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LANDING SIZE AND LANDING LAYOUT IN WHOLE-TREE HARVESTING OPERATIONS IN NEW ZEALAND.

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Abstract: *Landings are an integral part of modern whole-tree harvesting operations in New Zealand. A representative sample of 142 landings were measured using GPS; twelve recently constructed and unused, 38 live and the remaining 92 were older and closed out. The average landing size was 3900 m^2, with a range from 1370 to 12540m^2. On average the number of log-sorts cut was 11, the landings in use for 4 weeks, estimated daily production was 287 m^3/day, 47% were manual processing (53% mechanised), 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 900m^2 larger than recently constructed (unused) landings. Most recently constructed landings were much larger than the company design; whereby either 40x60m or 40x80m were common specifications. A comparable study in 1987 showed the average landing to be just over 1900 m^2, indicating landing size has nearly doubled in the last 20 years. Landings serviced by front-end loaders were on average 1100m^2 larger than those serviced by grapple loader, but this is compounded by front-end loaders being more commonly used in high production systems.*

1. **Introduction**

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 or stumps, and can vary in size depending on the processing, storage and loading out requirements.

Harvest system productivity for NZ operations range from 80 to over 450 tons per day (Visser 2009). Costs associated with landing construction range typically from $4000 to $7000. Some companies have prescriptions depending on the type of operation or location (Twaddle 1984), but they are rarely definitive or benchmarked. 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 are transferred to ground-based machine for further extraction to a larger processing landing. Where appropriate, contractors may attempt to integrate a mechanised processor onto a pad to delimb and top the trees. This aides 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 just service one harvesting crew and accommodate all processing, storage and loading functions (Figure 1).

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

'Superskid' : A superskid 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 are often forwarded to the superskid off-road by a two-stage type machine.

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

Figure 2: A CPY, showing the scale of the operation and the proximity to the mill.

2. Methods

Six regions in New Zealand were visited in 2009 and 2010. We typically met with a series of forest supervisor 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 device. The landing was defined as any area that had been 'built', with criteria that included the removal of topsoil, compacted, flat and contiguous. If a road clearly went through the landing it was included. If the road was besides the landing then it was excluded. Areas prepared for vehicle parking were included if it met the above criteria.

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 laptop computer and used to calculate the perimeter, the surface area, the length and the width of the landings, and of the functional areas.

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

For each of the visited landings, 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 knuckle-boom), number of log sorts, daily productivity, 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, describing the wood flow through the landing.

Using the GPS coordinates for each landing, where possible they were located on GIS digital terrain models. Average slopes were calculated for circular areas from the centre point of the landing for analyses of landing size with average slope.

3. Results

142 landings measured, with 131 landings captured in 2009, the remainder in 2010. Twelve were new (un-used), 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 (#)	10.2	1	15
Perimeter (m)	271	187	396
Length/Width ratio	2.12	1.1	4.0

Other summary data include:

- 63 % of the landings were ground-based, 27% were cable settings
- 47% had manual processing, 53% mechanized processing
- 79% used knuckle-boom 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, suggestion that during harvesting the crews will 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 and cut 10 logs sorts and be on the landing 3 weeks. A cable yarding crew will extract 232 tons/day, cut 11 log sorts and operate for 6 weeks. Yarder landings tend to be slightly more elongated (2.4 length to width ratio) than ground-based (ratio = 2).

Manual vs Mechanized Processing:
On average the manual processing crews will operation just under one week longer at a single landing and cut 13 log sorts. Their productivity is only just 26 tonnes per day less than a mechanised processing crew. The landing shape is the same.

Front-end Loaders versus Knuckle-boom:
For the 21% of the landings surveyed that were operated by front-end loaders, they were on average 1100m^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:

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

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

Comparison with previous data.
Rayomd (1987) carried out a similar study surveying landing size in four different regions. He measure 50 landings in 1986. The average landing size was 1900 m^2, which is 2000 m^2 less than in 2009. There were 3 times as many landings using front-end loaders as there were knuckle-boom loaders. Landings using front-end loaders were also twice (or as large (approximately 1000 m^2 larger). This trend has completely reversed with knuckle-boom type loaders dominating (79%) operations now, but the absolute difference in size is still about the same. In 1986 there was no discernable difference in landing size between ground-based and cable yarder.

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 indicated that a lot 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 only measured 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 different, and also measured stem length at the landing, which was a significant factor for the yarder landings. Socio

Evaluation of schematic diagrams.
The diagrams depicting the layout of the active operations are difficult to interpret. Attempting to differentiate between zones on the landing was also inconsistent 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. Smaller landings typically prefer to stack around the edge of the landings.

Evaluation of surrounding slope.
In general the steeper the surrounding slope the smaller the landing, and using 50 or 100 meter circles gave the best correlation, but no statistically significant relationship was found. Surrounding slope is compounded by a 'location' factor (Figure 3). 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 characterised by quite steep slopes leading up to it. The smallest landings are found at mid-slope, on steep slopes.

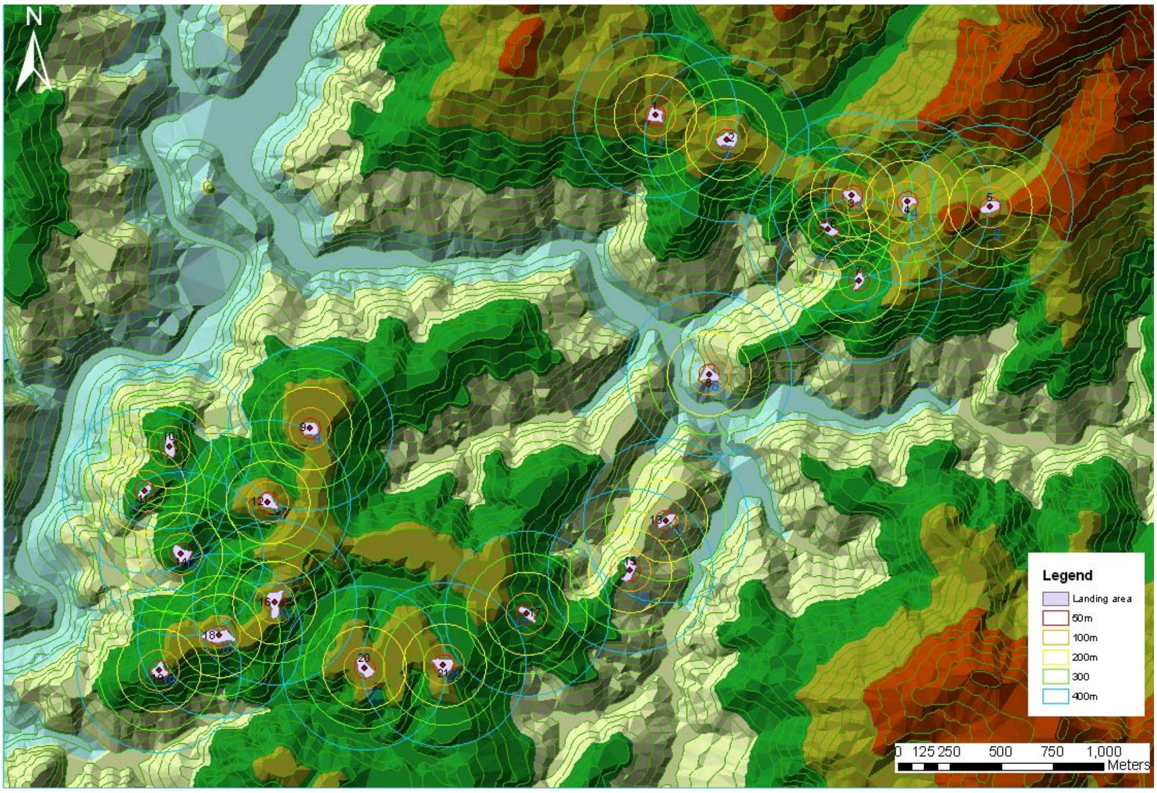

Figure 3: GIS map showing landing locations. The circles shown around the landings were used to determine average surrounding slope at different radii. Note that landings on top of the hills are generally larger than those mid-slopes (Figure prepared by Hamish Berkett).

4. Conclusions

Landings have always been an integral part of larger scale harvesting operations. They are expensive to build and their location and size is important to an efficient and safe operation. This study is effectively a repeat of a LIRO study completed in 1986 (Raymond 1987). It confirms the parameter production and number of log sorts as driving landing size, but has also added to the knowledge base by including landing age as a significant factor. A number of changes in equipment preferences, such as the current prevalence of knuckle boom grapple loaders, have also been established.

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