Precision Silviculture Programme

Battery Powered Chainsaws in Waste Thinning

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FOREST GROWERS RESEARCH

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EXECUTIVE SUMMARY

A trial was set up to evaluate the performance of battery powered chainsaws in New Zealand production forestry waste thinning operations. A North Island forestry crew were given the opportunity to test out chainsaws powered with Lithium-ion batteries in place of their petrol-powered counterparts. Two brands of battery chainsaws were introduced to the crew and element times were recorded by manual time keeping and camera-based analysis of cycle elements. The saws were tested out in four separate forestry blocks in the Western Bay of Plenty of the North Island, all of which had their own special characteristics. The battery powered saws (1.6 - 3 kW) had lower rated power output than the petrol saws (4.4 - 5 kW). However a direct comparison of the performance of electric and petrol motors is influenced by torque and engine management software - technical issues that were beyond the scope of this study.

Over all four blocks and in different average diameter at breast height (DBH) trees, the battery saws had slower felling times than the petrol powered saws, but the actual difference in felling times between the two types of saw appeared to reduce as tree diameter increased. This was supported by the results of a similar study carried out by the University of Canterbury (Appendix 2). These findings were endorsed by the video camera component of the study, conducted in Waterfall Block 2, which had large diameter trees (average 23.5 cm DBH), but found minimal difference in tree felling time between battery and petrol saws.

Worker comments endorsed the manual data collection findings as the operators felt the power of the battery saws was lacking against their petrol saws and the shorter bar length put them at a distinct disadvantage when clearing access to trees. Performance aside, there were other logistical issues that worked against the battery alternative for waste thinning. The main constraint was battery run time, which ranged between 25 and 45 minutes and meant that up to 12 batteries (24kg of weight), would have to be carried around to complete a full day's work ($6^1/_2$ hours). It was concluded that work practices may have to change if battery powered chainsaws were going to be used in waste thinning. These changes were most likely going to include a means of supplying charged batteries to the workers and taking away the discharged ones.

Another issue identified in the project was the charging of the batteries after the day's work. Originally, it was anticipated that someone would have to insert and remove batteries from chargers during the night to ensure a full suite of batteries were charged for the next day. The question was, who was going to do this on a regular basis if battery saws became the norm in waste thinning operations? To mitigate this quandary, a centralised charging facility was set up in a trailer to streamline the task of charging batteries for the next day's work. This trailer could be pre-loaded with batteries on the job and simply plugged in to a caravan port at the workshop for overnight charging. The concept worked well but it never really got the opportunity to be fully tested because the work periods with the battery saws was intermittent.

Exposure to carbon monoxide was another consideration to be measured in the comparison of the two types of saw. It was found that while emissions from the petrol saws did reach the 20 ppm threshold on the odd occasion, the length of exposure was short and not considered detrimental to the thinner's health. There was, however, a significant reduction in noise levels with the battery saws and this had both advantages and disadvantages.

INTRODUCTION

Waste thinning improves the quality of crop trees in a stand by selectively removing lower quality or suppressed trees. This process eliminates competition and promotes increased diameter growth by creating more space for the remaining trees, especially when crown closure begins to affect their growth.

Thinning is typically coordinated with pruning in New Zealand's commercial forestry operations to prevent the unpruned trees from outperforming the crop trees once pruning is completed and the competition for space increases. In certain countries, thinning is referred to as "cleaning" and is performed at a young age using brush cutters. However, due to the rapid growth of radiata pine in the local environment, chainsaws are predominantly used for thinning operations in New Zealand.

Waste thinning using chainsaws is a physically demanding job with a reasonably high level of risk. Statistics show that apart from travel to and from work, waste thinning has the highest injury rate of all silvicultural operations in New Zealand forestry (Safetree 2021). Reducing risk in silvicultural operations has become a priority in FGR's SFFF partnership with the Ministry of Primary Industries (MPI), so any opportunity to reduce harm to the workforce is actively pursued. Lowering exposure to noise and eliminating exposure to carbon monoxide from burning fossil fuels also has obvious merits.

The viability of waste thinning operations in forest estates has come under scrutiny as the industry faces increasing pressure to improve safety and account for its environmental footprint, including the burning of fossil fuels. Waste thinning is an essential component of managing a forest to achieve the best value product in the forest growing regime (Tree Alliance 2020). Traditionally waste thinning is carried out by highly skilled, extremely fit chainsaw operators, working in teams of four to six, sweeping through a stand, taking out the poorer quality and/or unsuitably located trees.

Attempts have been made to mechanise waste thinning operations using light-weight excavators with hydraulic shears (Ellegard 2020). This initiative has been very productive in some New Zealand forests, e.g. Kaingaroa and Kinleith, but operations tend to be restricted to easier terrain and require considerable investment to get established. While excavator thinning has the capacity to dramatically improved safety in thinning operations, these light-weight excavators burn diesel and require heavy duty transport options to move between blocks, so their environmental footprint is still significant.

Battery powered chainsaws have been around for about a decade, but primarily have been targeted at the domestic market, i.e. saws for the hobbyist clearing up the odd fallen branch or cutting firewood. Trials have been conducted, comparing the performance of battery powered chainsaws with similar sized petrol-powered machines over a range of different cutting situations and species types. However, results have been mixed with a wide range of differences between cutting speeds and cut through times, (Colantoni et al. 2016). More specific trials with the battery powered Stihl MS220C-B and the Stihl MS201C-M and MS261C-B, (both petrol powered) in a forestry environment, showed that the battery powered saw had poorer performance than the equivalent petrol chainsaws, (Neri et al. 2022), although the opportunity to minimise the exposure of operators to emissions, vibration and noise were considered advantageous.

The option to use a backpack type battery (such as the Stihl AR3000), to power the cutting unit, could offer an alternative to the slot in type battery saw, but anecdotal comments about a brief trial done with a similar product in the Masterton area, included concerns about the weight of the backpack and the heat build-up the operator faced when wearing it for a whole day. Other comments from suppliers noted the inconvenience of the umbilical cord from the batterypack to the motor unit and the method of connecting it to the saw as issues that might impact on acceptability. The umbilical cord in particular was seen as a definite hinderance when walking through heavy undergrowth or trying to clear access to the tree in a thinning operation.

Recent research has shown that exposure to carbon monoxide (CO) fumes from chainsaws can have a detrimental effect on operators, particularly in confined spaces where levels of CO can be as much as 76% higher than the recommended permissible limit of 20 parts per million (ppm). Waste thinning stands generally have high concentrations of undergrowth around the trees, especially in first thinning operations where there has often been no other silvicultural treatment since establishment. Situations like this are classic examples of where CO fumes can be trapped within the vegetative cover and create a toxic environment for the operators, (Hooper et al. 2016, Dimou et al. 2019, Lftime et al. 2020).

Most brands of lubricating oil are petroleum based and contain known carcinogens, which will irritate the respiratory tract in humans and the atomised oil particles in the mist off the chainsaw chain can cause damage to the environment. Trials with canola based vegetable oil as a chain lubricant have proven to be environmentally friendly, safe for the operator, effective as a lubricant, cheaper (according to this article), and readily available as a supplement for petroleum-based oils (Seaman 2010). Any trial aiming to reduce the carbon footprint of an operation would have to consider this option for chain lubrication.

Forest Growers Research Ltd. (FGR) signed a contract with the MPI to investigate mechanisation and automation in silviculture under the Sustainable Food and Fibre Future Partnership (SFFF). A component of this research was to carry out a structured and thorough evaluation of battery powered chainsaws and compare them with the currently used petrol powered chainsaws. A project manager was appointed, and chainsaw suppliers were invited to participate in the trials. A well-known contractor with a proven track record in silvicultural operations in the central North Island was engaged to carry out the field trials.

The purpose of the project was to establish whether battery powered chainsaws could replace petrol powered chainsaws in waste thinning operations. The following questions were posed of the project:

1. Would the productivity of thinning crews be adversely affected by switching to battery powered saws?
2. Could any performance variations in cutting efficiency be offset against other cost benefits such as reduced fuel costs?
3. Would eliminating the carbon monoxide from petrol saws improve the health of workers?
4. Would the outcomes from these trials be enough to convince a contractor to switch from petrol powered saws to battery powered saws?

APPROACH

1. A one-day workshop was held on the 20th of September 2022 where a selection of battery saws was trialled by an experienced waste thinning crew to see if they were a viable option for a commercial operation, *(see Appendix 1 for a report on the one-day field trial).*

2. FGR also funded a recent study by University of Canterbury, School of Forestry comparing battery and petrol-powered chainsaws in waste thinning operations in the South Island *(Results from these trails are summarised in Appendix 2).*

3. Over a seven-month period, the battery powered chainsaws were used in production situations in four Bay of Plenty forests where experienced thinners used both petrol and battery saws over the course of a day and data was collected on the performance of each type. The forests were:

3.1. Okahu Forest, Tikitere, *(December 2022).*
3.2. Dawson Forest, Kati kati, *(March 2023).*
3.3. Waterfall Forest, Tauranga, *(April 2023).*
3.4. Brown Forest, Waihi, *(June 2023).*

Fig 1: Crew induction to the battery saws.

OBJECTIVES

The objectives of the project were to evaluate the operational feasibility of battery powered chainsaws compared to internal combustion engine chainsaws in waste thinning operations. The procedure was to replace petrol powered saws used in production situations, with battery powered alternatives. The main steps to achieving this were to:

1. Review previous experience with battery powered chainsaw use in waste thinning operations.

2. Identify the different configurations of battery powered chainsaws available and determine their potential use in waste thinning operations.

3. Set up trials to evaluate the potential for using battery powered chainsaws in waste thinning operations, i.e. measuring performance.

4. Assess the benefits of using battery power to reduce the carbon footprint of using fossil fuels in waste thinning operations, i.e. assessing usability

5. Quantify the health advantages of battery powered chainsaws over petrol powered chainsaws, i.e. monitoring health and safety of workers.

6. Record maintenance issues.

FGR FIELD TRIALS:

Forest Sites:

Studies were carried out in four forests in the Bay of Plenty area (Table 1). The first study was carried out in November 2022, in Okahu block, owned by the Ruahine Kuharua trust at Tikitere, where the original Feasibility Workshop was held. Being a late thinning operation, and based on the experience at the Feasibility Workshop, it was likely that the trees were too big for the battery powered saws to perform well, but for completeness it was agreed that the data would be still be useful.

Table 1: Stand details of thinning blocks in Battery Chainsaw trials.

Stand ID	**Okahu**	**Dawson**	**Waterfall (1)**	**Waterfall (2)**	**Browns**
Location	Tikitere,	Katikati	Tauranga	Tauranga	Waihi
Tree age (yrs)	10	5	5	9	5
Stocking (SPH[a])	1,110	2,705	1,717	1,400	5813
Ave DBH[b] (cm)	24.0	18.2	10.5	23.5	9.8
Est height (m)	14.0	7.5	5.2	14.0	6.3
Average slope (°)	9°	15°	11°	17	12
Hindrance	Medium	Heavy	Medium	Medium	Light

[a] – stems per hectare (includes regenerated trees); [b] - diameter at breast height

The Dawson block in Katikati (Figure 2) was the second trial area. It was originally planted at 833 SPH but had subsequently become heavily stocked with a range of unwanted species, including regenerated pine, eucalyptus, wattle, wild cherry, deadly nightshade, gorse and blackberry. All of these unwanted species were included in the prescription and had to be removed in the thinning operation. Hindrance in this block was also quite heavy with gorse and blackberry throughout; Figures 3 and 4 illustrate different densities of undergrowth in the Dawson block.

Two separate age classes were evaluated, each over the course of a day, in the Waterfall block (Figure 5) near Tauranga (see Table 1); one was a small 0.75ha regen area aged 5 years and the other was a larger 6.08ha area aged 9 years. The contractor targeted smaller trees for the trials, which he considered would be better suited to the battery powered saws.

The final test was carried out at Brown's on Woodlands Rd near Waihi. This was a second rotation stand with heavy regeneration and numerous clumps of small tightly grouped trees in between the planted crop. While hindrance was relatively light in this block, there were patches of undergrowth in the small gullies with regen trees scattered within them.

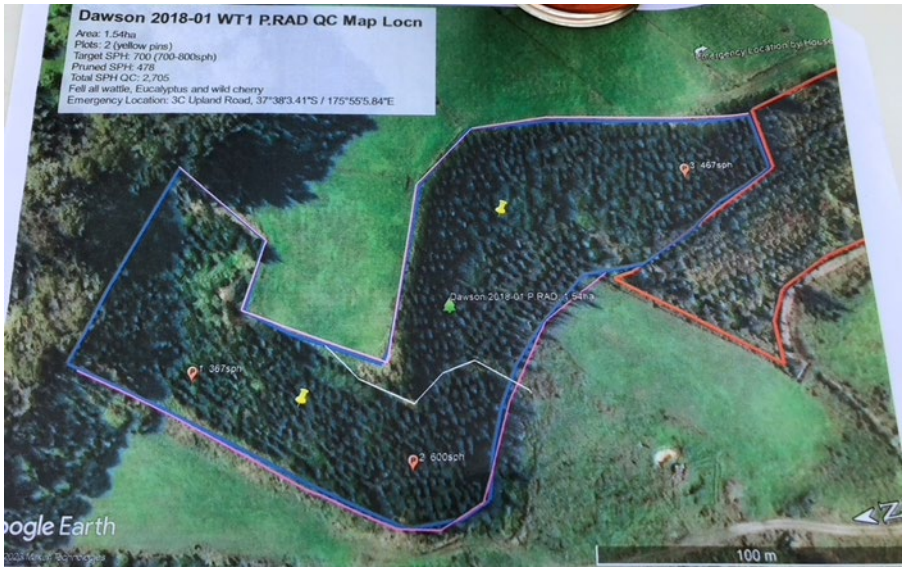

Fig 2: Map of Dawson Block near Katikati

Fig 3: Photo of undergrowth in Dawson Block, Tauranga

Fig 4: Medium to heavy undergrowth in the Dawson Block, Tauranga

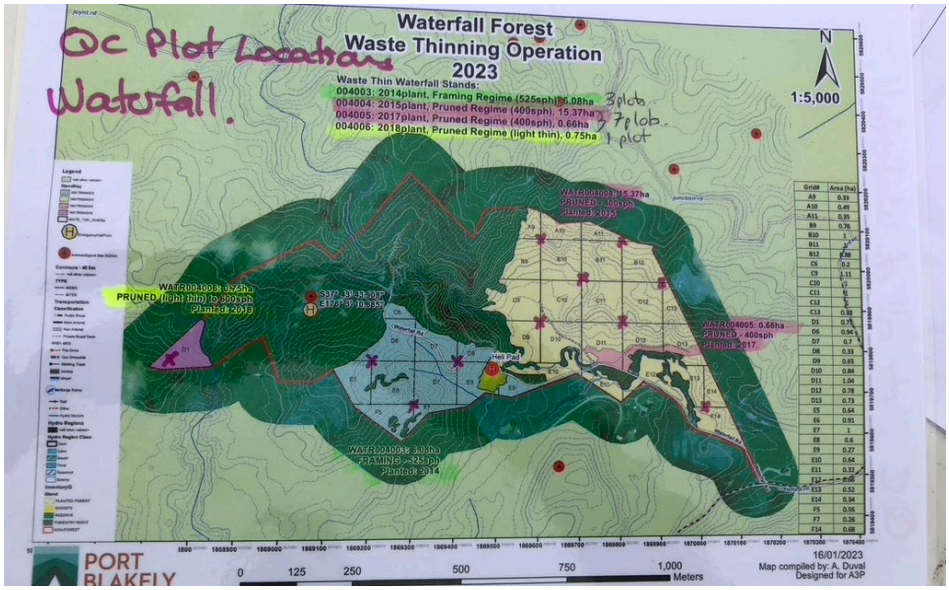

Fig 5: Map of Waterfall Block near Tauranga

Crew Description

Te Puke based Inta-Wood Forestry Ltd, a silvicultural contractor with multiple operations throughout the Central North Island, carried out the North Island battery powered chainsaw trials. Company owner Nathan Fogden has been in the industry for over 30 years and his crews often appear in the Top Spot competition, picking up awards for innovation and professionalism. Nathan's thinning crew, consisted of four workers who all participated in the study. They ranged in age from 42 to 54 years and had between 23 and 35 years of experience in waste thinning operations.

The Inta-Wood Forestry crew was selected because Nathan wanted his business to be at the forefront of development in the industry and participating in these trials did exactly that. His only conditions were that:

- the health and safety of his crew would not be compromised
- crew workers would not be financially disadvantaged by participating in these trials
- his business reputation would not be adversely affected if something went wrong.

Equipment Used

The crew normally used petrol-powered Stihl chainsaws, MS500is or MS462s with 20" bars and most of them have one or two old Stihl 460s as back-up saws. FGR purchased three Stihl MSA300 electric chainsaws and Makita NZ supplied two Makita UC013GZ electric chainsaws free of charge, for the trials. These five battery powered saws were compared with the MS462 and MS500i conventional petrol chainsaws (Table 2).

*Table 2: Manufacturer's Specifications for the Chainsaws used in the Trials**

Chainsaw	Bar length	Type	Power	Weight**	Chain Pitch	Chain Speed
Stihl MS500i	20"	Petrol	5.0Kw	7.47kg	3/8"	28.9m/s
Stihl MS462	20"	Petrol	4.4Kw	7.27kg	3/8"	28.9m/s
Stihl MSA300	16"	Battery	3.0Kw	6.50kg	.325"	30.0m/s
Makita UC013GZ	18"	Battery	1.6Kw	6.41kg	.325"	25.5m/s

* Specifications are from retailer's websites and were not tested in the field.
**Weight includes battery, bar and chain, but not fuel and oil.

Along with the five battery powered chainsaws, a total of 14 battery chargers and 44 batteries were purchased for the trials. Six of the chargers were Stihl AL 301-4 230 volt high speed chargers and eight were Makita XGT 40V Dual chargers. The Stihl chargers could sequentially charge 4 batteries at a time, taking approximately 300 minutes to do all four. The Makita chargers could only charge two batteries at a time but did so in 76 minutes. Of the batteries purchased, 24 were 8 amp hour Stihl AP500S's, 16 were 8 amp hour Makita 40V 8AH XGT 191X65-8's and 4 were 5 amp hour Makita 40V 5AH XGT 191L47-8's. The reason for purchasing the smaller 5 amp hour Makita batteries was to try and minimise the weight that a worker might have to carry, especially towards the end of the working day. The smaller 5AH Makita batteries were 600g lighter than the 8AH batteries.

The battery saws were selected because they were the largest and most powerful models available from two reputable manufacturers at the time of the study. While the Stihl brand of chainsaws has had a long and successful involvement with the forest industry, it was important that an alternative brand was included to avoid any bias affecting user acceptance. Makita was selected because it has a growing presence in both industrial and residential tool use (primarily gardening), and the New Zealand supplier was very keen to explore opportunities in the commercial forest industry. It was recognised that there was a significant difference in power output between the battery and petrol saws, but thinners tended to equip themselves according to the maximum size of trees to be felled and it was the concept that was being tested, not necessarily a direct comparison of performance.

Operational Issues:

It became apparent very early in the trials that battery management was going to be a critical factor in the acceptability of battery powered chainsaws in waste thinning. Collectively, the chargers drew too much current for all the batteries to be charged at once, so to fully charge sufficient batteries to last a whole day, the crew foreman (or contractor), would have to swap batteries in and out of charging facilities in the middle of the night to have everything ready for the next morning. To mitigate the need for nightly escapades down to the workshop to swap batteries in and out of chargers, a trailer was set up as a mobile charging station so that all the batteries would automatically be fully recharged overnight, by simply plugging the trailer into a single power outlet at the end of each day.

Inta-Wood Forestry provided the trailer and FGR built plywood shelves to mount the chargers on, (as shown in Figures 6 – 10). The shelves in the front compartment of the trailer were fixed to the aluminium framework using existing bolt holes (one of Nathan's conditions for lending the trailer was that no new holes were to be put into any of the trailer components). Two Stihl chargers and four Makita chargers were installed in the front compartment. The trays in the rear section of the trailer were constructed so they could slide in and out to enable easy placement and retrieval of the batteries from the chargers. Four Stihl chargers were mounted horizontally, (although it was later discovered that these could also be mounted vertically). The remaining Makita chargers were all mounted vertically.

Fig 6: Sliding trays for the chargers were installed in the rear section of the trailer.

Fig 7: Plywood shelves were mounted in the front compartment of the trailer.

Fig 8: The caravan plug installed to facilitate overnight charging.

Graeme Miller Electrical from Te Puke wired up the trailer with a timer so that the chargers could sequentially charge the batteries without overloading the electrical network in the workshop. A caravan type IP67 rated plug was installed on the trailer and a corresponding power outlet wired into the outside wall of the workshop so when the trailer came back to the yard, as long as all the batteries were in the right place, the foreman could simply plug the cord from the workshop wall into the trailer socket and everything would be charged overnight.

Fig 9: Batteries in the charging facilities, mounted on slide out trays in the trailer.

Fig 10: The trailer closed up, ready for the trip home.

STUDY PRODCEDURES

Fig 11: Inta-Wood Forestry's thinner Pae with the camera and CO monitor attached to his chest.

Fig 12: Inta-Wood Forestry's Adrian, fully kitted out for a run with the petrol powered chainsaw.

For the manual data collection, a continuous time and motion study was done using an Iron Body Dalps stopwatch. Where possible, the recorder walked ahead of the thinner in un-thinned trees, observing various tasks and recording the break points between activities. On some occasions, it

was difficult to separate these break points, especially when the thinner came across a clump of regen trees. On these occasions the cut times between trees was so rapid, it was impossible to differentiate between them. Where this occurred, total fell time was recorded and the number of trees were subsequently counted. Except for the above situation, where multiple trees were felled in a clump, the work cycle was based around the individual trees being felled. The cycle time was divided into elements as follows:

- *Walk and Select*, starts when the thinner begins to walk once the previous tree is on the ground, ends when the thinner starts cutting with the saw.
- *Clear Access*, starts when the thinner begins clearing undergrowth with the saw, ends when the thinner starts the felling cut(s) on the tree to be thinned
- *Fell,* begins when the thinner starts the felling cut(s) in a tree to be thinned, ends either when the tree lands on the ground, or when the tree is obviously hung up. (*Note: Felling cuts can be a single cut or a scarf and back-cut, it wasn't possible to differentiate between the two when recording element times*)
- *Take down Hang-up*, starts when the thinner either begins to; post, push, or drive the tree down, ends when the tree is on the ground.
- *Delay*, starts when the work cycle is interrupted by an activity or event that disrupts the above pattern and ends when normal cycle elements resume.

Note that while the work cycle does follow a pattern, some elements do not always occur, for example, clearing access doesn't happen with every tree, especially if undergrowth is light. Walk and select can also merge into clearing access if the two tasks are done concurrently. Common delays were: Changing batteries, refuelling, saw maintenance, jammed saw, clearing the fence line and resting.

Manual data collection was challenging, particularly in the Dawson block where medium to heavy undergrowth hindered movement and made it difficult to maintain a safe distance from the falling trees. Manual data collection was also disrupted by wet weather that interrupted both recording methods and stopwatch functions.

Data was collected at the Waterfall Block site using Garmin VIRB XE cameras, strapped to the chests of the chainsaw operators to record time and motion activity. When petrol powered chainsaws were being used, a Tango TX1 carbon monoxide detector was mounted on the operator's shoulder to measure his exposure to toxic fumes (Figures 11 – 16). In parallel with the camera data collection, a manual time study using a stopwatch was also carried out where possible. Originally, it was proposed to coordinate the camera data with the manual data to compare outcomes, but this proved too difficult to achieve in the field.

The Garmin cameras had a run time of approximately 60 minutes, so it was only possible to record between one and two batteries, or one and a half tanks of fuel with each saw. The carbon monoxide monitor was hired from Entec Services Limited and it had to be returned to them for downloading. The information was then sent to Scion for analysis.

Fig 13: Inta-Wood Forestrys's Dion trialling the Makita UC013GZ in the Okahu block

Fig 14: Adrian getting ready to try the Stihl MSA300 in the Okahu block

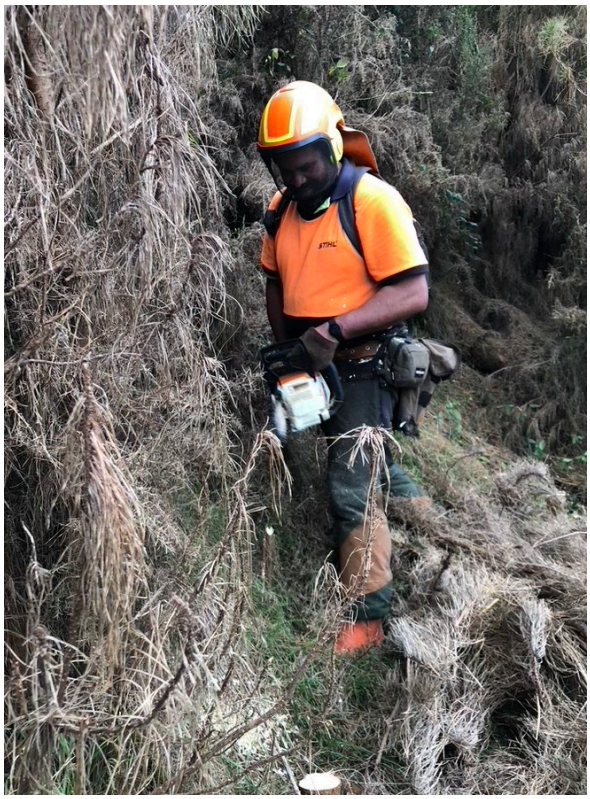

Fig 15: Aaron using the MSA300 Stihl in Browns Block

Fig 16: Pae clearing access with the Makita UC013GZ saw in Browns Block

RESULTS

MANUAL DATA COLLECTION

The results from the manual data collection are summarised by cycle times and tree diameter. While individual element times varied considerably, the difference was not necessarily related to the saw being used, and the data was by no means a reflection of worker performance. In all forests, there was considerable variation in tree spacing, form and the amount of hindrance the thinner had to deal with. Critical areas where saw performance may have been reflected in the element times were clearing access and felling, but again, technique does play a part, and overall performance cannot be measured by element times alone.

An example of this is the bringing down hang ups element. While thinners preferred the petrol saws for this task because they had more power and longer bars, in the Waterfall 2 block, the Stihl MS500i had the longest time for this element. The main reason for this appeared to be the location in the block, the thinner was working alongside the boundary fence at the time and the trees had been exposed to wind damage. Clearing access to the trees was also variable between blocks. Again, the thinners preferred the longer bars on the petrol-powered saws because they could reach further and reduce the cutting time.

In the data analysis, total time per element was divided by the number of trees felled to give average element times for each saw type. These are displayed in Figure 17. The graph shows that element times for the petrol-powered saws were quicker in all aspects, but it should be noted that walk and select and delay elements were not necessarily related to the type of saw being used. This data is based on 436 trees felled with the battery saws and 358 trees felled with the petrol saws.

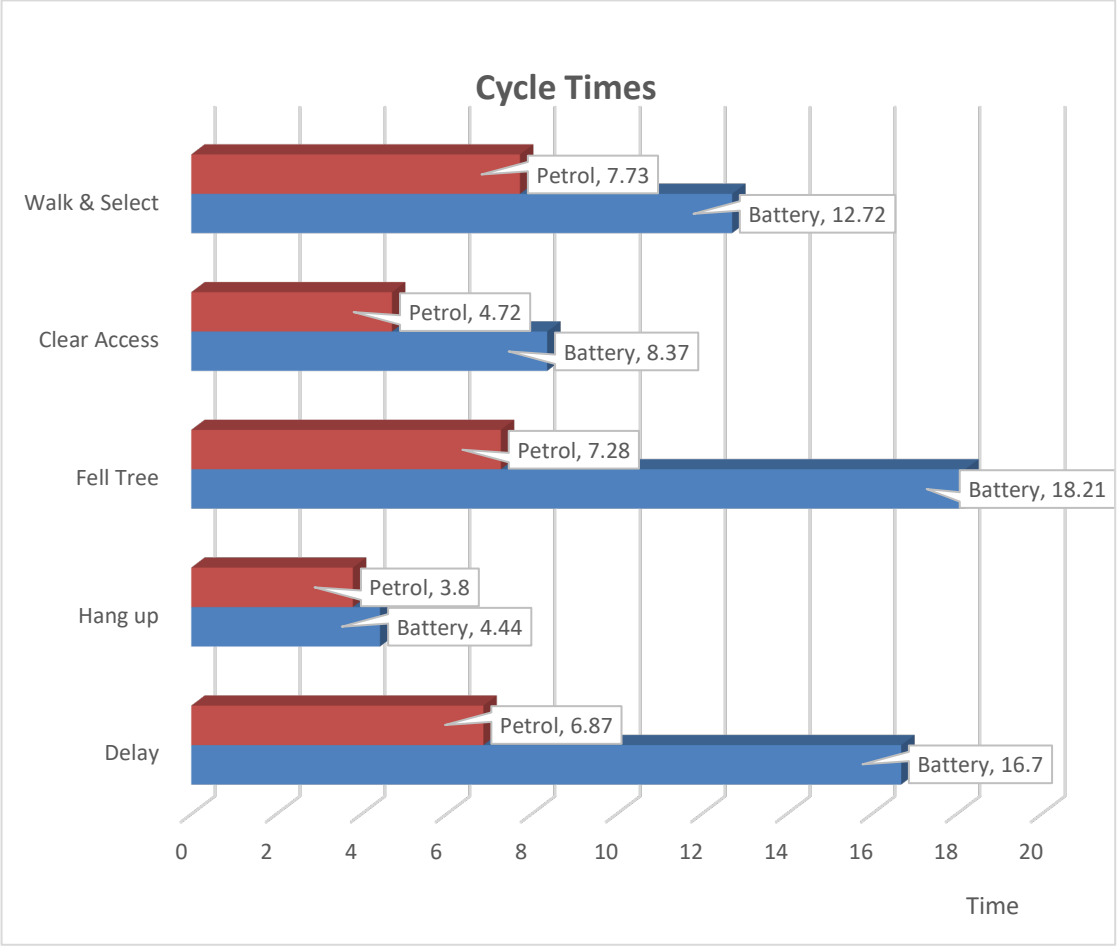

Fig 17: Graph of element times for petrol vs battery powered chainsaws over all four forests included in the study data.

The analysis showed that the petrol-powered chainsaws had a much faster cutting time than the battery saws; this difference is clearly illustrated in Figure 18 below. While the average diameter of the trees felled by the petrol saws was 4.5cm smaller, the cutting time was almost 8 seconds quicker. This is confirmed by looking at the ratio between the average fell time and the average diameter (DBH), which was 0.94 for battery saws, compared with just 0.66 for the petrol saws. Further analysis of the collated data shows that fell times are highly correlated with DBH (0.79),[1] which confirms that it is one of the key causal factors determining fell time. However, the relationship is not linear and we found that there was a smaller difference between battery and petrol saws as diameter increased.

The data also shows that stocking levels, stems per hectare (SPH) and mean tree height (MTH), are significant factors impacting fell time; i.e. lower stocking levels lead to faster fell times (-0.77) and taller trees increase fell times (0.9). The walk and select element has a moderate impact (0.64) on fell time, while clearing around the tree only has a modest impact, (-0.23).

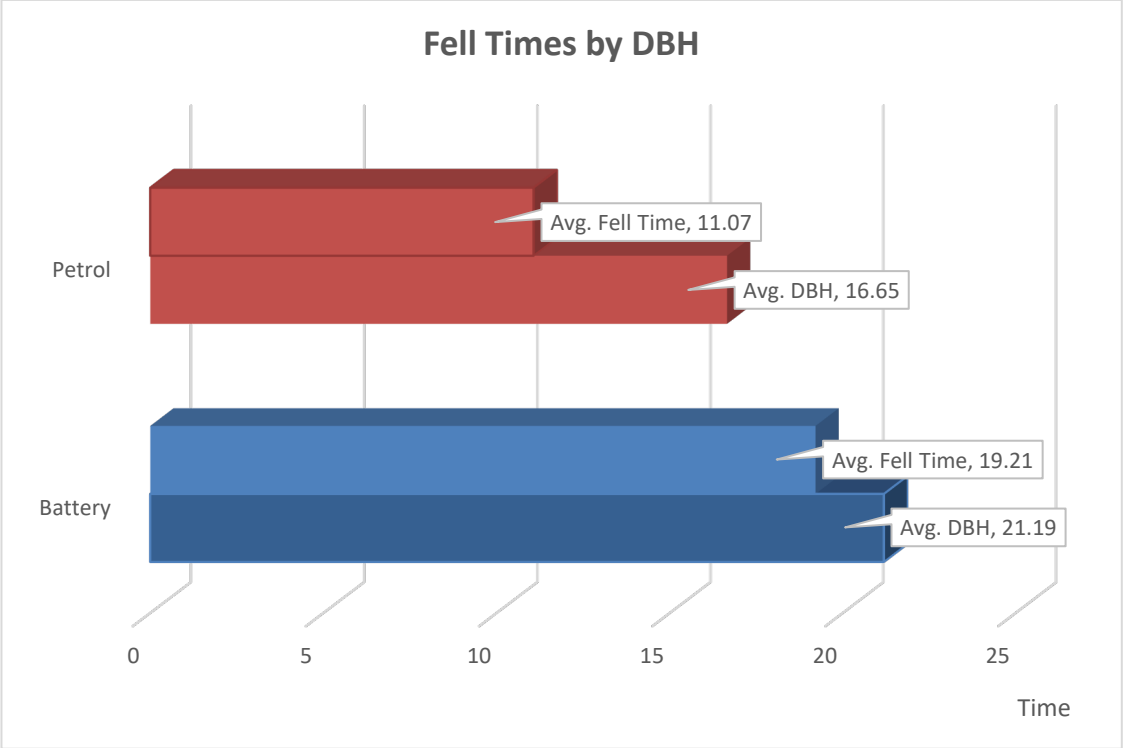

Fig 18: Graph of fell time vs average DBH for battery and petrol saws.

Analysis of cutting time vs tree diameter between the two types of battery saw showed that the Stihl had a slightly quicker cutting time in the same diameter trees (24.0 cm in the Okahu block). The MSA300 felling time averaged 26.74 seconds compared to the UC013GZ's time of 30.40 seconds. While the variation in the stand may have accounted for some of this difference, again both brands of battery saw were noticeably slower than the petrol-powered saws.

Battery run times ranged from 25 minutes to 45 minutes, depending on the amount of cutting done, the Makita UC013GZ appeared to have a slightly longer run time than the Stihl MSA300, but this did vary from operator to operator. The habit of blipping the throttle before entering a cut was identified as being an unnecessary drain on battery life, but there was no obvious link between operator technique and run time. The time taken to change a battery was significantly quicker than pouring petrol into the fuel tank but, the chain bar oil tank still had to be filled so the refuel element didn't disappear altogether.

[1] *Correlation coefficients are reported within the brackets.*

Battery transport was one area where opinions differed. Some operators would carry 5 or 6 batteries in their back packs, 10 - 12kg, while others preferred to carry less weight. The trade-off was that when the batteries all ran flat, the operator would have to walk back out to the trailer to replace them. This was also influenced by where in the block the thinner was working. If there was track access throughout the block, it was easier to plan the work pattern to coincide battery run time with replacement opportunity, but if the crew were sweeping an area, valuable time would be lost walking to and from the trailer. The logistics of battery management will be an important factor in any future trails with battery saws.

VIDEO BASED DATA COLLECTION AND CO-MEASUREMENT:

Data for both battery and petrol-powered chainsaws in the same block were available on 21 April 2023 in the Waterfall Block, see Table 3 for details. There was no statistically significant difference between battery and petrol-powered saws for the average time taken to walk and select trees and to fell trees. However, there was a statistically significant difference (at a 95% confidence interval) for the time taken to clear vegetation between and around trees. With the petrol powered saw more time was expended clearing vegetation (Figure 19).

Table 3: Data from video footage of Battery vs Petrol saws in Waterfall Block.

Chainsaw	**Work time (hh:mm:ss)**	**Number of trees felled**
Battery	02:13:30	137
Petrol	02:19:43	95

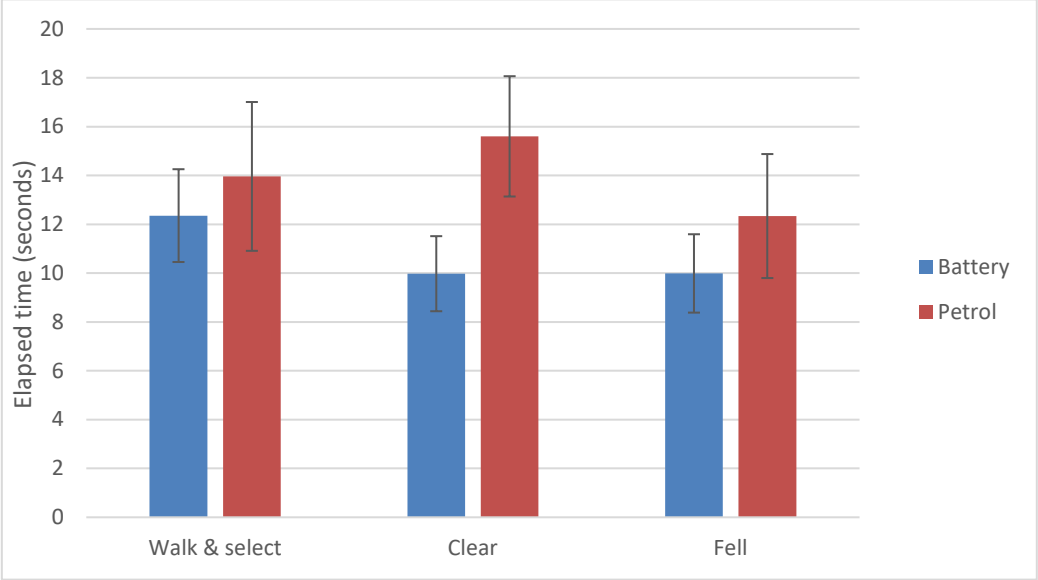

Figure 19: Mean (± SEM) time in seconds to complete tasks with the battery and petrol chainsaws in the Waterfall Block. Only clearing vegetation exhibits a significant difference between the two chainsaw types.

Carbon monoxide (CO), levels in parts per million (ppm) in the air near the thinner's mouth and nose varied considerably over time as illustrated in Figure 20. Relating the recordings to the video footage, the peaks in CO concentration corresponded with occasions when the thinner used the petrol chainsaw close to his face for extended periods of time. For example, cutting a lot of vegetation at chest or head height, as illustrated in Figure 21. The height, above the thinner's head, and density of undergrowth were also associated with peaks in CO concentration. Over the study period (including lunch break) the average CO concentration was 16.7 ppm CO, which is below the permissible Time-Weighted Average (TWA) of 20 ppm over an 8-hour day (Worksafe 2023).

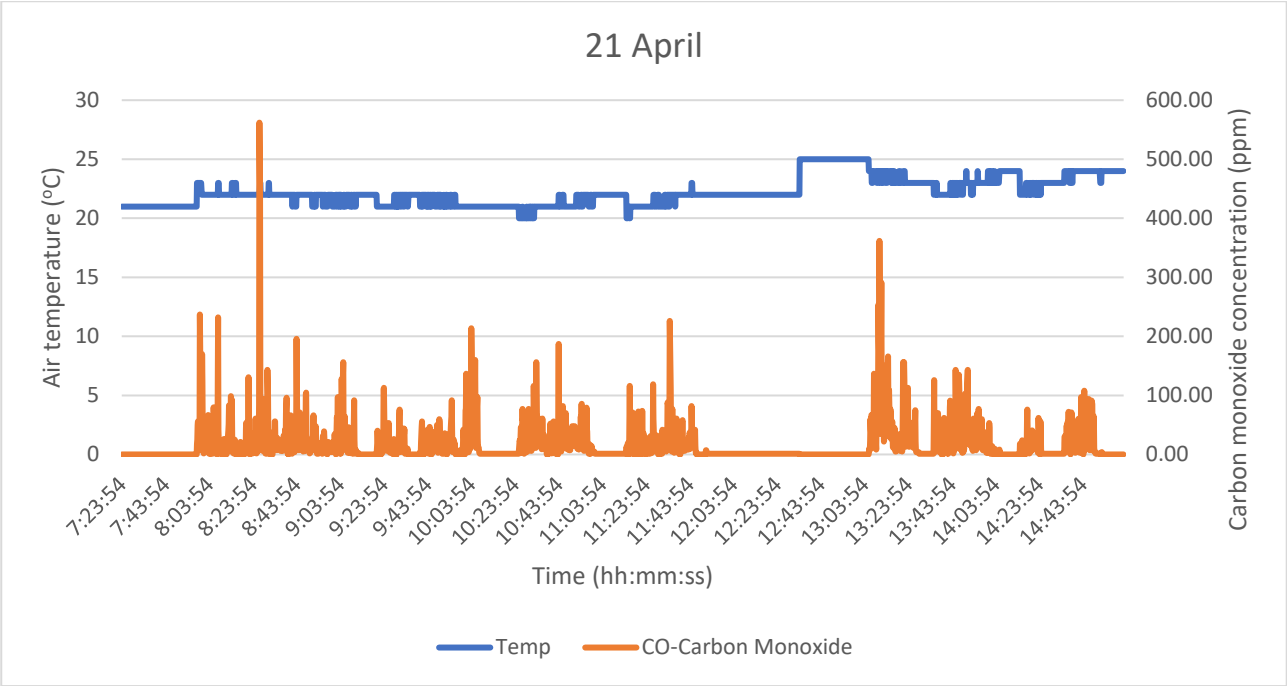

Figure 20: Carbon monoxide concentration in parts per million (PPM) plotted against time for 21 April in the Waterfall Block. Chainsaw was a Stihl MS462. Although the chainsaw operator is exposed to CO, the concentration does not reach dangerous levels because the duration is short.

Figure 21: Using a chainsaw near the mouth and nose and in dense vegetation resulted in peaks of carbon monoxide exposure (low resolution due to screen capture from video).

Noise is another factor that has to be considered when comparing battery saws with petrol powered chainsaws. Sound waveforms were extracted from the video footage and these have been plotted against time over a brief interval of work, as illustrated in Figures 22 & 23. As expected, the battery saws were considerably quieter than their petrol equivalents when used to clear undergrowth from

around the trees. This was reiterated by anecdotal comments from the thinners who noticed the lack of noise when working. The battery saws were silent when they were not cutting.

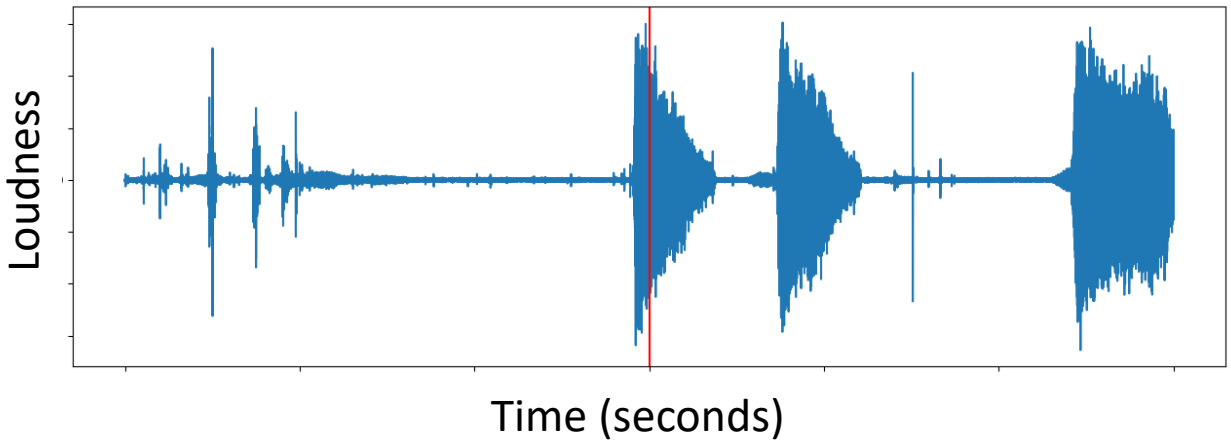

Figure 22: Sound waveform of a Stihl battery chainsaw while cutting limbs and vegetation around the base of a tree over a 30 second period. The saw is quiet when it is not cutting. The loudness scale is relative to the loudest sound recorded.

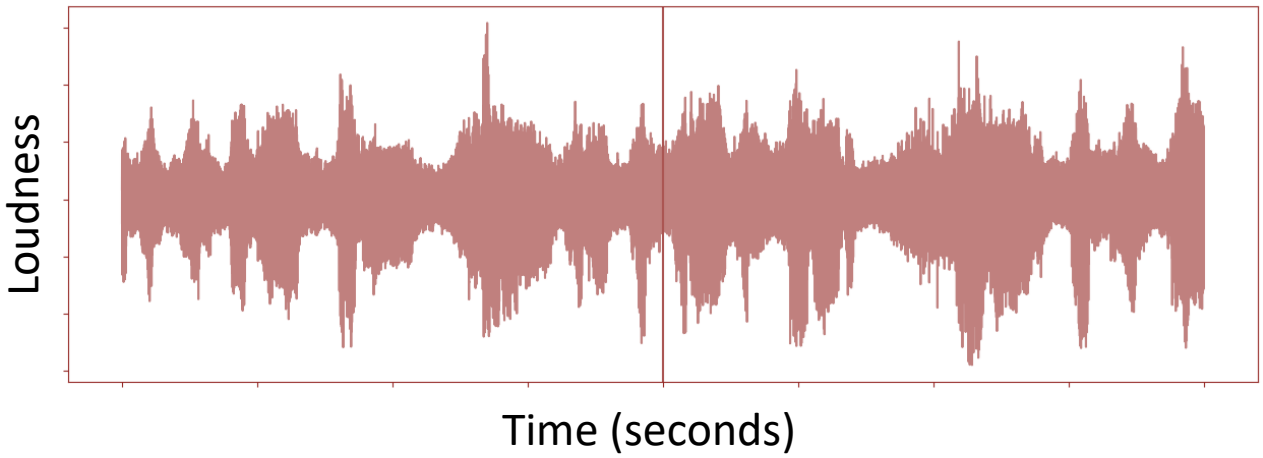

Figure 23: Sound waveform of a Stihl petrol chainsaw while cutting limbs and vegetation around the base of a tree over a 30 second period. The saw has peaks of noise when cutting and still emits noise when idling. The loudness scale is relative to the loudest sound recorded.

ANECDOTAL COMMENTS FROM THINNERS:

The crew were asked to complete generic questionnaires related to the operation of the chainsaws, (see Appendix 3 for details). Three of the four thinners returned the form, two of the three felt that the MSA300 Stihl was well balanced and had good power to weight, while the other thought the Makita was heavy and not well balanced. All three operators said that the battery saws lacked power and the bars were too short, although one said he preferred the longer 18" bar on the Makita, because it was better in heavy undergrowth when clearing access to the trees and trimming up the lower branches.

The question of fitting longer bars to the battery saws was discussed with the Stihl representatives in the project, and they advised that longer bars could be fitted to the MSA300, but that was likely to affect the run time of the batteries. Generally, the crew were not used to the 0.325" pitch chain and would have preferred the larger $^{3}/_{8}$ " chain, but once again, a heavier chain would have further

reduced run time. Sharpening was also an issue and part of the problem was that they didn't have a good supply of the correct sized files.

None of the operators liked the safety mechanism on the Stihl MSA300. From their perspective it cut in too quickly and didn't allow them enough time to clear a bit of slash out of the way or, in some cases, look up to see if the top of the tree had started to move. The need to pivot the thumb around to press the on/off button to re-activate the saw became an inconvenience that interrupted their work pattern and slowed them down. There were no complaints about the safety mechanism on the Makita saw. One operator commented that they used significantly less bar lubricating oil with the battery saws because the motor wasn't running continuously. Battery saws only use bar lube oil when the trigger is pressed.

All three operators commented on the lack of noise with the battery saws, although they felt that the noise from the chain spinning around the bar was still quite loud, in fact, louder than expected. One thinner thought that the lack of noise was a safety issue because it was difficult to tell how close your neighbour was while working parallel faces when strip felling. In contrast to that, another operator said it was easier to attract the attention of your fellow worker because you weren't competing with the noise of the petrol motor. The contractor also commented on the quietness, saying it was difficult to tell if the workers were actually working when he drove into the block.

There were several comments made throughout the trial about the fire hazard with Li-ion batteries and whether they posed a greater risk than petrol powered saws. Nathan in particular was concerned about liability if the batteries caused a fire in one of the blocks and who would be liable should a compensation claim be laid. FENZ were approached for comment and asked about the availability of specialised extinguishers to put out a fire started by the lithium-ion batteries. They responded that there weren't any extinguishers on the market that would be better than what is currently being used and that containment was the best approach if a lithium-ion battery caught on fire. One respondent mentioned that the batteries remained warm for a long time after use and wondered if they would heat up if left in the hot sun or during overnight charging. This is one area that requires further investigation.

When asked for general comments and whether they would consider using battery saws instead of petrol saws, the thinning crew came up with the following responses:

"Worked well but just too small, not powerful enough and bar too short".
"Batteries were heavy and didn't last long enough".
"No fumes so that was good".
"Only good for smaller trees".
"Maybe ok for scrub cutting or smaller trees".
"Not good for the size of trees we work in".
"No good for trees over 20cm, battery weight an issue".

The foreman liked the universal charging system set up to recharge the batteries overnight because it enabled the crew to set the trailer up on the job, so all he had to do was plug the power cord in at the workshop and charging was underway. He still had to fill up the chain bar oil tank built into the trailer but in general, the end of the day chores to prepare for the next day were significantly quicker. On the downside, however, was the restriction of having to return to the same workshop every night. If the crew were working away from home, they would have to find a suitable camping ground or similar, where the caravan connection could be plugged into overnight.

FINANCIAL VIABILITY:

While insufficient data was collected during the trials to determine whether switching from petrol saws to battery saws would be financially viable, there is sufficient evidence to confirm that battery saws would be less productive than petrol saws in typical waste thinning operations in the Central North Island. The set-up cost alone for just one saw would be a constraint for someone considering the move, as can be seen in Table 4. This table assumes that an operator would work a productive $6^1/_2$ hours per day and would require 12 batteries at 35mins run time per battery. It also assumes three chargers would be needed to charge the batteries each night. It is based on the Stihl saws because the petrol saws were the same brand.

Given all other peripheral costs would remain the same, i.e. bar oil, PPE, replacing bar & chain, etc., an operator could afford to spend over $9,000 on fuel before the battery saw came anywhere close to being competitive. This doesn't take into account the cost of electricity to charge the batteries each night, and it also doesn't account for any loss of production due to slower cutting performance.

Product	Make	Model	Number	Cost $	Total $
Battery Powered Chainsaw:					
Chainsaw	Stihl	MSA300	1	1,315.00	1,315.00
Battery	Stihl	AP500S	12	745.00	8,940.00
Charger	Stihl	AL301-4	3	595.00	1,785.00
Container	Oil	Plastic	1	9.53	9.53
Total Cost					12,049.53
Petrol Powered Chainsaw					
Chainsaw	Stihl	MS500i	1	2,755.00	2755.00
Fuel can	Toucan	Combi	1	210.00	210.00
Total Cost					2965.00

Table 4: Comparison of set up costs for battery and petrol-powered saws.

DISCUSSION:

Manual time study of chainsaw thinning operations is difficult because the observer must keep a safe distance away from the thinner, but still needs a clear view of what the operator is doing to code the activities. Using a chest mounted video camera allowed activities to be coded from the video file after the event, but the battery life of video cameras when continuously recording is currently limited to approximately one hour. Another limitation found when using the cameras was that coding from video footage is laborious and time consuming, so best done over short periods of work (up to one hour). A significant challenge in operational studies is controlling for differences in tree diameter, terrain, hindrance and even weather. These can vary within the forestry block and often cannot be controlled between saw type if the crew is to maintain a normal productive operation.

Regardless of the above restrictions, reviewing footage from the cameras enabled accurate and detailed analysis of the work cycles of the thinners. Even in the thickest undergrowth the thinner's work could be recorded. As expected, the camera data showed that there was no difference in the time taken to walk and select the next tree with a battery or petrol saw. Overall, there was little difference in the time taken to fell with either saw in large (23 cm diameter) trees.

These results contrasted with what was observed in the manual data collection process. The manual studies showed that the battery powered chainsaws were significantly slower than petrol powered chainsaws, although this difference decreased as tree diameter increased. This was particularly noticeable when fell times relative to tree diameter (DBH) were analysed and the finding was

consistent with anecdotal comments made by the thinning crew. They found that the lack of power and shorter bars on the battery saws were a distinct disadvantage when working in trees the size that they are usually required to fell. They also found that clearing access to trees was harder because of the shorter bars. Results from the School of Forestry studies drew similar conclusions over cutting performance and operational issues, such as battery management (MacDonald 2023). One aspect that demanded further investigation was cutting time vs tree diameter.

A recent study of saw chain performance at Oregon State University concluded that torque, (force) had a greater influence over cutting efficiency than power, (force times speed). (Otto et al 2015). Given that any tree over 20cm in diameter requires a scarf and back-cut for safe felling, the need to put three cuts in to fell the tree instead of one, could account for the reduction in difference in felling times as the diameters got bigger. The logic behind this conclusion is that to obtain sufficient momentum to optimise the performance of petrol powered saws, operator's tend to "blip" the throttle to get the engine revving within it's power curve, which in most cases means two to three "blips". This would undoubtedly increase the felling times for petrol saws as tree diameter increased. With the battery powered saws, maximum torque is reached almost instantly, meaning the saw can cut efficiently as soon as the throttle trigger is pulled, reducing the time taken to put a scarf in.

An obvious advantage of a battery chainsaw is the operator is not exposed to combustion gases from the chainsaw. CO can be measured easily, but the chainsaw also emits other combustion products such as particulates, nitrogen oxides, aldehydes, aromatic hydrocarbons and so on (Neri et al 2016). Operator exposure to carbon monoxide was measured with a calibrated Tango CO monitor worn high on the chest near the mouth and nose. Peaks in CO were identified when the thinner was using the saw near their face or in thick undergrowth. Overall, the average exposure of 16 ppm was below the allowable exposure of 20 ppm over an 8-hour day. Although the fact that one operator felt there was an advantage in eliminating CO from the working environment indicates that further testing in this respect could be valuable.

The University of Canterbury study showed that decibel readings with battery saws were 12.8 dB(A) lower than petrol saws and this was seen as advantageous to operator health, but anecdotal comments from the operators said that they preferred to wear the Grade 5 hearing protection required to operate the petrol saws. While battery saws expose the user to less noise over a day, the sound of the chain rotating around the bar is still significant, but it only emits sound when the motor is running. Between cuts the saw is silent in contrast to the petrol chainsaw which is always running, although the noise is lower intensity when the saw is idling (MacDonald 2023).

CONCLUSIONS:

While there is limited documented evidence of battery powered chainsaws being used in waste thinning operations, there is growing interest in the concept of battery powered tools and the technology appears to be advancing at a rapid rate. The trial outcomes represent an initial step towards reducing the carbon footprint of silvicultural operations and offer valuable insights for potential product adaptations for forestry-related needs.

The intention to evaluate different configurations of battery powered tools suitable for thinning trees was constrained by the limited availability of suitable hardware. The weight and heat build-up of alternative backpack battery configurations, combined with the link between them and the cutting units, raised doubts about their suitability for efficient application in waste thinning operations. The umbilical cord connection was likely to impede the walk and select and clear access elements and the slot in connection to the cutting unit looked clumsy and unnecessarily bulky.

The FGR trials showed that the battery saws lacked sufficient power for typical thinning operations in New Zealand forests. While the specification sheets already indicated this, the focus of the trials was to test the concept rather than conduct a direct comparison. It is widely known that thinners in New Zealand equip themselves with tools capable of handling the largest trees encountered across

various age ranges. Consequently, they often carry unnecessary weight during certain periods due to the need for versatility in handling different tree sizes.

Over multiple blocks and different average DBH the battery saws were slower cutting than the petrol powered saws. However the difference in felling time between the two types of saws actually reduced as tree diameter increased. This was supported by the findings of the video camera component of the study, which was conducted in Waterfall Block 2 with larger diameter trees (average 23.5 cm DBH). It found minimal difference (statistically non-significant) in tree felling time between battery and petrol saws. This finding is consistent with the University of Canterbury study which showed the difference in felling time between the two types of saws actually reduced as tree diameter increased. Further investigation of the torque and power output behaviour of battery and petrol saws would make a valuable contribution to the understanding of the best uses for battery saws. Is instantaneous torque advantageous in large or small diameter tree felling?

Battery management was identified as one of the main constraints in switching to battery powered chainsaws. The charging trailer set up in Inta-Wood forestry's operation was successful in mitigating the overnight charging issue, but on-site management of supplying batteries to thinners could not be resolved within the bounds of this project. While some ideas were discussed at various times, it appears a change in operational procedures may be necessary for efficient supply of batteries in their current configurations. Fire risk from Li-ion batteries remains a significant potential problem that must also be managed.

Surprisingly the levels of carbon monoxide near the operator were lower than expected when measured during the trials with the petrol saws. Longer term trials to measure a larger sample of carbon monoxide levels, along with other factors like noise and vibration will need to be done before there would be compelling evidence for thinners to claim health benefits as a reason to change from petrol to battery powered saws.

Anecdotal comments from the operators were the most telling evidence from the trial that indicates battery powered saws are not a viable alternative to petrol saws at this point in time. However, it is important to note there may be application for them in operations that are thinning smaller trees, or where other functions are a component of the work, such as applying chemicals to stumps after cutting. It is also likely that the rapid progress of battery technology may well see more powerful, longer run time battery products available in the near future.

RECOMMENDATIONS:

The following recommendations are made as a result of the findings from this project:

- That the industry, including FGR and other agencies, continue to monitor the development of battery technology and keep options open for further trials with battery chainsaws. Including sharing of the results from these trials with manufacturers for their consideration.
- Any future trials should investigate operating techniques that could extend battery run time and improve worker efficiency, i.e. eliminating "air shots".
- The use of GPS tracking technology to record worker movement and improve planning should be explored in future trials.
- That existing hardware purchased for these trials be made available for further trials in situations that are deemed more suitable for the size and power of the equipment.
- Work procedures, such as using a mule or a drone to improve the supply of batteries to workers in the field are analysed, costed and tested.
- Specific trials to understand whether the instant torque available from battery powered saws will actually reduce the difference in felling times between petrol and battery saws when scarf cuts are required to fell a tree, need to be undertaken.
- Further testing of alkylate petrol products and organically based lubricating oils are conducted to reduce the carbon footprint of existing operations.
- Development of safety technology that uses the availability of battery power to prevent injury from cuts by using proximity sensors to isolate cutting units.

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APPENDIX 1: FEASIBILITY WORKSHOP

Introduction:

On 20th of September 2022, FGR coordinated a field workshop to introduce the battery powered chainsaws to an experienced waste thinning crew and get their first impressions of using battery power in place of petrol-powered saws. The objective of the workshop was to lay down the foundations for a longer-term trial using battery powered chainsaws in thinning.

Stihl NZ Ltd, had very kindly offered to provide a selection of battery powered saws for the day and FGR had organised to hold the workshop at Inta-Wood Forestry's thinning crew's operation in Okahu Forest, Mourea, Tikitere. Participating in the workshop were:

- Philip Needham (Product Manager) & Brad Cathcart (Sales Manager) from Stihl Ltd,
- Aaron Motutere (Foreman), Adrian Watson & Dion Kahi from Inta-Wood Forestry,
- Richard Parker (Senior Scientist) from Scion, and Brian Richardson & Rob Prebble representing FGR.

Workshop Procedure:

After a brief introduction to the project, the product manager from Stihl presented the current range of battery powered chainsaws. He also presented the latest model MSA300 which, at that stage, had not been released for sale in New Zealand. The following battery saws were available for trial at the workshop:

- MSA220 C-B, 40cm bar.
- MSA161 T, 30cm bar.
- MSA300 C-B, 45cm bar.
- MSA220 T, 30cm bar.
- HTA66 pole pruner.

Also supplied with the chainsaws were AP300 S Lithium-ion batteries and two of the new AP500 S batteries.

Fig 1: Crew induction to the battery saws.

The built-in safety features of the saws were explained and the recent development using bluetooth connectivity to a cellphone to monitor performance and maintenance requirements was described. The type of data that FGR and Scion wanted to collect from any trials was explained and a brief description of the procedure was given. There was some discussion over how vibration and noise levels could be measured, but the need to do this was questioned because most of that information was already available from the chainsaw manufacturers.

After receiving instructions on the operating techniques, the thinning crew took the MSA300 and MSA220 battery powered saws into the felling face to try them out. All three workers tried out the MSA300 saw and the foreman tried the MSA220. While it wasn't clear whether the batteries were fully charged before starting, both AP500 batteries and one of the AP300 batteries were fully discharged after about two hours of operation.

Workshop Results:

With the AP500 battery in the MSA300, between 12 and 15 trees were felled before the “battery low” light started flashing. The discharged battery was replaced with the second AP500 and a further 12 to 14 trees were felled before it too ran out of charge. In the meantime, the MSA220 with an AP300 battery was trialled in another part of the block and about 10 trees were felled before the battery ran out. General impressions were positive. All operators liked the smooth application of power and were quite impressed with the cutting speed of the saws but felt that they didn’t have the “grunt” of the petrol-powered saws. They felt the weight of the saws was okay and both were reasonably balanced around the front and rear handles.

Two of the operators trying the MSA300 didn’t like the saw’s isolation switch; saying it felt like it was in the wrong place and should have stayed on longer before cutting out. Everyone commented on the absence of continuous noise and how that would make it much easier to communicate between workers. Participants not wearing earmuffs commented on how noisy the chain travelling around the bar was, and the product manager from Stihl confirmed that a large part of the petrol-powered saws 106 – 110dB noise rating was from chain noise. Generally, operators felt there was less vibration with the battery saws, but they would prefer to have a longer bar if possible. It was explained that a longer bar could be fitted to the battery saws, but it may be at the expense of a shorter run time.

General Discussions:

The general consensus was that the battery powered saws wouldn’t be as productive as their petrol counterparts, but they certainly had potential and the crew were keen to participate in further trials with them. Overall, the run time was a bit shorter than expected, but this could have been a function of the charge levels of the batteries at the start of the trial. There was an observation made that operator technique could also influence how long a battery lasted and the habit of “blipping” the throttle before making a cut, which everyone does with petrol saws, may reduce battery run time. There was discussion about measuring carbon monoxide levels around the operators of petrol-powered saws, especially in heavy undergrowth, and everyone felt this would be a very worthwhile exercise.

There was general agreement to continue with the proposed trials and a target date of November 2022 was set. FGR undertook to prepare a detailed workplan and share it with other stakeholders before starting the trials and Scion agreed to review available data recording options. The Canterbury University School of Forestry also had a proposal underway to trial battery saws in thinning operations in their local area. The scheduled release date for the new MSA300 saw in New Zealand was January 2023 but the Stihl representatives undertook to see if they could “jump the queue” and get additional MSA300s for use in the trial.

There was some discussion about using a vegetable-based oil as chain lubricant to further reduce the carbon footprint of forestry operations. It was explained that Stihl marketed a lubricating product based on soya beans. They also have an alkylate based fuel that could further reduce emissions from petrol powered chainsaws, but it was a lot more expensive than ordinary petrol. Apparently, the shelf life of alkaline based petrol is about 5 years as opposed to the 3 – 4 months for petrol from the pump. However, these products were not assessed in this trial.

It was acknowledged that any trial conducted had to address the charging facilities required to keep sufficient supply of batteries up to the workers on the saws. The question raised was, “how many 2kg batteries can we realistically ask thinners to carry around in their back packs?” Unlike fuel, batteries don’t get any lighter as they discharge. One suggestion was a change in approach with possibly a “mule”, or even perhaps a drone, circulating around the workers, replacing spent batteries with fresh ones. Another option discussed was employing multi-port charging stations that were due to come on the market, these could be mounted in a vehicle for overnight charging by plugging the vehicle into a power supply, meaning a suite of fully charged batteries would be ready for the next day, as long as the foreman remembered to plug the vehicle into a power supply.

The importance of fully charging lithium-ion (Li-ion) batteries to get maximum run time out of them was also explained. Apparently when all green lights are flashing with the battery on the charger, it

is only eighty percent (80%) charged and to get the full benefit out of a charge, batteries need to be up to 100%. An 80% charge doesn't equate with an 80% run time; in fact, it's more like 50 – 60% run time. With the global focus on mankind's carbon footprint and the use of fossil fuels, the shift to battery power is accelerating and associated technology surrounding battery power was seen to be progressing at a rapid pace, but there is also uncertainty about the supply of raw materials needed to manufacture the batteries. Recent developments with lithium-sulphur (Li-S) and Lithium Iron Phosphate (LFP) suggest trials evaluating battery alternatives may be a future possibility.

There was discussion about the fire risk with Li-ion batteries as a number of house fires had recently been attributed to them. Manufacturers warn operators of battery tools that over-heated or damaged batteries could increase the fire risk above that of exposure to petrol fumes. These were all factors that needed to be considered in the research trials being proposed.

APPENDIX 2: UNIVERSITY OF CANTERBURY STUDY

A parallel study of battery powered chainsaws, funded by FGR, was carried out by a student from the New Zealand School of Forestry at University of Canterbury, (MacDonald 2023). Three thinning crews in the Canterbury/West Coast regions were selected for the trials and over a two-day period, two crew members from each crew were supplied with Stihl MSA220 battery powered chainsaws. Parameters were measured and recorded with the operators using both types of saw so that ergonomic and productivity differences could be assessed.

To minimise the influence the time of day might have on performance, the operators used one type of saw in the morning and the other in the afternoon on day 1, then swapped around for the second day. To assess the ergonomic impact of the two saw types, both noise level and operator heart rate data were collected each day. A mobile weather station was set up to account for any variations in temperature, relative humidity and wind speed. Productivity was also measured by getting thinners to record the number of trees using a tele-counter. GPS tracking devices were trialled during this study, but results were not reliable due to canopy interference.

One key finding of the study was the reduction in noise decibel readings, with battery saws emitting 87.2 dB(A) and petrol-powered saws emitting 100.0 dB(A). Using the Worksafe criteria to determine hearing protection requirements by plotting noise over exposure, the hearing protection class for battery saws was *one*, compared to *four* for petrol saws. There was no significant difference in the level of exertion felt by operators according to the heartrate data and this appeared to be related to the battery saw being lighter and easier to manoeuvre but having less power and spending more time cutting. The shorter bar was also considered a factor, requiring operators to reach further and take more swipes when clearing access to trees.

The productivity data showed that the petrol-powered chainsaws were consistently more productive than the battery saws over all sites. The average productivity per hour for petrol saws was 93.6 trees per hour, compared to 43.8 with the battery saws. While both types of saw recorded decreasing productivity as tree diameter increased, an unexpected trend showed that difference was greater in smaller diameter trees than in larger trees. It was assumed that bar length may have been one of the factors influencing this result.

Run times were considered significant in the study with batteries lasting for consistently shorter periods than a tank of fuel. This was exacerbated by the size of trees being felled, with larger trees requiring greater frequency of battery changes. The average battery run time in one study was 32 ½ minutes, whereas a tank of petrol in the same area lasted 40.5 minutes. It was calculated that over a 5.5 hour productive day, each operator would have to carry 11 batteries.

For a full day's work, it was estimated that an operator using a MSA220 battery powered chainsaw would have to carry 23.4 kg, before accounting for chain lube, safety gear and food. By contrast an operator using a MS500i petrol powered chainsaw complete with fuel, would only have to carry 12.3 kg plus lube, safety gear and food, for the same period of time. It was also noted that the weight of petrol decreased as it was used whereas the weight of batteries didn't change as they discharged.

APPENDIX 3: OPERATOR SURVEY FORM – BATTERY CHAINSAWS.

OPERATOR SURVEY

Battery Powered Chainsaws, Project 4.2

Name:…….……Date:……..……Type of Chainsaw:……..

What I liked about the Battery powered saw	**What I disliked about the battery powered saw**
Balance	
Weight	
Power	
Bar length	
Chain type/size	
Ease of use	
Safety features	
Maintenance	
Noise	
Vibration	
Comments:	

Continue over page if necessary:

Comments - Continued
Would you be prepared to use a battery powered chainsaw on a regular basis?