HARVESTING TECHNICAL NOTE

HTN16-01
2023

Cost and Productivity Benchmarking Update 2022

Summary

In 2022 the FGR Benchmarking system continued to track cost and productivity of New Zealand harvesting systems, with a further 103 entries submitted. The data continued to show the benefits of higher levels of mechanisation on steep terrain. With 85% of harvest area entries using winch-assist harvesting systems, the average productivity for cable yarder systems was up to 31 tonnes/hour. Compared to the 2020-21 data, logging rates have climbed more so for ground-based than for yarder systems. The average ground-based rate was up $4.50 to $32.40/tonne, but interestingly average yarder harvest rates were up only $2.30 to $42.60/tonne.

While the increase in mechanisation from 2013-14 resulted in a jump in productivity for ground-based systems, from 30.5 tonnes/hour in 2008-10 to about 34.1 tonnes/hour (+12%), average productivity has increased only marginally since 2014. Conversely, for cable yarding operations the increase in productivity has been continuous and more significant, increasing from 23.5 tonnes/hour to 31.4 tonnes/hour over the last 12 years (33%).

This report provides updates in harvest area averages for the 2022 calendar year, and also establishes regional differences in both productivity and cost. Using regression analyses, the impact on logging rate from the stand and terrain parameters collected for both ground-based and yarder systems is also investigated.

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INTRODUCTION

Timber harvesting is a major cost in New Zealand's plantation forest cycle. As such, competitive logging systems are vital to sustaining an economically viable forest industry. Being able to track the changes to harvesting cost and productivity over time, and how they relate to harvesting system, stand and terrain conditions, helps logging planners to optimise system choice (Cubbage *et al.* 1988; Visser and Obi 2020).

The FGR benchmarking system has been successfully collecting and analysing harvesting productivity and cost data since 2008. This system is directly supported by New Zealand forestry companies, whereby they enter harvest system, stand and terrain data for recently completed harvest areas (Visser 2009).

This nationwide benchmarking system remains unique in the world in that companies voluntarily submit actual contracted rates on a sample basis. A summary report is produced annually that includes different analyses of factors (often as requested by industry members). A more comprehensive analysis was completed based on ten years of harvesting data that included both logging rate and productivity equations (Visser and Obi 2020).

There are other examples of tracking logging costs. Baker *et al.* (2014) created a logging cost index for harvesting operations in the southern USA, while Bell *et al.* (2017) was able to validate a logging costing model using a sample of real data. Based on the FGR data capture system, a one-off comparison of cable logging rates across central European alpine countries was published based on smaller datasets (Spinelli *et al.* 2015), as well as one for smaller harvest systems in the southern Alpine region with data collected from loggers (Spinelli 2017).

GROUND BASED HARVESTING

For ground-based operations a total of 46 new entries were received in 2022 (Table 1). Similar to the 2020-21 data, 72% were from grapple skidder, 13% from forwarder and 8% from shovel logging operations, with a few entries using tractor with arch and cable skidder. The increase of shovel logging as a preferred extraction method for almost 10% of operations was noted in the 2020/21 dataset, and with similar numbers from 2022 we can confidently state that this technique is now well-established at that level.

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Table 1: Summary of ground-based data over time (total n=985)

Attribute	2008-10	2011-12	2013-14	2015-16	2017-18	2019-21	2022
Scheduled Hours/day	8.4	8.5	8.5	8.4	8.3	8.75	8.6
Piece Size (t)	2.1	1.8	2.0	2.1	1.9	1.9	1.7
Extraction Dist. (m)	205	206	205	221	250	215	235
Slope (%)	14.5	19.5	15	15.1	16.7	16.3	19.5
# Machines	3.6	4.3	4.6	5.0	4.7	4.9	5.6
# Workers	7.9	7.1	6.7	6.8	6.3	5.8	6.3
# Log Sorts	11.2	10.8	11.2	10.2	11.5	9.9	14.5
Harvest Area (ha)	13.8	14.2	12.1	11.9	13.7	12.3	10.4
Stand Vol. (t/ha)	511	505	546	572	559	595	595
Productivity (t/hour)	30.5	28.2	31.6	34.1	34.4	34.8	35.9
Logging Rate ($/t)	22.70	24.70	25.60	23.90	27.60	28.30	32.40

*Note: data from 2008 through to 2021 have been averaged over 2-yearly periods.

The latest data show a slight increase of 3% in harvesting productivity from the previous period as measured in tonnes per scheduled hour, continuing the longer-term trend of increased productivity. The ground-based logging rate increased by $4.10/tonne against the average for 2019-21. One possible reason is that since 2021 fuel prices are up about 30% from 2016 to 2021, then a 50% further jump in 2022. Labour costs have increased with average NZ wages up from $29 to $37/hour in that same 6-year period), which is well above the average inflation rate.

This year's data show the average number of crew members over six per crew, similar to the 2017-18 period and still following the overall longer-term downward trend. Number of machines per crew has increased from below 5 to 5.6, indicating that ground-based harvesting crews have increased in size. This indicates the increase in machines may be responsible for the increased production in 2022.

The ratio of machines (5.6) to workers (6.3) per crew indicates a 90% level of mechanisation – a slight increase from 84% since last year.

CABLE LOGGING OPERATIONS

There were 57 yarder entries in 2022 (Table 2), with only 13 operations using tower yarders (24%), with the remaining 76% coming from swing yarder operations. The more extensive use of swing yarders over time has been a clear trend, increasing from less than a third a decade ago. This difference in entries continues to be somewhat surprising with the last yarder survey (2018) indicated that the majority of yarders were tower yarders – albeit also noting the strong trend over the previous 6 years from towers to either swing or excavator-based yarders.

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Table 2: Ten years of cable yarding data (total n=966)

Attribute	2008-10	2011-12	2013-14	2015-16	2017-18	2019-21	2022
Scheduled Hours/day	8.6	8.6	8.7	8.6	8.6	8.6	8.6
Piece Size (t)	2.2	1.9	2.2	2.3	2.1	2.0	2.0
Extraction Dist. (m)	204	202	110	216	238	202	268
Slope (%)	48	39	49	45	43	44	40
No. of Machines	4.0	4.6	4.7	4.9	5.6	6.5	7.5
No. of Workers	9.3	8.2	8.9	7.9	7.8	8.0	8.2
No. of Log Sorts	10.6	10.8	9.9	9.6	10.4	9.2	12
Harvest Area (ha)	13.5	14.2	11.2	12.8	13.9	11.7	12.5
Stand Vol. (t/ha)	510	504	517	553	590	601	661
Productivity (t/hour)	23.5	24.9	24.8	28.1	28.0	31.9	31.4
Logging Rate ($/tonne)	32.50	33.20	36.30	37.40	40.30	41.25	42.60

*Note: 2008 through to 2021 averaged over 2-yearly periods.

There has been an increase in both workers and machines per crew, similar to ground-based systems. Number of workers increased only slightly since the last period to 8.2, but machines increased to 7.5, one machine more than previous data. This continues the trend of having more machines in yarder crews than ground-based crews. A number of entries this year reported 11-12 machines in the system, including feller-buncher with winch-assist, yarder and mobile tail-hold, processor, two-stage skidder, multiple loaders and additional ground-based capacity.

The increase in the level of mechanisation (both felling and processing) from 2013-14 continues to be clearly evident with a corresponding steady increase in logging productivity over the years from 24.8 tonnes per hour to 31.4 tonnes per hour (+26%). The ratio of machines (7.5) to workers (8.2) indicates an average mechanisation level of over 90%, the highest recorded to date, compared to approx. 55% over the same period. There are still a few manual operations undertaken in cable operations today.

Mechanised felling is present in 78% of cable operations. This is being supported by 85% of cable crews using winch-assist. Similar to previous years, about 10% of operations involve two staging, with two-stage distances ranging between 50 and 850 meters.

Logging Rate Over Time

Figure 1 shows logging rate, as per the data submitted, over time. In addition to the overall average, plotted are the two most common extraction systems, being grapple skidder and swing yarder.

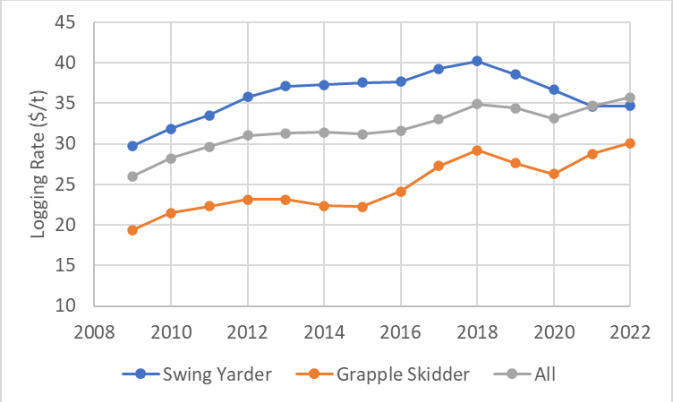

Figure 1: Average logging rates for Swing Yarder, Grapple Skidder and all harvest area entries.

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Although the benchmarking database averages over 100 new entries per year, there is year-on-year variation. For example, in some years yarder data is disproportionally from a region that typically has considerably higher rates. In contrast, in a given year a lot of data may come from the Central North Island, which typically has lower ground-based rates than other regions.

It should be noted that the Benchmarking system relies on participating companies to submit a sample of data based on actual harvesting contracts. No effort is made to ensure either a completely random approach to selecting these entries, and not all companies will submit data each year. The author notes the habit of some companies submitting data from high production 'flagship' swing yarder crews.

The overall average logging rate increased well above inflation rate in the period 2016-18. This coincided with a high demand and large increase in national production. It may have indicated that harvesting crews were being paid a premium to increase production, and that less cost-effective harvesting systems were being used.

A drop was noted in 2019-20 which coincided with the financial / China export 'crises'. This suggests that companies were rationalising their harvesting activities by using the lowest cost harvest systems. This included an increase in the proportion of shovel and forwarder systems, but also the increase in the use of winch-assist.

For grapple skidders and swing yarders there is enough data each year for the trends to be relatively smooth and clear. Grapple skidder rate was $20/t in 2009, increasing to $32/t in 2022. Like the overall rate, there was a climb in 2017-18, and a clear drop from 2019-20 before increasing again.

For swing yarders the rate started at $29/t and increased to $40/t by 2018. The rate for this extraction system dropped in 2019 and has continued to come down and averaged just $35/t in 2022. It appears swing yarders have benefited from the higher levels of mechanisation as well as winch-assist. Almost all swing yarder entries in the last 3 years have winch-assist support and mechanised felling.

There are some clear trends in stand data. On average smaller trees are being harvested than a decade ago; for ground-based from over 2 m^3/tree down to 1.7 m^3/tree, for yarder operations from 2.2 down to 2.0 m^3/tree.

ADJUSTING FOR INFLATION

Logging rates will of course increase over time with inflation and or the industrial consumer price index reflecting the increase in input costs. To be able to make meaningful analyses with regard to productivity and stand and terrain parameters, the logging rate for all entries is adjusted to 2022 values by the published inflation rate. For the period 2011 through to 2020, the average inflation rate was 1.75%. From 2021 to 2022 inflation was 7.1%. The logging rates have been adjusted to 2022 values using these inflation values for the purpose of the subsequent analysis.

AVERAGES BY EXTRACTION SYSTEM

By far the majority of data have been entered for clearfell operations. However, 122 entries have been received for roadline salvage operations. With the logging rate adjusted to 2022 values, Table 3 shows the average logging rate by extraction system, split between clearfell and roadline operations.

Table 3: Average logging rates (adjusted to 2022) by harvest system

System	Clearfell ($/t)	Roadline ($/t)
Cable Skidder	36.40	39.65
Forwarder	30.70	36.65
Grapple Skidder	28.50	34.60
Shovel	34.15	32.90
Tractor/Arch	37.35	33.60
Tower Yarder	45.20	38.35
Swing Yarder	42.70	39.05

It was expected that the logging rate would be higher for all Roadline operations, and this was true for the ground-based skidder and forwarder systems, ranging from $3/t to $6/t. However, for both yarder and shovel systems the reported average logging rate for Roadline operations was lower than clearfell rate.
This may suggest that steep terrain Roadline operations involve different payment structures, such as integrated harvesting and roadlining crews where productivity of roadlining operations is higher.

Only nine entries have been entered for Thinning operations, and as such no analyses was possible.
A recent final year student report provides some details on Thinning crews with regard to configuration, cost and productivity (Taylor, 2021).

With regard to productivity, the data are presented simply as an average from all 2008-2022 data. It is expected that there will be an increase over time as companies become more efficient with resources / improving harvesting systems.

Table 4 presents average productivity broken down by harvest system. While productivity has also improved over the years for both ground-based and yarder system, one main driver visible in the dataset is the increase in number of machines per crew. For Ground-based operations this has gone from less than 4 to more than 5, and for Yarding systems this has changed from 4 to more than 7. Conversely, the number of workers per crew has decreased.

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Table 4: Average productivity by harvest system for all 2008-2022 data.

System	Prod (t/hr)
Cable Skidder	18.7
Forwarder	31.6
Grapple Skidder	37.8
Shovel	23.1
Tractor/Arch	22.5
Tower Yarder	24.6
Swing Yarder	30.2

As might be expected, Grapple Skidder operations were the most productive extraction system with an average of 37.8 tonnes/hour (i.e. in an 8.6 scheduled hour day, daily production of 325 tonnes. Swing Yarder operations averaged 30.2 tonnes/hour (i.e. 260 tonnes per 8.6 scheduled hour day). Cable Skidder, Tractor Arch and Shovel Logging operations average around 21 tonnes/hour (185 tonnes/day), indicating they are lower producing, niche systems, hence are less common.

DIFFERENCES BY REGION

There is sufficient data in the database for extraction systems to make meaningful comparisons between regions. The data are summarised by four distinct regions to ensure a larger number of companies is represented in each region (5+) in order to produce a 'regional average'.

The Regions are:

SI – South Island
CNI – Central North Island
ECHB – East Coast / Hawkes Bay
RNI – Rest of North Island.

Note that the logging rate values presented in the following tables are the average of all Benchmarking data adjusted to 2022 values.

Grapple Skidder & Forwarder Systems

The Grapple Skidder data (Table 5) would appear reasonable based on 'average stand and terrain' conditions, confirmed with higher-than-average piece size and lower than average slopes. A clear jump between CNI and RNI, and the more cost-intensive SI and EC/HB.

Table 5: Ground-based Logging Rates by Region

Region	Grapple Skidder ($/t)	Forwarder ($/t)
SI	30.55	32.45
CNI	25.00	31.80
ECHB	31.50	28.70
RNI	26.85	28.60

For the Forwarder data the relatively high average rate from the CNI is noted, based on only seven entries, indicating that it is not a common system in that region. Almost half of all entries were from SI, possibly due to the smaller piece size / lower stand volumes. Of interest is that ECHB had a relatively low Forwarder rate, potentially showing a preference to use them in the better quality stands.

Using just the last three years of data, Forwarder crews were on average smaller, with 4.6 workers operating 4.3 machines. Grapple skidder crews averaged 6.3 workers operating 5.5 machines. In terms of stand and terrain parameters, the Grapple Skidder systems produced more log sorts (11.1 versus 9) compared to Forwarder systems.

Table 6 shows average ground-based productivity by region. In general, this showed less variation between regions. In comparing Table 5 and 6 it is logical that the higher average productivity regions in most cases are linked to lower logging rate for the same system.

Table 6: Ground-based Productivity by Region

Region	Grapple Skidder (t/hr)	Forwarder (t/hr)
SI	35.9	29.7
CNI	36.0	31.9
ECHB	35.5	33.8
RNI	40.6	33.5

Tower and Swing Yarder Systems

Table 7 shows that, with its challenging terrain (and highest average slope), ECHB had the highest rates for both yarder types. Consistent with rates reported from previous Benchmarking publications, the SI has the lowest rate; for Swing Yarder $4/t lower than the next nearest region, being CNI.

Table 7: Yarder Logging Rates by Region

Region	Tower Yarder ($/t)	Swing Yarder ($/t)
SI	42.35	38.00
CNI	45.30	42.65
EC/HB	47.45	44.20
RNI	44.75	43.70

With regard to Yarder system Productivity, the regional breakdown again reflects the inverse of the logging rate. That is, the SI had the lowest rates, and as shown in Table 6 also has the highest average productivity.

Table 8: Yarder Productivity by Region

Region	Tower Yarder (t/hr)	Swing Yarder (t/hr)
SI	26.4	37.8
CNI	28.1	30.5
EC/HB	23.6	28.4
RNI	23.8	27.8

Using the last three years of data, Tower Yarder crews have the same number of workers (8.3), but the Swing

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yarder systems have more machines on site (9.2 versus 6.2). In terms of stand and terrain parameters, the Tower Yarder systems produce fewer sorts (9.5 versus 13) compared to Swing Yarder.

Other Systems

Shovel is the most common other system in RNI, and the average Logging Rate of $35.65/tonne is higher than in SI where it is $31.50/tonne. Two thirds of all cable skidder data is from SI, so not enough to compare with any of the NI regions. Tractor/Arch data is almost exclusively from RNI but shows very high variability perhaps consistent with them mainly being used in lower production or woodlot type scenarios.

LOGGING RATE MODELS

It is possible to identify the main influencing factors, as well as the scale of those factors, by using regression analyses on the whole dataset – again using the 2022 adjusted logging rates as the dependant variable.

Note that the stand and terrain parameters, and the type of operation, are included in the regression analysis. Number of Workers or Machines are not included, as there is an obvious relationship between larger crews and higher productivity, and higher productivity and lower logging rates.

Two regression models were created. The first was for all Yarder operations, the second was for Ground-Based where only Grapple Skidder and Forwarder operations data were used. More niche operations such as Shovelling, and Cable Skidder, Tractor/Arch were not included as there was a high level of variability in those data.

For both models, only Clearfell data was used – that is entries relating to Thinning and or Roadlining were excluded. There was very limited data on Thinning, and while there is considerable data on RoadLining, it was highly variable in terms of Logging Rate.

Ground-Based Logging Rate ($/t) =

$38.30 (constant)
+ $0.35 if Forwarder
+ $1.80 if Chainsaw Fell
+ $0.90 if Manual Process
- $2.95 if 'Easy'
+ $3.40 if 'Hard'
- $2.40 x PieceSize ($m^3$/tree)
- $0.007 x Vol/Ha ($m^3$/ha.)
- $0.18 x Sorts (#)
+ $0.05 x AveSlope (%)
+ $0.70 if SI
+ $1.30 if CNI
+ $3.20 if ECHB

Stepping through the factors:

- Overall, the Forwarder system is only slightly more expensive ($0.35/t) than Grapple Skidder.
- Chainsaw felling, in contract to Mechanised, increased the Logging Rate by $1.80/t on average, and Manual Processing was also $0.90/t more.
- Over and above the parameters entered, the Harvest Area was rated as Easy or Hard (with the default being Medium). There was a strong correlation with Easy being $2.95/t less than, and 'Hard' being $3.40/t more than Medium.
- The larger the trees, and the greater the volume per hectare in the Harvest Area, the lower the logging rate. For example, a stand with 750 m^3/ha, compared with only 400 m^3/ha, reduced the Logging Rate by (750 – 400) x 0.007 = $2.45.
- The steeper the slope, the higher the logging rate (i.e. on a 40% slope the Logging Rate would be 0.05 x 40 = $2/t higher than flat terrain).
- Finally with regard to regions, in addition to the parameters already noted above, the RNI region had the lowest Logging Rate, SI only $0.70/t higher, but ECHB was $3.20/t higher.

Yarder Logging Rate ($/t) =

$42.20 (constant)
+ $1.15 if Small Tower Yarder
+ $2.80 if Larger Tower Yarder
+ $0.40 if Chainsaw Fell
- $0.15 if Manual Process
- $1.25 if 'Easy'
+ $6.20 if 'Hard'
- $2.30 x PieceSize ($m^3$)
+ $0.044 x AveSlope (%)
+ $2.55 if CNI
+ $3.20 if RNI
+ $4.55 if ECHB

Stepping through the factors:

- Overall, Tower Yarders have a higher average Logging Rate than Swing Yarders, With Large Towers (>85ft) being $2.80 more, and smaller Tower Yarders $1.15 more.
- Chainsaw felling, in contract to Mechanised, increased the Logging Rate by only $0.40/t, which is much lower than for Ground-Based systems.
- Manual Processing made little difference, being just $0.15/t less. Since 2015 there have been very few entries for Manual Processing, so this lower rate mainly relates to pre-2015 data.
- An 'Easy' Harvest Area is just $1.25/t less, suggesting there is not a lot of gain for settings that are perceived to be favourable.
- However, if a setting is rated 'Hard' it is $6.20/t, which is almost twice as much as Ground-based. So the perceived 'difficult' yarder settings do have a lot of challenges. Note that common reasons for rating a site 'Hard' included 'low deflection', 'heavy windthrow', or elements like 'power lines' or many 'native boundaries'.
- Larger trees are on average more cost effective to extract, with the Logging Rate decreasing by

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$2.30 for every one m^3 increase in average tree size.
- The steeper the slope, the higher the logging rate (i.e. on a 40% steeper slope the Logging Rate would be 0.044 x 40 = $1.76/t higher)
- Regarding Regions, in addition to the parameters already noted above, the SI region had the lowest cable yarding Logging Rate, with CNI being $2.55/t, RNI $3.20 and ECHB $4.55/t higher. SI has consistently had the lowest cable logging rates since FGR Benchmarking analyses started, which is also aligned to their overall higher average productivity, mainly for Swing Yarders.

SUMMARY

A total of 103 new harvest area entries were received in 2022 (47 ground-based entries and 56 yarder operations). The data continued to show the increase in mechanisation, with benefits in terms of production, albeit with harvesting costs increasing above the average inflation rate. This increase in Logging Rate reflects the main input costs such as fuel and labour, and also more recently, machinery and insurance have increased significantly over the last decade. As such the increasing logging rate is not a reflection of lower efficiency, but real gains in true cost-effectiveness remain elusive.

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