Discovering Global Automation & Robotics Relevant to Australia's Forestry Needs

An Industry-led Technology Scan

Final report

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Forest & Wood Products Australia

Discovering Global Automation & Robotics Relevant to Australia's Forestry Needs: An Industry-led Technology Scan

Prepared for

Forest & Wood Products Australia

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EXECUTIVE SUMMARY

This project, commissioned by Forest & Wood Products Australia (FWPA) and delivered by Lincoln Agritech Ltd, undertook a comprehensive global scan of automation and robotics technologies relevant to the Australian forestry sector.

The work focused on identifying technologies with potential to improve forestry operations in Australia and assessing their relevance across the value chain, from nurseries and silviculture through to harvesting, logistics, and fire management. This was supported by collaboration with an industry Steering Committee, targeted analysis of international developments, and the establishment of the Australian Forest Robotics Wiki as a shared knowledge resource.

The project positions automation and robotics as part of a broader transition toward more data-enabled, integrated forestry systems. Rather than treating technologies as standalone solutions, the report emphasises the importance of embedding them within operational, organisational, and data frameworks.

1.1 Context and Industry Opportunity

The global technology landscape shows that a wide range of automation and robotics solutions are already available, with varying levels of maturity and operational deployment. In a number of international forestry contexts, selected technologies are contributing to improvements in productivity, safety, and operational consistency. However, experience also indicates that the successful application of these technologies depends less on their technical availability and more on the conditions supporting their use.

For the Australian forestry sector, this creates a clear opportunity to selectively adopt and adapt technologies in a way that aligns with local operating conditions, workforce capability, and existing systems. The ability to translate global developments into practical, locally relevant applications is likely to be a key determinant of outcomes.

1.2 Potential Industry Benefits

The technologies examined in this project have the potential to contribute to:

- Improved productivity through more efficient and consistent operations
- Enhanced safety by reducing exposure to high-risk tasks and environments
- Greater resilience to labour constraints through changes in how work is performed
- More precise and environmentally controlled operations
- Improved workforce attraction through increased use of technology-enabled roles
- Enhanced capability for proactive and targeted fire management

In addition, the process of engaging with these technologies can support broader capability development in areas such as data management, systems thinking, and digital integration.

1.3 Key Considerations for Adoption

A consistent theme across the analysis is that the benefits of automation and robotics are closely linked to the broader system in which they are deployed. Factors that appear to influence adoption outcomes include:

- The level of understanding and confidence among decision-makers and operators
- The availability of locally relevant performance evidence
- Workforce capability, particularly in relation to digital systems and data use
- Supporting infrastructure, including connectivity and data platforms
- Integration with existing operational processes and systems
- Opportunities for collaboration and shared learning across the sector
- Alignment with regulatory and governance frameworks

These considerations are reflected in more detail throughout the body of the report and underpin the recommended approach to implementation.

1.4 Recommended Direction of Travel

Drawing on both the technology scan and international experience, the report suggests a number of practical areas of focus for the Australian forestry sector. These are consistent with, and directly informed by, the detailed recommendations provided in Section 7 of the report:

1. Focus on mature and proven technologies - initial efforts are likely to benefit from prioritising technologies that are already commercially available and have demonstrated value in comparable operating environments.
2. Adopt a staged and incremental approach - progression from mechanisation to operator-assist systems and, over time, to more advanced automation reflects the pathway observed internationally and aligns with current industry capability.
3. Strengthen awareness and capability - building understanding of technology capabilities and limitations, alongside investment in training and skills development, is likely to influence the effectiveness of adoption.
4. Support deployment through local testing and validation - structured trials in Australian conditions can play an important role in building confidence and informing investment decisions.
5. Enable integration through infrastructure and systems - connectivity, data platforms, and interoperability are foundational to realising value from many of the technologies considered.
6. Encourage collaboration and knowledge sharing - mechanisms such as the Australian Forest Robotics Wiki provide a basis for collective learning and more coordinated industry adoption.
7. Recognise the need for localisation - technologies developed in other regions may require adaptation to suit Australian terrain, species, and operational practices.
8. Engage early with regulatory and governance frameworks - early consideration of regulatory requirements can support smoother deployment pathways for emerging technologies.

1.5 Conclusion

This project provides a structured overview of automation and robotics technologies relevant to Australian forestry and establishes a foundation for informed decision-making.

The work indicates that the opportunity for the sector lies not only in identifying appropriate technologies, but in how they are introduced, integrated, and supported over time. A considered, staged approach, supported by capability development, collaboration, and locally relevant evidence, appears well aligned with both international experience and the current position of the Australian industry.

The Australian Forest Robotics Wiki, established through this project, offers a practical mechanism to support ongoing knowledge sharing and to maintain visibility of emerging developments as the sector continues to evolve.

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2. INTRODUCTION

2.1 Background

Australia's plantation forestry sector faces intense compounding pressures. While global demand for wood products is rising, the available workforce is shrinking, aging, and facing persistent labour supply challenges. At the same time, there is a need for businesses to progressively scale up high-quality silvicultural activities, including planting, while working toward reducing costs and maintaining high standards of efficiency and safety in harvesting operations.

To remain sustainable, the industry must meet rising health, safety, and environmental standards without sacrificing product quality. It should also balance societal expectations to boost forest ecosystem services and minimise bush fire risks while lowering detrimental environmental impacts, and attempting to increase ecosystem services such as biodiversity enhancement, water & soil conservation, and recreation.

Despite having to work in the outdoors and in challenging environments, potential recruits are still interested in the sector. However, to secure this future talent for operational and leadership roles, the industry should offer the same advanced technology support and workplace standards found in other industries.

For this comprehensive global scan of automation and robotics technologies - commissioned by Forest & Wood Products Australia (FWPA) and conducted by Lincoln Agritech Ltd (LAL, New Zealand) - the R&D team has worked together with a project Steering Committee of experienced staff from Australian forest management companies.

Together they identified and agreed on a shortlist of technologies with strong potential for the Australian forest management business context. These span augmented reality, operator-assist systems, digital twins, nursery automation, autonomous planting, novel fire control equipment (e.g. UAV/drones), truck platooning, and wearable support systems.

Although the focus of this report targets automation and robotics, the working group has shown that there are strong overlaps to technologies that are not automated yet but are essential in preparing the pathway to automation and even autonomy through robotics.

The listed technologies exist, with some in the early stage of adoption in other parts of the world. The challenge is whether the conditions exist to adopt them successfully and quickly to improve Australian Forest Industry's perspectives, grow more wood and strengthen Australia's Forest industry's position in the highly competitive global wood market.

2.2 Aim

The aim of this project is to identify a shortlist of areas of interest for the Australian Forestry industry and then prepare in-depth profiles of individual tools and technologies in these areas of interest.

2.3 Key benefits "desired"

Together, these initiatives aim to lift performance and resilience across the forestry value chain by delivering higher productivity through better use of technology, data, and automation, while also enabling the development of innovative work methods that move beyond traditional, labour-intensive practices. By redesigning tasks and introducing assisted or automated processes, they provide practical ways to address persistent labour supply challenges, ensuring critical operations can continue even as workforce availability tightens.

A strong emphasis is placed on enhancing safety, particularly by reducing the need for manual work in hazardous environments, lowering operator fatigue, and limiting exposure to high-risk tasks. At the same time, more precise operations help reduce environmental damage, minimising soil disturbance, unnecessary biomass removal, and collateral impacts on surrounding ecosystems. These improvements are not only operationally beneficial but also support broader sustainability and social licence objectives.

Modernising forestry work in this way also plays an important role in attracting new talent. Technology-enabled roles that emphasise skills, problem-solving, and digital capability are more appealing to more diverse entrants than physically demanding, repetitive work, helping to renew the workforce over time.

Finally, these approaches create opportunities to investigate how robotics and automation can contribute to fire-risk reduction, particularly through economical and proactive management of forest “fire fuel”. By enabling targeted, lower-cost treatment of residues, understory, and biomass, robotics-supported systems offer a pathway to reducing fuel loads at scale, complementing traditional fire management strategies while delivering measurable productivity, safety, and environmental benefits.

2.4 Objectives

1. Identify up to eight Australian foresters (project Steering Committee) and jointly define robotics search categories by prioritising focus areas that directly impact relevant forestry tasks and activities in Australian forest-growing regions.
2. Analyse global forest robotics innovations (realised, upcoming and R&D proof of concepts), focusing on Australia. Identify technologies aligned with Forest & Wood Products Australia's focus areas, profile industry-selected technologies, and highlight their potential benefits.
3. Organise an industry-wide discussion (growers, contractors, researchers, technology suppliers) to explore and critically prepare in-depth profiles of anticipated silviculture automation, identifying deficits, areas for improvement, and feedback for the equipment industry.
4. Disseminate and discuss project results and launch the collaborative Australian Forestry Robotics wiki to the Australian forest industry through an informative webinar.

2.5 Outputs

1. Stakeholder Engagement and Communication Plan: A roadmap for the project that includes establishing an industry project Steering Committee, building relationships, sharing information, and ensuring involvement and benefits for the Australian forestry industry.
2. Summary of industry engagement activities providing details of industry engagement, including workshop participation, key discussions, and insights from growers and industry representatives.
3. A plan offering guidance on implementing selected automation and robotics in the industry, defining R&D requirements and conditions for adoption, and summarising a system to keep the industry informed about relevant developments following the project.
4. A webinar, final report and presentations outlining the findings of the work, along with feedback from the project Steering Committee. The Wiki is a “living” repository of project findings and documents, being managed by industry for future input and commentary.

2.6 Findings will help Australian forestry industry

The findings are expected to provide significant value to the Australian forestry industry by guiding future direction and capability development. They will support the prioritisation of relevant adaptation measures and research and development efforts in automation and robotics, ensuring that investments are focused on areas with the greatest potential impact. In addition, the findings will contribute to building industry skills and improving understanding in key areas such as automation, data, and robotics, helping to prepare the workforce for emerging technologies. Ultimately, this work will support the gradual integration of robotics into forest management practices, enabling more efficient, innovative, and sustainable approaches across the sector.

2.7 Preconditions for Adoption

This section outlines the structural and organisational prerequisites needed for these technologies to deliver lasting benefits for Australia’s plantation forest industry and the nation. The following eight preconditions are necessary. They apply across all the technology areas identified in the scan of this report. None of them is optional; weakness in any one of these will limit the value of investment and adaptation efforts in the others.

2.7.1 Awareness and understanding

Foresters, contractors, and managers should remain informed about the technologies available on a global scale and have a clear understanding of each technology’s capabilities and limitations. The scan of this report identified over 300 technologies across six categories, aligned with Forest & Wood Products Australia's focus areas:

1. Site planning and tree inventory
2. Nursery and establishment
3. Silviculture
4. Harvesting and extraction
5. Logistics
6. Protection of humans, assets and the crop.

The review suggests that Australian operators are working to keep pace with developments in leading systems, although familiarity with many of these technologies is still developing. Closing this awareness gap is a necessary step. Decision makers in the businesses and operations should judge which technologies suit their terrain, species, and operational model - and at what stage of their business cycle investment in such technologies makes sense in advancing the business.

2.7.2 Evidence from Australian conditions

Many of the technologies reviewed were developed in Europe, North America, or New Zealand. European tree-planting machines, for example, are often designed for uniform terrain and homogeneous species. When transferred to Australia's more variable conditions - steeper slopes, heavier debris, eucalypt stock - performance of the technologies or economic viability may drop significantly. However, robust data is often missing, and Australian foresters are hesitant to invest without evidence from Australian trials. Ideally, these trails should encompass multiple seasons, multiple sites, and a range of operational contexts.

2.7.3 Investment readiness - financial and human

Adoption costs vary widely. Remote-controlled felling wedges cost between $3,000 and $12,000 per unit. Nursery automation lines range from $200,000 to over $2 million. Digital twin platforms (a set of computer models for a defined biological, technical or organisational system) can cost hundreds of thousands of dollars, most likely millions, on software and integration alone. Autonomous planting systems remain pre-commercial, and many emerging or anticipated autonomous systems will require some kind of human supervision, thus labour cost. Organisations need to plan for these costs realistically, including the costs of training, integration, and early-stage unreliability. The industry should consistently provide evidence-based datasets to support its assessments. Equally important is human investment: staff at all levels - operators, supervisors, planners – should become comfortable working with data, sensors, and digital systems. Industry-wide data literacy is not a luxury; it is a prerequisite for adoption and subsequently realising economic, organisational and environmental benefits.

2.7.4 Training and support

New technology adoption tends to fail when (i) decision-makers lack confidence in evaluating whether a technology is suitable for their operating conditions, and (ii) users are unable to anticipate, or are unfamiliar with, how to effectively use, maintain, or troubleshoot it. The technology scan indicates that operator-assist systems, already offered by major manufacturers such as Komatsu, Ponsse, John Deere, and Tigercat, are not being utilised to their full potential in Australia. While these systems are designed to improve productivity, precision, and safety through features such as automated boom control, optimised cutting patterns, and real-time performance feedback, their effectiveness depends heavily on operator understanding and skill.

In many cases, operators have received only basic training focused on machine operation, rather than on the advanced functionalities of these systems. As a result, key features remain underused, limiting the productivity gains and efficiency improvements that the technology can deliver and potentially reducing return on investment. Additional factors, including a lack of structured training programs, limited exposure to best practices, and variability in operator experience, contribute to inconsistent adoption across the sector.

While advanced operator-assist technologies are already embedded in much of Australia's harvesting fleet, their utilisation remains uneven and is often confined to basic functions. Consequently, many of the intended benefits, such as improved productivity, more precise value recovery, enhanced safety, and greater operational consistency, are not being fully realised. This gap suggests that the primary constraint is not the availability of technology, but rather the capability of operators and decision-makers to apply it effectively, supported by appropriate training, systems integration, and operational frameworks. Without addressing these factors, the industry risks under-leveraging its existing capital investment and limiting its transition toward more data-driven, efficient, and progressively autonomous forest operations.

Training relevant to operator-assist systems is available in Australia, but it remains fragmented across equipment manufacturers, registered training organisations (RTOs), and industry-led programs, rather than being delivered through a coordinated framework. Major original equipment manufacturers (OEMs), such as Komatsu and John Deere, provide the most directly relevant training, typically combining machine delivery instruction with advanced and customised courses, and, in some cases, simulator-based learning. Other manufacturers, including Ponsse and Tigercat, generally follow similar approaches, with training closely linked to machine deployment and focused on operational and technical capability. However, these programs are often relatively short and aimed at achieving basic competence, rather than fully developing operators' ability to exploit advanced operator-assist features.

In parallel, broader training pathways delivered through RTOs, TAFE institutions, and industry initiatives provide nationally recognised qualifications and build foundational machine operation capability, with some exposure to simulators and digital systems. While valuable, these programs generally do not emphasise the advanced use and optimisation of operator-assist technologies. Simulation-based training platforms, such as AVATAR (Skogforsk), offer a practical pathway to accelerate skill development without the cost and risk of on-machine learning. To fully realise the benefits of these technologies, training programs should extend beyond basic operation to include the silvicultural and operational logic underpinning the data being generated and applied.

2.7.5 Systems infrastructure

Technology cannot function without the infrastructure to support it. In Australian forestry, this means reliable high-speed connectivity in remote estates - currently lacking across much of the sector, but widely available satellite based mobile coverage systems such as Starlink can close that gap quickly. It also means access to equipment suppliers, service technicians, and spare parts in regional areas. It means cloud computing capacity with appropriate cybersecurity. And it means the organisational systems - inventory databases, GIS platforms, harvest schedulers, Forest Management Information Systems (FMIS) - into which new technologies should feed their data (and draw data for operations). The scan found that digital twins, for example, deliver little value in isolation; their benefit depends on integration with operational data from machines, logistics systems, and forest inventories.

2.7.6 Cross-industry data sharing and analysis

The full benefit of automation and digital tools will only be realised when data is shared and analysed across the industry, not just within individual companies. Stand-level thinning data from one operator, combined with seedling quality data from nurseries and survival data from planting crews, can reveal patterns that no single organisation could detect alone. The FWPA wiki - a living, industry-managed knowledge base launched as part of this project - is a practical first step. Cross-industry benchmarking, shared trial data, and collaborative analysis are the longer-term goal (see table below).

2.7.7 Integration with existing systems

New technologies should connect with what is already in place. An AI-based seedling grading system in a nursery can add value if its output feeds into planting logistics and field survival records. A digital twin is only useful if it draws on real data from in-forest or surveying sensors, machines (communicated through wireless telemetry) and real inventory from the forest, finally feeding into Forest Management Information Systems. Autonomous planting machines require tight integration with nursery propagation systems, site preparation standards, and digital planning tools. Compatibility (e.g. ISOBUS (ISO 11873) - an international standard for 'plug-and-play' in electronic communication in agriculture and forestry machinery – is necessary to lower adoption barriers due from challenges in technical connectivity and data exchange) is not a technical afterthought - it should be designed in from the start.

2.7.8 Regulatory compliance

Several of the technologies identified in the scan operate in regulated airspace or on public roads. Fire-suppression drones require airspace integration and regulatory approval before routine deployment. Truck platooning on public roads is subject to transport legislation that varies by state. Autonomous machinery on steep terrain or unpredictable and highly varying ground raises additional workplace health and safety obligations. Operators should map the regulatory landscape for each technology before committing to deployment and engage with regulators early to shape practical frameworks. Some of that requires negotiations between industry bodies (foresters, contractors, equipment manufacturers) and governance (regulators, R&D funders, educational) to ensure an industry and public good outcome.

2.8 Technology Infrastructure

Translating these preconditions into practice requires a Technology Infrastructure - a set of enabling capabilities that should exist at industry level, not just within individual businesses.

Without this infrastructure (key areas: see next table), individual technology investments will underperform. With it, the technologies identified in the scan can compound - each one making the next easier to adopt and more valuable in use.

Table 1 Technology Infrastructure - a set of enabling capabilities that should exist at industry level, not just within individual businesses.

Component	What it means in practice
Awareness and evidence	Long-term demonstration sites, managed by the industry; training at all roles and education levels; communicating and using the Australian Forest Robotics Wiki
Data literacy	Operators, managers and contractors who understand data, variability (of trees, sites, humans), and digital systems; digital technology-aware R&D providers, authorities and public governance.
Silvicultural understanding	Ability to connect data outputs to management decisions; trained in integrated 'system thinking' and learned to ask 'critical questions' when evaluating and deciding on technologies.
Data collection and benchmarking	Shared trial data; cross-industry analysis, openness to share and discuss performance data and learnings across the sector.
High-speed connectivity	Reliable internet access in remote forest estates, e.g. satellite supported mobile networks; network of GNSS base stations for high-accuracy and reliable RTK-GNSS (Global Navigation Satellite Systems).
Mechanisation and robotics access	Equipment supply, servicing, and training in regional areas; popular communication of advancements in forestry automation and robotics; technology testing facility integrated into forest R&D
AI and analytics capability	Industry-wide capacity to use and interpret data-driven tools; creating data pools for enabling company-agnostic, cross-regional training of AI systems for transferring and advancing the sector.
Cloud computing, cybersecurity and international standards	Secure, scalable, transparent and open, non-proprietary digital infrastructure; focusing on international technology standards, e.g. ISO Bus for data flow in forest equipment, up to the office and processing.

2.9 Implementing the Findings of this Report

The technology scan (targeting automation and autonomy (robotics) in forest equipment) identified eleven priority technology areas for Australia. The table below summarises their current maturity and the most important adoption considerations.

The highest-confidence pathway for Australia's forest industry is sequential. Digital cognition should precede physical automation. Biological variability in nurseries needs to be managed well (not always need to be reduced) before mechanised planting can succeed. Operator assistance should mature before labour is removed from the cab. Autonomy, when it arrives, should be the outcome of an integrated system - not its starting point.

Table 2 Technology Readiness Level

Technology	Technology Readiness Level	Key adoption consideration
Augmented reality (AR)	TRL 5–7	Data pipelines and connectivity should exist first; Augmentation devices (screens, goggles, contact lenses, headsets) need substantial advancement
Automated battery switching (for electric trucks)	TRL 5–7	Best suited to fixed route, high-utilisation corridors; fixed networks or photovoltaic energy supply. Higher TRL in China.
Autonomous planting	TRL 5–6	Requires nursery standardisation and site preparation discipline
Digital twins	TRL 6–8	Value depends on data quality and organisational adoption
Fire control UAVs	TRL 5–8	Regulatory approval and airspace integration required
Operator assistance (emerging)	TRL 6–8	Promising; requires adaptation for Australian conditions
Operator assistance (e.g. as OEM)	TRL 7–9	Available now; training is the main barrier
Truck platooning	TRL 6–7	Practical on fixed forestry corridors; regulatory framework needed
Nursery automation	TRL 8–9	Mature; modular adoption is feasible now
Remote-controlled felling wedge	TRL 8–9	Immediately deployable; strong safety return
Exoskeletons	TRL 9	Immediately deployable; low cost; high workforce acceptance

2.9.1 Roger's technology adoption curve

The Rogers technology adoption curve (Figure 1) is a useful frame. The first 16% of adopters - technology enthusiasts - will engage readily. The challenge is to cross the chasm to the early and late majority. That crossing requires demonstrated field performance over multiple seasons, not just 'polished' pilots. It requires business models that share risk between technology providers and operators. And it requires an industry that is organised to learn collectively, not just individually.

Figure 1 **Roger's technology adoption curve. https://i2.wp.com/www.business-to-you.com/wp-content/uploads/2020/03/Technology-Adoption-Life-Cycle-Crossing-the-Chasm.png?ssl=1**

2.10 Help from a valuable Industry Resource

The FWPA Global Scan has established a strong foundation through the development of the Australian Forest Robotics Wiki, creating a living, continuously updated knowledge repository for the sector. This presents a clear opportunity for the industry to move beyond knowledge sharing toward coordinated, industry-wide implementation. By prioritising technologies that are already mature, commercially available, and proven to deliver safety and productivity benefits under Australian conditions, the sector can accelerate adoption, capture immediate gains, and build confidence in the integration of more advanced systems over time.

3. METHODOLOGY

3.1 Steps

The project commenced with the identification of a project Steering Committee drawn from the Australian forestry industry to provide guidance and expert input. A comprehensive longlist of globally available technologies was then compiled and presented to the project Steering Committee for review. Based on this engagement, key focus topics for further investigation were identified, enabling the development of a refined shortlist of technologies and tools. In-depth profiles were subsequently prepared for these priority areas, covering both individual technologies and broader capability categories. Interim findings, including draft analysis and progress on the supporting wiki, were shared through a webinar presentation to stakeholders. The project concluded with the delivery of final findings, the publication of the final report, and the formal launch of the wiki as an ongoing knowledge resource. Artificial Intelligence tools were used to help compile findings into some of the tables in this report.

3.2 Technology Readiness Level

Technology Readiness Levels (TRLs) provide a standardised framework for assessing the maturity of a technology, from early scientific concept through to proven operational deployment. The TRL scale was originally developed by NASA to support consistent decision-making in technology development and acquisition, particularly for complex systems with long development pathways and high operational risk (Mankins, 1995). The framework defines nine discrete levels, with TRL 1 representing basic principles observed and TRL 9 representing systems proven through successful mission or operational use. TRLs do not measure performance or effectiveness; rather, they indicate the degree to which a technology has been demonstrated in increasingly realistic environments. In this report, TRLs are used to provide a consistent and transparent indication of technology maturity across emerging forestry, UAV, and workforce-support systems, enabling comparison of readiness for pilot deployment, scaling, or operational adoption.

Table 3 Standard interpretation of the NASA Technology Readiness Level (TRL) framework, Mankins, 1995.

Technology readiness level (TRL)	Readiness Classification	What This Level Represents	Deployment Implication
1	Fundamental research	Basic principles observed and described	Research only
2	Concept formulation	Practical applications identified, not yet tested	Research only
3	Proof of concept	Analytical or laboratory validation of key ideas	Not deployable
4	Component validation	Individual components tested in controlled environments	Lab / test-site only
5	Prototype field trials	Subsystems validated in limited real-world conditions	Pilot-only, high risk
6	Integrated field demonstration	Full system demonstrated in realistic environments	Late pilot, pre-commercial
7	Operational pilot trials	System operates in normal working conditions with real users	Early deployment possible
8	Initial commercial deployment	Production-grade system in routine operational use	Deployable at scale
9	Fully mature commercial system	Proven, widely adopted, stable performance	Low technical risk

3.3 Cost of implementation

Where available, the cost of implementation of the outlined tools and technologies are given is Australian dollars.

3.4 Wiki

3.4.1 Help from a valuable Industry Resource

The FWPA Global Scan has established a knowledge base, the Australian Forest Robotics Wiki. The wiki provides a living repository. The next step is structured, industry-wide implementation - starting with the technologies that are already mature, already available, and already proven to deliver safety and productivity gains in Australian conditions.

3.4.2 Justification for the Wiki-Based Approach

This project adopted a large-scale wiki approach, consisting of over 300 interlinked pages rather than a single consolidated document. The decision to structure the content in this way was guided by established practices in collaborative knowledge systems, where complex topics are decomposed into smaller, concept-focused pages that are extensively cross-referenced. This structure supports clarity, navigability, and incremental expansion, allowing readers to access information at varying levels of detail without being overwhelmed by long, linear texts.

Large organisations and public knowledge platforms commonly employ this approach when documenting complex subject matter. Encyclopaedic and documentation ecosystems such as Wikipedia, Mozilla Developer Network, and open-source documentation projects distribute knowledge across many interconnected pages to support reuse, updating, and collaborative development. By following this model, the project reflects real-world practices in knowledge organisation and emphasises structure, consistency, and accessibility over document length.

The wiki format also facilitates iterative development, enabling individual pages to be refined independently while maintaining coherence through a shared structure and linking strategy. This approach is particularly suitable for topics with diverse sub-concepts, methodologies, or applications, and aligns with best practices in digital knowledge management. As a result, the multi-page wiki structure was a deliberate and justified design choice rather than an accumulation of fragmented content.

The wiki-based approach aligns with knowledge-management practices documented by the Food and Agriculture Organization of the United Nations (FAO, 2026) and the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF), 2025, both of which justify the use of modular, interlinked knowledge systems to manage the complexity and multidisciplinary character of agricultural and forestry knowledge.

3.4.2.1 Example: Food and Agriculture Organization of the United Nations (FAO)

The Food and Agriculture Organization of the United Nations adopted a large, distributed, wiki-type approach to knowledge publication in response to the increasing complexity, interdisciplinarity, and geographic diversity of agricultural and forestry systems. FAO explicitly recognised that agrifood knowledge spans multiple domains - such as crops, livestock, forestry, soils, water, climate, nutrition, and policy - and should be continuously updated to reflect new evidence and region-specific conditions. Rather than relying on monolithic reports, FAO structured its knowledge across interconnected platforms and topic-level pages to enable modular updates, cross-linking, multilingual translation, and reuse by diverse users, including researchers, policymakers, extension services, and practitioners. Following the adoption of this approach, FAO reported improved accessibility and reach of its knowledge outputs, greater integration across thematic areas, and increased uptake through partnerships with platforms such as Wikipedia. These impacts were framed in terms of enhanced knowledge discoverability, broader dissemination to non-specialist audiences, and increased resilience of information systems to ongoing scientific and policy change.

3.4.2.2 Example: Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF)

CIFOR-ICRAF developed a similarly large, modular collection of interlinked knowledge pages due to the inherently cross-cutting nature of forestry and agroforestry research, which intersects with climate change, biodiversity, livelihoods, land governance, and agricultural production systems. The organisation explicitly noted that forestry knowledge cannot be meaningfully represented as a linear narrative, as individual concepts and findings are frequently reused across regions and policy contexts and should remain open to revision as new evidence emerges. By structuring its outputs as thematic portals and focused concept-level pages, CIFOR-ICRAF enabled incremental updating, clearer navigation across complex topics, and stronger connections between research, policy briefs, and practical guidance. The impacts reported from this approach included improved coherence across research themes, greater usability of knowledge products for policy and development audiences, and increased capacity to maintain and update content over time. While not always described using the term “wiki,” the resulting system functioned as a wiki-type knowledge base, supporting sustained knowledge accumulation and long-term relevance rather than static publication.

3.4.3 Project Overview

A Wiki site has been set up for Forest & Wood Products Australia (FWPA) as a systematically catalogued reference of global forestry automation and robotics technologies, with an Australian industry focus. The knowledge base collected spans over 300 technology entries across the six main categories, namely Planning & Inventory, Nursery & Establishment, Silviculture, Harvesting & Extraction, Logistics & Mills Interface, and Protection & Compliance.

An Excel spreadsheet served as the single source of truth for all wiki content, enabling every team member to maintain and update the catalogue without direct interaction with the wiki platform. A Python-based pipeline translates spreadsheet edits into live wiki updates. Markdown files are generated locally first, allowing changes to be reviewed before anything is pushed to the live wiki. The entire application runs within a Docker container, making the deployment portable and environment independent.

There are two possible hosting options, (1) hosting on a low-cost cloud server such as Hostinger, administered by Lincoln Agritech for the first six months then handed over to an Australian forestry member organisation; or (2) self-hosting within the IT infrastructure of a member organisation. Under either arrangement, the content update workflow remains straightforward.

3.4.4 Platform Selection: Wiki.js

We evaluated four wiki hosting platforms, namely Wiki.js, BookStack, DokuWiki, and a WordPress wiki plugin.

BookStack presented a good match in terms of interface quality and usability. Its Books/Chapters/Pages structure is intuitive and easy to navigate, and for a small, manually maintained knowledge base it would be a practical choice. However, this same structure becomes a limitation at scale, technologies rarely fit neatly into a single category and bulk updating 300+ entries from an external source is not designed for BookStack.

DokuWiki was considered for its simplicity and lightweight architecture, and like BookStack would be a reasonable choice for a small, manually maintained site. However, the lack of a modern, well supported API made it a less desirable choice for a project requiring automated bulk content management from an external source.

The WordPress wiki plugin was only briefly considered: as a plugin built on top of a general-purpose web platform, it carries a large amount of functionality irrelevant to a knowledge base, adding unnecessary overhead.

Wiki.js was selected for its ability to support a fully automated pipeline driven from a source spreadsheet, with each page stored as a local file that can be reviewed before any changes go live. The platform is open source with no licensing cost and can be hosted on any standard server at little cost.

3.4.5 Future work

The future of the Australian Forest Robotics Wiki will require further input from the Australian Forestry industry. Lincoln Agritech will maintain and host the wiki until mid-2027, by which time hosting will have to be renewed to keep the wiki live beyond mid-2027.

A potential future work is an AI-assisted update feature. It can be triggered manually or on a schedule. The topic and context of each technology entry is submitted to a cloud based LLM with live web search access, which returns suggested updates. Administrators are notified to review and approve each suggestion before it goes live. The mechanism keeps the catalogue current with minimum monitoring.

4. RESULTS – LONGLIST OF TOOLS & TECHNOLOGIES

The full long list of identified technologies, tools, papers and reports is given in Appendix 1, with the full details of each technology available on the Australian Forest Robotics Wiki page at http://australianforestrobotics.wiki/

5. RESULTS – RECOMMENDED TOOLS & TECHNOLOGIES

5.1 Summary

Table 4 lists the sub-sections and the recommended tools & technologies in that sub-section as per the co-design process with the project Steering Committee. Details of the sub-section and recommended tools & technologies are given in the next sub-sections.

Table 4 Recommended Tools & Technologies

Sub-Section	Technology / Initiative
Augmented Reality	European COST Action CA23135
	Paper on Shaping the Future of Forestry through AR
Automated Battery Swapping / Electrified Transport	Janus Side-Mounted Modular Battery Swap
	CATL battery swapping system
	Caterpillar Battery-as-a-Service (BaaS)
	Transition to Efficient Electrified forestry transport
	Scania Megawatt Charging System
Autonomous Planting	Södra BraSatt 01
	Skogforsk AUTOPLANT
	US Patent US448388319 automated planting system
Digital Twins	Remsoft-anchored composite digital twin
	AFRY Smart Forestry
Exoskeletons	Skelex 360
	Ottobock Paexo Back / Suit X Back Air
	SpanSet DeltaSuit
	NZ Forest Growers Research exoskeleton review
Fire Control (UAV systems)	Dryad Networks (Silvanet + UAV system)
	Ponderosa Systems UAV
	DJI UAV ecosystem
	Walkera Firefighting Drones
Operator Assistance (OEM systems)	Komatsu Smart Crane / Smart Forestry
	Volvo Co-Pilot / Dig Assist
	Ponsse operator assistance systems
	John Deere Intelligent Boom Control
	Caterpillar Assist systems
	Tigercat assist systems
	Rottne assist harvester systems

Operator Assistance (Emerging / Recommended)	Nordic Forestry Automation (ADAS)
	Skogforsk simulation training (AVATAR)
	FGR Harvesting Automation & Robotics Programme
	Skogforsk Troëdsson Teleoperation Lab
	Kodama Autopilot
Truck Platooning / Transport	FPInnovations / Kratos platooning system
	Skogforsk ETT One More Stack platform concept
	Bot Auto autonomous truck
	Two-Stage trucking using log trucks
Nursery Technologies (Recommended)	TTA-ISO FlexPlanter
	Atlantic Man Multi-Grip Transplanter
	FGR AI seedling grading system
	Ellepot propagation system
	TTA-ISO CuttingEdge system
Remote Controlled Felling	EDER Radio Titan 80
	Forstreich TR300
	ValRemote

5.2 Augmented Reality

Augmented Reality (AR, or in a wider sense the 'Mixed Reality'; MR) in forestry overlays geospatial information, silvicultural prescriptions, terrain models, safety envelopes, and machine guidance directly into the operator's real-world view. In Australian forestry, AR is particularly valuable due to terrain variability, mixed machine fleets, and variable operator experience. AR in machinery operation, including visual cues, alignment aids, and contextual feedback, is explored in Section 5.8. Further investigation could determine how these capabilities might be expanded and standardised to support safer, more precise, and less cognitively demanding machine operation across a wider range of forestry tasks.

AR overlays digital information (maps, models, guidance, alerts and other context-information) directly onto a user's real-world view via devices such as tablets, rugged handhelds, smart glasses, on-windscreen projectors or head-mounted displays. The central aim is to bridge the gap between abundant digital forestry data (remote sensing, digital forest twins, inventory data, models, and details from the forest company's Financial Management Information Systems (FMIS) and on-ground operational reality.

Current systems typically deploy via ruggedised tablets, projectors or head-mounted displays connected to GIS platforms, LiDAR-derived terrain models, and machine telemetry. Practical use cases include planting alignment guidance on steep terrain, visualisation of thinning or pruning prescriptions, identification of exclusion zones, and immersive training support.

This section investigates the potential role of augmented reality (AR) as a means of enhancing how work is performed, supervised, and optimised across the sector. In silviculture and logistics, AR has the potential to improve both efficiency and safety by overlaying task guidance, boundaries, and operational cues directly into the worker's field of view, reducing ambiguity and reliance on paper-based or retrospective instructions.

AR also offers opportunities to improve worker safety through real-time hazard identification and tracking. By visualising exclusion zones, machine movement, terrain risks, or proximity to other workers and equipment, AR systems could help prevent incidents before they occur, particularly in dynamic and low-visibility environments common in forestry operations.

In the area of inventory and planning, AR could enhance decision-making by improving visualisation of forest data in situ. Stand boundaries, tree attributes, treatment histories, and planned interventions could be displayed directly within the forest environment, supporting more accurate assessments, better sequencing of work, and clearer communication between planners, operators, and supervisors. Many potential benefits will eventuate during adoption and advancement of the technology.

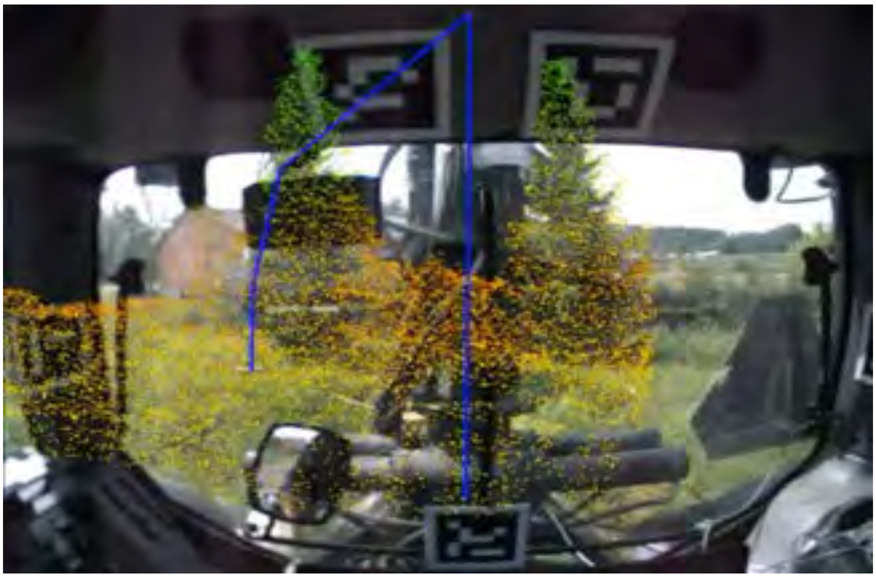

Figure 2 Image from the Augmented Reality in Forest Machine Cabin paper, Palonen et al., 2017. The crane and the tool are shown in blue together with point cloud data from the lidar.

5.2.1 Recommended – Augmented Reality

Other than the use of Augmented Reality (AR) in forestry machinery operations, which will be outlined in Section 5.8, we recommend that the Australian forestry industry consider and stay aware of developments of the following:

1. European Cooperation in Science and Technology project "Bringing Digital Data and Reality Together - Augmented Reality in Forestry"
2. Paper from the University of Freiburg "Shaping the future of forestry in Germany: Stakeholder perspectives on optimizing forest management through Augmented Reality"

5.2.1.1 European Cooperation in Science and Technology project COST Action CA23135 "Bringing Digital Data and Reality Together - Augmented Reality in Forestry" https://www.formec.org/images

The Horizon Europe COST Action CA23135 (ARiF) is a four-year European research and innovation network (2024–2028) explicitly established to address the disconnect between rapidly expanding digital data resources and their practical use in field operations. The Action brings together researchers, technology developers, forest managers, and end users to explore how Augmented Reality can function as a delivery and interaction layer, translating digital forest inventories, remote sensing outputs, planning data, and digital forest twins into formats that are usable in real operational settings. Rather than developing core AR hardware, ARiF concentrates on use-case development, workflow integration, data standards, positioning under canopy, and human-centred design, explicitly acknowledging that the technology bottleneck in forestry is not sensing or modelling, but interpretation and application on the ground.

Within the ARiF framework, augmented reality is treated as an enabling interface rather than a stand-alone solution. The COST Action documents position AR at an overall Technology Readiness Level of approximately 5–6, reflecting that while AR devices are commercially mature, forestry-specific implementations remain largely at pilot or prototype stage. ARiF identifies key constraints - including unreliable GNSS under forest canopy, limited connectivity in remote estates, fragmented data formats, and the durability requirements of forestry environments - as central research priorities. Indicative implementation costs are therefore driven far more by software development, data preparation, and system integration than by hardware acquisition. For Australia, the relevance of the ARiF work lies in its explicit alignment with large, remote forest estates, high safety demands, and growing pressure to do more with fewer skilled workers. As framed by the COST Action, AR does not reduce labour or manage fuel loads directly; instead, it amplifies the effectiveness, safety, and consistency of forestry operations, and becomes increasingly valuable when combined with digital twins, operator-assist systems, and mechanised or autonomous technologies.

5.2.1.2 Paper "Shaping the future of forestry in Germany: Stakeholder perspectives on optimizing forest management through Augmented Reality" [sciencedirect.com/science/article]

"Shaping the future of forestry in Germany" (Miguel-Díez & Purfürst, 2025) examines how augmented reality could be meaningfully integrated into forestry operations, moving beyond technical feasibility toward practical adoption. Using qualitative interviews with forestry practitioners and AR experts across multiple countries, the paper systematically identifies where AR is perceived to add real value and where it risks friction or rejection. Rather than proposing a single AR solution, the study frames AR as a context-dependent decision-support and visualisation interface, applicable across forest inventory, silvicultural operations, logistics, disaster and disturbance management, and stakeholder communication. The authors emphasise that AR's promise lies in real-time, spatially anchored interpretation of forestry data - particularly in situations where traditional 2D maps or office-based tools fail to support rapid decision-making in complex forest environments.

From a technology maturity perspective, the paper implicitly positions AR for forestry at TRL 5–6, consistent with current pilot-level deployments. While AR hardware, particularly mixed-reality smart glasses combined with high-precision GNSS or RTK positioning, is technically capable, the study highlights significant barriers to operational readiness. These include device durability under forestry conditions, discomfort and cognitive overload for users, positioning accuracy under canopy, offline functionality, and resistance from practitioners when systems are perceived as intrusive or poorly aligned with workflows. Implementation costs are therefore driven less by hardware acquisition than by customised software development, usability design, and organisational change management.

Figure 3 Opportunities of AR-supported occupational safety applications in forestry (de Miguel-Diez & Purfurst, 2025)

An example of a currently available AR tool is the V-Labs High-Precision AR Platform for Field Operations. In a forestry context, V-Labs demonstrates the potential of high-precision, hands-free AR where accurate spatial interpretation is critical, but also highlights practical constraints - including device weight, battery life, environmental robustness, and reliance on structured data pipelines - limiting broad deployment. As such, it is best viewed as a leading-edge, execution-grade tool suited to high-value applications where precision, safety, and quality control justify increased complexity and cost. Operating at approximately TRL 7, the platform has been deployed in industrial pilots across infrastructure, utilities, and construction, though forestry applications remain emerging. Typical costs range from under $1,000 (VITURE Luma Ultra AR Glasses) up to $20,000 per unit, plus software and integration requirements.

Figure 4 (Left) AR projection of planting lines & seedling positions (de Miguel-Diez & Purfurst, 2025); (Right) V-Labs Augmented Reality helmet.

For Australia, the relevance of this work lies in its strong alignment with large, remote forest estates and safety-critical operations. The paper reinforces that AR does not directly improve forest outcomes on its own but acts as a force-multiplier for planning accuracy, safety awareness, and communication, particularly when integrated with digital forest models, operator-assist systems, and structured forestry data pipelines.

5.2.2 Summary – Augmented Reality

Augmented Reality (AR) in forestry is an emerging technology that overlays digital information - such as maps, prescriptions, and hazard zones - directly into the operator's field of view, helping bridge the gap between complex datasets and on-ground operations. Its primary value could lie not in visualisation alone, but in improving decision-making, efficiency, and safety by providing real-time, spatially accurate guidance in complex and variable environments.

Current AR application-demonstrations focus on practical use cases such as planting alignment, thinning guidance, hazard visualisation, and training support, typically delivered through tablets or head-mounted displays. While the hardware is mature, forestry-specific implementations remain at mid-level readiness (TRL 5–7), with key constraints centred on data quality, positioning accuracy under canopy, connectivity, and usability in harsh field conditions. As a result, the greatest challenge is not technology availability, but integration into workflows and reliable data pipelines. Lacking effective and practical AR/MR devices for outdoor conditions and the need for developing special forest software may prevent a large-scale use of AR/MR in forestry for years.

Augmented reality has been successfully demonstrated in forestry operations such as harvesting and reforestation, where it supports tree selection, spatial planning, and safety visualisation; however, its application remains largely at a pilot stage, with significant research and development still required, particularly in adapting hardware to forest conditions, developing forestry-specific software and data pipelines, and addressing barriers to operational adoption.

For Australian forestry, AR is best viewed as an enabling interface rather than a standalone solution. It enhances the effectiveness of digital twins, operator-assist systems, and planning tools by making data usable in the field, improving consistency and reducing ambiguity. While it does not directly reduce labour or manage fuel loads, AR acts as a force multiplier for safety, communication, and operational precision, and provides an important stepping stone toward more automated and data-driven forestry systems. This section should be considered in conjunction with Section 5.8 which looks at commercially available AR offerings from forestry machinery companies.

5.3 Automated battery swapping

Automated battery swapping is an emerging approach to enabling continuous operation of large electric machinery, requiring a shift from vehicle-centric thinking to system-level optimisation of energy, infrastructure, and operations. In Australian forestry - characterised by heavy payloads, long distances, and constrained rural infrastructure - direct replacement of diesel trucks with battery-electric equivalents is insufficient. Instead, electrification should be targeted toward high-utilisation, repeatable tasks such as port-to-mill corridors and captive fleet operations, where uptime, energy supply, and productivity can be tightly managed. A key determinant of success is the energy replenishment model.

Battery swapping treats batteries as replaceable assets rather than fixed components, allowing depleted packs to be exchanged within minutes, minimising downtime. This aligns with corridor-based forestry haulage and reduces reliance on high-capacity charging in remote areas by centralising energy management. However, the model introduces significant system-level constraints, including high upfront investment in swap stations and battery inventory, dependence on standardisation across vehicle platforms, and increased operational coordination to manage logistics and asset availability. It is inherently best suited to fixed routes and predictable operations, with additional challenges around space, safety, compliance, and potential single-point-of-failure risks.

From a maturity perspective, truck-scale battery swapping sits at approximately TRL 5–7 - technically proven in pilots but not yet widely deployed. Its viability depends on high utilisation and controlled operating environments, as infrastructure intensity limits its application in dispersed forestry operations. Rapid advances in megawatt-class charging also create competitive pressure. As a result, battery swapping is best viewed as a targeted, system-specific solution, offering high-uptime electrification in suitable corridors rather than a universal replacement for conventional charging.

5.3.1 Recommended – Automated Battery Swapping

There are a growing number of providers offering automated battery-swapping and electrification solutions globally. From these, two suppliers stand out as leaders in heavy-vehicle battery-swap systems, supported by additional technologies that enable broader electrification of trucks and forestry machinery. Together, these technologies represent the leading options for enabling practical, high-utilisation electrified transport in heavy-duty and forestry applications.

1. Janus Electric: Side-Mounted Modular Battery Swap
2. CATL Battery Swapping System for Heavy Trucks
3. Caterpillar “Battery-as-a-Service” (BaaS) in Australian mines
4. Transition to Efficient Electrified forestry transport (TREE)
5. Scania Megawatt Charging System

5.3.1.1 Janus Electric: Side-Mounted Modular Battery Swap (Australia) januselectric.com/

Janus Electric is an Australian-developed heavy-vehicle electrification solution that enables rapid battery swapping for Class-8 trucks, specifically suited to high-load, regional and industrial transport such as forestry into fully electric trucks using large, containerised battery modules mounted externally behind the cab. Depleted modules are exchanged via a gantry or crane in approximately five minutes, delivering refuelling-equivalent turnaround times without the need for high-capacity fast-charging infrastructure. Batteries are charged off-vehicle at lower power rates, allowing operations to be located in regions with constrained grid capacity and enabling the use of on-site renewables.

Janus electric logging trucks were trialled in the Green Triangle forestry region in Australia from 2023 to 2025. The trial was led by Fennell Forestry using a Kenworth T609 diesel prime mover converted to electric by Janus Electric, incorporating a side-mounted modular battery-swap system (Green & Brine, 2026).

The trial set out to test three core questions: whether electric drivetrains could meet the torque, payload, and durability demands of log haulage; whether battery swapping could deliver productivity comparable to diesel refuelling; and whether the system could be commercially viable under Australian operating conditions.

From a technical and operational standpoint, the trial was successful. The electric truck demonstrated sufficient torque for heavy log loads, performed reliably on regional forestry routes, and achieved fast (<6 minute battery swaps), enabling continuous operations without the downtime associated with on-vehicle charging. Driver feedback was positive, particularly in relation to drivability, noise reduction, and power delivery. The trial conclusively showed that battery swapping is essential for heavy forestry applications and that fast-charging alone is not operationally viable in this context (Green & Brine, 2026).

However, the trial did not scale beyond demonstration due to economic constraints. Real-world loaded range was closer to 200 km, lower than early projections, reflecting vehicle mass and terrain. Most critically, electricity network demand charges and infrastructure costs made operating costs uncompetitive with diesel, even during periods of elevated fuel prices. Overall, the SA trials proved technical feasibility but economic immaturity, establishing a clear baseline for what must change - energy tariffs, policy settings, and infrastructure models - before broad deployment in the forestry sector becomes viable.

5.3.1.2 Battery-as-a-Service “BaaS”

A Battery-as-a-Service system is built around standardised, high-capacity chassis-mounted battery packs that can be automatically exchanged in diesel-equivalent refuelling times. BaaS separates vehicle ownership from battery ownership, where fleet operators purchase or lease trucks without batteries, while the BaaS providers owns, maintains, charges, and replaces the battery assets. This significantly reduces upfront vehicle cost, shifts battery degradation risk away from operators, and enables batteries to be charged off-vehicle at low, grid-friendly rates.

Technically, the system uses standardised battery “blocks” (typically \~300–800 kWh total per vehicle) mounted at the chassis level, allowing compatibility across multiple truck OEMs. Swap stations are highly automated and can support hundreds of truck movements per day when deployed on high-frequency freight corridors. BaaS is best suited to large, homogeneous fleets operating on predictable routes, where station utilisation is high and capital costs can be amortised quickly.

5.3.1.2.1 CATL Battery Swapping System for Heavy Trucks catl.com/en/news/6473.html

CATL (Contemporary Amperex Technology Co. Limited) has developed the world’s most advanced and commercially scaled battery-swapping ecosystem for heavy-duty trucks, now widely deployed across China in freight, construction, mining, and bulk haulage applications.

While the model is not yet widely deployed outside China, it represents the global benchmark for scalable heavy-truck electrification via battery swapping, and a likely reference architecture for future deployments in mining, ports, and bulk freight operations globally.

Figure 5 CATL battery swapping station for trucks (https://chargedevs.com/newswire/catl)

5.3.1.2.2 Caterpillar "Battery-as-a-Service" (BaaS in Australian mines) [bhp.com/news/media-centre/releases]

Caterpillar does not currently offer a formal, stand-alone "Battery-as-a-Service" model in Australia comparable to Chinese heavy-truck battery-swapping platforms such as QIJI Energy. Instead, Caterpillar's approach to batteries is embedded within a broader equipment-as-a-system and lifecycle services framework, delivered through its dealer network (notably WesTrac, Hastings Deering, and Energy Power Systems Australia). In the Australian market, batteries for electric and hybrid equipment are typically supplied as part of the machine, with usage risk, maintenance, and performance guarantees managed through Cat Customer Value Agreements (CVAs), finance packages, and long-term service contracts, rather than through separate battery ownership or leasing entities. This model prioritises equipment uptime, integrated maintenance, and predictable cost of ownership over modular, swappable energy logistics.

In practice, Caterpillar's battery strategy in Australia is most visible in battery-electric mining and underground equipment trials, particularly the Cat 793 XE battery-electric haul truck and underground battery-electric loaders and trucks being tested with operators such as BHP, Rio Tinto, and Newmont. These deployments rely on high-power charging, automated energy transfer systems, and site-level power integration, rather than mechanical battery swapping or off-vehicle battery pooling. Batteries remain tightly integrated with vehicle design, reflecting Caterpillar's emphasis on safety certification, structural integration, and performance validation in extreme operating environments. While Caterpillar does offer grid-connected and mobile Battery Energy Storage Systems (BESS) in Australia for power smoothing, microgrids, and renewable integration, these systems support site energy management, not mobile battery exchange or BaaS for haulage fleets. Strategically, this positions Caterpillar's model as infrastructure-integrated electrification, rather than energy-network abstraction. For sectors such as Australian forestry or mining, this means Caterpillar's pathway favours site-based charging ecosystems, OEM-controlled lifecycles, and bundled service economics, rather than third-party battery leasing or cross-fleet standardisation.

5.3.1.3 Transition to Efficient Electrified forestry transport [skogforsk.se/english/projects/tree/]

The Transition to Efficient, Electrified forestry transport (TREE) project is positioned as a central pillar of the broader green transition, with the vision of delivering a forestry freight system that is efficient, reliable, and fully compatible with decarbonised energy systems. The core aim of this transition is not simply to introduce electric vehicles, but to accelerate the adoption of electrified heavy forestry transport by removing system-level barriers. These barriers extend beyond vehicle technology to include logistics planning, charging infrastructure, grid access, business models, and enabling policy settings.

The headline ambition is bold: to achieve 50% electrification of new forestry trucks by 2030, a shift that would deliver material emissions reductions - equivalent to approximately 260,000 tonnes of CO_2 savings per year in Sweden alone. This target reflects both climate imperatives and the growing commercial viability of electric heavy transport when integrated effectively into forestry logistics chains.

Figure 6 Skorskog fully electric log truck equipped with a crane in southern Sweden in cooperation with VSV Unite and Åkeri AB Tage Palmqvist under the TREE project.

Evidence emerging from the TREE initiative demonstrates that many previously assumed technical constraints are no longer the limiting factor. Battery-electric forestry trucks have proven capable of operating year-round, including in cold northern climates, with reliability comparable to conventional diesel fleets. On typical forestry routes, regenerative braking on long downhill forest-to-port or forest-to-mill corridors materially improves energy efficiency, further strengthening the operational case for electrification.

Crucially, TREE's findings show that the dominant barriers are systemic rather than technological. Access to suitable charging infrastructure, coordinated transport and charging planning, and viable commercial and ownership models consistently outweigh vehicle performance as the key constraints. Addressing these system-level issues - rather than waiting for further vehicle innovation - will be decisive in unlocking large-scale electrified forestry transport.

5.3.1.4 Scania Megawatt Charging System scania.com/se/sv/home/insights/megawattsladdning

The Scania Megawatt Charging System (MCS) is a key enabler for large-scale electrification of heavy-duty transport, including forestry haulage, by aligning ultra-fast charging with driver rest breaks rather than requiring long downtime. Scania's initial deployment delivers up to 750 kW (≈1,000 amps), enabling a 20–80% charge in under 30 minutes, with the broader MCS standard scaling to multi-megawatt levels. The system incorporates liquid-cooled connectors and advanced communication protocols to support reliable high-power operation and sits at approximately TRL 8, with commercial roll-out commencing from 2026 alongside corridor infrastructure developments. Although deployment costs are high (over $1 million per site), these are offset by improved fleet utilisation, reduced battery size requirements, and lower operational downtime. For Australian forestry, MCS is strategically significant, as predictable, high-mass haulage routes between forests, mills, and ports are well suited to depot or corridor charging, making zero-emission transport viable without fundamentally altering operating models, with grid capacity remaining the primary constraint.

5.3.1.5 Summary

Australian forestry presents a distinctive electrification challenge: long haul distances, variable terrain, limited grid access at forest landings, and tight productivity margins. The five technologies outlined represent fundamentally different strategies for addressing energy supply, uptime, and scalability.

Janus Electric's side-mounted modular battery swap system is currently the most immediately applicable solution for Australian forestry. It has been developed and proven locally, is compatible with existing diesel truck conversions, and does not depend on high-capacity grid connections at the point of use. Its key strength is rapid battery swapping (typically minutes), enabling continuous operations on long and remote haul routes where charging infrastructure is not viable. This makes it well suited to Australia's dispersed forest-to-mill and forest-to-port logistics. However, the model relies on centralised battery logistics and remains constrained by battery transport, standardisation, and capital cost per converted vehicle.

CATL's heavy-truck battery swapping system represents a more industrialised, high-throughput version of the same concept, optimised for controlled freight corridors and logistics hubs. While technically mature and scalable, it assumes dense infrastructure deployment and standardised vehicle platforms, conditions that currently exist in China but only partially in Australia. For forestry, CATL-style swap stations could be viable at major ports or large mills but are less suited to dispersed harvest regions without substantial upstream infrastructure investment.

Caterpillar's BaaS model is highly relevant - but primarily within mining rather than forestry. Its strength lies in shifting battery capital risk, lifecycle management, and performance guarantees away from operators. Conceptually, this model could be attractive for large forestry operators owning fixed fleets and depots, but its current implementations depend on controlled sites, strong grid connections, and OEM-specific ecosystems, limiting near-term transferability to most forestry operations.

The Transition to Efficient Electrified Forestry Transport (TREE) initiative is not a single technology but a system-level framework. Its key relevance to Australia is strategic: it demonstrates that electric forestry transport is technically viable and that the dominant barriers are planning, infrastructure coordination, and business models - rather than vehicles themselves. TREE complements all other options by providing the logistics, policy, and network thinking required to scale electrification across forestry value chains.

Finally, the Scania Megawatt Charging System (MCS) represents the long-term backbone for electric forestry haulage once infrastructure is in place. MCS enables ultra-fast charging aligned with driver rest breaks and supports high-duty, long-haul operations. For Australia, it is most applicable on fixed, high-volume corridors between forests, mills, and ports where grid upgrades are viable. However, its reliance on megawatt-scale electrical infrastructure makes it a medium- to long-term solution, rather than an immediate answer for remote harvesting regions.

In summary, battery swapping (Janus now, CATL potentially later) offers the most practical near-term pathway for Australian forestry. Megawatt charging via Scania MCS is the likely long-term standard on major corridors, while BaaS models and TREE-style system planning provide the financial and organisational scaffolding needed to make large-scale electrified forestry transport viable over time.

5.3.2 Comparison of Electrification Pathways for Forestry Transport

The table below compares electrification pathways for forestry transport in Australia, outlining technology readiness levels, strengths, limitations and likely best use situation.

Table 5 Comparison of Electrification Pathways for Forestry Transport

System	Model	TRL	Strengths	Limitations	Best Use
Janus Electric	Battery swap	TRL 6-7	Fast swaps, proven in AU forestry	Economic viability, range limits	Forestry corridors
Scania MCS	Megawatt charging	TRL 8	Fast charging, scalable	Grid dependency	Port and depot routes
CATL Swapping	BaaS + swapping	TRL 8-9	Highly scalable, proven	Needs standardisation	Mining and freight hubs
Battery-as-a-Service	Leased batteries	TRL 6-8	Lower upfront cost	Needs high utilisation	Large fleet operations
Caterpillar	Integrated batteries	TRL 7-8	Reliable, OEM managed	No swapping flexibility	Mining / site-based
TREE Project	System-level model	TRL 6-7	Strong system insights	Not deployable	Strategic planning

5.3.3 Other alternative fuel systems

A range of viable alternatives to battery-electric systems are currently being developed and tested internationally for heavy-duty forestry trucks, reflecting the need to balance range, payload, and infrastructure constraints. Hydrogen fuel cell technology is the most prominent emerging option, with multiple large-scale trials demonstrating its ability to deliver long range, fast refuelling, and zero tailpipe emissions. Commercial deployments such as Hyundai's fuel-cell truck fleet operating across multiple countries and European projects like H_2Haul highlight its suitability for high-utilisation, long-distance haulage, conditions typical of forestry logistics. In parallel, natural gas (CNG and LNG) remains a mature and widely adopted transitional fuel, offering lower emissions than diesel while leveraging existing combustion engine platforms, making it a practical near-term solution for regions with limited electrification infrastructure.

In addition to these options, biofuels such as hydrotreated vegetable oil (HVO) and biodiesel provide an immediate, drop-in pathway to emissions reduction in existing fleets, with significant lifecycle carbon savings where sustainable feedstocks are available. Synthetic fuels (e-fuels) and hydrogen-derived fuels such as ammonia are also under development and are considered longer-term solutions for hard-to-electrify transport systems, including forestry haulage, where energy density and refuelling flexibility are critical. Overall, the international evidence suggests that forestry transport will likely adopt a mixed-fuel approach, where biofuels and natural gas enable near-term reductions, while hydrogen and synthetic fuels emerge as scalable long-term complements to electrification.

These technologies were not considered in detail as the project Steering Committee preferred that this review focussed on electrification options.

5.4 Autonomous planting

Investigation of pre-commercial autonomous planting systems highlights a rapidly evolving field in which early-stage technologies show strong potential but remain immature. This work complements existing commercial assessments, including those by Mike Sutton of Forest Innovation Services (Sutton, 2026). Common limitations include readiness gaps, integration challenges, reliability in complex environments, and uncertainty around cost and scalability. Successful deployment of European systems in Australia will require adaptation to local conditions (terrain, climate, and fire behaviour), alignment with regulatory frameworks, integration with existing workflows, and appropriate supporting infrastructure and data systems. Importantly, mechanisation represents a critical first step toward autonomy, providing the operational platform, data flows, and operator familiarity required to support more advanced, automated functions. As such, adoption of autonomous systems is more likely to occur as a progression from mechanised and operator-assist technologies rather than through direct transition to full autonomy.

Figure 7 Two currently available commercial tree planting machines. Bracke P22.b planter with seedling carousel (left); PlantMax automated planter (right).

Autonomous planting represents a broader shift in how silvicultural work is planned and executed, moving from operator-dependent processes toward data-guided, precision systems. By improving consistency and repeatability, it enables measurable, system-driven outcomes and supports continuous improvement in planting strategies. This approach can help address persistent forestry challenges, including labour constraints, physically demanding work, and variability in execution quality. While it introduces new requirements, such as digital planning tools, enhanced data management, and updated workforce skills, it also offers a pathway to long-term gains in productivity, operational resilience, and regeneration quality.

5.4.1 Recommended – Autonomous Planting

We recommend that the Australian forestry industry keep a watching brief on the three systems detailed below:

1. Södra BraSatt 01
2. AUTOPLANT - Skogforsk Autonomous Site Preparation & Tree Planting concept
3. Patent US448388319 for automated system & method for planting nursery seedlings

5.4.1.1 Södra BraSatt 01 sodra.com/en/uk-ie/about-us/innovation/sodras-innovation-projects

The Södra BraSatt 01 demonstrates how autonomy enables a shift from broad, uniform land preparation to site-specific, targeted regeneration. The machine identifies suitable planting locations, prepares the soil locally, and places individual seedlings under controlled conditions. As such, BraSatt 01 illustrates how autonomy can modernise forestry regeneration by embedding precision, consistency, and system intelligence at the core of operations, independent of electrification or propulsion choices elsewhere in the value chain.

Figure 8 Södra BraSatt 01 autonomous, driverless forest regeneration robot

BraSatt 01 represents a promising long-term model for precision, low-disturbance autonomous planting, but its current performance and robustness limit its near-term applicability in Australia's variable and challenging forest environments. It is best viewed as a strategic reference for future system design, rather than a deployable solution under current operational conditions.

5.4.1.2 AUTOPLANT - Skogforsk Autonomous Site Preparation & Tree Planting concept https://www.mdpi.com/1999-4907/15/2/263

AUTOPLANT is a Skogforsk-led research programme aimed at fully autonomous forest regeneration, integrating site preparation and seedling planting into a coordinated system rather than a single machine. Developed through multi-year collaboration between research institutes, equipment manufacturers, and forest companies, the concept addresses labour scarcity, inconsistent planting quality, and excessive soil disturbance. AUTOPLANT combines regeneration planning, autonomous navigation, low-impact site preparation, automated seedling handling, and planting-spot detection into a single workflow that embeds quality and environmental protection into algorithms rather than operator judgement.

Field trials demonstrated very low soil disturbance (under 3% compared with approximately 50% for conventional disc trenching) while maintaining planting precision, highlighting the strength of AUTOPLANT's systems-based approach. Technically, it represents a clear progression from mechanised assistance toward precision-driven autonomy and serves as a reference architecture for later platforms such as BraSatt 01.

AUTOPLANT remains pre-commercial (TRL 5–6), with integrated field demonstrations but no sustained commercial operation. While no official pricing exists, indicative modelling based on prototype complexity suggests a capital cost up to $3 million per machine, excluding development overheads, with operating costs expected to exceed manual planting until higher speeds, reliability, and utilisation are achieved. As such, AUTOPLANT should be viewed as a strategic cost-learning and risk-reduction platform, valuable for informing future commercial designs rather than a near-term, cost-competitive deployment solution.

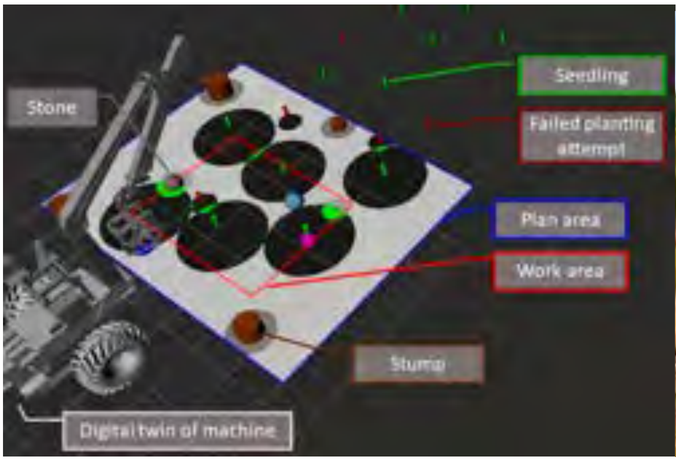

Figure 9 AUTOPLANT Planting Planner from the ROS Visualization (Rviz) tool in ROS (left); autonomous vehicle platform with the crane steering toward the self-selected planting spot (right) (Hansson et al., 2024).

5.4.1.3 Patent US448388319 for automated system & method for planting nursery seedlings patentscope.wipo.int/search/en/detail.jsf?docId=US448388319

This patent is included as an early, system-level step toward autonomous planting, most suitable for controlled environments rather than as a universal replacement for conventional forestry planting. It describes an automated system for planting nursery seedlings that captures many of the foundational concepts behind modern autonomous forestry. It treats planting as a controlled, mechanised process, using coordinated sensing, guidance, and actuation to handle and place seedlings with consistent depth, position, and alignment, shifting quality from operator-dependent judgement to system-embedded logic.

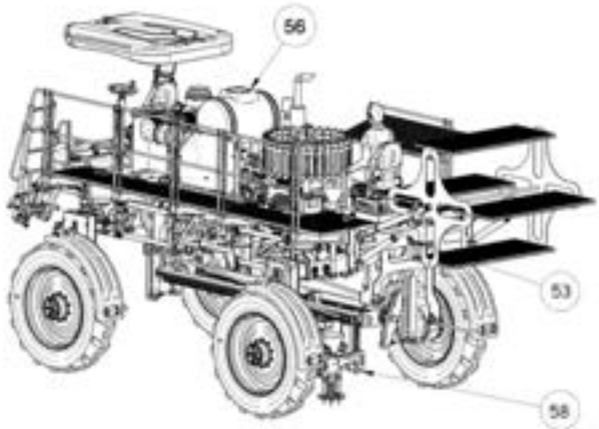

Figure 10 Patent for automated system & method for planting nursery seedlings (US448388319)

While conceptually important, the system has practical limitations: it performs best in uniform conditions and is less suited to the steep, rocky, and variable terrain typical of many forest sites. Its integration of multiple mechanical and sensing components increases cost, maintenance demands, and vulnerability to failure in harsh environments, while real-world productivity may be constrained by logistics such as seedling supply and refilling. The approach also focuses on physical placement accuracy, with limited adaptability to microsite variability or species-specific requirements, reducing its ability to optimise survival outcomes compared with skilled human planters. Additionally, broad patent coverage may constrain innovation and increase supplier dependency.

5.4.2 Limitations of using European tree-planting equipment in Australian conditions

European tree-planting equipment has been developed and optimised for highly structured, uniform forestry systems, typically characterised by consistent site preparation, relatively homogeneous species, and predictable terrain conditions. When transferred to the Australian context, these systems encounter a markedly different operating environment defined by greater variability in terrain, soil, debris, and planting conditions, as well as more heterogeneous stand structures and operational practices. As a result, technologies that perform well under controlled European conditions may experience reduced reliability, adaptability, and productivity in Australian forests. The following table outlines the key limitation categories observed when applying European planting systems in Australia, highlighting where environmental, technical, and operational constraints impact performance and scalability.

Table 6 Limitations of Using European Tree-Planting Equipment in Australian Conditions

Limitation category	Core issue	Mitigation / What can be done
Terrain & site availability	Poor performance in steep, messy sites	Target suitable terrain; redesign machines for better mobility and debris handling
Limited adaptability	Limited adaptability to inconsistent planting spots	Improve sensing and AI; use adaptive planting algorithms
Seedling variability	Low tolerance compared to humans	Standardise nursery outputs and align with mechanised systems
Perception and decision making	Weak sensing and judgement	Invest in advanced sensors, AI, and local data training
Productivity vs reliability	Speed vs accuracy trade-off	Optimise for reliability first, then scale speed
Site preparation dependency	High dependency on uniform prep	Implement consistent site preparation standards
Capital cost and risk	High capital risk	Use staged pilots and shared-risk models
Operational flexibility	Poor response to change	Deployment in controlled environments; use modular systems
Learning capability	Weak feedback loops	Integrate monitoring and data-driven improvement systems
Human trust	Human trust barriers	Conduct multi-season trials; prioritise usability and operator involvement

5.4.3 What is needed for automated forestry planters to succeed in Australia?

For automated forestry planters to succeed in Australia, they should be deployed as part of a deliberately engineered system, not as stand-alone machines. A critical prerequisite is tight integration with existing forestry nursery systems, ensuring that planting machinery, seedling form, packaging, and logistics are aligned from propagation through to establishment. Automated planters are inherently less tolerant of variability than human planters, which means site selection discipline is essential - they cannot be deployed indiscriminately across all terrain and soil types without facing unacceptably high failure rates. Success depends on high-quality, consistent site preparation, such as ripping, mounding, or scalping performed to measurable standards that automation can reliably work with.

The planting mechanisms themselves should be designed or tuned specifically for Australian planting stock, particularly eucalypts, which differ markedly from the conifer-centric systems that dominate overseas development. This extends to local calibration and training of sensing and perception systems using Australian datasets, capturing local soils, residues, vegetation types, and climate conditions. Trust in the technology will only be built through multi-season pilot deployments, demonstrating consistent performance across varying weather and site conditions, rather than single-season trials. Equally important are contractor economics and risk-sharing models that recognise the capital intensity and early-stage uncertainty of automation, ensuring that contractors are not exposed to disproportionate downside risk.

Finally, automated planters should integrate with digital forestry systems, enabling planning, monitoring, feedback, and continuous improvement at a system level. Ultimately, however, acceptance will not be driven by theory, promises, or demonstrations alone. In Australian forestry, trust is earned only through sustained field results, proving that automated planting can reliably deliver survival, productivity, and cost outcomes equal to or better than established methods.

5.4.4 Summary – Autonomous Planting

Autonomous planting is a rapidly evolving but still pre-commercial field, with technologies demonstrating strong potential to transform silviculture from labour-intensive, operator-dependent processes into data-driven, precision systems. While early prototypes and research platforms - such as BraSatt 01 and AUTOPLANT - show clear gains in consistency, soil impact reduction, and system-level optimisation, most remain at mid-level readiness (TRL 5–6) and are not yet cost-competitive or operationally robust across diverse forestry conditions. Common limitations include integration complexity, reliability in variable terrain, biological variability, and uncertainty around scalability and economics.

For Australia, direct adoption of European autonomous planting systems is constrained by more variable terrain, species diversity, and operational conditions, which reduce performance reliability and adaptability. Successful deployment will therefore require targeted localisation, including alignment with Australian nursery systems, site preparation standards, species characteristics, and operational workflows. These systems should be implemented as part of an integrated regeneration system, rather than as standalone machines, with strong emphasis on data quality, planning discipline, and contractor-aligned business models.

Despite these challenges, autonomous planting offers a compelling long-term pathway to address labour supply, improve planting consistency, and enable continuous performance improvement. The most realistic approach for Australia is to maintain a watching brief on leading systems, while pursuing incremental development and pilot deployment. Success will depend not only on technical capability, but on demonstrated field performance over multiple seasons, gradual integration into existing operations, and the ability to consistently match or exceed traditional planting outcomes in cost, survival, and productivity. Also refer to the recent report on commercial planting offerings (Sutton, 2026).

5.4.5 Note:

On 19 May 2026, Ponsse announced the release of their Buffalo Planter, which they claim combines soil preparation, planting, irrigation, and compaction into a single streamlined process, built on the reliable Ponsse Buffalo forwarder to support efficient, large-scale reforestation. The Buffalo Planter has not been evaluated in this work, but givens Ponsse’s string record in forestry, it is worth exploring it further.

5.5 Digital twins

A “digital twin” forest is a virtual data-driven representation of a forest. Purcell and Neubauer, 2023, have undertaken a review of Digital Twins in agriculture, identifying current trends and open questions with the goal of increasing awareness and understanding of the Digital Twin and its possibilities. A key feature of digital twins allows users to ask *‘if-then’* questions using their own data to identify the sensitivity of forest relevant outputs on of forest management decisions. Purcell and Neubauer, 2023, present an excellent graphical representation of a Digital Twin in Figure 11. They claim that the union of data, modelling and what-if simulations can provide an approach to overcome current limitations in decision-making support and automation. This ability has the potential to inform decision support systems and ultimately help enable digital extension services.

Figure 11 Digital Twin - Architecture overview (Purcell and Neubauer, 2023)

Digital twins provide a dynamic, data-driven representation of forest assets, operations, and constraints, allowing decision-makers to test scenarios, anticipate risks, and optimise choices before committing capital, labour, or infrastructure. In forestry, the digital-twin landscape spans a wide maturity spectrum. At the base level are long-established resource and growth-modelling systems used for yield forecasting, harvest scheduling, and carbon accounting. More advanced implementations extend into operational twins, integrating harvesting, roading, haulage, logistics, and mill supply. Leading platforms increasingly ingest telemetry, geospatial data, and logistics information, shifting digital twins from static planning tools toward near-real-time decision support.

Digital twins are rapidly gaining traction across primary industries such as mining, agriculture, and energy, where they are used to simulate operations, optimise asset performance, and improve decision-making in complex, remote environments. Their increasing adoption highlights strong potential for forestry, particularly in fleet management, logistics optimisation, and forest planning, where similar challenges of variability, scale, and operational efficiency exist.

The strategic value of a forestry digital twin lies not in visualisation, but in decision influence. Mature twins support capital planning, fleet and labour sizing, energy-transition pathways, climate and fire-risk analysis, and credible ESG and regulatory reporting. Conversely, tools that operate in isolation - focused only on the forest, machines, or GIS - deliver limited enterprise-level value. Critically, a "true" digital twin is not a single product but an integrated capability combining data governance, optimisation logic, and scenario analysis across biological, operational, and market systems. While many deployments now sit at TRL 6–8, most remain partial or pilot-scale due to the complexity of data integration, organisational adoption, and uncertainty around return on investment. Costs are driven primarily by software, data acquisition, and integration rather than hardware, ranging from low hundreds of thousands of dollars for targeted use-cases to substantially more for enterprise-wide implementations.

In Australia, digital twins should be designed for a fragmented and contractor-driven forestry system operating across long, sparse haul corridors with limited connectivity and highly variable forest types. Ownership is split across state agencies, private growers, Indigenous landholders, and joint ventures, ruling out highly centralised, monolithic twin architectures. ESG, carbon, and energy-transition pressures further increase scrutiny without necessarily increasing available capital, reinforcing a preference for incremental, modular, and federated approaches that deliver clear near-term value. While digital twins can unlock powerful insights, they also shift risk from physical execution to data quality, governance, organisational capability, and decision discipline. Where data is poor, adoption weak, or governance unclear, even technically sophisticated twins struggle to influence outcomes or justify their cost - underscoring that digital twins succeed through disciplined implementation as much as through technology.

5.5.1 Recommended Digital Twins

We recommend the following two digital twins because, they represent the most practical and credible pathway to digital twin deployment in Australian Forestry.

5.5.1.1 Remsoft-Anchored Composite Digital Twin remsoft.com/forestry/

A Remsoft-anchored composite digital twin represents the most practical and credible approach to deploying a true forestry digital twin in Australia. This model predominantly represents equipment-based forest operations and uses Remsoft's optimisation platform as the central decision engine to support forest managing the forest activities, integrated with operational, telemetry, and strategic systems to form a unified, decision-driven capability.

At its core, Remsoft provides a robust optimisation spine, integrating forest inventory, growth and yield, harvest scheduling, roading, haulage, and mill supply. Its strength lies not in visualisation, but in the ability to test trade-offs and optimise outcomes across competing objectives such as cost, fibre security, carbon, risk, and service levels. This makes it well suited to Australia's fragmented ownership structures, long haul distances, and variable operational constraints.

Around this core, the composite model incorporates local operational systems (such as FSCT, Forsite, Trimble, or equivalent contractor platforms) to manage day-to-day execution, and OEM machine telemetry where available to provide real-world feedback. An upper strategic layer - often tools such as AFRY Smart Forestry - can be added to explore long-term scenarios involving decarbonisation, energy transitions, policy change, or major capital decisions.

The key advantage of this model is resilience and adoption. It tolerates imperfect data, avoids vendor lock-in, and can be implemented incrementally, delivering decision value within months rather than years. Most importantly, it aligns digital twin investment with real decisions: harvest sequencing, infrastructure spend, fleet strategy, and emissions pathways.

5.5.1.2 AFRY Smart Forestry afry.com/en/services/advisory/afry-management-consulting

AFRY provides a mature, production-grade forestry digital twin capability through its Smart Forestry portfolio, using remote sensing, AI-based inventory, growth modelling, and scenario analysis to create operational digital representations of forest assets. Operating at TRL 8–9, its strength lies in delivering integrated, scalable estate-level planning with minimal operational disruption. Value is generated through improved data quality and decision-making rather than automation of field work, enabling incremental adoption. However, benefits are indirect and depend on data quality, update frequency, and whether insights are acted upon, with ongoing costs driven by remote sensing and cloud analytics requirements.

In practice, AFRY functions as a strategic decision layer of the forest operation rather than a real-time operational system, supporting long-term planning, carbon and Environmental, Social & Governance (ESG) analysis, and investment decisions. Its core tools - TreeMaps (inventory), Planner (scenario modelling), and Manager (operational integration) - form a cohesive digital-twin ecosystem linking high-resolution data with planning and management. As such, AFRY is best positioned as the “strategic brain” within a broader digital forestry architecture, complementing execution and optimisation platforms rather than replacing them.

5.5.2 Summary – Digital Twins

Digital twins in forestry represent a rapidly evolving capability that integrates data, modelling, and scenario analysis to improve decision-making rather than simply provide visualisation. At their core, digital twins create dynamic, data-driven representations of forest resources, operations, and constraints, enabling organisations to test scenarios, anticipate risks, and optimise outcomes before committing capital or labour. While the technology spans a wide maturity range - from traditional growth modelling systems to more advanced, near-real-time operational platforms - their value depends on effective integration across biological, operational, and market systems. As a result, digital twins are better understood as an organisational capability than a single simulation tool (product).

AI will boost the ease of use and automation in data collection and of analytical processes, including simulations (process, growth conditions, technology use etc.) for the operation. In collecting their own, highly specific data of a forest operation, the Digital Twins will gain extreme value for an organization over time. Strategically enabled (automated) benchmarking with other forest operations will provide unique information wins through the Digital Twins.

In the Australian context, digital twin deployment is shaped by a high variety of tree species and growing systems due to climatic and site conditions, fragmented ownership, contractor-led operations, long transport distances, and increasing ESG and decarbonisation pressures. Successful implementation therefore requires modular, federated approaches that can tolerate imperfect data and deliver incremental value. Leading solutions, such as composite digital twin architectures anchored by optimisation engines (e.g. Remsoft) and supported by platforms like AFRY Smart Forestry, demonstrate a practical pathway to adoption. However, realising benefits requires significant organisational commitment to data quality, governance, and decision discipline. When implemented effectively, digital twins provide a low-regret pathway to improved productivity, resilience, and long-term strategic planning, while also enabling future integration with automation and other digital technologies.

5.6 Exoskeletons

Exoskeleton technologies are emerging as a practical means of reducing fatigue, musculoskeletal strain, and injury risk in labour-intensive forestry work. Rather than replacing manual labour, these systems augment human capability by providing passive or powered assistance during repetitive, load-bearing, or ergonomically demanding tasks. Their value is greatest in environments where mechanisation is constrained, and cumulative physical strain remains a major contributor to injury and reduced productivity.

Powered and non-powered exoskeletons differ primarily in how they assist the user and their suitability for forestry environments. Powered exoskeletons use motors and batteries to actively augment strength and movement, providing higher levels of assistance for heavy lifting or repetitive tasks, but they are heavier, more complex, and less suited to rugged, remote forestry conditions due to durability, charging, and maintenance requirements. In contrast, non-powered (passive) exoskeletons use mechanical systems like springs or elastic supports to redistribute load and reduce fatigue without external energy, making them lighter, more reliable, and better suited to forestry work where simplicity, mobility, and robustness are critical. The relevance of exoskeletons varies by task environment and workflow. Accordingly, two distinct use cases are considered:

1. Nursery operations, characterised by repetitive, posture-intensive tasks in controlled settings;
2. Forest operations, where uneven terrain, environmental exposure, and task variability impose stricter performance and usability requirements.

Forestry workplaces impose sustained physical demands driven by repetitive bending, lifting, and twisting over long periods. These stresses are amplified by steep, uneven, and often slippery terrain, which limits stable working postures and increases fatigue and injury risk. Workers also operate heavy, vibration-intensive tools such as chainsaws and brush cutters, frequently in awkward positions and under time pressure. Because tasks and postures change constantly, fixed ergonomic interventions are of limited value. Exoskeletons should therefore balance assistance with comfort, freedom of movement, and heat management. As a result, exoskeletons in forestry - such as targeted back- or shoulder-assist systems - are best suited to specific tasks or motions, rather than continuous, all-day use.

Nursery environments present a more consistent physical profile. Work is dominated by repetitive stooping, crouching, and light-to-moderate lifting throughout the day. While individual loads are manageable, cumulative fatigue is significant over long shifts. Although terrain is typically flat, prolonged standing and movement on hard surfaces increase lower-back and joint strain. Endurance and posture support are therefore prioritised over peak strength. In this context, comfort, low bulk, and unrestricted movement strongly determine worker acceptance, particularly in warm or enclosed settings.

Consequently, lightweight passive back exoskeletons represent the most appropriate solution for nursery operations. These devices provide continuous support during bending and lifting without batteries or motors, reducing maintenance complexity while preserving natural movement. When properly fitted, they have minimal impact on walking, reaching, or task variability, and are generally well accepted by workers. Recent benchmarking work by Refai et al. (2024) supports this approach, showing that soft and rigid passive back exoskeletons can meaningfully reduce lumbar loading in industrial environments while maintaining usability and comfort.

5.6.1 Recommended – Exoskeletons

The exoskeleton solutions below are recommended because they represent practical, low-complexity interventions that directly address one of forestry's most persistent challenges: cumulative physical strain in labour-intensive tasks. They are all unpowered, because they are lighter, more reliable, and better suited to forestry work than powered exoskeletons. The inclusion of a global review being undertaken in New Zealand supports a structured, evidence-based pathway to adoption:

1. Skelex 360
2. Ottobock Paexo Back / Suit X Back Air
3. SpanSet DeltaSuit
4. NZ Forest Growers Research global review of exoskeletons

5.6.1.1 Skelex 360 skelex.com/skelex-360

Skelex 360 is a commercially available, passive upper-body exoskeleton designed to reduce shoulder and arm strain during repetitive mid-range and overhead tasks. It uses purely mechanical gravity-balancing - requiring no power, sensors, or software - which makes it well suited to Australian forestry and nursery environments where work is physically demanding, dispersed, and poorly suited to complex automation. Its role is to augment manual labour, not replace it, and it is most applicable to silvicultural and nursery tasks rather than mechanised harvesting.

In forestry, Skelex 360 is relevant for manual planting and regeneration, young-stand tending (such as pruning or guarding), and infrastructure-related work that involves sustained arm elevation. These tasks remain labour-intensive even in highly mechanised systems, particularly on steep or environmentally sensitive sites, and the exoskeleton can help extend endurance and reduce injury risk amid ongoing labour supply challenges. Tree nurseries represent an even clearer fit, as common activities like tray handling, inspection, spacing, and greenhouse work involve repetitive shoulder-height movements. In these settings, Skelex 360 can reduce chronic strain, support longer productive shifts during peak seasons, and improve staff retention.

Skelex 360 is a TRL 9 technology with indicative pricing of $7,000 per unit and with minimal ongoing costs. It should be viewed as a practical, incremental ergonomic intervention that improves safety and workforce sustainability in parts of the forestry value chain that are likely to remain manual for the foreseeable future, complementing - rather than competing with - automation and digital systems.

5.6.1.2 Ottobock Paexo Back / Suit X Back Air suitx.com/en/products/ix-back-air-exoskeleton

The Ottobock Paexo Back / Suit X Back Air is a commercially available, passive lower-back exoskeleton designed to reduce lumbar strain during repetitive bending and lifting. It uses a purely mechanical energy-storage principle that transfers load from the lower back to the thighs during lifting, providing relief equivalent to up to \~25 kg of lumbar load without restricting walking or mobility. Because it requires no power or electronics, the Paexo Back is well suited to Australian forestry environments that are remote, uneven, hot, and low-connectivity.

In Australian forestry operations, Paexo Back / Back Air is most applicable to manual planting and regeneration, silvicultural tasks such as spraying, fertilising, guarding, and weed control, and depot-based handling of equipment, tools, and supplies. These activities sit outside fully mechanised harvesting and still involve frequent stooping and lifting. Tree nurseries present an even stronger use case, as routine tasks - handling seedling trays, spacing, grading, and inspection - create high cumulative spinal load over long shifts. In these settings, Paexo Back can reduce injury risk, improve endurance, and support workforce retention during peak seasons.

Paexo Back is a TRL 9 technology, commercially deployed since 2020 across logistics, manufacturing, construction, and maintenance sectors. Indicative pricing is around $10,000 per unit, with low ongoing costs limited to fitting, training, and replacement of wearable components. Overall, it should be viewed as a low-complexity workforce-support intervention, complementing mechanisation and digital tools by protecting the manual labour that remains essential in forestry planting, regeneration, and nursery production.

Figure 12 Exoskeleton in use in forestry setting.

5.6.1.3 SpanSet DeltaSuit spanset.com/us-en/section/exoskeleton/deltasuit

The SpanSet DeltaSuit is a lightweight, passive overhead exoskeleton designed to reduce shoulder, neck, and upper-arm fatigue during repetitive or sustained work at or above shoulder height. Developed by Swiss manufacturer Auxivo and distributed by SpanSet, it targets industrial, construction, utilities, and maintenance environments where musculoskeletal strain is a persistent risk. The DeltaSuit mechanically off-loads arm and shoulder load using integrated elastic energy-storage elements, providing up to 6.6 Nm of dynamic shoulder support across two selectable assistance levels. Support engages only when the arms are elevated, allowing unrestricted, natural movement when the arms are lowered. The device is fully passive, requires no batteries or motors, and weighs approximately 2 kg, enabling extended wear with minimal encumbrance, and is currently being evaluated by a forestry contractor in Queensland.

Independent laboratory and field evaluations referenced by the manufacturer indicate reductions in shoulder muscle load of approximately 30–36% and reductions in neck fatigue of up to 75% during sustained overhead tasks. The DeltaSuit is not personal protective equipment and does not replace safe-work practices or fall-protection systems; instead, it functions as a preventative ergonomic intervention, supporting endurance, reducing fatigue-related injury risk, and improving consistency in overhead work.

From a deployment perspective, the DeltaSuit is a TRL 9 technology, fully commercial and in routine use across multiple industrial sectors. Indicative pricing is less than $7,000 per unit, depending on supplier, configuration, and service arrangements, with minimal ongoing costs beyond fitting, basic training, and inspection. Overall, the DeltaSuit should be viewed as a low-complexity, high-acceptance ergonomic support tool, well suited to roles involving frequent overhead or shoulder-height work where mechanisation or automation is impractical and workforce sustainability is a priority.

5.6.1.4 NZ Forest Growers Research global review of exoskeletons

The New Zealand Forest Growers Research organisation commissioned a piece of work to be undertaken by the Bioeconomy Science Institute (BSI: Scion) Human Factors team, to undertake a global review of exoskeletons and a Rapid Entire Body Assessment (REBA) for manual pruning. This approach uses ergonomics to evaluate postural risks. The intent is to then align exoskeleton technology to the areas of the body most at risk and then bring something out to test. The scan and review (Hooper & Parker, 2026) was completed shortly after this FWPA Technology Scan report was completed, and is available at https://fgr.nz/document/targeted-exoskeleton-adoption-for-silvicultural-tasks-pruning/

5.6.2 Summary - Exoskeletons

Exoskeletons represent an emerging but immediately deployable capability to reduce fatigue, improve safety, and support workforce sustainability in forestry operations. Their effectiveness is highly dependent on task environment: nursery operations benefit most from lightweight passive back-support systems that address cumulative strain from repetitive movements, while forest operations require targeted, task-specific support that preserves mobility and comfort in complex terrain. Across both contexts, passive systems are currently the most suitable, offering simplicity, durability, and high user acceptance without introducing power, maintenance, or integration burdens.

While exoskeletons do not replace manual labour or mechanised systems, they provide a complementary ergonomic layer that improves consistency and endurance in work that is likely to remain manual. Evidence from industrial benchmarking and forestry research indicates that properly matched systems can significantly reduce musculoskeletal loading while maintaining usability. As such, exoskeletons should be viewed as a low-regret, incremental intervention that delivers immediate benefits and supports longer-term productivity, health, and resilience outcomes in the forestry workforce.

5.7 Fire Control

This section focuses on fire control systems deployed following detection, recognising their growing role in improving response speed, safety, and operational efficiency in Australian forestry. While many current applications rely on remotely piloted platforms, fully autonomous capabilities are still emerging.

Research from the Australian National University (ANU) and Western Sydney University (WSU) highlights a complementary approach combining advanced detection technologies with fire-science modelling. ANU is developing integrated systems that use drones and multi-sensor networks for rapid ignition detection and response, while WSU's work focuses on modelling fire behaviour, risk, and environmental drivers. For forestry companies, the key implication is that UAVs should be integrated into broader, data-driven systems rather than deployed in isolation - prioritising early detection, targeted deployment, and decision support, with autonomous suppression likely to remain a longer-term capability.

5.7.1 Recommended – Fire control

Following review by the project Steering Committee, UAVs were identified as the most relevant technology for further investigation. These can be broadly grouped into two functional categories: ultra-early and hybrid detect-confirm-suppress systems, which aim to intercept fires at or near ignition, and hotspot and mop-up systems, which support monitoring and suppression once fires are established. Two systems in each category are recommended:

Ultra-Early & Hybrid Detect-Confirm-Suppress UAV Companies

1. Dryad fire-fighting UAVs (Germany)
2. Ponderosa.ai / Ponderosa Systems (USA)

Hotspot & Mop-Up UAV Companies

3. DJI Ecosystem (China / Global)
4. Walkera Firefighting Drones / DR1 (China / Global)

5.7.1.1 Ultra-Early & Hybrid Detect-Confirm-Suppress UAV Companies

Ultra-early and hybrid detect-confirm-suppress UAV companies compress detection, verification, decision-making, and intervention into small-scale loops that aim to extinguish fires before they meaningfully exist, rather than fighting them once they grow.

5.7.1.1.1 Dryad fire-fighting UAVs (Germany) dryad.net/silvanet

The core idea of the Dryad fire-fighting UAV system is to detect fires in the smouldering phase and extinguish them before they become fires at all. It comprises:

1. Silvanet – ultra-early wildfire detection sensors installed in forests
2. Silvaguard UAVs – autonomous drones that launch when a sensor detects fire
3. Solar drone hangars – off-grid bases for storage, charging, and automatic launch
4. Early-stage suppression payloads – experimental, not bulk water drops

Dryad Networks has developed one of the world's most advanced end-to-end autonomous wildfire response concepts, combining ultra-early ground-based detection with autonomous UAV-based verification and suppression. Rather than relying on aerial firefighting alone, Dryad's approach is designed to detect and extinguish wildfires within minutes of ignition, before they escalate into uncontrollable events.

Figure 13 Silvanet fire sensor on a tree (left); a Dryad Networks UAV takes off from its solar-powered "hangar" (right).

In the Australian context, Dryad's UAVs are best viewed as a pre-suppression and ultra-early response capability, particularly relevant for:

- Remote forests, plantations, and infrastructure corridors

- High-ignition-risk environments (e.g. lightning-prone or powerline-adjacent areas)
- Early attack scenarios where minutes matter more than payload size

The system is not designed to fight large, fast-moving bushfires, but to prevent them from forming. Regulatory approval, airspace integration, and ecological validation remain prerequisites for deployment at scale.

Dryad Networks represents the most mature and integrated option for autonomous ultra-early suppression. Its system is built around minute-scale detection using distributed gas sensors, which trigger fully autonomous UAV response for confirmation and, in prototype form, direct suppression. The strength of Dryad is not brute suppression volume but time advantage: deploying within minutes while fires remain small enough to be extinguished with limited payloads. Dryad's detection infrastructure sits at TRL 8, while the hybrid detect-and-suppress UAV capability is at TRL 5–6, having been demonstrated in controlled field pilots. Indicative costs are up to $500,000 per protected node, including sensors, autonomous docking, and UAVs. For Australia, Dryad is best suited to plantations, Wild-urban Interface edges (WUI), and infrastructure corridors, where preventing escalation delivers the highest return.

5.7.1.1.2 Ponderosa.ai / Ponderosa Systems (USA) ponderosa.ai/

Ponderosa Systems focuses on small-fire, first-attack suppression UAVs designed to reach ignitions faster than ground crews or crewed aircraft once detection occurs. Ponderosa does not seek to own or replace the sensing layer; instead, it is designed to integrate with existing wildfire detection and dispatch ecosystems, including fixed cameras, alerting networks, and agency command systems. This design choice simplifies deployment in jurisdictions where detection capabilities are already mature.

The system architecture centres on rapid UAV dispatch following an authorised trigger, with platforms designed to physically disrupt and extinguish fires at ignition scale. Suppression payloads are optimised for very small fires and are not intended for sustained attack or incident management. As with other first-attack autonomous concepts, the key operational advantage is response latency reduction, enabling intervention during the earliest phase of fire growth rather than increasing suppression volume.

From a technology-readiness standpoint, Ponderosa's system currently sits at approximately TRL 5–6, with agency pilots, demonstrations, and controlled operational trials underway. Indicative costs are in the range of A$80,000–A$250,000 per UAV, excluding detection infrastructure but including onboard suppression capability, autonomy software, and command-and-control integration. Additional costs are associated with software integration, communications, and governance frameworks.

In the Australian context, Ponderosa's approach is well aligned with environments where detection and governance structures are already established, and where authorities prefer a clear human-authorised activation while still demanding rapid autonomous execution. It is best suited to:

- Plantations and managed landscapes with defined perimeters
- Wildland–urban interface (WUI) zones with high ignition consequence
- Jurisdictions prioritising rapid first attack without full automation of ignition detection

Ponderosa's system is not intended to replace conventional suppression assets or manage large, fast-moving bushfires. Its value is concentrated in ignition-stage intervention, where early physical disruption can prevent escalation and reduce downstream resource demand.

Ponderosa Systems offers a pragmatically scoped, first-attack suppression capability that complements rather than replaces existing detection and command frameworks. For Australia, it represents a credible option where detection is already mature and governance favours a human-authorised trigger paired with rapid autonomous response. Its strongest applicability lies in plantations and WUI environments, where minutes of response time can determine whether a fire becomes an incident at all.

5.7.1.2 Hotspot & Mop-Up UAV Companies

The following two UAV systems are best operated after ultra-early systems to manage spot fires, night operations, and mop-up once crews or aircraft engage.

5.7.1.2.1 DJI Ecosystem (China / Global) enterprise.dji.com/public-safety/firefighting

DJI represents the most widely deployed general-purpose UAV ecosystem currently used in wildfire response globally, with platforms adapted for detection, monitoring, mapping, and tactical support rather than autonomous suppression. Unlike Dryad or Ponderosa, DJI does not deliver a vertically integrated wildfire solution; instead, it provides a flexible hardware and software base that agencies and integrators configure to suit local operational models.

DJI's wildfire relevance is centred on hotspot detection, situational awareness, and persistence, particularly through thermal imaging payloads, night operations, and rapid re-deployability. DJI platforms are commonly integrated with camera towers, dispatch systems, and existing agency workflows, making them highly interoperable but largely human-in-the-loop. Suppression is not a primary design objective; payload capacity and endurance are optimised for sensing and monitoring rather than physical fire extinguishment.

From a technology-readiness perspective, DJI's platforms operate at TRL 8–9, reflecting extensive real-world deployment across emergency services, industry, and government. Costs are relatively low compared with specialised autonomous systems, typically up to $60,000 per UAV depending on platform, sensors, and redundancy, with additional costs for training, operations, and software integration. This cost structure enables agencies to field large fleets, supporting persistent coverage rather than ultra-early intervention.

In the Australian context, the DJI ecosystem is best understood as the backbone of current UAV wildfire operations, particularly for detection confirmation, night-time hotspot monitoring, damage assessment, and real-time support to crews. It is most applicable in:

- Ongoing incident monitoring and mop-up operations
- Night and low-visibility conditions where crew access is restricted
- Large-area surveillance once fires are established
- Agency environments prioritising controlled, human-authorised operations

DJI platforms are not designed to independently prevent fires from forming, nor to autonomously suppress ignitions. Their value lies in persistence, situational awareness, and scale, rather than minute-scale detection or automated response.

DJI provides the most mature, scalable, and cost-effective UAV ecosystem for wildfire monitoring and operational support, but it does not address the ultra-early suppression gap on its own. For Australia, DJI platforms deliver maximum value when layered behind early-detection and first-attack systems, forming the persistence and visibility tier of a broader wildfire UAV stack. When combined with specialised early-response technologies, DJI fleets significantly enhance operational continuity, night capability, and overall situational awareness.

5.7.1.2.2 Walkera Firefighting Drones / DR1 (China / Global) en.walkera.com/index.php?id=1889

Walkera Firefighting Drones, through its DR1 platform, focuses on hotspot suppression UAVs designed to deliver targeted water or foam payloads against small fires, residual hotspots, and flare-ups rather than ultra-early ignition interception. The DR1 is a medium-class multirotor optimised for hover stability, precision delivery, and repeated short sorties, enabling direct physical suppression where human access is limited or unsafe.

Unlike detection-led or first-attack autonomous systems, the DR1 operates primarily in a tactical suppression role. It is intended to work from confirmed intelligence - such as crew reports, camera systems, or other UAV feeds - and to apply small but effective quantities of suppressant precisely to active hotspots. The operational value lies in access and persistence, particularly in complex terrain or low-visibility conditions, rather than in speed of first detection.

The DR1 platform has reached an estimated TRL 6–7, with field demonstrations and operational pilots conducted in European wildfire contexts. Payload capacity exceeds that of typical monitoring UAVs but remains far below crewed aerial firefighting platforms, positioning the system between reconnaissance drones and conventional suppression aircraft. In the Australian context, it is a strong fit for scenarios where precision suppression is required under conditions that restrict crew or aviation access. It is particularly applicable to:

- Night-time hotspot suppression and mop-up
- Steep, forested, or inaccessible terrain

- Situations where ember control or flare-up prevention is critical

The system complements existing detection and monitoring assets rather than replacing them, and its effectiveness is maximised when cued by other intelligence sources. Regulatory approval and integration with airspace and incident-management frameworks would be necessary for routine deployment.

Walkera Firefighting Drones' DR1 provides a credible and relatively mature hotspot-suppression UAV capability, occupying the middle tier between monitoring drones and crewed aerial assets. For Australia, its greatest value lies in night operations and terrain-constrained environments, where targeted suppressant delivery can reduce rekindle risk, limit crew exposure, and extend suppression capability beyond daylight flying windows.

5.7.2 Other technologies considered

The Magirus FireBull remote-controlled firefighting unit and the Kaman K-MAX Titan autonomous helicopter were presented to the project Steering Committee. Both, along with similar technologies, were assessed as more relevant to Australian firefighting agencies than to the forestry industry.

5.7.3 Magirus FireBull and other tracked, remote-controlled firefighting platform

The Magirus FireBull (magirusgroup.com) is a tracked, lightweight firefighting platform designed for off-road and unprepared environments, with proven capability in mud, snow, and forest terrain. Its tracked configuration enables operation where wheeled vehicles cannot, and in some cases, it can be air-dropped or forward-deployed into remote firegrounds. With indicative costs of up to $1.7 million, it sits below heavy aviation in capital intensity. However, the system is not autonomous, in decision-making human operators are required to define missions, direct suppression, and coordinate with crews. As such, it functions as a force-multiplier, improving safety and reach rather than acting as a standalone solution.

This type of firefighting platform includes the Rosenbauer RTE Robot (rosenbauer.com); Thermite RS3 (howeandhowe.com); Scrum Force (hazardexonthenet.net); Shark Robotics Colossus (www.shark-robotics.com); Firefighting robot RXR-MC40D (www.jjxffire.com), and various offerings from Hitech (www.hcrot.com), with a comprehensive review undertaken by Zhao et al., 2022.

These systems are primarily designed to reduce firefighter exposure in high-risk, industrial or urban environments, where access, water supply, and communications are reliable. They operate using a standoff suppression model, delivering high volumes of water or foam while keeping operators at a safe distance, with automation typically limited to movement and stabilisation rather than independent decision-making.

Figure 14 Magirus FireBull

Australian bushfires present fundamentally different conditions. Fires are fast-moving, wind-driven, and geographically extensive, often occurring in steep, remote terrain with limited access, water, and communications. As a result, ground-based firefighting robots are poorly aligned with these environments. While they may have niche roles in asset protection at the wildland–urban interface or within plantation or industrial settings, they lack the mobility and scale required for landscape-level fire suppression and are not substitutes for aerial systems, early detection, or conventional ground operations.

5.7.3.1 Kaman K-Max Titan, and other autonomous firefighting aircraft

The Kaman K-MAX Titan (kaman.com/our-businesses/kaman-air-vehicles/k-max/) is a commercial-grade, heavy-lift helicopter capable of fully autonomous flight, representing one of the few examples of autonomy proven at operational scale. Built on the reliable K-MAX (K-1200) airframe, it combines decades of heavy-lift experience with autonomous flight systems developed with Lockheed Martin. Its intermeshing twin-rotor (synchropter) design enables efficient lift, precise hover control, and stable operation, with payloads of up to ~2,700 litres and endurance of up to three hours, supported by minimal ground crew. The aircraft can operate fully autonomously or be conventionally piloted, providing flexibility across regulatory contexts.

In wildfire scenarios, the Titan has demonstrated capabilities rare at this scale, including autonomous water pickup and drop, precision sling-load delivery, and operation in high-risk environments unsuitable for crewed helicopters. While it reduces human exposure and extends operational capability, it remains a specialised force multiplier rather than a replacement for crewed fleets. High capital cost (up to $28 million), certification, and regulatory constraints limit adoption, and although production ended in 2023, it remains a globally significant proof-of-capability. For Australia, it represents the upper bound of autonomous aerial fire response - technically viable but most applicable to niche, high-risk roles.

Comparable systems are limited, reflecting the complexity of autonomous heavy-lift rotary-wing operations. Emerging efforts, such as Sikorsky's MATRIX autonomy programme, and Bell's optionally piloted aircraft concepts, focus on supervised or optional autonomy rather than full independence. Larger UAV cargo platforms are also exploring similar roles, but few are wildfire-specific or operational at scale. Collectively, these developments indicate that while autonomous aerial lift is advancing, most systems remain early-stage, reinforcing the Titan's status as a leading but niche example of current capability.

5.7.4 Summary – Fire Control

Fire control technologies in forestry are increasingly centred on UAV-based systems deployed after detection, with a clear shift toward faster, safer, and more targeted response. While most current applications remain remotely piloted, research and industry development indicate a move toward more integrated, semi-autonomous systems. Leading approaches combine technology and fire science, with detection and surveillance platforms guided by risk modelling and environmental data to improve where and how response is applied.

Two primary UAV roles are emerging: ultra-early detect-confirm-suppress systems, which aim to intercept fires at ignition, and hotspot and mop-up systems, which provide persistence, night capability, and situational awareness once fires are established. Technologies such as Dryad and Ponderosa represent the leading edge of early-stage suppression, while platforms like DJI and Walkera drones provide operational maturity in monitoring and targeted suppression. Together, these form a layered response model that prioritises early intervention and minimises reliance on large-scale suppression.

For Australian forestry, the key insight is that UAVs deliver the greatest value when integrated into broader, data-driven systems, rather than deployed as standalone solutions. Early detection, targeted deployment, and decision support provide the most immediate benefits, while fully autonomous suppression remains an emerging capability. Although alternative technologies such as ground-based fire robots and autonomous heavy-lift aircraft exist, they are generally better suited to specialised or agency-led firefighting roles. Overall, UAVs represent a practical, scalable pathway to improving fire response, aligned with Australia's remote landscapes, lightning-driven ignitions, and resource constraints.

5.8 Operator assistance

This section examines operator-assist technologies, including the remote operation of machinery, which enhance human performance rather than replace it. Operator-assist systems encompass a broad class of technologies designed to reduce cognitive load, physical fatigue, and improve worker safety while retaining full human decision-making authority. In forestry, these include motion and boom assistance, guided positioning and spacing control, depth and terrain-linked automation, teleoperation of hazardous equipment, and semi-automated safety interventions. Rather than full autonomy, these systems selectively automate high-risk or repetitive sub-tasks while leaving critical judgement with the operator.

Typically operating at TRL 7–9, operator-assist solutions are built on mature sensing, control, and actuation technologies, allowing relatively rapid deployment. Costs are generally incremental compared to full automation, while delivering immediate gains in productivity, safety, and operator wellbeing. Importantly, these systems play a strategic role as a bridge to future autonomy, supporting workforce capability, improving consistency, and preparing organisations to operate effectively alongside increasingly data-driven and semi-autonomous systems.

5.8.1 Commercially available currently

This section outlines commercially available operator-assist systems from major forestry machinery manufacturers, focusing on technologies that enhance operator performance while maintaining full human control. These approaches provide a practical and immediately deployable pathway to improved performance and workforce sustainability:

5.8.1.1 Komatsu Forest smartforestry.komatsuforest.com/

Komatsu is widely regarded as a leader in forestry operator assistance through systems such as Smart Crane, Smart Forestry, and Stability Assist. Its assistance tools automatically dampen crane motion, manage momentum, and improve precision during repetitive loading and felling tasks. Komatsu also integrates vision systems, guidance overlays, and operator-centric feedback, helping reduce fatigue and improving consistency, particularly in forwarding and processing operations.

5.8.1.2 Volvo Forestry & Heavy Equipment tdxltd.co.nz/volvo-co-pilot-/

Volvo Construction Equipment provides operator assistance through Co-Pilot, Dig Assist, and stability and guidance systems adapted from its construction portfolio. These tools provide machine guidance, motion control, load monitoring, and enhanced visibility, helping operators work more accurately and safely on complex terrain. Volvo's approach emphasises ergonomics, intuitive interfaces, and reduced cognitive load, particularly for multi-task machines.

5.8.1.3 Ponsse www.ponsse.com/company/news/

Ponsse's forestry-specific systems focus on crane control assistance, machine stability, and operator feedback, integrated tightly into its harvester and forwarder platforms. Features such as active boom control, ergonomic cab design, and task-oriented assistance help reduce repetitive strain while maintaining high productivity. Ponsse tools are designed to support skilled operators, rather than automate decision-making.

Figure 15 Ponsse OptiFelling automated assistant and control system improves cutting precision and operator safety by managing pre-tensioning during the cut.

5.8.1.4 John Deere Forestry eere.com.au/en/technology-products/forestry-and-logging-technology

John Deere's operator-assistance offering is centred on Intelligent Boom Control (IBC), Haptic Boom Control, and integrated camera and sensing systems on harvesters and forwarders. These tools smooth crane movements, reduce swing and bounce, and help operators place loads more accurately with less effort. Deere also layers in operator feedback and performance data through onboard displays and JDLink, supporting training and continuous improvement while keeping full manual control with the operator.

5.8.1.5 Caterpillar cat.com/en_GB/products/new/technology/assist.html

Caterpillar's assistance technologies revolve around Cat Assist, Cat Grade, Stability Monitoring, and advanced camera and sensing packages. While primarily developed for construction and mining, many of these features are applied in forestry-adjacent roles, supporting smoother machine motion, safer operation on slopes, and improved situational awareness. Caterpillar also places strong emphasis on health, fatigue reduction, and operator coaching through performance analytics.

5.8.1.6 Tigercat tigercat.com/feature/virtual-operator-training/

Tigercat offers operator-assist crane control, levelling support, and camera systems on its forestry machines, particularly for steep-slope and high-risk applications. The emphasis is on machine stability, smooth control, and visibility, enabling operators to work safely and confidently in difficult terrain while retaining full control.

5.8.1.7 Rottne forestmachinemagazine.com/the-new-rottne-e-cabin

Rottne's operator-assistance approach is highly operator-centric and forestry-focused, enhancing skilled performance rather than introducing heavy automation. Its systems - such as crane damping, smooth hydraulic control, levelling, and stability assistance - reduce strain and improve precision in repetitive tasks, supported by strong ergonomics, visibility, and optional camera systems. While providing operator feedback for learning and productivity, control remains fully with the operator, making these tools well suited to contractor-driven environments where reliability and acceptance are critical.

Table 7 give a comparison of operator-assist features from current commercial forestry machinery manufacturers.

Table 7 Comparison of operator-assist features from current commercial forestry machinery manufacturers

Manufacturer	Komatsu Forest	John Deere Forestry	Ponsse	Rottne	Tigercat
Overall positioning	Balanced productivity & safety	High-volume, integrated systems	Operator-centric precision	Value-focused simplicity	Heavy-duty performance
Automation maturity	High	High	Very high	Medium	Medium
Crane & boom assistance	Strong	Strong	Market-leading	Basic	Strong
Cutting & bucking assistance	Advanced	Advanced	Best-in-class	Limited	Limited
Guidance & mapping	Good	Very strong	Very strong	Moderate	Moderate
Vision & sensing	Limited	Cameras & sensing	Limited	Minimal	Cameras only
Safety & stability assist	Strong	Strong	Strong	Adequate	Excellent (terrain)
Ergonomics & fatigue reduction	High	High	Industry benchmark	Moderate	High
Operator feedback & analytics	Productivity-focused	Data-rich	Operator-friendly	Basic	Limited
Thinning precision support	Rule-based	Rule-based	Strong operator tools	Operator-dependent	Operator-dependent
Best-fit use case	Mixed harvesting & thinning	Large fleets, scale ops	Precision thinning & training	Value thinning	Steep, harsh conditions
Main limitation	Less tree-level perception	OEM-locked ecosystem	Less heavy-duty focus	Fewer advanced assists	Less precision tooling

5.8.2 Recommended – Operator assistance

This section recommends emerging operator-assist and automation systems combining automation, teleoperation, and training technologies to improve productivity, safety, and workforce capability. Together, they represent a shift toward digitally enabled, semi-autonomous workflows, extending operator capability while retaining human oversight:

1. Nordic Forestry Automation (NFA) advanced driver assistance system for thinning
2. Skogforsk Advanced Training & Simulation for Forestry Machine Operators (AVATAR) training
3. Forest Growers Research NZ program on harvesting automation & robotics
4. Skogforsk Troëdsson Forestry Teleoperation Lab
5. Kodama Autopilot

5.8.2.1 Nordic Forestry Automation (NFA) Advanced Driver Assistance System (ADAS) for thinning https://www.nordicforestryautomation.com/

Nordic Forestry Automation (NFA) advanced driver assistance system is an AI-driven decision support that helps operators deliver accurate, consistent thinning and forest treatments, while keeping full human control of the machine. NFA has developed an advanced driver assistance system (ADAS) for mechanical thinning that brings automotive-grade perception and AI into the harvester cabin. The system is designed as a retrofit solution for existing harvesters and excavator-based machines, combining lidar, cameras, GNSS, IMUs, and onboard AI compute to create a real-time digital map of the forest at individual-tree resolution. The intent is not autonomy, but decision support - helping operators consistently achieve prescribed thinning outcomes while reducing cognitive load and operator-to-operator variability.

In Scandinavia, the NFA system provides live thinning guidance (basal area, stem count, species ratios), strip-road spacing support, and automatic pre- and post-operation inventory. Each tree cut or retained is logged with centimetre accuracy, enabling auditable compliance reporting and improved downstream planning for forest owners. Large forest companies such as Södra have committed to staged rollout beginning in 2025, following multi-year pilot programs, and the system has accumulated several thousand hours across multiple machine platforms.

From a technology readiness perspective, NFA's thinning ADAS sits at approximately TRL 7–8: prototype systems have been extensively tested in operational environments, with early commercial deployment now underway in Sweden and limited international trials, including at least one installation in Australia.

Cost information is not publicly itemised, but industry indications suggest a mid-five-figure cost equivalent per machine for hardware and software, plus ongoing support and data services. The value case is driven by improved stand growth, reduced over-thinning, higher consistency across contractors, and lower training burden for less-experienced operators, rather than direct labour elimination.

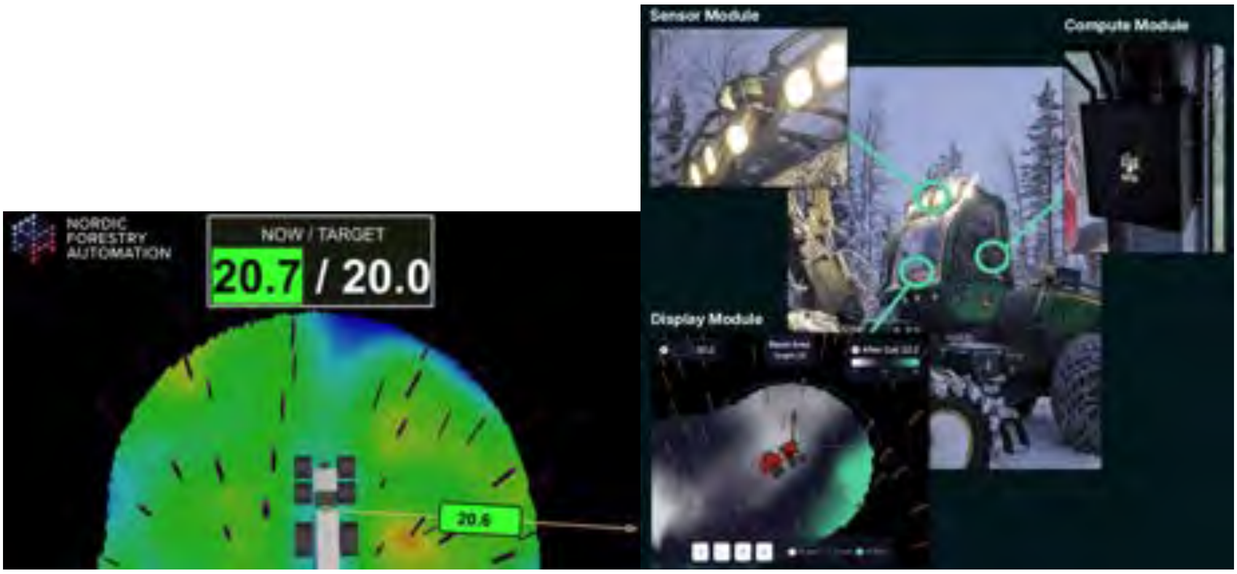

Figure 16 Left https://innovatek.co.nz/ai-company-partners-nordic-forestry-automation/ Right https://www.nordicforestryautomation.com/

For Australian forests, NFA's system appears most applicable to plantations and structurally regular native forests where thinning prescriptions can be clearly defined, such as softwood estates or managed eucalypt regrowth. Its reliance on onboard sensing rather than continuous connectivity is advantageous under canopy. However, adaptation would be required for higher species diversity, irregular stand structure, steeper terrain, and different silvicultural objectives compared with Nordic conditions. NFA's ADAS represents a near-term, low-risk augmentation of human operators rather than a disruptive automation leap. In Australia, it offers credible potential to lift thinning quality and consistency in suitable forest types, with moderate cost, manageable integration risk, and a mature technology base.

5.8.2.2 Skogforsk Advanced Training & Simulation for Forestry Machine Operators (AVATAR) training https://www.skogforsk.se/english/projects/avatar/

AVATAR is a research-developed digital training, coaching, and simulation framework led by Skogforsk, the Forestry Research Institute of Sweden, and funded under the EU Horizon 2020 and ForestValue programmes. Its core aim is to accelerate skill acquisition, improve operational consistency, and reduce mental workload for operators of harvesters and forwarders in fully mechanised forestry systems.

Unlike simple machine simulators, AVATAR combines high-fidelity simulation, real-machine data capture, and a "digital coach" concept. Using CAN-bus data, lidar-based environmental sensing, and motion analysis, the system identifies work phases, evaluates operator behaviour against best-practice patterns, and provides structured feedback through simulators and in-cab interfaces. This allows both novice and experienced operators to train against measurable performance and quality indicators, rather than relying solely on subjective instruction.

AVATAR is assessed at TRL 6–7. Core algorithms, simulators, and feedback concepts have been validated through multi-year field trials on production harvesters and forwarders in Sweden, Germany, and Norway, and demonstrated in professional training environments. However, AVATAR remains primarily a research-to-applied-training platform, not a fully commercial, off-the-shelf product.

Cost data is not published as a single commercial price. Based on comparable forestry simulators and the AVATAR project structure, deployment would typically involve capital costs in the low- to mid-six-figure cost range for simulator hardware, software integration, and course development at a training-centre level, with lower per-operator marginal costs once established. Ongoing costs relate to curriculum updates, instructor capacity, and data management rather than per-machine licensing.

Figure 17 Advanced Virtual Aptitude and Training Application in Real Time (AVATAR). Hartsch & Wagner, 2023.

For Australian forestry, AVATAR is best suited to plantation and mechanised native forest systems where harvesters and forwarders dominate operations and where workforce shortages make accelerated training valuable. The framework's emphasis on cognitive workload reduction, safety, and consistent execution aligns well with Australian conditions. Adaptation would be required for local silviculture, terrain, and species, but the underlying training philosophy is highly transferable. AVATAR is a mature training and simulation capability, not automation. It offers Australia a low-risk, high-leverage pathway to lift operator competence, safety, and productivity, particularly where rapid workforce development is a strategic priority.

5.8.2.3 Forest Growers Research NZ program on harvesting automation & robotics Te Mahi Ngahere i te Ao Hurihuri – Forestry Work in the Modern Age fgr.nz/research-programmes/harvesting-automation-and-robotics/

New Zealand' Forest Growers Research (FGR) Harvesting Automation & Robotics Programme is a nine-year, industry–government research partnership (2019–2028) designed to systematically reduce cost, improve safety, and address labour shortages across New Zealand's forestry harvesting and logistics value chain. The programme operates under the banner "Te Mahi Ngahere i te Ao Hurihuri - Forestry Work in the Modern Age" and is jointly funded by Forest Growers Levy Trust, the New Zealand forest industry, and the Ministry for Primary Industries (MPI). Details on this work, including new reports are available at

Rather than pursuing a single autonomous machine, the FGR programme adopts a modular, incremental automation strategy, targeting high-risk and labour-intensive subtasks within harvesting systems. Areas of focus include:

- remote-controlled and automated felling aids,
- automated attachment couplers and multi-function base machines,
- tele-operated and semi-automated cable-yarding systems,
- machine-vision-based bark detection and log measurement,
- automated log identification and load-securing systems, and
- data-driven human-factor tools to reduce fatigue and injury risk.

Multiple technologies have already reached early commercial deployment, while others remain in prototype or pilot phases depending on market conditions and manufacturing readiness.

The total programme value is approximately $18 million, and programme modelling indicates potential harvesting and logistics cost savings of around $4 per cubic metre by 2030, primarily through better machine utilisation, reduced downtime, and labour-efficiency gains rather than full labour displacement.

Because the programme spans many technologies, TRL varies by component:

- TRL 8–9: commercially deployed systems such as remote-controlled felling wedges, automated attachment couplers, and automated load-securing components.
- TRL 6–7: tele-operated yarding, automated log ID, and advanced machine-vision systems currently in pilot or early commercial stages.
- TRL 4–6: more integrated robotics and next-generation automation concepts still in development or paused due to market cycles.

Australia's plantation-dominated forestry sector, steep-slope harvesting regions, and persistent labour constraints closely mirror the conditions that motivated the FGR programme. The incremental, task-focused automation approach is particularly well-suited to Australian forests, where wholesale autonomy is neither economically nor operationally viable in the near term. Many solutions - especially in tele-operation, machine safety, attachment automation, and log-handling logistics - are directly transferable, with adaptation needed mainly for local species, terrain, and regulatory settings.

Forest Growers Research (FGR)'s Harvesting Automation & Robotics Programme represents a pragmatic, field-validated pathway to forestry automation, delivering measurable safety and cost benefits without relying on full autonomy. This is reflected in a portfolio of targeted technologies that address specific operational challenges, including the Automated Quick Coupler, automated cable yarder systems, remote-controlled felling wedges, and automated log identification and load securing. Complementary innovations such as machine vision for bark measurement, log sort yard optimisation, and improved residue management - including the use of shredded wood for roading - demonstrate a systematic focus on improving efficiency, safety, and consistency across the harvesting workflow.

FGR (New Zealand) and FWPA (Australia) are equivalent industry-led forestry research organisations that operate independently but collaborate across Australia and New Zealand to share knowledge and address common sector challenges. For Australia, this programme provides a credible reference model and technology pipeline well aligned with near- to mid-term industry needs. By focusing on modular, task-level automation rather than full system autonomy, FGR's approach enables incremental adoption within existing operations, delivering immediate value while building toward more advanced automation over time.

5.8.2.4 Skogforsk Troëdsson Forestry Teleoperation Lab skogforsk.se/contentassets/

The Troëdsson Forestry Teleoperation Lab, operated by Skogforsk, has developed a comprehensive suite of operator-assist and teleoperation technologies that extend human capability in forestry without removing the operator from the control loop. These systems combine advanced sensing, visualisation, and control technologies to support operators in performing complex tasks more safely and consistently, particularly in environments characterised by steep terrain, limited visibility, and high physical demands. Rather than pursuing full autonomy, the programme focuses on augmenting operator performance, ensuring that human judgement remains central while repetitive, high-risk, or precision-dependent elements are assisted or stabilised.

A key feature of the Troëdsson Lab's work is the integration of enhanced visualisation and situational awareness tools, including multi-camera systems, stereoscopic or virtual-reality (VR) views, and real-time environmental sensing. These technologies allow operators - whether in-cab or remote - to better interpret their surroundings, supporting more accurate crane control, improved placement of loads, and safer navigation in dense or obstructed forest conditions. Complementary assistance systems such as motion smoothing, crane stabilisation, and machine-levelling support reduce operator fatigue and variability in task execution, particularly during repetitive operations like forwarding or loading.

The lab also explores teleoperation and remote-assist models, where operators can control or supervise machines from safe, off-machine environments. This has significant implications for reducing exposure to hazards such as vibration, noise, heat, and slope instability, while also enabling more flexible workforce models. Importantly, these systems are designed to scale from assistance to higher levels of automation, providing a practical transition pathway rather than a disruptive shift. As such, the Troëdsson Forestry Teleoperation Lab represents a bridge between conventional machine operation and future autonomous systems, delivering immediate gains in safety, precision, and workforce sustainability while building the technical and organisational foundation for more advanced automation.

Figure 18 User interface of Troëdsson Forestry Teleoperation Lab

For Australian forestry, these operator assistance tools are well aligned with plantation and native forest operations, steep terrain, heat exposure, and workforce shortages. They offer a credible, near-term way to lift safety, productivity, and workforce sustainability without relying on full machine autonomy.

5.8.2.5 Kodama Autopilot™ kodama.ai/news/skidders-on-autopilot

Kodama Autopilot™ is a forestry-specific teleoperation and supervised-autonomy retrofit system developed by Kodama Systems to enable heavy forestry machines - initially skidders - to be operated remotely from safe, off-site control rooms. Rather than removing humans from the decision loop, Autopilot keeps operators fully in control via multi-camera video feeds, audio, and haptic inputs, using satellite and radio communications to handle the low-connectivity, dusty, and GPS-challenged conditions typical of forest environments. The system has been publicly demonstrated on commercial logging equipment, including the Weiler S340 wheel skidder, with operators controlling machines from hundreds of kilometres away while achieving productivity comparable to in-cab operation.

From a maturity standpoint, Kodama Autopilot sits at approximately TRL 6–7. The hardware and teleoperation stack have moved beyond laboratory validation into real-world pilot deployments and commercial demonstrations, including sustained skidding operations in active harvests, but have not yet reached broad, multi-fleet commercial rollout. Kodama positions Autopilot as a bridge toward greater automation, with supervised autonomy features planned but not yet the primary value proposition.

Cost structures are not published as a simple list price. Kodama currently offers Autopilot via pilot programmes and “skidding-as-a-service” models, with economics framed around daily or project rates rather than outright system purchase. Based on comparable teleoperation retrofits and public statements, indicative capital-equivalent costs are widely inferred to be in the low to mid six-figure cost range per machine, depending on configuration, communications infrastructure, and service terms, with the business case driven primarily by labour availability, reduced downtime, and improved safety rather than direct fuel or cycle-time gains.

Overall, Kodama Autopilot is best understood as a pragmatic, near-term autonomy enabler for forestry, focused on labour resilience, safety, and operational flexibility rather than full driverless operation. Its design philosophy - retrofit, human-in-the-loop, and purpose-built for forest conditions - makes it one of the most credible autonomy pathways for steep, dispersed, and safety-critical forestry operations.

5.8.3 Summary – Operator Assistance

This section focuses on operator-assist technologies in forestry, which enhance human performance rather than replace it. These systems - such as motion assistance, guidance controls, teleoperation, and safety interventions - help reduce fatigue, cognitive load, and risk while keeping operators fully in control. Typically, mature (TRL 7–9), they offer a practical, lower-cost alternative to full automation and act as a bridge toward future autonomous operations.

Major manufacturers (Komatsu, Volvo, Ponsse, John Deere, Caterpillar, Tigercat, and Rottne) already provide commercially available operator-assist features. These systems improve precision, stability, ergonomics, and productivity, with varying strengths depending on use case (e.g., precision thinning, steep terrain, or large-scale operations).

The section also highlights emerging and recommended technologies that extend operator capability through AI, teleoperation, and training:

- Nordic Forestry Automation (NFA) uses AI-driven sensing and decision support for accurate thinning, improving consistency without removing human control.
- AVATAR (Skogforsk) provides advanced simulation and coaching to accelerate operator training and performance.
- Forest Growers Research (NZ) demonstrates a modular, task-focused automation approach delivering cost savings and safety gains without full autonomy.
- Troëdsson Teleoperation Lab develops visualisation, stabilisation, and remote-assist tools to improve safety and reduce operator strain.
- Kodama Autopilot enables remote machine operation, enhancing safety and workforce flexibility.

Overall, operator-assist technologies represent a near-term, low-risk pathway to improved safety, productivity, and workforce capability in forestry, while preparing the industry for more advanced automation in the future. Operator-assist technologies provide a practical, mature pathway to improving productivity, safety, and workforce sustainability in forestry without removing human control. These systems - ranging from commercial OEM solutions to emerging research and teleoperation platforms - focus on reducing fatigue, improving precision, and supporting operators in complex and high-risk environments. With most technologies operating at high maturity levels (TRL 7–9), they can be deployed incrementally across existing fleets, delivering immediate value with relatively low integration risk compared to full automation.

A clear industry trend is the shift toward digitally enabled, semi-automated workflows, where repetitive or hazardous sub-tasks are assisted or partially automated while retaining operator decision-making. Commercial systems from major manufacturers already deliver strong gains in consistency and ergonomics, while emerging technologies - such as advanced driver assistance, simulation-based training, teleoperation, and modular automation programmes - extend capability further by improving decision support, workforce development, and operational flexibility.

For Australia, the key insight is that operator-assist systems act as a bridge to future autonomy, enabling organisations to build capability, improve consistency, and manage labour constraints without requiring disruptive change. The most effective pathway is incremental adoption, integrating assistance, teleoperation, and data-driven tools into existing operations. This approach delivers near-term benefits while positioning the sector to adopt higher levels of automation as technology, regulation, and workforce readiness evolve.

5.9 Truck platooning & other

Truck platooning in forestry refers to the operation of two or more log trucks travelling in a coordinated convoy, where the lead vehicle is driven by a human operator and one or more following vehicles are partially or fully automated, maintaining close spacing through vehicle-to-vehicle (V2V) communication and advanced control systems. This approach is particularly relevant in forestry haulage, where trucks often operate on repetitive routes between forests, depots, mills, and ports, making it well suited to controlled convoy-based operation.

In practice, platooning delivers safety, labour, and efficiency benefits. By reducing the number of drivers required per tonne hauled - particularly in follower vehicles - it helps address ongoing driver shortages while maintaining throughput. Automated following improves consistency in speed, braking, and spacing, which can enhance safety on long haul routes and reduce fatigue for operators in the lead vehicle. In forestry contexts, this model is especially attractive because it aligns with existing convoy-style operations on unsealed roads, and can operate in challenging conditions such as dust, reduced visibility, and variable terrain, provided the lead driver manages complex decision-making.

However, its effectiveness depends on predictable routes, communication reliability, and integration with existing logistics systems. Platooning is not a full autonomy solution but a human-in-the-loop model, retaining operator judgement where conditions are uncertain while automating repetitive driving tasks. For Australian forestry, it represents a practical, near-term pathway to autonomy, extending capability and improving productivity without the risks associated with fully driverless transport systems. In Australia's mixed public–private road networks and regulatory environment, these semi-autonomous, labour-multiplying approaches represent the most credible near-term strategy for haulage optimisation.

5.9.1 Recommended – Truck platooning

1. FP Innovations / Kratos Autonomous Truck
2. ETT One More Stack
3. Bot Auto Autonomous Truck
4. Two-Stage trucking using log trucks

5.9.1.1 FP Innovations / Kratos Autonomous Truck fpinnovations.ca/fpinnovations-and-kratos-defense

FPInnovations, working with Kratos Defense, is pursuing a leader–follower platooning model specifically tailored to forestry and natural-resource haulage. A human-driven lead truck provides navigation and decision-making, while one or more driverless follower trucks replicate its actions using vehicle-to-vehicle communications, sensors, and onboard autonomy. This system has been demonstrated extensively on Canadian forestry roads, including gravel, steep grades, degraded GPS, dust, snow, night operations, and mixed loads, covering thousands of kilometres in real timber-hauling conditions.

Figure 19 Kratos Unmanned Systems self-driving trucks platooning in Canada, 2025, in conjunction with FPInnovations.

The key strength of this approach is deployable in the near-term in harsh, off-road environments with low regulatory friction, because a trained human remains in the loop. Strategically, it is conservative but practical: it reduces labour demand and improves safety without requiring full Level-4 regulatory approval. The trade-off is that it does not eliminate drivers, and scalability is bounded by the need for a lead vehicle.

5.9.2 Other technologies

While the following technologies are not truck platooning systems, they offer similar benefits using other approaches.

5.9.2.1 ETT One More Stack skogforsk.se/contentassets/

ETT's One More Stack is a concept-driven productivity platform with early-stage autonomy enabling potential. It represents a fundamentally different framing of automation, shifting attention away from autonomous driving as the primary goal and instead redesigning the work truck as a system-level productivity platform. The core premise is that meaningful productivity gains in freight and worksite logistics can be achieved by rethinking vehicle architecture, loading workflows, and operational setup time, with autonomy acting as a downstream enabler rather than the lead feature.

The main concept is a focus on modularity and self-deployment. Public descriptions emphasise expandable or reconfigurable vehicle architectures that allow trucks to carry "one more stack" of cargo without proportionally increasing fleet size, labour input, or site congestion. This includes ideas such as integrated loading structures, rapid-deployment mechanisms, and reduced reliance on external handling equipment. The intended outcome is a truck that arrives on site already prepared to perform work, rather than one that requires significant manual staging, alignment, or auxiliary machinery before becoming productive.

Autonomy within the One More Stack vision is contextual and incremental. Rather than prioritising high-speed, long-haul autonomous driving on public roads, ETT appears to emphasise low-speed, task-oriented automation - for example, self-positioning, precision docking, coordinated movement with loading systems, or automated repetition of constrained manoeuvres in yards, depots, or worksites. In this framing, autonomy supports workflow consistency, safety, and reduced human fatigue, but does not replace the human operator as the system owner.

Crucially, there is limited public evidence of large-scale autonomous driving trials associated with the One More Stack concept, particularly when compared to programs such as FPInnovations/Kratos or Bot Auto, which foreground autonomous haulage as the primary deliverable. As a result, One More Stack is best described as TRL 3–5: a strong conceptual and architectural innovation, with promising applicability in controlled or semi-structured environments, but not yet a validated autonomous transport system.

Its primary differentiation lies in vehicle form factor and workflow redesign, not in demonstrated autonomy at scale. For sectors such as forestry, construction, or industrial logistics, this makes One More Stack an interesting future-enabling platform concept, but one that would require significant maturation, integration, and operational validation before deployment in Australian conditions.

5.9.2.2 Bot Auto Autonomous Truck bot.auto/

Bot Auto represents a full Level-4, humanless autonomy model, treating autonomy as the core product rather than an assist feature. It eliminates in-cab drivers and live human control, relying instead on sensor-driven perception, AI decision-making, and mapped routes to operate independently. In 2026, it demonstrated driverless commercial freight operations in the United States, signalling a shift from pilots to early commercial use.

Its economic advantage lies in removing drivers entirely, enabling continuous operation and higher asset utilisation. However, this model concentrates risk and is constrained to tightly defined operating conditions, with significant regulatory and scaling challenges. While technically mature within controlled corridors in the United States, its applicability to sectors such as Australian forestry remains limited in the near term, positioning it as a long-term reference rather than a practical deployment model.

5.9.2.3 Two-Stage trucking using log trucks fgr.nz/wp-content/uploads/2026/03/H081.pdf

This report (Best et al., 2026) examines the productivity and operational viability of two-stage trucking using off-highway log trucks in steep-land forestry operations in New Zealand, where direct access for High Productivity Motor Vehicles (HPMVs) is unsafe, impractical, or environmentally unacceptable. Two-stage trucking involves transporting stems or logs from the primary extraction landing to a secondary storage and loadout landing using dedicated off-highway trucks, thereby avoiding extensive mid-slope roading or costly road upgrades. The study reflects a broader industry shift, with adoption of two-stage systems increasing from approximately 8% of operations in 2016 to around 24% by 2024, driven by safety, environmental, and cost considerations.

Elemental time studies were conducted across four operational case studies using Astra HD9 8×8 and Scania 6×8 off-highway log trucks on haul distances ranging from 530 m to 5.4 km. The results show productivities between 19 and 41 tonnes per productive machine hour (PMH), with performance largely influenced by haul distance, payload capacity, and loading/unloading delays, rather than truck configuration itself. In all cases, two-stage trucking enabled safe access to harvest areas that were otherwise inaccessible to HPMVs. Importantly, when well-integrated into the harvesting system, two-stage trucking did not impose a productivity or financial penalty and, in many cases, reduced overall costs by lowering roading length, construction expense, and environmental risk.

The study concludes that two-stage trucking using off-highway log trucks is a mature, flexible, and effective solution for steep and erosion-prone terrain. It offers forest owners and planners a practical means of balancing safety, environmental stewardship, and cost control, particularly as harvest areas become more constrained and HPMV access more difficult.

5.9.3 Summary – Truck Platooning

Truck platooning represents a practical, near-term pathway to semi-autonomous haulage in forestry, combining human-driven lead vehicles with partially automated follower trucks operating in controlled convoys. It aligns well with forestry logistics, where trucks already operate on repetitive, corridor-based routes, enabling improvements in driver utilisation, safety, and operational consistency without requiring fully autonomous systems.

The primary value of platooning lies in its ability to reduce labour demand and operator fatigue while maintaining throughput, by automating repetitive driving tasks in follower vehicles and keeping human judgement in the lead truck. This approach is well suited to Australian conditions, including unsealed roads, variable terrain, and reduced visibility, as it retains human oversight where uncertainty is highest. As such, leader–follower systems - such as the FPInnovations/Kratos model - represent the most deployable form of autonomy in forestry today.

However, platooning remains dependent on predictable routes, reliable communication, and integration with existing operational systems, and does not eliminate drivers entirely. Alternative approaches, such as fully autonomous trucking or productivity-platform concepts, are either less mature or less applicable to forestry conditions. Overall, platooning offers a low-risk, incremental step toward automation, improving efficiency and resilience while building capability for more advanced autonomous systems over time.

5.10 Nursery technologies

This section investigates global nursery automation solutions and their relevance to the Australian forestry sector, supported by engagement with industry stakeholders including the Australian Forest Nursery Association and the New Zealand Forest Nursery Growers Association. Key areas of interest identified by Australian stakeholders include the development of robotic systems capable of taking cuttings from potted hedge plants and automated under-bench machinery for weed control, reflecting a focus on reducing labour intensity and improving consistency in high-volume nursery operations. Engagement with New Zealand growers further provides a complementary perspective, highlighting similar challenges and reinforcing the opportunity for shared technology pathways and cross-regional collaboration in advancing nursery automation. Large-scale, seed-based pine and eucalypt nurseries increasingly rely on automation to increase throughput, uniformity, and labour resilience while maintaining consistent plant quality. At the front end of the system, precision seed handling and automated singulation ensure individual seeds are placed accurately, improving germination uniformity and significantly reducing seed waste compared with manual sowing. This is complemented by automated tray filling and conveyance, where filling, stacking, de-stacking, and conveyor systems remove high-injury manual handling tasks and allow production lines to operate at much higher and more predictable speeds.

Downstream, sensor-driven irrigation and fertigation systems use real-time measurements of soil moisture, electrical conductivity, pH, and local climate conditions to tightly control water and nutrient delivery. This data-driven approach improves root development and batch-to-batch consistency, reducing variability that would otherwise propagate into the field. Vision-based grading and culling systems further enhance quality control by automatically assessing seedling size, vigour, and tray occupancy, reducing subjective manual grading and ensuring uniform output. Finally, internal transport automation - including conveyors, carts, and simple automated guided vehicles - moves large volumes of trays reliably with minimal labour input, enabling nurseries to scale production while mitigating workforce constraints and injury risk.

5.10.1 Commercially available nursery technologies

This section examines core nursery automation systems that underpin modern, high-throughput forestry production. These technologies span the full early-stage propagation workflow - from tray preparation and seeding through to irrigation control, internal logistics, and advanced propagation methods - and collectively define the operational performance ceiling of a nursery.

Across Australian conditions, their primary value lies in reducing variability and improving consistency, rather than simply increasing speed. By stabilising critical inputs such as substrate density, germination timing, water and nutrient delivery, and tray handling, these systems enable more predictable growth, better plant quality, and compatibility with downstream automation, including grading, transplanting, and mechanised planting.

Most of these technologies are mature and commercially proven (TRL 8–9), with modular deployment options ranging from targeted upgrades to fully integrated, automated nursery systems. As such, they represent foundational infrastructure for any nursery seeking to improve productivity, reduce labour dependency, and support broader mechanisation across the forestry value chain.

5.10.1.1 Automated tray disinfection, filling, and seeding systems

Automated tray disinfection, filling, and seeding systems supplied by Atlantic Man, Urbinati, Viscon Group, Bouldin & Lawson, Hort Tech Systems, KW Automation, and BCC / FiberCell now function as industrial infrastructure rather than optional mechanisation. These systems integrate tray washing and sanitisation, mechanically consistent substrate filling, dibbling, and precision seeding.

Their critical contribution is not speed alone but variance reduction. Uniform substrate density, consistent sowing depth, and hygienic starting conditions govern emergence synchrony, root architecture, and compatibility with automated transplanting, grading, and mechanised planting. In Australian nurseries characterised by mixed container formats and legacy layouts, this layer defines the limits of what downstream automation can achieve.

These technologies are mature (TRL 8–9), with capital investments typically ranging from $300,000 to more than $2 million depending on throughput and integration depth.

5.10.1.2 Controlled Germination and Early Growth Systems

Controlled germination systems provided by Conviron, BioChambers, Phytotronics, Urbinati, Viscon Group, and US Global Resources convert biological uncertainty into schedulable production. By tightly regulating temperature, humidity, airflow, lighting, and stratification protocols, these systems compress emergence windows rather than simply accelerating growth.

For Australian nurseries balancing climatic variability with seasonal labour availability, predictable emergence timing is critical. Controlled germination enables synchronised irrigation, transplanting, grading, and dispatch, reducing downstream bottlenecks. These systems are commercially mature (TRL 8–9), with capital costs ranging from approximately $200,000 for modular installations to multi-million-dollar facility-scale deployments.

5.10.1.3 Irrigation and Fertigation Precision Control

Irrigation represents the first closed-loop biological control layer in most modern nurseries. Platforms such as Priva integrate pumps, valves, EC/pH dosing, climate sensors, and root-zone feedback into centralised control systems. When paired with precision delivery hardware from Netafim, Rain Bird, and Baxter Irrigation, and substrate-linked systems from Grodan, irrigation shifts from calendar-based routines to plant-driven control.

In Australian conditions, these systems deliver rapid return on investment through reduced labour demand, lower water and nutrient use, decreased disease incidence, and more uniform growth. They also stabilise morphology, directly improving transplanting efficiency and grading accuracy. This layer operates at TRL 9, with typical investments between $150,000 and $2 million depending on nursery scale.

5.10.1.4 Transplanting and Internal Nursery Logistics

Tray transport systems - conveyors, elevators, buffers, and AGVs - form the circulatory system of an automated nursery. Suppliers such as Urbinati, Viscon Group, Green Automation Group, Hort Tech Systems, Bouldin & Lawson, KW Automation, and Taksas Tarim Automation provide solutions ranging from fixed conveyor lines to flexible AGV-based logistics.

These systems are typically TRL 8–9, with costs ranging from $200,000 for partial retrofits to $5 million or more for fully integrated logistics platforms. Their strategic importance is often underestimated; inadequate internal logistics is the most common cause of automation underperformance, as manual handling rapidly erodes upstream gains.

Tray transport and logistics systems including conveyors, elevators, buffers, and AGVs supplied by Urbinati, Viscon Group, Green Automation Group, Hort Tech Systems, Bouldin & Lawson, KW Automation, and Taksas Tarim Automation form the circulatory system of the nursery. Inadequate logistics remain the most frequent cause of automation underperformance in Australia. Mature implementations range from $200,000 retrofits to $5 million fully integrated logistics platforms.

5.10.1.5 Advanced Propagation Machinery

Ellepot integrated propagation systems replace rigid plastic containers with biodegradable paper-wrapped plugs that promote air-pruning and generate root systems inherently compatible with mechanised planting. These systems reduce plastic handling, align with ESG objectives, and directly support Australia’s plantation mechanisation programs. Ellepot systems are fully commercial (TRL 8–9), with integrated line costs typically between $400,000 and $1.5 million.

5.10.2 Recommended - Nursery

1. TTA-ISO FlexPlanter
2. NZ Forest Growers Research AI-supported seedling grading prototype
3. Ellepot integrated propagation system
4. Atlantic Man multi-grip automatic transplanting machine
5. TTA-ISO Cutting Edge

5.10.2.1 TTA-ISO FlexPlanter tta-iso.com/equipment/FlexPlanter%20S

The FlexPlanter is a flexible transplanting system designed to handle multiple tray formats and planting patterns without rigid standardisation. It uses automated mechanical extraction and placement mechanisms that can be reconfigured for different container geometries, making it well suited to nurseries with mixed production profiles.

The system operates at approximately TRL 8, with indicative capital costs up to $830,000 depending on configuration. Its strategic value lies in enabling mechanisation without forcing premature standardisation, making it a strong transitional technology for nurseries evolving toward full automation while still serving diverse species or clients.

Flexible systems such as the FlexPlanter enable mechanisation without premature standardisation - a critical requirement for Australian nurseries serving multiple clients or species. High-throughput systems deliver scale only where upstream uniformity is disciplined. Capital costs typically range up to $1.5 million at TRL 7–9.

5.10.2.2 Atlantic Man Multi-Grip Automatic Transplanting Machine (TPA) tech.atlanticgroup.it/equipment/automatic-transplanting-machine-tpa/

Atlantic Man’s Multi-Grip Automatic Transplanting Machine (TPA) exemplifies productivity amplification. Using a multi-grip robotic/mechanical head, it handles multiple seedlings simultaneously while preserving root plugs. Operating at TRL 8, with costs up to $1.1 million, it is best suited to nurseries that have stabilised upstream variability and reached labour capacity limits.

The Atlantic Man TPA employs a multi-grip robotic/mechanical transplanting head that can handle multiple seedlings simultaneously while preserving root plugs. This design prioritises throughput while maintaining gentle handling, making it particularly effective in labour-constrained nurseries with disciplined upstream processes.

Figure 20 Atlantic Man Multi-Grip Automatic Transplanting Machine (TPA)

The system is commercially mature at TRL 8, with typical capital costs ranging up to $1.1 million depending on grip configuration and integration depth. Its performance depends heavily on tray and plug uniformity and is less flexible across radically different container geometries. Strategically, the TPA functions as a productivity multiplier for nurseries approaching their labour ceiling, especially when paired with automated tray transport and AI grading.

5.10.2.3 NZ Forest Growers Research AI-supported seedling grading prototype https://fgr.nz/supporting-automated-seedling-grading-with-ai/

Forest Growers Research (FGR), through its Precision Silviculture Programme, has developed an AI-supported seedling grading prototype to automate a traditionally labour-intensive and subjective nursery process. The system combines computer vision and machine-learning within an in-shed conveyor, assessing seedlings against key quality metrics such as height, root-collar diameter (RCD), colour, and basic root characteristics. Trials with industry partners have demonstrated strong accuracy (±10 mm height, ±0.5 mm RCD), with grading outputs closely matching experienced nursery staff. Operator-facing software allows parameter tuning and produces batch-level reporting to support quality assurance and planning.

From a maturity perspective, the system sits at approximately TRL 5–6, having been validated in realistic nursery environments but not yet fully commercialised. Further development is expected in areas such as seedling singulation, automated packing, expanded trait detection, and integration with lifting or mobile grading systems. Indicative deployment costs are in the low- to mid-six-figure cost range per installation, primarily covering conveyor hardware, sensors, and software, with relatively modest ongoing costs linked to calibration, updates, and training.

For Australian forestry, the technology is highly transferrable. By shifting grading from subjective judgement to a consistent, data-driven process, it offers improved quality control, reduced manual handling, and better alignment between nursery production and field performance. More broadly, AI-based grading enables improved tracking of seedling outcomes, supports genetics optimisation, and strengthens reporting for carbon and ESG, providing a practical pathway toward more efficient and data-driven nursery operations.

5.10.2.4 Ellepot - Integrated Propagation System ellepot.com/

Ellepot systems replace traditional rigid plastic containers with biodegradable, paper-wrapped plugs that fundamentally improve root development while eliminating much of the plastic handling burden in nursery operations. The paper sleeve promotes air-pruning, preventing roots from circling or intertwining and encouraging the formation of dense, fibrous, and highly uniform root systems. This biological outcome is particularly important because it aligns naturally with mechanised planting systems, allowing seedlings to be handled, planted, and established more consistently than conventionally grown stock.

From a plant-health perspective, Ellepot-grown seedlings show lower transplant shock, reduced early mortality, and faster establishment after planting, particularly under operational planting conditions. High air circulation and controlled root architecture produce healthier, more uniform plants with improved resilience, including greater resistance to pests such as bark beetles. Because roots are well structured and individual plugs remain discrete, planting is faster and more reliable, supporting higher productivity in both manual and mechanised planting operations.

Commercially, Ellepot systems are fully mature (TRL 8–9) and are deployed globally across large-scale nurseries. Typical integrated line investments range from approximately $400,000 to $1.5 million, depending on capacity and automation level. Adoption requires deliberate workflow redesign and acceptance of ongoing consumable costs, but in return delivers strong ESG benefits by eliminating plastic pots - the degradable paper sleeve remains in the ground, creating no waste. At a system level, Ellepot's key strength is that it aligns plant biology with machinery, rather than forcing planting equipment to compensate for biological variability, making it particularly well suited where mechanisation, consistency, and sustainability outcomes are strategic priorities.

Plug-based nursery propagation systems represent a critical enabling layer for automated planting, as they produce seedlings with consistent geometry, root structure, and handling characteristics. This level of biological and physical standardisation aligns directly with the requirements of automated planting systems, enabling reliable mechanical handling, placement accuracy, and more consistent establishment outcomes under operational conditions.

5.10.2.5 TTA-ISO CuttingEdge automated cutting planting machine tta-iso.com/equipment/cuttingedge

The TTA-ISO CuttingEdge system automates the planting of rooted and unrooted cuttings using robotic arms, machine vision (CuttingVision), air-jet separation (VisionAir), and a shared learning platform (VisionHub). The system not only reduces labour but enables cutting setups and performance data to be shared across users, embedding learning into the machinery itself.

With capacities of approximately 1,800–2,500 cuttings per hour for single-head systems and up to 4,500 cuttings per hour for double-head systems, CuttingEdge operates at TRL 8–9. Capital costs typically range from $600,000 to $1.8 million. Strategically, it enables scalable clonal forestry under labour scarcity and exemplifies the transition toward AI-enabled nursery machinery.

Figure 21 TTA-ISO CuttingEdge automated cutting planting machine on eucalyptus

5.10.3 Summary - nursery

Nursery technologies are rapidly evolving into highly automated, integrated production systems that improve throughput, consistency, and labour resilience. Across both Australian and New Zealand contexts, the key drivers are reducing labour intensity, addressing variability in plant quality, and enabling scalable production under increasing workforce and environmental constraints. Modern nurseries achieve this by combining automated seed handling, tray preparation, controlled germination, precision irrigation, and internal logistics into coordinated workflows. These systems shift operations from manual, variable processes to predictable, data-driven production environments, which directly improves plant quality and downstream compatibility with mechanised planting.

Most commercially available systems are mature (TRL 8–9) and deliver value primarily through variance reduction rather than speed alone. By stabilising inputs such as substrate density, sowing depth, germination timing, and water and nutrient delivery, these technologies ensure more uniform growth, better root architecture, and improved grading outcomes. Internal logistics systems - often overlooked - are critical enablers, as inefficient tray handling can undermine gains made elsewhere. Together, these technologies form the foundational infrastructure required for modern nursery performance and any transition toward greater automation across the forestry value chain.

Emerging and recommended technologies build on this foundation by introducing flexibility, robotics, and data-driven decision-making. Systems such as flexible transplanting, AI-based grading, automated cutting propagation, and advanced propagation methods (e.g. Ellepot) demonstrate how nurseries can move beyond standardisation toward adaptive, high-precision production. These approaches enable incremental adoption, allowing nurseries to improve efficiency and quality without full system redesign. For Australia, the most effective pathway is modular implementation - combining proven automation with targeted innovation - to deliver near-term gains in productivity and consistency, while positioning the sector for longer-term advances in robotics, mechanisation, and data-enabled forestry systems. It is also worth referring to the report by Nanayakkara et al., 2022, titled “Modern Nursery Technology for Containerised and Bare Rooted Production Systems” produced as a Precision Silviculture Programme Technology Review for the New Zealand Forest Growers Research Limited.

5.11 Remote Controlled Felling Wedge

Remote-controlled felling wedges such as the EDER Radio Titan 79, Forstreich TR300, and ValRemote deliver disproportionate safety benefits by removing operators from peak-risk zones during tree felling. These systems retain manual control while enabling remote, precise application of lifting force.

Fully mature (TRL 8–9), these devices typically cost between $3,000 and $12,000 per unit and integrate seamlessly into existing workflows. Strategically, they act as cultural bridge technologies, delivering immediate safety return, possibly clearing trees damaged by forest fires, while preparing organisations for broader mechanisation.

There are three currently commercially available remote-controlled tree felling wedges:

1. EDER Radio Titan 80
2. Forstreich TR300
3. ValRemote

Figure 22 Remote-controlled tree felling wedges: EDER Radio Titan 80 (left); Forstreich TR300 (centre); ValRemote (right).

5.11.1 EDER Radio Titan 80 eder-maschinenbau.de/en/forestry-equipment/eder-remote-titan-80/

The EDER Radio Titan (often referred to as the Funk Titan 80) is a remote-controlled mechanical felling wedge system developed by EDER Maschinenbau, and it sits in the same category as the ValRemote/ValFast concept, high-force, remote-operated wedges designed for safer, controlled tree felling.

In essence, the Radio Titan is a compact, self-contained mechanical wedge with an integrated electric drive and radio remote control. It is designed primarily for heavy timber harvesting, where significant force is needed to push a tree over, particularly in back-leaning or high-risk situations. Rather than relying on manual hammering or separate drive tools, the system uses a battery-powered motor (typically a Milwaukee 18V system) to advance a threaded spindle, which steadily drives the wedge and generates controlled lifting force.

One of its defining characteristics is remote operation. The operator can control the wedge from a distance of around 80 metres, allowing them to move out of the immediate hazard zone while the tree is being brought over. This makes it particularly valuable when dealing with dangerous timber, such as trees affected by disease, storm damage, or dead limbs, where staying close during the final stages of felling presents significant risk.

In terms of performance, the Radio Titan is a high-capacity unit. It can generate up to approximately 25 tonnes of lifting force, with a lifting stroke of around 80 mm and a total wedge feed of about 160 mm. This level of force puts it firmly in the "heavy-duty" category, suitable for large-diameter trees and situations where substantial mechanical advantage is required to overcome natural lean or binding in the back cut.

The design emphasises portability and durability alongside power. Despite its output, the system remains relatively compact and can be carried in a backpack-style bag, making it practical for use in typical forestry environments. It also includes protective features such as a sealed drive spindle to prevent contamination from sawdust and debris, and anti-slip or fall-protection elements for use on steep terrain. These details are important in maintaining reliability in harsh, dirty working conditions.

Functionally, the Radio Titan represents a shift away from traditional felling wedges and even from mechanically driven wedges that rely on handheld impact wrenches. By integrating the drive system and adding radio control, it reduces operator effort, simplifies setup, and improves safety through distance operation. It is effectively a more self-contained and automated solution compared to systems that separate the drive unit and wedge.

Overall, the EDER Radio Titan is considered a premium, professional-grade felling aid, combining high lifting force, remote operation, and robust construction to enable safer and more controlled felling of large or hazardous trees.

5.11.2 Forstreich TR300 remote-controlled felling wedge forstreich.de/produkt/16242/

The TR300 is a remote-controlled felling wedge system designed to improve the safety and precision of directional tree felling in both forestry harvesting and arboriculture operations. Conventional felling wedges are driven manually into the back-cut of a felled tree using a sledgehammer or plastic mallet to guide the direction of fall and prevent the saw bar from being pinched; this places the operator in close proximity to the falling tree at the moment of greatest hazard. The TR300 replaces manual wedge driving with a battery-powered or pneumatic actuator that can be inserted into the back-cut and then activated remotely by the chainsaw operator from a safe distance via a handheld wireless controller, allowing the operator to step back out of the fall zone before the tree begins to move. The system typically incorporates a robust aluminium or reinforced polymer wedge body with an integrated piston or inflatable bladder mechanism capable of generating sufficient lateral force to steer large-diameter stems. TR300-type remote wedge systems have gained attention in European countries with strict occupational health and safety standards for manual chainsaw operators, and have also been evaluated by forestry safety organisations in Australia and New Zealand where chainsaw felling remains a significant cause of serious workplace injuries. In Australian plantation thinning and selective harvesting operations where mechanised harvesting heads cannot access terrain or stand conditions require manual chainsaw work, remote felling wedge technology represents a practical engineering control that reduces exposure to struck-by and crushing hazards without requiring major changes to established felling techniques. Training and certification for the device can be integrated into existing chainsaw operator competency frameworks.

5.11.3 ValRemote remotely controlled tree felling clark-engineering.com/product/valremote-with-valfast/

The ValRemote with ValFast, developed by BaSt-Ing, is a remote-controlled mechanical wedge system designed to significantly improve both the safety and efficiency of tree felling operations. Its primary advantage lies in allowing chainsaw operators to work from a safe distance, avoiding the need to stand beneath or near unstable trees, falling branches, or other hazardous conditions commonly encountered in forestry work.

At the core of the system is a detachable infrared remote control that operates a mechanical wedge via a portable drive unit, typically a Milwaukee impact wrench. This drive unit can be easily moved between multiple ValFast wedges during a single job, creating a flexible setup that supports continuous and efficient operation without the need for multiple powered devices. The mechanical wedge itself generates a high level of lifting force, making it particularly effective when felling trees that naturally lean in the wrong direction, commonly referred to as back-leaners.

By enabling remote activation, the ValRemote system enhances operator safety, especially when working with diseased timber, storm-damaged trees, or situations where overhead hazards such as hanging limbs are present. Instead of remaining in the danger zone while applying force, the operator can control the process from a safer vantage point, reducing the risk of injury.

In terms of performance, the system delivers substantial power, allowing for controlled and precise directional felling even under demanding conditions. This capability reduces reliance on more labour-intensive or less predictable traditional methods. As a result, users typically experience improved productivity, with performance gains in the range of 15 to 20 percent compared to conventional felling techniques.

Overall, the ValRemote with ValFast offers a modern, efficient solution for forestry professionals and arborists, combining portability, power, and safety in a system designed to handle challenging tree felling scenarios with greater control and confidence.

6. DISCUSSION

6.1 System-Level Transformation and Adoption Pathways

The findings of this project confirm that automation and robotics in forestry should be approached as a system-level transformation, rather than the adoption of isolated technologies. Across the value chain, the most effective pathway is incremental, starting with mature, deployable solutions such as operator-assist systems, nursery automation, and remote-controlled safety devices, and building toward more advanced, integrated capabilities such as digital twins and autonomous operations. This staged approach can reduce risk while allowing organisations to progressively build capability, confidence, and supporting infrastructure.

6.2 Integration as the Primary Value Driver

A consistent theme across all technology areas is that real value is unlocked through integration. Technologies deliver the greatest benefit when they are connected to existing workflows, data systems, and decision-making processes. For example, digital twins rely on high-quality data inputs and organisational adoption to influence decision-making, while automated machinery depends on consistent upstream processes, such as nursery standardisation or site preparation. Without these supporting systems, even technically advanced solutions are likely to underperform.

6.3 Organisational Barriers to Adoption

The project highlights that adoption barriers are primarily organisational rather than technical. These include gaps in skills, limited data literacy, insufficient infrastructure in remote areas, and a lack of locally relevant trial data. Addressing these constraints is likely to require coordinated effort across the industry, including investment in training, collaborative trials, and shared knowledge systems such as the Australian Forest Robotics Wiki.

6.4 Contribution to Fire Management

An important outcome of the project is the recognition that automation can contribute directly to broader industry challenges, including fire management. The analysis indicates a shift from reactive suppression toward more proactive fuel-risk reduction. Through the application of automation, robotics, and data-driven systems, forestry operations such as thinning, residue management, and biomass removal can potentially be undertaken more frequently, consistently, and at lower cost.

At the same time, technologies such as digital twins and remote sensing improve the ability to identify high-risk areas and target interventions more precisely. These capabilities are complemented by emerging UAV systems that support early detection and rapid response. Together, these advances integrate fire management into routine forest operations, supporting a more scalable and preventative approach to risk reduction.

6.5 Implications for Industry Capability and Future Development

Overall, the transition to automated forestry is best understood as a long-term evolution rather than a single step. It requires alignment across technology, people, systems, and business models. Organisations such as Lincoln Agritech are well positioned to contribute to this transition by translating high-potential concepts into operationally proven systems. This may involve targeted adaptation, structured multi-site trials, and data-driven evaluation of performance under Australian conditions. Building on the priority technologies identified in this report, a focused programme could advance selected high-potential areas, such as autonomous planting, AI-enabled nursery systems, and operator-assist or teleoperation platforms, through localised research and development aligned to Australian species, terrain, and operational models.

6.6 Implications for Technology and Equipment Providers

The findings of this technology scan indicate that the forestry sector is not constrained by a lack of available technologies. Instead, the primary challenge lies in the successful translation of these technologies into operational environments. For technology developers and equipment manufacturers, this highlights a shift in focus, from advancing technical capability alone toward ensuring that solutions are practical, integrated, and aligned with the realities of forestry operations.

A consistent observation is that many technologies perform well under controlled or standardised conditions, yet encounter limitations when applied in complex, variable forest environments. Terrain variability, debris, climate, and limited connectivity introduce constraints that are often underrepresented in development settings. As a result, there is a strong requirement for technologies that prioritise robustness, reliability, and operational resilience. Systems that can function effectively under these conditions, rather than those optimised solely for performance in ideal scenarios, are more likely to achieve broad acceptance and sustained use.

Closely related to this is the importance of integration. Technologies that operate as standalone solutions tend to deliver only partial value. In contrast, those that are able to connect with existing workflows, data systems, and equipment fleets have the potential to unlock significantly greater benefits. This is particularly relevant for digital tools, automation systems, and operator-assist technologies, where value is increasingly derived from how information flows across the forestry value chain. Greater attention to interoperability, open standards, and system compatibility will therefore be critical in reducing adoption barriers and enabling scalable deployment.

Another key theme is usability. Even mature technologies are often underutilised when they are complex to operate or require significant training to realise their benefits. Operators and contractors work in demanding environments, and solutions that increase cognitive load or disrupt established practices can struggle to gain traction. There is therefore a clear opportunity to place greater emphasis on intuitive design, embedded guidance, and decision-support features. Technologies that actively support operator performance, rather than simply adding functionality, are more likely to be adopted and used effectively.

The scan also highlights the importance of demonstrating value in real operational conditions. Decision-makers in forestry are typically cautious about new investments, particularly where capital costs are high and operational risks are significant. Technologies that can demonstrate clear outcomes, such as productivity improvements, cost reductions, or safety gains, under representative conditions are far more likely to gain industry confidence. This underscores the value of collaborative field trials and partnerships with industry, where technologies can be tested, refined, and validated in practice.

In an international context, it is evident that technologies rarely transfer seamlessly between regions. Differences in species, terrain, climate, and operational models mean that systems developed in one geography often require adaptation before they can perform effectively elsewhere. For the Australian forestry sector, this reinforces the importance of designing technologies with flexibility in mind. Modular systems, adaptable software, and the ability to calibrate performance to local conditions will be key factors in successful deployment.

The report further suggests that the most effective pathway toward automation is incremental. Mechanisation and operator-assist technologies provide a foundation upon which more advanced automation and autonomy can be built. Technologies that support this progression, by augmenting human capability, improving consistency, and reducing risk, are well aligned with current industry needs. In contrast, solutions that assume rapid transition to fully autonomous operations may face greater barriers in the near term.

Finally, the broader commercial and organisational context should not be overlooked. Adoption decisions are influenced not only by technical performance, but also by cost structures, risk allocation, and service support. Business models that reduce upfront investment, provide ongoing support, or align costs with realised benefits may help to lower adoption barriers. Similarly, the availability of local service networks, spare parts, and technical support is a practical consideration that can significantly influence decision-making.

Overall, the implications for technology and equipment providers are clear. Success in the forestry sector will depend not only on innovation, but on the ability to deliver solutions that are grounded in operational reality, integrated within systems, and adaptable to local conditions. Technologies that combine these attributes are more likely to move beyond demonstration and achieve meaningful, sustained impact in practice.

6.7 Summary

In summary, the findings indicate that the transition toward automation and robotics in Australian forestry is less about technology availability and more about how these technologies are implemented, integrated, and supported within the broader system. A staged, system-level approach, supported by capability development, local validation, and industry collaboration, appears well aligned with both international experience and the structure of the Australian sector. Technologies that are practical, adaptable, and integrated into existing workflows are most likely to deliver sustained value, while coordinated effort across industry participants will be important in translating potential into measurable outcomes.

7. CONCLUSION

This project provides a comprehensive and practical assessment of how automation and robotics can support the Australian forestry industry in addressing key opportunities and challenges, including labour supply constraints, worker safety, productivity, and environmental outcomes. By systematically reviewing global technologies and assessing their relevance to Australian conditions, the project establishes a clear and credible evidence base to support future decision-making.

The analysis indicates that many relevant technologies already exist, with varying levels of maturity, and that near-term gains may be realised through the considered adoption of proven solutions. At the same time, more advanced technologies, such as autonomous planting, digital twins, and integrated robotics systems, offer longer-term potential when supported by appropriate infrastructure, data systems, and organisational capability.

A central finding of the project is that automation should be viewed as a system-level transition, rather than the adoption of individual technologies in isolation. Outcomes are influenced not only by the technologies themselves, but by how they are integrated into operational workflows, supported by data, and aligned with workforce capability and business processes. In this context, an incremental pathway, progressing from mechanisation and operator-assist technologies toward more advanced automation, appears to offer a practical and lower-risk approach.

The findings also highlight that many of the key barriers to adoption are organisational rather than technical. Factors such as skills and training, data literacy, infrastructure in remote areas, and the availability of locally relevant performance evidence all play a significant role in determining outcomes. Addressing these constraints may require coordinated effort across the industry, including investment in capability development, structured field trials, and mechanisms for collaboration and knowledge sharing.

Importantly, the project also demonstrates that automation and robotics can contribute to broader industry priorities beyond productivity and safety. These include workforce modernisation, improved operational consistency, and enhanced approaches to fire risk management through more proactive and data-informed practices.

The establishment of the Australian Forest Robotics Wiki represents a key legacy of the project, providing a foundation for ongoing knowledge sharing, tracking of technological developments, and continued industry engagement. It offers a practical mechanism to support collective learning and informed adoption over time.

In summary, automation and robotics present a credible pathway toward a more productive, safe, resilient, and sustainable forestry sector. Realising this potential is likely to depend not only on technology availability, but on the industry's ability to adopt a coordinated, system-based approach, supported by incremental implementation, local validation, and ongoing collaboration.

8. RECOMMENDATIONS

The technologies identified in this scan are not emerging in isolation; many have already reached varying levels of uptake internationally. Operator-assist systems, exoskeletons, nursery automation, and remote-controlled safety tools are already in commercial use in regions such as Scandinavia, Central Europe, and parts of North America, where they contribute to measurable improvements in productivity, safety, and workforce sustainability. Similarly, digital twins and UAV-based fire monitoring systems are being deployed at increasing scale in sectors such as forestry, mining, and agriculture. However, the level of uptake varies significantly by technology maturity, operational context, and supporting system readiness.

Across these international deployments, a consistent pattern emerges: technologies with high readiness levels (TRL 8–9), such as operator-assist systems, exoskeletons, and nursery automation, are already widely adopted where they align with existing workflows and deliver clear, immediate benefits. In contrast, technologies at lower readiness levels (TRL 5–7), including autonomous planting, AR applications, and advanced electrified transport systems, remain largely in pilot or early-deployment phases, with uptake concentrated in controlled environments or supported by substantial R&D investment.

International experience also highlights a consistent set of barriers to adoption that are directly relevant to the Australian context. These include:

1. System integration challenges, where technologies deliver limited value when not embedded within broader operational, data, and decision-making frameworks (e.g. digital twins requiring high-quality, integrated data systems).
2. Infrastructure constraints, particularly connectivity, energy supply, and access to service support, which limit deployment in remote or dispersed forestry environments.
3. Workforce capability and training gaps, which reduce the effective utilisation of otherwise mature technologies, especially operator-assist and data-driven systems.
4. Economic uncertainty and capital risk, particularly for pre-commercial or system-dependent technologies where return on investment is not yet proven at scale.
5. Regulatory and governance barriers, especially for UAVs, autonomous systems, and transport innovations, where approval pathways and operational frameworks are still evolving.
6. Localisation requirements, where technologies developed in Europe or North America require adaptation to different terrain, species, climate, and operational models before they can perform reliably.

These international lessons reinforce that successful adoption is not primarily limited by the availability of technology, but by industry readiness, system alignment, and the ability to integrate technologies into real operating environments.

Based on these insights, the following recommendations are proposed for the Australian forestry sector:

1. Prioritise adoption of mature, proven technologies - focus initial investment on technologies already widely adopted internationally and operating at high readiness levels, such as operator-assist systems, nursery automation, and remote-controlled safety tools, to deliver immediate gains in productivity and safety while building industry confidence.
2. Adopt a staged, system-level implementation pathway - consistent with international practice, technologies should be implemented incrementally, with mechanisation and operator-assist systems forming the foundation for more advanced automation and autonomy over time.
3. Strengthen workforce capability and training systems - address one of the most consistent global barriers by investing in structured training, simulation platforms, and data literacy, enabling operators and decision-makers to fully utilise available technologies.
4. Establish coordinated, multi-site field trials in Australian conditions - international evidence shows that adoption accelerates when technologies are demonstrated under local, operational conditions. Trials should be multi-season, across diverse sites, and designed to generate robust, shareable performance data.

5. Invest in enabling infrastructure and data systems- build the connectivity, data platforms, and interoperability frameworks required to support technologies such as digital twins, UAV systems, and advanced machine automation.
6. Promote cross-industry collaboration and knowledge sharing - leverage platforms such as the Australian Forest Robotics Wiki to replicate successful international models of shared learning, benchmarking, and collective problem-solving.
7. Engage early with regulators and stakeholders - reflecting international constraints, proactive engagement is needed to establish practical regulatory pathways for UAVs, autonomous systems, and transport innovations.
8. Plan for localisation and adaptation rather than direct importation - recognise that technologies proven overseas will typically require modification to suit Australian conditions, and support this through targeted R&D and industry collaboration.

Overall, international experience indicates that the pathway to successful adoption lies not in access to technology, but in coordinated, system-level implementation that aligns capability, infrastructure, regulation, and operational practice.

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APPENDIX 1 – LONGLIST OF TOOLS & TECHNOLOGIES

Technology Name	Company	Brief Description	Website
3D Dataset Generation Using Virtual Reality for	**Labelling Flora**	Labelling Flora is a novel approach based on the use of VR (Virtual reality) to bring ecological value to 3D point clouds.	https://github.com/cyprienfol/LabellingFlora
Acoustic monitoring to monitor biodiversity	**Rainforest Connection**	Our bioacoustic hardware monitors threats in the soundscape.	rfcx.org
Advanced driver assistance system for	**Nordic Forestry**	The core technology developed by NFA is a retrofit system solution that enables forestry machines to continuously build	https://www.nordicforestryautomation.com/#product
AECOM forest inventory services	**AECOM**	AECOM offers a comprehensive suite of forest inventory services through its Forestry, Geomatics and Remote	https://aecom.com/en-ca/services/forestry-geomatics-and-remote-sensing/
Aerial surveys & inventory mapping	**Aerometrex**	Aerial LiDAR plays a critical role in modern forestry and carbon farming by capturing detailed information about	https://aerometrex.com.au/industries/forestry-agriculture/
AFRY smart forestry tools	**AFRY**	AFRY Smart Forestry provides advanced digital solutions and consulting to optimize forest management, valuation,	https://afry.com/en
Agile-X Robotics Ranger robot	**AgileX Robotics**	The AgileX Ranger is a 4-wheel-drive, 4-wheel-steering omnidirectional UGV built for both indoor and outdoor	https://global.agilex.ai/products/ranger
Agri-Copter UAV	**SPS Automation**	SPS Automation produces specialized agricultural drones. Based on recent developments, here are the key details	https://spsautomation.com/
AgRob v18 autonomous forest robot	**Institute for Systems and**	AgRob V18 is a research-grade autonomous forest robot developed by INESC TEC and partner universities in	https://iris.cnr.it/retrieve/11f337ff-9f11-4216-aa9d-22bb6299fa51/prod_477490-doc_195366.pdf
AI Remote fire detection system	**Pano**	Pano's AI-powered detection and real-time situational awareness empowers enterprises and fire agencies with	https://www.pano.ai/
AI tool to assess forest damage	**Scion Group**	ForestInsights Enabling smarter forest planning through advanced strategic	https://indufor-applications.projects.earthengine.app/view/tasman-
AI-powered robots for forestry navigation/track	**Lincon Agritech**	The "Robotics Spearhead" project, led by Lincoln Agritech in New Zealand, is a $2 million initiative aimed at developing	https://lincolnagritech.co.nz/robotics-research-strengthens-relationships/
Analysis of high-density airborne LiDAR point	**Xiang et al.**	Detailed forest inventories are critical for sustainable and flexible management of forest resources, to conserve	https://www.sciencedirect.com/science/article/pii/S0034425724000890
AORO Autonomous forwarder forest tests	**Hera et al.**	AORO is an electric, remote-controlled forest machine designed to operate autonomously. It uses a large array of	https://www.forsler.com/post/aoro-the-worlds-first-autonomous-forest-machine

Technology Name	Company	Brief Description	Website
ARA field precision sprayer	**Ecorobotix**	Powered by Ecorobotix's AI-driven precision spraying technology, ARA dramatically reduces the use of plant	https://ecorobotix.com/en-us/crop-care/ara-field-sprayer/
Arbonaut forest operations planning	**Arbonaut**	Arbonaut is a Finnish technology company providing high-tech forest intelligence, specializing in LiDAR-based	https://arbonaut.com/services/forest-operations
Arbor Day Foundation climate-based cataloguing	**USDA Forest Service**	Arbor Day's Climate-Based Cataloguing Tools uses a Forest Priority Index (FPI) to catalogue, score, and prioritize forest	https://www.arborday.org/perspectives/inside-high-tech-nursery-supporting-future-forests
Arbor Day Foundation custom seed sorter	**USDA Forest Service**	The Arbor Day Foundation custom seed sorter:	https://www.arborday.org/perspectives/inside-high-tech-nursery-supporting-future-forests
Arbor Day Foundation stratification	**USDA Forest Service**	refers to the standard cold-moist seed-conditioning process (typically 30–120 days in the refrigerator) that simulates	https://www.arborday.org/perspectives/inside-high-tech-nursery-supporting-future-forests
Article on the use of digital instructors, intelligent	**Manner**	This article explores the history, current status, and technological possibilities of AWED. Additionally, key	https://www.skogforsk.se/english/research--results/research-Modeltes/2024/automatic-work-element-
Atlantic Man Multi-Grip Transplanter	**Atlantic Man**	The Atlantic Man Multi-Grip Transplanter is an automated transplanting system designed to increase nursery	tech.atlanticgroup.it/equipment/automatic-transplanting-machine-tpa/
Atlas Cruiser forest inventory assessments	**Integral**	Atlas Cruiser enables the forest manager to reliably estimate yields using forest inventory assessments.	https://integral.co.nz/cruiser-inventory-assessment/
Automated cutting planter	**TTA-ISO**	The Cutting Planter works as revolutionarily as it is effective. Based on self-learning vision software, the robot selects the	https://tta-iso.com/equipment/cutting%20planter
Automated production time analysis using	**Mologni et al.**	The digital transformation of the forest sector has been supported by the development of data loggers and onboard	https://www.sciencedirect.com/science/article/pii/S0168169924004381
Automated sweep measurement project	**Interpine**	This study aims to support the development of an automated system for measuring	https://forestengineering.org/wp-content/uploads/2021/11/Automated-Sweep-Measurement-
Automated timber loading for timber mills	**Smart TEM**	SmartTEH automatic log loaders are specialized, customizable solutions designed to safely and efficiently	https://www.smartteh.eu/industries/4/wood-and-timber
Automatic data logger for weed management & tree	**STA**	A STA logger device is equipped to your weed control equipment with an integrated switch system fixed to the	https://stalogger.com/
Autonomous extraction machine concept &	**Treanor et al.**	The purpose of this project was to design and build a prototype autonomous forestry extraction	https://ir.canterbury.ac.nz/server/api/core/bitstreams/5325433f-9891-45aa-93fe-29419e355aa2/content
Autonomous forester to plant & nurture young trees	**Milrem Robotics**	The Milrem Autonomous Forester is an unmanned, multi-function forestry platform designed to support	https://www.newscientist.com/article/2264401-pair-of-robot-foresters-could-plant-thousands-of-trees-a-day/

Technology Name	Company	Brief Description	Website
Autonomous forestry loader project	**FP Innovations**	FPInnovations is developing the "brains" for future autonomous harvesters capable of working in harsh forest	https://web.fpinnovations.ca/automated-forestry-loader/
Autonomous or remote controlled robot for	**Univ Nanjing Forestry**	The invention discloses a pesticide spraying robot for orchard pesticide spraying. The pesticide spraying robot	https://www.lens.org/lens/patent/199-716-937-686-971/frontpage?l=en
Autonomous robot & UAV with fire extinguishing	**Jiangsu Polytechnic**	The invention discloses a forestry autonomous operation cruise robot, which belongs to the technical field of forestry	https://www.lens.org/lens/patent/129-401-095-474-853/frontpage?l=en
Autonomous UAV & automated forestry	**Deep Forestry**	Deep Forestry develops autonomous, below-canopy drones equipped with AI and Ouster LiDAR to digitize forest	https://www.deepforestry.com/
Autonomous UAV swarms in forestry	**Treeswift**	Treeswift is an AI-powered forest monitoring system that uses autonomous drones and hand-held sensor packs to	https://www.treeswift.com/
AutoStix cutting transplanter	**Viscon Group**	The system consists of a transplanter, different compatible strips and a transport tray. The transplanter with special	https://viscongroup.eu/news/autostix-revolutionizing-the-cutting-industry/
AVATAR operator training	**Björheden**	The AVATAR-project develops operator support through feed-back on operational skill, methods, value recovery,	https://www.skogforsk.se/english/projects/avatar/
Backpack LiDAR scanner	**Purdue University**	The objective of the research is to develop a terrestrial system/platform and biometrics extraction algorithms for	https://ag.purdue.edu/digital-forestry/projects/terrestrial-mobile-lidar-for-high-resolution-forest-inventory.html
BCC Fibercell	**Fibercell**	BCC Fibercell refers to a biodegradable fibre-based growing container system produced by BCC (Becker Underwood /	https://bccfibercell.com/
BeMatic Meto SWT spraying robot for	**Berg Hortimotive**	The Meto SWT spraying robot allows you to spray spot by spot. The touchscreen control panel is user-friendly. With the	https://berghortimotive.com/en/the-bematic-meto-at-kwekerij-de-westhoek/meto-swt
Best practice for tree breeding in Europe	**Mullin and Lee (E.)**	Best practices for breeding strategies starts with a broad outline of tree breeding to show	https://www.skogforsk.se/contentassets/99f6d3d0ee0d48ec9e96b6bdadb95d73/best-practice-hela-low.pdf
BioChambers plant growth chambers & rooms	**BioChambers**	BioChambers is a specialised manufacturer of controlled-environment growth chambers and research	https://www.biochambers.com/
Biodiversity data management software	**Natural Solutions**	Natural Solutions' biodiversity data management software provides a digital platform for collecting, organising, and	https://www.natural-solutions.world/
Biora Technologies environmental control	**Biora**	BioRA Technologies (operating as Biora) is a specialist provider of controlled-environment systems for plant	https://bioratechnologies.com/
BioScout disease sensing	**BioScout**	BioScout has developed a patented, AI-powered platform that brings together autonomous air-sampling hardware, a	https://www.bioscout.com.au/detection-services

Technology Name	Company	Brief Description	Website
Bot Auto autonomous trucking company	**Bot Auto**	Bot Auto is a Houston-based autonomous trucking company founded in 2023 by Dr. Xiaodi Hou, operating SAE Level-4	https://bot.auto/
Bouldin & Lawson automated nursery &	**Bouldin & Lawson**	Bouldin & Lawson (B\&L) is an established manufacturer of automated nursery and greenhouse equipment, widely	https://bouldinlawson.com/
Bracke accumulating felling head	**Bracke Forest**	Bracke Harvester Heads are for accumulating felling head for silviculture and biomass applications. The head has a	https://www.brackeforest.com/products/felling-heads
Bracke disc trencher	**Bracke Forest**	These disc trenchers and forest mounder machines can efficiently prepare the soil for forest replanting.	https://www.brackeforest.com/products/disc-trenchers
Bracke forest mounder	**Bracke Forest**	Bracke Forest mounders are specialized site-preparation machines used in forestry to create humus mounds covered	https://www.brackeforest.com/products/mounders
Bracke seedling planting carousels	**Bracke Forest**	The Bracke P11.b seedling carousel, the precision of the plant depth and the compaction are a few of the details that	https://www.brackeforest.com/products/planters-seeders
BurnBot controlled burn machine	**BurnBot**	The RX is BurnBot's remote-operated fire system, built to safely scale prescribed burning, expand treatment windows,	https://burnbot.com/technology/
Calculating the volume of a single tree crown based on	**Powerchina Kunming Eng**	The invention discloses a foundation laser point cloud individual tree crown volume extraction method based on	https://www.lens.org/lens/patent/146-511-685-426-708/frontpage?l=en
Camera array system to provide early warning &	**Shanghai Medo**	The utility model discloses an array type fusion imaging monitoring system applied to forestry monitoring, and	https://www.lens.org/lens/patent/146-786-290-032-774/frontpage?l=en
Carbon Direct markets & carbon management	**Pachama**	Carbon Direct is a science-based firm that helps organizations manage their carbon emissions, achieve	https://www.carbon-direct.com/
Carbon tracking standardised data platform	**Connect Earth**	Connect Earth is a London-based environmental data company founded in 2021 that provides API-based carbon	connect.earth
Caterpillar battery-as-a-Service (BaaS)	**Caterpillar**	Caterpillar Battery-as-a-Service (BaaS) is a service-based energy model that allows customers to use battery-electric	bhp.com/news/media-centre/releases
Caterpillar forestry machinery	**Caterpillar**	Cat forest machines are purpose-built, rugged, and powerful hydraulic machines (swing machines) designed for high-	https://www.cat.com/en_US/by-industry/forestry.html
CATL Battery Swapping System for Heavy Trucks	**Contemporary Amperex**	CATL's battery swapping system for heavy trucks is a large-scale electrification solution based on standardised,	catl.com/en/news/6473.html
CFForest: L& Resource Manager	**Trimble Forestry**	Trimble Forestry's CONNECTED FOREST™ Forest: Land Resource Manager (LRM) solution is an	https://forestry.trimble.com/wp-content/uploads/2019/02/CFForest_LandResourceManager

Technology Name	Company	Brief Description	Website
Chunk robotic forest ranger concept	Segev Kaspi	On of a group of robotic forest rangers were developed to support reforestation efforts and sustainable forest	https://www.megosu.com/project-details/forest-ranger-druids-6b3f4849
CLEAR methodology for assessing & reporting on	**Holmgren and**	CLEAR is a methodology for assessment and reporting of the climate effects of corporations in the forest-based sector	https://www.skogforsk.se/english/projects/clear/about-CLEAR/
Colossus firefighting robot	**Shark Robotics**	The Colossus is a heavy, remote-controlled firefighting robot developed by Shark Robotics to handle extreme fire,	https://www.shark-robotics.com/colossus-firefighting-robot/
Compliance & supply chain transparency tool	**Satelligence**	Satelligence is a satellite-powered environmental intelligence company that uses remote sensing, machine	satelligence.com
Concept paper on the felling machine of the	**n.n.**	The focus of the project is the felling machine of the future, whose positioning and mobile laser	https://mmm.fi/en/-/towards-more-climate-sustainable-and-diverse-logging-through-sensor-techModellogy-and-
Conviron controlled-environment	**Conviron**	Conviron is a global leader in controlled-environment plant growth technology, best known for designing and	https://www.conviron.com/
CSIRO mapping & data analysis tools	**CSIRO Data 61**	CSIRO runs multiple national-scale forest-mapping, monitoring, localization, and remote-sensing programs used	https://research.csiro.au/data61/
Customised solutions for forest seed centres &	**BCCab**	BCC provides complete, customized solutions for forest seed centres and nurseries worldwide. With decades of	https://www.bccab.com/
Deltasuit	**SpanSet**	The SpanSet DeltaSuit is a wearable, passive industrial exoskeleton designed to reduce strain on the shoulders,	https://www.spanset.com/au-en/products/deltasuit-32555/2025629
Disease detection via spore collection	**BioScout**	Our technology uses unique data and artificial intelligence (AI) to track the spread of fungal diseases on farms,	https://www.bioscout.com.au/
Dixon robotic forest ranger concept	Segev Kaspi	On of a group of robotic forest rangers were developed to support reforestation efforts and sustainable forest	https://www.megosu.com/project-details/forest-ranger-druids-6b3f4848
DJI UAV ecosystem	**DJI**	The DJI UAV ecosystem provides a widely deployed, flexible platform for wildfire monitoring, detection support, and	enterprise.dji.com/public-safety/firefighting
DroneSeed reforestation UAV's	**DroneSeed**	DroneSeed reforestation drones are heavy-lift, autonomous aerial vehicles designed to rapidly replant forests, especially	droneseed.com
Dronstar remote controlled forest management	**Dronstar / VFT Vallfirest**	Dronstar is a high-performance professional machine designed to work in the emergency sector to enhance	https://www.vallfirest.com/en/dronster-forestry-mulcher-robot
Dual-arm robot for nursery tree planting in Amazon	**ABB**	The dual-arm ABB YuMi IRB 14000 automates seed-planting tasks in remote Amazon reforestation	https://new.abb.com/products/robotics/robots/collaborative-robots/yumi/dual-arm

Technology Name	Company	Brief Description	Website
Dwell Forest Insights spatial layers & analytics	**Dwell Systems**	Dwell's ForestInsights delivers spatial layers and analytics that precisely map and describe planted forests. Such	https://www.dwell.systems/forest-insights
Dynamic Forest data collection & carbon	**OCELL**	Dynamic Forest is the premier digital tool for modern forest management. Cross-platform, offline-first, and built to	https://www.ocell.io/en-us
Eco Log harvesters & forwarders	**EcoLog**	Eco Log offer a wide range of harvesters, forwarders, options and accessories. The common denominator for all our	ecologforestry.com
Ecological restoration company using UAV, AI &	**Morfo**	Morfo is a French–Brazilian ecological restoration company that uses drones, AI, biotechnology, and multi-species	https://www.morfo.rest/
EDER Radio Titan 80 remotely controlled tree	**EDER - Maschinenba**	The EDER Radio Titan 80 is a continuation of the proven EDER Titan 80 Pro. It is used in heavy timber harvesting and	https://www.eder-maschinenbau.de/en/forestry-equipment/felling-wedges/eder-remote-titan-80/
Ekso EVO exoskeleton	**Ekso**	Ekso EVO is a wearable exoskeleton that provides assistance to the user's shoulder and back muscles when	https://eksobionics.com/ekso-evo/
Ellepot integrated propagation system	**Ellepot**	The Ellepot Propagation System allows you to propagate faster while facilitating the conditions that plants need in	https://www.ellepot.com/
EOSDA L&Viewer multispectral imagery	**EOS Data Analytics**	EOSDA Forest Monitoring is an AI-powered satellite analytics solution designed for sustainable forestry	https://eos.com/forest-monitoring/
E-SEED self-burying seed carrier	**Morphing Matter Lab,**	A wood-based biodegradable seed carrier that mimics seeds of Erodium, a genus of plants with seeds that unwind coiled	https://morphingmatter.org/
European Cooperation in Science and Technology	**COST Association**	European research networking initiative (2024–2028) that brings together scientists, industry partners, and forestry	https://www.formec.org/images
Exoskeleton for forestry workers	**Rojgren & Widell**	The aim of the project was to investigate the possibilities of using an exoskeleton as a facilitator for prevention of	https://odr.chalmers.se/items/bc5e63ff-0c66-4ba1-ac0c-5d28a5535396
Explanation of the Australian Fire Danger	**Nova Systems**	The Australian Fire Danger Rating System uses four easy to recognise rating levels, each with a message to encourage	https://www.novasystems.com/au/feature/australian-fire-danger-rating-system-explained
Exploration of excavator-mounted EcoPlanter	**Ersson**	The EcoPlanter is a boom-mounted, automated planting head developed in the early 1990s, designed for attachment	https://www.researchgate.net/figure/The-EcoPlanter-planting-head-from-Modelrmark-Modelrr-
EXTRAFOR exoskeleton	**FCBA**	EXTRAFOR is a FCBA initiative designed to adapt wearable exoskeletons for the forestry sector, reducing	https://www.fcba.fr/en/travaux/extrafor-exoskeletons-for-forestry-work/
Eyesky aerial imagery services	**EyeSky**	Photogrammetry and 3D mapping is a very useful tool during site development.	https://www.eyesky.com.au/

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FarmDroid FD20 for row crops	**FarmDroid**	FarmDroid FD20 is a solar-powered field robot that seeds and weeds. By using high-precision RTK GPS, the	https://farmdroid.com/products/farmdroid-fd20/
FieldGeo forest inventory services	**Field Geo**	Field Geospatial is a prominent Nordic-based company specializing in forest management, inventory, and data	https://fieldgeo.com/service/forest-inventory/
Finnish project about creating a forest digital	**n.n.**	In the project, more accurate laser scanning and aerial photography data will be acquired from	https://mmm.fi/en/-/kansallinen-kaukokartoitus-ja-metsien-digitaalinen-kaksonen-metsakaksonen-
Fire Foresight wildfire detection system	**Fire Foresight**	Fire Foresight combines satellite data, lightning intelligence, ground sensors, drone response and AI-powered analysis	https://www.fireforesight.com/
FireBox & CharBoss: An alternative to open burning	**Oyier at al.**	Open burning is commonly used to dispose of piles of forest residues generated by forest management activities;	https://ucanr.edu/sites/default/files/2024-11/404452.pdf
FireBox TrackBoss vegetative waste-	**Air Burners**	The portable TrackBoss is a powerful vegetative waste-reduction machine. Mobile-friendly, easy-to-manoeuvre, and	https://airburners.com/products/boss-series/trackboss/
FireBull fire fighting robots	**Magirus Robotics**	The Magirus FireBull tracked fire engine on caterpillar chassis is a worldwide unique, production-ready	https://www.magirusgroup.com/de/en/products/special-vehicles/firebull/
FireMan unmanned aerial fire-fighting systems	**Finnish Geospatial**	The objective of the FireMan consortium is to develop novel, disruptive AI-based technology for the fast detection of	https://www.jyu.fi/en/projects/fireman-unmanned-aerial-systems-based-solutions-for-real-time-management-of-
FireSense airborne observations over wildfires	**NASA**	NASA's FireSense Project conducts airborne observations over wildland fires and prescription burn areas to evaluate	https://cce.nasa.gov/firesense/airborne_campaigns.html
Flash Forest LiDAR-based forestry intelligence	**Flash Forest**	Flash Forest Intelligence refers to the forestry-intelligence system that Flash Forest uses to analyse forests with AI,	https://www.flashforest.com/fis
Flyability Elios 3 indoor UAV	**Flyability**	The Elios 3 drone is designed for complex, confined, and GPS-denied environments, making it suitable for	https://www.flyability.com/elios-3
Forest & Wood Products Australia virtual reality	**FWPA**	The ForestVR Loan Kit includes pre-loaded VR headsets featuring a suite of Forest Learning's award-winning	https://fwpa.com.au/tool/forestvr-loan-initiaitve/
Forest Digital Twin Component (DTC) digital	**Forest DTC (ESA Digital**	Forest Digital Twin Component (DTC) is funded by the European Space Agency (ESA) as part of ESA's contribution	https://www.foresttwin.org/
Forest ecosystem LiDAR inventories	**Arbonaut**	Arbonaut's area-based inventories with 20 years of experience deliver insights in micro-stand level on timber	https://arbonaut.com/services/forest-ecosystem-inventories
Forest management & data analytics platform	**Remsoft**	Stratus is a comprehensive SaaS solution that consolidates all forestry life cycle and timber supply chain activities. Built	https://remsoft.com/stratus/

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Forest scanning using 3D Gaussian splatting (3DGS)	**Meta Hyperscape**	3D Gaussian Splatting (3DGS) in forests enables high-fidelity, photorealistic, and scalable 3D modeling of complex,	https://www.youtube.com/watch?v=MXLMNAfPXKU
Forest Stewardship Council International	**FSC Trace**	FSC Trace is not just a technological upgrade. It is a strategic	https://fsc.org/en/fsctrace
Forestry digital twin using Landsat 7	**Jiang et al.**	Modeling forests using historical data allows for more accurately evolution analysis, thus	https://arxiv.org/pdf/2204.01709
Forsite forest inventory services	**Forsite**	Forsite combine the power of foresters, data (LiDAR/spectral) and machine learning. We use Forsite's	https://forsite.ca/forest-inventories/
Forstreich TR300 remote-controlled felling wedge	**Forstreich GmbH**	The remote-controlled TR300 felling wedge now has a new, more robust, bidirectional radio remote control in accordance	https://www.forstreich.de/produkt/16242/?lang=en
Forward-Looking Infrared thermal cameras for fire	**FLIR Thermal Cameras for**	Biomass is at risk for spontaneous combustion as biomaterials are prone to self-heating during decomposition.	https://www.flir.com/instruments/fire-prevention
Fotokite tethered UAV for fire management	**Fotokite**	Fotokite is a Swiss/American company that makes actively tethered drone systems used by firefighters for instant aerial	https://fotokite.com/
FPInnovations / Kratos Autonomous Trucking	**FPInnovation s**	FPInnovations' Autonomous Trucking Initiative efforts aims to accelerate the use of advanced autonomous truck	https://web.fpinnovations.ca/Autonomous-transportation-on-resource-roads/
GIS-based soil strength estimation	**Mohtashami et al.**	The aim of this study was to evaluate the use of soil moisture map, i.e., depth-to-water (DTW), maps and soil type maps,	https://www.skogforsk.se/english/research--results/research-notes/2024/estimating-soil-strength-using-
GNSS/RTK-integrated Augmented Reality	**V-Labs**	The V-Labs solution is a hands-free augmented reality headset that combines survey-grade GNSS/RTK positioning	https://www.v-labs.ch/product/
Goohier battery	**Goohier Guohai Green**	Goohier Guohai Green Energy Co., Ltd. (国海绿能) is a China-based provider of industrial battery-swapping systems	https://www.made-in-china.com/showroom/3a0e0e997b96bc86/
Green-Tec forestry harvester	**Terex**	Green-Tec's TH3 Tree Care Handler incorporates a distinct hydraulic circuit, enabling the use of various attachments for	https://www.terex.com/green-tec/en/products/tree-care-handlers/tree-care-handlers/th3
Grodan growing media	**Grodan**	Grodan is a global leader in stone wool growing media, widely used in commercial horticulture, greenhouse	https://www.grodan.com/global/
HARDWARIO IoT Sensors for forestry	**HARDWARIO**	HARDWARIO provides Industrial Internet of Things (IIoT) solutions for forestry management, focusing on monitoring	https://www.hardwario.com/industries/agriculture
Hort Americas advanced horticulture technology	**Hort Americas**	Hort Americas is a specialist supplier of advanced horticulture technology, focused on controlled-environment	https://hortamericas.com

Technology Name	Company	Brief Description	Website
Hort Tech Systems nursery automation	**Hort Tech Systems**	Hort Tech Systems is a US-based supplier and integrator of nursery automation equipment serving commercial	https://horttechsystems.com/
Hovermap autonomous SLAM-based LiDAR	**Emesent**	Hovermap is a mobile LiDAR mapping system that uses SLAM technology to produce highly accurate 3D data and	https://emesent.com/
Hydrogen-powered aircraft to create digital twins	**Kelluu**	Kelluu creates autonomous, hydrogen-powered airships that provide persistent, high-resolution aerial surveillance and	https://kelluu.com/
Hypershell	**Hypershell**	The Hypershell is a powered, consumer-focused wearable exoskeleton ("PowerSuit") designed primarily to reduce	https://hypershell.tech/products/hypershell-x-ultra?variant=46795829477612
iLand - free research software for digital forest	**iLand by TUM**	iLand explicit simulates the principal adaptive agents in forest ecosystems, i.e., individual trees, over large areas.	https://iland-model.org/startpage
IML PowerDrill Resistograph for timber	**IML**	The IML PowerDrill® is an electronic, handheld wood-inspection drill that measures drilling resistance as a	https://iml-na.com/product-category/wood-testing-systems/
IML Resi timber resistance tool for timber quality	**Forest Quality**	The Resi generates a cross-section trace with a 0.1mm sampling interval of resistance (torque), effectively providing	https://www.forestquality.com/resistograph
Immersal precise point-cloud maps	**Immersal**	Immersal enables forestry teams to create accurate point-cloud maps and GPS-independent AR localization so	https://immersal.com/technology
INDICUM DataBus eagle nest supervision	**Iridium Cloud**	The INDICIUM DataBus was used to collate data from these devices, after which it was analysed to determine the activity	https://www.indicium.cloud/wedge-tailed-eagle-monitoring
Indufor Dwell remote sensing technologies & AI	**Indufor**	ForestInsights combines image data, analysis, and modelling to produce high-resolution forest maps that	https://induforgroup.com/services/resource-monitoring/
INESC TEC – AgRob Programme	**The Institute for Systems**	Research programme developing AgRob V16–V18 autonomous robotic platforms for forestry and agricultural	https://www.inesctec.pt/en/centres/cras/projects/agrob
InSAR remote sensing for forest inventory	**Innovatek**	Interferometric Synthetic Aperture Radar (InSAR) is a cost-effective ($0.16/hectare) remote sensing technique for large-	https://innovatek.co.nz/insar-remote-sensing-for-forest-inventory/
Insight Robotics aerial survey for forestry	**Insight Robotics**	Insight Robotics provides advanced aerial survey services and geospatial intelligence (GIS) tailored for forestry and	https://www.insightrobotics.com/en/services/aerial-survey/
Integral FOLPI-XL estate-wide production modeling	**Integral**	FOLPI-XL is an optimisation tool for evaluating forest management and investment strategies. It is intended to	https://integral.co.nz/folpi-xl/
Integral PlantIT nursery tracking app	**Integral**	Integral is a New Zealand–based software company (founded in 1991) that develops digital solutions for forestry,	https://integral.co.nz/plantit/

Technology Name	Company	Brief Description	Website
IQ FireWatch automated fire detection	**IQ FireWatch**	IQ FireWatch is a multispectral sensor system that detects smoke and smoke-like phenomena in real time. Combining	https://www.iq-firewatch.com
Janus Electric: Side-Mounted Modular	**Janus Electric**	Janus Electric's system enables heavy trucks to operate as electric vehicles by using large, externally mounted battery	januselectric.com/
Janus *ex vitro* transplanter	**NuPlant**	The Janus Transplanter is NuPlant's newest robotic system. It is designed for seamless ex-vitro transfers and automates	https://www.nuplant.com/products#Janusproducts
John Deere Intelligent Harvester Head Control	**John Deere**	Intelligent Harvester Head Control - Waratah Intelligent Harvester Head Control (IHC) is a smart, sensor-driven	https://www.deere.com.au/en/forestry/harvesting-heads/ihc
John Deere Wheeled Harvesters (H-Series)	**John Deere**	John Deere wheeled forestry harvesters are specialized, high-mobility cut-to-length machines designed for thinning	https://www.deere.com/en/wheeled-harvesters
Kaman autonomous fire fighting helicopter	**Kaman**	Quick to launch and cost-effective to operate, the K-MAX® is a proven, reliable responder in demanding environments.	https://kaman.com/kaman-k-max-continues-as-a-proven-firefighting-asset-for-u-s-forest-service/
KATAM digital services for forestry	**Katam Technologies**	Katam provides tools to measure tree height, diameter, density, and spatial distribution using:	https://www.katam.se/
Kesla Hydrax fire-fighting unit	**Kesla**	KESLA HydraX turns commonly used agricultural tractors into a fleet of rapid wildland fire fighting forces off-road, in-	https://kesla.com/en/products/category/kesla-hydrax
KISS planting method	**Midlands Spraychem**	The KISS (Keep It Simple & Sustainable) planting system is a highly productive, streamlined method designed for	https://saforestryonline.co.za/articles/%EF%BB%BFkiss-planting-system-keeps-it-simple-and-productive/
KM Forestry Services forestry monitoring	**KM Forestry**	KM Forestry Services Limited provides specialized, technology-driven forest management solutions in New	https://kmforestry.co.nz/services/
Kodama Autopilot™	**Kodama Systems**	One of Kodama's major innovations is teleoperation kits that let operators control forestry machinery (e.g., skidders) from	https://kodama.ai/
Komatsu Forest BR D61EM Planter	**Komatsu Forest**	The Komatsu Forest BR D61EM Planter is a machine designed to prepare the pit, plant and irrigate eucalypt	https://www.komatsuforest.com.br/-/media/komatsu-forest/files/komatsu-forest-br/arquivos/produto/d61/d61em-
Komatsu Smart Crane / Smart Forestry	**Komatsu**	Komatsu's Smart Crane and Smart Forestry systems are operator-assist technologies designed to improve precision,	smartforestry.komatsuforest.com/
Komatsu Wheeled Harvesters	**Komatsu**	Komatsu wheeled harvesters are specialized, high-performance forestry machines designed for cut-to-length	https://www.komatsuforest.com/forest-machines/our-wheeled-harvesters
Konrad Forsttechnik forestry machinery	**Konrad Forsttechnik**	Konrad Forsttechnik develop, manufacture, and market timber harvesting machines, particularly for extremely steep	https://www.forsttechnik.at/en/

Technology Name	Company	Brief Description	Website
KW Automation Horticultural Equipment	**KW Automation**	KW Automation is a long-established, family-owned Australian company based in Palmwoods, Queensland, specialising in the design and manufacture of nursery and	https://www.kwautomation.com.au/
L& Life tree seeding robot	**Land Life**	Land Life offers the Tree Seeding Robot – in partnership with AUMOVIO Engineering Solutions and seed tech specialists Inovtec. Together with AUMOVIO's dedicated green tech	https://landlifecompany.com/en-us/updates/revolutionizing-reforestation-introducing-tree-seeding-robot
LegerSAS GPS transplanter	**Leger SAS**	The Leger SAS Transplanter is a mechanical, GPS-guided planting machine designed for orchards, vineyards, nut plantations, and forestry-related planting. It is manufactured	https://www.legersas.com/en/gps-transplanter/
LiDAR scanning & data processing software	**GreenValley International**	GVI's turnkey Applications for forest industries include hardware and software products that make LiDAR data collection, processing, and analysis possible and easy.	https://www.greenvalleyintl.com/forestry/
LiDAR Solutions inventory mapping	**Lidar Solutions**	LiDAR Solutions is an Australian company that specialising in LiDAR surveying, forest inventory mapping, modelling, and inspection services. Their forestry-focused services are	https://www.lidarsolutions.com.au/lidar-solutions/lidar-survey-inspection-services/lidar-forest-survey-forestry-inventory-mapping-modelling/
LiDAR survey processing software	**Propeller Aero**	Propeller Aero provides a cloud-based 3D drone mapping and analytics platform for construction, mining, and quarrying, enabling high-precision, actionable site data	https://www.propelleraero.com/
LINDA - AI forest analytics	**CollectiveCrunch**	Linda Forest Inventory is an AI-powered, cost-efficient forest inventory product from CollectiveCrunch. It provides accurate, actionable operational yields for forest	https://www.collectivecrunch.com/inventory/
Link-Belt forestry machinery	**Link Belt Forestry (LBX Company)**	Link-Belt forestry machinery consists of purpose-built, heavy-duty excavators designed for forestry applications, including log loading, road building, harvesting, and	https://en.lbxco.com/forestry/
Log Max Harvester Heads	**Log Max**	Log Max heads stand out much due to their unique patented Active Friction Control™ (AFC) system, which determines how the head handles the stem	https://www.logmax.com/en
Logset hybrid forestry machines	**Logset Oy**	The Logset Hybrid Harvester is a high-performance forestry machine designed by Logset (Finland) featuring a diesel engine paired with an electric motor and supercapacitors.	logset.fi
Long-range UAV's for fire management & mapping	**Ninox Robotics**	Ninox Robotics' long-range drones are more cost effective than traditional crewed aviation solutions. Our drones are safely operated remotely, easily kept on	https://ninox-robotics.com/services/forestry
Megawatt charging system	**Scania**	The Scania Megawatt Charging System (MCS) is a next-generation ultra-high-power DC charging solution designed for battery-electric heavy-duty trucks, capable of	https://www.scania.com/group/en/home/electrification/e-mobility-hub/megawatt-charging-all-you-need-to-know-about-mcs.html
Menzi Muck walking excavator	**Menzi Muck AG**	The Menzi Muck is a walking excavator used extensively in forestry because it can operate safely and efficiently in terrain where normal machines cannot work – including	https://menzimuck.com/en/menzi-muck-ag/
Microtec WoodEye timber grading system	**Microtec**	WoodEye recognizes wood defects reliably and accurately in order to automate, streamline and optimize your production. The grading and optimization software considers	https://www.microtec.com/en-us/products/woodeye
Milrem Robotics fire-fighting robot	**Milrem Robotics**	The Multiscope Rescue Hydra is a firefighting unmanned ground vehicle (UGV) jointly developed by Milrem Robotics and InnoVfoam, integrating Milrem's Multiscope Rescue	https://milremrobotics.com/milrem-robotics-and-innovfoam-present-the-multiscope-rescue-hydra-ugv-at-sofins/

Technology Name	Company	Brief Description	Website
Monarch autonomous tractor	**Monarch Tractor**	The Monarch Tractor (specifically the MK-V) is the world's first fully electric, driver-optional, smart tractor designed to	https://www.monarchtractor.com/
MOTTI forest growth model	**OptFORESTS Project**	MOTTI is a forest growth model with tools to simulate stand development under different kind of management	https://www.optforests.eu/toolkit/models/motti
M-Planter mechanical tree planter	**M-Planter**	The M-Planter is a mechanical tree-planting device that mounts to an excavator (or, in some models, a	https://m-planter.fi/m-planter-en.html
Multi-grip automatic transplanting machine	**Atlantic Man**	Atlantic Man design and manufacture automated equipment for nurseries, including:	https://tech.atlanticgroup.it/product-focus/nursery-techModellogies-for-forestry-applications/
Multiscan photogrammetry & LiDAR forestry scan	**Multi Scan**	Multiscan enhance forest management with our drone-powered forestry surveys. We use high-resolution imagery	https://www.multiscan.digital/
Multiscope forester brush cutter	**Milrem Robtics**	The Robotic Forester Brush cutter, is equipped with a hydraulic power unit, brush cutting tool, and necessary	https://www.weforum.org/stories/2021/02/robot-tree-planter-deforestation-climate-change/
Multiscope forester planter	**Milrem Robtics**	Robotic Forester is a semi-autonomous forest regeneration system which will cover all the main regeneration operations	https://www.forsilvitech.com/article/future-of-planting-with-the-robotic-forester/
NCX forest carbon data analytics	**NCX (SilviaTerra)**	NCX (Natural Capital Exchange) is a data-driven forest carbon marketplace that connects landowners with buyers to	ncx.com
Netafim precision irrigation solutions	**Netafim**	Netafim is a global leader in precision irrigation solutions, best known as the pioneer of drip irrigation technology,	https://www.netafim.com/en/
Nordic Forestry Automation (ADAS)	**Nordic Forestry**	Nordic Forestry Automation's Advanced Driver Assistance System (ADAS) is an AI-enabled operator-assist platform	https://www.nordicforestryautomation.com/
Northwest Management forest inventory services	**Northwest Management**	Northwest Management undertake Data Collection, Inventory and Biometrics	https://northwestmanagement.com/
Novelquip mechanised precision tree-planting	**Novelquip Forestry**	NOVEL ProPlant machines are fully mechanized, precision tree-planting systems designed to perform all major	https://www.nqfsa.com/products/novel-automated-planting-equipment/
NZ FGR AI-supported seedling grading prototype	**Contempo Lab / Tui**	Prototype system improving automated measurement incl. root collar diameter/roots	https://fgr.nz/supporting-automated-seedling-grading-with-ai/
NZ FGR global review of exoskeletons	**NZ FGR**	The NZ Forest Growers Research (FGR) global review of exoskeletons is a structured assessment of emerging	https://fgr.nz/
NZ FGR program on harvesting automation &	**Forest Grower**	The programme goals are to redesign harvesting, log manufacturing and logistics processes. Our aims are to	https://fgr.nz/research-programmes/harvesting-automation-and-robotics/

Technology Name	Company	Brief Description	Website
NZ FGR program on nursery block-lifting	**Jonathan Sudano at**	The block lifter, which attaches to the rear plough arms of a small tractor and is controlled by the tractor's GPS, can	https://fgr.nz/mechanised-lifting-of-bare-root-nursery-stock/
Open-source forest growth model (3-PG2Py)	**Song et al.**	Process-based forest growth models have increased applications in forest ecology, carbon sequestration, and	https://www.sciencedirect.com/science/article/pii/S1364815222000640
Open-source UAV's for sowing seed balls	**DroneCoria**	Dronecoria is an open-source reforestation initiative that develops drones, seed-processing tools, and sowing	https://dronecoria.org/en/
Operating systems for autonomous horticultural	**Nature Robots**	Nature Robots provide a navigation solution designed specifically for open-field applications like ploughing,	https://naturerobots.com/en/
OPSEL tree breeding software	**Skogforsk (Forestry**	OPSEL is a fully integrated software tool that uses mathematical programming for optimized selection in tree	https://www.skogforsk.se/english/products-and-events/software/opsel/
Ottobock Paexo Back / Suit X Back Air	**Ottobock**	The Ottobock Paexo Back and SuitX Back Air are passive lower-back exoskeletons designed to reduce lumbar strain	suitx.com/en/products/ix-back-air-exoskeleton
Oxin autonomous tractor	**Oxin**	The Oxin is a fully autonomous, driverless, tracked robotic tractor designed by New Zealand-based Smart Machine	https://www.oxin.nz/oxin
Paper comparing LiDAR system to measure DBH &	**Tran et al.**	Precise forest inventory is the key to sustainable forest management. LiDAR technology is widely applied to tree	https://www.mdpi.com/1999-4907/16/4/643
Paper evaluating of a prototype field factory in	**McGuinness et al.**	Radiata pine is the most widely grown plantation forestry species in New Zealand and is a major	https://www.sciencedirect.com/science/article/abs/pii/S1537511023000089
Paper evaluating three different robots in the	**Ehrlich-Sommer et al.**	This study evaluated the usability and effectiveness of robotic platforms working together with foresters in the wild	https://pmc.ncbi.nlm.nih.gov/articles/PMC12394322/#Abs1
Paper examining statistical & silvicultural model needs	**Gilson et al.**	Literature around climate change adaptation in forestry has repeatedly called for climate-sensitive growth and yield	https://academic.oup.com/forestry/advance-article/doi/10.1093/forestry/cpaf020/8120574
Paper exploring concept of quadcopter swarm to	**Roldán-Gómez et al.**	Forest firefighting missions encompass multiple tasks related to prevention, surveillance, and extinguishing. This	https://www.mdpi.com/2076-3417/11/1/363
Paper modelling forest growth models under	**Boukhris et al.**	Forests are integral to global ecological stability, climate regulation, and economic resilience. They function as major	https://link.springer.com/article/10.1007/s40725-025-00249-5
Paper on a framework LiDAR point clouds into	**Shao et al.**	Large-scale forest inventory at the individual tree level is critical for natural resource management decision making.	https://www.sciencedirect.com/science/article/pii/S266601722400052X
Paper on automated calibration procedures to	**Pukkala et al.**	The current study first developed such a model set for stand dynamics that is technically suitable for simulating the stand	https://academic.oup.com/forestry/article/94/3/333/6172082

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Paper on developing a forest description from	**Pearse et al.**	Remote sensing is increasingly being used to create large-scale forest descriptions. In New Zealand, where radiata	https://www.sciencedirect.com/science/article/pii/S2666017224000671
Paper on identifying near-term opportunities in	**Visser and Obi**	Technology development, in terms of both capability and cost-effective integration, is moving	https://hrcak.srce.hr/file/370939
Paper on LiDAR-based framework for accurate	**Ibraham et al.**	Accurate characterization of tree stems is critical for assessing commercial forest health, estimating	https://www.mdpi.com/2072-4292/17/3/445
Paper on MECANT walking robot	**Helsinki University of**	MECANT was a six-legged walking machine constructed in the Helsinki University of Technology for research and test	https://pdf.sciencedirectassets.com/271086/1-s2.0-S0967066100X00044/1-s2.0-
Paper on operation of UAVs by manned tender to	**Univ George Washington,**	The operation of multiple unmanned vehicles (UAV) commanded and supported by a manned "Tender" air	https://www.lens.org/lens/patent/076-655-802-064-546/frontpage?l=en
Paper on remote sensing to estimate tree diameter	**Univ Yunnan**	The invention relates to the technical field of forest resource monitoring, and particularly discloses a Yunnan province	https://www.lens.org/lens/patent/058-737-651-007-961/frontpage?l=en
Paper on sensors for forest health monitoring sensors	**Ehrlich-Sommer et al.**	Smart forestry, an innovative approach leveraging artificial intelligence (AI), aims to enhance forest management while	https://www.mdpi.com/1424-8220/24/3/798
Paper on Shaping the Future of Forestry through	**Univresity of Freiburg**	The XR Future Forests Lab develops virtual (VR), augmented (AR) and mixed (MR) reality applications, initially	https://uni-freiburg.de/enr-xrlab/
Paper on stakeholder perspectives on optimising	**Miguel-Díez and Parfürst**	Augmented Reality (AR) is revolutionizing various industries by enabling the real-time, context-driven integration of data	https://www.sciencedirect.com/science/article/pii/S0301479725015774
Paper on using AI for forest harvest scheduling	**Bettinger et al.**	In this work, many of the operations research, heuristic search, and simulation methods that have been	https://bioone.org/journals/international-forestry-review/volume-26/issue-
Paper outlining concept of robotic planting machine	**Radics & Duong**	The study introduces the cost and benefits of applying planting robots. Four generations of planterbots were	https://www.researchgate.net/publication/350412265_PLANTERBOT_-
Paper reviewing advances in the automated	**Abreu-Dias**	The classification and identification of individual tree species in forest environments are critical for biodiversity	https://www.mdpi.com/2227-7080/13/5/187
Paper reviewing remote sensing in forestry	**Fassnacht et al.**	Remote sensing has developed into an omnipresent technology in the scientific field of forestry and is also	https://academic.oup.com/forestry/article/97/1/11/7159227
Paper surveying advances in forest robotics	**Oliveira et al.**	The development of robotic systems to operate in forest environments is of great relevance for the public and private	https://www.mdpi.com/2218-6581/10/2/53
Paper testing human-robot interaction for two robots	**Schraik et al.**	This study explores the usability of human-robot collaboration in the previously under-researched field of	https://link.springer.com/article/10.1007/s10209-024-01163-6

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PATAS delimbing machine	**AdvaligModel**	PATAS is a mechanical, high-speed tree-delimbing machine developed by advaligno GmbH in Germany. It is designed to	https://advaligno.com/en/machine/
Patent for a device configured to receive	**Caterpillar Inc**	A work machine including a sensing device, a user interface, and a control unit is disclosed. The control unit may be	https://www.lens.org/lens/patent/063-228-743-528-102/frontpage?l=en
Patent for a forest harvester configured to	**Nfa Forestry Automation**	A forest harvester for cutting trees includes a harvest sequencing system (10) configured to determine a	https://www.lens.org/lens/patent/167-662-247-165-915/frontpage?l=en
Patent for a method of artificial & swarm	**Ceballos Melo Andre**	A new artificial intelligence and swarm intelligence method and system in simulated environments for autonomous	https://www.lens.org/lens/patent/170-605-437-053-727/frontpage?l=en
Patent for a nozzle for attaching to a firefighting	**Jacintto Margues De**	The present disclosure falls within the field of firefighting using drones, in particular accessories that can be coupled	https://www.lens.org/lens/patent/041-473-339-305-901/frontpage?l=en
Patent for a RGB camera based mapping of tree	**Katam Technologies**	A surveying apparatus comprising a controller (CPU), the controller (CPU) being configured to: receive an image	https://patents.google.com/patent/US11769296B2/en?q=(forest+robotics)&oq=forest+robotics
Patent for a system compromising of a remote	**AirForestry Ab**	The invention relates to a system for remote and/or autonomous holding at least a portion of a tree trunk, said	https://www.lens.org/lens/patent/116-817-992-277-638/frontpage?l=en
Patent for AI-driven off-grid fire prevention system	**Vigillent Inc**	A system and method that is both effective and accessible. The system is machine-learning enabled, reliable, scalable,	https://www.lens.org/lens/patent/159-312-254-986-770/frontpage?l=en
Patent for an autonomous forestry vehicle	**Inesc Tec Instituto De**	The present invention is enclosed in the area of forestry maintenance vehicles, which provide for more or less	https://www.lens.org/lens/patent/012-118-929-534-095/frontpage?l=en
Patent for automated system & method for	**Freire Marcello**	The present invention belongs to the autonomous and precision agriculture sector, and refers, more specifically, to	https://www.lens.org/lens/patent/127-015-808-136-961/frontpage?l=en
Patent for method of operating a forestry	**Komatsu Forest Ab**	Method to operate a forestry vehicle, wherein the method comprises determining (110) a position of the forestry	https://www.lens.org/lens/patent/101-937-697-852-689/frontpage?l=en
Patent for monitoring of unstructured environments	**Univ Illinois**	The present disclosure provides a system for monitoring unstructured environments. A predetermined path can be	https://www.lens.org/lens/patent/148-381-179-984-459/frontpage?l=en
Patent on method of controlling an Autonomous	**Blue White Robotics**	Method, device and computer program product for controlling an autonomous vehicle coupled to an implement,	https://www.lens.org/lens/patent/059-004-424-412-340/frontpage?l=en
Patent on method of marking Bark Beetle	**Ceske Vysoke Uceni**	Method of marking bark beetle infested trees, and means for executing this method, comprises acquiring a map of a forest	https://www.lens.org/lens/patent/127-376-668-534-987/frontpage?l=en
Patent on reforestation planning method & device	**Komatsu Mfg Co Ltd**	A data acquisition unit acquires terrain data representing a terrain of a target area. An area specification unit specifies a	https://www.lens.org/lens/patent/054-339-634-573-655/frontpage?l=en

Technology Name	Company	Brief Description	Website
Pathfinder tool to plan routes for replanting	**Hansson et al.**	Pathfinder, plans the regeneration and routes based on the harvested production files, soil moisture and parent material	https://www.skogforsk.se/contentassets/82bdfe0593a04a1091620e9e1c34d8fe/pathfinder-a-tool-for-operational-
Pfanzelt radio-controlled forestry crawlers	**Pfanzelt Maschinenba**	The Moritz FR70 and FR75 are remote-controlled, tracked multifunction mini felling tractors designed for forestry,	https://www.pfanzelt.com/de/faellraupe/
Physiological Processes Predicting Growth (3-PG)	**University of British**	The 3-PG model (Physiological Processes Predicting Growth) was developed by Landsberg and Waring (1997). It	https://3pg.forestry.ubc.ca/
Phytotronics precision greenhouse and nursery	**Phytotronics**	Phytotronics (Phyto-Tronics), Inc. is a long-established U.S. manufacturer of precision greenhouse and nursery	https://www.phytotronics.com/
Pioneer 3-AT general purpose mobile robot	**ROS Robots**	The Omron Adept MobileRobots Pioneer 3-AT is a rugged general purpose four-wheel skid-steer mobile robot platform	https://robots.ros.org/pioneer-3-at/
Pixxel hyperspectral satellite imaging	**Pixxel**	Pixxel uses its high-resolution hyperspectral satellite constellation to provide advanced forest monitoring, species	Pixxel | Hyperspectral Imaging for Earth Observation
Planet Labs satellite imagery	**Planet Labs**	Planet Labs provides high-frequency satellite imagery and AI-powered analytics to monitor forest health, track carbon	https://www.planet.com/industries/forestry/
Planters guide - Scots Pine seed source software	**Skogforsk (Forestry**	Planters guide – Scots pine is a decision support tool for selecting forest regeneration material (stand seed and seed	https://www.skogforsk.se/english/products-and-events/software/planters-guide---pine/
PlantMax - mechanised plantation of forestry	**PlantMax by Plantma**	PlantMax is a mechanized afforestation unit that mounts onto a forwarder (typically 14+ tonnes, 268+ hp). It performs	https://plantmaforestry.com/what-is-plantma-x/
Plantolin planting robot	**University of Surrey**	Plantolin is a tree-planting robot inspired by a pangolin, developed at the University of Surrey (UK). It was the winner	https://www.surrey.ac.uk/news/meet-plantolin-tree-planting-robot-pangolin-built-university-surrey
PlotSafe data collection software	**Interpine Innovation**	PlotSafe is a software tool for collecting forest inventory data. It can be used for a range of forest surveys from a forest	https://interpine.nz/plotsafe/
Plustech Oy autonomous forestry machine	**Timberjack**	Plustech Oy was a Finnish R&D company and Timberjack affiliate (later part of John Deere) known for developing the	https://www.solhem9.se/broschyrbank_skogsbruk/Timberjack_spindeln.pdf
Polychromix Phazir portable NIR for timber	**Forest Quality**	The Phazir is a rugged, portable and reliable hand-held unit, increasingly finding a place in commercial eucalypt forestry.	https://www.forestquality.com/portable-nir
Ponderosa Systems fire suppression UAVs	**Ponderosa**	Ponderosa Systems develops rapid-response UAVs designed for first-attack fire suppression, focusing on	ponderosa.ai/
Ponsse buffalo planter	**Ponsse**	The Ponsse Buffalo Planter is an integrated mechanised planting system combining a forwarder platform with a	https://www.ponsse.com/news2/-/asset_publisher/ZE4CjSrtQpXR/content/ponsse-expands-

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PONSSE EV1 electric-powered forwarder	**Epec Flow Electrificatio**	Ponsse and Epec present a new, electric forest machine technology concept, the PONSSE EV1. The forest machine	https://epec.fi/ponsse-ev1
Ponsse forwarders & harvesters	**Ponsse**	Ponsse builds purpose-designed CTL logging equipment, meaning trees are felled, delimbed, and cut into logs at the	https://www.ponsse.com
Ponsse operator assistance systems	**Ponsse**	Ponsse's operator assistance systems are designed to enhance precision, productivity, and ergonomics in	www.ponsse.com/company/news/
POPSIM tree breeding simulator	**Skogforsk (Forestry**	POPSIM is a computer software tool for simulating the management of closed breeding populations through several	https://www.skogforsk.se/english/products-and-events/software/popsim/
Ported nozzle system fire-fighting UAV	**University of Coimbra**	A large drone hovers about 15m (49ft) above, a fire-proof hose dangling from its belly. A pair of jets on either side of	https://www.bbc.com/future/article/20230609-can-we-use-firefighting-drones-put-out-wildfires
PosTex Laser for geolocating trees	**Haglof**	The Posted system is a field instrument used to accurately position individual trees or objects within forest sample plots.	https://haglofsweden.com/project/positioning-of-individual-trees/
Potential of UAV's for forest thinning	**Cedergren et al.**	The objective of this study, a desk study, was to evaluate the usefulness/potential of an airborne system in thinning	https://www.skogforsk.se/english/research--results/research-notes/2024/the-potential-of-aerial-drones-
Priva climate, energy and process control solutions	**Priva**	Priva is a global leader in climate, energy, and process control solutions for horticulture, indoor farming, and smart	https://www.priva.com/
Program for Identifying Nursery Trees (PINT)	**University of South**	PINT (Program for Identifying Nursery Trees) is a software tool developed by the University of South Australia designed	https://fwpa.com.au/research/operational-transition-of-pint-software/
Project Forest Foresight: Enhancing Tasmania's fire	**Iridium Cloud**	Project Forest Foresight will deploy a range of Digital Forest Technologies to collect real-time data across selected	https://www.indicium.cloud/indicium-projects-23/project-forest-foresight
Project to develop, pilot & make available methods of	**n.n.**	The aim of this project is to develop, pilot and make available methods of verification of	https://mmm.fi/en/-/verification-and-methods-of-sustainable-precision-forestry
QIJI Energy battery	**Qiji Energy**	QIJI Energy, a subsidiary of CATL, officially launched its heavy-duty truck battery-swapping solution on 12 June	https://www.catl.com/en/news/6041.html
Rain Bird irrigation products and smart	**Rain Bird**	Rain Bird is a global leader in irrigation products and smart water-management solutions, widely used across	https://www.rainbird.com/
Rakka-3000UGV experimental autonomous	**Rakkatec, Now**	Rakka-3000 is a tele-operated and autonomous unmanned ground vehicle (UGV) and logistic systems to carry out	https://innovationplus.fi/Rakka-3000UGV/
Remote high resolution data acquisition for	**Forico**	Solutions for the optimal use of remotely acquired, high resolution data by the forestry sector.	https://forico.com.au/key-projects-in-estate-monitoring-and-individual-tree-quality-assessment

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Remote machinery operation	**Teleo Inc.**	Teleo retrofits heavy machinery so operators can run equipment remotely using joysticks, screens, and Teleo's "Supervised Autonomy" system	https://www.teleo.ai/
Remsoft AFRIDS LiDAR-based forest inventories	**Remsoft**	AFRIDS is web-based decision support tool, built on Esri ArcGIS, that offers advanced mapping, data analysis, and reporting tools for lidar forest inventories. Optional	https://remsoft.com/afrids/
Remsoft Log365 automated file transfer system	**Remsoft**	Log365 automates file transfers between harvesters/processors and offices via high-speed satellite internet, enhancing productivity and resource management	https://remsoft.com/log365/
Remsoft OpTracker forest machine telematics solution	**Remsoft**	Op Tracker enhances operational efficiency and reduces costs by automating data transfer and leveraging GIS data for real-time machine tracking and analysis. This versatile	https://remsoft.com/op-tracker/
Remsoft Prism forest inventory data collection, analysis & reporting	**Remsoft**	Remsoft Prism is a forest inventory data collection, analysis, and reporting platform built on Esri ArcGIS technology. It is designed to streamline and modernize how forestry	https://remsoft.com/prism/
Remsoft-Anchored Composite Digital Twin	**Remsoft**	A Remsoft-anchored composite digital twin integrates forest inventory, growth modelling, harvest scheduling, and logistics into a single optimisation framework, using Remsoft	remsoft.com/forestry/
Resistograph Series 650 for wood quality assessment	**Rinntech**	The Series 650 machines come in several configuration to match differing needs and regions. The R650-PR is designed for power poles and timber structures. The R650-	https://rinntech.info/products/resistograph/
Review of modern nursery technology for containerised & bare	**BSI / Interpine**	This review provides guidance on most of the critical decisions for designing an automated crop flow plan and supports the growing body of evidence that nursery	https://fgr.nz/wp-content/uploads/2024/06/PSP-TR004_G11.pdf
RIEGL LiDAR tools	**RIEGL**	RIEGL's advanced LiDAR sensors provide the foundational high-precision digital data that empowers critical decisions and drives innovation across a wide range of industries	https://www.riegl.com.au/
Rikko robotic forest ranger concept	**Segev Kaspi**	On of a group of robotic forest rangers were developed to support reforestation efforts and sustainable forest management. Each robot is assigned a defined role in	https://www.megosu.com/project-details/forest-ranger-druids-6b3f4847
Risutec PM compact mounding tree planting machine	**Risutec**	Risutec is a Finnish manufacturer of mechanized tree-planting systems designed to automate and integrate the entire forest establishment process. Their machines	https://risutec.fi/pm-tree-planting-machine/
Robotics Plus log scaler	**Robotics Plus**	Available as a fixed or mobile scaler, the world's first robotic log scaling machines have been developed by Robotics Plus. Previously, log scaling and other checks were a slow	https://www.roboticsplus.co.nz/products/port-automation/log-scaler
ROBOVOLC autonomous sampling machine	**Dunbabin et al.**	The main objective of this project is the development and trial of an automatic robotic system to explore and perform measurements in a volcanic environment. A major aim of the	https://www.researchgate.net/publication/243460749_ROBOVOLC_A_robot_for_volcano_exploration_result_of_first_test_campaign
Rottne forestry machines	**Rottne Industri AB**	Rottne forestry machines are professional, purpose-built harvesters and forwarders manufactured by Rottne Industri AB, a Swedish company that has been producing forest	rottne.com
Rottne harvester simulator	**Rottne**	The Rottne simulator is equipped with a complete control and measurement system. This makes it possible to change machine settings and directly experience the change on the	https://rottne.com/en/catalog/products/rottne-simulator

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Sabanto autonomous tractor upgrade	**Sabanto Ag**	Sabanto is an agricultural technology company that retrofits conventional tractors with autonomous hardware and	https://sabantoag.com/
Safety systems for autonomous robots	**3Laws**	3Laws Robotics is a robotics and autonomy-safety company that develops software safety layers for autonomous and	https://3laws.io/
Sam Hand autonomous forestry forwarder	**Luleå University of**	SAMHand is a major research project at Luleå University of Technology focused on developing sustainable, fossil-free,	https://www.ltu.se/en/research/research-subjects/machine-design/project/project/2023-12-07-samhand
Satellites for wilderness inspection & forest threat	**SWIFTT Forestry**	SWIFTT (swiftt.eu) is an EU-funded project that develops satellite-based, AI-powered forest threat monitoring tools to	https://swiftt.eu/
Scaffold AI forest sensing & mapping	**Scaffold AI**	Scaffold AI is a technology company focused on developing robotics and AI infrastructure for unstructured outdoor	https://www.scaffoldai.com/
Scion & Interpine case study of using LiDAR data	**Gunn**	Port Blakely has been using LiDAR for inventory purposes since 2015 and this technology has now	https://nzif.org.nz/nzif-journal/publications/downloadfulltext/23078
Search & rescue under the forest canopy using	**Tian et al.**	Multi UAV system for GPS-denied search and rescue under the forest canopy. Forests are particularly	https://arxiv.org/pdf/1908.10541
Seed pod biotechnology & precision aerial seeding	**AirSeed**	AirSeed offers: 1. Rapid, Large-Scale Reforestation Using Autonomous Drones	https://www.airseedtech.com/
Seedcopter UAV-based forest seeding for	**Seedcopter**	Seedcopter is a UAV (drone) system designed specifically for aerial seeding, enabling rapid reforestation in areas that	https://marutdrones.com/seedcopter-2/
Semantic LiDAR sensing & mapping for forest	**Chen et al.**	This paper describes an end-to-end pipeline for tree diameter estimation based on semantic segmentation	https://arxiv.org/pdf/1912.12726
Sennebogen forestry machines	**Sennebogen**	Sennebogen forestry machines include tree-care handlers, log handlers, and material handlers designed for harsh,	sennebogen.com
Silvalytics forest inventory services	**Silvalytics**	Silvalytics is an evidence-based forestry consultancy providing specialized services in forest valuation, resource	https://www.silvalytics.com/lidar-for-forestry-1
Silvanet AI wildfire sensing and remote UAVs	**Dryad Networks**	Silvanet provides ultra-early AI wildfire detection, as well as forest health and growth monitoring. It provides actionable	https://www.dryad.net/silvanet
Skelex 360	**Skelex**	Skelex 360 is a passive upper-body exoskeleton designed to reduce shoulder and arm fatigue during repetitive or	skelex.com/skelex-360
Skogforsk "One More Stack" project	**Löfroth and Svenson**	The project addresses the challenge of effectively transitioning to electrified heavy road transport. TREE	https://www.skogforsk.se/contentassets/89406f3dca31444d9ef3b3df0b3fd4bc/ett---modular-system-for-timber-

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Skogforsk Autonomous Site Preparation & Tree Planting concept	**Hansson et al.**	Sustainable forestry requires efficient regeneration methods to ensure that new forests are established quickly. In Sweden, 90% of the planting is	https://www.researchgate.net/profile/Linnea-Hansson/publication/377790755_Autoplant-Autonomous-Site-Preparation-and-Tree-Planting-for-a-
Skogforsk detection of forked trees project	**Manner and Lundström**	Forked trees should be harvested during thinning, as they can be handled efficiently in multi-tree processing. Waiting until final felling greatly increases time and leads to loss of	https://www.skogforsk.se/english/research--results/research-Modeltes/2024/forked-trees-significantly-increase-harvester-time-consumption-during-final-felling/
Skogforsk study on virtual reality remote-controlled crane operations	**Rossander et al.**	The study was performed using the full-scale forwarder prototype Xt28, where remote control is implemented with ROS (Robot Operating System) and the video transmission	https://www.skogforsk.se/english/research--results/research-Modeltes/2024/remotely-controlled-forwarder-crane-with-VR-can-be-operated-despite-delays/
Skogforsk Troëdsson Forestry Teleoperation Lab	**Skogforsk (Forestry Research**	The Skogforsk Troëdsson Forestry Teleoperation Lab is a world-leading research and test facility in Sweden dedicated to the remote operation, automation and future autonomy of	https://nordictestbednetwork.se/auto-2/
SKYLAB remote sensing & AI for forest health monitoring	**Skylab**	Skylab (Skylab aerial vegetation mapping GmbH) is a German company that uses Artificial Intelligence (AI) and aerial data (drones, planes, satellites) to digitize forest	https://skylabglobal.com/
SkyPlanter ultralight, seedling–planting UAV	**Lloyd et al**	SkyPlanter is a drone-based system for aerial reforestation with tree seedlings. Traditional tree planting is labour-intensive, physically demanding and expensive, making it	https://ieeexplore.ieee.org/abstract/document/11178078
SmartClone tissue culture pod system	**NuPlant**	The SmartClone™ is a unique robotic system designed for a new paradigm of tissue culture for clonal plant propagation. It addresses the limitations of conventional tissue culture	https://www.nuplant.com/smartclone
Sodra BraSatt autonomous planting machine	**Södra**	BraSatt is a driverless machine that uses the latest technology to scarify and plant forest seedlings with precision, efficiency and care. An autonomous planting	https://www.sodra.com/en/uk-ie/about-us/innovation/sodras-innovation-projects/brasatt/
SpanSet DeltaSuit	**SpanSet**	The SpanSet DeltaSuit is a lightweight, passive shoulder-support exoskeleton designed to reduce fatigue and strain during repetitive or sustained overhead and	spanset.com/us-en/section/exoskeleton/deltasuit
Sprayito spot sprayer	**Burro**	Sprayito is the ultimate autonomous spot sprayer for orchards and vineyards. Sprayito is a fully autonomous robot equipped with WEED-IT precision spray sensors. This	https://burro.ai/sprayito/
StanForD (communication standard)	**Möller**	StanForD is a standard for communication with forest machine controllers (computer systems). Skogforsk is responsible for the development and maintenance of the	https://www.skogforsk.se/english/projects/stanford/
STEMS (Single TrEe Metrics & Stand assessment)	**FP Innovations**	STEMS (Single TrEe Metrics and Stand assessment) is a simple natural colour (RGB) image based powerful, versatile tool designed for optimizing forest management strategies	https://app-dev-stems-asp.azurewebsites.net/about
Stereoscopic camera for automated log grasping	**Semberg et al.**	This study presents a simple method for automated log grasping using only a single stereo camera for object detection (log and grapple) and a simple controller moving	https://www.skogforsk.se/english/research--results/research-notes/2024/stereoscopic-camera-suitable-for-automated-log-grasping/
SuitX exoskeleton	**Ottobock**	SuitX is a California-based company acquired by Ottobock in 2021, produces modular, wearable robotic exoskeletons designed to reduce physical strain, prevent injury, and	https://www.suitx.com/en/home
Survey of localisation for robots in forestry	**Aguiar et al.**	Research and development of autonomous mobile robotic solutions that can perform several active agricultural tasks (pruning, harvesting, mowing) have been growing. Robots	https://www.mdpi.com/2218-6581/9/4/97

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Survey on Robotic Technologies for Forest	**Overstory (20tree.ai)**	Overstory is a vegetation-intelligence and wildfire-risk analytics company that works primarily with utility	overstory.com
Sylvanaut	**Lincoln Agritech**	SylvaNaut is an autonomous navigation and control system designed to retrofit motorised forestry equipment, enabling it	SylvaNaut.pdf
Terrain Tools forestry engineering & 3D mapping	**Softree**	Terrain Tools allows users to: • Work with a wide variety of survey data formats	https://www.softree.com/application/files/5017/5284/8734/Terrain_Forestry.pdf
TerraScan for managing & processing all types of	**Terrasolid**	TerraScan is the main application in the Terrasolid Software family for managing and processing all types of point clouds.	https://terrasolid.com/products/terrascan/
Terri forestry machines	**Terri**	Terri produces a full line of small, flexible, and powerful forestry machines, including:	https://www.terri.se/en/
The CuttingEdge Single is an automated sticking	**TTA-ISO**	The CuttingEdge Single is an automated cutting-sticking machine designed to plant rooted and unrooted plant	https://tta-iso.com/equipment/cuttingedge-single
Thermal UAV surveys to detect fauna	**Wagner et al.**	Sound methods to determine species occurrence and abundance are crucial for successful wildlife management	https://esajournals.onlinelibrary.wiley.com/doi/10.1002/eap.70091
Thermite robotic firefighter	**Howe & Howe**	Thermite robotic firefighters are one of the most capable, durable firefighting robots on the market. Designed to	https://www.howeandhowe.com/civil/thermite#overview
Thesis on semi-automating forestry	**Westerberg**	The process of forest harvesting is highly mechanized in most industrialized countries,	https://www.diva-portal.org/smash/get/diva2:718380/FULLTEXT01.pdf
Thinning bio-mass harvesters	**Silvatec**	GreenChip harvesters are self-propelled, high-capacity wood chipping harvesters designed for efficient biomass	https://greenchip.dk/
Tigercat harvesting heads	**Tigercat**	Tigercat harvesting heads (TCi Forestry Attachments) are high-performance, heavy-duty attachments designed for:	https://www.tigercat.com/products/harvesting-heads
Tigercat RemoteLog Telematics	**Tigercat**	Tigercat's automated log measurement systems are integrated into their harvesting and processing heads,	https://www.tigercat.com/feature/remotelog/
Tigercat steep-slope machines	**Tigercat**	Tigercat Industries has released two new track carrier models based on the new sloping tail platform for steep	tigercat.com
TimberID image processing for timber	**Deeplai**	TimberID solution is an AWS cloud global platform delivering multiple services powered by proprietary AI/ML processing	https://www.deeplai.com/technology/
Timberjack walking harvester	**Timberjack**	The Plusjack walking harvester is a prototype six-legged forest harvesting machine developed in 1999 by Plustech,	https://lusto.fi/en/exhibitions-and-events/whats-on-at-lusto/time-of-the-machines/

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TimberMAX T-WINCH remote controlled felling	**TimberMAX**	The T-WINCH is a remote-controlled traction-assist winch system designed for steep-slope forestry operations.	https://timbermax.ca/
Timbeter log measurement software	**Timbeter**	Timbeter allows the user to take a photo of the timber pile with their smartphone or tablet. AI then analyses the image,	timbeter.com
T-MAR winch-assist machines	**T-Mar Industries**	The TimberMAX (T-Max) Traction Winch is a specialized, high-performance winch-assist system designed for forestry	https://t-mar.com/
TREE Project: Transition to Efficient Electrified	**Pernestål**	TREE is a major Swedish national initiative focused on accelerating the shift to electrified heavy forestry transport,	https://www.skogforsk.se/english/projects/tree/
Tree swinging robot concept	**inFact by Scion and**	The Tree to Tree robot has been developed as a feasible mechanical engineering concept, fit for purpose robot for the	https://www.infact.co.nz/project/tree-to-tree-robot
TreeRover tree-planting robot	**IOTA Enterprises**	TreeRover is a prototype electric, autonomous robot designed by University of Victoria engineering students Nick	https://www.uvic.ca/news/archive/topics/2016+building-a-tree-planting-robot+ring
TreeTools online LiDAR analysis	**Interpine Innovation**	The TreeTools Online tool leverages LiDAR technology to deliver precise and efficient remote forest inventory	https://interpine.nz/treetools-online-lidar-analysis/
TreeTools VirtualPlot	**Interpine**	Capture your own data and process virtual plots on-site to obtain immediate results. Utilize these results to optimize	https://interpine.nz/treetools-near-realtime-tree-stocking-application/
Treevia forest monitoring	**Treevia**	Treevia Forest Technologies is a Brazilian startup that provides smart, IoT-based SmartForest solutions to	treevia.com.br
[Trimble CFLogistics scheduling tool](https://forestry.trimble.com/solutions/cflogistics/)	**Trimble Forestry**	Trimble Forestry's CFLogistics helps you to reduce log logistics costs by making transportation scheduling and	https://forestry.trimble.com/solutions/cflogistics/
Trimble DataSync cloud-based data storage	**Trimble Forestry**	Trimble DataSync is a cloud-based data storage solution in the Forestry industry. It empowers customers to seamlessly	https://forestry.trimble.com/solutions/trimble-datasync/
Trimble DataVuze data integration system	**Trimble Forestry**	Trimble DataVuze is a forestry data integration and analytics platform that turns raw machine data from harvesters,	https://forestry.trimble.com/solutions/trimble-datavuze/
Trimble Mobile Builder for field workers	**Trimble Forestry**	Mobile Builder allows forestry clients to mobilize spatial and tabular business processes enabling field workers to quickly	https://forestry.trimble.com/wp-content/uploads/2020/04/Mobile-Builder-datasheet-new-
Trimble SilvaPRO integrated forest	**Trimble Forestry**	Trimble Forestry's CONNECTED FOREST™ Forest: SilvaPRO™ is a SaaS-based Enterprise	https://forestry.trimble.com/wp-content/uploads/2019/02/CFForest_SilvaPRO_DS_ENG_1
Trimble timber supply chain management	**TimberSmart**	TimberSmart is a specialized information management and ERP software platform for the timber, forestry, and	https://www.timbersmart.co.nz/

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TrimBot2020 autonomous cutting machine	**Mapix Technologies**	TrimBot2020 is a European Union Horizon 2020 research project aimed at developing the first fully autonomous	https://www.mapix.com/case-studies/trimbot/
Trovador autonomous tree planting robot	**Trovador**	Trovador is an autonomous, all-terrain tree-planting robot designed to restore forests in steep, burned, and	https://trovador.eu/
TTA-ISO CuttingEdge system	**TTA-ISO**	The TTA-ISO CuttingEdge system is an automated propagation platform designed to plant rooted and unrooted	tta-iso.com/equipment/cuttingedge
TTA-ISO FlexPlanter	**TTA-ISO**	The TTA-ISO FlexPlanter XF is a flexible, automated transplanting system designed to handle a range of tray	tta-iso.com/equipment/FlexPlanter%20S
TTA-ISO forestry nursery equipment	**TTA-ISO (Merged from**	With TTA-ISO, forestry nurseries acquire the tools to scale sustainably, decrease labour dependency, and fulfil the	https://www.tta-iso.com/sectors/carbon-and-forestry\
T-WINCH remote harvest winch	**Ecoforst**	The compact traction winch T-WINCH is used wherever unsecured driving poses high risk for people and machines.	https://www.ecoforst.at/t-winch-2/
Two-Stage trucking using log trucks	**NZ FGR**	Two-stage trucking is a logistics approach where logs are transported in two steps: first from the harvest site to an	fgr.nz/wp-content/uploads/2026/03/H081.pdf
UAV hyperspectral imaging	**Airborne Logic**	AirborneLogic is an Australian-based company specializing in remote sensing, drone imagery, and data analytics,	https://airbornelogic.com.au/
UAV LiDAR module	**DJI**	The DJI Zenmuse L2 is an integrated aerial LiDAR mapping system used for high-precision 3D surveying, forestry	https://enterprise.dji.com/zenmuse-l2
UAV navigation in dense forests	**Liu et al.**	Semantic maps represent the environment using a set of semantically meaningful objects. This representation is	https://ieeexplore.ieee.org/abstract/document/9720974
UAV precision aerial water bombing	**Sprayon**	FIRECHAIN's firefighting drones deliver safer aerial firefighting in lightning, high winds, smoke, and turbulent	https://firechain.com.au/
UAV-based forest seeding for revegetation	**Flash Forest**	Flash Forest deploys UAVs (drones) equipped with seed-firing systems to plant tree seed pods rapidly across	https://www.flashforest.com/
UAV-based pest detection	**BIOSYNTRIX**	Biosyntrix is a South African biosecurity and environmental intelligence company that provides real-time surveillance,	https://biosyntrix.co.za/
UAV-based tree thinning	**AirForestry**	AirForestry makes it possible to thin forests in a completely new way, namely from the air. Through our innovative	airforestry.com
UAV-based wildlife monitoring & habitat	**Aeroscan**	Aeroscan (Aeroscan Technology / scan.aero) provides drone-based forestry intelligence, using LiDAR, thermal	https://aeroscantechnology.com/forestry-solutions/

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UAVs for forest fire monitoring & prevention	**Aeroscan**	Drones are revolutionizing forestry management by providing a fast, cost–effective, and highly accurate way to	https://aeroscantechnology.com/forestry-solutions/
UAV's for forest inventory & biomass estimation	**Aeroscan**	Aeroscan Technology offers a wide range of drone services for the forestry industry, enabling professionals to gather	https://aeroscantechnology.com/forestry-solutions/
University of Sydney forest robotics research	**Australian Centre for**	The University of Sydney research focuses on resourcing and inventories, forestry automation and forest health,	https://www.sydney.edu.au/engineering/our-research/robotics-and-intelligent-systems/australian-centre-
Unmanned orchard sprayer robot S450	**LJ Tech**	The Meto SWT spraying robot allows you to spray spot by spot. The touchscreen control panel is user-friendly. With the	https://ljtechag.com/product/unmanned-orchard-sprayer-robot-
UON Smart DC-FC Fast Charger	**UON**	UON Charging refers to the electric-vehicle (EV) charging solutions developed and delivered by UON, an Australian	https://uon.com.au/uon-smart/dc-fc/
Urbanati Nursery Technology	**Urbinati**	Urbanati Nursery Technology refers to advanced automation and mechanisation systems for forest and horticultural	https://www.urbinati.com/en/
USDA Forest Inventory & Analysis	**Forest Service -**	Forest Inventory and Analysis (FIA) is a congressionally mandated program that delivers current, consistent, and	https://research.fs.usda.gov/programs/fia
USDA forest vegetation simulator	**U.S. Department**	The Forest Vegetation Simulator (FVS) is the official forest growth and yield model used by the U.S. Forest Service	https://www.fs.usda.gov/managing-land/forest-management/fvs
ValRemote remotely controlled tree felling	**BaSt-Ing GmbH**	The ValRemote with ValFast by BaSt-Ing is a remote-controlled mechanical wedge system designed for safe,	https://www.clark-engineering.com/product/valremote-with-valfast/
Van Horlick's Cultivator Planter	**Tim C. Van Horlick**	The Van Horlick's Cultivator Planter "VHCP", is the next generation of mechanized site preparation and reforestation	https://www.agriculture-xprt.com/products/cultivator-planter-559969
Vehicle to measure & analyse a forest area	**Deere & Co**	The invention is a method for measuring and analysing a forest area for a forestry vehicle, the vehicle comprising a	https://www.lens.org/lens/patent/115-164-562-969-085/frontpage?l=en
VEICHI Intelligent Solution battery	**VEICHI**	VEICHI's Intelligent Solution for Battery Swap Stations is an industrial automation and control platform designed to	https://www.veichi.com/news/intelligent-solution-for-battery-swap-station-helps-heavy-trucks-develop-vigorously.html
Vibrant Planet mapping forests using remote	**Dragonfly Data Science**	Vibrant Planet is a cloud-based environmental technology platform focused on wildfire risk reduction, ecosystem	https://www.dragonfly.co.nz/
Vicon vision grading transplanters	**Viscon Group**	Viscon Plant Technology provides automation solutions for young tree production, and supplies everything required for	https://viscongroup.eu/markets/flowers-and-plants/forestry/
Volvo Co-Pilot / Dig Assist	**Volvo**	Volvo Co-Pilot and Dig Assist are operator-assist systems designed to improve accuracy, efficiency, and safety in	tdxltd.co.nz/volvo-co-pilot-/

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WaldoLog forestry data platform	**Waldo Solutions Inc.**	Waldo (waldologs.com) is a digital platform designed for the forestry industry to manage timber supply chains from the	https://www.waldologs.com/
Walkera hotspot suppression UAVs	**Walkera**	Walkera UAV platforms are designed for targeted hotspot suppression and firefighting support, using multi-rotor	en.walkera.com/index.php?id=1889
Waratah harvester heads	**Waratah Forestry**	Waratah harvester heads are high-performance, versatile forestry attachments used for felling, delimbing, cross-	waratah.com
Web-based forest growth model	**Chen et al.**	To facilitate forest research, simulations of the whole forest growth process can be employed to analyse forest dynamics	https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019EA000748
Weiler Forestry heavy equipment	**Weiler Forestry**	Weiler Forestry's product line is the ideal addition to Weiler's current product portfolio. Weiler has a proven track record of	https://www.weilerforestry.com/
Wildfire detection & aerial surveys	**Insight Robotics**	Insight Robotics provides AI-powered, automated wildfire detection systems for forests, using long-range thermal	https://www.insightrobotics.com/en/services/aerial-survey/
Wood purchasing & supply chain software	**Conifer Soft**	ConiferSoft develops Enterprise Resource Planning tools specifically for forest-purchasing organisations, helping them	https://www.conifersoft.com/
World Resources Institute global map of tree canopy	**Meta**	Meta and World Resources Institute believe that democratizing access to artificial intelligence can be an	https://sustainability.atmeta.com/blog/2024/04/22/using-artificial-intelligence-to-map-the-earths-forests/
Xdesign tree breeding software	**Skogforsk (Forestry**	XDesign is a computer software tool for preparation of complex mating designs in tree breeding, including those	https://www.skogforsk.se/english/products-and-events/software/xdesign/
XGRIDS digital forest models	**Xgrids**	XGRIDS) is a high-precision 3D scanning and mapping technology used to digitize environments. Here is what	https://www.xgrids.com/industryDetails?page=geomatics&id=4
Yamha Fazer SAR unmanned helicopter	**Yamaha**	The Yamaha Fazer SAR is an uncrewed helicopter drone used for environmental management, including wildfire	https://global.yamaha-motor.com/design_technology/technology/electronic/008/
YellowScan UAV LiDAR Systems	**YellowScan**	YellowScan builds professional drone-based LiDAR mapping systems that are widely used in forestry for precise	https://www.yellowscan.com/industries/forestry
Ziyan Tech Shadow S3 long range UAV	**Ziyan**	The ZIYAN Shadow S3 is a portable, long-endurance unmanned helicopter designed for industrial inspections,	https://www.ziyanuas.com/qiyezhan/Aerocraft/17