in 1987 showed the average landing to be just over 1900 m^2 (0.47 acres), indicating landing size has nearly doubled in the last 20 years. Landings serviced by front-end loaders were on average 1100 m^2 larger than those serviced by grapple loader, but this result is compounded by the fact that front-end loaders are more commonly used in high-production systems

Keywords: forest operations; landings; skid sites; timber harvesting; processing.

Introduction

Landings are an integral part of modern whole-tree harvesting operations. However, a forest landing (also called a deck, skid or skid site) is not a well-defined term. In general it is a designated area in the forest used during times of harvest to further process stems or trees extracted from the forest, store them, and then load out the logs (Stokes et al. 1989). This designated area is usually cleared of obstacles such as trees and stumps, and can vary in size depending on the processing, storage and loading-out requirements.

Landings should be designed to ensure an efficient flow of product and process (Sinclair and Wellburn 1984). They must not only accommodate the processing machinery and systems but also ensure that both the extraction of the trees onto the landing, and the log loading onto the truck transportation systems are effectively integrated. Safety becomes critical when machines and workers interact in a confined area (OR-OSHA 1993). Log storage requirements can significantly influence the size of the landing (Samset 1985), ensuring adequate separation between workers and mechanized machinery as well as moving stems for safety (Raymond 1987). In a previous study, Raymond (1987) established that both the productivity of the harvesting system, and the number of different log sorts being produced influenced landing size. The cost of setting up an efficient landing can be considerable, depending on scale (Dramm et al. 2004).

Dramm et al. (2002) noted that larger log yards are more flexible in accommodating wood flow but add to capital cost. Optimizing landing layout and size to accommodate required wood flow is critical in achieving the most cost-effective option. Common zones on a landing include unloading, processing, storage and loading. Equipment options will also influence zone interactions (Dramm et al. 2002). On forestry landings these zones are dynamic in that they can change both in size and in location as the operation demands. Operations research techniques have been used to model dynamic facility layout (Zhao and Tseng 2007). Li et al. (2004) showed how different machine allocation optimization techniques can be used to minimize storage requirements in material processing

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while optimizing just-in-time delivery. Some similarity can also be found in the approach to solving dynamic container terminal problems with an interaction of space, processing and flow constraints (Kozan and Casey 2007). Castillo and Sim (2004) noted that facility layout is a hard problem, and therefore exact solution methods are feasible only for small or greatly restricted problems. No literature was found that successfully applied these types of operational research techniques to landings or log yards.

Harvest system productivity for typical New Zealand pine plantation operations range from 80 to over 450 tons per day (Visser 2009). Costs associated with landing construction range typically from $3,000 to $5,500, depending not only on size but also very much on soil type and terrain slope. The result is an inverse relationship between construction cost and landing size, as the most expensive landings are small because they are difficult to construct. Also, few New Zealand forestry companies keep record of individual landing construction costs; they are normally considered part of a larger infrastructure contract.

Some companies have prescriptions, depending on the type of operation or location, but they are rarely definitive or benchmarked. Two typical company specifications for landings are 40x60 m or 40x80 m, but especially on sloped terrain the shape is dictated by the result of attaining the desired area with the least amount of excavation. Most companies also design their landings with their own harvest system requirements in mind. They do not deliberately adjust landing size for total harvest area, but some make allowances for exceptionally large volumes.

For the purpose of this project it is appropriate to distinguish at least four different types of landings:

Pad: A pad is a small landing usually used in a two-staging operation. The pad normally serves the purpose of transferring the stems and/or trees from one to another extraction machine. For example, a common use of pads is in steep terrain where a cable yarder will be positioned on a pad to extract the trees, at which stage they will be transferred to a ground-based machine for further extraction to a larger processing landing. Where appropriate, contractors may attempt to integrate a mechanized processor onto a pad to delimb and top the trees. This aids subsequent extraction and also leaves the slash at the pad to avoid accumulation at the processing landing.

Skid: A skid is by far the most common landing type. It will typically service just one harvesting crew and accommodate all processing, storage and loading functions (Figure 1).

Super-Skid: A super-skid is a processing area that services a number of smaller landings (pads) to concentrate the log-making, cross-cutting, sorting and loading activities. Multiple crews, over a larger forest area, will provide stems, and they will often be forwarded to the super-skid off-road by a two-stage type machine.

Central Processing Yard (CPY): CPY is the largest landing type. Stems are transported there either by off-road or on-road trucks. In the USA they may be referred to as Log Sort Yards (Dramm et al. 2004). CPYs are normally located close to a mill, port or railway head. CPYs are also characterized by more automated, or sophisticated, processing capability. CPYs are still relatively rare, with just a few in use around New Zealand.

Figure 1: A typical (cable yarder) skid-site that incorporates all the extraction, processing and loading-out phases of the operation.

The goal of this study is to improve our understanding of landing size, the parameters that influence landing size and landing layout. Because central processing yards (log sort yards) are few and their design is very specific to their operation (Dramm et al. 2004; Sinclair and Wellburn 1984), the study will focus only on pads, skids, and super-skids.

Methods

Six regions in New Zealand were visited in 2009 and 2010. We met with a series of forest supervisors from different companies and were taken to a ‘typical’ range of landings. During the visit to each landing the perimeter was mapped with a *Garmin GPSmap 60 CSx* hand-held GPS receiver. The landing was defined as any area that had been ‘built’, with criteria that included the removal of topsoil and stumps, compaction, flatness and continuity. If a road clearly went through the landing it was included. If the road was beside the landing, it was excluded. Areas prepared for stacking of logs or vehicle parking were included if they met the above criteria.

On live landings the GPS was also used to collect position points inside the landing to separate the following functional areas: extraction, processing, fleeting, stacking, and loading. Position points were then downloaded into a computer. The surface area, perimeter length, length and width of the landings and of the functional areas were calculated.

The use of a simple hand-held GPS device entails a certain error in the positioning, normally indicated by the device itself. Given the favorable conditions encountered when mapping landings (i.e., the absence of a forest canopy), the positioning error was normally contained within 2-4 m. A few landings were tested using different numbers of GPS points to measure the perimeter, and it was found that when using more than 30 points were used to define the landing, the area accuracy would be less than 2% error.

For each of the landings visited, forest managers were asked to provide the following data: type of operation (ground base or hauler), type of processing (manual or mechanical), type of log loader used (front-end or knuckleboom), number of log sorts, daily productivity, and duration of the harvesting operation in weeks. During the visits of active landings, the type, number and tasks of all machines were noted, as well as the number of the crew and the tasks of its members. At the same time, sketches were produced to describe the wood flow through the landing.

GPS coordinates were used for each landing, and where possible, they were located on Geographical Information System (GIS) digital terrain models. Average slopes were calculated for circular areas from the center point of the landing for analyses of landing size with average slope.

The program R was used for data analyses and all results stated are statistically significant at the $p<0.05$ level unless otherwise stated.

Results

One hundred and forty-two landings were measured. One hundred and thirty-one landings were captured in 2009 and the remainder in 2010. Twelve were new (unused), 38 were in operation, and 92 were recently completed. Table 1 shows the mean, 5th, and 95th percentile values for each of the parameters.

Table 1. Mean, 5th, and 95th percentile values for each of the parameters.

Parameter	Mean	5th Percentile	95th Percentile
Landing size* (m^2)	3868	1944	7476
Weeks in Operation	4.3	1	10.5
Production (t/day)	287	150	450
Log Sorts (n)	10.2	1	15
Perimeter (m)	271	187	396
Length/Width ratio	2.12	1.1	4.0

** Note: for conversion from m^2 to acres divide by 4047*

Other summary data include:

- 63% of the landings were ground-based, 27% were cable settings
- 47% had manual processing, 53% mechanized processing
- 79% used knuckleboom type loaders for loading out, 21% used front-end loaders

When analyzing the data it is possible to determine other interesting facts.

Landing Age:

Used landings are 900 m^2 larger than new, suggesting that during harvesting the crews will considerably enlarge their operating area. They may do this to make additional space for log stacks, but it will also occur as residue is pushed over the side and the landings are scraped clean during the operation.

Ground-based versus Cable Yarding:

On average a ground-based landing is 430 m^2 larger than a cable landing. On average a ground-based crew will extract 320 tons/day, cut 10 log sorts and be on the landing three weeks. A cable yarding crew will extract 232 tons/day, cut 11 log sorts and operate for six weeks. Yarder landings tend to be slightly more elongated (2.4 length-to-width ratio) than ground-based (ratio = 2).

Manual versus Mechanized Processing:

On average the manual processing crews will operate just under one week longer at a single landing and cut 13 log sorts. Their productivity is only 26 tonnes per day less than that of a mechanized processing crew. The landing shape is the same.

Front-end Loaders versus Knuckleboom Loaders:

For the 21% of the landings surveyed that were operated by front-end loaders, they were on average 1100 m^2 larger, produced 35t/day more, and worked with an average of 15 log sorts.

Regression Analyses:

The best regression equation for the data is:

$$\text{Landing Size (m}^2) = 390 + 560 \times \text{LandingAge} + 173 \times \text{LogSort} + 3.5 \times \text{DailyProd}$$

Where LandingAge = 0 when new; = 1 when in use; and = 2 when complete

LogSort = number of log sorts processed (n)

DailyProd = estimated average daily production (tonnes/day)

Comparison with Previous Data:

Raymond (1987) carried out a similar study surveying landing size in four different regions. He measured 50 landings in 1986. The average landing size was 1900 m^2, which is 2000 m^2 less than in 2009. There were three times as many landings using front-end loaders as there were knuckleboom loaders. Landings using front-end loaders were also twice as large (approximately 1000 m^2 larger). This trend has completely reversed, with knuckleboom type loaders dominating (79%) operations now, but the absolute difference in size is still about the same. In 1986, there was no discernible difference in landing size between ground-based and cable yarder.

The number of log sorts and production were two parameters that were the same in the landing size regression analyses for both studies. The coefficients were 160 and 5 for number of log sorts and daily production, respectively, and they remain very similar, with the 2009 data showing them to be 173 and 3.5. This finding indicated that much of the increase in landing size can be explained by both the increase in average productivity and the number of log sorts currently being cut.

The 1986 study measured only landings in operation, so it did not record a change in landing size over time. As that study focused on four regions, Raymond was able to establish a regional difference, and also measured stem length at the landing, which was a significant factor for the yarder landings.

Evaluation of Schematic Diagrams:

Diagrams depicting the layout of the active operations are difficult to interpret. Attempting to differentiate between zones on the landing was difficult, as most areas serve multiple purposes. Landing layout analyses of the schematic drawings for the live landings indicate that as landing size grows, there is a preference for using multiple rows to manage log inventory on the landing. Landings serviced by front-end loaders also had wider spacing between stacks. Smaller landings typically prefer to stack logs around the edge of the landings.

Manual processing areas (decks) were more clearly defined than mechanized, and most larger scale manual operations had two clearly defined processing decks on the landing that were aligned with the skidder access to the landing. This allowed the loader either to prepare a deck with stems or fleet the cut logs while the manual skid workers processed at the other deck. Many ground-based landings with mechanized processing attempted to centralize the processor to minimize subsequent fleeting distances (Figure 2).

Figure 2. Mechanised processor located more centrally on the landing to minimize fleeting distance.

The production through cable landings was typically more 'linear' with the cable yarder at the 'far end' and clearly separated from the landing processing and loading activities (Figure 3).

Figure 3. Arrow overlaid on cable landing showing linear flow of production.

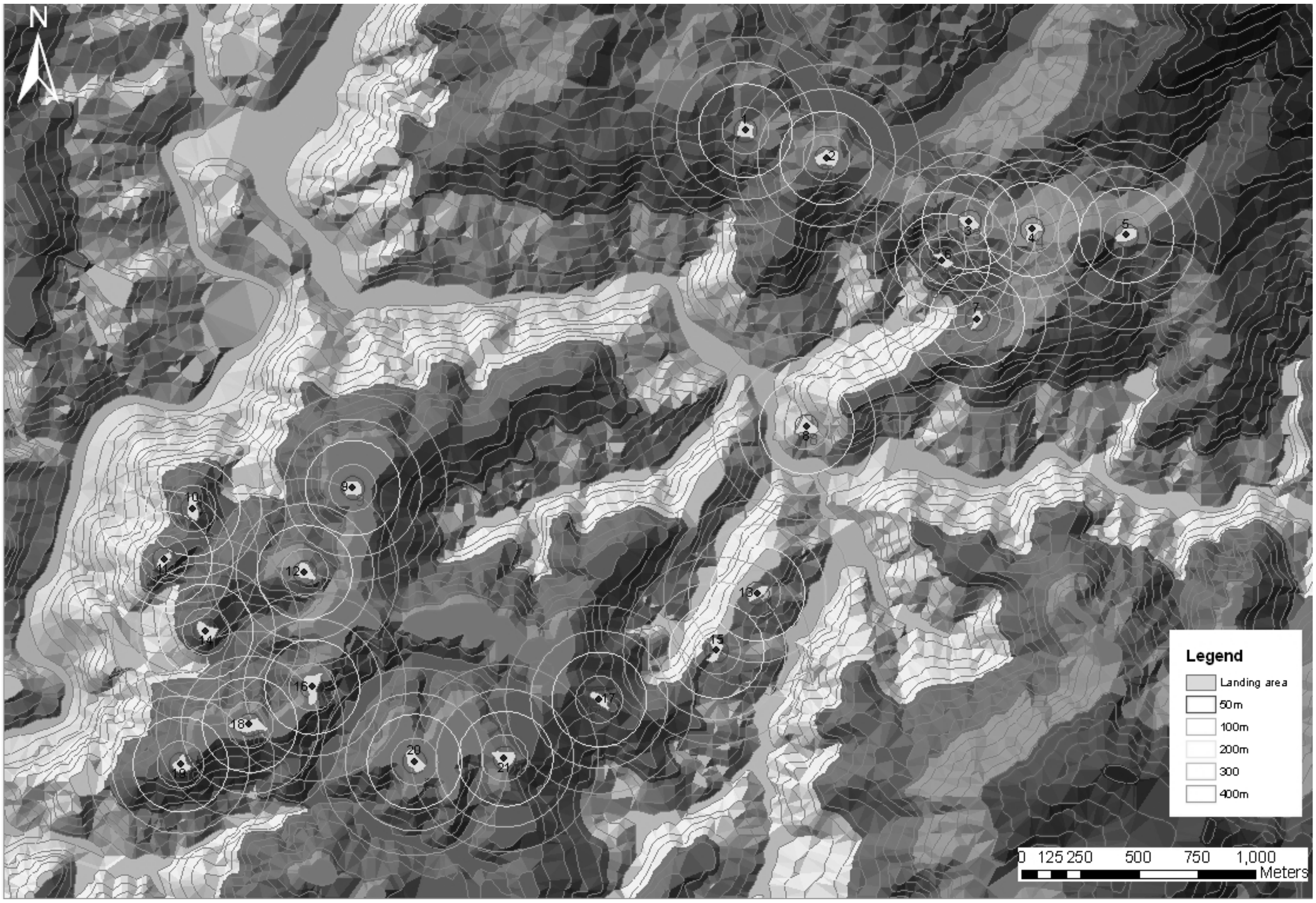
Evaluation of Surrounding Slope:

In general, the steeper the surrounding slope, the smaller the landing, and using 50- or 100- m circles gave the best correlation, but no statistically significant relationship was found. Surrounding slope is compounded by a 'location' factor (Figure 4). The largest landings are typically found on the lowest elevations and have the lowest surrounding slope. However, large landings are also easily constructed at the top of a hill, but will be characterized by quite steep slopes leading up to it. The smallest landings are found at mid-slope, on steep slopes.

Conclusions

Landings have always been an integral part of larger scale commercial harvesting operations. They are expensive to build and their location and size are important to an efficient and safe operation. This study provides a benchmark in terms of current size and parameters that influence size and shape. It shows that production and number of log sorts are the main drivers that determine landing size. This finding has not changed when compared with an LIRO study completed in 1986 (Raymond 1987). It also showed that landing size had almost doubled in the last 20 years. It added to the knowledge base by including landing age as a significant factor. Logging operations significantly increase their landing area over time. A number of changes in equipment preferences, such as the current prevalence of knuckleboom grapple loaders, have also been established.

Figure 4. GIS map showing landing locations. The circles shown around the landings were used to determine average surrounding slope at different radii. Note that landings on top of the hills are generally larger than those at mid-slopes (Figure prepared by Hamish Berkett).



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