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TECHNOLOGY REVIEW

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**Manual and Mechanized Pruning
Technologies:
a review of the literature**

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EXECUTIVE SUMMARY

Precision Silviculture – Mechanized Pruning

This review of literature related to mechanized tree pruning covered published information as well as unpublished industry trials in New Zealand and personal observations and opinions from New Zealand and International forest industry members.

Silviculture is broadly described as the practice of controlling the composition, structure, growth and quality of a forest. Silviculture is an essential part of managing and creating value from New Zealand's plantation forests yet remains highly manual.

The aim of pruning is to restrict the size of the knotty core as far as possible without unnecessarily affecting the growth of the tree. Healthy trees usually carry more foliage than they need, so a light pruning has no effect on growth, and the foliage removed is quickly replaced. This then produces a knot free clear-wood which then provides benefits to both strength and appearance

The pruning of commercially grown trees in New Zealand and Internationally has predominantly been completed manually. This is very physical manual work with the use of loppers, handsaws and ladders. Given the high proportion of New Zealand's forests being on steeper slopes this also makes access difficult for both man and machine.

INTRODUCTION

New Zealand maintains a strong forestry sector contributing 1.6% of the nation's GDP with wood products being the third highest export earner. A contribution of 1.1% to the global supply of industrial wood and 1.3% of trade in forest products can be attributed to the New Zealand forestry industry. Approximately 1.7 million hectares of land is utilised as forested plantations and exported wood products were valued at \$6 billion in December 2020 with logs contributing over half of this. Of the 32.9 million tonnes of harvested volume in 2020, 20.1 million was exported as logs (mostly to China) and 12.8 million tonnes was processed domestically (NZFOA 2020/21). The industry employs 36,000 people

Of the 1.7 million hectares of planted land approximately 700,000 hectares or 40% of this land is pruned (NZFOA 2020/21). This is predominantly in non-production thinning areas. Pruning has been completed for a variety of reasons, access, fire control, stability but now the primary reason for pruning is to produce clear wood and to add value to the estate.

Pruning has all been completed manually and is a very physical task. Common practice in New Zealand is for people using pruning loppers, with a handsaw for larger branches, to remove all branches and greenery up to the height of approximately 6.5 metres. This is generally done over 2-3 lifts with the 2nd and 3rd lifts requiring a ladder and once over a height of 3 metres the pruner is also required to be harnessed to the tree.

Figure 1 Pruning from the ground and ladder



This has continued to be a very manual process apart from the use of smaller chainsaws. These have improved productivity but also introduced health and safety risks such as cuts and hearing damage. Some forest owners moved away from chainsaw pruning due to tree damage, where additional cuts and nicks were appearing on the bark. This is caused by the fast-moving saw chain. With ongoing issues with labour supply some forest owner/managers are now finding it difficult to get their targeted pruning areas completed.

OBJECTIVES

Presented in this study is a review of pruning technology developments that have potential application in the New Zealand commercial forestry sector. The objective was to;

1. Undertake a literature review of international technology that is currently available or being developed for both manual and fully mechanized pruning systems that may be applicable to the NZ commercial forestry sector.
2. Review domestic developments in manual and mechanized pruning, including developments in other sectors such as viticulture and horticulture, progress made, potential

for further development and record any learnings from such developments.

3. Identify opportunities to modify, enhance or scale technologies to the New Zealand forestry context

Literature used in this review have been accessed primarily through New Zealand and International contacts, Google, and Google Scholar.

OVERVIEW OF NEW ZEALAND PRUNING PRACTICES AND REGIMES

Approximately 40% of the New Zealand forest estate is currently pruned, (NZFOA, 2021) This has been reducing each year as changes of ownership occur and cost structures have increased.

Below is a snapshot of pruning regimes currently completed by 3 of New Zealand's larger forest owners

Company Name	Timberlands LTD
Lifts	Currently no large-scale pruning. Access pruned archives and other trials only when needed
Fixed or Variable	For current trial access prune to 2.0m Previous was variable 2-3 lift regime 75% SPH@5.4m
Target heights or green crown remaining	4.0m 1 st 4.5m 2 nd
Target SPH	Was 380 sph
Lopper or chainsaw or combo	Lopper
Contour or up and down planted	Both combinations
Planned Pruned Area per Annum	Nothing for F22. possibly F23 site specific with PT option
Achieved Pruned Area per Annum – why?	Was about 40% of an age class. Market Volume related
Total area of Estate	179,000 NSA
Company Name	Juken New Zealand Ltd, Wairarapa Forest Estate.
Lifts	Pruning is done in 3 lifts; low, medium, and high.

Fixed or Variable	Fixed targeted pruned heights. Low prune = 3m, medium prune = 5m, high = 7m. Some stands are done as a double lift to 5m if the gorse levels are too high.
Target heights or green crown remaining	Generally target around 4.5m of green crown remaining.
Target SPH	Targeted 350 pruned sph.
Lopper or chainsaw or combo	Lopper/jacksaw. Some stands require pruning chainsaws to take off the larger branches, however this is at the contractor's discretion.
Contour or up and down planted	Planted along the contour.
Planned Pruned Area per Annum	Approx. 1,200ha.
Achieved Pruned Area per Annum – why?	Will be lower than budgeted at the end of this fiscal yr. The fire danger has not increased to a point where our thinning operations normally stop. The budget allows for approx. double the number of pruners over 2 months as the thinners join the pruning crews over the fire season.
Total area of Estate	Approx. 12,000ha in the Wairarapa.
Company Name	Ernslaw One Ltd
Lifts	Pruning is done in 2 variable lifts
Fixed or Variable	1 st Prune 0.0 – 3.5 m, leaving a min of 3.5m green crown. 2 nd prune 3.5 – 6.0 m, leaving a min of 3.5m green crown
Target heights or green crown remaining	Generally target around 3.5m of green crown remaining.
Target SPH	Targeted 375 pruned sph.
Lopper or chainsaw or combo	Lopper/jacksaw.
Contour or up and down planted	Planted along the contour.
Planned Pruned Area per Annum	Approx. 1,200ha.
Achieved Pruned Area per Annum – why?	Is lower than would like due to labour supply thinners join the pruning crews over the fire season.

Total area of Estate	Approx 90,000 hectares, which include 20,000 hectares of DFir which is unpruned
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CURRENT PRUNING TOOLS USED IN NEW ZEALAND

The manual tools currently being used in New Zealand consist of a mix of hand tools and different height ladders depending on the pruned lift



Figure 2 Loppers



Figure 3 Jacksaw



Figure 4 Step



Figure 5 Ladder 4.0m

The second method of pruning in New Zealand is still manual but uses a motorised device. This is a top handled chainsaw



Figure 6 Stihl 021 Top handled pruning chainsaw

There are pros and cons for both methods, but generally pruning loppers produce a better job. A branch that is pruned with a clean cut will heal over faster and cleaner. Other advantages of using loppers and handsaws is the low cost of buying and maintaining the equipment compared to a chainsaw.

On the other hand, using a top-handled chainsaw usually means increased productivity and less physical effort from the operator for each pruning lift. Chainsaws can be expensive to buy, as can the necessary safety gear, as well as the maintenance. Chainsaws are also noisy, they create saw dust, and the risk of branch collar damage is generally more of a problem. Finally, there is a higher risk of injury associated with the use of a chainsaw while perched on the top of a ladder up a tree. There has only been one reported incident since 2012, which was a tendonitis injury from lopper pruning. (IRIS, 2012)

Minimum equipment for manual pruning

The choice of equipment is a personal decision. If you decide to prune using manual equipment, then the bare minimum in equipment that is needed is –

- Forestry pruning lopper
- Forestry pruning saw
- Epicormic knife
- Holster to carry the above tools
- Ladders, generally a 2.4 metre ladder for your second prune and a 4.2 metre ladder for further prunes

For chainsaw pruning, as a bare minimum you will need –

- Top-handled chainsaw with a 250 mm to 300 mm bar
- Earmuffs grade 4 or 5
- Mesh goggles or a visor
- Chainsaw chaps
- Chain safety guard
- Belt hook to secure the chainsaw while manoeuvring up and down the ladder and between trees
- Fuel and oil containers
- Ladder

Other equipment includes safety boots, harnesses, safety lanyards and hydration packs whether manual or chainsaw pruning.

INTERNATIONAL TECHNOLOGY AVAILABLE FOR MECHANISED PRUNING SYSTEMS



Figure 7 Poplar pruning in Europe (Spinelli, 2022)

In Europe on the flat country where they call it tree farming not forestry they are using a twin lift attachment run behind a tractor; The tractor movements are made by the tree pruners. The pruners used are a pneumatic secateur. This is not something that would suit most of New Zealand's plantation forestry conditions but may suit the flatter conditions of the central North Island.

Similar machines from South Africa are the Red Ant Pruning Tower



Figure 8 Red Ant Pruning Tower

Features

- Heavy-duty steel frame
- Stable structure with a low centre of gravity
- 19 Kw Perkins Diesel Engine
- Hydrostatic drive
- Working floor lifts to 6m
- Operator with extended tools able to operate to 9m height
- Hydraulic Chainsaw (with 2 m extension - optional extra)
- Electric Pruning Shears (with 2 m extension – optional extra)

Benefits

- Easy access to the top of the tree
 - Easily controlled
 - 360 degrees turn point
 - Full control from Crow's Nest
- (Red Ant Pruning Tower, n.d.)

In New Zealand we have the Hydralada options which are generally used in the horticulture industry



Figure 9 Hydralada 540H MAXI

This comes in either petrol, diesel or electric options and can also have a rubber tracked option on the drive wheels. There is also the option of a slew which may give the opportunity to give better access to the tree or access to a number of trees. These have been used in seed orchards also for the collection of seed pine cones from the Whirinaki nursery, Hawkes Bay (Hydralada Blog, n.d.)



Figure 10 Hydralada PH12 Slew Boom

Attachments for this equipment include a pole or pistol grip saw and pole secateurs



These tools will all be powered hydraulically by the lifting platforms power source



Figure 11 50mm opening

There are a number of manual and now battery pole saw options available, none of which are currently used in the New Zealand forest industry. Small amount used in Farm Forestry operations Nelson (Rod, 2022)

BATTERY OPERATED SECATEURS AND SAWS



Figure 12 Makita DUP362



Figure 13 Pellenc Prunion 250 and Selion M12



Figure 14 Infaco Electrocoup F3015



Figure 15 Campagnola Cobra



Figure 16 Campagnola T Rex

COMPARISON OF AVAILABLE BATTERY EQUIPMENT

Battery Operated Tool	Makita DUP362 (Japan)	Pellenc Prunion 250 (France)	Infaco Electrocoup F3015 (France)	Campagnola Cobra Pro (Italian)
Cutting Capacity	33mm	45mm	40/45/55mm	40mm
Battery Capacity	2 x 5Ah batteries	1 x 5.8Ah	1 x 2.5Ah Claim 9hrs use/charge	1 x 3.5Ah Claim 9hrs use/charge
Power	36v	43v	47v	50.4v

Weight	0.8kg	0.86kg	0.79kg (add 0.48 for maxi 55mm)	0.84kg
Backpack	yes	yes	yes	yes
Blade opening options	Yes- manual, half opening	Yes – electronic, optical trigger/half opening (Pellenc Patent)	Yes – electronic, half aperture 10 programs to select	Yes – electronic, half aperture 5 programs to select
Saw	No	Pistol grip saw Selion M12	No	Yes, compatible with cord battery or has its own
Safety glove	No	No	Electronic conductive safety glove	No
Available in NZ	Yes - Makita agents	Yes Hydalada NZ	No	Yes – Silky Store Nelson
Other	Make a separate pole saw, 2-3m	Compatible with pruning pole (2m) and saw	Compatible with pruning pole (2-3.5m telescopic)	Compatible with pruning pole (2-3.2m telescopic). Number of pneumatic units

				available at low cost ~\$350
Cost	~\$1800	\$2200 (Selion M12 saw additional \$1800)	€1750 or ~\$2800 (NZ)	\$2700 for Cobra, but comes with longer life battery

Key to Scale of Functions	
	1
	2
	3

MECHANIZED OPTIONS

Excavator attachment



Figure 17 OMEF CS 100 Tree pruner

The OMEF CS 100 tree pruner is an excavator attachment that will fit a 1.5t machine and will cut branches from 100 – 250 mm dependant on the attachment size, this is Italian made. This would be slow in its current form and have trouble cutting the branch flush with the branch collar. (\$7,000 from Forest Quip NZ) (Gill, 2022)

Clouston Tree Pruner



Clouston Hydraulics of Oregon state USA produced the prototype Clouston Tree Pruner or Tree Shaver in 1997

The unit is powered by a chainsaw engine driving four small rubber tires that rapidly propel the machine as it spirals up the tree. Instead of a flat cutting blade that can bind, the “Tree Shaver” uses a round mill end (side-cutting) bit to quickly cut limbs up to several inches thick. An on-board air compressor powers the pneumatic gripping system which maintains a constant grip on the tree as the machine ascends along the decreasing diameter of the stem. The engine throttle and grip strength can be adjusted by radio remote control, allowing the operator to control pruning on each tree, compensate for heavy branches or wet bark, and stand clear of falling limbs. Stub length can be manually adjusted.

The current design of “Tree Shaver” can prune trees 3.5 to 11.5 inches in diameter, John said. This would make it useful for the second and third pruning “lifts” after initial training and pruning is accomplished from the ground by manual means. As many as 30 trees can be pruned up to 27 feet above ground on one tank of gas, he said. A two-person team is required to move and operate the machine which consists of two halves, weighing a total of 100 pounds, that are fitted together around the base of the tree. John said that he hopes to increase the horsepower and reduce the weight of the next prototype, so that only one operator is required.

The “Tree Shaver” has so far been tested on Douglas fir and hybrid poplar, and John said he would like to test it on black walnut and other commercial species. He said that the current model works best on straight-stemmed trees without large forks or bulges at branch nodes, e.g. not like radiata pine. (Merwin, 1999)

Gifu Robot – Japan



Gifu University in Japan had developed a pruning robot with an energy-saving chain saw drive for more than 10 years, as shown in Figure 2. The whole robot was a ring structure. It was driven by the servo motor turbine reduction mechanism, with two climbing functions: linear climbing and spiral climbing. At the same time, the machine could realize self-locking fastening and prevent biting with the branches during the working process. The pruning chainsaw had the function of adjustment, and the position control of the chainsaw can be realized according to the actual working condition through the principle of fuzzy control. The climbing device consists of four driving wheel mechanisms with steering devices and an adjustment mechanism, so that the robot could always maintain a horizontal posture during tree climbing. At the same time, the robot could achieve self-locking only by gravity. (Wang, 2021)

Although patented the Gifu was more of a university student side-line for students at Gifu University in Japan, and never went beyond the prototype stage.

Advaligno Patas – Tree Monkey



Figure 18 Advaligno Patas Cutting Head

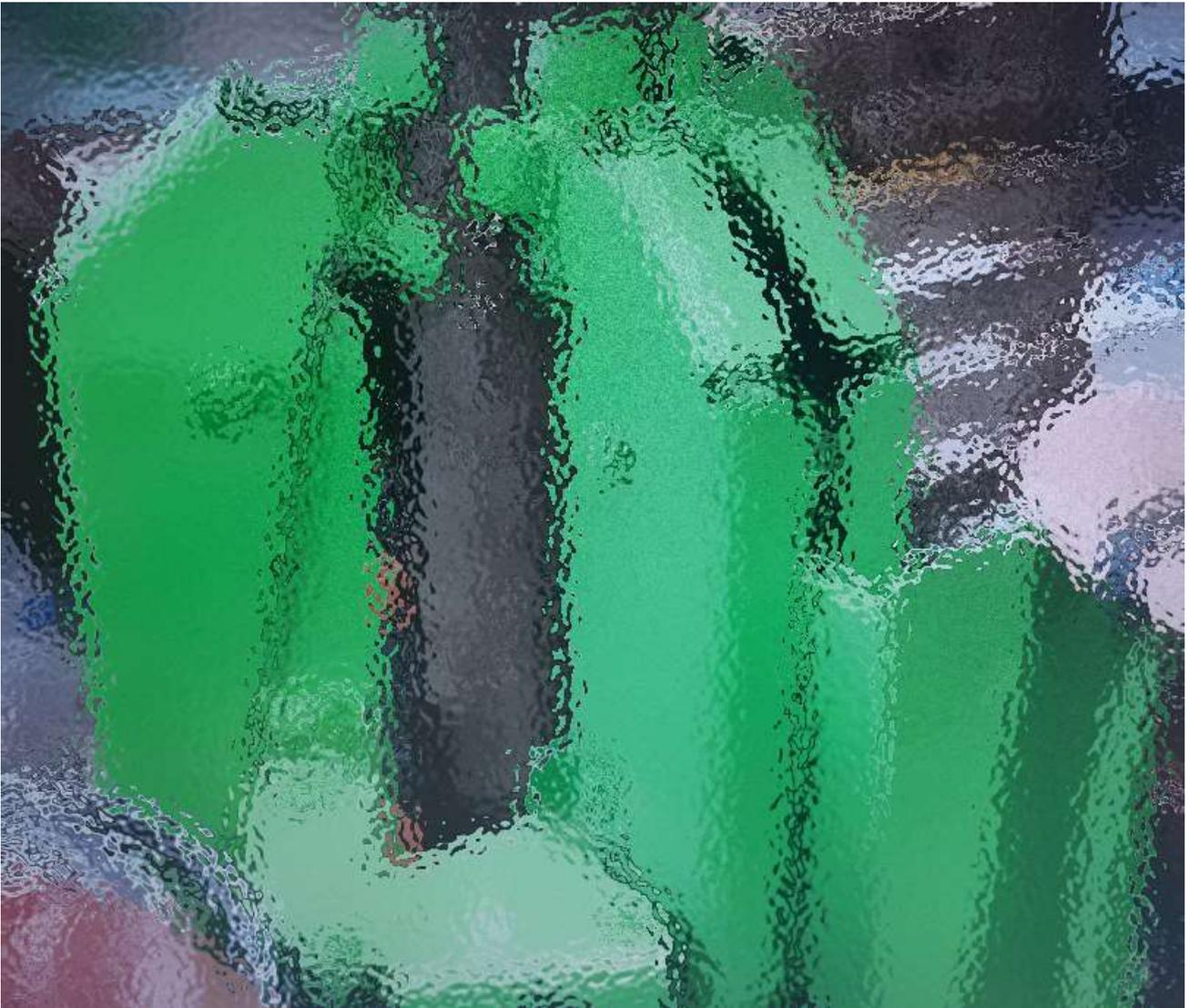


Figure 19 Advaligno Patas Drive Unit

The Advaligno PATAS was developed by the Jordan family company in Germany. It is named after the fastest climbing monkey. The system consists of two modules: a drive unit for connecting to a small tractor (min 40hp), and a cutting unit, which then works on the tree. When working, the required speed is achieved through a hydraulically driven rubber umbilical cord. This ensures minimal bark pressure and maximum grip. The blade on the cutting head separates all branches from the tree cleanly. Possible output 30 to 50 trees per hour. Simple operations could be performed within a range of 12 to 15 meters. Cutting head part alone is 50 kg. (Advaligno, 2019)

This is the only Tree Climbing pruning machine currently commercially available. Panpac Forests Lts in Napier has purchased one of these machines and is in the process of undergoing trials. A visit was planned but Covid 19 prevented this from taking place.

NZ option Marsh Hudson – Hudson Clearwood



Marsh Hudson from Hudson Clearwood is working on his own ‘tree climbing machine’. This is a hydraulically actuated pruner mounted on an 8 tonne excavator platform. As this is still under construction the developer has asked that everything is kept confidential at this point (Hudson, 2022)

In 2015 Juken New Zealand purchased a tree climbing pruner from Japan. Due to issues with getting the machine to deal with nodal swelling on New Zealand’s *Pinus Radiata* and the costs associated with remediating this, the project was discontinued.



Figure 20 Scion Tree to Tree Robot

In NZ, our own tree to tree robot was developed by the FGR Harvesting theme. This could be adapted to not only thin trees but also prune.

The concept of the Robotic Tree-to-Tree Felling Machine (dubbed the “Stick Insect”) whereby the machine uses standing trees as a means of locomotion has been developed to overcome the issues of steep terrain, soil damage and complex operating environments by remaining above the ground, overcoming the complexities of ground surface travel. (Parker, Lamborn, & Bayne, 2016)

ROBOTICS IN OTHER INDUSTRIES

Robotics Plus Kiwifruit picker



Figure 21 Robotics Plus Kiwifruit picker

Figure 14 is a robotic kiwifruit picker which has 4 arms and an array of cameras are at the heart of the machine, which uses a series of learning algorithms to map the canopy above in three dimensions. (RoboticsPlus, 2022)

FFRobotics multi arm apple picker (<https://www.ffrobotics.com/>)



Israeli company FF Robotics continued improvements on its robotic picker, which uses multiple arms with pronged “fingers” to grip, twist and pull fruit from trees, but was grounded from any trials outside the country due to the coronavirus travel restrictions (Kahani, 2022)

SUMMARY

Labour availability, forest ownership variation and economic drivers will continue to be a driver for innovative and cost effective silviculture management. The continued use of unsustainable practices involving the use of tools used last century will subject the New Zealand forestry sector to further difficulties and then costs to get their trees pruned at the correct time and standard. Pruning of trees adds value, but the cost of this cannot reduce the current differential between prune log and a structural sawlog. If this is the case the forest owners will continue to question the economic viability of pruning their respective estates.

The low hanging fruit options for mechanization in tree pruning are the use of battery-operated pruners and saws. There are readily available options used in the horticulture and viticulture industries that with small adjustments will be a viable option for use in the forest industry. These not only provide the potential for greater productivity in the near term but also gains in the environment and safety through things like no fuel use and less fatigue. At the other end of the scale, there is/has been little use of machines for tree pruning both nationally and internationally. Commercially available units from Germany need modifications to suit the tree species grown in New Zealand. Locally the Hudson Clearwood machine is at prototype stage so will hopefully be able to deal with the issues associated with Pinus Radiata branch size and nodal swelling. Adapting the robotics used in other industries may be an option, where similar arms, sensors and movements mirror the movements of a tree pruner. These would need to be ruggedised to suit the harsher environment and conditions of a forest

The industry may have to look at reviewing the establishment and tending regimes to suit new equipment, this a long-term requirement. With safety and environment a key requirement, feasibility and success requires machines to travel up the slope rather than across the slope. Under current regimes this will be more difficult to achieve. Ultra high pruning lifts using machines will create additional clear wood but will require longer rotation lengths to grow this clear wood.

New technology will also require a different type of employee to operate these machines. The aim is to make the work less physical, safer and more attractive to more of the available workforce.

There will also be some potential synergies and crossover between the pruning and thinning mechanization processes.

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