Advancing Sustainable Forestry GIS Platforms for Future Challenges

Ashwood Caesar

Gottstein Fellowship Final Report

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The Joseph William Gottstein Memorial Trust Fund, known as The Gottstein Trust, began in 1971. It is a national educational trust which encourages innovation and the pursuit of excellence through the people, processes and products within Australia's renewable wood products and forestry industry.

The Trust is the living legacy to honour Bill (Joseph William) Gottstein - who died in a tragic field accident in 1971 while visiting PNG. He was an exceptional, innovative man and was internationally respected. He was a scientist and a leader in the CSIRO forest products division.

The Gottstein Trust invests in capacity building which directly contributes to the success and evolution of Australia's wood products and forestry industry.

Governed by several Trustees - all with close industry links – every year the Trust calls for applications from interested candidates for Fellowships, Scholarships and Skill Development grant awards. These grants are awarded to individuals through a competitive selection process. The funding provided enables recipients to pursue projects, further their studies or undertake specific skill development. Regular short courses and industry field trips are also run each year, with a focus on understanding both forest science and wood science.

People involved in Gottstein activities have opportunity to build their knowledge and networks and expand their own capacity to contribute to the industry. The Trust is funded with the support of industry donations arising from an annual appeal and by investment earnings.

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About the author

Ashwood Caesar brings over 25 years of experience delivering geospatial solutions across diverse sectors including engineering, energy, rail, government, defence, mining, aviation, and since 2021 forestry. After earning a degree in Forestry Science from the University of Canterbury in 1997, Ashwood has come full circle, now serving as GIS Manager at OneFortyOne, a trans-Tasman forestry company.

He leads strategic direction, stakeholder engagement, and spatial service delivery, combining technical expertise with business acumen. Ashwood holds an Executive MBA from QUT (2021) and postgraduate qualifications in Spatial Information Science (1999) and Enterprise Systems (2016). He is widely respected for his ability to translate complex geospatial concepts into actionable, real-world outcomes.

Driven by a passion for innovation, Ashwood continually seeks new ways to harness geospatial systems, data, and technology to meet corporate objectives and deliver measurable value.

This Gottstein Fellowship was awarded in 2024.

Acknowledgement

I would like to express my sincere gratitude to the Gottstein Trust for awarding me the fellowship, and to my employer OneFortyOne particularly my direct manager Jan Rombouts for their generous support throughout this journey.

I am especially thankful to the following organisations for their valuable contributions to my workshops and site visits: The Center for Advanced Forestry Systems (CAFS), Campbell Global, Rayonier, Alberta-Pacific

Specific representatives from these organisations are acknowledged in the individual site visit reports.

I also appreciate the participation of Dan Christiansen, GIS/IT Manager at Weyerhaeuser, who attended workshops 1 & 2 online and provided insightful input.

Lastly, I extend heartfelt thanks to my wonderful wife and family for their enduring support before, during, and after my Gottstein journey.

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Executive Summary

My approach to gathering information for this report followed four key stages: Discover, Learn, Analyse, and Reflect.

- **Discover:** I conducted site visits, facilitated workshops (both online and in-person), held interviews and discussions, and collected relevant materials.
- **Learn:** I identified pain points and opportunities from the forestry companies I engaged with; documented lessons learned, explored their purpose and context, and compared their similarities and differences.
- **Analyse:** I developed a capability maturity matrix, a data management framework, and an R&D model, while also identifying critical dependencies for success.
- **Reflect:** I synthesised the insights gained, outlined the conditions necessary for success, drew conclusions, and formulated recommendations.

The five key take home learnings from this report are:

Strategic Importance of GIS in Forestry Operations

Geospatial technology underpins core forestry workflows and reporting. The sector's growing interest in expanding GIS capabilities highlights its vital role in tackling emerging challenges and unlocking new opportunities. This includes upholding best-practice data governance while responsibly integrating innovations like artificial intelligence especially when guided by a well-defined purpose and strategic direction.

Current Constraints and Opportunity Costs

Despite strong enthusiasm, GIS advancement is constrained by manual data processes, fragmented systems, and limited data accessibility. These limitations carry significant opportunity costs and underscore the urgency of coordinated interventions and a structured roadmap for capability uplift.

Future-Ready Capabilities Required

To stay competitive, forestry companies must digitise analog data capture, ensure records are accessible and analysable, and build capacity to harness generative AI. The utilities and energy sector provides a strong precedent having transformed legacy infrastructure maps and data into digital formats, integrated them into relational databases and GIS platforms, and begun applying AI to derive operational insights. These capabilities are critical for generating actionable knowledge that supports long-term viability and strategic decision-making.

Strategic Interventions for GIS Maturity

A phased, 12-month roadmap is proposed to build foundational capabilities, foster engagement, and embed sustainable governance. Key interventions include cross-industry collaboration, enterprise-wide data governance, digitised workflows, and empowering GIS experts with cross-functional autonomy.

Leadership and Organisational Culture Shift

Unlocking GIS's full potential requires executive-led data leadership such as appointing a Chief Data Officer and cultivating a trust-enabled, innovation-supportive culture. These shifts are central to harmonising data efforts and positioning the industry for resilient, future-ready growth.

Background

Geographical Information Systems (GIS) are widely used in forestry companies, integrating systems such as Trimbles Land Resource Manager (LRM) and supporting various business groups. In estate management, it maps and manages forest estates. For harvesting, it plans and monitors activities, ensuring sustainable practices. In silviculture, it manages tree planting and health monitoring. For resource information, it centralises data on forest resources. In marketing, it aids in market analysis and strategic planning. For planning, it supports long-term strategies and scenario analysis. In compliance, it ensures adherence to environmental regulations and certification standards. By integrating GIS across these groups, forestry companies enhance efficiency, sustainability, and profitability.

The return on investment (ROI) for GIS in forestry is widely accepted to be 1:4, meaning that for every dollar spent, there is a four-dollar return in tangible benefits (Kloos, 2016). Personally, I believe the ROI is even greater when factoring in non-tangible benefits such as enhanced decision-making and improved collaboration. However, providing concrete evidence for these benefits can be challenging. Nevertheless, any forestry company would be significantly impacted if their GIS platform were disrupted or made redundant, much like how everyone notices when there is a power outage. This underscores the importance of GIS in forestry.

Forestry companies in Australia vary in size, managing 1.9 million hectares of forest estates, some with adjoining timber mills (Sciences, 2020) (ABARES, 2025). In contrast, many U.S. forestry companies are large conglomerates, managing 54.3 million acres (22 million hectares) of commercial plantations (Congress, n.d.) (Foresters, 2025). In Canada, there are approximately 165 million hectares of managed forests, which accounts for 45% of the country's total forest area of 367 million hectares. This managed forestry is primarily located on public land, but it is not known how much of this is actual commercial plantation forestry land. (Canada, 2025)

The size of a forestry company is driven by market demand, investment levels, technological advancements, government policies, environmental factors, and economic conditions. In Australia, the heavily regulated forestry industry, governed by Commonwealth Regional Forest Agreements (RFAs) and state legislation, focuses on balancing economic, social, and environmental benefits. (ABARES, 2025)

Australia's forestry sector is smaller compared to North America but is a significant exporter of woodchips (5.741 million bone-dry metric tons) (Australia, n.d.). In contrast, North America, particularly the U.S. and Canada, leads in sustainable forest management and is among the largest exporters of timber and paper products in the world (Forestry.com, 2025). North America's forestry industry benefits from extensive private ownership of timberland, a larger workforce, and higher investment, giving it a technological edge. (Statista, n.d.) Both regions face challenges like forest fires and labour shortages.

The differences in forestry practices between North America and Australia are influenced by historical land ownership, regulatory frameworks, and economic factors. In North America, extensive private ownership of timberland allows forestry companies to integrate land management with real estate services. (USGS, 2025) Conversely, Australia's forestry sector is more regulated, with significant portions of forest land managed by government agencies under strict environmental guidelines, limiting private companies' involvement in real estate. (Fastmarkets, 2025) Additionally, North America's larger market size and advanced technology enable diversification, while Australia's focus remains on export markets and sustainable practices (Statistics, 2025) (ABARES, 2025).

These differences impact local economies: North America benefits from economic stability and growth in forest-dependent communities, while Australia's emphasis on sustainability supports rural employment and regional resilience, though with less economic diversification. (Wilson, 2024)

Given the differences between North American and Australian forestry practices, I initially believed Australia could benefit from the U.S. approach to provisioning and managing GIS platforms, systems, and data products/services. I was particularly interested in how forestry companies can navigate and thrive amidst challenges like climate change, carbon sequestration and credits, AI, and automation. While innovative technology platforms and governed data are crucial, I wanted to understand the underlying conditions and factors that contribute to the success of one forestry company over another.

It is my assumption that the "X factor" that makes a forestry company more successful than another often lies in its ability to innovate and adapt to changing conditions. This includes leveraging advanced technology platforms, such as GIS and Artificial Intelligence (AI), for efficient forest management and data-driven decision-making. Additionally, successful companies excel in navigating market challenges like climate change, carbon sequestration, and automation by implementing sustainable practices and diversifying their operations. Strong leadership, effective risk management, and community engagement also play crucial roles in driving success.

My report aims to test this assumption by gathering evidence through site visits to some of the world's largest forestry companies. I am particularly interested in how these companies navigate challenges and seize opportunities. While innovative technology platforms and governed data are crucial, I want to understand the underlying conditions and factors that contribute to the success of the forestry industry. Observing these companies firsthand will provide valuable insights to help improve the application of GIS within Australia's forestry industry.

Future Technologies

In forestry, GIS plays a crucial role in monitoring climate change impacts, detecting deforestation and degradation, assessing biodiversity loss, and managing pest and disease outbreaks. It also supports carbon sequestration measurement, water resources management, forest inventory and mapping, and fire management. (Kumar, 2011) AI-driven remote sensing techniques enable precise mapping and monitoring of plantations, early detection of pests and diseases, and optimised resource use through activity like precision agriculture. AI-driven yield prediction and automated machinery improve harvest planning and operational efficiency. Additionally, AI helps supply chain management and aids timely interventions for better crop health and reduced losses. These advancements make plantation management more sustainable, cost-effective, and profitable (Sairone, 2024).

Indoor GIS offers significant perceived value through enhanced asset management, improved space utilisation, streamlined operations, safety and compliance, and data-driven decision-making. However, it remains out of scope for mainstream GIS capabilities in businesses, requiring needs and benefits identification, stakeholder buy-in, data integration, and pilot projects to change this (Esri, Indoor GIS, 2025).

Generative AI in GIS, particularly in remote sensing, allows users to create custom AI models for detecting objects, changes, or patterns in geospatial imagery. Platforms support various geospatial imagery types and integrate with tools like Esri ArcGIS Pro and Safe software's FME, providing industry-specific solutions and professional services to enhance productivity, compliance, and sustainability (Viswambharan & Singh, 2024).

AI significantly enhances forestry by automating complex data processes, enabling faster and more accurate insights. It helps detect patterns and anomalies in vast datasets, reducing uncertainty and improving predictive modelling (Liang, 2023). AI also allows for real-time monitoring and iterative refinement of solutions, maximising resource efficiency (Joppa, 2018).

Esri's generative AI, demonstrated at the International User Conferences 2024/2025, has significant potential to support novice GIS users in performing spatial analysis by simplifying the user interface with natural language prompts, automating workflows, and providing step-by-step guidance. This technology can reduce the learning curve, increase efficiency by handling routine tasks, and make complex spatial analysis accessible to a broader audience, empowering beginners to achieve accurate results with ease (Theodore, 2024).

As Environmental, Social, and Governance (ESG) considerations become integral to business operations, companies are likely to enhance their spatial analysis capabilities to deliver better data products and services. The integration of ESG factors into forestry investments has been growing, driven by the need to address climate change and sustainability. This trend is expected to continue with more institutional capital flowing into the forestry sector as investors seek to ensure their assets are sustainable and compliant with ESG standards

(Environmental, Social and Governance Factors in Forestry Investment & Management, 2020).

Carbon accounting, particularly embodied carbon accounting, is becoming crucial in various industries, including forestry. The use of spatial-temporal models for carbon accounting highlights the importance of spatial analysis in accurately estimating carbon footprints (Zhang, 2024).

As companies strive to meet ESG criteria and accurately report their carbon footprints, they will need to invest in advanced spatial analysis tools and techniques. This will enable them to produce more precise and comprehensive data products and services. The demand for geospatial data providers and analytics solutions is already on the rise, reflecting this shift according to my observations.

I am interested in understanding the industry's appetite for adopting these types of technologies, as well as the barriers and opportunities that influence their adoption. I have identified certain business drivers that I believe shape this appetite:

Historical Business Drivers

- *Understand Forest Condition:* Monitor and assess the forest's operational state.
- *Ensure Compliance:* Adhere to regulations, standards, and stakeholder objectives.
- *Produce Mapping Products:* Transition from paper to digital formats.

Current Business Drivers

- *Build on Historical Drivers:* Continue historical practices.
- *Integrate Field and Office Data:* Seamlessly connect data provisioning and access between the office and the field, even in real time.
- *Analyse Operational Data:* Retrospectively model and analyse operational data.
- *Digital Data Publishing:* Publish and provision data digitally and seamlessly.

Future Business Drivers

- *Expand on Current Drivers:* Continue current practices.
- *Predict Operational Outcomes:* Retrieve data to prescribe and predict operational activities and outcomes.
- *Track Product Provenance:* Determine the pedigree of timber products from nursery to market.

- *Explore New Opportunities:* Discover potential in other business areas, such as indoor GIS for mills, supply chain tracking, applied AI, and addressing ESG factors like carbon, climate, and biodiversity, plantation acquisition, while working towards automation.

Are these realistic? What does the industry say? My study tour aims to confirm whether these drivers exist and, if they do, what actions are being taken to expose and counteract them appropriately.

Cohesion

I aim to uncover the cohesive characteristics essential for fostering vision and strategic thinking, leadership, business alignment, innovation, and trust. By identifying these traits, I am hoping to demonstrate that we can create a unified, forward-thinking environment that drives success and inspires confidence within the industry. As mentioned above I seek to discover the "X Factor" in managing and maintaining spatial excellence in forestry, focusing on the human qualities needed to face future challenges. I also aim to explain how the Australian forestry industry can thrive and learn by adopting a success-oriented culture like that of its northern counterparts.

Report Methodology

My methodology for gathering information for my report is illustrated in Figure 1 and involved four stages: Discover, Learn, Analyse, and Reflect. In the Discover stage, I conducted site visits, workshops (both online and on-site), interviews, discussions, and gather material. During the Learn stage, I identified pain points and opportunities from the forestry companies I visited, documented lessons learned, understood their purpose and background, and examined similarities and differences between them.

In the Analyse stage, I built a capability maturity matrix, data management framework, and R&D model, and determined the dependencies for success. Finally, in the Reflect stage, I summarised the learnings and conditions for success, drew conclusions, and made recommendations.

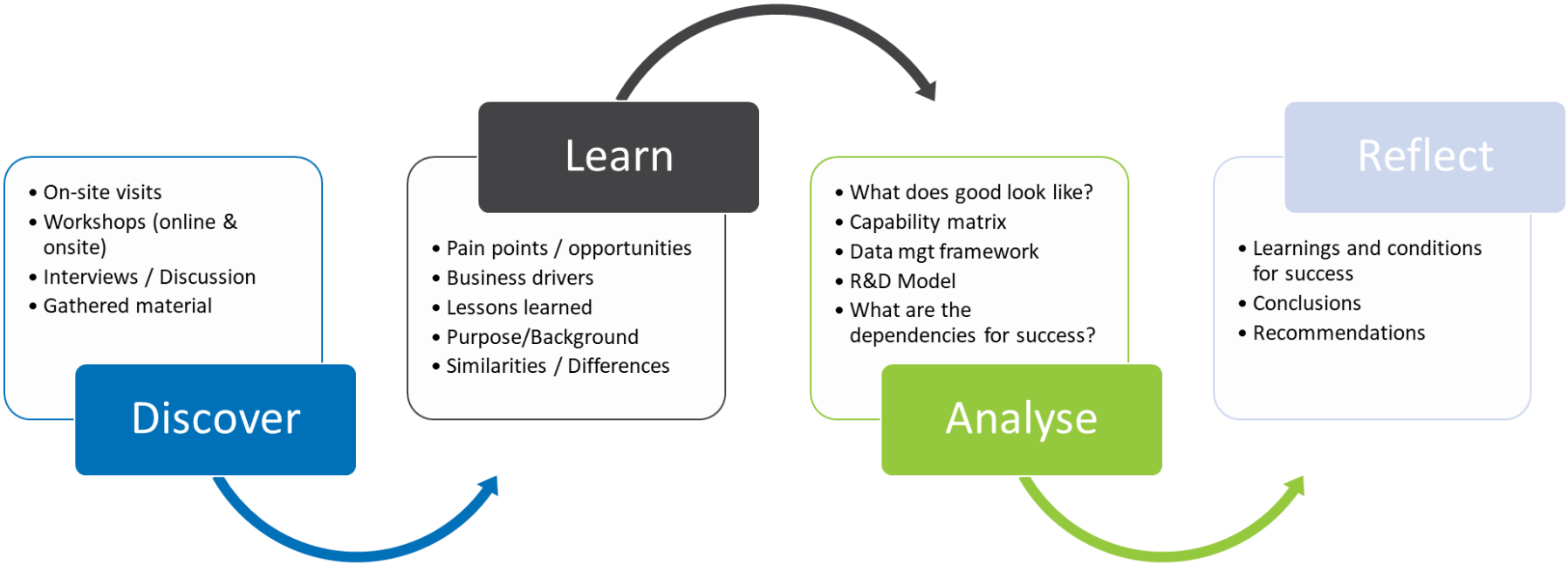


Figure 1 Four phase study and report methodology

Discover & Learn

The start of the tour began at the Annual Conference of the Centre of Advanced Forestry Systems in Kona Hawaii. Onsite visits were conducted with Campbell Global in Port Angeles Washington and Portland Oregon, Rayonier in Wildlight Florida, and Alberta-Pacific in Athabasca Alberta Canada. An online workshop was conducted with all the onsite participants to also include Weyerhaeuser online.

Profile	Details
Business	The Center for Advanced Forestry Systems (CAFS) established in 2007 is a National Science Foundation Industry/University Cooperative Research Center (NSF I/UCRC) in the United States that bridges top academic forestry research programs with 138 industry members to solve complex, industry-wide problems.
Headquarters	The University of Maine's Center for Research on Sustainable Forests (CRSF), through its Cooperative Forestry Research Unit, is a member of CAFS and serves as the lead site.
Jurisdiction	USA – Its mission is to optimise genetic and cultural systems to produce high-quality raw forest materials for new and existing products by conducting collaborative research that transcends species, regions, and disciplinary boundaries.
Website	https://crsf.umaine.edu/forest-research/cafs/program-summary/

The Semi-Annual CAFS In-Person IAB Meeting, held from June 10–12, 2025, took place at the stunning Mauna Lani Resort on the Kohala Coast of Hawaii. I was honored to attend as an invited guest and had the opportunity to deliver a brief presentation on my project and my role as GIS Manager at OneFortyOne Green Triangle.

The event featured a series of insightful presentations from academic staff, showcasing cutting-edge research that is helping to shape the future of forestry science and practice. Representatives attended from a range of leading institutions, including the University of Maine, North Carolina State University, University of Georgia, Purdue University, University of Idaho, University of Washington, and Oregon State University.

Figure 2 Selected Images from the Conference & Mauna Lani Resort

Site Productivity and Environmental Variation

Several studies focused on assessing regional variation in site productivity and carrying capacity, as well as the physiological response to fertilisation and throughfall reduction. These projects help identify optimal locations for planting and managing forests by understanding how environmental factors like water availability, soil quality, and nutrient inputs affect tree growth. This knowledge enables foresters to tailor management practices to site-specific conditions, improving yield and resilience under climate stress.

Species Performance and Climate Adaptation

Research comparing nine conifer species across water deficit gradients, analysing Douglas-fir stem form, and evaluating carbon sequestration in loblolly pine provides insights into species-specific responses to environmental stress and silvicultural treatments. These findings support strategic species selection and treatment planning to maintain wood quality, productivity, and carbon storage in the face of changing climate conditions.

Remote Sensing and Machine Learning Applications

Projects involving machine learning for species mapping, remote sensing of leaf area index, and 3D-NAIP/Sentinel data for stand attribute prediction demonstrate the growing role of technology in forestry. These tools allow for large-scale, cost-effective monitoring of forest composition, health, and structure, reducing reliance on field surveys and enabling more precise forest planning and conservation efforts.

Forest Inventory and Statistical Modelling

A suite of studies focused on small area estimation (SAE) and sampling design to improve timberland inventory and stand-level predictions. These methods enhance the accuracy of forest data, especially in heterogeneous or sparsely sampled areas, supporting better decision-making in timber valuation, harvest scheduling, and growth forecasting.

Silvicultural Impacts and Forest Health

Research on thinning effects using carbon isotopes, pine beetle mortality dynamics, and silvicultural impacts on stem form and carbon sequestration provides critical insights into how forest management practices influence tree physiology, pest vulnerability, and ecosystem services. These findings help refine silvicultural strategies to promote forest health, resilience, and economic value.

Together, these projects contribute to a more data-driven, adaptive, and sustainable forestry industry. They enable better resource allocation, enhance forest productivity, support climate mitigation efforts, and improve forest health monitoring all essential for meeting ecological and economic goals in modern forest management.

Field Day

The highlight of the conference was the field day where we visited Siglo Forest at Kapoaula a 565-acre reforestation and sawmill project focused on restoring native koa-ʻōhiʻa forest, advancing koa cultivation research, and producing high-quality koa wood for musical instruments as shown in figure 3.

Figure 3 Siglo Forest, Koa Guitar, Koa Foliage

We also visited the Waikola Dry Forest Reserve where I saw 300-year-old Wiliwili trees growing in lava with less than 50 inches (127cm) of annual rainfall. Just incredible, the wood is extremely light and was used by the ancient Hawaiians for boat building, see Figure 4.

Figure 4 Wiliwili Trees at Waikola Dry Forest Reserve

Attending the CAFS conference illuminated the fact that funding research is critical for technological advances and industry solutions. CAFS is taking a multi-faceted approach to raise funding for its research which includes centralising a portion of site resources, seeking new members with national interests, and pursuing Federal grants and contracts. Australian forestry research centres have adopted a similar approach and enjoy some complementary outcomes to CAFS. Examples include the following:

- **Forest and Wood Products Australia (FWPA)**: A not-for-profit industry services company that supports Australia's forest and wood products sector through research, development, and marketing. FWPA operates as a Rural Research and Development Corporation (RDC), partnering with the Australian Government and industry stakeholders and leads initiatives like The Ultimate Renewable™
- **Australian Forest and Wood Innovations (AFWI)**: A national research institute supporting Australia's forest and wood product industries. AFWI collaborates with industry partners to deliver industry-wide innovative outcomes in sustainability, wood product development, and forest management
- **University of Tasmania's Centre for Sustainable Architecture with Wood (CSAW)**: Focuses on innovative timber and wood products for the construction industry. CSAW conducts research on resource efficiency, engineered wood products, and sustainable building practices
- **National Institute for Forest Products Innovation (NIFPI)**: Supports research and development in the forestry sector, aiming to enhance the value and sustainability of forest products. NIFPI Centres collaborate with various stakeholders to drive innovation in timber processing and product development

- **Forest Research Institute (FRI) at the University of the Sunshine Coast**: This institute includes the Forest Industries Research Centre, the Tropical Forests and People Research Centre, and the National Centre for Timber Durability and Design Life.
- **Forestry Centre of Excellence at the University of South Australia**: Located in Mount Gambier, this center focuses on innovative forest research, including automated forest fire detection, forest health and biosecurity systems, and sustainable forest management.

These centres play a crucial role in advancing forestry and timber product research in Australia, contributing to sustainable practices and industry growth. The benefits and challenges that they face are well known (AFWI, 2025) (Guldin, 2019).

Benefits:

- **Enhanced Research Capabilities**: Combining academic expertise with industry insights can lead to innovative solutions and advancements in forestry and GIS technologies
- **Improved Industry Practices**: Research findings can be directly applied to improve forestry operations, sustainability, and productivity
- **Economic Growth**: The centres can drive economic growth by developing new technologies and practices that enhance the forestry sector
- **Environmental Impact**: Focused research on sustainable practices can help mitigate environmental issues and promote conservation

Challenges:

- **Funding and Resources**: Securing consistent funding and resources from both government and industry partners can be challenging
- **Coordination and Collaboration**: Ensuring effective collaboration between diverse stakeholders, including universities, industry, and government, requires robust governance structures and cross-organisational commitment
- **Adapting to Local Needs**: Research must be tailored to address specific regional and ecological conditions in Australia, which may differ from those in other countries as well as regions within Australia.

I'm sincerely grateful to Meg Fergusson and Aaron Weiskittel from the University of Maine for the kind invitation to attend. The experience was both intellectually enriching and thoroughly enjoyable, made even more memorable by being set in breathtaking locations on the big island of Hawai'i.

Profile	Details
Rayonier	
Business	Forest Products, Timber & Land Management
Headquarters	Wildlight, Florida
Jurisdiction	USA and New Zealand
Managed Area	[2.1 M acres] 308k acres US Pacific Northwest, 1.75 M acres US South
Annual Revenue	Full-year net income attributable to Rayonier of US$359.1 million (2024 Q4 Results)
Website	https://www.rayonier.com/

Rayonier Inc. is a global leader in sustainable forestry and land management, operating across the United States. Founded in 1926 as Rainier Pulp & Paper Company, it has evolved into a major timberland REIT (Real Estate Investment Trust), managing about 2.1 million acres of timberland. Rayonier distinguishes itself through its commitment to long-term sustainability, advanced forestry technologies like remote sensing and GIS, and a diversified portfolio that includes timber production, land development, and conservation initiatives.

What sets Rayonier apart is its science-driven approach to forest management and its global reach combined with deep local expertise. The company also invests heavily in community engagement, environmental stewardship, and innovative land use, making it a respected name in both the forestry and real estate sectors.

While visiting Rayonier's Atlantic Region (specifically Florida and Georgia), I learnt that it primarily supports the pulp and paper industry, with loblolly pine (*Pinus taeda*), slash pine (*Pinus elliottii*), and longleaf pine (*Pinus palustris*) being the most commonly planted species due to their rapid growth and adaptability.

Figure 5 Rayonier Forest - Georgia

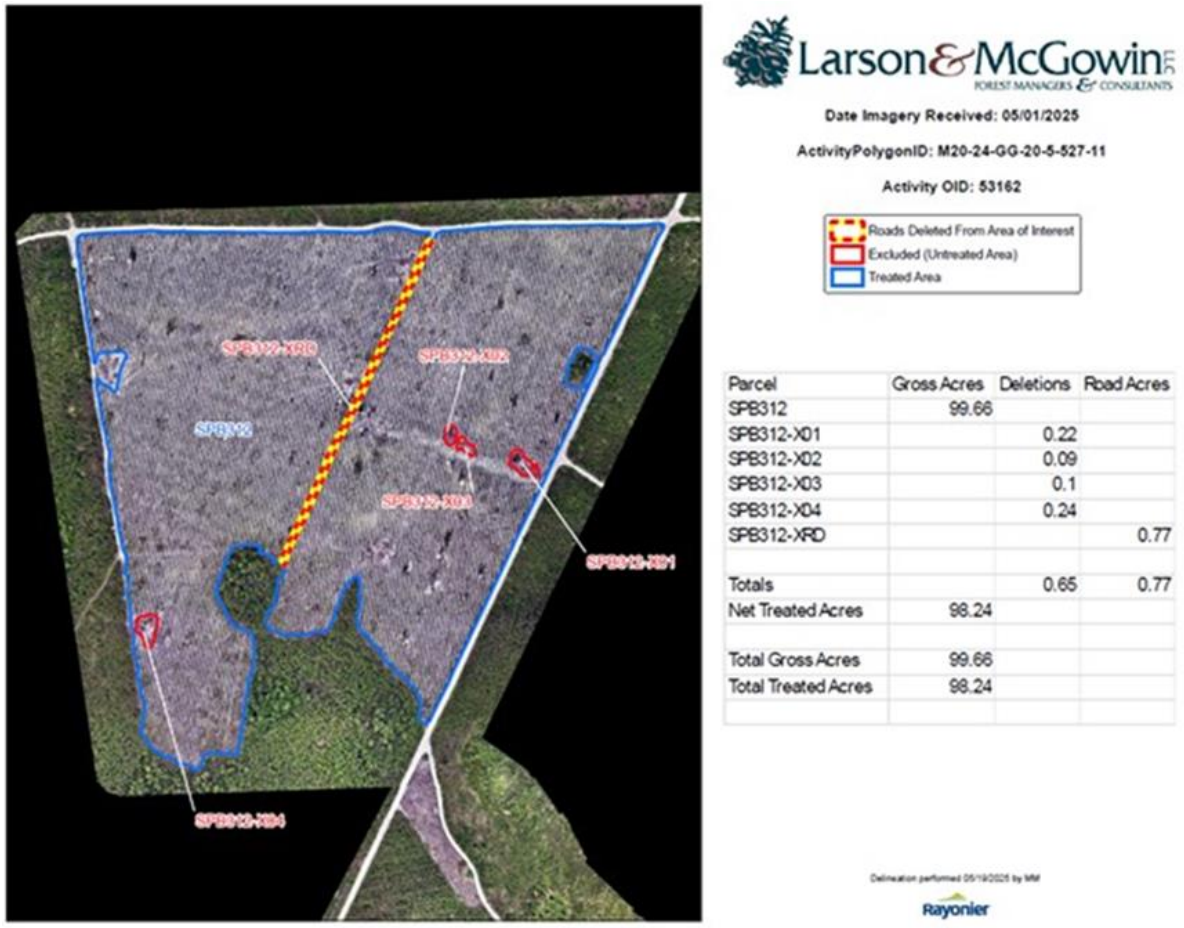
The region has a humid subtropical climate, receiving 50–60 inches (1270–1525 mm) of annual rainfall and experiencing mild winters and hot, humid summers. Soils are typically sandy or loamy, acidic, and low in fertility, often requiring fertilisation and site preparation for optimal productivity. Climate projections suggest that warming temperatures, increased rainfall, and elevated CO_2 levels may enhance pine growth in the coming decades.

Figure 6 Skidder Transporting Bunched Loblolly Pine

Rayonier integrates geospatial data and imagery wherever possible to support the planning and monitoring of its operations. Due to the region's high rainfall, the company employs elevated bedding mounds during planting to ensure plantlet roots remain above water levels. Since this mounding work is outsourced, Rayonier uses high-resolution aerial imagery captured via fixed-wing aircraft to verify completion.

Figure 7 Elevated Mounds for Planting

This method of monitoring not only reduces the burden on Rayonier to prove the work has been done, but also builds trust with contractors, who receive the remainder of their payment once quality assurance is confirmed. This approach highlights how spatial data can enhance and streamline the entire operational process.



Parcel	Gross Acres	Deletions	Road Acres
SPB312	99.66		
SPB312-X01		0.22	
SPB312-X02		0.09	
SPB312-X03		0.1	
SPB312-X04		0.24	
SPB312-XRD			0.77
Totals		0.65	0.77
Net Treated Acres	98.24		
Total Gross Acres	99.66		
Total Treated Acres	98.24		

Figure 8 Consultant Supplied Mounding Report to Rayonier

Figure 9 Georgian Soil, Thriving Juvenile Longleaf Pine, Mobile GIS Data

Upon enquiring about Rayonier's GIS operations, I discovered that they are supported by a substantial team servicing both traditional forestry activities and the company's real estate ventures. This dual focus is relatively common among US-based forestry enterprises, where private land ownership allows for greater flexibility in land use.

In contrast, Canadian companies tend to concentrate more intently on plantation forestry, with less emphasis on real estate development. The situation differs further in Australia and New Zealand, where land use is more tightly regulated and autonomy over land development is comparatively limited, shaping a distinct approach to integrating forestry with broader land management strategies. Comparison information on land ownership is summarised below in Table 1.

Comparison of Land Ownership: Australia vs United States

Table 1 Land Ownership Comparison

Category	Australia	United States
Legal Framework	Torrens Title system with government-guaranteed registration.	Deed-based system under common law with title insurance.
Types of Ownership	Freehold and Crown land; fee simple is most common.	Fee simple, life estates, leaseholds, and community property.
Indigenous Land Rights	Native Title recognises traditional rights; established by Mabo decision.	Tribal lands are held in trust by federal government; governed by tribal law.
Foreign Ownership	Requires approval from Foreign Investment Review Board (FIRB); restrictions apply.	Few federal restrictions: some state-level limitations.
Government Powers	Compulsory acquisition under just terms as per Constitution.	Eminent domain allows taking for public use with just compensation.
Subsurface Ownership	Belongs to the Crown (government)	Can belong to private individuals
Mineral Rights	Usually retained by the state	Can be sold, leased, or inherited
Landowner Control	Limited to surface rights	May include full control of subsurface
Compensation	For surface disruption only	Royalties and profits possible

A common characteristic among forestry companies is their use of what I describe as a visualised interoperable zone, otherwise an integrated interface environment that seamlessly connects a wide range of GIS tools, data systems, and information applications. This unified platform empowers GIS users and stakeholders to access, analyse, and apply business intelligence effectively, supporting both operational needs and strategic decision-making.

I have diagrammatically represented this concept as shown in Figure 10.

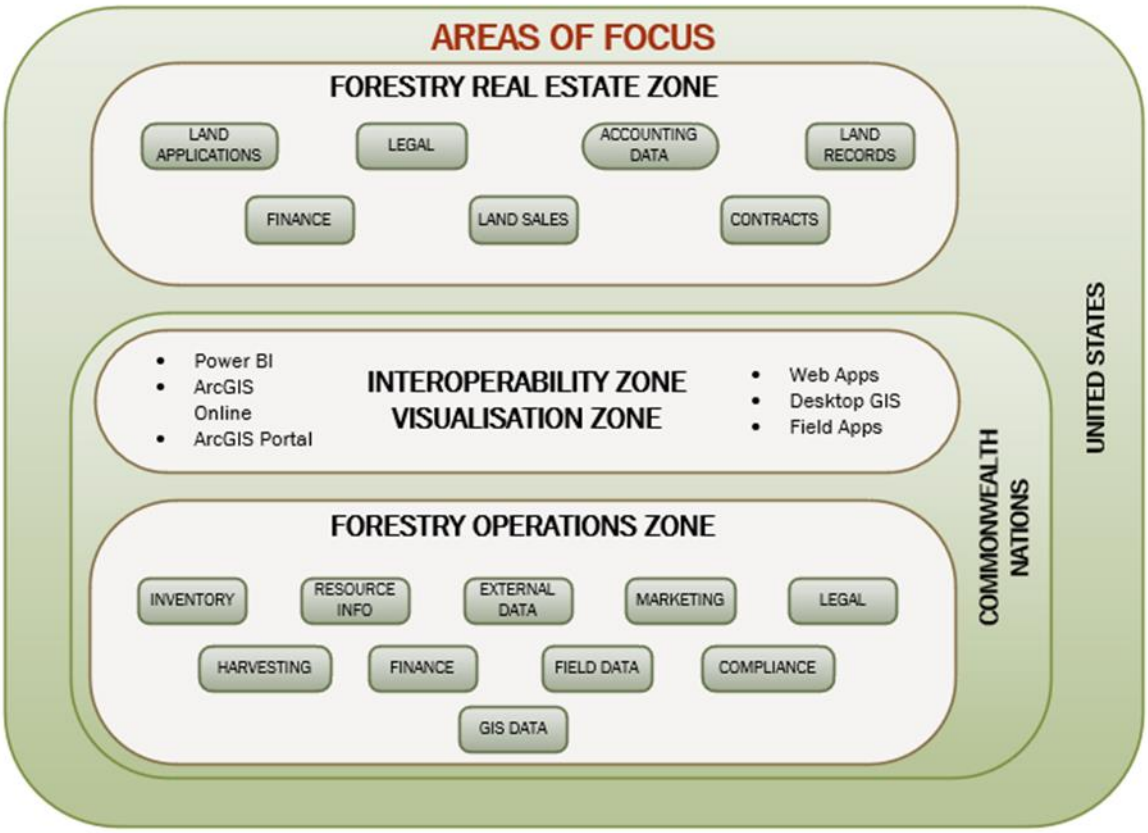


Figure 10 Areas of Focus

Rayonier demonstrated a sophisticated suite of applications and tools within the geospatial domain, reflecting industry standards commonly seen across Australasia and North America. Several key priorities underpin their approach, including:

- **Designing and developing tools and interfaces** that are tailored to specific use cases and aligned with the needs of the intended end users.
- **Providing robust troubleshooting and user support** to ensure operational continuity and user satisfaction.
- **Effectively managing the demand for geospatial services** beyond traditional forestry, including support for non-forestry business units.
- **Applying sound judgment in technical development and transformation**, with decisions guided by the scale and diversity of the user base.
- **Exploring the integration of emerging technologies such as AI**, ensuring they enhance rather than disrupt existing workflows, while maintaining relevance and accuracy.
- **Aligning systems, databases, products, and services** with broader enterprise goals.

- **Preparing for and managing alternative business opportunities**, such as solar farming, mining, property and land development, and carbon sequestration initiatives.

What impressed me most was Rayonier's measured approach to enabling capability across different dimensions. For technical solutions, they adopt a "must-have" mindset, ensuring robust and reliable systems. When it comes to resource availability, the attitude is "more is nice to have otherwise do your best where possible", reflecting practical constraints. For future challenges, the philosophy shifts to "should try to have, pursue it where feasible", encouraging innovation without overcommitting.

Their overall approach is defined by a nuanced balancing act in data development, products, and services carefully weighing improvements in geometry against enhancements in attribute data. Tool and application development is approached through a blend of custom-off-the-shelf solutions and bespoke in-house systems, maintaining alignment with the Gartner Hype Cycle to manage expectations and adoption timelines.

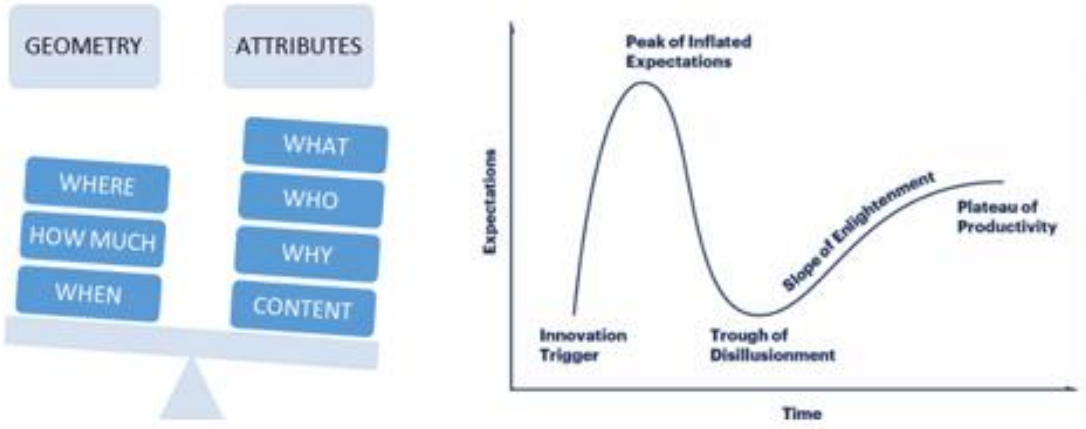


Figure 11 Getting the Balance Right Infographics

They also demonstrate and aspire to a thoughtful delineation of workflows and responsibilities between executive leadership and technical teams what I've nicknamed "the kitchen." This model fosters autonomy and mutual respect, empowering each group to deliver on their responsibilities while staying harmonised across the organisation.

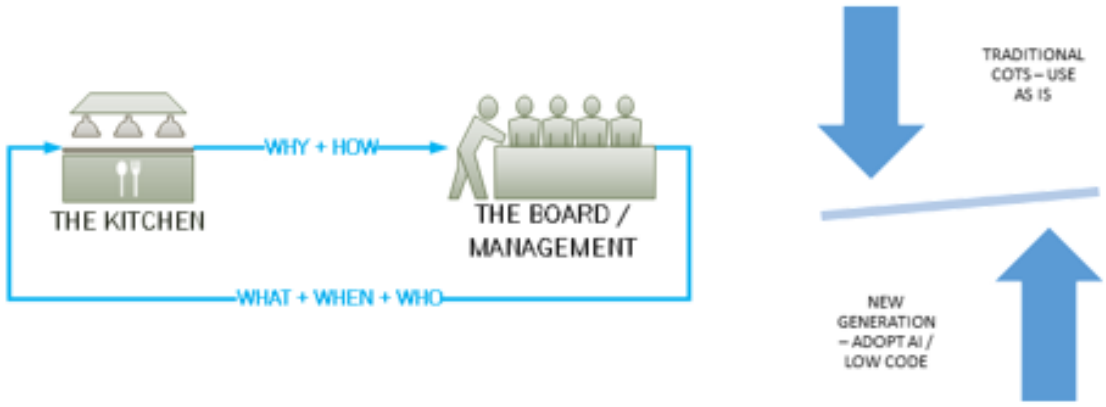


Figure 12 The Kitchen & Trade Off Balance

Reflecting on my project, *Advancing Sustainable Forestry GIS Platforms for Future Challenges*, my visit to Rayonier provided invaluable insights into how such goals can be realised. One of the most significant takeaways was the importance of cultivating a trusted and empowered workforce equipped with the right tools and data to carry out their responsibilities effectively.

Equally vital is the role of thoughtful corporate governance, which enables internal teams to collaborate seamlessly and deliver shared outcomes. I am deeply grateful to John Bryant, Vice President of Land Information Services, and his exceptional team at Rayonier for the opportunity to visit and learn from their expertise.

Figure 13 Rayonier Head Office Wildlight Florida

Profile	Details
CampbellGlobal a J.P.Morgan company	
Business	Forest Products, Timber & Land Management
Headquarters	Portland, Oregon
Jurisdiction	USA, Australia, Chilie, New Zealand
Managed Area	Since 2024 0.6 million Ha (1.4 million acres)
Annual Revenue	$44.7 million
Website	https://www.campbellglobal.com/

Campbell Global, based in Portland, Oregon, is a leading forest management and timberland investment firm with over 30 years of experience. Managing 1.4 million acres across the U.S., New Zealand, Australia, and Chile, it oversees approximately $10.1 billion in assets. Known for its commitment to sustainable forestry and ESG principles, Campbell Global was acquired by J.P. Morgan Asset Management in 2021 to support global carbon and biodiversity initiatives.

Starting with a visit to the Olympic Tree Farm in the top peninsula of Washington State, I was struck by the breathtaking beauty of the natural landscape and the meticulously managed forests. Guided by Justin Knobel, one of Campbell Global's leading silviculturists, I received an insightful masterclass in forest management learning how the company balances productivity with efficiency and sustainability to optimise outcomes.

Figure 14 Justin and Ashwood at the newly acquisitioned Tyee estate

The northern part of Washington's Olympic Tree Farm area is characterised by a rich and diverse temperate rainforest ecosystem. Dominant tree species include Douglas-fir, Western hemlock, Sitka spruce, Western redcedar, and Red alder species which are well-adapted to the region's cool, moist climate.

Figure 15 Ashwood in Tree Heaven

Rainfall in this area is among the highest in the continental United States, with some locations receiving over 140 inches (3,550 mm) annually, particularly in the western and northern zones. Temperatures are generally mild, with summer highs ranging from the 60s to low 70s °F (15–22 °C) and winter temperatures typically in the 30s to 40s °F (0–7 °C).

The soils are deep, nutrient-rich, and well-drained, shaped by glacial deposits and volcanic ash, and are ideal for supporting vigorous forest growth. These conditions make the Olympic Tree Farm area a prime location for sustainable forestry and ecological research.

Figure 16 Olympic Tree Farm

Forestry operations are governed by comprehensive riparian protection laws designed to preserve water quality, fish habitat, and ecosystem health. Under the Washington Forest Practices Rules, forestry companies must maintain Riparian Management Zones (RMZs) buffer areas along streams and rivers. In Western Washington, this typically includes a 50-

foot core buffer adjacent to fish-bearing or shoreline waters, protecting functions such as bank stability, shade, sediment filtration, and woody debris recruitment.

Before any forestry activity, companies are required to submit a Forest Practices Application (FPA) to the Department of Natural Resources (DNR), detailing proposed operations like logging, road building, or pesticide use. These applications are reviewed to ensure compliance with environmental standards, including riparian protections.

Additionally, forestry companies may propose alternate management plans, which must be approved and demonstrate equal or greater environmental protection. The Adaptive Management Program allows for rule updates based on scientific research and monitoring (Resources, 2025). Small forest landowners can also participate in the Forest Riparian Easement Program (FREP), which offers compensation for voluntarily protecting riparian zones.

These regulations ensure that forestry in the Olympic region is conducted responsibly, balancing timber production with long-term ecological stewardship. It was comforting to see examples of all these types of activities being adhered to by Campbell Global.

Figure 17 Riparian Management Zone Example 1

Figure 18 Riparian Management Zone Example 2

With over 25 years of experience, Justin Knobel has implemented and managed forestry systems using platforms like Trimble's LRM/LMS and Esri ArcGIS, integrating a wide range of aerial, drone, satellite, and LiDAR data. His deep understanding of forest ecology has highlighted the importance of aligning digital information systems with the realities of natural environments.

He often uses a "rubber band" analogy to explain how stretching a model to fit site-specific conditions can lead to errors emphasising that applying a one-size-fits-all approach across diverse landscapes is risky without local insight.

The Olympic Tree Farm area exemplifies this complexity. It's cool, wet climate and fertile soils support fast-growing, shade-tolerant species like Western hemlock and Sitka spruce, which require different establishment strategies than species like Douglas-fir. While natural regeneration works well for shade-tolerant species, Douglas-fir often requires clearcutting or gap-based harvesting, followed by mechanical site preparation and planting to ensure successful growth.

Silvicultural practices here also include variable density thinning and gap creation to mimic natural disturbances and promote biodiversity approaches that differ from more uniform systems used in other regions.

Justin stresses the importance of retaining practical knowledge without being overwhelmed by excessive data, advocating for a "consume as needed" approach. He cautions that more data doesn't always lead to greater clarity, highlighting the value of experience and ecological understanding in forestry decision-making.

Field validation is essential to ensure that model predictions reflect real-world conditions. As one of my newly found mentors, Kevin Harding from the Gottstein Trust, emphasises, desktop modelling particularly in tree breeding must be grounded in rigorous statistical

analysis to identify the most influential variables for measurement and analysis. Yet, even the most sophisticated models must be tested against field observations. As Kevin often says: *"If what you see in the field doesn't gel with the model prediction… always go with the biology of what you actually observe."* This principle reinforces the need to balance analytical rigour with ecological intuition. While modelling helps guide decision-making, it's the biology observed in the field that ultimately validates and informs our understanding.

I fully concur with Justin's perspective and would suggest that autonomy and the inclusion of subject matter expertise should be foundational to the design and development of forestry information systems. Systems must not only reflect ecological realities but also be shaped by the insights of those with deep, practical experience in the field. Allowing space for expert judgment ensures that models and tools remain adaptable, context-sensitive, and ultimately more effective in supporting sustainable forest management.

I'm incredibly grateful to Justin for his warm hospitality and for sharing his remarkable knowledge and expertise during my visit to his stunning "office" the Olympic Tree Farm. In my view, it truly stands as an additional wonder of the world.

Figure 19 Beautiful Olympic Tree Farm Washington USA

A few days later I visited the Campbell Global head office in Portland Oregon, where I had the opportunity to meet with key executives of the company and members of their GIS and Resources teams. It was a valuable exchange of ideas, offering insight into the different ways our organisations leverage GIS technology.

One of the key takeaways from our discussion was the contrast in our GIS platforms. Campbell Global primarily operates within the ArcGIS Online ecosystem, while OneFortyOne utilises ArcGIS Enterprise Portal. This distinction reflects different strategic priorities and operational needs.

Key Differences Between ArcGIS Online and ArcGIS Enterprise Portal:

ArcGIS Online:

- **Cloud-Based**: Hosted by Esri, which means no need for internal infrastructure or server maintenance.
- **Scalability & Accessibility**: Easily accessible from anywhere with an internet connection, ideal for distributed teams.
- **Data Storage & Management**: Esri handles storage, backups, and updates, reducing administrative overhead.
- **Rapid Deployment**: Quick to set up and integrate with other Esri cloud services.

ArcGIS Enterprise Portal:

- **On-Premises or Private Cloud**: Hosted and managed internally, offering greater control over data and infrastructure.
- **Custom Integration**: Easier to integrate with specialised systems like **Trimble LRM** and **web-based field applications**, which is a significant advantage for forestry and resource management workflows.
- **Security & Compliance**: Allows for tighter control over data security, user access, and compliance with internal IT policies.
- **Advanced Configuration**: Supports more complex enterprise-level configurations and customisations.

Overall, both ArcGIS Online and ArcGIS Enterprise Portal offer robust capabilities tailored to different organisational needs. ArcGIS Online excels in its cloud-native architecture, providing scalability, ease of access, and reduced infrastructure overhead. Campbell Global has effectively leveraged this platform, using interoperable third-party software to seamlessly exchange data between their field applications and ArcGIS Online, enabling efficient workflows and real-time data integration.

On the other hand, ArcGIS Enterprise Portal offers greater control over data and system configuration, which suits organisations like OneFortyOne that require tight integration with systems such as Trimble LRM and custom field apps. Its on-premises deployment allows for advanced customisation and alignment with internal IT policies.

Rather than one being better than the other, the choice between the two reflects strategic priorities and operational contexts. Both platforms support powerful GIS capabilities just through different models of deployment and integration.

When it comes to provisioning field connectivity, both ArcGIS Online and ArcGIS Enterprise Portals rely on derived web applications designed for use in remote environments. However, these solutions remain subject to the same limitations faced by organisations such as Campbell Global, OneFortyOne, and others namely, the persistent challenge of overcoming black spots in data coverage. These connectivity gaps continue to affect much of the industry, highlighting the need for more robust and adaptive infrastructure in the field.

However, emerging solutions are increasingly focused on leveraging satellite data and deploying Wi-Fi-enabled mesh networks in the field, using receivers and other specialised equipment to extend connectivity. It's certainly an area to watch, as these technologies evolve to support more reliable and scalable field operations.

Figure 20 Beautiful Landscape Olympic Tree Farm

I am deeply grateful to Justin Knobel for his generous hospitality and for showcasing Campbell Global's beautiful forest landscapes, as well as for sharing his time and knowledge. I also sincerely appreciate the opportunity to spend a day with Curtis Lilly, Director of Forest Resource Solutions, and his team at Campbell Global's head office in Portland, Oregon. Additionally, I would like to thank Matt Armstrong, Executive Director – Portfolio Strategy and Research, whose support was instrumental in facilitating introductions to personnel at CAFS and Rayonier.

Profile	Details
Business	Forest Products, Timber & Land Management
Headquarters	Boyle Alberta
Jurisdiction	Canada
Managed Area	7,000,000 Hectares
Annual Revenue	$128.9 million
Website	https://alpac.ca/

Alberta-Pacific Forest Industries Inc. (Al-Pac): Innovation in Sustainable Forestry

Alberta-Pacific Forest Industries Inc. (Al-Pac) is a Canadian pulp and paper company founded in 1993 and headquartered in Boyle, Alberta. Now a subsidiary of Japan's Hokuetsu Corporation, Al-Pac operates one of North America's largest and most advanced single-line kraft pulp mills.

The company produces bleached hardwood and softwood kraft pulp used in coated papers, books, envelopes, and sanitary products. Serving the pulp, paper, and paperboard sectors, Al-Pac is widely recognised for its commitment to environmental stewardship and sustainable forest management.

Integrated Forest Strategy and Planning

In addition to pulp production, Al-Pac develops sawlogs as part of its broader forest strategy. Long-term planning tools such as the Forest Management Plan and the Spatial Harvest Sequence a mapped schedule of forest areas designated for harvest over a 10-year period guide sustainable harvesting and reforestation efforts. Sawlog operations are integrated into logistics through advanced modelling, optimising timber flow and enhancing productivity.

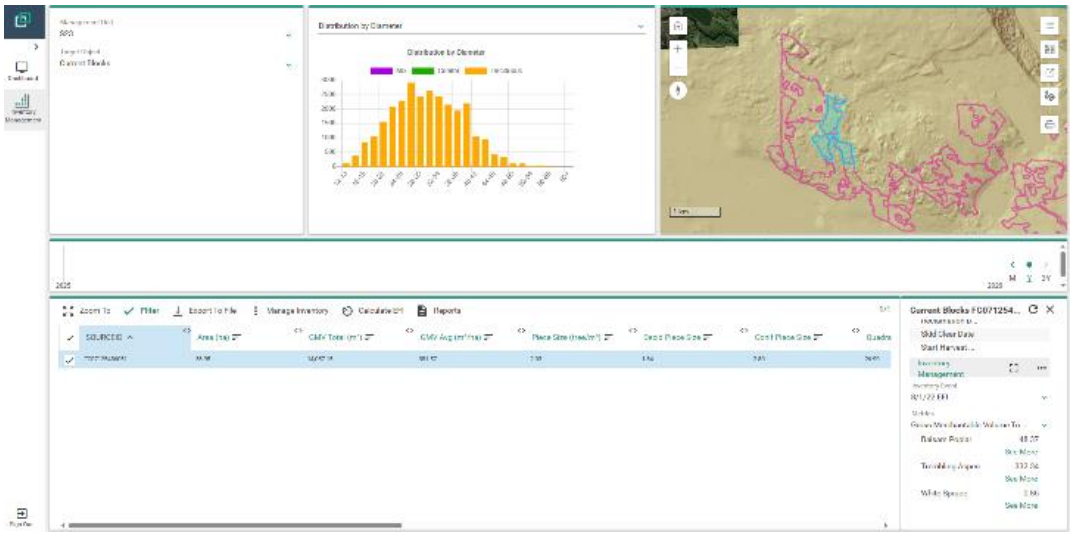


Figure 21 AFRIDS Software used to manage Al-pacs estate

Managing Scale and Complexity

After speaking with Al-Pac's GIS Lead, Chad St. Amand, the logic and necessity of advanced forest management tools became strikingly clear. Al-Pac manages an immense land base of over 7 million hectares under a Forest Management Agreement; an area roughly 350 km by 350 km or approximately the same size as the Republic of Ireland. To put that into perspective, the company's pulp mill consumes 2.8 million cubic metres of fibre annually, with 55,000 logging trucks crossing its weigh scales each year. Each truck can carry up to 90 tonnes of fibre and may travel up to 14 hours round-trip, underscoring the logistical complexity involved. The map below of SE mainland Australia with Al-Pac's forest estate area over-laid on this emphasizes how large their estate is in an Australian context.

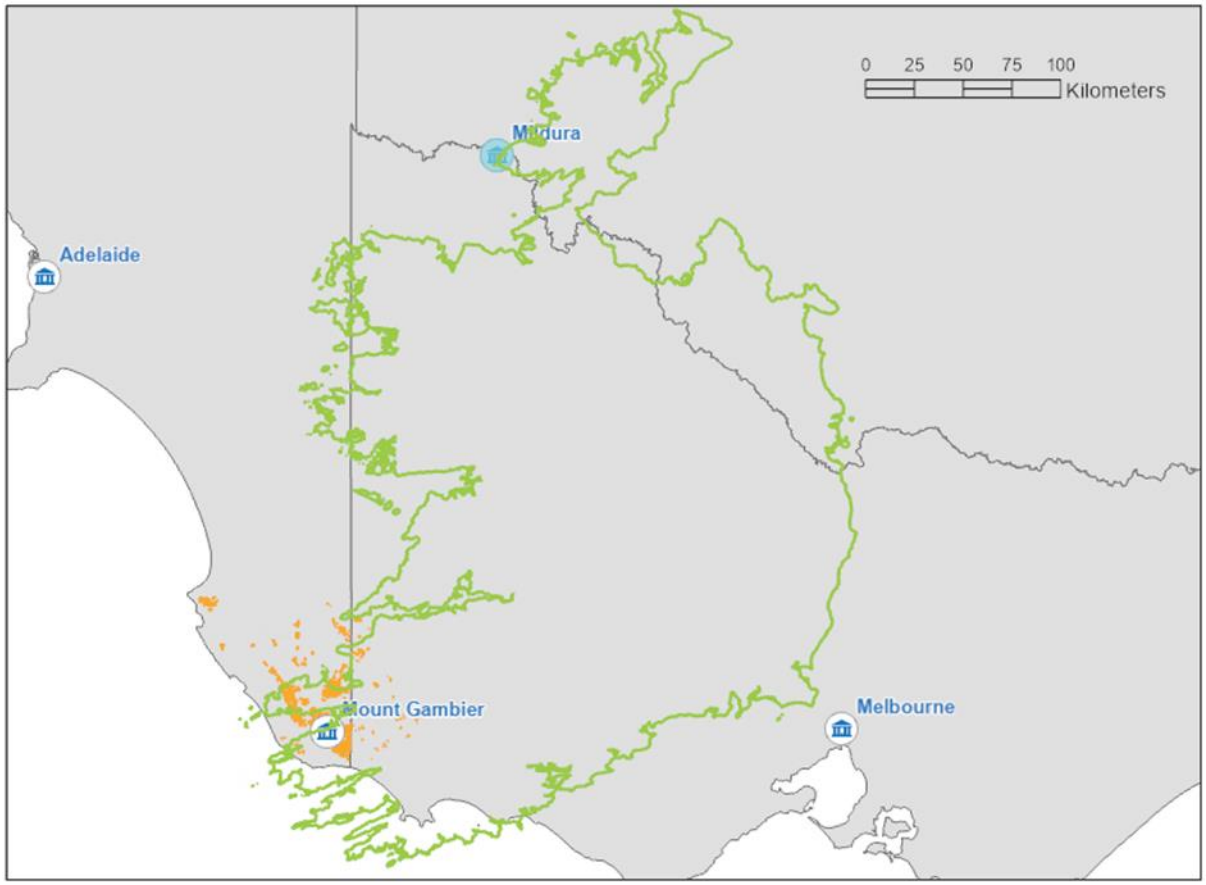


Figure 22 Comparison Map of Ireland in relation to OneFortyOne's Green Triangle Estate

Al-Pac's pulp mill is the largest single-line mill in North America, with 60% of its pulp exported to the United States, 30% to China, and 10% to Europe.

Alberta's forest ecosystem is highly diverse, featuring a mix of coniferous and deciduous species such as white spruce, black spruce, lodgepole pine, jack pine, balsam fir, trembling aspen, and balsam poplar. These species grow in varied soil types including clay-rich forest soils (Luvisols), brown forest soils (Brunisols), and acidic soils (Podzols) which influence growth rates based on moisture and nutrient availability.

The province's continental climate, with temperatures ranging from -40°C in winter to over 40°C in summer, further affects forest growth. Optimal conditions are found in well-drained soils with moderate rainfall and a frost-free growing season of 60 to 100 days.

Given these variables, Chad's primary mission is to determine where Al-Pac can operate in summer versus winter, a decision shaped by terrain, species distribution, and seasonal accessibility. Accessing otherwise unreachable timber is only possible during the deep freeze of January and February, when frozen ground conditions allow entry into sensitive areas. This narrow window means Al-Pac must act swiftly to take advantage of the harvesting and management windows of opportunity.

Figure 23 Soils Legend for Al-pacs estate

Figure 24 Al-pacs estate in winter

Spatial Tools and Data-Driven Decision Making

The Spatial Harvest Sequence is essential for navigating this complexity. It helps balance fibre supply with ecological sustainability, ensuring that harvesting aligns with growth cycles, soil conditions, and climate patterns across Alberta's vast and varied forest landscape.

Chad utilises a robust combination of spatial data, forest inventory systems, and Extract, Transform, Load (ETL) technologies to generate operational insights critical to Al-Pac's forestry planning. These insights are shared with stakeholders through platforms like AFRIDS (Alberta Forest Resource Inventory Data System) and LRM (Land Resource Management), which translate complex datasets into actionable visual tools.

Even with these advanced systems, the information represents the best available understanding, not absolute certainty. Ground-truthing by forest planners and field staff remains essential to validate and refine the data. Chad's ongoing challenge is to stay ahead of seasonal operational needs, continually working to determine where summer ground versus winter ground lies, a task that remains dynamic and complex across Alberta's landscape.

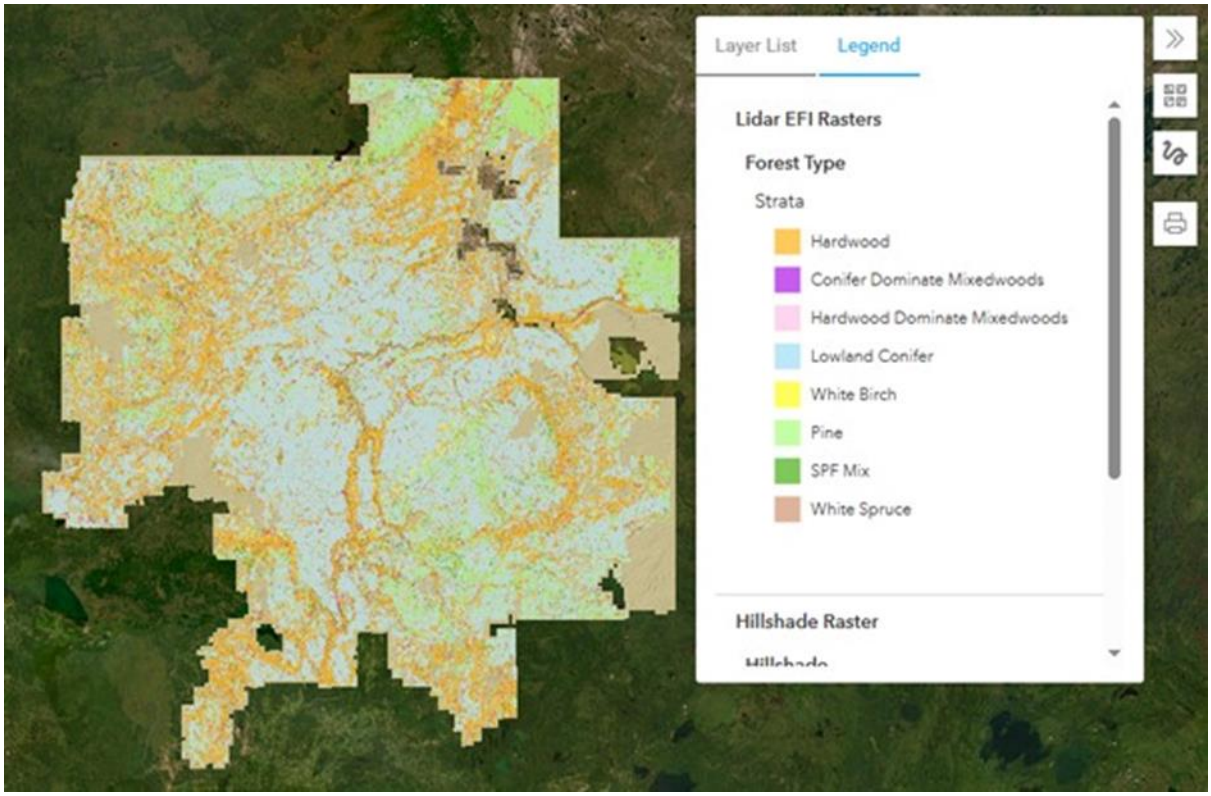


Figure 25 Al-pacs Estate per Forest Type

Strategic Investment in Spatial Data

A strong indicator of the value placed on this work is Al-Pac's executive-level decision to invest $3 million in 2022 to acquire LiDAR data for its land base every 10 years. This significant expenditure reflects a strategic recognition of the importance of high-resolution spatial data. Historically, Alberta's government funded such initiatives, spending around $25 million to capture LiDAR across the province. However, this responsibility has since shifted to industry. Al-pac implements data acquisitioning budgeting to accommodate this expenditure.

To manage these costs, Al-Pac employs a Forest Resource Inventory financing model, setting aside funds over time to support future LiDAR acquisitions. Given Alberta's relatively slow tree growth rates, a single LiDAR capture can remain relevant for up to 10 years. Looking ahead, applying similar long-term investment models to the systems and software needed to process, analyse, and deliver insights from these datasets could create a sustainable and scalable approach for other forestry operations to follow.

Collaboration and Emergency Response

Al-Pac proactively notifies government-registered trappers when its operations intersect with designated trapper lines, ensuring respectful coordination with traditional land use. The estate supports rich biodiversity, including birds, black bears, and deer.

To facilitate this, Al-Pac uses Safe Software's FME to extract contact information from government databases an excellent example of effective collaboration between industry and government.

Another instance of this partnership is with the Canadian Ministry of Culture, which shares anonymised culturally sensitive site data with Al-Pac via a secure URL-based web service. This helps safeguard heritage areas during planning and operations.

Al-Pac also leverages satellite imagery for emergency response. During the last fire season, the company responded to over 250,000 hectares of forest fires by integrating Sentinel and commercial satellite imagery to triangulate fire locations and coordinate a rapid logistical response.

Al-Pac exemplifies how modern forestry operations can balance industrial productivity with environmental and cultural responsibility. Through strategic planning, advanced spatial tools, and collaborative partnerships, the company manages a vast and ecologically diverse land base with precision and care. Investments in technologies like LiDAR, satellite imagery, and data integration platforms such as AFRIDS and FME demonstrate Al-Pac's commitment to innovation and sustainability. By aligning operational decisions with seasonal constraints, ecological conditions, and stakeholder needs, Al-Pac continues to lead the way in responsible forest management, setting a benchmark for the industry in both Canada and beyond.

I'm incredibly grateful to Chad St. Amand, GIS Lead at Al-Pac, for his generous time and warm hospitality. It was a privilege to get a glimpse of the company's vast estate though not all of it and to receive a quick tour of the impressive mill they operate. A truly memorable experience that I deeply appreciate.

Analyse

Workshop 1 Summary: GIS Pain Points & Opportunities

Date: 15 May 2025
Facilitator: Ashwood Caesar
Participants: Alberta-Pacific, Campbell Global, OneFortyOne, Rayonier, Weyerhaeuser

Before beginning my study tour of North America, I was eager to engage with forestry industry professionals to explore how Geographic Information Systems (GIS) can remain resilient in the face of current and emerging challenges, and to take a deeper dive into the pain points and opportunities companies are experiencing with GIS.

Workshop 1 commenced with a fact-finding session using a Mural virtual whiteboard. Participants from Weyerhaeuser and Rayonier shared individual perspectives on the challenges and aspirations they associate with GIS. Their feedback revealed several key themes:

Pain Points:

- Operating within a mature yet strained GIS environment
- Significant concerns regarding data governance, quality, and integration
- Organisational and strategic difficulties in managing GIS
- Increasing complexity and financial burden of maintaining Esri software
- Budgetary constraints and staffing challenges in delivering effective GIS solutions
- A growing crisis in GIS capacity
- Risks and limitations tied to vendor dependency
- Technical hurdles in managing multi-platform GIS environments
- A strong desire to streamline workflows, improve visibility, and reduce manual effort

Opportunities:

- Investigating applications of artificial intelligence
- Continuing adoption of extract, transform, load (ETL) technologies like FME
- Expanding the use of mobile web applications
- Documenting and standardising work processes
- Enhancing imagery management, accessibility, and delivery

- Standardising procurement practices and promoting best practices
- Advancing data discovery capabilities
- Exploring GIS applications in nontraditional areas, such as indoor GIS for mills
- Addressing field connectivity challenges to enable digital data access in remote locations
- Investing in staff training and education to build GIS capability
- Exploring additional drone applications to support operations

These insights laid a valuable foundation for understanding the evolving GIS landscape in forestry and identifying areas ripe for innovation and improvement. They also noted that the experiences shared were common across all participants, which fostered a sense of connection and compassion for the challenges we collectively face as an industry.

Following the evaluation of Workshop 1 findings, it became clear that the challenges facing the forestry industry's use of GIS reflected the characteristics of a "wicked problem," as conceptualised by Peter Checkland through Soft Systems Theory (SST) (Checkland, 1990). SST addresses complex, ill-structured issues that resist definitive solutions due to incomplete, contradictory, and evolving requirements. These problems are often deeply rooted in social systems, where stakeholders hold diverse perspectives and values, as outlined in Table 2.

SST proved particularly well-suited to this context, as it encourages the exploration of multiple viewpoints through tools such as rich pictures and systemic analysis. Rather than rushing to solutions, SST promotes a deeper understanding of the problem space using systems thinking and supports learning and adaptation through iterative cycles of inquiry and action. By illustrating a rich picture (Figure 26) to represent the complexity of the situation, it became easier to align the identified pain points with the criteria of a wicked problem.

Table 2 Wicked Problem Criteria Mapped to Pain Points

Wicked Problem Criteria	**Mapped GIS Pain Points**
Ill-defined and evolving • Wicked problems have no clear, agreed-upon definition. • Understanding the problem is inseparable from finding a solution. • The problem often evolves as you try to solve it.	- Effective governance of GIS resources with limited team - Aligning with IT on procurement and licensing - System/IT/bugs limitations and outdated versions - New versions hard to implement due to testing needs - Lack of enterprise data management framework - Change management for software

	transitions (e.g., ArcMap to ArcGIS Pro) - Replacing legacy infrastructure - Hosted software complicates integrations
No right or wrong solutions • Solutions are not true or false, but better or worse. • There's no definitive test to know if a solution is successful. • Every solution has consequences that may be irreversible.	- Esri licensing changes and cost impacts - Named user license structure increases costs - Nearly complete reliance on ESRI products - Users going rogue with software and later seeking integration - Reporting needs vs. skill sets vs. resource constraints - Regulatory & financial alignment
Unique and context-dependent • Each wicked problem is essentially unique. • Solutions that work in one context may not work in another. • They are often symptoms of other, deeper problems.	- Influencing executive management to value GIS - Ad hoc requests with short notice - Integration of large RS datasets into spatial DBs - Providing product management across GIS platforms - Hosted software complicates integrations and reporting
Conflicting stakeholder perspectives • Multiple stakeholders have different values, goals, and definitions of success. • These differing worldviews make consensus difficult.	- Users avoiding IT governance and going rogue - Data governance: users keeping data in spreadsheets - Esri licensing changes affecting different teams differently - Committee roles and responsibilities unclear - Regulatory & financial alignment - Executive buy-in vs. operational needs
Interconnected and complex • Wicked problems are entangled with other issues. • Solving one part may create new problems elsewhere. • They require systemic, not linear, thinking.	- Data quality and single source of truth - QA/QC data automation - Integration of spatial and non-spatial data - Governance across web/mobile/desktop GIS - Licensing issues affecting integration and reporting - Nearly complete reliance on ESRI products limiting flexibility

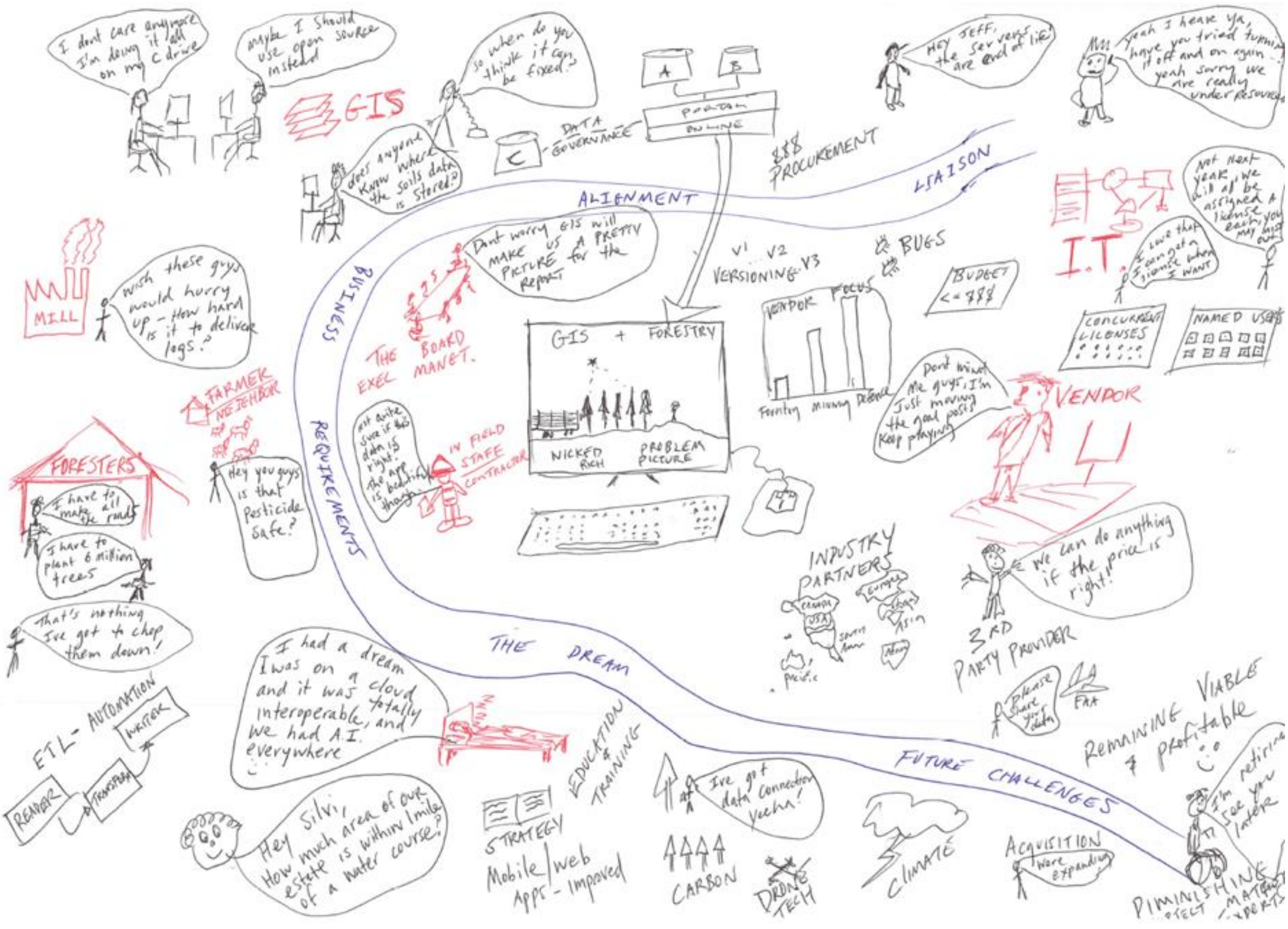


Figure 26 Wicked Problem Rich Picture

Initially, I believed it was important to define a wicked problem statement to guide the next phase of inquiry. The statement I developed was:

"*How can the forestry sector align people, technology, data, and resources to collaboratively govern and integrate geospatial systems ensuring sustainable, interoperable, and stakeholder-responsive forest management in a complex and evolving digital landscape?*"

Reflecting on this and revisiting the principles of Soft Systems Theory (SST), it became evident that targeted interventions should be pursued to address the identified pain points and opportunities. This formed the basis for Workshop 2, which focused on exploring potential strategies and actions aligned with the wicked problem framework.

Workshop 2 Summary: Finding Interventions for a Wicked Problem

Date: 19 June 2025
Facilitator: Ashwood Caesar
Participants: Alberta-Pacific, Campbell Global, OneFortyOne, Rayonier, Weyerhaeuser

Key Themes & Insights

Historical Context & Governance Gaps

- Many organisations are dealing with decades of ungoverned data and systems, leading to cluttered environments and inconsistent practices.
- There is a shared recognition that data governance has historically been weak, with little deletion or archiving of legacy data.

Investment in GIS & Capital Challenges

- Large-scale GIS investments are rare, and even when initiated, capital planning often doesn't extend beyond the first year.
- Securing ongoing funding is difficult, especially in industries like forestry where economic conditions are volatile.
- Despite growing recognition of data systems as strategic assets, capital remains limited and hard to justify without clear return on investment (ROI).

Business Drivers & Real Estate Influence

- In the U.S., the real estate component of forestry businesses is expanding, increasing the demand for GIS capabilities.
- GIS is becoming more central to alternative land use planning, pushing it into broader business functions.

Project Stewardship & Leadership Balance

- The balance of project leadership between IT and business units varies widely across organisations.

- A key takeaway: strategic stakeholder leadership must be in place early, before deciding who should lead a project.
- Participants emphasised the importance of appropriate autonomy for teams to operate effectively, while benefiting from enterprise-level data governance, a model that promises long-term value through harmonisation and interoperability.

Licensing & Esri Model Shifts

The transition to Esri's named user licensing model is a major concern:

- It introduces significant administrative overhead.
- Costs are rising, with 5–10% annual increases since 2023.
- Some relief may come from Esri's proposed 2:1 or 3:1 conversion ratios for concurrent licenses but needs to be explored further.
- Organisations are exploring license tiering, web-based alternatives, and even open-source tools like QGIS to manage costs but it is difficult to adopt.
- Organisations are preferring to build web application tools to alleviate demand for desktop GIS software.

Field Tools & LRM Integration

- Integrating field apps like Field Maps with LRM is technically challenging due to schema complexity, business rules, and legacy systems.
- Some organisations are moving datasets out of LRM to simplify mobile workflows.

Vendor Influence & Collective Action

- Participants expressed frustration with limited influence over vendors like Esri but feel they have more influence with Trimble.
- Inspiration was drawn from the oil and gas industry, where customers vote on software development priorities.
- A Western Canada LRM working group was highlighted as a successful model for collective feedback and influence.
- There's growing interest in forming customer advisory boards or industry coalitions to advocate for shared needs.

Final Reflections

- The session highlighted that many organisations are grappling with similar systemic challenges. Participants appreciated the open dialogue, shared learning, and the opportunity to foster ongoing collaboration.

- There was strong support for industry-wide cooperation to influence vendor design and development, with the goal of driving more cost-effective and fit-for-purpose solutions.
- Achieving the right balance in internal projects particularly through the proactive formation of cross-functional teams was identified as essential for success.
- Advocating interventions for enterprise-wide data governance leadership was seen as a strategic imperative. Such leadership is expected to deliver long-term value by enhancing performance, sustainability, and ROI.

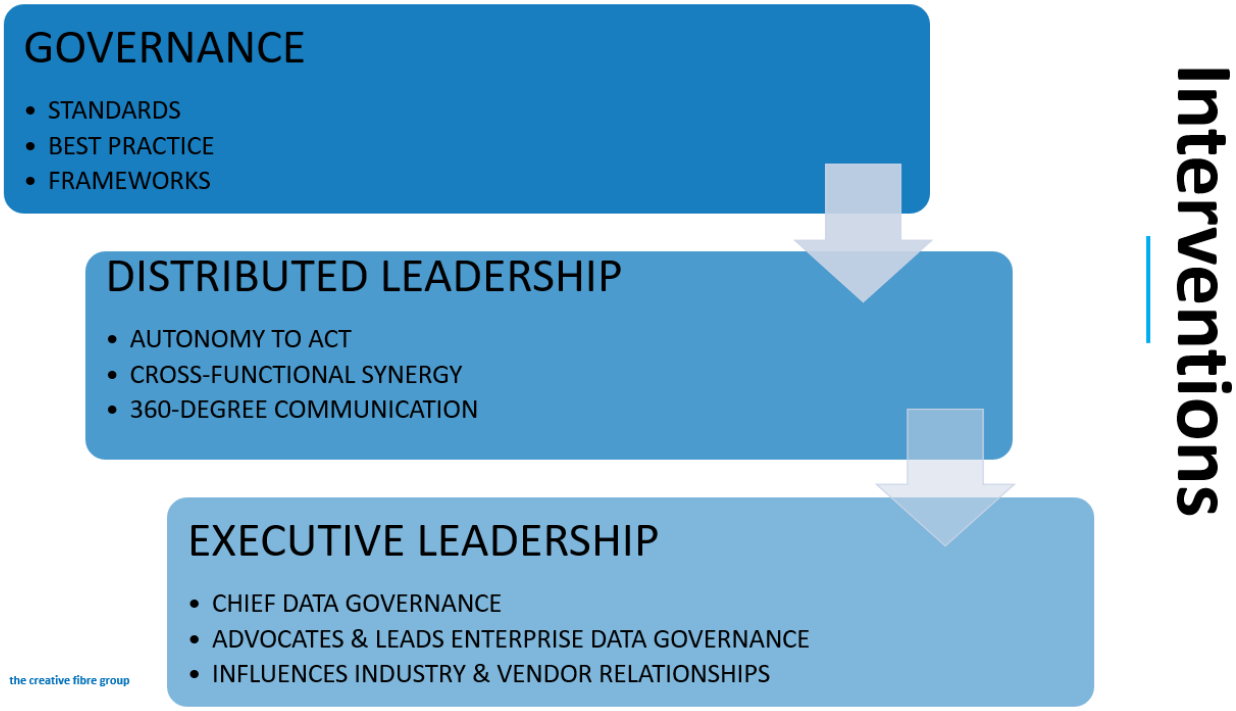


Figure 27 Interventions Graphic

Workshop 3 Summary: Gaining an Australian Perspective

Date: 7 August 2025
Facilitator: Ashwood Caesar
Participants: OneFortyOne, PF Olsen, HVP, Uni SA – Forestry Centre of Excellence, SFM, PIRSA, Green Triangle Plantation Forest Company of Australia, Australian Bluegum Plantations

Participants were presented with key findings from Workshops 1 and 2, along with a presentation of Ashwood's Gottstein study tour. Following this, they were surveyed on three main themes related to the sessions.

Feedback on Pain Points and Opportunities from an Australian Perspective

GIS and forestry professionals share common challenges and opportunities across Australia. Key pain points include data confidentiality when working with multiple stakeholders, integration difficulties with external datasets (especially government data), staffing shortages, and budget constraints affecting recruitment, training, and system management. There's also a noted gap between GIS officers and developers, which limits tool creation and scalability.

On the opportunity side, there's strong support for the cost-benefit of system adoption, the growing potential of drones for forest monitoring, and the value of expanding spatial capabilities within organisations. Overall, there's alignment in experiences and a shared recognition of both the hurdles and the transformative potential of GIS in forestry.

Feedback on Interventions from an Australian Perspective

To overcome current GIS and forestry challenges, several strategic interventions were suggested. These include leveraging the tech-savviness of the emerging workforce, aligning GIS initiatives with business objectives through a clear data and digitisation strategy, and mapping existing systems to identify efficiencies. Collaboration across organisations such as workshops, case study sharing, and inter-company visits was highlighted as a way to promote innovation and capacity building.

Standardising data interoperability and improving governance were also seen as key enablers. Budget constraints remain a barrier, especially for smaller organisations, but strong leadership and coordinated efforts can drive growth and adoption. Overall, fostering a culture of shared learning and strategic alignment is essential for advancing GIS capabilities in forestry.

Feedback on establishing a GIS alliance from an Australian Perspective

Participants strongly supported the idea of a regional GIS and forestry alliance, emphasising its potential to enhance collaboration, data access, and innovation. AI was highlighted as a transformative tool that could streamline workflows, improve forest monitoring, and support strategic decision-making through advanced data analysis.

An alliance could facilitate shared subscriptions and collective procurement of satellite and LIDAR data, while also enabling the development of a regional database with key operational insights such as crop years, fire status, and pest outbreaks especially valuable for adjacent (other growers) forestry operations. Familiar frameworks like the Green Triangle Forest Industries Hub and the Australia Centre of Forestry Excellence could help overcome data-sharing, establishment and management hurdles.

While commercial arrangements and internal approvals may pose challenges, coordinated efforts and AI integration were seen as key to improving efficiency, resilience, and sustainability across the region.

Next Steps

Continue to gauge interest and clarify the purpose, value, and dependencies that could inform the development of a charter to drive momentum and incentivise the formation of a GIS alliance. Begin by engaging with existing organisations already active in this space and share findings with local GIS and forestry colleagues. Plan an in-person meeting to consolidate ideas and align on a path forward.

Figure 28 Workshop 3 Teams Meeting

Reflection

Throughout the site visits and workshops, several strong themes emerged. One of the most prominent is that GIS is mission-critical to the operation and management of forestry businesses, driven by passionate and highly capable professionals. The challenges within these environments reflect a wicked problem that is complex, interconnected, and resistant to simple solutions. Addressing these challenges demands thoughtful and strategic interventions. Success will depend not only on operational excellence but also on becoming unified in project work internally and even across organisations.

X Factor Heavy Lifting

There is an underlying race in data management - a race to make data not just accessible, but truly useful and valuable in addressing business requirements. The ability to access and analyse data is becoming a strategic differentiator.

AI, particularly through large language models, is demonstrating that when data artefacts are properly collated, they can be filtered and interpreted to generate intelligence. Traditional approaches like Extract, Transform, Load (ETL) have delivered measurable gains by enabling derived outcomes from structured data pipelines. However, a shift is underway. As organisations increasingly gather data into commonly known enterprise and cloud computing contexts as data lakes, the Load, Extract, Transform (LET) paradigm may offer a more efficient path to insight especially in environments where flexibility and scale are critical.

To support this shift, the activities of capturing, monitoring, observing, and detecting operations must become increasingly digitised. Manual recording should be phased out in favour of automated, sensor-driven, or system-integrated methods. Alongside this, metadata capturing provenance, purpose, and context will be essential to strengthen understanding and maximise the utility of collected data. I refer to this transformation as “X-Factor Heavy Lifting” the foundational effort required to realise the full potential of AI-enabled systems. It may well be the final frontier in achieving the AI-driven vision.

Importantly, this transformation I feel must be driven at the enterprise level. Attempting to implement it within isolated teams or departments such as a GIS group risks fragmentation and short-lived impact. Only a coordinated, enterprise-wide approach can ensure the end-to-end influence, sustainability, and longevity needed to embed this capability across the organisation, even beyond the tenure of individual roles or projects.

Higher Level Governance

To effectively maintain and manage data and services, higher-level governance and leadership models must be established. This includes the introduction of executive roles such as Chief Data Officer (CDO) or Data Governance Officers, who can provide strategic oversight and ensure that data is treated as a core corporate asset.

These roles are increasingly recognised across industries like finance, banking and insurance due to their large storage of data and their ability to drive value through:

- **Creating a data-driven culture** that aligns with business goals
- **Developing enterprise-wide data strategies** that improve decision-making and operational efficiency
- **Ensuring data governance and compliance**, which is especially critical in regulated sectors like forestry
- **Managing data products and analytics initiatives** that deliver measurable ROI

In forestry, where data spans spatial, ecological, operational, and commercial domains, the absence of executive leadership in data governance often results in fragmented systems, duplicated efforts, and missed opportunities for innovation and sustainability.

In my experience as well as from what I witnessed on my project tour, data governance is often underdeveloped in the forestry industry. While there is typically strong leadership overseeing IT infrastructure, systems, and applications, there is rarely formal oversight of data at the enterprise level. As a result, data management is left to individual business units, which can lead to inconsistencies in standards and procedures for storing and handling data with increased potential corruption loss and accessibility issues over time. This fragmentation makes it difficult to integrate and utilise data effectively across the organisation, especially for enterprise-wide reporting and strategic insights.

To illustrate this, consider the analogy of water flowing through a pipe network:

- The water source represents the raw data and business context, which is rich, valuable, and essential.
- The pipe network is the organisation's IT infrastructure, software, and systems designed to transport and deliver data.
- The tap is the interface where data becomes usable through dashboards, reports, or applications.

Without proper governance, the water (data) may leak, become stagnate, or be misdirected. The infrastructure may be robust, but if the water is not clean, well-managed, and purposefully directed, its value is diminished, investments lost and costly errors flourish.

The key questions now are: what further reasoning is there for this to be implemented and how can these aspirations be realised?

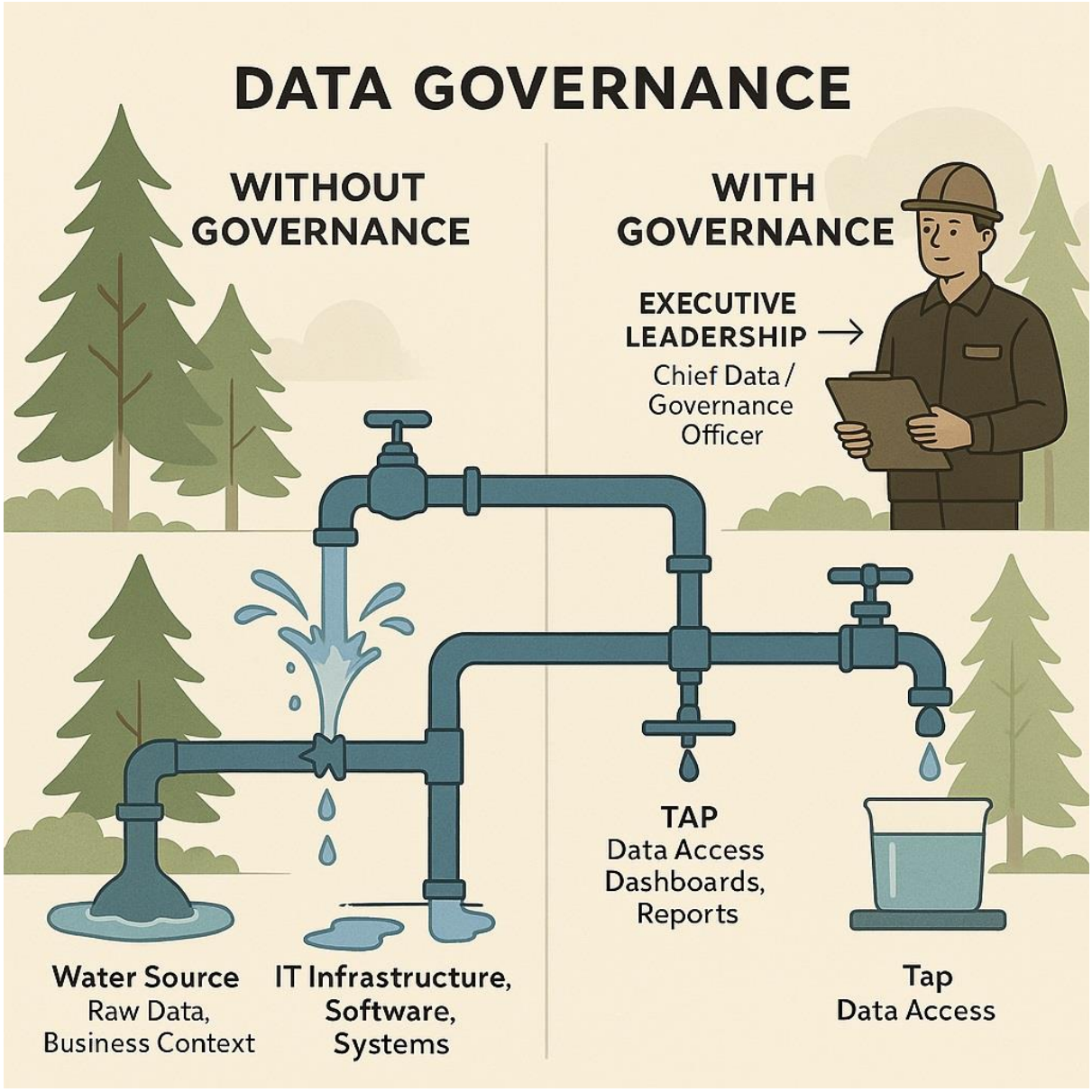


Figure 29 Water to Data Analogy Graphic

Elevating GIS Through Enterprise Integration

GIS is uniquely positioned to bridge the gap between spatial and non-spatial data. When integrated, they enable location-intelligent decision-making e.g., linking harvest volumes (aspatial) to compartments (spatial), or aligning workforce deployment with terrain and access constraints.

Within a forestry context, GIS capabilities deliver products and services tailored to the business requirements placed on its operational scope. To achieve this effectively, GIS must remain interoperable with data sources across the entire organisation.

This level of integration requires alignment in data schemas and metadata standards across business units. However, such harmonisation depends on strategic decisions made at a level higher than where GIS typically resides within the organisational structure. Elevating this as a business-critical initiative requires understanding and support from executive leadership to ensure it is prioritised and embedded into enterprise-wide data governance efforts.

Leadership for Data Cohesion

The wicked problem analysis has highlighted key interventions needed to champion and support effective data integration. The pain points identified the need for a leader with both the authority and capacity to advocate for the business's goals around reliable and robust data products and services. This leadership role would act on behalf of the GIS team and all other teams within the business, navigating organisational challenges and securing enterprise-wide support ultimately benefiting the entire business through improved data cohesion and strategic alignment. Surely this role warrants a Senior Executive Leadership Team member to ensure integration of results and investment to maximise ROI for the organisation.

Strategic Data Stewardship for Future Readiness

Given the future challenges facing the industry, the ability to efficiently capture, store, retrieve, merge, edit, model, analyse, and map corporate data will be significantly enhanced when data is properly owned, stewarded, and strategically managed. Establishing clear custodianship and governance ensures that data remains reliable, accessible, and interoperable making the organisation more capable, agile, and responsive.

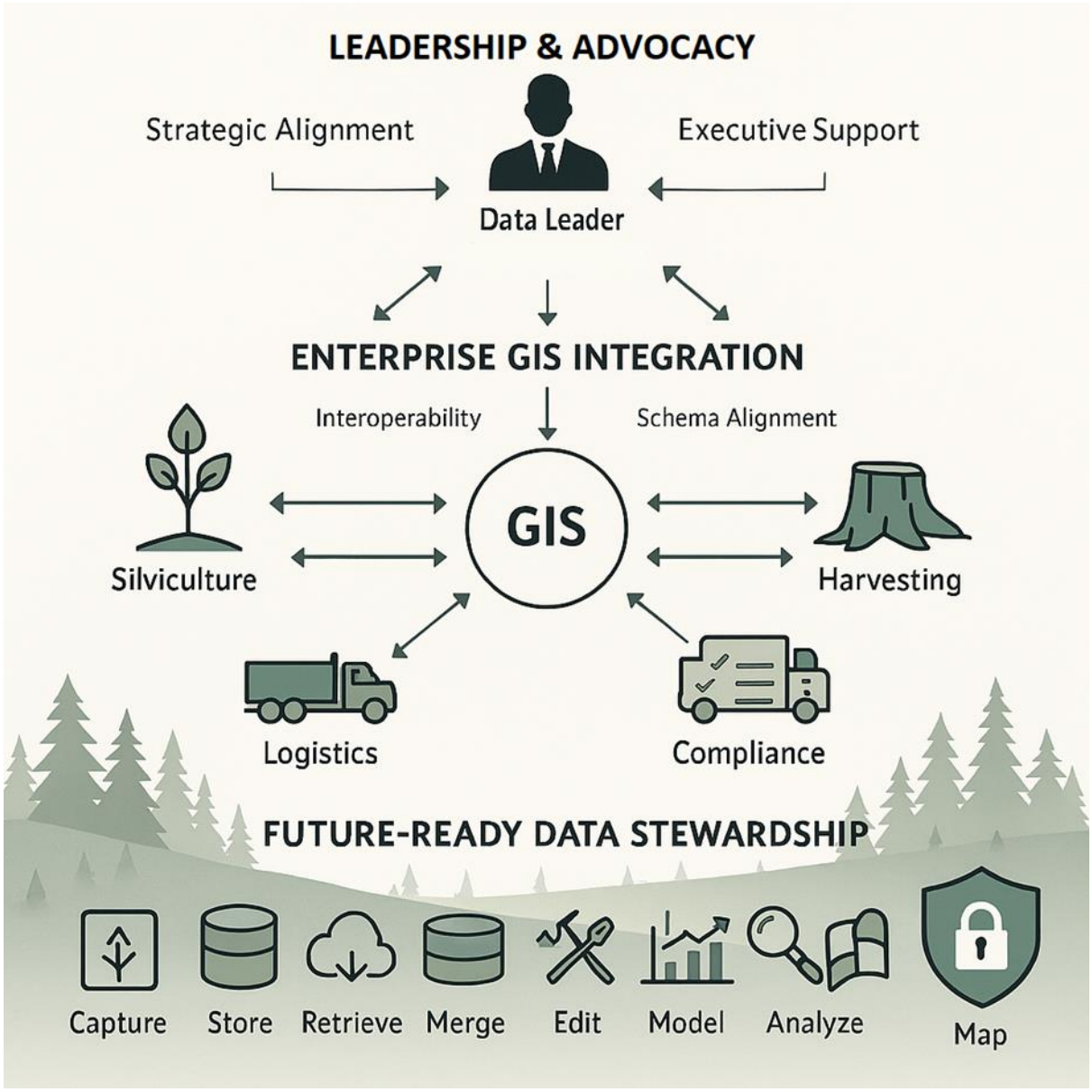


Figure 30 Strategic Data Leadership

Strategic Data Governance Roadmap for Forestry

To realise the aspirations of unified project work, enterprise-level data governance, and strategic leadership, a structured roadmap is essential. This suggested roadmap outlines a phased approach over 12 months, designed to build foundational capabilities, foster engagement, and embed sustainable governance practices within a forestry organisation.

Phase 1: Foundation and Alignment (Months 1–3)
The initial phase focuses on securing executive buy-in and establishing the leadership structure necessary for effective data governance. This includes presenting a compelling business case for appointing a Chief Data Officer (CDO) or Data Governance Lead, with clearly defined responsibilities and strategic objectives. Concurrently, a Data Governance

Council should be formed, comprising representatives from GIS, operations, IT, and executive leadership. This council will draft a governance charter that outlines roles, decision-making authority, and key performance indicators. A comprehensive assessment of the current data landscape should also be conducted to identify existing assets, gaps, and inefficiencies across systems and workflows.

Phase 2: Enablement and Engagement (Months 4–6)
With foundational structures in place, the next phase focuses on empowering teams and standardising practices. A Data Stewardship Program should be launched, nominating stewards within each business unit and equipping them with training in metadata standards, data quality, and lifecycle management. Simultaneously, metadata and cataloguing standards should be developed and implemented ensuring data is discoverable and consistently described. To demonstrate the value of unified efforts, a pilot project should be initiated ideally one with high operational impact, such as fire risk modelling or harvest planning applying governance principles and fostering cross-team collaboration.

Phase 3: Integration and Expansion (Months 7–9)
This phase focuses on integrating technical solutions and expanding governance practices. A centralised data platform should be selected and deployed, capable of securely hosting spatial and operational data while supporting analytics and reporting. Platforms such as ArcGIS Enterprise, Azure, or AWS may be considered based on organisational needs. Data quality automation should be introduced, incorporating validation workflows, version control, and monitoring mechanisms to ensure data remains accurate and timely. Additionally, efforts should be made to establish inter-organisational data sharing agreements with external partners such as government agencies and research institutions, aligning on formats, standards, and governance protocols to support broader collaboration.

Phase 4: Optimisation and Sustainability (Months 10–12)
The final phase focuses on embedding governance practices and ensuring long-term sustainability. Performance monitoring systems should be implemented to track governance KPIs, such as data usage, quality metrics, and return on investment from data initiatives. These insights should be shared with executives and stakeholders through dashboards and reports. To reinforce a data-driven culture, success stories and lessons learned should be communicated across the organisation, supported by ongoing workshops and forums. Finally, a strategic review should be conducted to evaluate progress, refine the governance model, and plan for scaling governance practices to new domains such as biodiversity monitoring or carbon accounting.

What responsibilities would a Chief Data Officer have?

A Chief Data Officer (CDO) sets the strategic direction for enterprise data management, ensuring robust governance, standards, and effective data utilisation. They lead data modernisation and transformation initiatives, overseeing the data landscape, lineage, insights, and value while ensuring security and sustainability. The CDO also guides data procurement, fosters vendor and industry engagement, and promotes collaboration across internal teams and external partners to drive innovation and maximise the value of data assets.

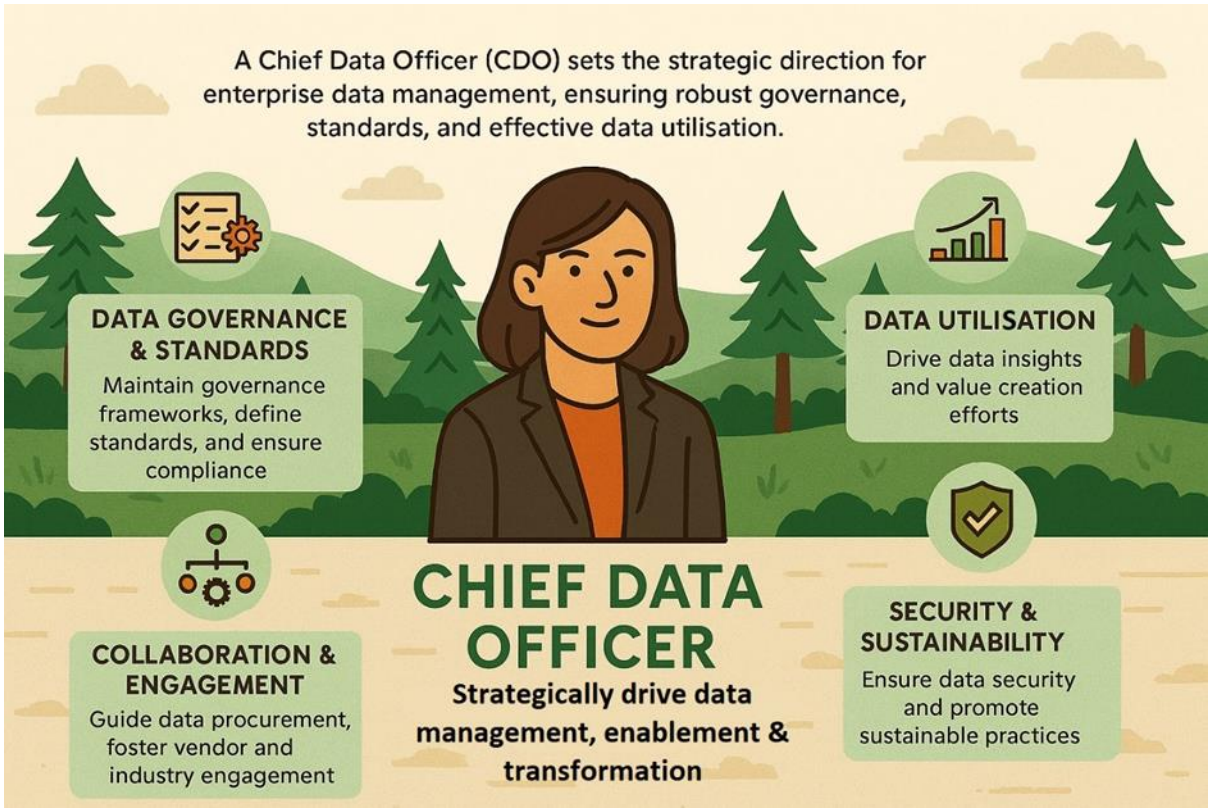


Figure 31 The role of a Chief Data Officer

Strategic Response

Having an executive leader to manage and develop frameworks, maturity models, and collaboration efforts within a business, especially in data and GIS domains, brings significant strategic and operational benefits. An executive champion ensures alignment with organisational goals, securing buy-in from senior stakeholders and integrating these initiatives into broader business strategies.

Their leadership provides clear direction and accountability, helping to prioritise resources, manage risks, and drive consistent progress across departments (Publishing, 2019). They also play a critical role in fostering cross-functional collaboration, breaking down silos between IT,

operations, and field teams, and ensuring that data and GIS efforts are not isolated but embedded in everyday decision-making (Spisak, 2022).

Moreover, an executive leader can advocate for investment in infrastructure, talent, and innovation, so that they are fit for purpose and use and that maturity models and frameworks are not just theoretical tools but catalysts for real transformation. Ultimately, their involvement elevates the visibility, credibility, and impact of these initiatives across the organisation (Spisak, 2022).

To address the complexity of aligning people, technology, data, and resources in forestry geospatial systems, I propose a multi-pronged governance and capability-building approach:

Select & Adopt Industry Frameworks: Implement frameworks like ITIL (Information Technology Infrastructure Library) and COBIT (Control Objectives for Information and Related Technologies) to standardise service management and IT governance, ensuring consistency, accountability, and value delivery (Mangalaraj, 2014).

Establish Data Management Standards: Apply frameworks like DAMA-DMBOK (*Data Management Body of Knowledge* by DAMA International) to ensure data quality, stewardship, and lifecycle management across the sector (Diversity, 2023)

Foster Collaborative Initiatives: Encourage cross-sector partnerships and knowledge-sharing platforms to align stakeholder goals and co-create solutions (Olson, 2025).

Use Maturity Models: Assess and guide organisational progress in data governance, digital capability, and interoperability using recognised maturity models.

Appoint a Chief Data Officer (CDO): Provide leadership and strategic oversight to unify data governance efforts, drive cultural change, and ensure alignment with sustainability and interoperability goals (Diversity, 2023).

Figure 32 Multi-Pronged Governance

Governance Frameworks

These frameworks provide structured methodologies that help align IT services including GIS with business goals, improve service delivery, and manage risk. ITIL focuses on service lifecycle management. It helps organisations improve service reliability, reduce downtime, and enhance customer satisfaction (Academy, 2025).

TOGAF (The Open Group Architecture Framework) supports enterprise architecture development, ensuring that GIS systems are scalable, interoperable, and aligned with strategic goals. COBIT emphasises governance and control, helping organisations manage risk, ensure compliance, and optimise IT resources (Less, 2024). These frameworks have been adopted by major organisations like NASA, NHS, and Disney, demonstrating their effectiveness in complex, high-stakes environments.

Effective GIS relies heavily on high-quality, well-governed data. Data management frameworks (such as DAMA-DMBOK) provide best practices for: Data quality and integrity, Metadata and lineage tracking, and Data stewardship and ownership (International). These practices ensure that GIS outputs are trustworthy and actionable, especially in sectors like forestry.

Collaboration

Cross-sector collaboration in forestry and GIS is not just a strategy for addressing data fragmentation and achieving interoperability it's a catalyst for broader transformation. By aligning standards across platforms like Esri, and, Trimble, stakeholders can co-develop governance models, streamline workflows, and integrate critical forestry data to support sustainable land management. Beyond technical alignment, collaboration fosters stronger professional networks, enhances collective influence in procurement negotiations (e.g., for software and imagery), and opens doors to shared learning opportunities.

Culturally, collaboration thrives when there's a shared challenge such as fragmented data or complex licensing and when vendors are open to co-creation rather than simply selling solutions. Trusted conveners like forestry councils or GIS alliances play a key role in building trust, coordinating efforts, and sustaining momentum. These partnerships also help participants stay current with emerging trends, technologies, and policy shifts.

Maturity Models

I have developed a GIS Capability Maturity Matrix structured around four key dimensions: Vision, Leadership & Governance; Data & Platform Management; Business Alignment & Professional Development; and Innovation & Trust.

This framework provides forestry companies with a powerful tool to assess and enhance their spatial data capabilities (see Appendix 1). It enables organisations to evaluate the strategic direction and governance of GIS initiatives, the effectiveness of data and platform

management, and the alignment of GIS efforts with business objectives and workforce development. By integrating innovation and trust, the matrix also underscores the importance of cultivating a forward-thinking culture that embraces emerging technologies while safeguarding data integrity and stakeholder confidence.

Ultimately, it offers a clear and actionable roadmap for continuous improvement, empowering forestry companies to become more agile, data-driven, and future-ready.

In parallel, I have also developed a Data Management Maturity Model focused on four foundational pillars: Institutional Policies & Procedures; IT Infrastructure; Support Services; and Metadata Management (see Appendix 2).

This model provides a comprehensive lens for evaluating the operational and technical readiness of forestry organisations in managing both spatial and non-spatial data. It assesses the strength of internal policies and procedures governing data use and compliance, the scalability and robustness of IT infrastructure supporting GIS and data systems, the availability and quality of user support services, and the maturity of metadata practices that ensure data discoverability, consistency, and interoperability.

Together, these elements highlight the critical enablers of a sustainable data ecosystem ensuring that GIS and data management efforts are not only technically sound but also institutionally supported and resilient to future challenges.

Conclusion

This project set out to examine what the forestry industry must do to strengthen and sustain its GIS capability to effectively respond to emerging challenges and capitalise on business-enabling opportunities.

Through site visits, workshops, and interviews, it became evident that geospatial technology and the products derived from it are foundational to the industry's operational workflows and reporting functions. The research revealed a strong appetite across the sector, both in Australia and North America, to further leverage GIS capabilities. However, this ambition is currently constrained by persistent challenges which, if left unaddressed, represent significant opportunity costs.

To meet future demands, forestry companies must build the capability to harness generative AI, digitise manual and analog data capture processes, and ensure that information and records are accessible for analysis. This will enable the generation of insight and knowledge critical to assessing the long-term viability of remaining competitive in the forestry sector.

Several strategic interventions were identified to overcome current limitations, including accelerating innovation through collaboration and shared learning across the industry, digitising manual data-generating processes, implementing enterprise-wide data governance, and empowering GIS subject matter experts with autonomy to operate across organisational boundaries. Central to these efforts is the establishment of executive-led data leadership, such as appointing a Chief Data Officer, whose primary role is to drive data harmonisation and foster excellence.

Across all findings, key themes emerged: the need to clearly define the purpose and intent of GIS, to ensure the right support and capability are in place to foster innovation and efficiency, and to build a trust-enabled organisation. These elements are essential to unlocking the full potential of GIS and positioning the forestry industry for a resilient, future-ready trajectory.

Appendix 1

GIS Capability Maturity Matrix

	Level 1 **Immature**	**Level 2** **Developing**	**Level 3** **Established**	**Level 4** **Advanced**	**Level 5** **Mature**
	Product is non-existent or *ad hoc*	Product is under development	Product is standardised, communicated	Product is managed, measured	Product focus is on continuous improvement
Vision, Leadership, Governance	GIS strategy is non-existent, leadership is unaware of GIS capability, procedures and process are not documented.	Initial strategy is being developed, but not fully implemented, Some leaders are aware of GIS capabilities, but understanding is limited, Basic procedures and processes are documented, but inconsistently followed	A clear GIS strategy is in place and aligned with business goals, Leadership is generally aware of GIS capabilities and supports its use, Standardised procedures and processes are documented and followed consistently	GIS strategy is well-integrated into the overall business strategy and regularly reviewed, Leadership actively promotes and leverages GIS capabilities for decision-making, Advanced procedures and processes are documented, optimised, and continuously improved	GIS strategy is fully integrated, innovative, and drives business transformation, Leadership has a deep understanding of GIS capabilities and champions its strategic use, Best-in-class procedures and processes are documented, optimised, and serve as a model for others
Data & Platform Management	Data governance is absent, data is siloed, cultural acceptance and understanding are lacking, and procurement is ad hoc	An initial data governance framework is in development but not fully implemented. Efforts to reduce data silos are ongoing, but they persist. Awareness of data governance benefits is emerging but not widespread. Procurement processes are becoming structured but remain inconsistent	A clear data governance framework is partially implemented. Data silos are being actively addressed with significant integration progress. Cultural acceptance and understanding are growing. Procurement processes are standardised and consistently followed	The data governance framework is well-integrated and regularly reviewed. Data silos are largely eliminated, with seamless integration. There is high cultural acceptance and widespread use of data governance practices. Procurement processes are optimised and strategically aligned with business goals	The data governance framework is fully integrated and innovative, driving business transformation. Data is seamlessly integrated, enabling real-time access and analytics. There is universal cultural acceptance and deep understanding of its value. Procurement processes are best-in-class and serve as a model for others
Business Alignment & Professional Development	GIS expertise and knowledge transfer are not supported. Personnel are not encouraged or permitted to explore, propose, or implement innovative GIS solutions	Growing GIS expertise and capabilities are somewhat supported. Knowledge transfer is sporadic and informal	GIS expertise and capabilities are recognised and supported. Knowledge transfer is more structured	GIS expertise and capabilities are highly supported and integrated into organisational processes. Knowledge transfer is systematic	GIS expertise and capabilities are fully embedded in the organisational culture. Knowledge transfer is continuous and proactive
Innovation & Trust	A culture of trust, essential for purpose, support, capability, and growth, is absent throughout the business	Initial efforts to establish trust are underway but inconsistent. Some initiatives support purpose, capability, and growth	Trust is recognised and supported across the organisation. Regular initiatives build and maintain trust, with consistent support for purpose, capability, and growth	Trust is deeply integrated into business processes. Strong efforts foster trust at all levels, with comprehensive support for purpose, capability, and growth	Trust is fully embedded and drives business success. It is a fundamental part of all interactions and processes, with full support for purpose, capability, and growth

Appendix 2

Data Management Framework: Capability Maturity Model

	Level 1 **Initial**	**Level 2** **Development**	**Level 3** **Defined**	**Level 4** **Managed**	**Level 5** **Optimised**
	Process is non-existent or ad hoc	Process is under development	Process is standardised, communicated	Process is managed, measured	Focus is on continuous improvement
Institutional policies & procedures	Policies & procedures may be undeveloped, not up to date, and/or inconsistent.	Policies & procedures are developed & harmonised.	Policies & procedures are promulgated & absorbed into behaviours.	Policies & procedures accepted as part of the culture & subject to audit.	Policies & procedures are subject to review & improvement.
IT infrastructure	IT infrastructure provision is patchy, disorganised & poorly publicised.	Funds are invested in technology & skills. Responsibilities are defined. Processes are established, defined & documented.	Management shows active support. Facilities are well-defined & communicated, standardised & integrated.	Funding adapted to need. Management actively engaged. Documentation kept up to date.	Concerted efforts to maintain, update & publicise infrastructure. Metrics & feedback used to optimise services.
Support services	Training is ad hoc, curation & preservation services are disorganised, data management planning is unsupported & other services inconsistent & poorly publicised	Investment in skills. Services identified & staffed. Responsibilities are defined. Documentation & training developed.	Active participation in training & widespread availability of services.	Widespread take up of services. Curation & preservation acknowledged as critical to the institutional mission.	Customer feedback used extensively to update & improve services.
Managing metadata	Metadata management is chaotic & understood by only a few.	Responsibilities are defined & skills developed. Processes are established, defined & documented. Metadata applied to key datasets & shared externally.	Processes are standardised & integrated. Metadata applied to new datasets & shared externally.	Metadata quality metrics collected. All datasets described & metadata shared.	All datasets & metadata are managed, monitored and updated. Continuous improvement applied to processes & capabilities.

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