Which Plant Where

How to measure your Urban forest

A best practice guide to establishing a tree inventory

NOVEMBER 2021

ACKNOWLEDGEMENT OF COUNTRY

We acknowledge Aboriginal and Torres Strait Islander peoples as the First People and traditional custodians of the land and waters of this place. We express our gratitude in sharing this land, our sorrow for the personal, spiritual and cultural costs of that sharing, and our hope that we may walk forward together in harmony and the spirit of healing.

We acknowledge the importance of Aboriginal custodial and cultural connection to place, which is embodied in the term 'Country'. 'Caring for Country' is used to describe ongoing stewardship of and responsibility for the land and seas by First Peoples.

We recognise the ecological knowledge of Aboriginal people that has developed from thousands of generations of careful, sustainable land management practices. This knowledge can be harnessed to protect and enhance our urban forest, water, biodiversity and soil. There is an opportunity for Aboriginal values around Country to co-exist alongside scientific and mainstream land management approaches.

FIGURE 1 Welcome ceremony at Macquarie University – situated on the land of the Wallumattagal clan of the Dharug Nation *(Image owned by Macquarie University)*

WHICH PLANT WHERE

is a culmination of 5 years of research investigating which horticultural species will survive in Australian urban landscapes, not only now but under future climates. The project is underpinned by the latest scientific evidence, providing growers, nurseries, landscape architects and urban greening professionals with the integrated tools and resources needed to develop resilient and sustainable urban green spaces for the future.

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ORGANISATIONS

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01. INTRODUCTION

Trees provide a multitude of ecosystem services for our cities and their inhabitants, from temperature reduction to improved health and wellbeing. To ensure these services are maximised, cities require healthy, functioning and diverse urban forests. Increased temperatures and shifts in rainfall patterns due to climate change are putting pressure on our existing urban forest, and some species that have succeeded in the past may fail to do so in the future. It is vital that we put resources towards maintaining and monitoring our urban forests to ensure they are resilient and can adapt to climate change.

Good data is critical for decision-making and strategic planning in any organisation. It can provide valuable insights into the quality and value of an asset and uncover underlying issues or barriers to success. This approach also applies to our urban forests. To maximise the environmental, economic and social return of these natural assets, we need to know what we have, how it performs, and what resources are required to maintain them through the life cycle of these assets. It is crucial to identify and quantify successes and failures in urban settings as this can help policymakers and urban forest managers to optimise use of resources and minimise losses when investing in urban forestry programs.

This best practice guideline provides an easy-to-follow process for undertaking and implementing a best practice tree inventory for your urban forest. This guide aims to assist local councils to apply basic principles consistently so that:

- a standardised measuring and monitoring method can be implemented across multiple organisations
- tree species' suitability to changing local conditions can be tested, measured and evaluated
- councils can collaborate, and results can be compared among different locations
- knowledge can be shared to increase species diversity and enhance urban forest resilience
- resources can be maximised by collecting key data according to specific objectives

Most Councils are recognising trees as assets in their operational planning and maintenance programs and manage their trees with a 'whole of life' asset management approach. This ensures that risks from trees are managed and that costs associated with maintaining trees over their life cycle are accounted for. This asset management approach can be further enhanced by adding measurement and monitoring to the cycle. This is illustrated in Figure 2.

FIGURE 2 The strategic 'whole of life' tree asset management cycle.

"You need to know what you have to know how to manage it."

02.
BEFORE YOU GET STARTED

It is essential to first identify where you are in your urban forest journey. Have you just begun and need to get a basic understanding of what it is you are managing, or are you part of the way there and already have some of the information you need to start making strategic decisions? To establish this, the key questions to ask are generally why, what and how?

Why

Why are you measuring the urban forest and who will be using the information?

Start with the Why! This will help you define the outcome. What is your vision? What are your goals? Key to these questions is the principle that 'you need to know what you have to know how to manage it'. **Some of the key reasons to undertake an inventory are to:**

- Identify and mitigate risk
- Plan future maintenance and renewal programmes including budgeting
- Inform future strategic directions and planning

Good data is a prerequisite in planning for and making sound management decisions. The more data you have on your urban forest, the better the decision-making capabilities. Also, consider who will (or should) be using the information within your organisation. Key users of the information are usually your operational tree management teams, strategic planning teams and environment/ resilience teams.

What

What are you measuring and what will you be doing with the data now and in several years' time?

What are your metrics? What information are you going to collect to inform your work? Have you established a list of requirements? These questions are really important to determine upfront. Consider what you are using the information for and how you plan to use it in the future. This is essential in terms of repeatability and accuracy, as you want to be able to compare 'apples with apples' when you repeat the process down the track.

How

How will you be undertaking the measurement and how often will you be doing it?

There are many ways to measure the urban forest. The majority of urban forest measurement is conducted by ground-based field surveys but other approaches exist including windshield surveys and remote sensing methods. The approach to data collection must be considered in the context of the desired outcomes, as not all approaches can provide the same level of information.

To gain accurate insights and to be able to answer your questions correctly, you need a robust and systematic data collection method. The more you can repeat the measurement, the more accurate your data set will be.

Once you determine your why, what and how, it's time to get stuck into it. There are three main steps in the process;

Measure
Assess your assets

Monitor
Analyse your data

Maintain
Keep your data up-to-date

03.
PROCESS

Measure

Measure what you have.

A tree inventory can be the most powerful and accurate method of collecting and analysing urban forest data in the public realm, including metrics such as species diversity, tree health and condition, age and useful life expectancy. There is limited capability to measure these metrics from any other method.

Inventory data can either be collected over time or in one bulk acquisition. Data collected over time (ad-hoc) can pose issues with accuracy and consistency unless the parameters are well defined upfront and the inspections are undertaken by similarly qualified personnel using a standardised methodology. Bulk acquisitions - data collected as part of one process or project – are generally more accurate as the information is usually collected with a clear set of specifications and by a select group of assessors working to the same objective. The cost of bulk acquisitions can be a limiting factor for some organisations.

Traditionally these inventories are collected by qualified arborists conducting ground-based assessments on individual trees - this method is the focus of this report. However, it is worth mentioning new methodologies are emerging that utilise aerial imagery and LiDAR technology that can collect large data sets of tree information with high repeatability. LiDAR sensors can generate three-dimensional point clouds of trees, from which data on structural variables, such as tree height and crown width, as well as species identity and georeferenced location, can be extracted. LiDAR sensors can be attached to an aerial platform (e.g. fixed-wing aircraft), a terrestrial platform (tripod), or a mobile platform (e.g. car). This approach is fast and generally cost-effective when compared to traditional ground-based inventories, with the added advantage of being able to acquire data on both public and private tree assets. However, at the moment this method cannot replace the qualified eye of an arborist to assess variables such as tree health, structural defects or pest and disease impact. It is currently used as an enhancement to a traditional inventory or an excellent starting place for Council to to collect tree inventory data – watch this space.

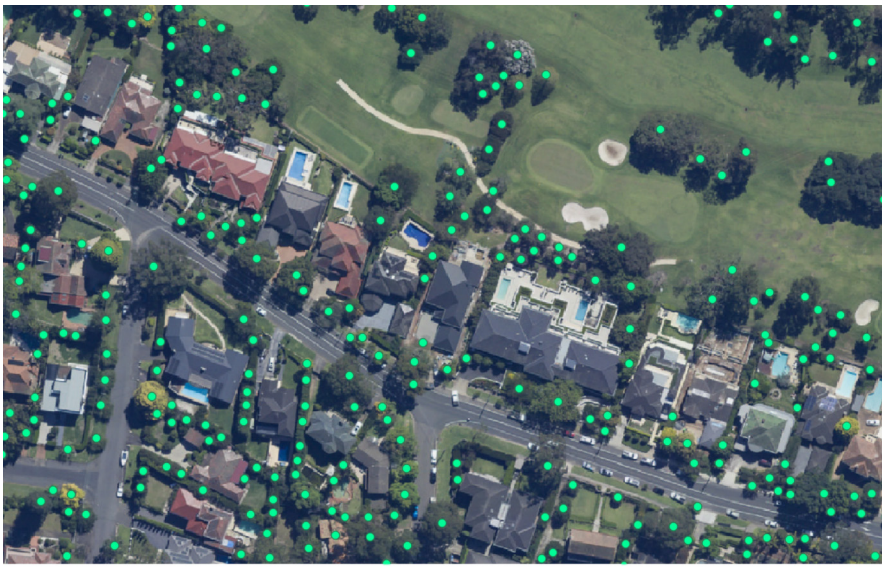


FIGURE 3

Example of inventory location data generated from aerial imagery. Each green dot represents an individual georeferenced tree that can be linked to information on that tree such as species, size and condition. *(Image courtesy ArborCarbon)*

WHAT INFORMATION DO I NEED TO COLLECT?

You will need to identify the categories of information required, and how that information will be accessed and used in the field. The tree assessments should be carried out by a minimum

Australian Qualifications Framework Level 5 (AQF5) qualified arborist. A minimum set of information must be collected to ensure the data is valuable and provides the required metrics.

This basic information could include:

- location of the tree (by GPS and street name and building number)
- botanic name of the tree species (common name is less important)
- diameter of the tree's trunk at a standard height (DBH)
- tree height and canopy width
- condition of the tree (good, fair, poor, dead/dying)
- pest and diseases present
- useful life expectancy (ULE)
- risk profile of the tree (using an industry recognised methodology)
- maintenance requirements of the tree
- location and type of potential planting sites for new trees…

The list goes on and is generally only limited by what your organisation is financially resourced to collect or what your asset system/ software can accommodate. We have provided an extensive list of possible attributes you could collect in Section 4 - Data sharing and additional resources', prioritised by 'essential to have' and 'nice to have' data fields.

The addition of site metadata, such as photos of the site, slope, aspect, soil attributes (e.g. drainage, type or texture, compaction and nutrient levels), infrastructure damage, distance to roads and buildings (among other things), provides useful information for further interpretation and analysis. Data text fields (i.e. large blocks of text) should be avoided, and automated lookups should be utilised to allow for more detailed analysis and interpretation.

FIGURE 4 Collecting tree inventory data *(Image courtesy Homewood Consulting)*

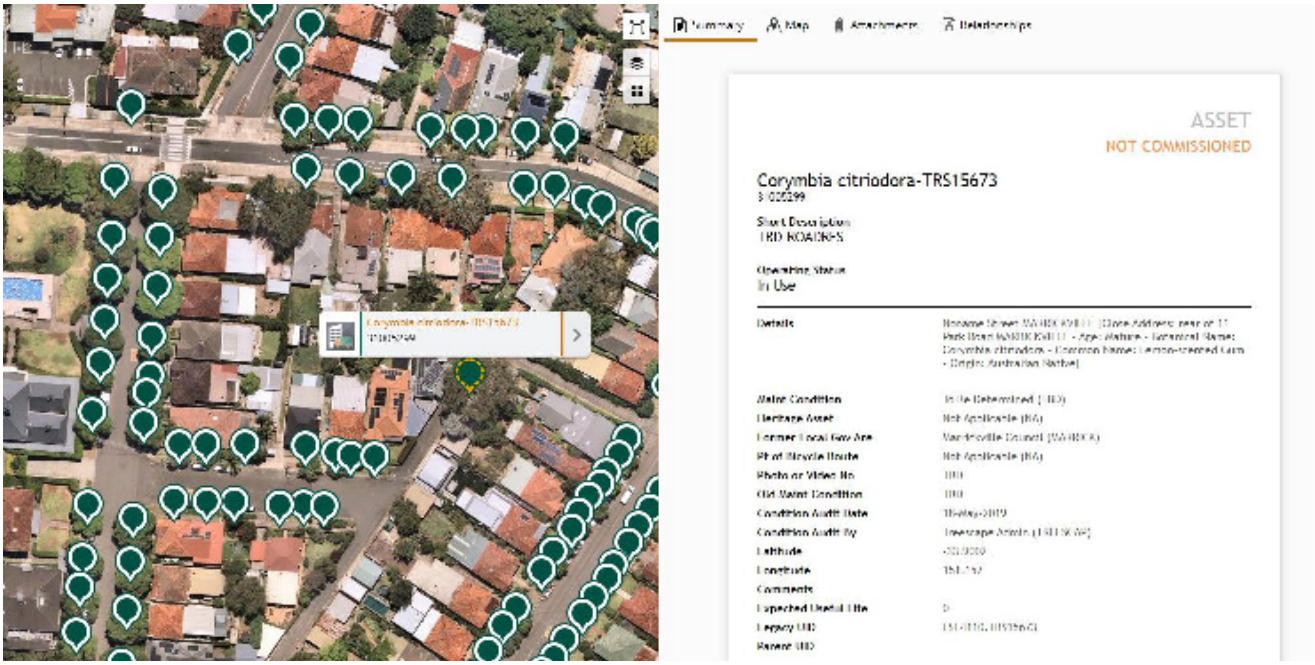
INVENTORY SYSTEMS

Inventory database systems (software) can vary from a basic spreadsheet to a customised tree asset management platform. It all comes down to useability, function and cost. A spreadsheet is fine if you are just using the data for analytics, but from an asset management and operational programming point of view, custom tree asset management systems offer a far superior level of functionality, including spatial mapping; see examplebelow in Figure 4.

Several companies in the market offer bespoke asset management systems specifically designed for Council tree operational management. These are worth looking at, as much of the hard work in defining data fields and enabling GIS capability is done for you. However, if you are with a Council, you may have an existing asset management system that the organisation uses for other assets such as roads and footpaths, that you are required to use.

It is important with these systems that there is flexibility with custom fields to allow for treespecific data to be collected. The benefit of having an existing Council system is that you can generally get support from other asset teams, and the system is usually integrated with other reporting systems.

FIGURE 5 Example image of a Council asset management system *(Image courtesy Inner West Council)*



The ability of the asset system to export the data into programs that can display the information in appealing ways for decisions makers and the community is an added feature that is worth considering. Quite often these asset systems sit behind closed doors and the power of communicating the data is not able to be realised. Extras such as dashboards and other visualisation tools can also be useful for community engagement; some examples of where this has been done well include platforms provided by Lane Cove Council https://au.pg-cloud.com/LaneCoveNSW/ and the City of Melbourne http://melbourneurbanforestvisual.com.au/.

WHERE DO I START?

Establishing an inventory can be costly for an organisation and collecting a full range of data in one bulk acquisition may not be possible. There are generally two approaches to this problem. One is to only collect basic information, thus reducing the time it takes to complete the inventory. The other is to focus on specific areas, such as town centres or precincts, and collect a full range of information. Each method has its pros and cons.

Collecting only basic information (level one assessment) will limit the effectiveness of the data collected and may reduce the viability of the inventory. However it is a reasonable place to start and will provide you with some key metrics to start analysing and understanding your urban forest. The data can also potentially be added to as time goes on to further enhance the functionality of your inventory. For example, an aerial imagery tree inventory, as mentioned above, could be added later.

Undertaking a partial inventory for target areas or key precincts such as town centres or main roads can be a worthwhile exercise from a risk management point of view. With this approach you can focus your tree maintenance resources or high target areas or areas with higher risk trees. This method however provides reduced capability for meaningful analysis of key urban forest metrics such as species diversity, age distribution and ULE.

There is a scale of economy that comes with the bulk acquisition of tree inventory data, which is usually realised at tree numbers above 10,000. Project start-up costs are a significant portion of the cost to acquiring bulk acquisitions and the more trees in the project the better the per tree rate. Meaningful cost efficiencies can be achieved by combining forces with adjoining Councils to put out a larger contract for an inventory.

Monitoring

Monitoring involves repeatedly measuring over time in order to observe and analyse changes in your urban forest.

Monitoring enables you to track the progress and condition of your tree assets over a period of time and implement adaptive management to address any issues as they arise. Monitoring also enables the measurement of progress against your strategic goals and objectives, for example as defined in a strategic document such as an Urban Forest Strategy (if your organisation has one). As you implement planned actions, such as tree planting and maintenance, monitoring will allow you to see if progress is being made against your strategic goals – this is known as Strategic Asset Management.

Knowing how to analyse your data is the key to harnessing its potential. Monitoring your urban forest is key to successful planning for your operational maintenance and planting programs. Your urban forest data provides you with the information required to build a business case, for example to apply for more resources within your organisation, or to access grants and funding from state government.

WHAT DATA TO LOOK FOR

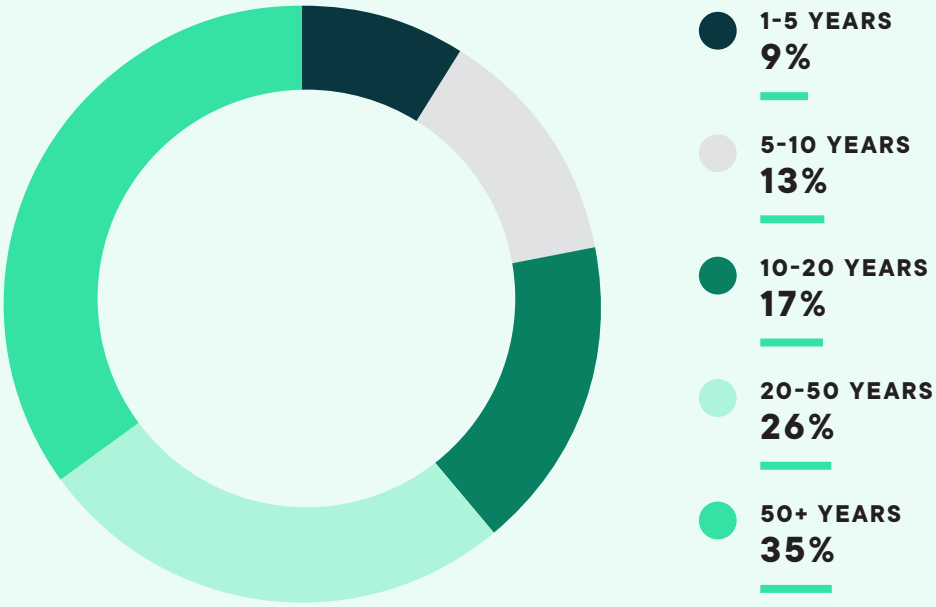
When analysing your data there are some key areas to focus on to allow for informed decision making. Some of these include:

SPECIES DIVERSITY What percentage of your urban forest is represented by one particular genus or species? What is your proportion of native vs exotic? A highly diverse urban forest is a resilient urban forest. Low species diversity will leave your urban forest vulnerable to pests and diseases and future climate scenarios. If you have low species diversity you should focus on diversifying your planting palette and avoid planting species that are over represented. A general rule of thumb is that it is best to have no more than 10% represented by one species, no more than 20% represented by one genus, and no more than 30% representation from a single family.

AGE DISTRIBUTION AND USEFUL LIFE EXPECTANCY What is the age class distribution of your urban forest? Do the majority of your trees sit within the mature age category? It is best to have an even distribution of tree age across your urban forest, allowing for succession of the canopy through the age class categories. Trees should be managed to their full ULE to maximise their benefits – this is often a fine balance with effective risk management.

If you have an over-mature urban forest you will need to plan for the allocation of resources to manage the risk of these aging trees and to increase planting programs to tray and diversify the age distribution – it is likely you will inevitably see a decline in canopy as the over-mature trees eventually require removal.

FIGURE 6 Example of urban forest data presented graphically to represent Useful Life Expectancy (ULE).



RISK PROFILE how many high-risk trees do you have that need to be more frequently monitored or removed and replaced within a determined timeframe? Budgets should be in place to effectively implement these removals and allow for replacement trees to be planted. Analysis of risk profiles allows you to plan ahead and stage your programs based on risk ie high risk trees to be removed first and low risk trees last. A recognised risk methodology such as Quantified Tree Risk Assessment (QTRA), Tree Risk Assessment Qualification (TRAQ) or VALID should be utilised.

HEALTH AND STRUCTURE What is the condition of your urban forest? Is further resourcing needed to improve your maintenance program and effectively maintain the health and condition of your trees? What are the contributing factors to tree condition, is climate change impacting species' resilience and do you need to consider planting other, more resilient species?

TREE SIZE Measuring the various elements of tree size, such as canopy width, height and trunk diameter helps us learn more about the tree's ability to provide benefits. This information can inform calculations to provide tree benefit values such as those provided by 'i-tree' including carbon sequestration value, stormwater abatement value, ecological services and monetary value.

RECORDING SUCCESS AND FAILURE

Recording data on successes and failures can assist in improving species selection and in the development of management plans for climate resilience of your urban forest. Currently, many organisations focus on successful plantings and only record the tree in the inventory once it has established. Collecting data on failures, including the reason for failure (e.g. incorrect species selection, pest or disease, vandalism, lack of water, competition with infrastructure, etc) can provide valuable information for management.

Failure can occur at different times during a tree's lifespan and can include post- planting, during the establishment period and times of stress (such as drought). Notably, the early stage of a tree's life (after planting and early establishment) is the most vulnerable and has higher mortality rates. Thus, monitoring and collecting data on failures during this time is crucial to identify resistant and vulnerable species.

Collecting tree and branch failure information, including a description of the nature of the failure, the condition of the tree, and pre-existing structural defects that may have contributed to the failure (inclusion, decay, etc), can assist in developing species' profiles and 'failure potential' data. This information can assist with long term maintenance plans and in future species selection.

FIGURE 7

Recording branch failures is important to build 'failure potential' data profiles *(Image G.Griffiths)*

Maintain

Your data is only as accurate as the last time you updated it. For any tree inventory database to be successful, it is essential that there are adequate resources and processes in place to ensure it is well maintained and regularly kept up to date.

Inventory data maintenance should be embedded in every process associated with tree maintenance and planting. Every time a tree is inspected, pruned, planted or removed, it should be updated in the inventory. This is called 'live' database management. The inventory should not be a static entity, it has to be continually maintained to stay relevant.

Quality control is also important, as you want to make sure the information you are collecting is correct and accurate. This level of quality control is often achieved by limiting the number of users in the system and by ensuring that each user is qualified and trained in how to use the system.

FIGURE 8

Maintaining your tree inventory data is important *(Image courtesy Homewood Consulting)*

PROCESS

In Councils with tree maintenance programs undertaken by contractors, it is advisable that tree maintenance contracts are updated to: (1) require the Council's contractor data to be integrated with the asset management database; and (2) require the Council's contractor to update tree records as they undertake works on individual trees. This should involve not just updating the database with the works they are undertaking at the time but also updating key data fields such as height, condition, DBH, risk rating, etc.

Establishing a forward inspection program to have your trees assessed on a regular basis is the most effective way to maintain your database and address tree risk. This involves a proactive scheduled inspection of your trees, often on a precinct basis, to assess any potential hazards and update key inventory date fields. Inspections are then followed up with scheduled maintenance if required. The aim is to assess the potential risks before an issue arises and undertake maintenance works if needed – this is called proactive tree maintenance and the best way to manage your trees to their full ULE.

Funding and resourcing of this level of inspection and data management can be an issue for some Councils, however the cost savings associated with maintaining the data rather than collecting it all over again are worthwhile.

The operational tree management teams within Council should become 'owners' of the system and ensure it is maintained as a live database.

04.
DATA SHARING AND ADDITIONAL RESOURCES

Data sharing

Sharing is caring. To help inform the selection of appropriate species for future plantings, it is important that you share the findings of your monitoring.

This can be done at a local-scale when you are deciding what species to plant via the networks that shared their knowledge. By feeding information back into this knowledge base, you are enabling it to grow, which will mean the next people to plant a species will have a greater amount of information on which to base their species selection.

Sharing results can be an advantage to those undertaking new plantings, to help them avoid reinventing work already done or to consider how to value-add to work already done. Making your monitoring data available for collaborators in different localities can help to evaluate factors contributing to good/poor performance, including identifying climate resistance/ vulnerability. Collaboration among organisations will provide greater insights to improve urban forest management and planning.

An example of where this collaboration has come into practice can be seen here;

OPEN COUNCIL DATA STANDARDS

standards.opencouncildata.org/#/trees?

TREENET STREET TREE TRIALS

treenet.org/research/street-tree-species-trials/

OPEN TREES DATABASE

opentrees.org/#pos=1/-37.8/145

Additional resources

The table below outlines the ideal data fields for collection when undertaking an inventory.

They are arranged by 1) Location Details; 2) Tree attributes; and 3) Tree Maintenance. An asterisk (*) against a field suggests that this is essential/ minimum requirement data that should be captured.

LOCATION DETAILS	Type of data to be entered
Asset Number*	Free entry
Status	Current / removed
House No*	Free text entry
Street*	Load all streets in Council Area
Suburb*	Load all Suburbs in Council Area
Maintenance Precinct	Pre-determined
Land use	Park/ Street/ Reserve/ Carpark/ Property
Park/ reserve/ carpark name	Load all parks and reserves in LGA
GPS Location*	X, Y Coordinates and/or Lat/long
Planting scenario	Grass/ concrete pit/ other
Soil compacted	Yes/ No
Power lines	None/ ABC/ LV/ HV
Surrounding infrastructure damage	Yes/ No
Photo	Attach

DATA SHARING AND ADDITIONAL RESOURCES

TREE ATTRIBUTES	Type of data to be entered
Botanical Name*	Species look up values to be provided
Height (m)*	Free entry
Canopy width (m)*	Free entry
Height to base of canopy (m)	Free entry (needed for i-tree assessment)
Percentage canopy missing (%)	Free entry (needed for i-tree assessment)
Diameter Breast Height (DBH)*	Free entry
Diameter at Base (DAB)	Free entry
Age*	Young/ Semi Mature/ Mature/ Over Mature
Visual Condition*	Good/ Fair/ Poor/ Very Poor/ Dead
Structure*	Very poor/ poor/ fair/ good/ has failed
Defects*	Included bark/ previous branch failure/ epicormic growth/ bracket fungi/ mechanical damage/ cavity (decay)/ split or crack/ hanger/ crossing branches/ dead wood/ excessive kino or resin

TREE ATTRIBUTES	Type of data to be entered
Pest and disease*	Termites/ borer/ wax scale/ stink bug/ sooty mould/ leaf chewing insect/ sap sucking insect/ myrtle rust
Hollows or nests	Yes/ No
Habitat tree (artificial hollows installed)	Yes/ No
Useable Life Expectancy (ULE)*	Zero/ up to 5/ 6 to 10/ 11 to 20/ 21 to 50/ over 50
Whipper snipper damage	Yes/ No
RISK ASSESSMENT*	Use your organisation's adopted tree risk methodology (Below are the required fields for QTRA)
Target	1 to 6
Size	Property/ 1 to 4
Probability of Failure	1 to 7
Risk of Harm Value	*Formula value linked to above*

TREE MAINTENANCE	Type of data to be entered
Tree maintenance required	None/ Annual inspection/ Branch pick up / Broken branch/ hanger/ Crossing branches/ Canopy lift (footpath/road)/ Property clearance/ Climbing inspection required/ Codominant reduction / Create habitat tree (stag)/ Deadwood/ Epicormic removal/ Formative prune/ Remove stakes/ Remove guards/ Remove Concrete or Asphalt/Remove tree/ Remove tree (retain logs)/ Stem injection/ Pest management/ Tree base maintenance required (mulch etc)/ Remove bee hive/ stump removal
Tree maintenance priority	**1** – Emergency (within 1 hr), **2** – 24hrs, **3** – 1 week, **4** – 1 month, **5** – 3 months, **6** – 12 months

OTHER FIELDS	Type of data to be entered
Comments	Free entry
Tree maintenance priority	Free entry
Inspected date	Free entry
Tree planted date (if known)	Date format xx/xx/xxxx
Root Barrier Installed	Yes/ No
Nomination for significant tree register	Yes/ No

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