Precision Silviculture Programme

TECHNOLOGY REVIEW

Project Number: 2.1
Milestone 2.1.1

PRECISION PLANTING TECHNOLOGY SCAN

Tim Petro

Date: 30 September 2022

Ref: PSP-TR003

FOREST GROWERS RESEARCH

Table of Contents

supported by forestgrowers commodity levy

EXECUTIVE SUMMARY

Precision Silviculture – Mechanised Planting

This technology scan on mechanised tree planting covered publically available information as well as unpublished industry trials in New Zealand, and personal observations and opinions from New Zealand and international forest industry members.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 planting of commercially grown trees in New Zealand and internationally has predominantly been completed manually. This is very physical manual work with the use of spades and bags. Given the high proportion of New Zealand's forests being on steeper slopes, access is often difficult for both man and machine.

Recommendations from this review are that further work should be completed on the existing machines currently being used in New Zealand. This should be completed by a work study

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 value. 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

The commercial nursery survey results just released by MPI (MPI, 2022) show that 96.5 million seedlings were planted in 2021, which corresponds to an estimated 95 thousand hectares of new planting and replanting. Survey respondents indicated their intention to plant 120 million seedlings in 2022.

The total area of forest planting in the winter of 2021 is provisionally estimated from the nursery survey data and associated modelling to be 95,000 hectares. The total area of new planting in 2021 is estimated to be in the order of 45,000 hectares. Replanting of harvested areas is provisionally estimated to be 50,000 hectares in 2021.

The 2021 nursery survey asked commercial forestry nursery managers about anticipated sale levels in 2022. All nurseries responded. Their estimates indicate that total seedlings sales may increase to 120 million seedlings in 2022 (MPI, 2022).

Tree planting is carried out for a variety of reasons including for production forestry, carbon sequestration, erosion control and riparian protection.

Most planting is carried out manually (Figure 1), generally during the May to September period, and is a very physical task. Common practice in New Zealand is for people to use planting spades, with the trees carried in a planting bag, The planting bags generally contain 100 trees, and the planter and contractor are paid on a piece rate.

Figure 1 Manual tree planting

Three of New Zealand's largest forest owners have been trialling mechanised planting over about 500 hectares at this point and is predominantly on the easier country.

OBJECTIVES

This review evaluates planting technology developments that have potential application in the New Zealand commercial forestry sector. The objectives were to:

1. Undertake a literature review of international tree planting technology that is currently available or being developed for both manual and fully mechanised planting systems that may be applicable to the NZ commercial forestry sector.

2. Review domestic developments in manual and mechanised planting, including developments in other sectors such as agriculture, 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.

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

OVERVIEW OF NEW ZEALAND PLANTING PRACTICES AND REGIMES

Of the approximately 90,000 hectares likely to be planted in New Zealand in 2022 (MPI, 2022), 50,000 hectares is restocking and approximately 40,000 hectares is new planting.

Tree crops are generally planted to provide timber production and financial returns to the forest owner, and more recently carbon sequestration. They may also provide environmental benefits including:

- Erosion control
- Water quality improvement
- Recreation opportunities
- Scenic improvement
- Shelter and shade
- Wildlife habitat
- Carbon uptake

Key elements of successful planting include:

- Tree handling.
- Soil cultivation.
- Planting hole depth.
- Root placement.
- Tree firmness.

The planting operation is a very important first step in the life of a tree crop. If not done properly, the following may result:

- Inadequate or excessive stocking rates.
- Tree mortality.
- Poor early growth.
- Toppling and subsequent windthrow.
- Poor tree straightness, large branches and poor wood quality.
- Uneven growth within a stand.

These effects may reduce future returns to the forest owner. In some cases, a site may need to be re-established,

Tree planting can be divided into the following tasks:

- Selection of planting spot.
- Screefing (if necessary, this is clearing of the planting spot before cultivation).
- Soil cultivation and opening the hole.
- Root placement in hole.
- Filling in loose soil.
- Straightening and firming in.
- Quality control.

Trees are planted in rows (Figure 2) to:

- Make it easier to achieve the required stocking
- Produce uniform branch and diameter growth.
- Allow planted trees to be identified from regenerated trees for future tending.
- Assist in the management of later silvicultural operations (e.g., spraying, pruning, and thinning).

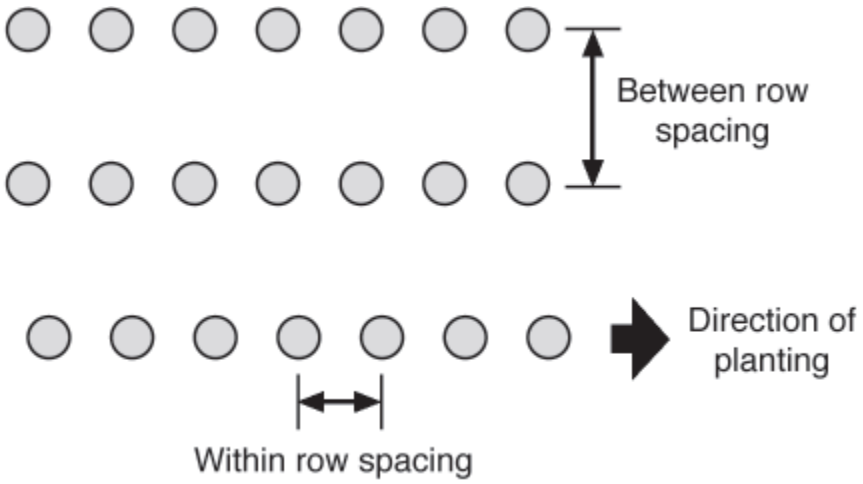

Figure 2 Row and tree spacing

The required stocking is achieved by planting trees at the correct spacing within and between rows (FITEC, 2000).

These rows can be either up and down the slope or planted across the contour; most are now contour planted. Planted stocking rates in New Zealand are generally between 800 and 1,200 stems per hectare.

All of the above factors are important and valid considerations when moving towards mechanisation.

CURRENT PLANTING TOOLS USED IN NEW ZEALAND

The manual hand tools currently being used in New Zealand consist of a spade (Figure 3) and planting bag (Figure 4). This is a very physical task and although there have been no recorded planting incidents since 2009 (NZFOA, IRIS, 2022) it has associated risks such as slips, trips, falls and wrist injuries.

Figure 3 Planting Spade

Figure 4 Planting Bag with Shoulder Strap

The ‘Smart Spade’ which includes a GPS unit and is tethered to a cell phone has been developed by Fear Contracting Ltd. The spade will collect the location data of each planted tree which can then be reprogrammed for a drone to then complete spraying and tree measuring and later stages. The data also can be used as a day-to-day management tool during planting to check the movement, numbers, and spacing of each individual planter. Accuracy of the GPS is still an issue, but calculations can be made and adjusted based on the fixed data points to determine how far out each waypoint is using Real Time Kinematic data (RTK). The system is still subject to human error given the point is recorded by the planter pushing a record button at the completion of each tree being planted.

The other method of planting in New Zealand is mechanical planting. As mentioned previously this remains a small proportion of New Zealand’s commercial planting procedure. In the 1970’s easier country was planted using tractor towed intermittent tree planters (Figure 5).

Figure 5 FRI Intermittent Tree Planter

However, the FRI Intermittent Tree Planter was restricted to relatively flat to rolling terrain and, more importantly, couldn't compete with the cost of manual labour in cutover sites. Therefore, it was not operationally deployed by the New Zealand Forest industry (Baker, 2018).

More recently there have been trials, and now full operational use Central North Island, of machines from Scandinavia such as the Finnish M Planter.

Figure 6 M Planter - Kaingaroa Forest, NZ

Increased uptake of mechanised planting and adaptations to steeper country may help relieve the industry issues with labour supply.

REVIEW OF INTERNATIONAL TECHNOLOGY

MANUAL PLANTING

Similar spades are used internationally as we do here in New Zealand. Other manual tools are shown below.

Pottiputki planting tube – Finland

According to the manufacturer, the Pottiputki planting tube is the most efficient tool for manual planting of various sizes of containerised seedlings (Figure 7). The planters can work in an ergonomically correct position, making the method both fast and comfortable. BCC (the parent company) also develops long lasting and comfortable carriage systems. (Pottiputki, 2022) Comes in a 35 to 75 mm range and is valued at approximately NZ $227.

Figure 7 Pottiputki planting tube

The Pottiputki is a planting, not digging tool, so the ground being planted needs to be prepared in some manner, be it ripped or cultivated to enable the Pottiputki to easily penetrate the soil.

Pottiputki also makes a seedling bag similar to those used in NZ (Figure 8).

Figure 8 the harness can also carry planting boxes

Hamilton tree planter - Australia

The Hamilton tree planter (Figure 9) is designed for planting square Super Forestry Tube seedlings, with the Super Forestry Tube typically being square 68mm at the top, 52mm wide at the base and up to 180mm deep. Hamilton Tree Planters make a planting hole the right shape and depth for the seedling type, eliminating air gaps.

Figure 9 Hamilton tree planter

Planting Hoe (Hoedad) Pacific Northwest

. The Hoedad (Figure 10) has been used over many years in the USA by both the National Forest Service and on tree-farms (Terratech, 2022). It is unlikely to offer any advantages over NZ's current planting spades.

Figure 10 Hoedad planting blade

Dibble Bars - Pacific Northwest

Jim-Gem Speedy Dibble

This dibble (Figures 11 and 12) has a bevelled arrow point, is light weight (0.9 kg), and is slightly shorter than some other dibbles. Dibble bar is approximately 2 lbs. lighter and 2-1/8” shorter than standard dibble bars. Works well in a variety of soils, especially light to medium and moist soils (Supplies, n.d.).

Figure 8 For containerised seedlings

Figure 72 For bare root seedlings

MECHANISED PLANTING MACHINES

Despite Sweden and Finland being industry leaders in forest technology and equipment, they still predominantly plant trees manually. In 2020 only 1% of the planting in Sweden was completed by machines (Johnson, 2020). Now, with changes in labour supply, generation movements and movements in the wage market, it looks as though this is about to change. Manual planters are harder to come by and mechanisation is developing. One of the early machines from the 1970's and 80's that had some success, despite being complicated and heavy, was the Silva Nova planting machine (Figures 13 and 14). This looks similar to a forwarder with a trailer rather than a log cradle.

Figure 13 Silva Nova 1985

Figure 94 Silva Nova 1993

Silva Nova

The Silva Nova project, which lasted until the beginning of the new millennium, represented the culmination of development work on continuously advancing planting machines. In 1997, the implementation of mechanised planting peaked when 9 and 12% of the total regeneration area of Norrland and Svealand respectively was planted mechanically. Productivity improvements, quality, survival rates, creaming of best clearcuts and then availability of cheaper labour from western Europe put a halt to further development of the Silva Nova. (Ersson, 2010)

Other Developments

A few other prototype machines were developed in 90's, again, based on the pivot steer forwarder type machine (Figures 15 - 17).

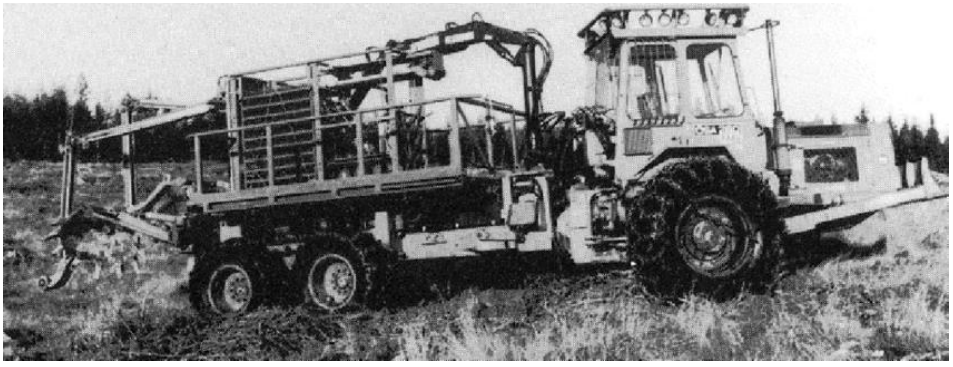

Figure 105 FIAB YPM 30

Figure 11 the Reforester

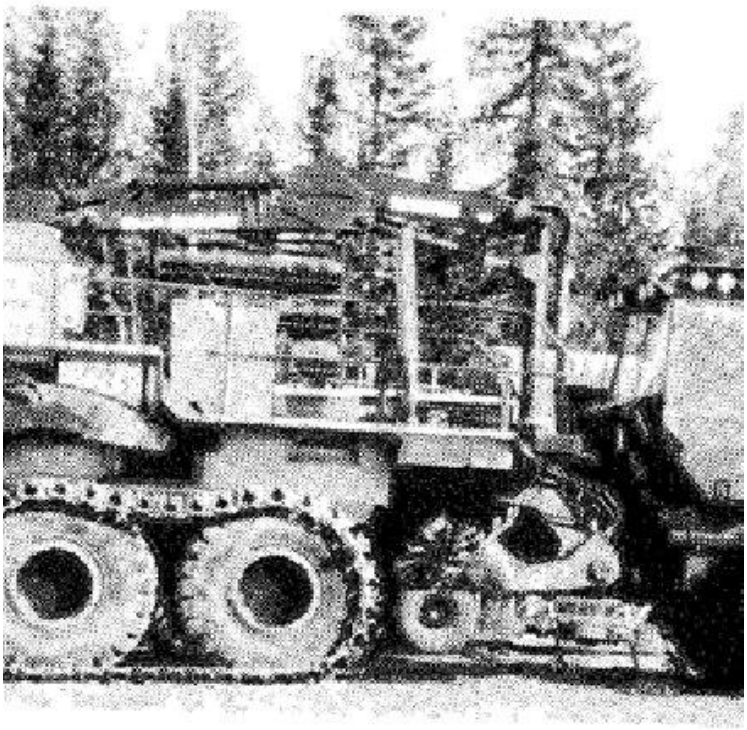

Figure 12 and the Serlachius

Now we move to the 2020's and the modern Silva Nova appears…

Plantma X – old concept in a new suit (Figure 18)

Figure 18 Plantma X and a planted seedling

The machine will:

- In one pass, cultivate the ground, compact it, and plant a seedling.
- Under perfect conditions the machine can plant over 40 seedlings/minute.
- Collect and store location data of the operation.

And work is underway on

- continuous collection of data from the planting.
- the option to add fertilizer to each seedling as it is planted.
- the option to add water to each seedling as it is planted.

the machine has been trialled with 3 Swedish forestry companies and has now planted more than one million seedlings. The machine is also now on tour in the USA, follow up photo of the trees planted in the USA.

Specifications of the machine

Base machine	Eco Log 574E
Engine	Volvo Penta 210kW
Transmission	ECO19
Crane pump	180 ccm
Wheels	8st 710/45×26,5

Scarifier	MidiFlex
Crane	Effer 100 2S
Weight	ca 24,5 metric tons, evenly distributed front/back
Width	3.09 m
Length	11 m
Wheelbase	5.7m
Height	3.85 m
Plants/hour	Every arm is capable of making a planting attempt every third second
Plant storage	10,000-20,000 seedlings, depending on the size of the plant and how its packed.

The Plantma X has a midflex scarifier (Figure 19) for cultivating the soil before planting. This operates intermittently and creates a mound (Plantma, 2022).

Figure 13 Scarifier

The other mechanised planting machines are end tipped machines meaning they are fixed to the end of an excavator or harvester boom.

M-Planter - Finland

The M-Planter M-160M (Figure 20) is:

- A one-headed mounding planter; it mounds and plants the seedling, and hydraulically seals the seedling into the soil from two sides.
- Specially designed to be used with a harvester.

- Uses electrically piloted one-way auxiliary hydraulics of the base machine, with 170 bars pressure and 100 l/min flow.

Other specifications and functions include:

- Weight 1000 kg, width 1000 mm, height 1600 mm.
- Planting tube depth 2100 mm 60 mm.
- Seedling capacity 160 seedlings M-Planter M-160M
- Adjustable planting depth (120/150 mm).
- Mounding claw M-Planter M-160M.

- Adapter tilt.
- Fertilizer system.
- Herbicide/insecticide/pesticide spray system.
- Spade/rake (for more efficient harvesting residue sweep ability and additional soil preparation).
- Watering system.

Figure 20 M Planter on a harvester

M-Planter M-320...

- Is a two-headed planter (Figure 21) that plants two seedlings at the same time, and hydraulically seals the seedlings into the soil from two sides.
- Is an extremely efficient planter for bigger plantations.
- Inserts 2-3 fertilizers per seedling and waters the planted seedling.

- Requires an excavator as a base machine. The excavator should be min 14 ton for flat areas and min 17 ton for steep areas.
- Uses electrically piloted one-way auxiliary hydraulics of the base machine, with 170 bars pressure and 100 l/min flow.
- Weight 1 850 kg / 2050 kg, width 2890 – 4890 mm, height 1500 mm, depth of planting tube 1550 mm 60 mm.
- Seedling capacity 324 seedlings.
- Seedling spacing 2000 – 3000 mm
- Adjustable planting depth (120/150 mm) or customized planting depth (200 mm).
- Customized seedling spacing (2.0 meters to 4.0 meters client chooses).
- Fertilizer system.
- Standard tilts (adapter tilt and head tilts that enables conforming to uneven soils and enables planting with one head only).
- Watering system.
- Herbicide/insecticide/pesticide spray system
- Spade(s)/rake(s)

Figure 21 M Planter 2 heads

M-Planter M-160R (Figure 22):

- Is a one-headed mounding planter that rips (700-900 mm deep) and plants the seedling, and hydraulically seals the seedling into the soil from two sides.
- Also inserts two granular fertilizers, and waters the planted seedling.

- Has reinforced body to sustain the stress caused by ripping.
- Requires an excavator as a base machine. The excavator should be min 20 ton to ensure efficient ripping ability.
- Uses electrically piloted one-way auxiliary hydraulics of the base machine, with 170 bars pressure and 100 l/min flow.
- Weight 1150 - 1500 kg, width 1250 mm, height 1500 mm, depth planting tube 2100 mm 60 mm.
- Seedling capacity 160 seedlings.
- Adjustable planting depth (120/150 mm) or customized planting depth (200 mm).
- Spade/rake (for more efficient harvesting residue sweep ability and additional soil preparation)
- Watering system.

M-Planter M-160R additional functions include:

- Adapter tilt
- Cabin camera
- Cultivator discs
- Deep fertilizer system (for third fertilizer to be inserted deep into the soil)
- Herbicide/insecticide/pesticide spray system

(http://www.m-planter.fi/en/Products.html, 2022)

Figure 22 M Planter 160 being used by Timberlands in Rotorua

Two of New Zealand's largest forest owner/managers have had the M-Planters operating in their forests for a few years now, planting about 100 hectares per year. Timberlands and Manulife have had similar results from their machines from a productivity and quality perspective. When productivity was higher the quality was lower, i.e. at 1400 stems per day the level of quality was only approximately 80% (i.e. 20% of planted stock had quality issues). The machines require containerised seedlings and the primary issues found were seedlings were not planted at the right depth or were not vertical. The M-planters are being run on 20-30 tonne excavators, the reason for machines of this size is for hydraulic pressure. Manulife operate their machine in Tokoroa and are not required to mound or fertilize, so the machine will move slash if necessary and then plant. Timberlands machine in Rotorua is mounding (due to frost), planting and then fertilizing to overcome nutrient deficiencies.

Both companies have stated that to make things more economic they need to increase the speed of the planting head, increase the tree stock capacity, improve planting quality and to make reloading more efficient (Cameron & Baker, 2022).

Figure 143 Manual reloading

Risutec – Finland

Risutec offer 3 models,

- ASP – Large Plantations - the ASP Planter is geared toward maximal productivity for large establishments and reforestation projects. This head has a pitting machine for cultivation (Figure 24)
- SKB – for demanding conditions - The SKB-range of planters comes with a versatile range of accessories, which makes it easy to test different soil cultivation and soil preparation methods and settings.
- PM – for wet conditions - A compact mounding tree planting machine for professional contracting

All heads offer the following

Guidance

The Risutec guidance system is for establishing forests in grids for different species. The guiding system enables planting at night.

Soil Cultivation

Prepare the soil to create optimal conditions for seedling growth. Risutec machinery comes with a wide range of cultivators.

Planting

Achieve optimal tree growth by planting into a fresh spot. Plant with mechanical and uniform accuracy for the best results.

Figure 154 Risutec ASP

All of the above models also include the ability to extend the planting season with water or water-gel application and also add fertilizer.

Risutec appear to have made significant process towards integrating the planting system with GPS technologies to create real time information on planting locations, soil characteristics etc., in effect, creating a digital twin of the forest. (https://risutec.fi/pm-tree-planting-machine/, 2022).

A company in central Chile LOGINFOR is a good example of a company that has adopted the concepts of precision planting and uses 14 Risutec machines to plant both pines and eucalyptus (Figure 25). Information taken directly from their website (http://www.loginfor.cl/index.php/quienes-somos) follows:

1. AUTOMATED PLANTATIONS OF PINUS PINE AND/OR EUCALYPTUS, ON LAND WITH A MAXIMUM SLOPE OF 30%, USING CATERPILLAR EXCAVATORS, EQUIPPED WITH A HEAD SPECIALLY DESIGNED FOR THESE TASKS.

I. Clearing the specific area where the seedling will be planted using the planting head: branches from harvesting are moved, to allow the correct placement of the plant.

II. The planting head cultivates the soil where the tree is to be planted.

III. The location of the point to plant is directed by a GPS system, with an accuracy of 3 centimetres.

IV. Automated planting, the plant is arranged automatically, and the correct pressure is exerted on the soil to give the corresponding firmness and achieve the expected setting.

V. Application of inputs at the same time as tree planting:

- Up to 0.75 litres water, this amount will depend on the particular conditions of the soil and the date of the tasks in each area.
- Granular fertilizers.
- Herbicide.

Daily information on planted area:

VII. Digital plan delivery for each planted area

VII. Supervision, control and coordination of the tasks

(LOGINFOR, 2022)

Figure 165 Eucalyptus plantation – Chile

Forestry Corp Australia also had a Risutec machine on trial in 2020. All Above Reforestation leased the machinery from a New Zealand business to assess its suitability for use in NSW forests, according to Managing Director Shay Radcliffe. An assessment of this planting technology concluded that it offers many benefits for the replanting program, including extending the planting day (by operating at night under lights) and planting season (with the option of irrigation), spot site preparation, and GPS navigation and tagging of tree planting locations. (Campbell, 2020).

Bracke Planter – Sweden

The Bracke P12.a (Figure 26) is intended for planting in warm, dry conditions. It is suitable for plantation forestry, e.g. eucalyptus plantations. The Bracke P12.a can perform the entire scarification and planting process, or solely planting. The P12 could be equipped with our new, bigger seedling carousel. Integrated systems for irrigation and fertilization are also available as optional equipment for the Bracke P12.a. The Bracke 12 planting carousel can hold up to 196 seedlings. The Bracke planting head can also be attached to a bulldozer which can run 3 planting heads.

Figure 26 Bracke 12

Figure 27 Bracke B12b planting Eucalyptus in Brazil

Komatsu D61 EM

In 2019 Komatsu forest presented to Brazilian companies the Komatsu D61 EM (Figure 28), specially developed for mechanised planting. The Planter version was developed by Brazilian, Japanese, and Swedish engineers, especially for forestry applications. A subsoiler will prepare the site and the planter will then travel down the rows, which can be up one kilometre long. The machine can operate on up to 10-degree slopes.

Figure 178 Komatsu D61 EM planting machine

With a theoretical planting capacity of 900 seedlings/hour, the Komatsu D61EM plants three rows at a time, fully automatically, in planting spacings ranging from 3 to 3.5 meters in approximately 12 seconds, which increases productivity. The equipment prepares the pit, positions the seedling and irrigates it. The “seedling holder” is quick and easy to change.

The machine is controlled by an autopilot that keeps on track and has a high-precision planting georeferencing system, using GNSS, which records the result of the process and the position of each plant.

Komatsu D61EM reduces manual work, lowers production cost, can be operated overnight, with job status visualization and planting information recorded (Komatsu, 2019)

In June 2022 it was announced that Komatsu Forest has purchased the Swedish Bracke company (Newsroom, 2022).

Ancoman Planting System – South Africa (semi mechanised)

This system (Figure 29) uses pressurised water for pitting and cultivation and also provides the moisture for seedling establishment. Up to five planters can follow the machine.

Figure 189 Komatsu D61 EM planting machine

Novelquip – Proplant 1 – South Africa

The Novelquip Proplant 1 (Figure 30) can cultivate, spray, plant, water and fertilise. This machine can operate on a 6 tonne excavator. (at prototype stage) (Novelquip, 2022).

Figure 30 Novelquip Pro Plant 1

FUTURISTIC AND ROBOTIC PLANTERS

There are a number of concept planting machines that if successful could completely change the tree planting process.

AutoPlant

KTH, a European technical and engineering university is working on a robotic, teleoperated planting concept.
The goal is to implement a collaborative project with a focus on economically, ecologically and socially sustainable technology solutions for gentle and productive forest rejuvenation through automation. (Autoplant, 2022). .

AutoPlant is a Vinnova-funded (Sweden's Innovation Agency) collaboration project between the parties Skogforsk, LTU, KTH, Bracke, the Forestry Technology Cluster, SCA, Södra, Sveaskog and Holmen.

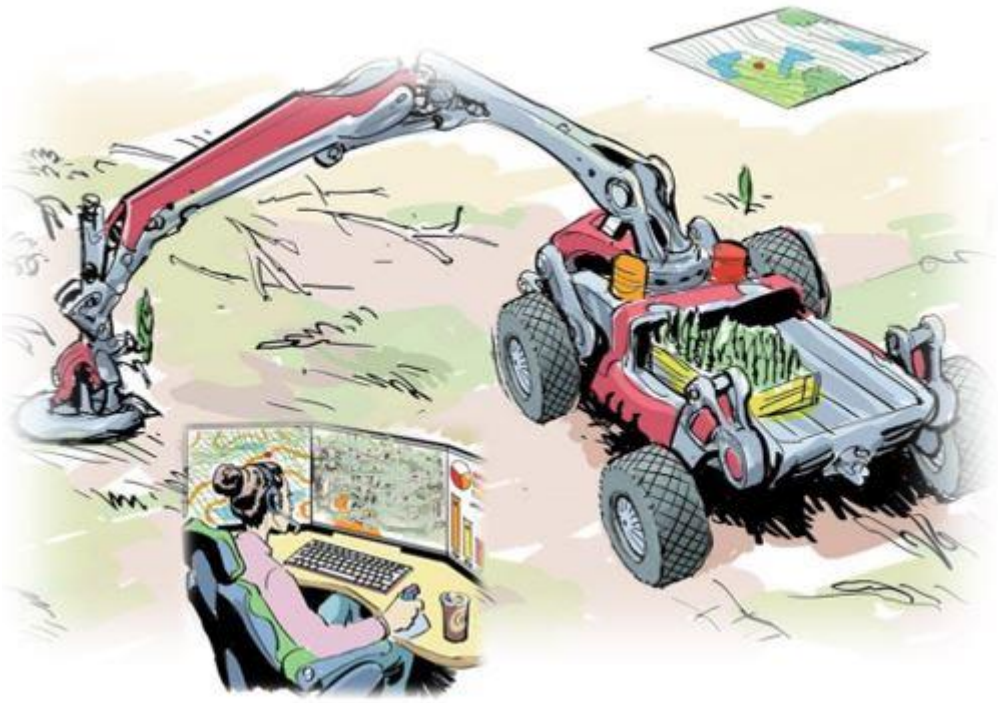

Figure 31 Autoplant

EBeaver

Södra which is a Swedish forestry cooperative has a forestry modernisation project called the BraSatt Project with the goal of developing new forest technology for soil preparation and planting (Figure 32). The hope is to have a prototype machine ready for testing during the 2023 planting season (Ramantswana, 2021).

Figure 32 E Beaver

Real Carbon Capture Machine – Forest Bot

This concept is being developed at a theoretical stage in Brazil.

RCCMv.4.0 is a100% autonomous machine (Figure 33) that plants (silviculture) without any human interference. RCCMv.4.0 aims to plant trees faster and with more quality than any planting team, making afforestation a cheaper, faster, and smarter process. Planting at a speed of 10,800 seedlings per hour, and using 1,600 seedlings per hectare, the machine will plant an average of 6.75ha per hour, a record in the forestry sector. In 8 hours, without any human operator, the machine plants 54ha of seedlings. RCCMv.4.0 will georeference all planted seedlings, and uses intelligent systems to move, avoid obstacles and plant..

The autonomous functionality includes self-driving, selection of trays(seedlings), loading of the planting mats, Geo process planting by seedling Artificial intelligence.

Figure 33 Forest Bot

Milrem Robotics Multi-Scope Robotic Forester – Estonia

Estonian company Milrem Robotics, who make unmanned ground vehicles for military and rescue services, are also working on a robotic forestry planter (Figure 34). This is a semi-autonomous forest regeneration system which will cover all the main regeneration operations such as: soil preparation, planting and early tending/clearing. This machine will automate the first five years of forest management and it will provide the forestry industry with a more productive and cost-effective regeneration solution. The concept of the Robotic Forester includes two different functionalities integrated to the Multiscope UGV. The Multiscope includes the Forester Planter and the Forester Brushcutter. These machines will be working hand in hand autonomously in the field. Soil preparation and planting will be carried out by Multiscope Forester Planter and vegetation management such as early tending will be carried out by the Multiscope Forester Brushcutter which will move autonomously between the planted trees and cut the unwanted vegetation to decrease competition (Milrem Robotics Multiscope Forester Planter, 2022)

Figure 194 Milrem Robotic Planter

PLANTING BY AIR

There are a number of Unmanned Aerial Vehicles or commonly known as Drones now testing how planting can be conducted by air. This is completed by firing or dropping a seed pod from the air.

Envico Technologies Ltd – Tauranga

Envico has been working with a number of companies on seed planting (Figures 35 and 36), but to date this has only been for indigenous tree restoration where final spacing is less important, Sam from Envico says 'we will spread 50,000 seeds in an area where we expect 5,000 will survive and the stocking may be higher in certain areas'. They are currently considering a trial with seedlings.

Envico has been conducting pre plant spot spray trials and is currently working on spray calibrations with Scion. Their drones are all made in their own workshop and can currently lift 50 kilograms. The batteries will last 20 minutes, and they run a number of batteries so that there is always one charged by the onsite generator to ensure downtime is minimised.
(Vye & Envico, 2022)

Figure 205 Envico drone

Figure 216 Envico seed pod

Aerolab – Auckland

‘New Zealand’s home of smart agriculture’ markets two products, unmanned aerial Figure 37), and unmanned ground vehicles (Figure 38). The UAV have been trialled in Hawkes Bay by PF Olsen for spot spraying and have also been successfully used for spraying of weeds in native areas. The UGV could be used for spot spraying on the ground or for tree delivery in manual operations. Both can run RTK accuracy with good satellite signal.

Figure 7 Aerolab XAG UAV

Figure 22 Aerolab UGV

Droneseed – USA and New Plymouth, NZ

Droneseed is an American start up tech company that was established about three years ago. They have bought Silverseed to assist with seed sourcing and aims to be a one stop shop for reforestation. The aim is to do this at scale, such as the reestablishment of forests burnt in the US and Canada.

Drone seed uses a seed vessel (Figure 39) or puck (50 x 50 x10mm) rather than a pod to establish the seedling. Seed pods tend to get damaged on impact and the vessels are dropped from a UAV (Figure 40) at a lower altitude and speed to allow for better survival.

'Droneseed has been involved in trials in NZ but is not at the commercial stage yet' (Keith Mitchell, 2022).

Figure 239 Droneseed vessel

Figure 40 Droneseed UAV can hold 1000 seeds

At this point drone planting does not provide a survival rate that is acceptable for plantation forestry. Survival may be successful in certain areas, but this is due to the amount of seeds deployed and would therefore not meet our spacing requirements.

SUMMARY AND RECOMMENDATIONS

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 hand tools used last century will subject the New Zealand forestry sector to further difficulties and then costs to get their trees planted at the correct time and standard.

To date New Zealand has been slow to uptake mechanisation in tree planting, this is probably due to the lower operational cost of planting and the risks associated with planting. This operation has not come with risk associated with harvesting and engineering, so research and development has tended to focus on these areas. Manual tree planters have always been very efficient and economic, so to be competitive we need machines to be replacing a number of labour units and be productive and of good quality. All of the machines will be unsuitable for certain NZ sites, this will be more about soil conditions than slope, the machines are still large so soil disturbance during winter months will be an issue in certain soil types.

There is interest in moving towards mechanised planting as we have seen three of New Zealand's largest forest owner/managers now using machines from Nordic and Scandinavian countries. The machines have been typically the more robust and less complex machines (such as M-Planter) which has also come with good service. Further work needs to be done on how these machines are operating in New Zealand. Worldwide we are seeing a move towards mechanisation in tree planting with more work being conducted on new machines and now a number being utilised in South America.

The pivot steer forwarder type machines may offer better productivity due to the twin arm planters and less down time with restocking of the planting head/s.

There is a real opportunity for data capture with planting mechanisation as each tree can be given its own identity and location at point of planting. Do we see a shorter and larger diameter tree planted as our production thinning crop planted in between our top end crop trees? This would then provide more volume and value from our initial stocking.

Aerial options for tree planting are still limited for our requirements but are now becoming more of an option in pre-plant and post-plant spraying, and then for data capture once the tree is established.

Moving forward we need to understand the different objectives of our owners and measure the different mechanised operations we have on our doorstep. NZ can also develop its own mechanised planters that suit our trees and conditions. Industry needs to work with the engineers, contractors and nurseries and industry needs to work with aerial operators and the nurseries on solutions for successful aerial establishment

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.

New technology will also require a different type of contractor and employee to operate these machines. There will be capital outlay requirements and considerations of what the machines can do in the off season such as land preparation or potentially summer logging with the pivot steer equipment. The aim is to make the work less physical, safer and more attractive to more of New Zealand's available workforce.

There will also be some potential synergies and crossover between the other silviculture mechanisation processes.

REFERENCES

Autoplant. (2022). Retrieved from https://www.kth.se/mmk/mechatronics/current-projects/autoplant-1.1076636

Baker, M. (2018). *Mechanised Silviculture.*

Cameron, & Baker. (2022). pers comm. *Manulife and Timberlands.*

Campbell, R. (2020). *Mechanical planting trials show promise for plantation establishment*. Retrieved from Forestry Corp: https://www.forestrycorporation.com.au/about/releases/2020/mechanical-planting-trials-show-promise-for-plantation-establishment

Ersson, B. T. (2010). *Possible Concepts for Mechanized Tree Planting in Southern Sweden.*

FITEC. (2000). *Best Practice Guidelines for Tree Planting.*

http://www.m-planter.fi/en/Products.html. (2022). Retrieved from http://www.m-planter.fi/en/Products.html: http://www.m-planter.fi/en/Products.html

https://risutec.fi/pm-tree-planting-machine/. (2022). *https://risutec.fi/pm-tree-planting-machine/*. Retrieved from https://risutec.fi/pm-tree-planting-machine/

IRIS. (2012). *Incident Recording Information System*. Retrieved from Safety Alerts: https://nzfoa-iris.com/safetyalerts.aspx

Johnson, P. (2020). Swedish forestry # 3 – Reforestation. *Swedish forestry # 3 – Reforestation*.

Keith Mitchell, p. c. (2022, June 2). Liason Manager. New Plymouth.

Komatsu. (2019). *Komatsu Forest presented the Komatsu D61EM Planter*. Retrieved from www-komatsuforest-com-br

LOGINFOR. (2022). Retrieved from www.loginfor-cl

Milrem Robotics Multiscope Forester Planter. (2022). Retrieved from https://milremrobotics.com/commercial/

MPI. (2022). *MPI*. Retrieved from MPI.

Newsroom. (2022, June 17). *Komatsu Forest AB acquires Bracke Forest AB*. Retrieved from https://www.komatsuforest.com/media/newsroom/komatsu-forest-ab-acquires-bracke-forest-ab

Novelquip. (2022). *Novelquip Proplant 1*. Retrieved from https://www.nqfsa.com/products/#PlantingEquipment

NZFOA. (2021). *Facts and Figures.*

NZFOA. (2022). *IRIS*. Retrieved from https://nzfoa-iris.com/safetyalerts.aspx

Plantma. (2022). *Plantma*. Retrieved from Plantma: https://plantmaforestry.com/

Pottiputki. (2022). *Pottiputki*. Retrieved from http://pottiputki.com/produkter-hallare-eng/

Ramantswana, M. (2021). BraSatt project – planting machine developments.

Risutec. (2022). Retrieved from Risutec: https://risutec.fi/pm-tree-planting-machine/

Robert Radics, L. D. (2019). *PLANTERBOT – PLANTING ROBOT.* Christchurch: Scion .

Supplies, F. (n.d.). *Forest Supplies*. Retrieved from https://www.forestry-suppliers.com/product_pages/products.php?mi=66351&itemnum=69048

Terratech. (2022). *Hoedad*. Retrieved from https://terratech.net/products/fire-equipment-control/planting-hoe-hoedad-forest-planting-tool-complete/

Vye, S., & Envico. (2022). Envico Technologies Ltd. Tauranga, NZ.