

AERIAL ANALYTICS

Investigating the use of drones &
spatial data to assess urban plantings

MICHAEL G. WHITE

Acknowledgements

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Research and writing team:

Michael G. White (UNSW/Hassell), in consultation with industry partners and research collaborators across the fields of landscape architecture, ecology, horticulture, and geospatial science.

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Illustrations, diagrams, and photography were developed by the author unless noted otherwise.

This project was conducted on the lands of the Gadigal and Wangal people of the Eora Nation. We acknowledge the Traditional Custodians of these unceded lands and waters, and pay our respects to Elders past and present. We recognise their ongoing custodianship of Country and the deep knowledge systems that continue to inform care for place.

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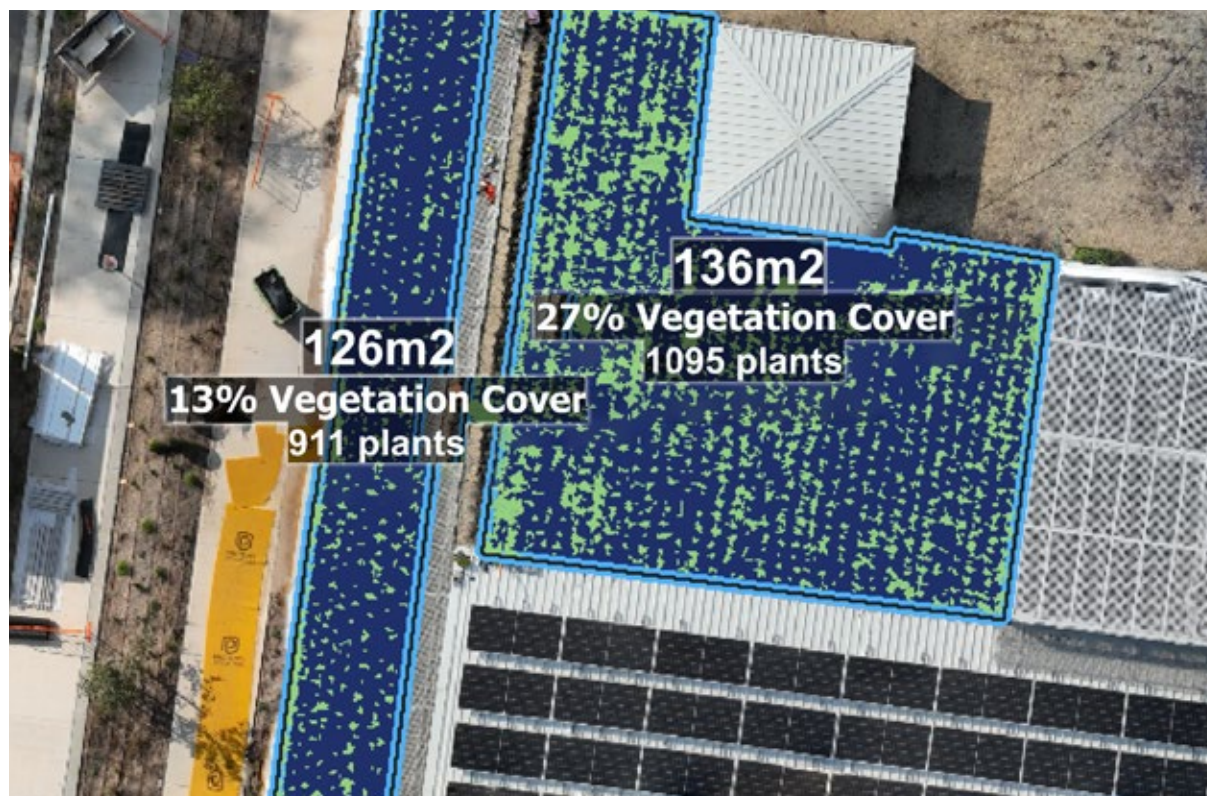
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Executive Summary

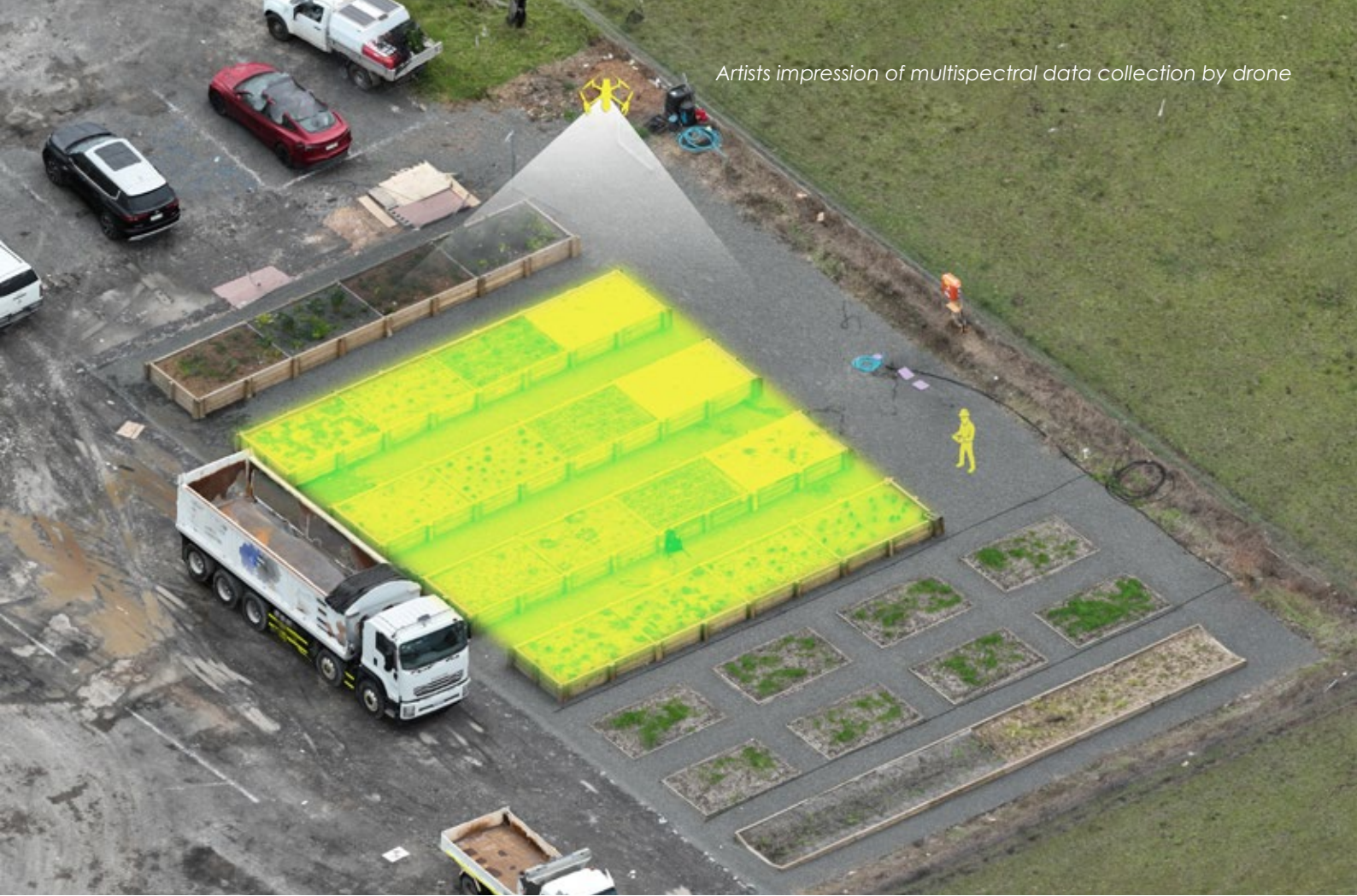
As our urban environments face increasing ecological and climatic pressures, the ability to create resilient, high-performing green spaces is essential for biodiversity, public well-being, and long-term sustainability. This project investigates the use of drones and emerging spatial data technologies to measure, to understand and to design more sustainable urban landscapes.

The integration of advanced vegetation monitoring tools such as drones, multispectral imaging, point-cloud capture and GIS into the design and delivery process of new plantings has the potential to transform the way we view our urban landscapes. By capturing data at multiple stages from installation through establishment, we can better track plant health, survival rates, and growth patterns. This data has the potential to identify areas of success and failure, and provide valuable insights into species performance, microclimate interactions, and site-specific challenges during the critical first year of plant establishment.

By generating 'as-built' and '12-month established' GIS planting plans derived from drone imagery, it is possible to create a standardized, geolocated record of vegetation development. These spatial datasets may serve as both a tool for evaluating individual projects and a foundation for cross-industry knowledge sharing. In this project, five pilot study sites were selected to demonstrate how drone-based monitoring can be applied across varying project scales, budgets, plant palettes, soil types and installation methods. The sites include a mix of native and exotic plant species, tested in urban contexts ranging from light rail corridors to rooftop meadows. This variation ensures that the project outcomes are widely applicable, addressing different environmental conditions, planting densities, and design intents.



Example output of aerial vegetation survey showing plant quantities, density and vegetation cover



A consultation phase engaged a broad network of experts from industry, academia, and the public sector to establish guidelines for successful drone monitoring and performance assessment. This collaborative effort revealed key challenges, including defining clear performance goals, and the difficulty of long-term monitoring in urban settings. Stakeholders consistently highlighted the need for more rigorous post-installation evaluations and the value of integrating digital tools to streamline data collection and improve accuracy.

Future Directions

The integration of drone monitoring has the potential to introduce significant benefits to the performance of living infrastructure. Drones offer high-resolution imagery and multispectral analysis that reveal plant health, detect stress, and map biodiversity with centimeter-level precision. This data-driven approach may improve our ability to adapt planting designs based on real-time feedback, ultimately reducing the financial and environmental costs associated with plant failure. Additionally, spatial data provides a powerful communication tool for engaging clients and stakeholders, offering clear visualizations that demonstrate how plantings evolve over time. This transparency not only fosters trust but also strengthens the case for investing in green infrastructure, reinforcing the ecological and social value of urban vegetation.

Over time, the goal is to build a collaborative platform where performance data from trial sites can inform future design decisions, fostering a more adaptive, evidence-based approach to urban planting across Australia. By building a network of monitored planting sites and sharing findings, the industry can develop more resilient, adaptive planting strategies that respond to the unique challenges of urban environments. Ultimately, this project aims to increase urban resilience and biodiversity, leveraging technology to shape more sustainable, vibrant cities. The insights gained from this work will not only inform individual projects but also contribute to a broader cultural shift towards greener, healthier urban futures.

The importance of urban vegetation and living infrastructure

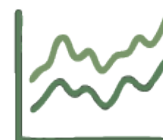
Urban vegetation is vital for enhancing environmental quality, public health, and biodiversity in cities. The development of this living infrastructure is a significant investment in our future.

Urban vegetation delivers a wide range of environmental and social benefits essential to sustainable city planning. These include urban cooling through shade and evapotranspiration, improved air quality, and enhanced stormwater management by reducing flood risk and improving water quality. Vegetation also supports biodiversity by providing habitat, contributes to carbon sequestration, stabilises soil to reduce erosion, and promotes physical and mental health and wellbeing for urban populations.

5x

Living infrastructure or hybrid grey-green approaches can cost less than traditional models, while also delivering substantial social and environmental co-benefits.¹³

Vegetated areas can be 5–6°C cooler at the surface during extreme heat events.⁴



\$3.6b

Australian nurseries sold an estimated 2.3 billion plants worth approximately \$3.6 billion in 2021–22.¹⁹

Australians living near areas with ≥20% green space are significantly more likely to engage in weekly physical activity.²¹



Native understorey plantings in Melbourne increased insect biodiversity by a factor of seven within three years.¹⁶

'While our national parks and wilderness areas are essential for protecting biodiversity, our cities and towns also provide critical habitat for threatened species.'
— Australian Conservation Foundation



Diverse planting at the Showground Metro Planting Trials - Hassell

The role of the understorey

While much research has focused on tree canopy benefits, understorey plants also contribute significantly to urban biodiversity by providing habitat and food sources for various insects and animals. A diverse understorey layer enriches the soil, cycles nutrients, and offers shelter, thereby supporting local fauna and promoting ecological balance. Increasing understorey cover and incorporating native plantings in urban green spaces have been shown to improve biodiversity outcomes. Research indicates that the probability of occupancy for many species is substantially reduced in urban areas with sparse understorey vegetation and few native plants. Understorey vegetation can also improve air quality by collecting dust and other airborne particles, in addition to capturing CO₂ and releasing oxygen. Enhancing understorey vegetation can mitigate these effects, leading to healthier urban ecosystems.

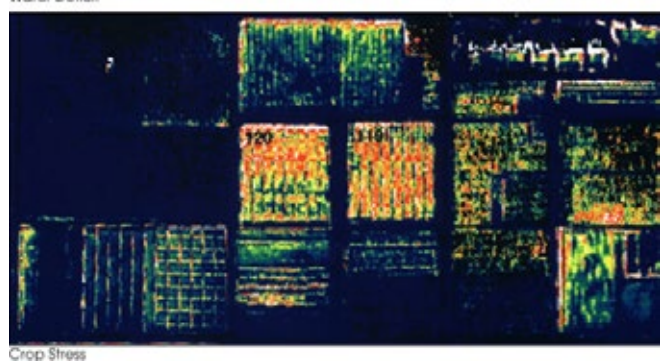
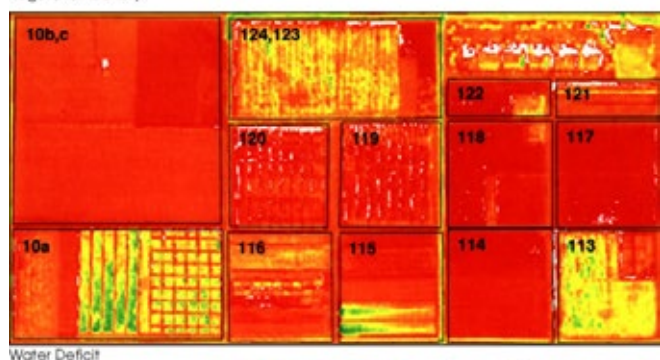
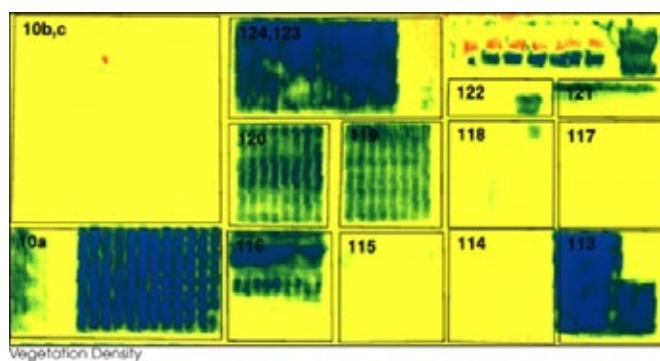
Beyond ecological benefits, understorey vegetation also contributes to human health and well-being. Access to diverse urban green spaces, including those rich in understorey plants, has been linked to reduced stress and improved mental health. Incorporating nature into urban planning is increasingly recognized as crucial for creating healthier cities.

Innovations in Agri-technology

The use of digital technology in farming has rapidly expanded over the past decade, becoming a cornerstone of modern agriculture.

Precision agriculture

Precision agriculture is a farming management approach that uses advanced technologies to observe, measure, and respond to small-scale variability in crops and soil. By leveraging data from GPS, sensors, satellite imagery, and drones, precision agriculture enables site-specific management of agricultural practices, aiming to optimize productivity while minimizing environmental impact. This approach contrasts with traditional blanket methods by allowing inputs such as water, fertilizers, and pesticides to be applied only where needed, and in the right amounts. The goal is to improve the efficiency of farming operations, reduce waste, enhance crop yields, and support long-term sustainability in agricultural systems.



Multispectral analysis of crops - Susan Moran / NASA

The rise of drones

Drones allow for highly detailed spatial analysis of crop conditions, enabling farmers to make data-driven decisions about irrigation, fertilization, pest control, and harvest timing. Through the use of multispectral and thermal sensors, drones can assess crop health, identify areas of stress, and generate vegetation indices such as NDVI (Normalized Difference Vegetation Index), which offer insights beyond what is visible to the human eye. The combination of georeferenced aerial imaging and real-time positioning systems ensures that applications are confined to exact field locations, enhancing efficiency and reducing costs.

Globally, drones in agriculture are becoming ubiquitous. According to the World Bank and industry reports, the agricultural drone market is expected to reach over USD 10 billion by 2030, with annual growth rates exceeding 20%. In countries like China and Japan, drones are used on more than 30% of farms, and adoption is rapidly increasing in Australia, the US, and the EU.

"Drones can map water flow to determine dam placement, survey crops to identify areas of low yield or predict future yields, and distribute fertilisers to support better crop outputs. Aerial photography can also identify weed infestations, which can be followed up with ground analysis to determine specific soil or pest issues. Drones can improve the accuracy of pesticide and herbicide delivery, which reduces excess spraying and the potential impacts of runoff on local ecosystems." - Drones.gov.au



DJI Agras T16 drone used for precision spray application

"Drones could reduce the use of chemicals by 30%, and water by 90%, and they were able to reduce carbon emissions from heavy diesel machinery, which would otherwise pollute the environment" ¹⁴



Drones can deliver more accurate observations of natural systems than manual counts⁹, and provide more accurate geospatial data at lower cost as compared to other surveying technologies.²

38,000 drones could be deployed in Australia by 2030 for agricultural uses.⁵



29%

Adoption of drones for agriculture and horticulture in the Murray-Darling basin was predicted to increase from 5% to 29% from 2016-2021²⁰

Applying new tools to urban landscapes

How can technology developed for the agricultural and forestry industries be used to create high performing urban landscapes?

New ways of seeing landscapes

New technologies such as drones, multispectral imaging, and GIS (Geographic Information Systems) may enhance our capacity to assess, track, and refine living infrastructure with unprecedented accuracy. A key insight from the work of Jeffrey Claridge, reviewing the development of evidence based practice in medicine, is the recognition that technological advancements can reshape the questions that practitioners ask and the frameworks through which they interpret results. The introduction of new diagnostic tools and scientific methods transformed medicine from a field grounded in anecdotal observations to one rigorously guided by empirical data and reproducible experiments. The ability to detect subtle variations in internal organs through imaging enabled early diagnosis of conditions that might otherwise have been missed, expanding the field's understanding of disease progression. The use of spatial and multispectral data may lend an equivalent capability to assess the health of urban landscapes.

Benefits of integrating advanced vegetation monitoring may include:

- **Reduced failure rates** – Early detection of plant stress or under-performance allows for targeted interventions, reducing the likelihood of widespread planting failures and in turn reducing costs.

- **Optimised species selection** – Continuous monitoring provides data on which species thrive under specific conditions, refining future plant selections to match site contexts.

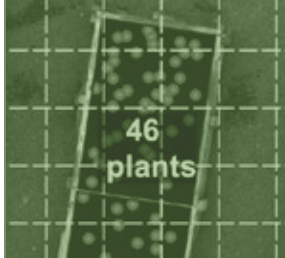
- **Increased accountability** – Objective, quantifiable data supports transparent communication with clients and stakeholders, demonstrating the success (or necessary adjustments) of planting schemes and performance against contract specifications.

- **Scalable insights** – Data collected across multiple sites contributes to broader industry benchmarks, supporting large-scale urban greening initiatives and climate adaptation strategies.

- **Reduced inputs and use of herbicides, pesticide and fertiliser** - Identifying weed spread, variations in health and site conditions allows landscape managers to only apply interventions where needed

However, the application of drones in complex urban planting contexts presents additional challenges. Unlike large, homogeneous crop fields, urban plantings are often species-rich, spatially constrained, and structurally diverse. These environments may include a wide variety of vegetation types: trees, shrubs, herbaceous species, green roofs, interspersed with infrastructure, vertical elements, and microclimatic variation. As a result, techniques developed for broad-acre agriculture must be adapted or re-engineered to account for the fine-scale heterogeneity and complexity inherent in urban landscapes.





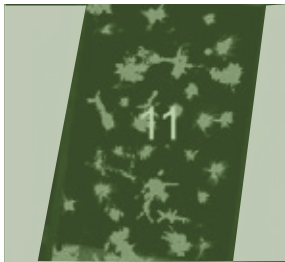
Plant counts

Counting plants can be completed automatically using spatial analysis tools or AI-based object detection. When linked to initial planting layouts, they may help to provide performance feedback and rates of survival. While results are not 100% accurate and are typically reported with error margins, some research suggests that well calibrated systems can outperform the accuracy of manual counts.



Vegetation cover

Vegetation cover can be estimated from aerial images using colour or multi-spectral photographs. Changes in cover over time may indicate establishment progress, seasonal variation, or disturbance. High-resolution imagery from drones allow fine-scale mapping of cover across entire sites.



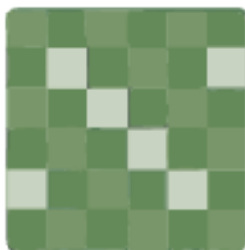
Estimating plant health

Vegetation indices such as NDVI, GNDVI, or OSAVI can be used to estimate plant health by comparing spectral reflectance in visible and near-infrared bands. These indices may highlight differences indicating areas of stress, drought, or nutrient deficiency, however in diverse plantings this may be challenging due to variation between species.



Individual plant measurements

Ground-based or aerial captures generate 3D models, from which measurement of individual plant dimensions such as height and canopy spread is possible. These measurements may be useful in comparing growth rates and evaluating planting performance against design targets. Over time they may provide a benchmark for species.



Zonal statistics

Zonal statistics are used to summarise vegetation metrics within defined areas such as trial plots or planting mix areas. Statistics such as plant density or percent cover are then calculated per zone, revealing spatial patterns in establishment and performance. By overlaying planting plans with other data, results can be compared between different mixes or communities.

Rethinking Landscape Metrics

The integration of new technologies also prompts a re-evaluation of how success is defined in landscape projects. Integrating plant counts and density checks, vegetation cover and zonal statistics into specifications, contracts, quality assurance processes and post-occupation studies may be a powerful tool in the creation of higher performance, more sustainable urban landscapes that address the challenges of the future.

Consultation & feedback

The first phase of this research project involved consulting with a wide range of groups with experience in urban planting projects including designers, researchers, contractors and nursery growers.

Consultation process

Prior to conducting the pilot studies, a range of groups were consulted to provide input on their experiences and inform methods and data collection. Online or in-person interviews were conducted with representatives from each group to help to understand their needs and perspectives in the area of urban planting performance. Interviews were transcribed and summarised, leading to insights which shaped the pilot process.

Key consultation groups:

- | |
|---|
| • Landscape architects & landscape designers |
| • Researchers in urban horticulture and ecology |
| • Nursery & Greenlife industry |
| • Non-profit organisations for green infrastructure |
| • Landscape construction and management teams |
| • Asset managers & public infrastructure |

Survey Questions

1. What does a successful established urban planting look like to you?
2. Which variables would you track or map to provide useful feedback on plant establishment success?
3. What are some of the primary issues you encounter in plant establishment that might lead to failure?
4. Do you have an example of a project in which you have measured or evaluated planting success in detail? What was the process? What were the challenges?
5. Are there any specific tools or assessment frameworks you have experience with or recommend for assessing urban plantings?
6. Are you currently using any spatial data tools or digital technologies to monitor plantings?

Note: not all questions apply to all consultation groups

Outcomes

Following this consultation a number of pilot studies of recently planted sites were conducted, with the aim of evaluating the use of emerging technologies for monitoring urban vegetation. The feedback received in these sessions led to the following outcomes:

- Perform drone surveys at multiple intervals throughout the year to monitor seasonal changes, species competition, and variations in growth rates.
- Collect longitudinal data on species performance to validate the use of less common or trial plants, contributing to reliable datasets that can guide future plant selections.
- Monitor climate (rainfall, temperatures) and microclimate variations (e.g., sun exposure, wind patterns) across different areas of the site, for comparison against variations in performance.

Feedback summary & takeaways

Note: this feedback was provided through consultation with a wide variety of stakeholders and representatives from industry and academia. The summary below has been collated from all responses by the author and may not represent the views of any particular individual or group.

Challenges

- Urban landscape projects face numerous intersecting challenges across procurement, species selection, planting, and maintenance. Nurseries are often given minimal lead time to supply plants, leading to mismatches in pot sizes and densities. Larger container sizes frequently suffer establishment shock. Early engagement with suppliers can reduce this risk. The cost of planting is a significant capital investment that can be wasted if the planting is not properly maintained
- Species selection is hindered by limited performance data, especially for less common plants. Designers may inadvertently specify species that are not appropriate for the context, highlighting the need for collaboration with horticultural experts. Timing and technique at planting are critical, issues such as hot weather, root-bound stock, and soil incompatibility frequently contribute to failures. Plant competition adds complexity; some species dominate or underperform against their neighbours, and dynamics shift seasonally. Reported first-year survival rates from the surveyed groups range widely from 5–40%.

Monitoring

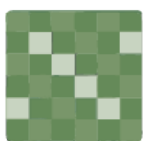
- Defining clear goals, performance metrics, and monitoring schedules from the outset is essential for the success of both trials and built projects. A lack of clear benchmarks often leads to incomplete assessments and missed opportunities for improvement. Evaluating success depends on typology. Metrics like survival, cover, and plant counts are common, but need to be contextualized by design goals such as structure, legibility, and biodiversity. Over- or underperformance of individual species complicates assessment. Long-term monitoring is often limited. Establishing baselines for soil, irrigation, and microclimate is vital. Internal QA checklists during establishment help maintain plant health.
- Digital tools including drones, cameras, QR codes, GIS, and tablets are emerging for monitoring landscapes, though high-end systems remain costly and require specialised skills. Uniform data collection and formatting ensure that findings are comparable across different sites and timeframes. By standardizing aerial imagery, QA processes, and site surveys, practitioners can create reliable datasets that inform future projects.
- Manual measurements, such as quadrat sampling and ground surveys, remain vital for validating drone data and ensuring accuracy. Combining high-tech monitoring with on-the-ground inspections strengthens confidence in the results. Involving horticulturalists, ecologists, and soil scientists with specialised skills and training is essential to ensure the quality and accuracy of data collected for decision-making.

Maintenance

- Successful plantings require ongoing attention. Allocating adequate resources to maintenance and ensuring that maintenance teams understand the design intent enhances survival rates and overall project longevity. The establishment of urban landscapes is a substantial financial investment that should be managed and maintained as 'green infrastructure' asset in a similar process as other urban infrastructure
- Insufficient maintenance budgets are a key driver of poor outcomes. For diverse plantings, shared understanding of year-round appearance and care requirements between client, designer, and maintenance team is essential. Performance-based maintenance specifications may encourage healthier plantings but require horticultural expertise and robust QA processes. Weed management is the most intensive recurring task and should be anticipated in design. Designers must also consider chemical use impacts.

Gathering information from site

Direct observations made on site are essential to understand, assess and improve urban vegetation outcomes.



Vegetation cover

Assessing the overall percentage of vegetation cover as a proportion of the plot area provides insights into the density and distribution of plant life.



Plant counts

Counting how many plants are currently present in 'plots' or defined site areas allows the calculation of survival rates by area, or by species over time.



Individual plant measurements

Individual plant measurements may be taken including height, spread, volume, and bench-marked against the same or similar species.



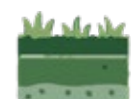
Diversity

Diversity can be measured by identifying the number of unique species (richness), or by more detailed counts assessing relative abundance and distribution.



Fauna presence

Fauna measurements may include observing and noting signs of wildlife presence and interaction, or advanced methods like e-DNA and acoustic monitoring.



Soil & Environmental characteristics

Soils can be tested to determine chemical, physical and biological properties that are fundamental to plant health and survival.



Climate conditions

Climatic conditions can be measured on site with simple tools like rain gauges, or data can be collected from the large network of public weather stations.

“Failure can be attributed to multiple factors around site issues, plant biological tolerances and maintenance, but is also related to poor plant selection... to improve plant performance in urban landscapes we need to learn more from plant failure to improve decision-making”¹²

Conducting a vegetation survey

Direct, ground-based observation is a vital tool, enabling us to assess whether the intended plant densities are being achieved, which species are thriving or failing, and whether adjustments in maintenance or future design strategies are needed. This may include using simple tools like quadrats or tape measures, recording species identification, estimated percentage cover, and any signs of stress, flowering, or mortality. Photos taken on a phone help to provide a visual record support later cross-checking.



Using a folding 1 x 1 m quadrat frame

- 
1. Use random or systematic sampling to decide quadrat locations.
- 
2. Place the quadrat. It may be helpful to mark locations with pegs.
- 
3. Take photographs for records.
- 
4. Identify plant species and estimate percentage cover within the quadrat.
- 
5. Repeat this process at multiple quadrat locations
- 
6. Compare results across the site and over multiple visits to identify patterns.

Using quadrats to track vegetation presence and abundance on site.

Collaboration

Engaging with experts including soil scientists, horticultural researchers, and experienced landscape contractors is essential for informed decision-making in environmental and landscape projects. Soil scientists provide critical insights into soil health, composition, and suitability for plant growth, while horticultural researchers contribute knowledge about plant species, growth patterns, and disease resistance. Landscape contractors bring practical experience in implementing designs and understanding site-specific challenges. Collaborating with these experts ensures that projects are grounded in scientific knowledge, practical expertise, and sustainability, leading to better long-term outcomes and plant health.

Tools for measuring planting success

Measuring landscape performance on site requires the right tools for the job, both physical and digital.

Building a site toolkit

When conducting vegetation assessments on site, having the right tools is essential for accurate data collection and ensuring safety. Quadrat frames can help define sampling areas for assessing plant density and diversity, while a tape measure is invaluable for measuring distances and dimensions. A trowel or auger is useful for collecting soil samples, and plastic bags can be employed to store both soil and plant tissue samples for later analysis. Safety items should not be overlooked; wearing high-visibility clothing, hats, and sunscreen protects against sun exposure, while staying hydrated with plenty of water is crucial for maintaining focus and energy during fieldwork.



Clockwise from top left: i) Mobile phone (Samsung Galaxy), ii) Trowel, iii) Seed dibber with depth increments, iv) Collapsible or folding quadrat, v) Several Ziplock bags, vi) Drone (DJI Mavic M3E multispectral), vii) Drone controller (DJI Mavic 3 Enterprise remote controller), viii) Tape measure, ix) Soil Coring tool, x) Gardening Gloves, xi) Spiral bound notebook

Digital hardware for data collection

Digital tools for assessing vegetation on sites range widely in cost and complexity. A phone camera can capture basic visual data for plant identification and health monitoring, while a handheld LiDAR scanner may provide detailed 3D models of vegetation structure in point-cloud format. Drones equipped with RGB or multispectral cameras offer aerial views and can monitor vegetation health, canopy cover, and stress indicators using both visual and spectral data. Desktop or laptop computers are needed to run GIS software, allowing for the analysis and mapping of spatial data, integrating multiple data sources like satellite imagery, drone outputs, and field observations to provide comprehensive vegetation assessments.

Evaluation of digital tools for site

As part of this study a range of hardware was tested to evaluate its effectiveness in monitoring landscape performance. These tools included standard mobile phones, handheld LiDAR scanners, and drones equipped with RGB and multispectral cameras for aerial vegetation assessments. Tests conducted during the pilot studies with a handheld Zeb Revo LiDAR scanner had limited success due to proprietary data formats and inconsistent results. A follow-up test with research-grade LiDAR equipment to produce high density scans was much more successful but would be well out of budget for most landscape applications. LiDAR equipment however, is quickly becoming more affordable and is likely to be an essential tool in the future due to its ability to penetrate dense canopies, with some sensors even included on newer mobile phones. A summary of the strengths, limitations, and potential applications of each tool is included in the table below.

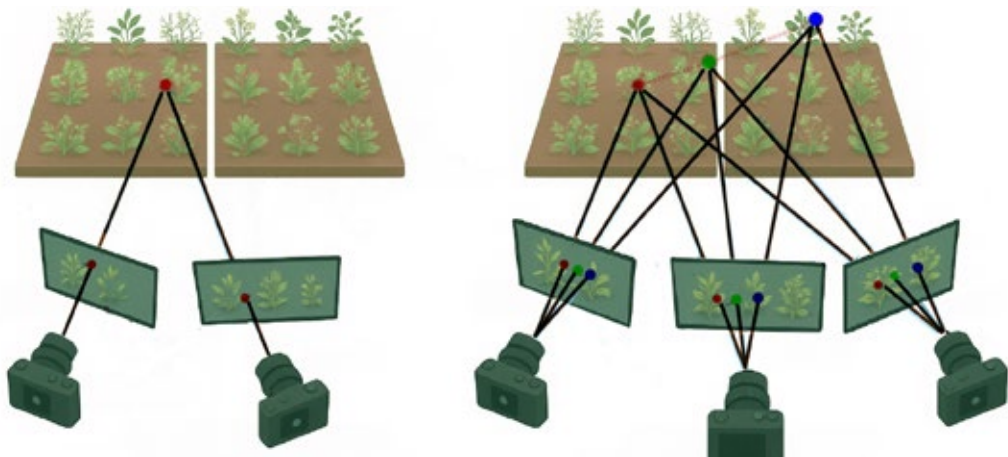


Digital hardware

HARDWARE	COST	CAPABILITIES	GAPS & LIMITATIONS
Mobile Phone (e.g. Samsung Galaxy S21 FE)	\$200- \$1500	RGB image capture for use in photogrammetry software (manual)	No geo-location capability, RGB images only. Some models e.g. iPhone Pro series have limited LiDAR capability. Significant time to capture, examples included 1500 photos for 100m2 area captured manually.
GoPro (pole-mounted)	\$400- \$600	RGB image capture for use in photogrammetry software	No geo-location capability, RGB images only
Drone - Mavic M3E Multispectral	\$7000.00	RGB/multispectral capture for use in photogrammetry or mapping software (automated flight capability for area capture)	Geolocation requires base-station or RTK capability with NTRIP service (not included in base package)
Drone - DJI Mini 2	\$750.00	RGB image capture for use in photogrammetry or mapping software.	No geolocation capability, RGB images only. Maximum GSD is around 2.5cm.
Zeb Revo RT	\$10000+	Handheld lidar device can capture 3D vegetation data.	Proprietary processing software. Limited support.

Photogrammetry for site capture

Photogrammetry is a technique which constructs 3D models or point clouds from multiple 2D images taken at different viewpoints. This method allows low-cost, accessible spatial data capture suitable for smaller projects or trial plots where drone use may be impractical.



1. Triangulate location of matching points in overlapping images

2. Add more images and points to create point cloud

Photogrammetry reconstruction process

The process of photogrammetry requires the identification of the same point in multiple overlapping images, which allows software to triangulate the three-dimensional position of those points relative to the camera. By capturing a series of images from different angles with an overlap typically around 60–80%, photogrammetry software can reconstruct detailed 3D models or orthophotos of a site. Accurate results depend on consistent camera settings, ground control points, and full overlapping coverage of the subject area.

Photogrammetry processing software

SOFTWARE	COST	CAPABILITIES	GAPS & LIMITATIONS
Reality Capture	\$0.00	Powerful software for processing photographs into 3D point clouds and models.	Requires powerful computer hardware to run locally, including memory, storage and processing power.
PolyCam	\$100/y	Phone app for photogrammetry.	Limited image inputs based on subscription.
AGIsoft Metashape Professional	\$5350	Professional photogrammetry, point-cloud & mapping software	Requires powerful hardware. Significant investment required in professional license.

A range of software is available for processing images into 3D outputs using photogrammetry techniques. These tools process image data by identifying common features across multiple angles and reconstructing spatial geometry through triangulation. RealityCapture is known for its high-speed processing and support for large datasets, making it suitable for professional surveying and is free for non-commercial use, or businesses with <\$1m revenue. Polycam, by contrast, offers a more accessible mobile-based interface, useful for rapid field capture. Agisoft Metashape is widely used in research and industry for its balance of accuracy, control, and compatibility with GIS workflows.

How to capture vegetation

To capture areas of planting, walk in a circuit around the target area with a DSLR or smartphone, taking overlapping images towards the centre of the plot from multiple angles. Maintain consistent lighting and avoid fast movement to reduce motion blur. A circular path at multiple elevations helps to cover all angles and produce accurate 3D models. Including reference objects of known size allows for accurate scale, e.g. by placing a tape or measuring tool within the captured area. Use manual camera settings if possible: high shutter speed, small aperture, and low ISO.



1. Take photos with any digital camera or phone.



2. Measure reference dimensions on site.



3. Manual Camera settings with a high shutter speed, f/stop.



4. Complete circular paths at multiple heights



5. Overlap each photo by around 70%.

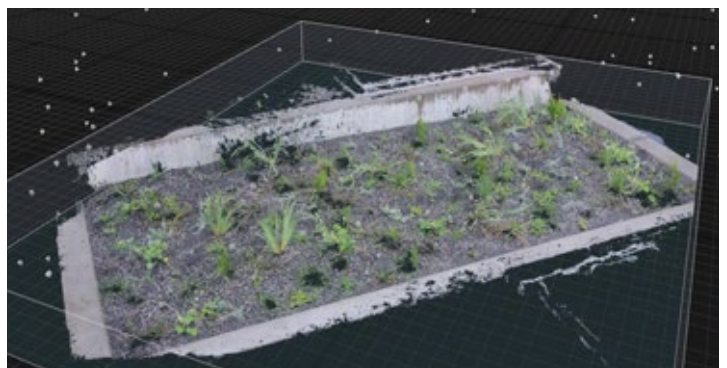


6. Use software to reconstruct 3D model

Photography process for vegetation capture

Outputs

From these models a variety of measures can be taken: digital elevation models (DEMs) can be derived, providing a map of plant height across the study area, or visual comparison can be made between captures at different points in time, allowing changes in vegetation growth or structure to be tracked across seasons or maintenance interventions.



High resolution digital vegetation model (in RealityCapture)

Monitoring landscapes with drones

Recent improvements in drone technology have made digital site capture more accessible than ever. High-resolution aerial imagery or 3D point clouds can be created with for detailed monitoring of urban vegetation.



1. Check safe flight zones online and get permission if needed from landowners.



2. Plan flight path to cover site area using mapping tools on controller or PC.



3. Review obstacles and people on site for safety.



4. Maintain line of sight to drone and monitor progress.



5. Land safely in a clear area.



6. Download data to PC with USB-C cable for processing.

Collecting data with drones on site

Planning drone capture

When flying drones for spatial data capture, always check weather conditions; clear skies and minimal wind are ideal for ensuring stable flight and accurate data. Understanding Ground Sampling Distance (GSD) is crucial, as it determines the spatial resolution of your images; a smaller GSD (from flying lower or a higher resolution camera) yields finer detail. For drones with positioning capability, you may need to connect to positioning networks before takeoff. Additionally, adhere to safety guidelines by staying within allowed altitudes, maintaining a clear line of sight and avoiding restricted airspaces. Be aware of local regulations regarding drone usage, including altitude limits, licensing requirements and no-fly zones. Finally, ensure your equipment is well-maintained and conduct test flights to familiarise yourself with the drone's capabilities before use on site.

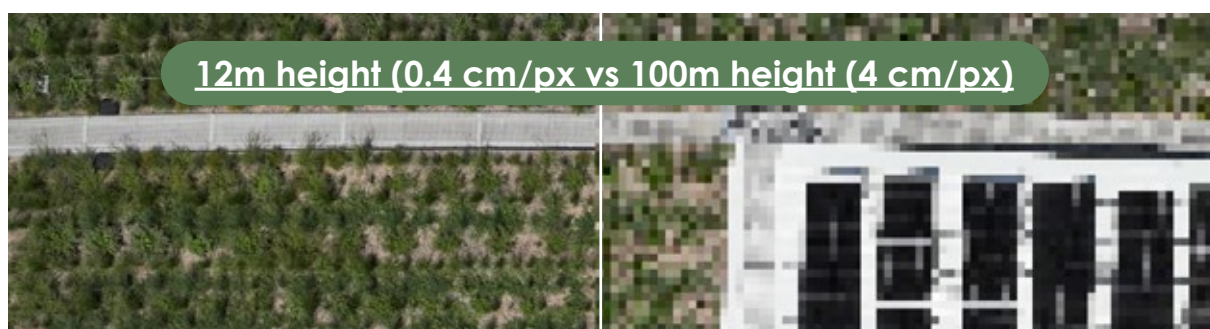
Note: for the latest information about drone regulations in Australia, refer to the Civil Aviation Safety Authority (CASA) at <https://www.casa.gov.au/drones>

“Drones unlock the potential to capture data at finer spatial and temporal resolutions than satellite or airborne remote sensing platforms offer. Information about a particular environment, individual, or group of organisms can be collected in greater detail, meaning smaller features can be detected, comprising a larger number of pixels at finer resolution. Drone-based data can also be collected more frequently (i.e. surveys could be conducted at varying frequencies, from daily to multiple times or specific times of day).” - WWF Drones for Conservation

Geolocation of drone images

To overlay GIS data, BIM models or surveys, it is necessary to record spatial coordinates for each image or data point collected during flight. Advanced systems use RTK (Real-Time Kinematic) or PPK (Post-Processed Kinematic) positioning to achieve centimetre-level accuracy by correcting GPS signals with data from ground-based reference stations. These technologies are critical for high-accuracy mapping, enabling reliable alignment of imagery and models with real-world coordinates.

Image quality and Ground Sampling Distance (GSD)



Examples of images captured at varying GSD

GSD refers to the distance between two adjacent pixels in the aerial image, as captured by the drone's camera. It determines the spatial resolution of the imagery; a smaller GSD value indicates higher detail and resolution. For detailed vegetation mapping, a rough guide is that Target GSD = Average Plant Size / 30 px - e.g. a 15cm diameter plant will require a GSD of approximately 0.5cm. The relationship between GSD and flight height depends on the camera quality and can be calculated with: $GSD = (altitude \times sensor\ size) / (image\ size \times focal\ length)$.

Further considerations

Digital capture using drones and photogrammetry can offer a powerful means of monitoring vegetation over time. These techniques allow for detailed spatial analysis of plant growth, coverage, and health. To ensure reliable results, consistent capture practices are critical. This may include flying at the same altitude, using geolocation capabilities or identifying key reference points for alignment of captures on different dates.. Establishing a regular schedule enhances the value of the dataset by enabling meaningful comparisons across seasons or stages of plant establishment.



Planning and executing a flight plan

Interpreting aerial data

Once imagery has been collected from drones, aerial surveys, or ground studies, it requires processing to transform images into useful analysis such as plant counts or vegetation cover.

The first step involves formatting the collected images into a georeferenced combined image using aerial mapping software like DJI Terra or WebODM (OpenDroneMap). These tools stitch together individual drone images to create a cohesive aerial image layer that is georeferenced, meaning each pixel corresponds to a real-world location, and an accurate scale is established.

1 Aerial Mapping

Indices like NDVI or OSAVI can be calculated by comparing reflectance across different wavelengths or bands. These indices can help to highlight vegetation presence, health and density. This step may be built in to the aerial mapping software, or may be completed in GIS software.

2 Creating Indices

Areas of the aerial map may require manual cleanup due to deep shade, different substrates or other variation across the site. Calibration is needed to determine the range of values that represent vegetation, bare ground or materials and surfaces. Manual measurements, counts and ground-level photographs are invaluable to validate and cross-check the aerial survey.

3 Validation

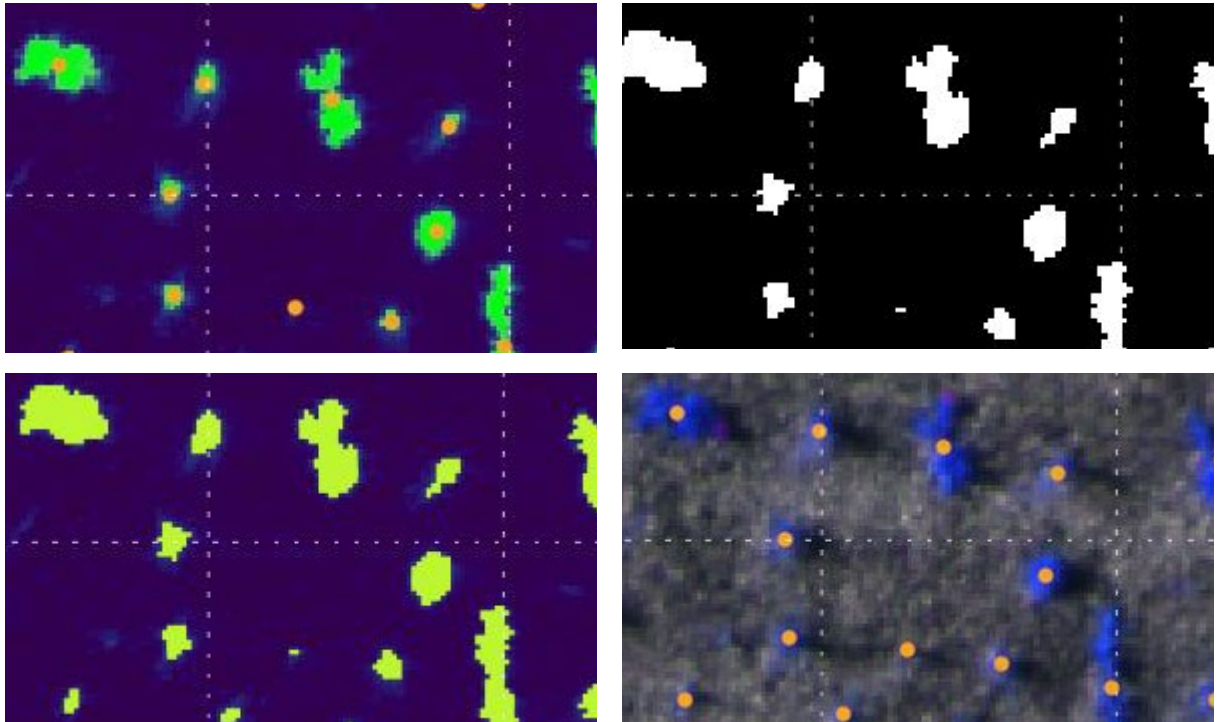
With a clean map established, areas of live vegetation can be separated for analysis. Parameters can be extracted such as area or plant locations for counting.

4 Extracting Features

To create useful reports from the collected data, specific areas or test plots may be marked and used to track values such as percentage of vegetation cover or number of plants in that plot over time. This can help to reveal critical issues related to species performance, soil conditions, or other factors that may be influencing plant health. Identifying these patterns allows for targeted interventions, and may improve overall project outcomes.

5 Analysis

Spatial analysis



i) Vegetation indices calculated from aerial mapping ii) Segmentation with binary mask, iii) Vector geometry created for measurement, iv) Plant locations identified and labelled.



Aerial Mapping Software

SOFTWARE	COST	CAPABILITIES	GAPS & LIMITATIONS
DJI Terra	\$2000+	Aerial mapping, vegetation indices, 3D output.	Professional grade software. High cost.
DroneDeploy Aerial	\$4000/y	Professional and user-friendly software for deploying drones for analysis.	Online-only. High cost.
WebODM	\$0.00	Open-source with capability for aerial mapping and vegetation indices.	Requires powerful computer hardware to run locally. Cloud processing is available at a cost.



Vegetation/Crop Analysis Software

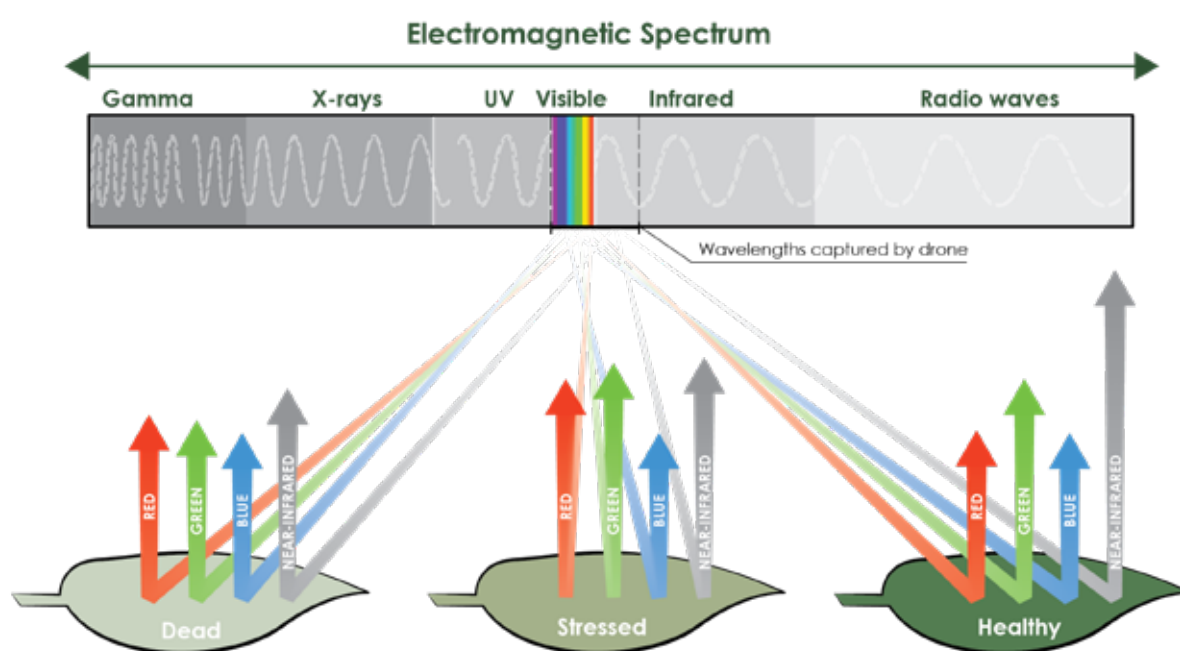
SOFTWARE	COST	CAPABILITIES	GAPS & LIMITATIONS
ARCGIS	\$165/y	GIS software with extensive tool suite. Industry standard.	Use of proprietary file formats and data. Moderate cost.
QGIS	\$0.00	Open source GIS software with potential for vegetation mapping.	Some ARCGIS processing tools and capabilities not available.
Pix4D Fields	\$3180/y	Web or offline platform for agricultural analysis.	Relatively high cost for non-agricultural use cases.
Solvi	\$900+/y	Powerful automated agricultural analysis tools including counts.	Must pay per area unit for analysis (per ha).

Understanding multispectral data

Multispectral data captures information across multiple wavelengths of light beyond the visible spectrum, providing critical insights into vegetation health, soil conditions, and environmental performance that are not detectable through standard images.

What does multispectral mean?

As part of this project, drone-mounted multispectral cameras were used to capture data beyond what is visible to the human eye. Visible light, what we perceive as colour, is only a small portion of the broader electromagnetic spectrum. Multispectral sensors detect reflected light in discrete wavelength bands, including but not limited to those in the visible range. These bands are aligned with specific wavelengths such as blue, green, red, and near-infrared (NIR), allowing us to record information that can reveal subtle differences in vegetation condition not discernible through standard photography.



Vegetation reflectance for stressed and healthy vegetation - adapted from di Fisica et al 2022

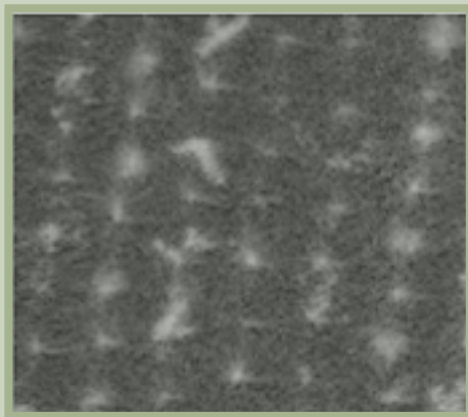
Vegetation reflectance

The relative reflectance of different wavelengths varies depending on plant health. Healthy vegetation strongly reflects NIR light and absorbs visible red light due to the presence of chlorophyll, resulting in high vegetation index values. Stressed or dead vegetation reflects less NIR and more visible red light, leading to lower index readings. Indices such as the Normalised Difference Vegetation Index (NDVI) or the Optimised Soil-Adjusted Vegetation Index (OSAVI) use ratios of these spectral bands to quantify plant health. By comparing reflectance across these bands, we can spatially identify areas of decline, stress, or robust growth, enabling more targeted management responses and long-term monitoring of landscape performance.

Multispectral Indices

Multispectral images captured by drones or satellites can produce various indices that provide valuable information about the health and characteristics of vegetation, soil, and water bodies. These indices are typically derived from different combinations of specific spectral bands, such as visible light RGB, near-infrared (NIR), and red-edge bands. While there are some conventions for representation with false colour for interpretability, these indices represent a range of values on a single scale.

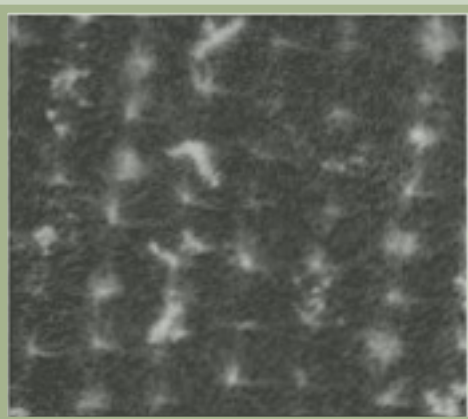
* **NIR = Near-infrared, R = Red, G = Green**



Normalized Difference Vegetation Index

$$\text{NDVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R}}$$

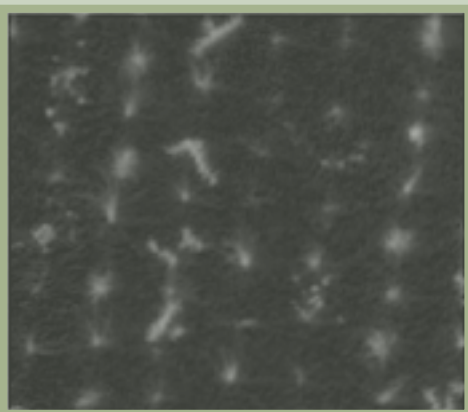
■ Measures the health and density of vegetation by comparing the red and NIR bands. Healthy vegetation reflects more NIR light and absorbs more red light, leading to higher NDVI values.



Green Normalized Difference Vegetation Index

$$\text{GNDVI} = \frac{\text{NIR} - \text{G}}{\text{NIR} + \text{G}}$$

■ Uses the green and NIR bands to assess plant health, particularly chlorophyll content, making it useful in early vegetation growth stages.



Optimized Soil-Adjusted Vegetation Index

$$\text{OSAVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R} + 0.16}$$

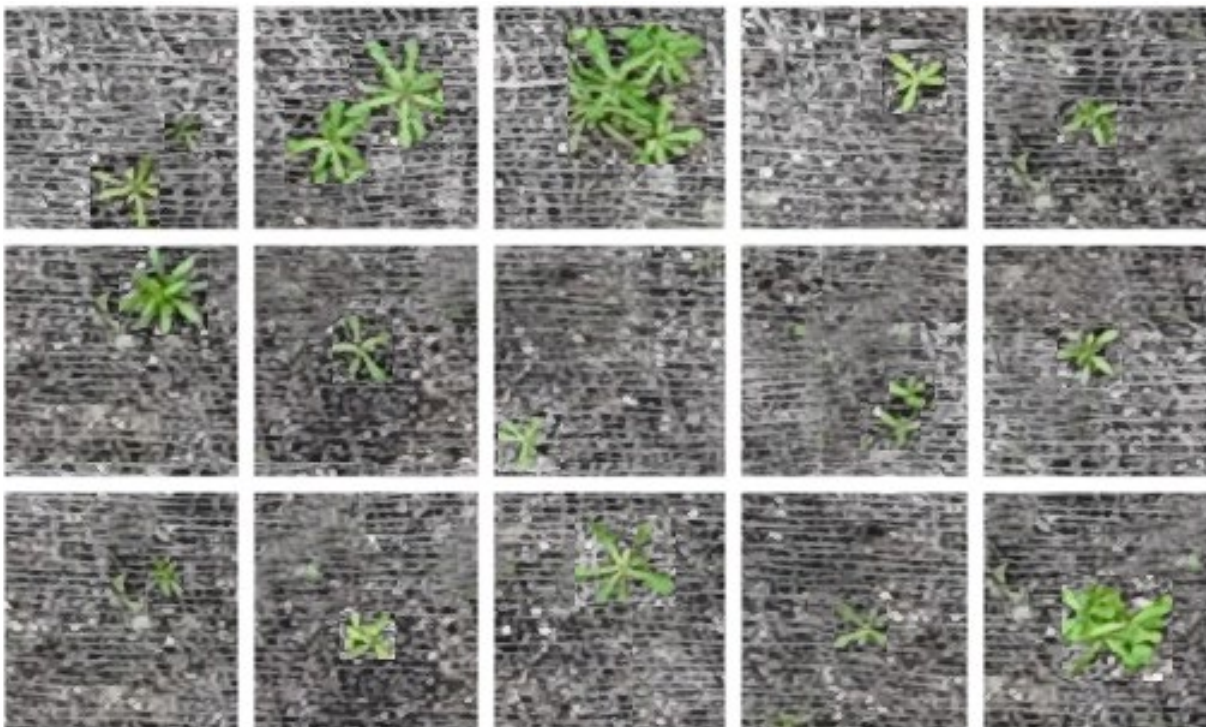
■ Is designed to minimize the influence of soil brightness on vegetation indices. OSAVI is particularly effective in areas with sparse vegetation where soil visibility might distort the vegetation signal.

AI & machine learning tools

Artificial intelligence (AI) can be used to automate some vegetation analysis tasks from aerial imagery. Models can be trained from labelled data to detect plant locations, identify species, or predict health status using multi-spectral or RGB imagery.

Training data

Machine learning methods require substantial, well-labelled training data to identify complex patterns that enable detection. For vegetation applications, this may include annotated images showing individual target plants, weed species, soil backgrounds, and other context elements. Data diversity is critical: different lighting conditions, growth stages, and plant health states should be represented. Each image must be paired with precise labels, bounding boxes, or segmentation masks. Generating this data can be labour-intensive, but it directly influences model accuracy and generalisation to new sites. Augmentation techniques (flipping, scaling, color shift) can help expand datasets without requiring additional annotation.



Labelled image examples to train a weed detection model

Object detection

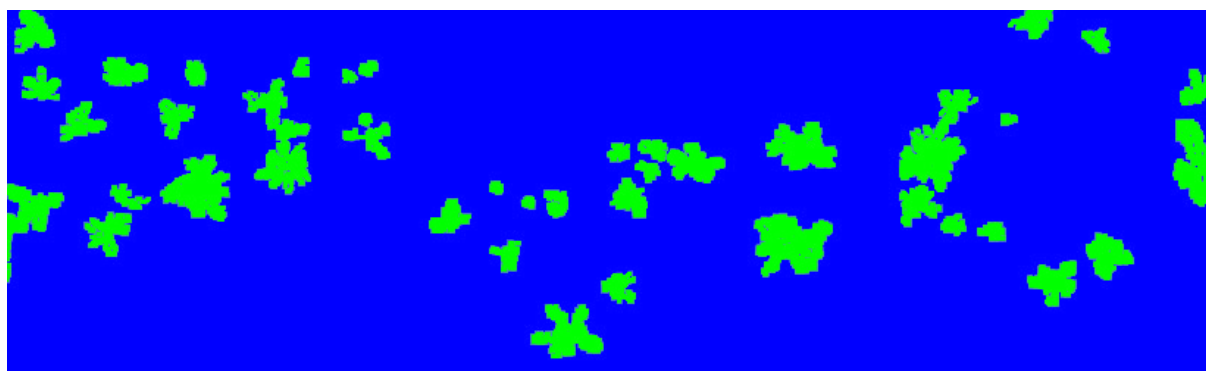
Object detection models can be used to identify and count individual plants in images. These models work by scanning imagery and drawing bounding boxes around detected objects that match patterns in training data. Trained on images of known plant forms, these models can be used to count seedlings, track survival, or identify weeds. Clear, labelled training data is needed. Detection accuracy varies with image quality and species distinctiveness but can be improved with additional training.



Weed detection using YOLOv5

Segmentation

Semantic segmentation algorithms can be used to divide an image into regions classified as vegetation, soil, mulch, or other categories. Tools such as U-Net or DeepLab use convolutional neural networks to produce pixel-wise masks that highlight plant material. Compared to manual cover estimation, segmentation may be a more scalable method. When combined with time-series imagery, cover dynamics may be quantified to support site management decisions and assess the success of planting interventions.



Segmented aerial image showing weeds highlighted against soil background

Future of AI tools

Advances in AI tools continue to transform this space. The number and quality of training examples required for accurate detection and identification of objects such as weeds or specific plant species are decreasing as models and techniques are improved. New AI coding tools make the development of custom implementations more accessible than ever. The availability of open datasets such as WEED-AI hosted at the University of Sydney allows for collaborative development and sharing of the labour involved in creating high quality labelled training data. With continued developments the use of digital technology for plant monitoring will undoubtedly continue to grow over the coming decades.



Pilot Studies



Monitoring pilot study projects

These projects were used as pilots for the testing of spatial data collection using digital technologies. The sites featured in this report are all landscape architecture projects or experimental planting trials undertaken by Hassell as landscape architects with contributions from a range of clients, consultants, landscape contractors, and researchers.

Project locations

The trial sites were located across south-eastern Australia, including projects in Sydney, Melbourne, and Canberra. These sites span a diverse range of climate conditions, soil types, and urban contexts, and also vary in scale, from small demonstration plots to larger public landscapes, allowing for a broad understanding of plant establishment and landscape performance under different constraints.



Location of pilot project sites across south-eastern Australia (NSW, ACT, VIC)

Timeline

	2022				2023				2024				2025			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Site 1			P													
Site 2											P					
Site 3							P					P				
Site 4												P				
Site 5													P			
LFA Grant																

1 Sydney Metro Trial, Castle Hill, NSW



2 Green Track Prototype, National Arboretum, ACT



3 AMRF First Building, Bradfield, NSW



4 MAPT Trial Roof Garden, Burnley, VIC



5 Sydney Metro Trials, Orchard Hills, NSW



Pilot Study 1:

Sydney Metro Planting Trial, Castle Hill



A collaboration between Sydney Metro, Hassell & the University of Melbourne, the planting trials at the Castle Hill Showground Metro Station were established to guide species selection and inform maintenance practices for future Metro projects across Sydney.

Existing planting in the Hills Showground Station plaza was replaced with a highly diverse, floral naturalistic planting of woody, grassy and herbaceous species. Designed to achieve a biodiverse public landscape with minimal maintenance inputs, the plants were monitored to assess high and low performing species and mixes, and a learnings report was developed to inform the design of future transport landscapes across Sydney.

Now installed for over two years, the trials have enabled the observation of vegetation growth and change over a number of repeat seasons. This has provided valuable data on flowering time and length, inter-species competition and the persistence of species beyond establishment including self-sowing.

PROJECT NAME: Sydney Metro Planting Trials

TYOLOGY: Planting Trial/Prototype

LOCATION: Castle Hill, Sydney

CLIENT: Sydney Metro

DESIGN TEAM: Hassell, University of Melbourne

COMPLETED: 2021

SCALE: Medium

AREA: 6,000m²

NO. OF PLANTS: 1750

MONITORING PERIOD: 18 months

PERFORMANCE CRITERIA:

Vegetation cover, species survival

DATA COLLECTION: Photographic, point-cloud



Monitoring process

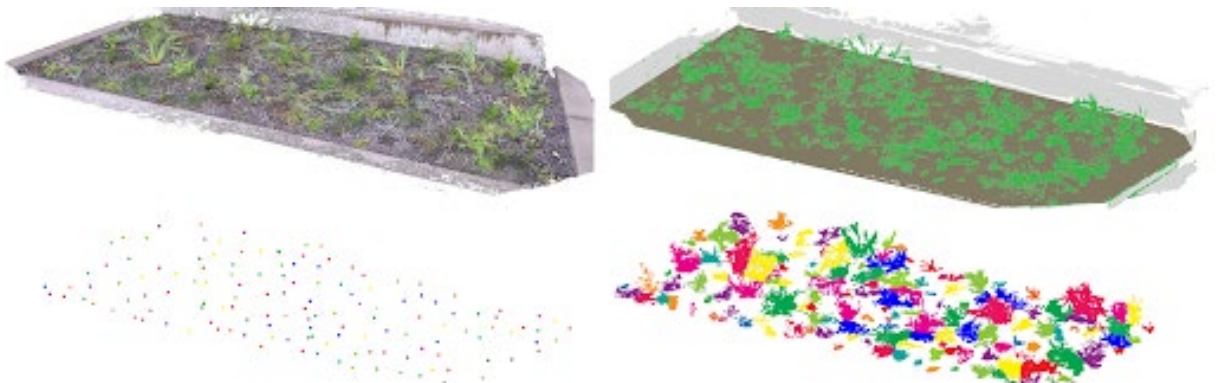
This initial digital monitoring pilot utilised ground-based photographic surveys only, as aerial and multispectral data were not available. Photogrammetry was employed to create detailed 3D models of a sample of planting on site, with a series of captures taking place over 18 months. Each point cloud was segmented to isolate individual plant specimens, which were subsequently analyzed to assess growth and change. This preliminary effort served as a foundational trial to evaluate the feasibility of photogrammetric techniques in plant monitoring.

Photogrammetry



Raw point clouds captured over the trial period showing progression of plant growth and seasonal change over time. These were captured using a Samsung Galaxy S20 FE phone camera and processed in RealityCapture.

Segmentation



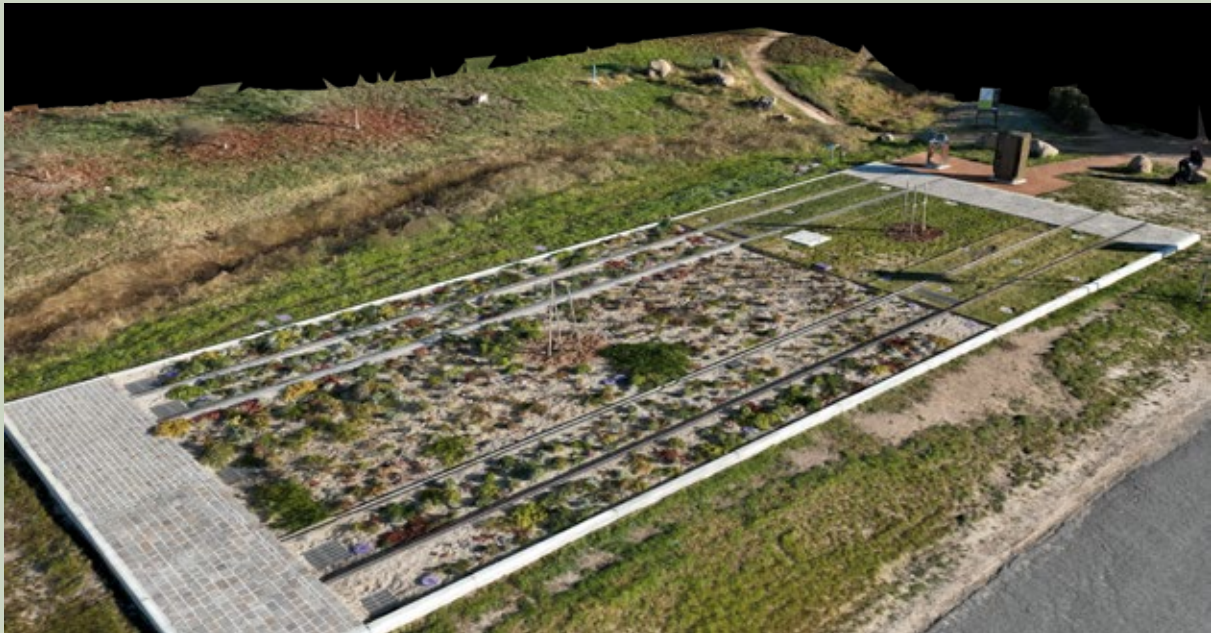
Point cloud including colour data produced in RealityCapture from images taken on site; ii) point cloud segmented in CloudCompare into concrete, soil and vegetation classes; iii) seed locations identified from orthophoto to define start points for plants; iv) point cloud segmented into individual plants.

Outcomes

This project shows what is achievable without any specialised equipment or additional cost. The methodology tested provides a high resolution of spatial data, enabling detailed spatial monitoring of urban vegetation. Planning camera paths and conducting scans at regular intervals demands careful attention and may necessitate significant time investment. Environmental conditions, such as poor lighting, rain or strong winds, can prevent the capture of sufficient quality images to produce point clouds. Handling, registering, and processing large point cloud datasets can be computationally intensive and time-consuming, requiring software licensing and expertise. The time series aspect of the methodology offers unique advantages. It permits the tracking of vegetation growth in space over time, aiding in the assessment of growth patterns, plant health, and responses to environmental variables. These time-captures may provide an aid in the understanding of plant growth to designers and managers.

Pilot Study 2:

Green Track Prototype, Canberra



The Green Track Prototype (GTP) represents an innovative approach to integrating green infrastructure into urban transit systems. This trial focuses on identifying plant species capable of thriving in Canberra’s challenging environmental conditions, including frosts and extreme heat, while growing directly beneath a moving rail vehicle.

45 plant species were tested in a variety of conditions including soil types, irrigation strategies, and rail systems. To date, three months of data have been collected from the site, with plans to introduce a new set of plants in September. The project investigates species performance and vegetation cover, supported by detailed data collection and on-site tracking.

Although the trial area is relatively small, it provides critical insights into plant behavior under these unique conditions. The plots include approximately 1,750 plants across 40 species, a mix of native and exotic herbaceous groundcovers and succulents. The outcomes from this prototype trial will directly inform species selection for the broader light rail project, ensuring a resilient and sustainable planting strategy.

PROJECT NAME: LRS2A Green Track Prototype
TYPOLOGY: Planting Trial/Prototype
LOCATION: National Arboretum, Canberra
CLIENT: CMC/iCBR
DESIGN TEAM: Hassell, AECOM (reference design), Aurecon
COMPLETED: 2023
SCALE: Small
AREA: 200m2
NO. OF PLANTS: 1750
MONITORING PERIOD: 18 months
PERFORMANCE CRITERIA: Vegetation cover, species performance
DATA COLLECTION: Multispectral, quadrats

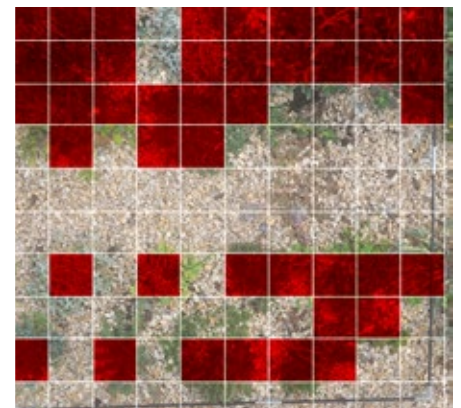
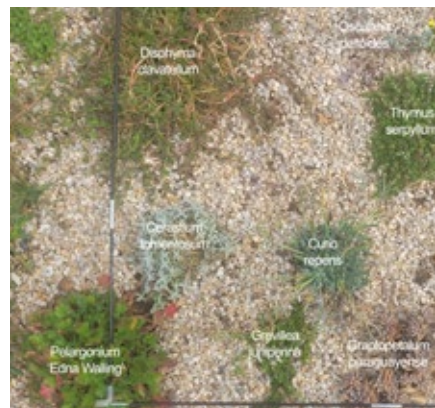
DRONE PARAMETERS	
System	DJI Mavic M3E
Survey Area	200m2
Altitude	RL + 12.00
Flight Time	8m
GSD	0.5cm
Speed	2m/s
Forward Overlap	70%
Layers	MS/RGB
FOV	15°
Image Processing	OpenDroneMap
Flight Planning	DJI Pilot 2

Monitoring process

This pilot included a wide range of vegetation survey techniques, including qualitative species observations, manual counts, sample counts with quadrats and aerial mapping assessment of vegetation cover, plant quantities and plant height. Site visits were conducted approximately every 2 months to capture a range of seasons and identify performance issues before failure.

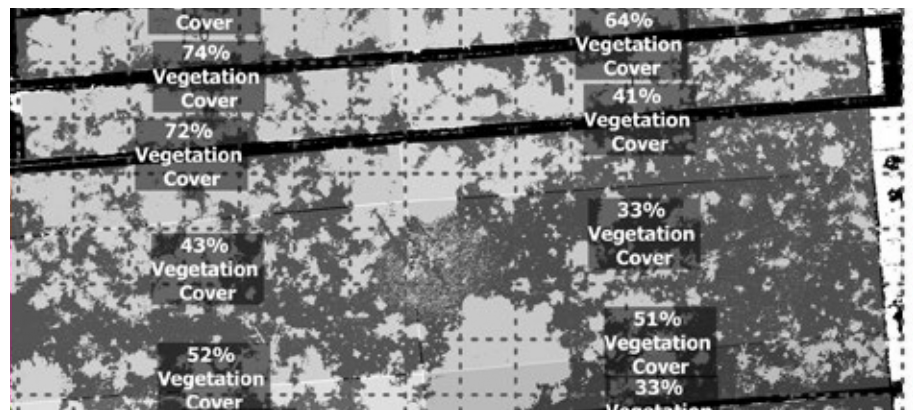
Quadrats

A series of detailed 1m x 1m sample quadrats were studied to track plant performance across the duration of the trial, and assess species survival, plant density and vegetation cover.



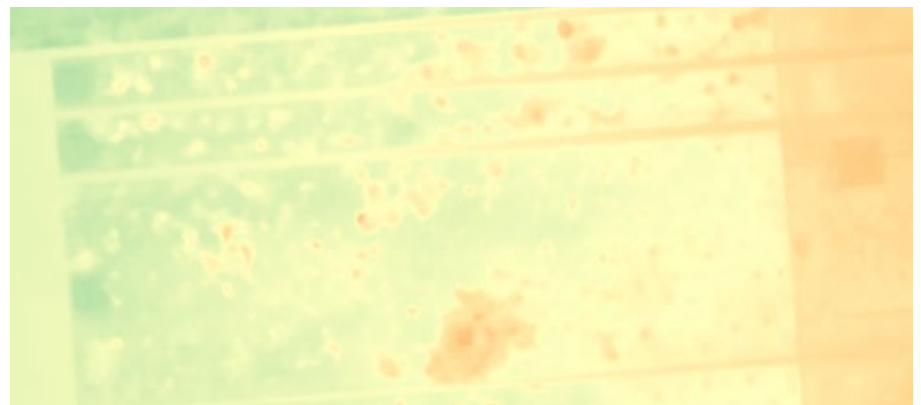
Vegetation Cover

Multi-spectral image capture was used to assist in planted track assessment and identify areas of vegetation cover using the Optimised Soil and Vegetation Index (OSAVI).



Plant Height

A digital terrain model (DTM) and digital surface model (DSM) were used to record the height of plants above the rail, as this would be a key consideration in selecting plant species for this area.



Outcomes

The combination of quadrat surveys, ground-based photogrammetry and multi-spectral aerial mapping provided a comprehensive record of plant survival and success at the prototype. This data was used to inform the evidence-based selection of species to be used in the final design. Detailed site models can be revisited at any time to explore the changes that have transformed the site.

Pilot Study 3:

AMRF First Building, Bradfield



AMRF First Building - Image: Hassell / Vinchy Wu

The project aims to celebrate the Cumberland Plain through immersing users and activities within a richly planted, permeable ground plane of local, underused species. This will play an important role in re-establishing an ecological identity for the site and set an important precedent for future development of Bradfield.

In 2024, the AMRF First Building in the new city of Bradfield came to life with the installation of around 69,000 plants, including over 120 species indigenous to the Cumberland Plain. This vibrant mix included over 1,000 plants grown from seeds collected on-site, and a number of whole salvaged plants and habitat logs. A standout feature is the extensive green roof, planted with 1,400m² of native grassland. The ground level includes rich, flowering grassland meadows established through a combination of tubestock and seed.

PROJECT NAME: AMRF First Building, Bradfield

TYOLOGY: Public Landscape

LOCATION: Bradfield City Centre, NSW

CLIENT: Bradfield Development Authority

DESIGN TEAM: Hassell, Jiwah

CONSTRUCTION: Taylor, Precision, Three Owls

COMPLETED: 2024

SCALE: Medium

AREA: 9,000m²

NO. OF PLANTS: 69,000

MONITORING PERIOD: 12 months

PERFORMANCE CRITERIA: Vegetation cover, species survival, species cover change

DATA COLLECTION: Multispectral, ground truth

DRONE PARAMETERS

System	DJI Mavic M3E
Survey Area	200m ²
Altitude	RL + 20.00
Flight Time	21m
GSD	0.5cm (Roof)
Speed	3m/s
Forward Overlap	70%
Layers	MS/RGB
FOV	15°
Image Processing	WebODM
Flight Planning	DJI Pilot 2

Monitoring process

The aerial monitoring of the AMRF landscape focused primarily on the establishment of the extensive green roof. Aerial photos captured by a DJI Mavic M3E Drone were used to reconstruct a 3D point cloud of the site at monthly intervals during construction. This high detail model was valuable in coordinating and reviewing the construction process on site.

Multispectral

Multispectral imagery was captured with a DJI M3E and used to produce a variety of indices for analysis including NDVI, OSAVI and NDWI. This was useful in tracking the success of seeding.



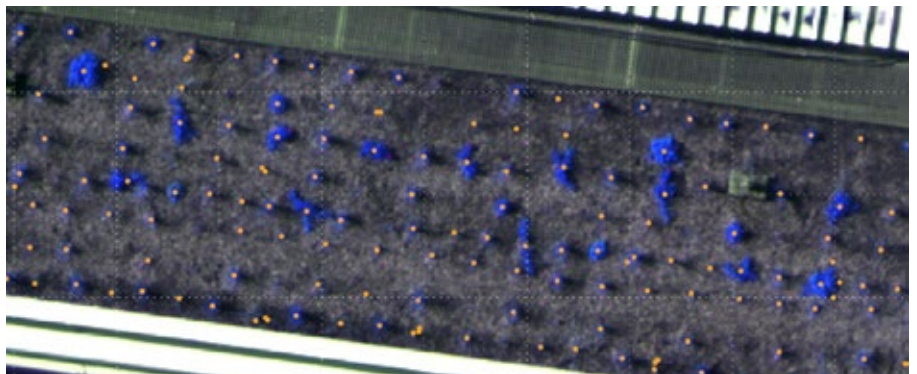
GIS Analysis

A series of GIS processing steps were developed to take collected multispectral, RGB and 3D photogrammetric data and analyse areas of the site to track the number of individual plants and vegetated ground cover over time.



Plant Counts

Plant counts were generated from aerial mapping, both to track planting performance and failure over time, and to validate planting densities at a 1m grid resolution across the site.



Outcomes

This pilot demonstrates the effectiveness, and the challenges of implementing these methods on a real project during construction rather than a controlled trial. Coordination was required with site managers as staged works were completed. Variations in substrate and lighting required calibration for accurate monitoring of different areas across the site. Although there are logistical challenges to survey on a live site, drone technology in construction is becoming increasingly common and can be accommodated, providing significant value in quality assurance and management.

Pilot Study 4:

MAPT Trial Roof Garden, Melbourne



Laak Boorndap will be a biodiverse, highly dynamic, multi-layered garden created at Melbourne’s National Gallery of Victoria.

The trial roof garden at the University of Melbourne's Burnley campus serves as a preliminary investigation to gather data for plant species to be used in the creation of a highly diverse and floral public garden Laak Boorndap at the NGV, designed by Hassell in partnership with New York’s SO-IL, world-renowned horticulturalists Nigel Dunnett and James Hitchmough, and plant expert Jac Semmler from Melbourne company Super Bloom. The planting trials conducted by University of Melbourne staff (Claire Farrell, John Rayner, Dean Shrieke) consist of three plots with varying soil depths (100mm, 150mm, and 200mm), planted with 75 species arranged in a randomized matrix. This two-year trial, initiated in October 2024, is Phase 1 of a larger research program to evaluate growth characteristics, species performance, flowering times and plant traits for the Melbourne Arts Precinct Transformation and Laak Boorndap.

PROJECT NAME: MAPT Trial Roof Garden
TYOLOGY: Planting Trial
LOCATION: University of Melbourne, Burnley
CLIENT: NGV, Development Victoria
DESIGN TEAM: Hassell, University of Melbourne, Superbloom, J. Hitchmough, N. Dunnett
COMPLETED: 2024
SCALE: Small
AREA: 48m2
NO. OF PLANTS: 900
MONITORING PERIOD: 24months
PERFORMANCE CRITERIA: Plant counts, individual plant statistics
DATA COLLECTION: Multispectral, RGB

DRONE PARAMETERS	
System	DJI Mavic M3E
Survey Area	48m2
Altitude	RL + 10.00
Flight Time	4m
GSD	0.5cm
Speed	2m/s
Forward Overlap	70%
Layers	MS/RGB
FOV	15°
Image Processing	OpenDroneMap
Flight Planning	DJI Pilot 2

Monitoring process

While the planting trial is ongoing into 2026, two monitoring visits were undertaken to Burnley as part of the pilot study, with a multi-spectral drone survey conducted at 3-month intervals. Intensive horticultural research is being conducted by the UOM team, providing an opportunity in the future to compare aerial mapping data including vegetation cover, plant counts, plant measurements and zonal statistics to accurate on-site measurements from the trial.

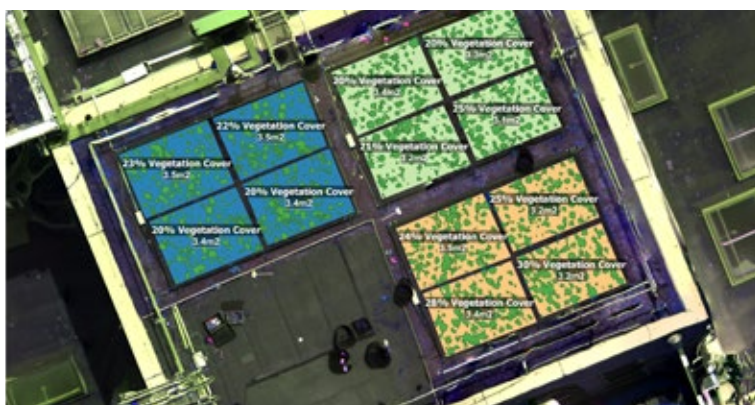
Trial Plots

Aerial view of the trial plots with three soil depths: 100mm, 150mm, and 200mm. Each plot contains a randomized arrangement of 75 plants representative of the species to be used in Laak Boorndap. These include a wide variety of native and exotic species not in common use.



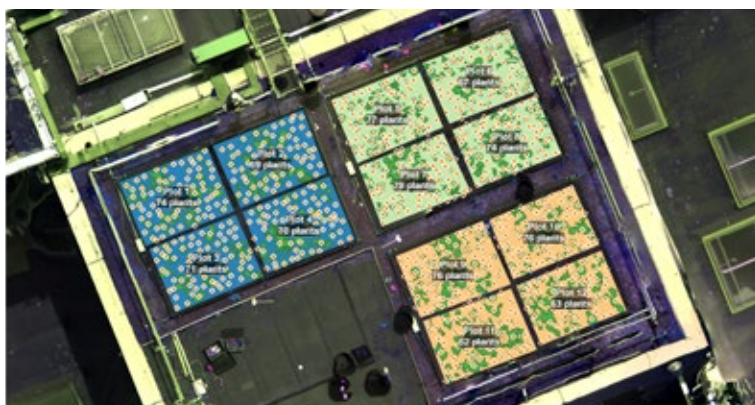
Vegetation Cover

Example of segmentation analysis for vegetation cover. The OSAVI index was used to differentiate living plant tissue from soil background using multispectral data. Consistent soil media with no mulch enabled soil segmentation, but the highly diverse plant palette proved challenging.



Plant counts

Following the segmentation of aerial maps into vegetation and background layers, individual plants were located and compared to validated counts. This site demonstrated some of the challenges with installation of larger plants at high density that may be overlapping in many locations.



Outcomes

This pilot provides a valuable opportunity to validate analysis produced using the drone-based methods proposed in this report against known installation quantities and detailed monitoring records produced by expert horticultural researchers at the University of Melbourne. The trial demonstrates the potential of digital tools to streamline data collection and analysis, with some areas showing accurate counts with minimal manual adjustment. Further validation of drone-based data is required particularly in cases of high density or diversity.

Pilot Study 5:

Sydney Metro Trial, Orchard Hills



The second phase of planting trials for Sydney Metro is underway at Orchard Hills, preceding the construction of the Western Sydney Airport Metro stations. These trials include a range of different plant mixes, mulches and substrates to inform the final landscape design and management of the project.

Following the success of the planting trials at Castle Hill Showground Metro from 2021-2023, a second trial phase was developed to inform the planting species and management techniques to be used in the Sydney Metro Western Sydney Airport station plazas, corridors and facilities. Building on Phase 1, this trial includes the use of a variety of substrates and mulches to determine their effectiveness in reducing management inputs.

A diverse palette of plant species were installed in containers, by hydromulching and by hand-broadcasting of native seed. Many of these species are indigenous to the local area. A variety of low-input management and construction techniques are planned for the trial, including seasonal slashing, and oversowing of native seed mixes. The intent is to demonstrate and record the required inputs to achieve a biodiverse, flowering landscape in an urban setting within the Cumberland Plain.

PROJECT NAME: Sydney Metro WSA Trial
TYOLOGY: Planting Trial
LOCATION: Orchard Hills, NSW
CLIENT: Sydney Metro, Webuild
DESIGN TEAM: Hassell
CONSTRUCTION: Regal Innovations, Webuild
COMPLETED: 2025
SCALE: Small
AREA: 200m2
NO. OF PLANTS: 1,200
MONITORING PERIOD: 12 months
PERFORMANCE CRITERIA: Vegetation cover, species survival, species cover change
DATA COLLECTION: Multispectral, ground truth

DRONE PARAMETERS	
System	DJI Mavic M3E
Survey Area	200m2
Altitude	RL + 12.00
Flight Time	9m
GSD	0.5cm
Speed	2m/s
Forward Overlap	70%
Layers	MS/RGB
FOV	15°
Image Processing	OpenDroneMap
Flight Planning	DJI Pilot 2

Monitoring process

The methods used for monitoring the trial include monthly manual counts and ground-truths, with 3-monthly aerial mapping surveys. Parameters investigated by the aerial survey included vegetation cover, and species survival. Tests were also conducted to identify weed presence and locations using aerial photographs and machine learning tools. In this case the dominant weed species was *Senecio madagascariensis* (Fireweed). Given the small size of the individual trial plots in raised beds (3 x 2m), the use of quadrats was not necessary.

Trial Setup

The planting trial includes multiple variables such as plant species mixes, substrate and installation method. By embedding this information in the GIS model these can be analysed against performance.



Cover

Vegetation cover was tracked as in other pilots using OSAVI and a threshold mask. Unlike other pilots, a wide range of substrates had varying soil reflectance, and large areas of weed growth needed to be separated from desirable vegetation.

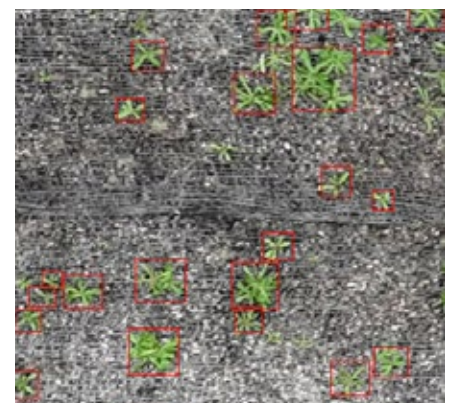


Plant Survival

Individual plant survival and failures were tracked for each trial plot over time.

Weeds

Weed recognition was trialled using YOLO v5 with a training set of images taken from site.



Outcomes

While the planting trials are yet to be completed, early testing demonstrates the potential for aerial mapping to assist in monitoring both of the test plots and the completed landscape, which covers more than 10 km of surface corridor works and station plazas. The identification of weeds is likely to be an asset in this application, however it was noted that seedlings of multiple species are very challenging to differentiate even with good training data.

Key lessons learned

The Aerial Analytics project was successful in demonstrating the potential for drones and new spatial data tools to provide valuable insights into the success of urban plantings. Additional research, pilot projects and industry consultation will continue to improve results.



Plan for success

Clearly defining goals at the outset of any project is crucial. Define performance at the beginning, what does good look like and how is it going to be measured. This could be a percentage of vegetation cover at 6 months, or a number of plants per m2 surviving establishment. Success should be defined with measurable outcomes and a clear timeline. This ensures that the project remains focused and all stakeholders are aligned.



Create consistent data structures

Maintaining uniformity in data structure and formatting is essential for keeping the project on track. Set up checklists, GIS base-files and reporting templates before commencing monitoring. Consistency allows for easier comparison and more reliable insights, whether using georeferenced aerials or consistent camera angles.



Validate data with manual measurements

Spatial analysis results will vary from site to site, affected by soil colour and moisture, and potentially weather conditions and time of day. Implementing a site validation process is vital. By setting up detailed areas for manual measurements to check against aerial survey outcomes, you can make sure larger-scale analyses are consistent with reality on site.



Collaborate with experts

Engaging with qualified experts in fields like soil science and horticulture is invaluable. Their insights help validate findings and ensure that projects benefit from a comprehensive understanding of the site and conditions. Collaborating with these experts ensures that projects are grounded in scientific knowledge, practical expertise, and sustainability, leading to better long-term outcomes for vegetation management and site development.

"we must be careful with an overabundance of "unfiltered" data. As history, has clearly shown us, evidence and data do not immediately translate into evidence based practice."
(Claridge 2005)



Keep track of environmental data

Recording site conditions like wind, rain, and minimum and maximum temperature throughout the test period is critical. This data can be correlated with plant performance, providing insights into how different conditions affected growth and success. Conditions during the time-frame may be typical or outliers for the subject site.



Confirm site access strategy

Planning for access to site and permissions is critical to complete a successful survey program. Ensure all stakeholders are informed and that information sharing is transparent. Leave some allowance for rain-checks in the project program as weather conditions may prevent aerial mapping.



Drones are powerful and accessible

Using drones offers significant advantages, such as geolocation capabilities that facilitate easy time-series comparison, and the ability to cover large sites quickly. Today they are accessible with minimal training and provide high-resolution images. However, the cost of both software and hardware and investment in time to develop skills may be a barrier for small organisations.



Plan for outcome utilisation

Early planning on how to utilise trial outcomes is essential. Make a plan early on for how to transfer learnings back to design or onto future projects. What outputs will enable this knowledge transfer? Whether it be through reports or datasets, having a clear plan ensures that the knowledge gained is effectively shared and utilized.

Further Resources

1. A Landscape Performance + Metrics Primer For Landscape Architects - Emily McCoy (ASLA)
2. Drone Futures: UAS in Landscape and Urban Design - Paul Cureton
3. Drone Technology in Architecture, Engineering, and Construction - Daniel Tal, & Jon Altschuld
4. Evaluating Landscape Performance: A Guidebook for Metrics and Methods Selection - Canfield, Yang, Whitlow
5. Biodiversity in Place, GANSW State of New South Wales - Department of Planning, Housing and Infrastructure
6. Drones in Australia, Department of Transport - <https://www.drones.gov.au>
7. Civil Aviation Safety Authority (CASA) - <https://www.casa.gov.au/>
8. Drone Technologies for Conservation. WWF Conservation Technology Series



About the author

Michael G. White is a lecturer in landscape architecture and PhD Candidate at UNSW, and an Associate Landscape Architect at Hassell. His research explores the application of digital technologies and simulation to planting design and living systems. Working at the intersection of design, ecology, and digital systems, he draws on both site experience and research to investigate evidence-based design practices, urban biodiversity and habitat creation, the development of custom software tools, and the design and documentation of major landscape projects using BIM.

Glossary

DSM (Digital Surface Model): A digital representation of the Earth's surface that includes all natural and built features such as trees and buildings.

GIS (Geographic Information System): GIS is a system that allows for the capture, storage, analysis, and visualization of spatial and geographic data to understand patterns and relationships.

GNDVI (Green Normalized Difference Vegetation Index): GNDVI is a vegetation index similar to NDVI but uses green light instead of red light to better capture photosynthetic activity and plant health.

GNSS (Global Navigation Satellite System): A satellite-based system that provides geolocation and time information anywhere on Earth.

GSD (Ground Sampling Distance): the distance between the centers of two consecutive pixels on the ground, as captured by the drone's camera. It determines the spatial resolution of the imagery; a smaller GSD value indicates higher detail and resolution in the map or model.

LiDAR (Light Detection and Ranging): LiDAR is a remote sensing method that uses laser pulses to measure distances and generate precise, 3D information about the shape and surface characteristics of the Earth.

Multispectral: Multispectral imaging captures data at different wavelengths across the electromagnetic spectrum, typically using sensors that record specific bands like visible, infrared, and near-infrared light.

NDVI (Normalized Difference Vegetation Index): NDVI is a commonly used remote sensing index that measures vegetation health and density by comparing the difference between near-infrared and red light reflectance.

NIR (Near-Infrared): NIR refers to the part of the electromagnetic spectrum with wavelengths just beyond visible red light, commonly used in remote sensing to detect plant health and water content.

OSAVI (Optimized Soil-Adjusted Vegetation Index): OSAVI is a vegetation index that improves on NDVI by adjusting for the effects of soil brightness, providing more accurate assessments of vegetation in areas with sparse plant cover.

Photogrammetry: Photogrammetry is the science of obtaining measurements and creating maps or 3D models from photographs, commonly used in surveying, remote sensing, and 3D modeling.

QGIS (Quantum Geographic Information System): QGIS is an open-source geographic information system (GIS) software that allows users to visualize, analyze, and manage spatial data and create maps.

RGB (Red, Green, Blue): RGB represents the three primary colors of light in digital imaging, and RGB images are composed of these colors to produce full-color representations of scenes or objects.

RTK (Real-Time Kinematic): RTK is a satellite navigation technique used to enhance the precision of position data, achieving centimeter-level accuracy by correcting GPS signals in real-time.

UAV (Unmanned Aerial Vehicle): An aircraft operated without a human pilot onboard, commonly used for aerial data collection and remote sensing.

Vegetation Cover: Vegetation cover refers to the proportion of land surface covered by plants, including trees, shrubs, and grasses, often used to assess ecological health and land use.

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Credits & Contributors

Primary Investigator: Michael G. White

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Landscape Foundation of Australia Board:

Linda Corkery	Chris Champion	
Noel Corkery	Catherin Bull	Kieran Power

Consultation Group:

Hassell	Transport NSW & Sydney Metro	University of Melbourne
Jon Hazelwood	Andrew Brophy	A/Prof John Rayner
Sam Westlake	Lee Andrews	A/Prof Claire Farrell
Andrew Ewington	Darren Mansfield	Dr Benjamin Wagner
Andreasens Green	Leigh Trevitt	Dr Rachael Bathgate
Darren Mason	Habitat Solutions	MCQ
University of New South Wales	Joel Hall	Dr Caragh Threlfall
Dr Joshua Zeunert	Will Thurston	Professor Michelle Leishman

